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DENUDATION, DEPOSITION, AND UPHEAVAL.

FORCES—FROST AND FIRE.

PREFACE.

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CHAPTER I.

CINDER HEAPS.

A CERTAIN hardy English traveller, in excellent health and spirits, returning from Iceland, with the appetite of a hunter, and the condition of a race-horse; declared to his shipmates that the country was "not worth seeing." "It was nothing," he said, "but a big cinder heap, as interesting as the dust hills at Wolverhampton, and not a whit more fertile."

The traveller's description, though *not* complimentary, was pretty accurate.

Volcanic products are very like furnace refuse, and all Iceland is volcanic; but cinder heaps, great and small, are worth sifting, for they throw light upon each other, and on dark subjects. Slag, Lava, and Trap, were all melted stone, and they are equally products of heat.

Even in a cinder heap there is much to be learned.

One branch of geology may be studied at a foundry where stones are melted; but something is first wanted to bridge over the gulf which separates a rill of slag from a lava flood; and a visit to Iceland supplies the want.

One great steam-engine must be seen at work before the ways of steam can be learned from a kettle; but when it is understood that steam power is limited only by the size of the engine and the amount of heat applied as force, then models, drawings, descriptions, or even traces of work done by natural steam-engines, are comprehensible.

So it is on the large scale.

The tool marks of natural heat must be seen in a large volcanic country, before the action of tame heat working at home on a small scale can be identified with volcanic action.

Earth heat has done great work in Iceland. The country whose bare barren surface has recently been altered by two mechanical forces, which upheave and grind down the crust of the world, teaches principles on which geology is founded; and when the lesson is learned, the scholar sees that a smelting house, a rubbish heap, a frying-pan, and the kettle, all shew the action and the effect of the same forces working on a smaller scale.

Iceland is a "cinder heap," but it is a very large one; and the lesson which it teaches is well worth the cost. Hecla may only be one large valve in a great caloric engine; but it is not too large to be seen, and it is well worth looking at. The two forces which have been set to shape the outer surface of the crust of our globe, if not the globe itself, are now employed in busily finishing an island as large as Ireland. They have worked and are working within such narrow bounds, that their work can be seen as a whole; but on such a vast scale that the performance of still greater tasks by the same agents can be understood. These twin giants, Fire and Frost, Heat and Cold, are as busy near Hecla as at Wolverhampton or Coatbridge, and their work is alike at home and abroad.

They move steam, the atmosphere, and the ocean, and things moved by them; they melt and freeze gas, water and slag, lava and metal, and move things moved by them; they shape clouds in the air, plates of slag, mounds in lava, and great mountains on the earth; they have upheaved and depressed Iceland, Norway, and Scotland; they have altered the whole surface of the globe, and its upper crust, so far as it is

explored; and they may have done still greater things, if they were the servants employed to do the work.

So a traveller, surrounded by mountains of ice and cinders, may be driven by the work before him to think of the agents employed to do it, and of him who set them their tasks, who said "Let there be light, and there was light," in the dawn of time.

In furnaces and volcanoes, in models and steam engines, in cinder heaps and in Iceland, in art and nature, certain mechanical forces work, and movements and forms produced by them are alike on all scales.

The tool marks of fire and frost may be learned in their workshop, and they may be set to work at home.

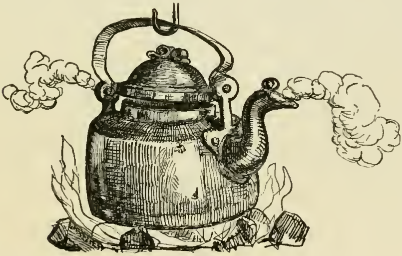

FIG. 1. PORTRAIT OF AN OLD FRIEND AND PRECEPTOR.

CHAPTER II.

HOME GEOLOGY.

A HOME student of geology is forced to take a great deal upon trust, and has often to work sorely against the grain. He may understand the teaching of practised men, and believe what he is told; but he cannot be familiar with the irresistible power of natural forces, whose power he has only seen displayed upon some pigmy scale.

A landsman who has only seen a puddle in a storm, has no clear notion of the Atlantic in a gale; and so it is with a man who has never been far from home.

He may have been familiar all his life with the form of some great mountain covered with rich soil, grass, heather, trees, and yellow corn in summer; sprinkled with snow, and glittering with icicles in winter. He is taught that the rounded form which he has known from his childhood, and which has never changed within the memory of man, is due to the wearing of floods of water, or of fields of ice.

But no home-bred Englishman has ever seen any power in action which seems strong enough for the work described as denudation.

The rivulets which trickle down the mountain could not have done work of the kind if they had worked as they do now for countless ages. They do not make rounded shoulders; they cut deep furrows on smooth hill-sides.

Burns meet in quiet lakes which mirror swelling hills on either side of some great glen, along which a river

winds to the sea; but the shape of the glen bears no resemblance to that of the small transverse furrows which rivulets make, or to the winding river bed at the bottom of the glen.

If scooped out, it is clear that the main glen was made with some coarser tool; and that the hill was rounded by something different from streams of rain water.

The great glen which crosses Scotland at the Caledonian Canal never could be hollowed by streams like those which have furrowed the long, smooth, steep hill-sides which make its southern boundary.

Ben Wyvis, and hills like it, were not rounded by streams like those which flow from their sides, and furrow them.

A little scratch on a rounded smooth rock which peeps through heather on the steep side of a burn, is shewn triumphantly to prove how an enormous glacier, now replaced by a little winter icicle, once filled up the glen, overspread a whole tract of country, and ground its way slowly downwards, bearing earth and stones on its surface, as leaves and sticks float down a river to the sea. Green hillocks, from which loose stones are now dug to gravel the roads, are pointed out at the mouth of the glen to mark the spot where a local glacier once ended; and the student is told that ice carried stones overland from the mountains, and left them in heaps when it melted, like piles of floating rubbish stranded by some winter spate.

It is said that ice and cold water ground down the hills and scooped out the glens, and left water-worn moraines behind them, because there is an ice-mark on the rock.

A man may believe it all vaguely, but he cannot realize it if there is nothing like a glacier within his experience.

The face of a peasant who is told for the first time that ice rounded the hill-tops where his sheep feed, is a study.

But glaciers and cold rain-water alone will not account

for many great glens, because of their peculiar forms; and there are ice-marks which no mere land-glacier could make.

It may be that a man has lived all his life beside some great stone fixed in a rich plain, buried in an old wood, or perched upon a hill-top. He may have seen it gray with lichen, or green and brown with moss and fern, or sparkling in the sun like a great jewel when powdered with hoar-frost.

It has been an "earth-fast stone" ever since he can remember; it looks as if it never could be moved from its place; perhaps tradition tells that some ancient giant hurled it at his foes. The teacher declares that it is a "wandering block" which first broke off and rolled down from a mountain hundreds of miles beyond the limit of vision, in some far distant country; and then sailed over the ocean on an ice-raft, and finally sank to the bottom, where it lies.

The tradition seems far more probable. It is just as likely that another stone of the same kind should now come sailing on a cloud, and plump down amongst the hens in the barnyard, for there is no sea near the stone, and the nearest sea has no ice-rafts.

It is vain to point at an ice-groove on the tip-top of a high hill, and then assure a canny Scotchman that like marks are to be found upon many similar isolated hill-tops, in the British isles and elsewhere; that all these high grooves seem to bear some relation to each other, and that they were all made by ice-floats while sailing over the hills, and dropping cargoes of clay and stones in the sea, to make land for farmers to plough on shore. It is contrary to the evidence of the senses. The sea is far away, hills are high and steadfast; and many ice-grooves are but faintly marked now.

It is vain to point at illegible characters on the stone or on geological maps, and try to explain how it must all have

happened long ago. It is not easy to expel old ideas and take in a new stock ; and so the usual first-fruits of an explanation of a fire-mark or a frost-mark is a look of incredulity or contempt.

A geological student is taught that mountain-chains were ocean beds, that continents were groups of islands, that islands are sunken mountains, that hills pop up their heads, and dive down again like seals ; that if some glens are grooves, some are rifts in the earth's broken crust; that the land has waves, and that the sea is comparatively at rest ; but he never sees any of these changes happen.

He is assured that the cold, solid, gray rock, from which an old moss-grown tower has watched for centuries over generations of actors in the world's history was once white hot, and rose up through the sands of the sea ; that a quarry was a sand bank, and a stone in it a drifted log. But no rocks, hot or cold, ever rise now in neighbouring seas, nor do sand banks and forests turn to stone and coal.

He knows that it is the nature and habit of all the rocks and stones that he has ever seen, to fall as fast and as far as they can, and then lie still. He is taught that rocks and stones move about, float in water, and fly through the air, and have done so time out of mind.

By vigorous submission to authority, or by hard thinking, a man may bring himself to believe that these are truths, not waking dreams of book-learned men, or travellers' tales ; but it is no light labour for simple men who have never seen fire and frost at heavy work, to take it all in.

A certain venerable professor of natural history was in the habit of taking a walk round Arthur's Seat once a year with his class at his heels ; and it was his custom to pause beneath certain basaltic columns, and gather his flock about him to

pick up crumbs of knowledge, and hear the yearly open-air Edinburgh lecture on geology.

In these days—some twenty years ago—there was no "Queen's Drive," but there was some fine green turf near the rocks, and on one of these occasions a bevy of Edinburgh wives and lasses had chosen the spot for a bleaching green.

"What the diel's a' thae folk doin' there?" said one cummer.

"Oh, it's a daft chiel gien them a lectur aboot Samson's ribs," said another.

And then they laughed a mocking chorus, and fell to work again at their wet napery.

Not all the professors in Edinburgh, not even Sir Roderick himself, could have persuaded the washerwomen that Samson's ribs had been pumped up hot out of the earth, or had ever been anything but solid rocks since the world was first created.

This hard crust of experience must be quarried through before knowledge can reach the understanding of home-bred men, for daily experience seems to contradict what they are taught.

But daily experience really agrees with geological teaching, for the mechanical action of natural force is always the same, though it varies in degree; and this is felt and understood when cold has been seen battling in earnest with heat.

A man begins to feel that cold is a mighty engine when he has seen a glacier, and heard it. When he has seen it move with acres of stones and gravel on its surface, and launch cargoes upon ice-rafts, to sail wherever the wind may blow them. He has learned a new alphabet when he has seen polished rocks under and near moving ice, and grooves and scratches freshly gouged out by stones in the ice. He

gains a new view of an old ridge of gravel, when he sees a conical mound of loose rubbish newly shot from a groove in blue ice, by a snow rivulet, and the end of a glacier fringed by ramparts of such mounds. Thenceforth he knows a "terminal moraine." He begins to understand how a clay field may have come from some neighbouring glen or distant country, when he has seen a thick, white, muddy river, smelling of sulphur, bursting out of an ice cave, tearing through heaps of debris, and busily engaged in spoiling a delta of its own building to make another lower down, or to freight an iceberg.

When he has seen all these movements and changes, these tools and their marks—and they are all to be seen in Iceland, Norway, and Switzerland—it is easy to believe that similar work was similarly done by the agency of cold and weight elsewhere.

Then the action of large masses of ice, and great floods of water, which hew out rock forms, and carry and arrange banks, mounds, and plains of drift, clay, and boulders, is recognised in the sliding of a plate of ice upon the bank of a rivulet, or in the miniature work of a mill stream on a frosty day. Having learned the alphabet and the living language, he can decipher the rock inscriptions of old ice.

So, when a man has seen one smoking volcano, with its lava floods and cinder heaps still warm beneath snow and ice, and the curl that once played upon a river of melted stone as sharp and clear upon a rock as the curl upon the glacier river beside it, his ideas about steadfast and eternal hills are changed. When he has seen stones, sand, and ashes, that once rose up, repelled by heat, and flew through the air in defiance of gravitation, now strewed on the ground where they fell, because the laws of attraction were the strongest in the end, he gains another new experience, and recognises a

force opposed to gravitation, which meets him at every turn.

When he has seen the workshop of heat and cold, he learns to know the tool marks of the two giant slaves wherever he finds their work, and he finds it everywhere when the lesson has been well learned.

The heat of a volcano is but the same force which works a furnace and a steam-engine; the same forms result from its action, and he sees them in familiar hills, in cinder heaps, and everywhere. When the natural heat of the earth has been seen to hurl clods and stones, drops and jets of water, steam and smoke, far away from the earth's surface, to move freely for a time in obedience to laws which govern the movements of planets and earthly projectiles, it ceases to be an effort to realize the fact that heat, cold, and gravitation, are forces which together move projectiles in well-defined paths within the bounds of our world, and it may be beyond them.

A man becomes familiar with these, his fellow-servants, when he has eaten food cooked by nature's fire, and has slept on a turf bed warmed by mother earth. As he lights his morning pipe through a lens, with fire direct from the sun, beside a pool of water boiled by fire in the earth, and watches distant ice mountains through condensing steam, and thinks whence all the water came, how it was moved, and by what forces, a traveller must realize that these useful giants who can turn their hands to so many things, great and small, do not confine their labours wholly to this world.

He sees that heat boils a kettle, a steam boiler, a geyser, and a volcano; lifts water at the equator to drop it at the poles; and will hand a cigar light from his quarters in the sun, to a friend on earth who knows his ways.

He knows that cold cools the tea, and stops the engine, seals up the hot spring and the volcano, shakes down snow to

grind the mountain which the other raised. Cold arrests the motion which heat started: he knows that cold puts a man's pipe out when the time is come.

An Englishman seldom thinks of heat and cold as natural mechanical forces, though he sees their work everywhere.

An Icelander who lives within sight of Hecla may have seen the top of a mountain larger than Ben Nevis, red hot; with a stream of melted stone, as broad as the Thames at London, flowing down its sides.

The stream is there now, though frozen, hard, cold, and dark. Every year he sees water fall, flow, and freeze, and hang on the slope as lava does. There is snow upon lava now, and ice in caves beneath it.

He sees steam and boiling water burst up and spout from the earth, and condense, and fall, and flow into still lakes, freeze hard, and split; and he can understand that the great shattered plain of stone on which he lives was liquid, and rose, flowed, froze, and split, like the water.

He knows that lava boils over, froths and freezes outside Hecla; so he can understand how bigger streams boiled up elsewhere, before his ancestors came to the land.

A traveller who has gained a part of this Icelandic experience can apply it at home, and recognise past glacial and igneous action in forms which remain to tell their origin to those who can understand their meaning.

So a trip to Iceland is worth its cost.

The rugged features of nature are hidden or veiled in fertile lands; in the cold barren north they are clearly seen, and stern though they be, they are well worth contemplation.

The desolate country is one of the grandest in the world, though the prevailing feature in its landscapes may be dust and ashes.

Atmospheric circulation, water falling and flowing, fluid and solid; sliding glaciers, freezing seas, ice rafts floating, rocks wearing, sediment falling to form new beds, "denudation," and "deposition:"—downward movements from the action of cold and weight:—

Rising land, hot springs, intruded rocks, lava, boiling, rising, flowing, and freezing; volcanic projectiles rising, freezing, and falling in air; upheaval of land, upward movements in gas, fluid and solid, caused by heat:—

Demolition and reconstruction by natural forces,—are not all within daily experience at home.

Therefore, teaching and experience may seem to differ, but they really agree; for natural agents work everywhere in the same way, and the form of their work is alike at home and abroad, on the smallest and on the largest visible scale. The same powers work in a kettle, and in the Great Geyser; both boil, and sometimes they boil over.

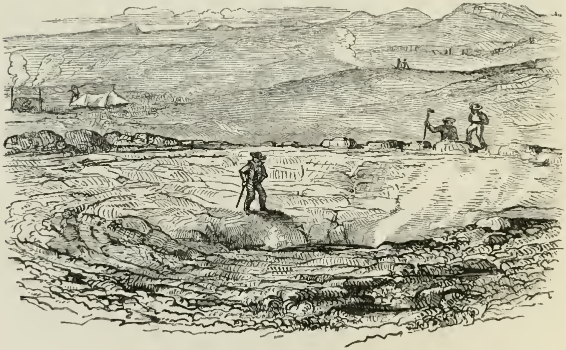

FIG. 2. BOILING UP.
Tube and Basin of the Great Geyser, after an Eruption, 1862.

CHAPTER III.

GEOLOGY.

Geology teaches generally that great changes have taken place on the surface of the earth, and it seems to point back to some distant time when a crust first cooled about a molten interior.

But there is nothing like a molten surface within common experience. The world with which we are familiar is green and smiling, and the old rugged crust is buried far out of sight, or worn away. It takes skilled eyes to read the lessons of our rocks. In Iceland nearly the whole surface has been fused ; it is warm still in many places, and most of the rocks are bare, so he who rides reads.

The modern geologist generally works slowly but surely downwards through the outer crust of sedimentary rocks which have settled layer upon layer above each other, and about the cooled surface of the first crust, whose formation is assumed in the meantime. From sedimentary beds he digs out the shapes of creatures and plants that once lived, and he marks off the layers in which they are found, and knows their order, and their fragments, by these forms of buried plants, shells, and skeletons.

The thickness of this outer shell is measured along its broken upturned edges, and it is calculated how long it may have cost air, water, and ice—the gaseous fluid and solid matters which now move about upon the earth's surface—to grind down mountains at a given rate, and so produce, transport, and arrange enough of mud, sand, gravel, and boulders to make up sedimentary beds whose thickness is known.

The time is estimated during which the formation of these rocks lasted; while plants grew, withered, died, fell, and accumulated, and became peat beds and coal fields; and while races of creatures lived, died, and were buried and turned to stone.

Each step so gained seems to rest upon a pile of facts as hard as the fossils themselves, each link in the chain is firmly joined to its fellow, and geology has become a science. But the rate of action may have varied in former times. The whole chain of reasoning in this direction, proves at least the endurance and activity of one mechanical force, which still acts towards the earth's centre.

The formation of sedimentary rocks under water, and the transport of their materials from a higher to a lower level, are facts which prove that the force which causes an apple to fall has acted in the same direction ever since it first moved silt: whatever the rate of action may have been.

There is not much to be learned in this branch of geology in Iceland. There are few sedimentary rocks, and very few fossils; but of the present activity of the weight-force which must have acted upon the original crust of the earth, there are striking examples.

Falling water has not yet smoothed the shattered, wrinkled surface of the lava; the sediment which it washes off and carries has not yet buried the rough outer crust; but water and ice are busily grinding igneous rocks to make others, and they have ground and buried many surfaces which were bare and wrinkled at first.

There are few sedimentary rocks yet formed, but they are forming everywhere upon igneous rocks, so there is much to be learned about the past, from that which now takes place in Iceland.

But gravitation is only one of the mechanical forces which

act at the earth's surface, and denudation and deposition are but one-half of geology.

At every step there is evidence of a force opposed to gravitation, which has counteracted the downward movement of sediment.

The rain which washed down materials enough to make known beds of rock, would have washed all the land into the sea long ago, and ocean currents would have levelled the bottom, had not land been raised above water by a force sufficient to balance weight.

No apple could ever have fallen from a tree unless the tree had first grown ; water could not fall from clouds unless it were first raised from the earth ; and stones could not fall from mountains unless mountains were raised above the plain. There could be no new sedimentary rocks unless mountains were raised up as fast as they are ground down. If there has been denudation, there has also been upheaval of the surface.

A second mechanical force is recognized in all modern geology ; it has helped to model the outer crust of the earth, and it is still very active in Iceland.

Heat helps to raise trees upon which apples grow, and the ground on which they fall ; it acts upwards ; weight acts downwards, and the action of the earth's heat is seen in hot springs, in volcanic eruptions, and in their work all over Iceland.

Heat drives matter away from the centre, gravitation drags it back.

Heat expands that which contracts when cold. Hot particles repel, cold ones attract, each other.

So heat raised up hills from which sediment falls ; it shatters the earth's crust, and heaves up the broken fragments, and thrusts up molten matter through openings so made ; it raised up islands, and continents, and sea bottoms,

and is raising them slowly still ; it hurls projectiles away from the earth's surface, and it has probably worked in the same direction from the beginning.

And this mighty force is manifest within a week's sail of the English coast ; where its activity is often forgotten till some earthquake startles a sleeping town.

It seems impossible to visit Iceland and deny the importance of internal heat as a geological agent, or to revisit old haunts without recognizing traces of extinct volcanic action everywhere.

To ride over lava and gaze into craters is to gain fresh knowledge, and learn new tool marks. It is like visiting some asteroid still warm from nature's laboratory, or to read an early chapter in this world's history.

If any stones be preachers, surely these are eloquent.

Modern geology, then, treats of sedimentary and of igneous rocks ; it recognizes the activity of two mechanical forces, which act in opposite directions, upward and downward, from and towards a centre, in radiating and converging lines ; and Iceland is peculiarly fitted for studying the effects of both.

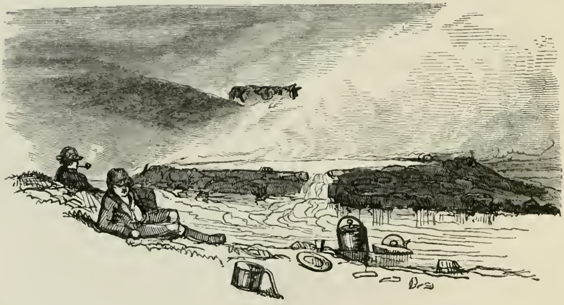

FIG. 3. NATURE AND ART.
Northern Iceland.—Badstua, near the Uxahver, 1861.

CHAPTER IV.

FORM.

Visible objects of all kinds are known by their forms, by their outlines, and by their internal structure, as well as by colour, weight, and chemical composition : and form has this advantage—it can be used as a test where others cannot be applied.

Fossils, for example, are known to have been plants, shells, or bones, only because of their outward forms and internal structure.

Organized forms indicate previous orderly movements, and forces which produced them ; and the former activity of vital and mechanical forces which now arrange the component parts of living plants and animals is proved by form ; when colour, weight, and chemical composition differ from those of any living thing.

A knowledge of form is very important to the student of extinct life.

So it is to students of other branches of geology.

The rounded shape of a pebble tells that a stone was rolled till its angles were ground away, wherever it may now rest. It is the same whether it is found in a stream, on a beach, in a dry bed of loose gravel, or in a hard rock ; in a deep mine, on a hill top, or buried in lava and ashes. The form of a water-worn pebble of any material cannot well be mistaken when the tool-mark is learned.

An ice-ground stone differs from one that is simply water worn.

There are many degrees of wearing, and many varieties of gravel and rolled stones ; and a skilled eye can distinguish them.

The outlines tell part of the story ; internal structure tells more of it.

A bit of water-worn bottle-glass, for instance, shews by its structure that it is glass, which was artificially fused before it was broken and rolled ; and its fracture, and the shape of chambers in it, shew the direction in which heat, cold, and human skill worked on tough glass while cooling and passing from fluidity to hardness—from heat to coldness.

The glass may be a pebble in a sea-beach, so far as outward form and position are concerned ; but internal structure tells of the agency of man, and the action of heat and cold.

A jasper pebble, a bit of rolled obsidian or agate, or calcedony, all of which break like glass, tell their history too. Because of its outward form the stone has been rolled in water, or ice-ground ; because of its internal structure it has been heated to fusion, or perhaps to sublimation.

A broken bottle proves the former existence of men.

A scratched jasper pebble picked up in a field near the Clyde, means previous aqueous and glacial action where there is now dry land ; and volcanic action at the place whence the jasper was moved, before it became a pebble.

If a square block of jasper is found on some neighbouring hill, it points to a possible place from which the pebble may have started ; and if a vein of jasper is there found *in situ* it points out the site of an eruption, though there may be no other record of it.

So a fragment of rolled brick, a slate pebble, a limestone

boulder, and a bit of water-worn chalk, all have something to tell about forces which moved their particles.

Brick, though rolled, is easily known to be manufactured brick, and it tells of a bed of clay somewhere on shore, of the labour of men, and of the action of a certain temperature artificially applied to bake, without fusing, clay and sand. It may be part of a delta now, but a brick is human work.

Slate, sandstone, and limestone, though rolled pebbles, tell of the fracture and wearing of old beds of stone, of old denudation, and of deposition of silt to form new beds; of some action which changed silt to stone, and of the breaking and wearing of these new beds. A pebble of metamorphic clay-slate or marble may tell of a heat sufficient to bake without fusing clay and lime; and the materials tell of still older changes which formed and packed the minute fragments of which the rocks consisted before they were baked hard.

The minutest visible grain of sand has a well-marked form of its own, which tells a separate story.

But because these inorganic forms are as well marked as those of plants, shells, and bones, they prove the past action of mechanical forces as clearly as fossil shells do the action of vital force.

The form of sand tells of motion in gas or fluid as clearly as a fish-bone records swimming in water; and if sand and a fish-bone are found together in the same place, they tell of mechanical and vital forces acting much as they now do, and in water, cold enough for fish to live in.

These separate inorganic forms, then, give much information. But other forms tell their story with equal clearness.

A dry river delta tells as clearly of flowing water and moving silt, as a shell does of the life and death of a living creature. It is a water-mark.

The minute delta which forms in a gutter during a shower, is the result of flowing water ; so is the delta of the Nile, or the moving delta which is creeping seawards, out of valleys about Hecla ; or a fossil delta of any size, anywhere.

They differ, but their general form is the same ; and though all big rivers were dried up, their former existence might be known from their work, if but one flowing rill survived to explain the way in which silt is packed at a river mouth.

Size is of no importance when movements and forces, from which natural forms result, are known. The forces can be inferred, if only the forms can be recognised.

Distance does not affect the test by outward form.

A tree is known though it grows on some inaccessible cliff, and the vital vegetable force is inferred from the shape of the tree.

A river delta is recognised from a hill top, though it may be far away.

If there were a large delta or river-bed upon the moon's surface, it could be recognized there as easily as upon the earth, for it has a conspicuous shape. It is a tool-mark. No Λ is to be seen in the moon ; no forks and meanderings ; no V, no Y, no S. There are no clouds there from which rain can fall. There can neither be river nor tree, like earthly trees and rivers, on the moon's surface, because familiar water and air forms are absent.

But fixed, solid forms are there. It is known how similar forms are produced in this world. So it is fair to conclude that these lunar shapes, these O craters, also resulted from a combined action of heat, cold, and weight, which did their work, and have now ceased to work on that surface, though still active here.

Visible forms then, whether accessible or not, mean

previous movements, forces which caused them, and a temperature sufficient to make the movements possible in the material moved; and similar natural forms, wherever they may be, probably indicate similar action and agents, movements and forces.

A delta is a water-mark; a round crater a fire-mark; and every force which acts on a surface makes a tool-mark which may be learned.

Each mark is like a letter. It has a form and a meaning, but only for those who learn to read.

To learn the character, the language, and the meaning of inscriptions sculptured on the world by fire and frost is worth some trouble. The geological alphabet—the first lesson to be learned is—Form.

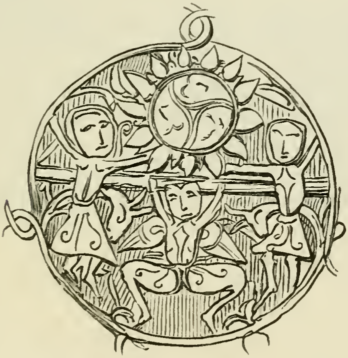

FIG. 4. AN EASTERN SYMBOL.

CHAPTER V.

ATMOSPHERIC FORMS.

If ever there was a time when the solid surface of our world was a newly-formed hot crust of stone, there must have been an atmosphere about it, whatever its composition may have been ; for our gases and fluids, air and water, only expand by heat.

Movements in any gaseous shell must have resembled those which now take place in the air from the action of heat, cold, and gravitation, whatever the surface-temperature may have been ; and these atmospheric movements surely left marks upon the solid crust from the beginning, because they do now.

We have but to look above us to read some of the ancient characters, which are and have been written in air, and to learn their meaning. They are forms which reveal forces. On a calm clear summer evening, after a thunder shower, when the setting sun is near the horizon, and the wind is still, great masses of vapour often pile themselves up into fantastic shapes which can only be seen in profile from a distance. They are easily drawn, and easily photographed. Those to the eastward shine like snow in the evening sunlight, and their shapes are clearly defined by light and shadow. Those to the west are dark, or edged with brilliant light, and their outlines cut sharply against the western sky.

Such clouds float steadily in the air ; they are unaltered by

wind; but when they are closely watched, they are seen to change their forms at every instant.

There are magazines of force within them and without, and changing forms point out the directions in which these forces act.

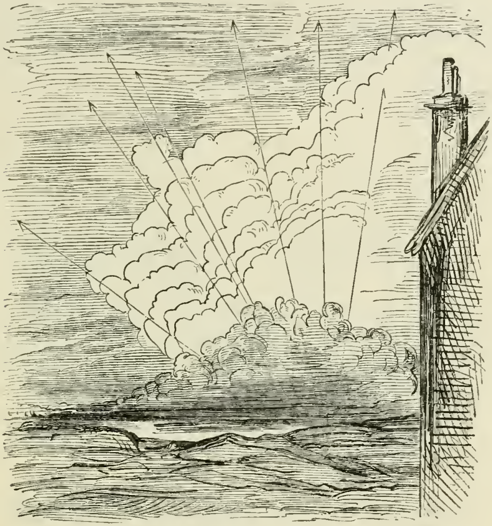

FIG. 5. DIAGRAM TO SHEW THE GROWTH OF A CLOUD.

The outlines were traced with a pencil on the ground glass of a camera obscura, at short intervals, on a still, bright, hot evening.

Whoever has been enveloped in a mountain mist or a city fog, knows that a cloud is commonly made up of minute floating spheres of water, and these are moved about by currents of air, which are moved by some force.

These liquid spheres form at one place and disperse at another, according to the temperature and humidity of the air about them; but while they exist as drops in clouds they collect and scatter, and move according to movements of the air in which they float. Clouds are but fleeting characters written in air; but while they endure, they tell their story by their form and by their movements. In order to see these cloud-forms, and note changes which take place in them, they must be far off, for clouds are of enormous bulk.

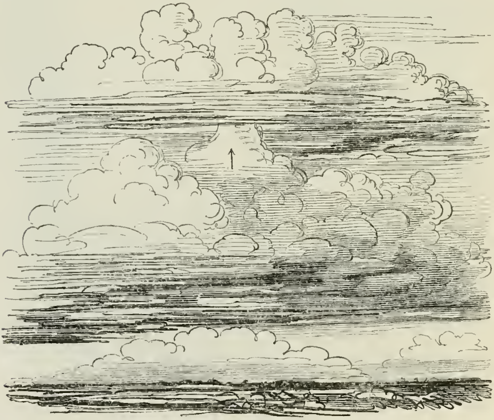

FIG. 6. "CUMULI." SKETCHED FROM A RAILWAY TRAIN.

"Cumulus" clouds which form above London are higher than the Alps, and, like Alps, they must be seen from a distance before the eye can take them in. But when they are seen, under favourable circumstances, their movements tell of upward and downward currents in air—of expansion

and contraction in particular regions—of currents which are analogous to those which move up and down, and sideways, in boiling water.

The lower edge of a distant cloud is often nearly a straight line; it is, in fact, the outline of the under side of part of a dome of vapour, forming at a certain distance above the earth's convex surface. The upper side is a heap of great rolling mounds which are constantly moving, swelling, and shrinking; rising and falling.

As warm currents of air rise through the vapour, rolling clouds expand upwards, and change from rounded domes to conical piles, and they flow over, and spread out upon the higher layer of atmosphere through which they have been

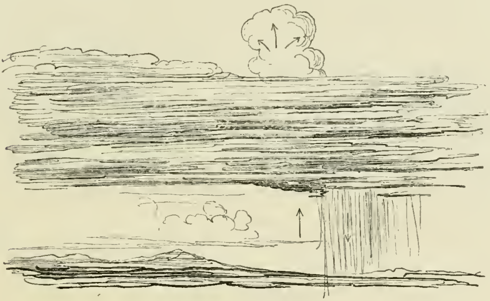

FIG. 7. RISING AND FALLING.

thrust, taking the shapes of mountains. So long as the sun warms the cloud, or the earth beneath it, the upward expanding motion continues. But when the sun disappears below the horizon, the action grows less, and the movement is reversed.

The great boiling mass ceases to boil; and settles down into layers of even thickness. The "Cumulus" becomes a "Stratus,"

or perhaps a cold wet current of air joins company with the cloud; drops grow larger and heavier, and the whole fabric tumbles down as a heavy shower. Then the "Cumulus" is a "Nimbus," and the source of a flowing stream.

It is the same whether the growth and decay of such clouds be watched from below or from above.

At sea there are no mountains to interfere with winds which blow along the surface of the water; so clouds, if they change their form, alter because of forces within them.

Thus, off the Orkney Islands, with a strong north-westerly breeze below, a distant mass of cloud on the southern horizon was seen to move so as to indicate upward and downward currents moving within the system of air which moved eastwards along the sea. The clouds also shewed higher currents moving in various directions. Steep conical peaks rose up out of flat clouds, which moved with the wind towards the south-east; more and more followed, rising till there were rounded domes; and these in their turn spread out and flowed over, and broke up into detached masses, which drifted away before upper currents. But the cloud spread to windward as well as to leeward, eastward and westward from its own centre of movement. It contained a radiating force.

When the upper sides of clouds are seen from a high mountain, the same forms appear.

From the top of the Rhigi, before sunrise, the Swiss lakes may often be traced among the mountains. Each is covered with a canopy of gray cloud, beyond which there stretches a frozen sea of mountain peaks cutting clearly against the rosy sky. Distant detached hills to the northward stand up like blue islands in lakes of gray mist, resting becalmed upon wide plains. But when the sun rises motion begins. The stratum of flat mist rises up, and heaves, and the gray plain

becomes a troubled moving sea of rounded hills of vapour, all bright and shaded, and glittering in the morning light. As the day wears on these rounded masses separate, break up, and creep along the glens and hill-sides, rising as they go, and by noon piles of rounded white cumulus clouds are peering over the tops of the highest mountains, or covering them. Later in the day a traveller in a valley may find himself drenched by heavy rain, while one upon a higher level, or in the plain, is rejoicing in bright sunshine. But if a wet pedestrian ascends an outlying mountain like the Faulhorn, he may pass through the falling shower into the cloud of little floating drops, and so through gray mist into bright sunshine and clear air. He may see the mist creeping up the glens, because the sun is warming the hills, and rain is condensing about the cold snow.

This engine is worked by fire and frost.

Shortly before sunset, on such a day, the lookout from such a spot is very beautiful. The great snowy Alps glitter in the bright light and clear frosty air, and seem to be close at hand, till some distant thundering noise calls attention to a few rolling grains of white dust. Then the real distance is measured by the help of the grand sound of a falling avalanche, and the giants assume their true proportions.

The sea of cloud which surges against the mountain a few hundred feet below the peak, changes its shape at every moment, as currents of air rise from glens below. The atmosphere is all in motion, though there may be no general horizontal movement at a particular spot and time.

But, when the sun sets, this local motion gradually decreases, and cold moon-beams may play upon a quiet stagnant silvery ocean of gray cloud resting becalmed upon hill and plain, or creeping slowly upon still water.

We live in a sea of boiling air, and when its local movements are made visible by clouds ; heat, cold, and gravitation —radiating and converging forces—are seen at work in the atmosphere.

Force is revealed by form.

On these forces and on these movements depend all atmospheric changes and the science of meteorology, which treats of them.

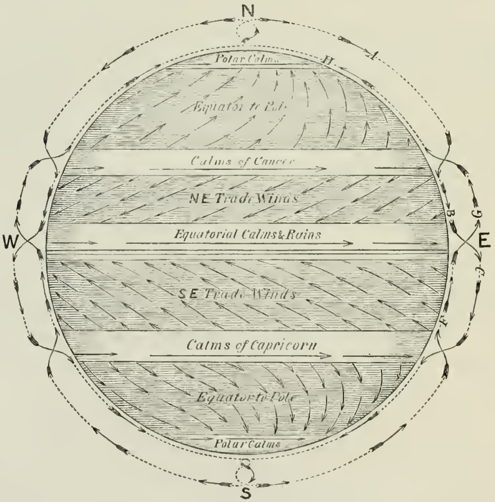

FIG. 8. DIAGRAM OF THE WINDS, BY LIEUT. MAURY, U.S.N.

"Abstracts of Meteorological Observations, etc.," edited by Lieut.-Col. James. London: Eyre and Spottiswoode, 1855.

CHAPTER VI.

METEOROLOGY.

THE modern science of meteorology is founded upon upward and downward movements in the whole atmosphere.

All storms have been traced to the movements of two great currents in each hemisphere, which move like local currents, and for the same reason. These are north-east or north polar, south-west or equatorial, in the northern hemisphere; south-east or south polar, north-west or equatorial, in the southern hemisphere.

These great currents are attributed to upward and downward movements:—to the rising of light warm air near the equator, and to the falling of heavier colder air at the poles. Atmospheric movements then, whether large or small, general or local, are attributed to the action of heat, cold, and weight. But these simple movements are modified by the earth's rotation and by change of weight.

A cold heavy current of air, moving southwards from the north pole towards the equator, moves also towards the west along the earth's surface. It appears as a north-easterly wind, and it gathers heat and loses weight as it moves.

The equator is a larger circle than any other which is described by a point on the earth's surface about the earth's axis, and its parts move through a larger space in a given time.

A mass of air moving southward from a small revolving circle near the north pole, and also moving eastward together

with that part of the earth from which it sets out, lags behind a point upon a larger circle which is nearer to the equator, and is revolving eastward with greater speed.

So a north wind becomes a north-easter. A point on the edge of a disc, ten miles from the north pole, travels round the axis, a distance of about sixty miles, in twenty-four hours : it moves about as fast as a man walks : but a point on the disc, whose edge is the equator, moves eastwards more than a thousand miles in an hour.

So a north wind moving southward over Scotland, and eastward at the rate of Iceland, is passed by a Scotch tree as a man walking eastward is passed by an express train. A polar wind is a north-easter in the northern hemisphere, and a south-easter south of the equator, because air lags behind earth and sea when moving from smaller to larger circles. But the polar wind does not blow furiously, because air is dragged round and gains easterly motion as it gathers heat and loses weight on its way to the equator.

For a like reason, an equatorial calm, which sets off along a meridian, and blows from large to small circles, becomes a westerly wind. It plays the part of the railway train, and overtakes the crawling tree which grows on the British Isles. It bends trees, but does not always tear them up by the roots, because it is held back by friction.

The warm light equatorial south wind blows because air expands, and loses weight, and rises ; it becomes a south-west wind because the earth turns eastwards.

The prevailing direction of the wind in the British Isles is about south-west, and trees proclaim the fact by form.

In Wistman's Wood, near Dartmoor Prison, at an elevation of about 1200 feet above the sea, a curious stunted scrub of gnarled oak, said to be "as old as the creation,"

shews that the prevailing wind has been south-west since the oaks were acorns.

The strange old trees stretch out their twisted, tangled, moss-grown, fern-clad arms towards the north-east, and bend their hoary trunks in the same direction, as if seeking shelter. But on the hill above them, a great boulder, as big as a house, proves that some force stronger than the wind has acted in the contrary direction, *towards* the south-west. The stone has been pushed from its place, and rests on the hill side.

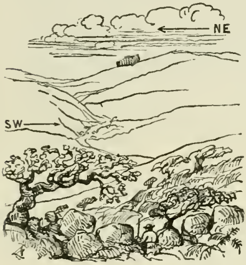

Fig. 9. Old Trees and Boulders. Wistman's Wood, Dartmoor.

Wherever a tree grows on the western coast of Ireland it bows its head to the north-east.

Every exposed Welsh tree bends towards the dawn.

Every exposed tree on the west coast of Scotland seems to be driven by a furious wind on the calmest day. About Edinburgh it is the same. On the east coast, on North Berwick Law, an old thorn tree streams towards the north-east, and every tree in that neighbourhood that dares to peep over a wall, straightway assumes the form of an old broom, and points eastward.

At Dalwhinny there is something almost ludicrous in the stormy look of a whole wood of fir trees which point their fingers down Strathspey, and bend their trunks as if yielding to a furious gale.

In Scotch islands, at least as far north as Orkney, it is still the same. Trees are vanes, and no other wind-gauge is wanted to shew that the atmosphere has a habit of rushing

past the British Isles from west to east on its way north. If the true bearings of exposed trees were taken and mapped, a wind chart might be added to the physical atlas.

But though there are prevailing winds, and a general atmospheric system of movement; the easterly and westerly, heavy and light, cold and warm, polar and equatorial streams, which cross meridians in travelling north and south, one above the other; get entangled and whirl round as rotatory storms. On one side of the equator the storms revolve one way, on the other they whirl in the opposite direction, as whirlpools do when a stream flows into still water; or when streams cross or meet; under bridges and behind posts.

The meteorological department of the Board of Trade have a hard task, though an able leader, when they try to forecast winds. But for all that, the strongest wind that presses on British trees goes towards the north-east.

At places where winds meet and mingle, currents flowing in opposite directions neutralize and roll over, and whirl about each other; and so whirlwinds, circular storms, calms, and partial winds of every strength and direction, occur; though light and heavy currents keep their places, and surface winds are almost constant in some latitudes.

When opposite currents are flowing, clouds betray them by form, and they are commonly seen.

When a strong south-wester is driving in a flock of detached clouds from the sea, the clouds transform themselves as they fly.

The wind drags along the surface.

The under side of the cloud drags also and stretches backwards, but the upper side is pushed forwards and rolls over like a curling wave. There may be a strong breeze below, but a gale higher up; and higher still clouds may be spread

out on calm ripple-marked plains, where currents are passing each other, and rolling up the clouds between them into mackerel sky.

FIG. 10.

All these forms do but indicate movements which result from the action of two forces ; one radiating from a centre, the other converging towards it, and the science of meteorology is founded upon these two forces and on their action, above the earth's surface, in the air.

Air is constantly moving up, and down, and sideways, above water and solid ground. Meteorology attempts to explain the movements, and the moving forces are heat and weight.

The main facts were known to men when the first chapter of Ecclesiastes was written, as Maury points out in his writings.

" 5. The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.

" 6. The wind goeth toward the south, and turneth about unto the north : it whirleth about continually; and the wind returneth again according to his circuits.

" 7. All the rivers run into the sea ; yet the sea is not full :

unto the place from whence the rivers come, thither they return again."

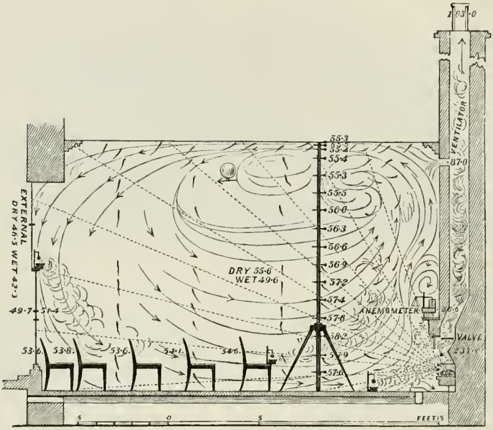

FIG. 11. DIAGRAM OF DRAUGHTS IN A ROOM.

Section of a large room, shewing the positions and mean amount of deflection of silk vanes; temperature shewn by thermometers; force of upward current at the mantlepiece in grains per square foot; moving fumes; balloon; radiation from fire; and the direction in which air circulated under these conditions.

From the "Report on Warming and Ventilation of Dwellings," 320, Sess. 2, 1857.

CHAPTER VII.

AIR.

A CAUSE is found by working up stream—by creeping along any one spoke of a wheel towards the centre. The effects of a known cause are got at by working the other way. Starting from cloud forms, heat is reached. If heat be a mechanical power which moves the atmosphere, forms like clouds should be found at the outer end of shorter spokes in the same wheel.

If a principle be established, many phenomena can be traced to it. In meteorology, as in all sciences, a result is reached by observation of facts, but experiment is the final test of theory, however formed.

A power may be used when found.

If great and small atmospheric currents flow, for the reasons given, and heat and gravitation are radiating and converging forces by which air is moved, then any quantity of air, great or small, ought to be moved in the same way and by the same forces. And so it is wherever the experiment is tried.

Air in a conservatory may be taken to represent an atmosphere. The ground is warm, the roof is cold, and the general mass of air cannot escape beyond certain limits.

If one part of the floor is hotter than the rest, cold currents converge, and fall and flow towards that spot, absorb heat there, and rise like warm fountains to the roof. Thence warm

currents radiate in all directions, and flow towards the cold sides of the building, away from the warm region, and as they move above, they part with the heat which they acquired below. The smoke of a few charges of gunpowder, burned upon the floor of a hot-house, makes the currents visible, and the experiment always gives a like result, because it is founded upon a general law which affects air.

Air expands and rises when heated, contracts and falls when cooled, and moves sideways to find its own level, or escape pressure.

Air within a cottage, with a fire on the floor, obeys the law, and clouds of peat-smoke float overhead, and roll in emulation of clouds in the sky, while small storms blow amongst the plenishing on the clay floor. There is good fresh air in poor huts.

Air in a cave moves in the very same way for the same reason. When a fire is lighted at the extreme end, smoke rises to the cold roof, but it speedily cools and falls again, and returns along the cold floor to the fire, which set air and carbon in motion. It takes some time for heat to force smoke to the cave's mouth, because the hot air which carries it is cooled by cold air in the cave. So revolving systems of radiating and converging currents move in opposite directions, above and below; while men near the fire sneeze and cough, and are lost in clouds of rolling peat-reek. But as the air of the cave warms, the system moving within it enlarges its sphere. The smoke gets nearer and nearer to the door, and finally two regular currents are established. A warm stream flows outwards along the roof, bearing smoke and glowing in the firelight; and a cold chilly draught of pure, clear, fresh air creeps along the floor towards the bivouac. Because they breathe pure air, cottagers, gipsies, and travellers seldom wheeze.

A sail or some other screen makes all snug, and then a wanderer may stretch himself at ease on his bed of heather or leaves, and watch forms in the smoke, and rapid steady movements, which fire, kindled by a spark, keeps up in air, so long as fire gives off heat-force.

It is the same in a cubic foot of air confined under a glass shade. The movements may be seen by the help of smoke ; or delicate vanes made with gold leaf, will point towards the fire and the window, the hottest and coldest spots which can influence air in a room.

Polar and equatorial currents are found under a glass shade when they are sought, and they blow even in close cellars.

Perhaps the largest mass of air enclosed artificially is at the Sydenham Crystal Palace, and there draughts and warm currents are in proportion to the size of the building.

At one end a high temperature is preserved for the benefit of tropical plants, birds, and fish, but the rest of the building is kept cool.

According to theory, there should be a warm moist current flowing along the roof from the warm tropical regions, and a cold dry current flowing along the floor towards them ; but if there were, the temperature within would be too evenly spread by the air. To keep temperature off the balance, the currents were arrested, but they assert their presence nevertheless, and shew pressure by form.

The tropic which divided the torrid zone of the Crystal Palace from more temperate regions was at first a great canvas screen, and its form betrayed the invisible forces which pressed upon it. It bulged outwards *above,* like the topsail of a big ship, and inwards *below* like the mainsail of a first-rate taken aback. The imprisoned breezes could have driven big ships

and large balloons, waves and clouds, east and west, for the sails tugged hard above and below.

A visitor passing the tropics below, passed the door with a cold fair wind behind him, but one who attempted to enter by the upper gallery was met by a strong, damp, warm, head wind. Heat expanded the air, weight squeezed it, and air pushed the canvas, two ways at once.

Thermometers shewed that the lower current was cold and dry, but the upper warm and moist, and the outer glass in the tropical region streamed and dripped with condensed vapour, which light hot expanded air had absorbed.

So, in the Crystal Palace at Sydenham, are tropical and polar currents, and local winds ; evaporation and condensation ; as well as specimens, models, and copies of most of the world's productions, old and new, living and dead.

The principle on which these currents of air move is worth learning, for it may be turned to practical use.

Without oxygen any animal dies ; without fresh air constantly supplied it suffers for want of oxygen ; and these sufferings are in proportion to the absence of oxygen from the air which is breathed, or to the presence of something hurtful in it. Men die for want of air under water. That they often suffer in dwellings for want of fresh air is notorious ; but few ever think why they suffer in mines, or in rooms. Every breath drawn by every living creature is a chemical operation, in performing which oxygen is taken away from nitrogen, and carbonic acid added to it. Within a given time a set of lungs will absorb so much of the oxygen in a certain limited quantity of air, as to leave a spoiled mixture of air, nitrogen, carbonic acid, and exhalations ; a mixture which stops the play of lungs, stills the beating of hearts, and quenches fire as effectually as a like volume of water.

If any one is cruel enough to try the experiment, let him put a mouse on a plate under a tumbler, oil the edge of the glass, and watch the result. The mouse, unless relieved, will certainly drown himself in his own breath. But men and women, for want of knowledge, voluntarily subject themselves every day to sufferings which are the same in kind, though less in degree. The evil is glaring, and the results are but too well known ; the difficulty is to find out the best remedy, and to persuade the patients to take it. Anything is blamed rather than invisible air, and every smoke doctor and engineer has a special nostrum of his own for keeping out " draughts," while persuading fresh air to come where it can be breathed. The plan is called by a long name, and when tried it often fails. Surely it is wisest to teach that fresh air is necessary, and foul air hurtful ; to shew why air moves, and leave men to apply the knowledge, and help themselves. Air driven by heat moves exactly as water does in a boiling kettle. Hot air, or hot water, is lighter, bulk for bulk, than cold air or cold water, at a certain pressure ; and the cold heavy fluid will flow towards the hottest place, and the warm lighter fluid will flow from it as certainly as winds blow and rivers flow, and for the same reason.

There is nothing simpler than "ventilation," if the principle is known and the law of nature obeyed.

Air under the earth obeys the same laws which govern air in the free atmosphere.

In coal mines ventilation is carried out artificially, but according to natural laws, by heating air in one shaft, and letting cold air sink down another ; or by dividing a single shaft, and lighting a fire on one side. By partitions, doors, screens, and brattices, the downward current, set up by gravitation, is made to flow where it is wanted, to dilute and

carry off noxious gases, and supply the means of existence to miners, horses, lamps, and fires, which cannot breathe and burn without oxygen. In some mines air is thus moved a distance of thirty miles, at a steady rate, and more heat moves it faster. A ton of coals burned in a day boils up a breeze. Burned in an hour, the fuel drives an upward gale which blows out candles in rushing down to the furnace.

The system is good, and it only fails when ill carried out, or when the machinery breaks down.

In cold metalliferous mines, driven into hill sides, and out at the top, like those of Yorkshire; where the so-called system of natural ventilation prevails; currents of air move different ways under ground when the outer air is in different states of heat and pressure.

Changes in weight, which move mercury in a barometer, also move columns of cold air shut up in vertical shafts.

Changes of temperature, which affect fluids in a thermometer and in the free atmosphere, also affect air shut up in big tubes and chambers of rock.

Shafts and levels, pits and galleries, mines and chimneys, are but barometers and thermometers on a large scale.

So it happens that when air within one of these mines is colder and heavier than the air outside, a current flows along the adit and out into the glen below, as water does; and it draws air down into shafts at the hill top. Because the air within is heavy and runs out, the upper air falls in after it to fill the void.

When the air outside is cold and heavy, and the air within warmer and lighter, the current is reversed. Light air rises out of the highest shaft like smoke from a chimney, while heavy air flows in below, as water would if the glens were flooded.

In either case, there is sufficient movement to change air in most parts of a mine, with openings at high and low levels.

If barometric pressure is removed outside, the air within expands, and so escapes till the balance of pressure is restored. If there be noxious gas in chinks in rock, or in coal, it escapes most when the barometer is low.

If pressure is added, the confined air is compressed, and the outer air enters till the vacant space is filled.

When a strong wind is blowing outside, it acts upon air within a mine, sucking it out of a shaft as the current passes over it; and driving it in when the wind blows upon the entrance to a level.

But in certain states of pressure and temperature there must be stagnation in a mine, as there are calms at the surface, and on these occasions men are driven from their work.

When no one is able to predict which way the current will flow at any time or place, it is impossible to direct it.

Thus it happens that close ends abound in nooks and corners of mines, in spite of "windy kings," "windylators," "fans," and "water-blasts;" engines which substitute muscular force, water and steam power, for nature's power—heat.

Men are often driven from their work and choked out of mines for days by changes in the weather, when a fire would remedy the evil; though strong fires are burning to waste beside most mines. "Lead miners are as good as barometers" for their neighbours, but nevertheless they and their class generally, seem to be convinced that "weather ventilation" is the best of systems for them, and that fires are only fitted for coal mines where fuel is cheap.

In deep hot mines like those of Idria and Cornwall, where the natural heat of the earth is felt—at a depth of 1800 feet below the surface—in hot lodes, and hot rocks, where tem-

perature rises to 90° and 100°—there is true "natural ventilation," which only needs direction to secure good air. But even in such mines men often trust to nature while working against natural laws.

In one hot Cornish mine everything went wrong at "the end," till a great storm made a commotion in the atmosphere, which reached the hot levels below. The currents changed, and since that time they have constantly and steadily followed their own paths, and all goes well. The men suffer from heat, but they breathe good air—for the natural heat of the earth ventilates the mine.

In all cold mines where atmospheric ventilation prevails, there are "close ends," "poor air," "cold damp," "carbonic acid," and other evils, which cause sickness and excessive mortality, while engine fires are burning to waste at the surface near most of them.

"Levels" which are open at one end and closed at the other; where work is going on, ventilate themselves, though slowly and imperfectly, on the general principle. They are like long low caves, 7 feet high and sometimes 300 feet long, and men and candles heat the inner end. There is consequently a light warm column of air at one end, six or seven feet high, while at the other is an equal column of colder and heavier air, which presses upon and displaces the other. Heat forces out a wedge of air along the roof, while weight forces in a wedge of purer air along the floor. When a shot has been fired, the smoke is seen rolling slowly out in thick volumes along the roof, while there is little or none below. In an hour or in many hours the smoke is gone, and in time it will be found rising out of some shaft, if followed. But smoke often hangs for days in close ends, because men and candles are weak caloric engines.

If a regular and constant current, however slow, passed through a mine, down one shaft and up another, which would be the case if an upcast shaft were joined to an engine furnace-door; then brattices and trap-doors would turn the current into any corner, however distant, and so miners would suffer less from bad air if they used power which they throw away.

In dwelling-houses it is the same. Heat and weight cause movement in air everywhere, but the simple law is often forgotten, unknown, or misunderstood. So it happens that contrivances meant to promote ventilation impede movement in air.

To warm a room is easy. Every savage who kindles fire knows the art. It is only requisite to burn enough of fuel to warm a hut; and a leaky hut ventilates itself.

Fuel burned on the floor of a cave or hut, in an open fire-place or a closed stove, in a mine, a lamp, or candle, or in any other contrivance, is a source of heat, and that is power which may be used or wasted.

The fire radiates directly to all places to which straight lines can be drawn from it; indirectly wherever rays of heat can be reflected or refracted, and the radiated heat is absorbed and given off by everything within its reach, in proportion to the supply. The fire is to things in a room what the sun is to the outer world; but a room is a small world, and, unlike a hut, it is nearly air-tight.

To change the air in dwellings with chimneys and doors, or in mines, it is only necessary to put right fires in right places, and let air follow its natural course. To ventilate close rooms air-holes must first be made.

Fire acts mechanically by expanding air about it, and every separate object which is warmed by radiant heat and is warmer than air in contact with it, gives heat to air, both by contact and by radiation; expands it, and so moves it. Cur-

rents, like those which are caused by natural heat in the atmosphere, circulate in dwellings because heat is set free, reflected, and refracted. But fresh air cannot get in if " draughts" are kept out.

There is a general system of currents which radiate upwards, away from the hottest place in a room—be it fire, or stove, or heated pipe—and which converge downwards and move towards it, after the spreading currents have carried heat to the coldest places, and have left it there. There are miniature radiating and converging equatorial and polar currents in every room, as in every mine, and ventilators should use them.

There are small local systems which circulate about every candle, or heated chair or footstool, stove, or living creature, in a human dwelling, mine, or other closed space. These are as eddy winds, land and sea breezes, domestic whirlwinds, and family storms ; and their progress may be watched in graceful curves which form in clouds rising from peat fires, pastiles, tobacco pipes, newly extinguished candles, matches, powder, steaming tea-cups, or the kettle.

To warm and ventilate, it is only necessary to burn fuel, and direct the currents of air, which must move somewhere.

Let the window of a warm room be partially opened above and below, and let threads, ribbons, grass, feathers, or any other light material, be hung in the openings to act as vanes. It will be shewn that light air is escaping above, with a charge of heat taken from things in the room ; that heavy air is entering below to be warmed, and that the air in the room is revolving as a current of water eddies in a bight. It is the case of the mine in a hill.

If the same thing is tried in a room colder than the outer air, heavy cold air flows down and falls out of the window,

as water might do; and light warm air enters the window above, deposits a freight of heat in the room, and then follows the outward stream. In either case the movement goes on till the mechanical force is expended, till the unequal weights are balanced, and pressure and temperature the same.

A living being is a source of heat, and a cause of movement in the air of a room, a mine, or any closed or open space. The warm breath and natural heat of a man who enters a cold room and takes up a position in it, moves air and cobwebs on the ceiling, at a distance of 30 feet, in about a minute. A miner moves the air in which he works; a mouse moves air under a glass shade; so does a rabbit in his hole.

The smell of a newly-lighted cigar moves about 30 feet in two minutes in cold air in a room; but the rate of motion depends upon the coldness of the room, and the energy of the smoker. The sun and a pipe are different sources of heat and power, and currents of air flow when power acts, whatever the source of it may be. But a man and a candle work on air in a large mine, as a sailor's pipe does on a calm at sea.

An elastic balloon filled with a light gas, and carefully weighted, so as barely to rest on a table, expands and ascends when placed on the floor opposite to the fire. It is like a cloud warmed by the sun. It moves along the ceiling, away from the fire, towards a window, falls where it cools, and drifts back towards the fire along the floor. It rises because it expands; it expands because it is warmed; and it follows the stream of air, and shews its rate and direction. It does not move of its own accord, neither do the currents which move it. They move because they are expanded and compressed, and go fast or slow in proportion to the heat used to move their weight.

The smoke of a lamp where it blackens a ceiling, shews the course of currents of air by forms in which carbon is arranged. The forms are tool marks, and the tool is air.

Ice forming on a window, and hoar frost under a door, take the shape of streams of air moving in a room and entering a house.

Silk vanes, cobwebs, or any light substances hung about any closed space, shew currents of air by form as clouds do.

Air escapes from the garret windows of a warm house, but enters the cellar door. The cause is still the same.

There is pressure where currents are impeded, as shewn by the skreen at the Crystal Palace. There is outward heat-pressure on a garret window when closed; inward weight-pressure on the lowest door, and cold air will open the door and enter, if the latch be turned on a winter's day.

When pressure is greater than resistance, as when a house burns, air, urged by strong heat and weight, shews more power; upper windows burst outwards, lower windows are crushed in, and hard glass is shattered by invisible gas.

Imprisoned air, aided by more heat, bursts iron in a mould.

The atmosphere and weight crush iron boilers when water inside is deserted by heat, and steam loses the ally, without whose aid steam is ice.

And the atmosphere, when urged by the sun, and by the earth's gravity and rotation, sometimes becomes a hurricane which sweeps away trees and houses in its resistless course.

So heat and weight are strong useful powers; good servants if bad masters; and they work with air.

Some years ago an experiment on a very large scale was made in a coal mine below the sea-level, and it affected gases of very different specific gravities.

A northern mine in full work is a strange busy scene.

At the pit-mouth fires flare and smoke; steam-engines pant, and puff, and wheeze; chains clank, wheels rattle, and waggon loads of coals rise up, rush from the pit, and crash down shoots into railway trains. There is a fearful din.

Men step on a smoky platform, and down they go like Don Giovanni and the commandatore. Down they sink rapidly; and if unused to falling, their hearts seem to rise.

If the pit be an upcast, the smoke is dense, and the air grows hot, and hotter, and hotter still, as the skip slides down the chimney. It passes the furnace vent, the air clears, and the journey ends; it may be, far below the sea-level.

At the bottom of the pit there is bustle and busy work. Shouting and grinning, black, half-naked urchins, push waggons of coals rattling over iron plates, and up they go like a puff of smoke. Sleek steaming ponies, who never see daylight, trot in with trains of waggons from distant ends, grimy postilions with lamps in their hands ride in from distant stations, with arms clasped about the necks of their steeds, and heads bent low to avoid the roof. Black railway guards crouch in their trains and grin, and clouds roll from every open mouth and nostril.

The boys always ride home from their work if they can, and sometimes they ride races.

Lights flit about, gather, and disperse. Half seen forms, —a man's head and hands, or half a face; a tobacco-pipe smoking itself; horses' heads with glittering eyes and smoking nostrils, with a figure of fun grinning out from under the mane; all the fancies of Teniers, in his wildest mood, seem to float about in the darkness.

A cluster of these visions and their lights gather and

grasp a bar; three raps are heard, and they fly smiling up the chimney after the coals and the smoke.

At the end where the work goes on, these gnomes are constantly burrowing on, and bringing down their roof. The coal foundation is picked out, and the upper coal, the old sandstone flags, and the shales above; the arched roofs of this vault, with all their loads, begin to yield and split with a strange ominous noise. "CRICK." Wooden props shoved in feel the load, and they too complain and creak. When the full strain comes on them they are crushed and riven to splinters, and the roof "roars like cannons when it is coming down."

A spoke in the world's wheel is cut through and mended with sticks; the scaffold which supported the flat arch is dug away, so the arch comes down and the sticks are crushed.

With his head touching the roof, and his feet on the floor of a mine, a collier stands under a stone column it may be 2000 feet high. A weight sufficient to squeeze him as flat as a fossil fish is coming down, and he hears it coming, but he works on and smokes placidly under the lee of his prop, rejoicing to see weight help him to quarry coals.

That is working according to natural laws. That is using a power which has been found. That is one use of weight.

Some years ago, the workings of two such coal mines near Newcastle were purposely joined. Each underground world had its own atmosphere, with its system of currents. It is important to keep the stream moving, to make it move along the face where men work, and to know the way the stream flows, in order to be able to guide it. So these black gnomes, with shining oil stars on their foreheads, and gleaming teeth and eyes, argued keenly in their separate burrows. They are a shrewd, knowing race these northern Teutonic gnomes;

they know that fire-damp or choke-damp may blow them to bits, or drown them if their atmospheric systems go wrong. They know their own interests, and generally know how to secure them. So they held high council about their winds, when their systems were approaching each other.

The pits were miles apart, but a thin block of coal divided the workings at last.

On either side stood an anxious man reading the weight-power that pressed on the coal, from the dial-plate of an aneroid barometer. That was another use for weight.

A blow demolished the wall, and the mines were successfully joined. Weight turned the scale again. The lightest column went up, the heaviest came down. The trade wind blew towards the barometer which shewed least pressure, away from that which shewed most, by standing highest; and the coal wall being gone, the barometers marked the same pressure at the same level, and regular circulation went on.

There was less pressure in one mine, because there was more heat; and the colliers poked their fires, and rejoiced in fresh air, and scorned danger overcome.

They had got the mastery over weight and heat; and the giants and the gnomes now work amicably together in their united dens under the earth.

In deep cold metal mines, where a few narrow pits all open about the same level, stagnation is the rule. So long as air inside the stone bottle with the slender necks is colder than air outside, it is heavier. There is no natural power applied to lift it, and it cannot flow out for want of fall. Like water collected in an old working, the cold, heavy mine air is a foul deep stagnant pool, which evaporates a little, overflows now and then, and swings about in its rocky bed; but it never changes like water in a river pool, because

there is no stream flowing through it. Such a mine is a contrast to one through which air moves constantly.

On a fine, warm, breezy, bright, sunny day, with the sweet breath of fields and heather hills in his nostrils, a pedestrian in search of information comes to a trap-door and a hole like a draw-well. Odours of bilge water and rotten eggs, mildew and worse things rise when the trap is lifted, and they contrast abominably with the delicate perfume of beans and hedge-rows. The pool moves when it is stirred; but when left to its own devices, the most delicate tests often fail to shew any movement at a pit mouth. Cobwebs, paper, silk, soap-bubbles, and smoke, which shew movement in the stillest room, all indicate repose at the neck of the bottle, for the unsavoury air stagnates in the cold dumb well which holds it.

If the average temperature inside be 60°, and outside 61°, there is nothing to lift the lowest stratum.

There is no rattle, no din, no movement here. A dull sleepy creaking sound comes faintly in from a big water-wheel, which is slowly turning and pumping water from a neighbouring hole. The only cheery sound about the place is the rattle of hammers and stones, where boys and girls and strong-armed women, are smashing and washing ore in sun-light and fresh air. Like bees they sing as they work cheerily. Their cheeks are ruddy, and their bright eyes dance with fun; but down in the dark well is sickness, silence, and gloom.

A distant sound is heard below; the yellow glimmer of a candle shines out of the black earth; hard breathing approaches, and the regular beat of thick-soled boots on iron staves comes slowly ticking up the pit, like the beating of a great clock. A mud-coloured man appears at

last, and he stares amazed at the stranger perched at the mouth of his den ; seated on a sollar, and watching cobwebs with a pipe in his cheek. The miner may be blue, or yellow, green, brown, orange, or almost red, but he is sure to be gaunt and pale-faced. His hair and brow are wet with toil; his eyes blink like those of an owl in day-light; he wheezes, and he looks fairly blown. With scarce a word of greeting, he stares and passes on to the changing house; and the cobweb which he disturbed settles like a pendulum at Zero once more.

When a lot of miners who work in such mines gather amongst other folk, they are as easily distinguished as blanched celery from green leaves.

When visitors go down, guides and strangers dressed in their worst, each armed with a vile tallow dip, stuck in a ball of clay, cluster about the well, which is called the "foot way," and one after another they vanish from the upper air.

The TICK : TICK : TICK : of many feet wakes up echo, and hot breath stirs the air. For the height of a town-church, down they go into the darkness, and their steaming breath rises up like blue smoke. When daylight fails, a halt is called, and candles are lit on the ladders.

This travelling is, to say the least, uncomfortable. A man in the middle has to watch that he may not tread on the fingers next below him, and to look out for his own knuckles; to hold the sharp, cold, greasy, gritty iron rounds, and the candlestick of soft wet clay, so as to hold the grip without losing the light, or singeing his nose with the candle. He has to feel for his footing, watch for damaged or missing rounds, and generally keep his wits bright; for there may be fifty fathoms of sheer open depth at his elbow, and nothing earthly to save him if he slips or stumbles in this "foot-way."

The Col de Geant in the Alps, Eriks Jökull in Iceland,

a long day after the deer, and a day's march with a heavy pack, are easy journeys to a mining scramble through dirt, darkness, and foul air.

Like a train of Irish hodmen, slipping down from a London house, down goes the procession; and those who are unused to the work find it hard labour. The way into this Avernus is not a facile descent. In half an hour, or an hour and a half, according to pace and distance, a journey which costs minutes and seconds in a coal mine, ends at the bottom of the mine where machinery is unknown. It is the goat's track against the railway; the fox's mine against the work of human brains. It is the old story of brute force and skill, giants against dwarfs; and the clever dwarfs who circumvent the giants best get most work out of them in mines as elsewhere.

On the floor of a coal mine the footing is sure. In the other, passages are made at different levels, and they are full of pitfalls, and uneven in height and width. Tramping and splashing through mud and mire, over hard rock and piles of rubbish, the train moves off. When the level is reached, a miner leads, another brings up the rear, and strangers file off and keep their places as best they can.

"Shoot:" cries the leader, and ducks his head. The next finds the edge of a sharp ironshod trough at the level of his eyes, dives under it in his turn and passes the word; "SHOOT." It is the place where ore is shot down from upper levels into waggons, and it is a trap to break the heads of the unwary.

"Sump:" cries the leader, and the follower, with his candle flickering in his eyes, finds that he stands on a single plank, or a narrow ledge of stone, above a black abyss. In daylight, heads are apt to swim above such depths, in the dark that feeling is absent; so each in turn passes the bridge and the

word: "SUMP." It is the place where ore is sent down, or the top of an air chimney, or the mouth of a pit dug into the vein.

"Deads:" and the leader proves his descent from some burrowing ancestor, perhaps a badger, a rabbit, or a rat, by crawling up a heap of rusty stones, wriggling through a long hole, and sliding down head foremost into the passage beyond. He looks very picturesque. The soles of his boots disappear at last, and one by one the procession struggle through and take the colour of the mine from its roof and sides. And so for half a mile, or a mile or more, it is "heads!" "shoot!" "sump!" "deads!" splash, tramp; and by that time all hands are wet, hot, greasy, smoky, and muddy. The smallest hole in an air-way is the measure of the current which can pass, so deads throttle the mine.

Having driven two long caves, one above the other, so far that candles will no longer burn at the ends, and men can hardly breathe, the next step in metal-mining is to "rise" and "sink" and join the caves; to make a passage for air to move through if nature so wills. It is easier to rise than sink, for loose stones fall when blown out of the roof, but as men rise into the rock, smoke, breath, hot air, and light exhalations rise with them. Thermometers rise also to 70° and 80° though water in the level and the rock may be at 60° or 64°.

To get up to the top of a rise "stemples" are often fixed for steps. These are bars of wood on either side, and to mount is like climbing a chimney. The stones which are quarried at the top are thrown down and gather in a conical heap below. So the place is well called "a close end."

In order to get oxygen into this black hole, a small boy, whose life, like Mr. Mantelini's, is one perpetual grind, is stationed at some place where the air is thought fit for -

With a circular fan and a leaky tube, or with a thing like a magnified squirt; by the muscular force of a young male caloric engine, with the idle nature of a boy, some air of some sort is driven to the end, and half-choked men and dim candles struggle on for life in the burrow.

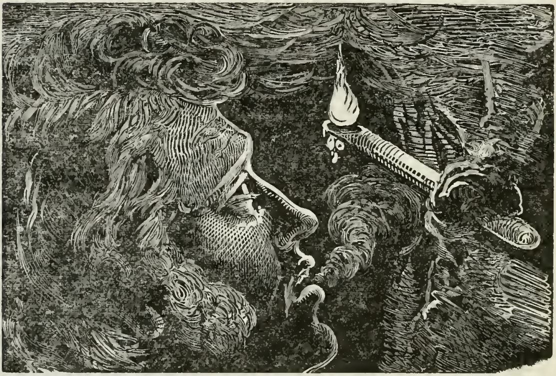

FIG. 12. Ventilating engines, commonly used at close ends in Metal Mines.

The lungs of a healthy man hold as much air as some of the squirts used, and one was expected to supply oxygen to three men and three candles.

The collier laddie who does like work, has a lamp and a book; he sits beside a door with a string in his hand, and his duty is to open the door when any one passes; to keep it shut, and keep his own eyes open at other times.

The one guides air intelligently, the other urchin drives it by weak brute force, and with bad engines. The ventilating boy engine passed, the leader dives into a rolling cloud of thick fœtid smoke. His candle turns into a nebu-

lous haze, his legs are seen wading alone after his body has disappeared, but both are found together at the end. With hands and feet on either side of the rise, in the graceful posture of a split crow, or a wild cat nailed on a kennel door; through showers of dust and falling stones, up sprawl guides and followers with many a puff and cramp till they crowd a shaky platform at the top of the rise. It is the place where men work for hours, days, and months.

One effect of these close ends on one who is unused to them is to cause perspiration to break out freely while standing still, or sitting quietly, resting where a thermometer marks 64° or less. There is a feeling of tightness about the neck; the chest heaves with a gasp, instead of rising steadily; the shoulders take a share in working the bellows; and generally there is distress, and a feeling like nightmare. Men at work in bad places pant and seem to breathe painfully; their faces are red, or purple; their veins swelled; their brows wet and begrimed with soot. They seem to labour hard, though their work is not harder than quarrying stones elsewhere. In such places candles flicker and sometimes go out altogether; no puffing or drawing will light a pipe or keep it lighted. There is no laughter, no fun; no busy cheery clatter of active labour at close ends; there is silent toil; for carbonic acid is not laughing-gas.

When a sump and rise meet, where they have "holed through," the hot air in the rise flies up into the upper level, and the cold air falls in behind it. The temperature changes instantaneously and the hole clears as fast. Heat and weight have room to act, and they do the work of many boys. Fans and squirts are thrown aside, till the levels have been driven another stage.

But the foul air of an end is only diluted with less foul air if there be stagnation at outlets, where cobwebs are still.

To retrace downward steps, to return to upper air, has ever been labour and hard work. From the bottom of a deep mine, perhaps from under the sea whose waves are heard rolling stones above the roof—up perpendicular ladders, perhaps in the pumping shaft with the rods moving up and down within a few inches of his back; with foul stinging mine-water dripping on his head, and a smoky candle sputtering in front of his open mouth; edgeways through clefts, on all fours, feet foremost, head foremost, on his back, his belly, and his sides, the amateur miner follows his guide. Greasy, muddy, drenched, streaming with perspiration, with throbbing ears, giddy, tired and gasping like a fish, the man who is used to climb mountains in fresh air struggles back to it.

When daylight appears, glimmering far over head, when the trap-door is passed, the first long greedy draught of the clean pure air of heaven seems too strong. It flies to the head like brandy. Even miners who are used to such places often stagger and totter like drunken men when they come "to grass." These were the sensations of the winner of a Highland hill-race, in good condition, at the age of twenty-eight. In well-ventilated mines ordinary fatigue was the sole result of many a long scramble under ground. An ill-ventilated mine is a crying evil; air in it is slow poison; working in it shortens life; it proves ignorance, parsimony, or poverty—for ventilation is easy to intelligent men, who will learn an easy lesson.

By analysing air collected in close ends, Dr. Angus Smith has proved the existence of poisonous gases, in places where these sensations are felt. So working in these places must

be injurious. It has also been proved that mining shortens life, where ventilation is faulty.

It appears, from calculations made by Dr. Farr, immediately after the census of 1851, that Cornish miners who work where currents of air are weak and uncertain, die faster than the Cornish population who live above ground. They die faster than colliers who, in Durham and Northumberland, work in places where air is moved by the direct application of heat-power to it; where currents are strong and regular in the mines.

Foul air fills the black list faster than fire-damp and choke-damp, and all the perils which colliers brave.

The death rates between certain ages were as follows :—

Ages.	Cornish people above ground.	Northern Colliers.	Cornish men under ground.	
35 to 45	10	10	14	per 1000.
45 to 55	15	17	34	
55 to 65	24	24	63	

So the principle upon which currents of air move has been turned to practical use in northern coal pits.

A leader in the *Times* of February 4, 1864, shews the evil in dwellings.

Festiniog, in Merionethshire, has been a healthy place for many years. It stands where mountain air is pure, and natural drainage good. The people were well off, and neither intemperate nor uncleanly in their personal and domestic habits; they earned good wages, but they slept in foul air.

A new slate-quarry drew men to the district; no one had time to build; the work went on day and night; so houses, rooms, and beds, like the lodgings of Box and Cox in the

farce, were occupied continuously by successive tenants. In two low bedrooms, 8 × 6, and 12 × 6 feet, ten and twelve people were lodged. In some lodgings the beds were never vacated, nor the rooms aired, either by day or night. So fever broke out amongst the overcrowded. There were six or seven hundred cases amongst six or seven thousand people, and sixty or seventy died.

Without fresh air constantly supplied, men do suffer; but air is free to all, if they will only open their mouths and take it.

The law which governs air above the sea-level is good law under it; and governs all gases and all fluids, fire-damp and choke-damp, steam and water, as well as air. It governs air in copper-mines and in coal-pits, in houses and in the atmosphere.

Bacon was right when he wrote long ago, "IT WERE GOOD FOR MEN TO THINK OF HAVING HEALTHFUL AIR IN THEIR HOUSES" (vol. iii., 297).

There are many tool-marks which moving air leaves on the earth. It bends trees; it uses them as levers to tear up turf and stones; it blows sand; it blows waves against a coast, and the coast wears into cliffs. The atmosphere is but one part of one wheel in a vast machine; and it leaves its mark on the world which turns within it.

The moving powers are few and simple, and the forms which shew their action are easily learned from smoke, trees, snow-drifts, sand-drifts, waves, and clouds.

These have a meaning which can be read and translated; they shew movements in air by their forms. Motion shews force, and its direction; its nature is found by experiment.

Experiment proves that Heat, Cold, and Weight are forces which produce upward, lateral, and downward movements in air, and so mould forms, and wear solids.

Observation finds these forces distributed in the world so as to fulfil conditions which produce these movements in air; and that heat comes from the sun, and from the earth. So cloud-forms and air-marks shew the mechanical action of solar and terrestrial heat, and of weight, in the air. They are tool-marks.

All atmospheric movements, great and small, can be traced to one general law, which governs gases; and fluids also. But before a law can be applied, it must be well known to those who apply it; and the laws of natural ventilation are often unknown to men who try to fill houses and mines with pure air.

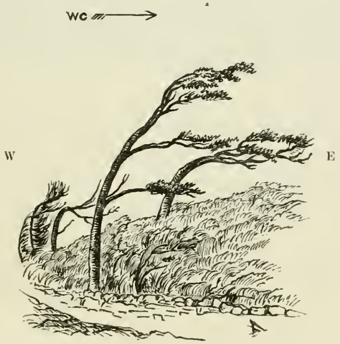

FIG. 13. BENT TREES NEAR LITTLE ORMES HEAD.
Sketched in a calm. 1863.

CHAPTER VIII.

WATER.

If heat be a force which moves all gases away from centres, then for that reason alone it is probable that heat also moves liquids, and in the same direction.

It is not necessary to begin at the dial-plate, and work through a whole train of machinery, in order to find the centre of every wheel; or to go back to the rim of each wheel to find the axle for every spoke. All British railways converge on London, but all railway journeys up to town need not begin at the furthest station. Without travelling round the world, we know that chimneys at the Antipodes smoke opposite ways, and that blacks fall towards each other, and the earth's centre.

If a natural law is known, its results follow. Powers which move the atmosphere and all gases, which radiate from, and meet at a point, bring a traveller to a large junction, from which to make a fresh start, or take a short cut, towards his object.

It is easily seen that forces which move air also move water.

Clouds whose forms betray movements in air are made up of water.

When air expands, it takes in water like a sponge; when it is lifted air lifts water. When it contracts it drops the load.

But air is expanded by heat, and contracts when cold;

so heat, weight, and air, are as hands which open and close about a wet sponge while lifting and lowering it.

In lifting air heat certainly lifts water to the highest point reached by clouds, and it carries them from the Equator to the Poles, and far above Coxwell, Glaisier, and Kunchinjunga.

But heat also acts directly on fluids. The sun's direct rays, when absorbed by water, and accumulated in it, lift it. They move water away from the centre, along a spoke, as fire drives steam out of a kettle.

In May 1857, during hot clear weather, two similar glass vessels were placed on opposite sides of a house, and filled with water. When weighed in the evening, the vessel which stood on the sunny side had lost nearly twice as much weight as the other. The sun's light, and its heat, had lifted water into the air, and the air had carried it off. But air on one side of the house could differ little from air on the other side ; so in this experiment the sun's rays drove the water out of the vessel. In the next trial, a thirsty terrier lapped up the water and spoiled the result ; but both did the work of mechanical powers.

According to Sir John Herschel, the amount of solar heat which reaches the surface of our globe would suffice to melt a crust of ice an inch thick in an hour, or evaporate a layer of water nine feet deep in the year ; if part of it were not expended in warming earth and air as well as ice and water. According to the same high authority, the actual fall of water in all shapes, and therefore the evaporation, amounts to a depth of five feet on the whole globe in each year. The sun's rays do notable work when they lift and drop such floods.*

Evaporation is a result of heat, and every experiment

* Good Words, January 1864.

shews it to be much or little in proportion to heat-power used, or weight-power removed.

It is common to fix the value of fuel by the weight of water lifted by heat set free while burning a certain weight of the fuel under a boiler. But fuel may be so burned as to spend heat-power on air instead of water.

In like manner, sun-power is differently applied at every different latitude, at every season, at every hour of the day, at every spot on the earth's surface, and the most of the rays shine into space or on other planets.

Most of the solar heat which gets to our world stops about the Equator, where the sun's rays beat directly on the ball by day, and from tropical regions most heat is radiated onwards by hot ground at night.

Least solar heat is absorbed at the Poles, where the rays glance off the slanting white surface.

So evaporation goes on most rapidly near the Equator in summer, and about noon, when the sun's rays strike into the earth, and drive water out into the air.

Though heat coming from the sun is the power which acts most conspicuously on air and water in the atmosphere, it is not the sole heat-power used, for it only penetrates a small way into the earth.

At Yakutsk, in Siberia, lat. 62° N., the earth is frozen to a depth of 382 feet. The summer sun thaws $3\frac{1}{2}$ feet of the surface, but the ice-crust is always hard lower down. If the sun were the only source of heat, this crust would be found at all depths. It is not so. Under the ice-formation is earth-heat. Temperature rises in descending: below 382 feet ice melts, and hard ice conglomerates are melted beneath the frozen crust. The mean temperature at the surface is 14°: below the ice-region it is more than 32°. But at 217 feet the

temperature of the ground is 27° ; and at 50 feet 18°. So heat is below and cold above, at Yakutsk.

On the American side, the ice-crust comes further south, but it is thinner at the same latitude. Perhaps the earth's heat comes further up from its home near the centre.

At Mackenzie River, the mean annual temperature at the surface is 25°, the ice-crust 17 feet thick, and summer melts 11 feet of the frozen surface.*

Solar evaporation goes on wherever the sun shines on water or damp ground, though at different rates; and terrestrial evaporation goes on also. Winds blow ; dew, rain, snow, and hail fall ; rivers collect and flow ; glaciers gather and slide above the earth's surface, chiefly because the side that is next the sun absorbs heat by day, which travels onwards into space by night, leaving water behind it. But rays which the earth absorbs radiate back from the earth's centre, together with rays which the earth gives off, and together they lift water and air up the spokes, as far as they have power ; for radiating heat is radiating force, whatever its source may be. Solar heat is not much absorbed by smooth reflecting surfaces.

Mercury in a thermometer placed behind a mirror, exposed to sunlight, is less expanded than mercury placed behind a black board. But a thermometer, placed in the focus of a concave mirror, on a sunny day, shews that reflected heat is strong reflected force when it meets resistance. Placed in the focus of a strong lens, a spirit thermometer shews that refracted solar heat bursts a glass boiler.

A thin dark object like a leaf or a slate sinks straight down into ice on a bright day, but a thick stone protects ice, absorbs heat, and gives it off by night as the world does. For this reason large stones often stand upon raised pedestals

* Keith Johnston's Physical Atlas, etc. etc. etc.

of ice, on glaciers, while fine dust melts ice, sinks in, and is buried in ice, at night.

So in nature. Solar heat is more absorbed by land than it is by sea, because the sea is smooth ; and least of all in high latitudes, where the frozen surface slants most and reflects best ; and it penetrates little anywhere.

But when a hill-side faces the sun, and rays strike it fairly, sun-power is as strong in high as in low latitudes and levels. All arctic voyagers, mountain travellers, and æronauts, have found it so. Pitch melts on the side of ships ; men, balloons, and thermometers feel the power, and measure it. A white tent, pitched on a spit of white sand beside the Tana, lat. 70° N., became so insupportably hot about noon on a summer day in 1851, that panting inmates were forced to move it to the cool shade of a birch tree, where mosquitoes were thick and bloodthirsty. "Cuoikædne læ olla"—there are many midges, quoth a Lapp boatman ; but in the shadow of a hill there was frost.

A balloon rising through a cloud feels the sun-power, and expands with dangerous rapidity ; though transparent air above the clouds is cold as air in Arctic regions.

The power of the sun's rays to lift water depends on accumulation of heat-power ; and that depends on the nature of the substance on which the rays fall, and on the shape of the surface which they strike.

A rough black surface gathers more heat than a white one, and reflects less ; a black bulb thermometer stands higher than one with clear glass. A glass vessel, filled with black sand and water, loses more weight on a sunny day than a vessel placed beside it, and filled with white sand and water. White gun-cotton will not readily explode in the focus of a burning-glass, because it is transparent. A lens of clear ice

will transmit and condense the sun's rays, and light tinder. Clear air is little warmed by the sun's heat, which it transmits and refracts. Clear fluid absorbs more heat, but it transmits a great deal; for a glass bulb filled with spirit is a powerful burning-glass, though not so powerful as a solid ball of clear glass.

All these are questions of degree; the facts remain. The action of solar heat is directly opposed to that of weight at the earth's surface, and it lifts water when absorbed by it.

The earth's heat has a like power, and acts in the same direction.

When pressure is removed from water, placed under the bell of an air-pump, water rises from the vessel which contains it; and heat is the moving power, for water which remains cools and freezes. The heat acts upwards.

When air is cold enough, water steams up into it visibly, and heat is the moving power still; for water freezes, and vapour which evaporates turns to rain, and falls down when it parts with the heat which raised it up. Lower down, water in a dark mine steams under greater atmospheric pressure. The earth's heat lifts it, and the earth's weight drags it down when it cools. Still lower, water from a hot spring boils and spouts up, and blows off in clouds of steam; but it rains down in floods when it gets out of reach of the earth's heat which raised it. Heat in the earth lifts water at the end of every spoke where water is, but with varying force at every point on the sphere; because heat is variously impeded by various rocks.

Heat artificially set free acts in the same direction, whatever the source may be. Water rises from a kettle on a fire, and hot steam lifts a piston, or bursts the boiler.

Having found a centre from which air moves, and a power

which moves it ; the movements of water are found to coincide with those of air, so far as anything is certainly known about them. Rising columns of steam move opposite ways at the antipodes, like columns of smoke or mist. Air and water circulate together in the atmosphere, and within their bounds they are moved up and down by heat and weight.

If these two forces so act on water above the sea-level, they probably act in the same way on water in the sea.

There are polar and equatorial winds; and similar ocean-currents flow in like directions unless impeded by land. When they can be seen, water-clouds are found drifting under water, and their forms repeat the story told by clouds in air.

We deal with the bottom of the air-ocean, and look up for signs of movement in it. We must look down on the sea and through waves at water-clouds.

Air rises far above the solid earth. It flows over mountains as the sea flows over sunken rocks ; and its surface is out of reach. We cannot dive to the bottom of the sea ; but we may look to the surface of the ocean for information as to the surface of the atmosphere, and seek at the bottom of the air-ocean to learn something about the bottom of the sea.

From the movements of air, movements in water can be inferred, when powers which move both are known ; and experiments made with one fluid test theories formed about another.

It is easy to see movements in water.

The first difficulty is to get a smooth surface through which to look. On the calmest day waves disperse rays of light, and reflect them, so that a sea bottom is hardly seen, except in shallow water. A diver cannot see clearly under water ; his eyes are not made to see there, and objects seem blurred and indistinct. A lump of chalk is white, but has no

definite shape ; a silver coin shines like light behind ground glass; the distance fades away into dark green, or blue, or black.

Smugglers of former days found a way to meet the difficulty, and their contrivance is used by seal-hunters and others. When smugglers were chased, their practice was to chain their cargo of tubs together, and sink them ; taking cross bearings at the spot. Their foes used to drag hooks about at random, and sometimes they fished up the prize. The smugglers, when the coast was clear, returned and peered about with a marine telescope. A sheet of strong glass was fixed in one end of a barrel, and sunk a few inches ; a man put his head into the other end, shut out the light from above, and saw clearly, because light came straight, to eyes in air, through a plane from which no light was reflected.

With this simple contrivance, fish, sea-weeds, shells, sand, stones, ripple-marks, flickering lights refracted by waves, dead seals, and brandy tubs are easily seen in four or five fathoms of clear water; and water-clouds are seen rolling below when water is thick with mud. The gazer gets a vertical view of things under him, as an aëronaut does of land and clouds beneath his car.

So far as this contrivance enables men to see the land under the waves, movements under water closely resemble movements under air. Sea-weeds, like land plants, bend before the gale ; fish, like birds, keep their heads to the stream, and hang poised on their fins ; mud-clouds take the shape of water-clouds in air; impede light, cast shadows, and take shapes which point out the directions in which currents flow. It is strange, at first, to hang over a boat's side, peering into a new world, and the interest grows. There is excitement in watching big fish swoop, like hawks, out of their sea-weed

forests, after a white fly sunk to the tree tops to tempt them, and the fight which follows is better fun when plainly seen.

Of late years glass tanks have been used as fish cages, and the ways of fish are better known, because they are now plainly seen in their own element.

The ways of water may be studied in the same contrivance.

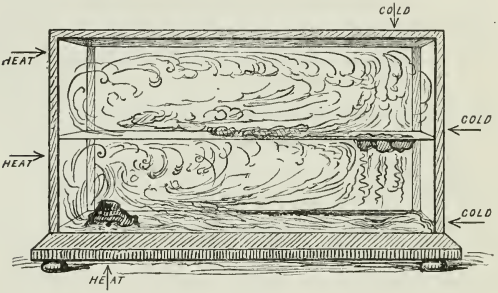

FIG. 14.

The principle might be extended. A boat with plate glass windows beneath the water line would make men and fish still better acquainted, by bringing them face to face. The man would be in the cage, and the cage might be in a salmon pool where fish are free.

If air in a hothouse be a miniature atmosphere, water in a glass tank is a working model of a sea, and heat and cold may be set to work the model engine at home.

Let one of the common fish-tanks be half filled with clear water, and placed where the sun may shine upon it.

Float a few lumps of rough ice at one end, and sink a black stone at the other; and, when the water has settled,

pour milk gently on the ice. An ounce to a gallon serves the purpose.

Milk consists of small white vesicles and a fluid, and, bulk for bulk, milk is heavier than water. So at first the white milk sinks in the clear water, and spreads upon the bottom of the tank, leaving the dark stone like a sunken rock in a muddy sea, or a mountain top peering over a low fog.

But this arrangement is unstable, because two powers are shut up in the tank with the water.

The sun warms the stone at one end, and the stone warms the water below. At the other end melting ice cools water above. Temperature is unevenly distributed, so weights are uneven, and the machine turns round.

Heavy cold streams pour down from the ice at the cold end, and flow along the bottom towards the stone, driving milk vesicles like drops of water in a gray mist.

Light warm fountains float up from the stone at the warm end, and flow along near the surface towards the ice, driving milk like wreaths of mountain mist rolling up into a summer sky from a mountain side.

The water is circulating, and every movement is shewn by milk-clouds, for the glass tank gives a vertical section of a circulating fluid system, driven by the sun's rays and by weight.

Cloud-forms are copied with marvellous fidelity in this water toy, and because the movement is very slow, they are easily seen and copied.

But the tank gives a section of air as well as water. The miniature sea has an atmosphere, and the same forces work both engines. Let a bit of smouldering paper, tinder, rope, touchwood, or any such light combustible fall on the ice-raft,

and cover the tank with a sheet of glass to keep in the smoke.

If there be small ocean-currents in the water, there are storms in the smoky air; and the systems revolve in the same direction, because the moving forces are the same. Cooled air streams down upon the floating ice, and drives gray smoke rapidly before it, drifting along the water towards the warm end, like a cold sea-fog before a north-easter.

At the warm end the mist lifts, like a sea-fog when it nears a warm shore. The smoke rises to the glass roof, spreads there and returns along the top towards the ice, whirling, streaming out, and taking the forms of fleecy summer clouds, which float high in air above the Atlantic in fine weather. "Stratus," "cumulus," "cirrus," "cirro cumulus," "comoid cirrus," and the rest of the learned tribe; "mackarel sky," "mare's tails," "Noah's arks," and vulgar popular clouds of their class; nameless cloud-forms which are the joy of an artist, and his despair when he tries to copy them; all appear drifting with streams, which various degrees of weight and heat cause to flow in air and water shut up within a cubic foot of space.

The amount of power used: the difference in temperature between the ice and the stone, moves air a great deal faster than water, because it is lighter, and there is less resistance to be overcome. It follows that winds should move faster than ocean-currents; and they do in fact.

When damp air has cooled and contracted to a certain point, it lays its load of water on any cold substance which takes in part of the charge of heat—which expanded air. Vapour is condensed. It follows the heat out of the warm air to the cold substance, and if it cannot get in, it stops on the surface, and gathers in small round drops. In the ex-

periment above described, cooled glass at the cold end of the tank stops water coming from the outer air; while the heat passes through glass and cold water to melt floating ice. Dew forms in curves on the outside, and it marks the dew-point temperature in the moving streams which cool the glass within. The curve is like a section of a river whirlpool, or a waterspout, and it coincides with the shape of the milk-clouds.

When the damp air of a room lays its load of vapour on cold glass windows in hard frost, similar curves are copied in solid ice. The dew-point temperature of the air in the room is marked out by a fog on the window, at first; then drops change to crystals, and ice-trees grow up by robbing the air which falls along the glass.

When a fire is lighted in a large room with windows encrusted with these beautiful forms, the march of the heat may be seen. As hot air rises and flows to the windows, ice begins to thaw at the top pane; crystal trees change to haze and vanish, wiped from the glass by dry air; or melted branches slide and stream down the window, dragged by weight when freed by heat. Where the fire radiates directly, the windows clear first. In corners sheltered from the rays ice lasts longest; and the lowest pane is the last to thaw and the first to fog. Heat pushes water towards the glass, away from the fire; weight pushes it towards the earth's centre. The radiating and converging forces do not part and meet at one point in a room; so the dew-point temperature is not in a regular figure. In the atmosphere, the dew-point curve has reference to the earth's centre; and vapour forms in shells about the solid earth because the two forces meet and part within the shell.

The facts shewn by experiment are confirmed by every fresh trial and observation. When temperature and weight

are unevenly disposed in fluids, it takes time to adjust the balance, but it tends to equilibrium, and to regular forms.

A warm bath is arranged in layers of various thickness, and varying temperature. When a human body is placed in it, natural observers stationed at the extremities send nerve telegraphs to head-quarters, to announce that one foot or hand is in warm or cold regions, and uncomfortable.

To prevent this evil, a bath attendant, who knows his work, stirs the water with a paddle; but much stirring hardly spreads heat evenly throughout a bath.

Near Reykjavik, in Iceland, is a hot spring from which a scalding burn escapes. French man-of-war's men, who frequent the harbour to protect French fishermen, have built a turf dam across the burn, about a quarter of a mile from the source; and they use the steaming pool as a hot swimming bath and washing establishment. The place was thus described in 1862:—

Last night we wandered along the shore to a hot spring, which rises in a small hollow about two miles from the town. We found the place, and a dam, made by French sailors in the burn, which runs from the spring. The water was about 80°; so we stripped, and plunged in, and swam about in the tepid water. The spring itself is about 170°, hot enough to cook eggs. We had none to cook; but there were plenty of egg-shells and broken bottles to shew the ways of the place.

A lot of cows were browsing on rich grass, which grows in the hollow, and some of them stood close to the spring chewing the cud thoughtfully in the steam. The setting sun threw their blue shadows on the cloud of white mist, like great long-legged ghosts of cows. It was dead calm, and very warm; and the hills, and the golden sea, and the purple islands floating in the bay, made a beautiful Claude landscape.

It was Italy in Iceland. There we lay stretched at ease on a velvet turf, and smoked, and watched the growing shadows, exclaiming, "how beautiful;" and the old cows seemed to feel as jolly as we did.

At last, when it was nearly ten o'clock at night, the cows seemed to think it time to go home to be milked. So one stepped deliberately down to the scalding burn, and smelt at it. She put one foot in, then another, and then the demure old brute sprang out on the grass, curled her tail over her back, and capered a wild dance, so utterly at variance with her former staid demeanour, that we all lay back and roared with laughter.

Next came a giddy young calf, who went through the same performance; but he, being more active, shook his scalded heels in the air in a way that was perfectly ludicrous.

The brutes, who should have known better, speedily resumed their placidity and walked away; so we got up and walked off to our floating home, where we drank tea on deck, and went to bed by daylight at midnight.

The next night was as fine, as warm and calm. Snæfell, sixty miles away at least, showed his head against a golden sky, in which clouds floated steadily, like the eider ducks and gulls floating about us on the calm water; but every now and again a strong cold blast fell down from the still sky, broke up the mirror of the sea, and then died away as suddenly as it came.

The air was in layers, the layers were of different weight and temperature, and the wind was "straight up and down," like an Irishman's hurricane.

The natural hot bath was a good illustration of a similar arrangement, and the glass tank and glass windows show the movements which result from it.

Water which stands in this hot bath is not stirred. The warm stream flows in above, and it cools by radiation as it flows to the far end, where it cools and sinks. The supply at the source is 170°, the waste at the dam is scarcely tepid, and the pool is circulating and rolling over and over because of its uneven weight. When a bather takes a header into it, he finds himself shooting through all sorts of climates. He feels summer, autumn, and winter rolling along his skin, as he shoots down. When he stands upright, he feels that temperature is packed in horizontal layers in the water about him, and that the cold layers are below. When he swims about, he finds hot and cold regions in different corners at the same level, for the heat is nowhere evenly spread. Lower down the ground may be frozen, but under all is the boiler from which the hot water rose. From this experiment with nature's thermometers, it appears that the coldest strata of water in a pond are generally below, but sometimes warm regions are below colder layers in the pond, as in air and sea.

The movements of water about to freeze are well seen in the glass tank above described.

At one corner a glass thermometer is hung with the bulb near the bottom ; at the opposite corner the stalk of a thermometer is thrust through a bung, and so placed that it can be raised or sunk without disturbing the water much. Thin ice formed in the tank floats at the surface, and a block-tin bottle filled with hot water is sunk. The heat of the water put into the bottle is 212°, the ice is 32°. On the ice, about the centre of the tank, some lamp black is painted on with a brush, one side of the tank is covered with a screen of thin paper, and then the machine is ready for action.

As the colour is at the coldest place :—on the ice, it marks the position of the coldest water when the ice begins to melt,

and the cold is easily measured with the instruments. As the hot bottle is in clear water, white paper seen through clear water marks the position of the water which is warmed. As lamp black takes many days to settle in a tumbler, it shews the movements of water, for it only moves about the tank, because water is moved by weight and temperature.

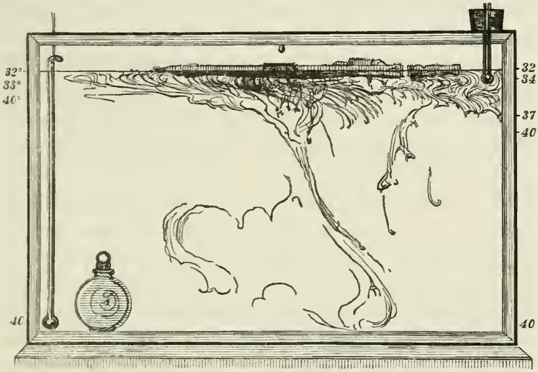

FIG. 15. FREEZING.

Ice being at the top is lightest, and its temperature is **32°**. When it is melting the colour begins to move. If it is warmed by the sun, a dark revolving column sinks very slowly down. But beneath the ice are layers which contain intricate patterns of curved lines of black, which bend and wave slowly, but keep near the ice. The temperature in the coloured band is

Ice, 32°
Water, 33°
34°
37° As shewn in the woodcut.

So the coldest of these layers is the lightest, and the solid crust is lightest of all. The clear water in contact with the coloured layer is at 40°, and so is the water elsewhere in the tank, after the hot bottle has given off its charge of heat and melted the equivalent weight of ice. So water at 40° is heavier than water at 37°, and the different temperatures are drawn in black on a white ground. But water that is warmer than 40° is lighter than water at 37°.

When a water-bottle filled with hot water, coloured with lamp black, is sunk through an ice dome, without the stopper, a warm dark column rises up like the Afret whom the Arabian fisherman let out of the copper vase ; or the foul air which in cold weather rises out of a copper mine. When the water is hot, a thing like a round-headed mushroom grows rapidly out of the neck, and takes all manner of strange shapes. The head is like some monster which a painter sees in his waking dreams, a vision by Gustave Doré, for example. The stalk bends and winds through the clear water like an eel, or a black snake creeping out of its hole. When it gets to the cold region, the top spreads out like a palm tree, waving its drooping boughs, and shedding a crop of rings, and spheres, and streamers ; like fire-works in daylight. The temperature of the coloured water which rose from the bottle to the top is in this case about 44°, when clear water is 40° at the bottom and elsewhere. So of this series the warm layer is lightest.

While the bottle is hot the pace is fast, as it cools the phantom growths are nipped. When the water is almost boiling, it rises in water at 33° like smoke from a furnace chimney rising in air.

When the temperature has fallen in the bottle and spread through the tank, small jets of colour rise up and sink back into the pipe whence they rose. Their shapes are like those

of plants rising through the earth, their action is that of a boiling spring.

When all the extra charge of heat has escaped from the bottle, there is rest at the source ; the rapid action ceases, and the coloured water slowly takes its place in the tank.

On a frosty evening when there is no ice, but when ice is about to form in the tank, the water which rose out of the bottle forms an even layer above clear water, and the temperature then is 37° above, and about 40° below.

In that case the water which rose because it was warmed, stays where it cools, beyond 37°, and after that the more it cools the higher it rises, till it is 32° at the top and a floating solid.

When the hot bottle spends its force beneath a solid ice roof, thermometers mark 32°
33°
34°
35°

and the blackest layer in the series is the lowest and the warmest.

When freezing water freezes, crystals expel colour from ice, and water-currents distribute paint amongst the remaining fluid. Circulation goes on under ice, for some of the dark water which was next below the ice when it began to form is found at the bottom when all the instruments read close upon 32°, and the solid crust has formed.

Water, then, is a gas, a fluid, and a solid at different temperatures ; and the formation of one crust on one fluid illustrates the formation of other crusts.

The ice crust forms next the coldest place, and the fluid remains shut up inside.

In a tank the process can be watched, and the disposi-

tion of the crust is seen, because ice is transparent, and vertical glass walls bound ice planes through which rays pass undistorted. A plate of ice seven inches broad is more transparent edgewise, than an equal thickness of plate-glass.

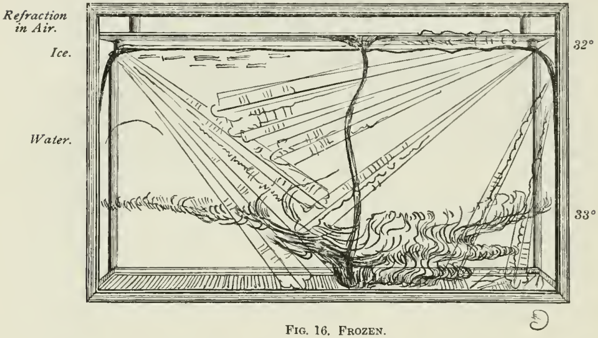

Fig. 16. Frozen.

It refracts rather less than water. On the surface, the ice is disposed in layers, whose planes coincide with those which colour shewed in freezing water. The layers are added below; they are horizontal and regular where the ice is smooth above; where the ice is rough outside, the planes of stratification within are bent and crumpled. The surface next the wall is a plane, where the layers are flat and undisturbed; it waves where the strata are bent and wrinkled.

The thickness of the upper crust varies; at corners, the angular solid is rounded off, so as to form a dome.

From these solid corners long blade-like crystals radiate at all angles from 1° to 90°. They are like spokes of wheels, whose common centres are the corners of the tank; or as

fans behind the glass, opening from the angles where three planes meet.

Each of these blades is like the back of a saw with crystal teeth growing into the water, away from the glass.

When a tank is so placed that frosty air circulates under it, ice crystals form at the bottom also, and radiate from the lower corners. The glass box is lined at last with a box of solid ice, and fluid water is shut up in a curved crystal chamber, wherein it circulates till it is frozen.

By pouring hot water on the ice, a hole is quickly bored through it. When coloured water is poured on the surface, near the hole, it is warmer than ice, however cold it may be, and it sinks through, falling like the column which rose out of the bottle, but very slowly. It strikes on the bottom and rises up again, steadily working its way through the colder water, and forming itself into crumpled layers below. A thermometer marks 33° when placed in the colour. So water at 33° is heavier than ice at 32°, and, therefore, solid ice must float in water at any temperature.

The charge of heat which a mass of fluid water contains, passes outwards ; and leaves ice where it passes through any substance which stops water but cannot stop heat.

It is the rule that cold water is heavier than warm water, but the rule does not hold good for all temperatures. At 32° fresh water is ice, at 37° and all lower temperatures it is about to become ice, and it floats on water at 40°.

At 44° it rises through water at 40°, and then it melts ice floating above.

So fresh water is heaviest about 39° at some temperature between 40° and 37°, and many other fluids appear to have a temperature of greatest density.

Salt water of the specific gravity of 1.026 freezes at 28°. At the specific gravity of 1.104 it freezes at 14°.

As steam at 212°, or as vapour at any temperature, water takes up most space, is lightest, and refracts light least. As ice at 32°, 28°, or 14°, it takes up more space than it does when fluid. As fluid, water takes up least space, and is heaviest; it has greatest density, and refracts light most.

So vapour floats on ice, and ice on water. At or about 37°, water, having got rid of extra heat, seems to begin to assume the angular shape of ice crystals. Curves become straight, waves are calmed, bends change to angles, while coloured water is freezing. The angular shape takes more room, the crystal is bigger than the cold drop, but there is no more water in it. So the crystal floats, and crystallizing water floats up next beneath crystallized ice.

From these experiments it follows that layers of water of various changing temperatures must move; and the temperatures being known, the direction of movement can be inferred.

From other experiments it appears that air and sea are in fact arranged in moving layers of various thickness, temperature, weight, and density.

On a fine summer evening when the sun is nearing a sea horizon, some of the air-shells may be seen. Rays of light are variously refracted by lenses of different densities, and the atmosphere is a great compound concave lens.

The glass of an argand burner, though transparent, appears to cut across the flame like a dark bar at the bent shoulder. Any lamp shews the effect. When the sun is near the horizon, his light slants through domes of air which surround the earth, and, like a nest of glass shades, they refract the rays more or less according to their shape and density.

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The round ball is distorted. As it sinks the disc of light is bent and broken up into irregular figures. The sinking light in passing the layers darkens, but the bars are flat and stationary, so the edge of the sun appears to bend and wave, as a lamp does when the shoulder of the glass chimney is lifted or lowered. If any clouds hang about the horizon in the twilight, they too are flat, for they are the edges of thin shells of condensing vapour, which made the air dense before sunset.

Fig. 16.

These upper regions have often been explored. In Mr. Glasier's late balloon ascents, in which pluck was a very conspicuous feature, it was found that although high regions, which correspond to regions of perpetual snow on high mountains, are cold, still sensible heat decreases irregularly, and is constant at no stage on the scale. Because snow falls upon the highest mountains, water in some shape must be carried higher than 28,000 feet above the sea; and accordingly, in June 1863, cirrus clouds and a blue sky were

seen far above a balloon raised four and a half miles above England.

The temperature was 17° at the highest point reached, but far above that cold shell of air, water was packed in the form of cirrus clouds. They marked a dew point. Lower down, from 13,000 down to 10,000 feet was a deep bed where the temperature was 32° or 33°, and the air thick with vapour and frozen water. Mist, snow, and crystals of ice were floating and falling ready to be moved in any direction. The water was there in a solid form, ready to rise higher if the air rose, or to fall into lower and warmer strata, or on the earth. It was colder below, but near the surface was summer weather, and a temperature of 66°.

The arrangement was unstable. It was one to cause motion; the heavy snow was above and the light vapour below; the one must fall and the other rise. But if the snow came down to the region of 66° and summer weather, the earth's own heat and the extra store which the sun had given it, were ready to send the piston up again to the dew-point.

In a former ascent at Paris, a temperature of 16° was reached at a height of 23,000 feet above the ground where the temperature was 87°. The mean temperature at the ground in Nova Zembla is 17°.

It is not given to every one to mount so high with a whole battery of instruments, but it is easy to understand the arrangement of the atmosphere from models worked by heat and weight, when it is known that temperature decreases as the distance from the earth's centre increases, and that heat is disposed in layers above the ground.

Air in high regions is pressed by less weight. It is colder than air near the earth; but like a sponge relieved from pressure, it is better able to hold water the higher it is.

There is more room in it, so to speak, and the dew-point is colder. When air at 32° was found resting on strata sensibly colder, the upper layer was still better able to hold water, because still more expanded by the heat which it had absorbed.

A stream of warm, damp air, rising because it is warmed and expanded ; expanding still more as it rises ; because there is less air above to squeeze it, is like a balloon ; and carries great part of its load of water to high regions, where there is little sensible heat, but much heat latent.

Clouds, high snowy mountains, and balloon ascents, prove that water is somehow lifted more than 28,000 feet above the sea, and there seems nothing to stop it short of the limit at which the earth's weight and the earth's heat balance each other in their action on water.

As water evaporates spontaneously at all temperatures, and even in vacuo when the weight of the atmosphere is taken away, heat moves water one way, and weight moves it in the opposite direction. That is the working principle of the atmospheric engine, though the machinery is complex and hard to comprehend.

The depths of the sea have also been explored, though they have not been visited. Deep sea soundings have been taken ; living star-fish have been brought up from a depth of 15,600 feet ; the sea is fluid at the lowest depth reached ; so it must obey laws which affect fluids in smaller quantities.

The sea is packed in layers like the bath, the pond, the model tank, and the atmosphere, and these all circulate for the same reason.

Let a few of the temperatures which are given in scientific works be arranged in the following shape, and the movements shewn on Mauray's diagram, page 28. On the diagram page 34°, and on the woodcuts page and and will be

found to coincide in principle and direction with the ascertained movements of ocean and air.

Fig. 17.

Fluid water being heavy at the Poles and light between the Tropics, would move like air and clouds if it were deep as the atmosphere ; and the sea does, in fact, move diagonally on meridians, where land will permit.

Water, then, is found in three conditions at different temperatures and pressures, at different distances from the earth's centre ; and the order of the arrangement above the solid crust is

	Weight and Cold.	
1	Gaseous matter,	Air and watery vapour.
2	Solid,	Ice and air.
3	Fluid,	Water and air.
	Heat.	

Two opposing forces meet at some layer of the sphere, and so work the air and the water-engines, to which geological denudation is ascribed. Characters which these engrave upon the solid earth are written with heat and weight.

But because the double engine consists of many cutting wheels, and each wheel makes a different tool-mark, rocks which bear marks of air and of water, are variously marked by the contriver of the engine, which carves hills and glens.

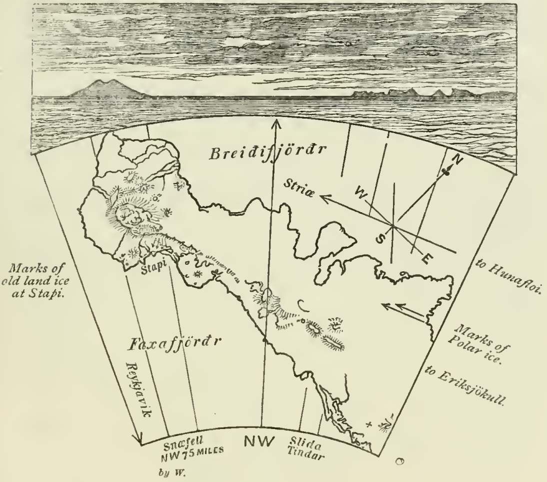

FIG. 18. PLAN AND ELEVATION.

Map and Sketch of the SNÆFELL Peninsula, opposite to Reykjavik. After sunset, June 27, 1862.

CHAPTER IX.

DENUDATION—TIME.

There is an ingenious device for sculpturing marble, which illustrates the working of engines which carve hills.

An artist's thought is modelled in clay, and cast in plaster of Paris. A block of marble is laid beside the solid thought, and the engine is placed between the stone and the model. Power is got out of fire and water, or water and weight, and it is passed through a train of wheels, strings, and levers, to a small cutting wheel which revolves rapidly at the end of a bar.

Let this wheel stand for a circulating atmosphere charged with water.

At the other end of the bar a point touches the model, and universal joints allow the bar to move every way. But the engine is so contrived, that if the point rises, the wheel rises as much; if it falls, the cutting-wheel falls also, and where it touches, it cuts away marble, and makes tool-marks and a pile of chips. Gradually the artist's thought looks out of the block of stone. It bears the marks of a steam-engine worked by heat and weight, but it is a man's thought nevertheless.

Geologists have to learn the tool-marks of their trade.

Every tool makes a different mark. The cutting-wheel of the sculpturing engine cuts grooves, which the engineer could distinguish from an artist's touch, and many different wheels are used to make coarse and fine carving.

The brass wheel of a glass-cutter makes a different mark from the iron wheel, and the wooden polisher makes a different mark from a leather wheel.

A carpenter's adze cuts out a curved hollow, an axe makes a flat-sided notch, a handsaw marks straight lines and acute angles on two parallel flat sides, a circular saw draws cycloids on opposite planes. A gouge, a chisel, a rasp, a file, a centre-bit, a bradawl, a plane, a plough, a glass scraper, sandpaper, all the tools in the chest leave marks on wood which a carpenter knows. The work of a particular tool with a notch in it, of a blunt tool or a sharp tool, may be known by the mark.

A blacksmith knows the dent of a sledge-hammer from hand hammering; the groove cut with a cold chisel from the hole punched out with a square point. He has but to look at iron-work to know the tools used to fashion it, because he knows the tools and how they work.

A mason knows pointing from chiseling, dressing, and polishing; he can distinguish a stone that has been hand worked, or sawed up, from one broken out of a quarry.

A miner knows the mark of a pick from that of a jumper; the crushed surface broken by a blow, from one torn by a blast.

A goldsmith knows the touch of a graver wielded by skilled or by unskilled hands.

A wood-engraver, a shoemaker, an optician, an engineer, a tinker, a painter, a crossing-sweeper, a shoe-black—any craftsman or artist knows the tool-marks of his familiar art or mystery, or the sweep of his brush.

A geologist ought to know the tools whose marks he strives to understand.

It is taught, and it is true, that the earth's outer shell has been enormously "denuded."

So many feet of rock are wanting to complete an arch whose piers remain; the missing stones have been removed. The uppermost layer of a stone arch has been taken away, and the next course laid bare at one part of the bridge, which remains standing, though it is worn down by tracks. The crown of an arch has fallen, enough stone to make a mountain has been denuded from a particular part of the earth's crust. How the mountain was removed is to be learned from the marks of the engines used to remove it.

But unless the engines, and their modes of working, are studied, their work may be misunderstood.

It is often said that a big strath was hollowed by the river which flows in it; or that a mountain is a weathered rock which crumbled into its present form; but in many cases the river has little to do with the carving of the glen, and the weather has scarcely touched the hill since it was sculptured.

The river might have done a great deal in a long time, but if the whole land was under the sea, river-work must date from the rise of the land. If there be a sea-shell high on a hill-side, rain could not get at the rock, when the shell was buried under water; so rock-weathering, like river-work, had a beginning, if sea-shells and loose rubbish are above the worn rock.

Iceland is one of the great battle-fields of the powers of the air which grind down the earth.

It is a good place to watch the cutting wheel, the engine fire, and the smelting furnace; it is a place to see work in progress, to study the engines, and learn the tool-marks of fire and frost. Heavy work is there going on between large ocean currents. The same work is doing wherever air, vapour, ice, and water, heat and weight, are together, but the rate in

Iceland is faster than it is in countries where the heavy work is done. There also is a starting-point from which to reckon time, for the finished work of fire is wholly different from the tool-marks of the grinding engines of frost.

At the outset, it is clear that the carving engine has been long at work.

The beginning from which to reckon geological time is commonly wanting. The supposed rate of wearing by waves and of deposition by rivers, the thickness of beds deposited or destroyed within some historical period, these, or such as these, are the common measures for time. But, if ocean currents moved faster, climate altered or changed place, then work done may have taken more or less time to do than its finishing touches seem to show. There is a river-mark in Iceland from which to count time with tolerable certainty.

If the first mark of denudation was made upon an igneous surface, the cooling of the crust is a point in time from which to reckon. At Thingvalla is a river called the Oxerá, which, in ordinary weather, is about the size of an English mill-stream. The water would pass through one of the large iron pipes which carry Thames water to London. The Oxerá falls over a large cliff into a rift. There can be no doubt that the cliff over which the stream now falls, was formed by the falling away of the opposite side of the rift, and that the cliffs and the rocks in the valley were as fluid as water in the river at some time. To see the place is to be convinced of these facts. The Oxerá began to fall over this cliff, and denudation began at the edge, after the lava cooled, and after it split. There is no water-mark on the opposite cliff, so the stream most probably began to flow in its present channel when the bottom of the valley sank, and the plain became a slope.

The whole surface of this lava for many square miles is

marked by certain rope-like coils, which formed while the hot fluid was curdling, and these rise about two inches above the surface. They are fire-marks.

The water of the Oxerá has worn the stone at the edge of the cliff for a breadth of about thirty yards, at the place where water is always flowing, unless frozen ; the channel is about two feet deep, and three or four wide. Where water flows only during floods, the coils have not been worn away, but they are smoothed and worn ; and near the deep channel, the lava surface is very like that of slag which has been used to mend a road, and has been worn by traffic. Specimens are common in Lanarkshire and other iron districts.

Calculating from the angle which the sides of the rift make with each other, and with the horizon, the beds of lava may be about 600 feet thick, and it must have taken a long time to cool such a mass. As it happens, the Icelandic Parliament have met at the Logberg, on the surface of the lava, for 800 years, and there has been no great change in the valley during that time, for the ground is minutely described. At the earliest date recorded, the Oxerá fell into the rift ; a deep pool in it was the place in which wicked women were drowned ; trees grew on the lava, horses found grazing by the river side. It must have taken a long time for soil to gather after the lava had cooled. But things had arrived at this stage 800 years ago. Say that water has been wearing its stone channel for 1000 years only, and the depth from the fire-mark, the wrinkle on the lava, to the bottom of the water-mark, two feet, gives a rate of one foot of lava in five hundred years. The rate, in all probability, is far too rapid, but it gives a great age for these Icelandic rocks, and for those on which they rest.

At other spots streams have cut wide and deep channels in lavas of the same kind. The river at Godafoss, in the

north, has cut a deep channel, and has worked its way backwards for some hundreds of yards. The smoothed water-worn surface is plainly seen on cliffs far below the fall. The river is large, so it must work faster than the Oxerá ; but if one has cut 900 feet, while the other has only cut two, they cannot have begun to work at the same time. Giving one river credit for only one-third of the work done, the rate makes the age of the lava at Godafoss 150,000 years.*

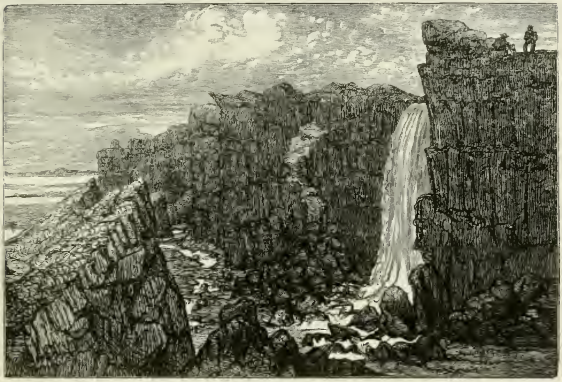

FIG. 19. ICELAND, July 30, 1862.—FALL OF THE OXERA.

But where streams do not flow on the lava about Godafoss, the wrinkles have not been worn off, so weathering has not denuded a quarter of an inch of igneous rock in that time at least.

Other Icelandic rivers have done a great deal of work. The Bruerá has drilled large pits, and it has scooped out smooth channels of considerable depth.

* 300 feet, at one foot in 500 years.

At Merkiarfoss, near Hecla, a small stream has dug out a large trench, and it has drilled the most fantastic peep-holes through a black conglomerate of ashes and stones, and this river began to work after the volcanic mountain had grown.

At Skogarfoss, a river falls over a cliff on a sea-beach, and it has dug backwards into the hill for some fifty or sixty yards. It began to dig after the sea had done its undermining, and had retired towards the horizon away from the base of the old sea-cliff. At the wearing rate the sea made the cliff 75,000 years ago.*

All these times may be wrongly calculated; they may be too short or too long; but when the last formed igneous rocks have endured so long, it is plain that the wearing of rocks to form known sedimentary beds must have gone on during ages, which it is vain to calculate. However rapid the rate may have been when the grinding-engine first began to work, it has been carving and packing chips for a very long time. The world is an old world; and sculptures on it are old inscriptions, though made with engines which are working now.

A river is a grinding-wheel in the denuding engine; a soft tool which makes a mark. Tools of the same kind are cutting and have been cutting patterns on rocks ever since water rose from the sea, fell on shore, and flowed towards the earth's centre; but each river had a beginning, and the time which has elapsed, since land rose above the sea, is too short for the work attributed to many rivers.

* 150 feet at 1 in 500 years.

CHAPTER X.

DENUDATION—RIVERS.

Before a craftsman can recognise a tool-mark, he must be familiar with the tool; before a geologist knows river-marks, he must study the ways of rivers.

Falling water proverbially wears a stone; stones wear in many ways, and at different rates; but that which the Oxerà and other Icelandic rivers have done to lava, streams must have done to rocks, from the time when the first shower fell, and the first stream began to flow. So ancient river-marks ought to be found on the oldest rocks, and these ought to resemble modern river-marks.

Clouds rise up from earth and sea. A river takes its rise in the clouds, from which drops fall. Fallen drops collect and roll from hills into hollows, and so a river grows. On the stony top of a granite mountain puddles may be seen forming during a shower. They fill from above, overflow, and so help to fill lower hollows in every rock and stone. These, in their turn, overflow and send off larger rills, which take the shortest way towards the earth's centre, and roll down the steepest slope.

Streams which flow straight down steep hill-sides must cut straight furrows, if they cut at all. Such trenches may be seen on the flanks of Icelandic volcanos, which have grown up in modern times; and on the sides of steep hills everywhere, and this river-mark always has the same general form.

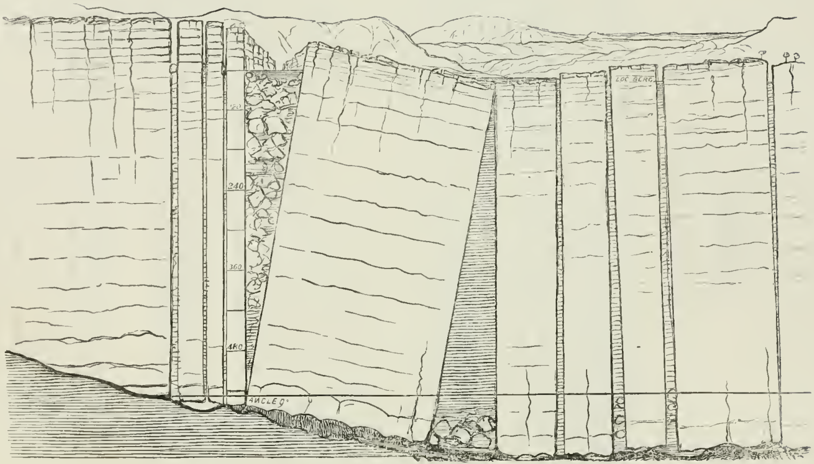

FIG. 21.

The steeper the mountain, the straighter are its gorges ; the deeper the trench dug by rain, the more rain-water tends to gather in it ; the water makes a path, and follows it, and it works faster as the work grows deeper. The mark is like V.

For this cause an ancient mountain, which has borne the brunt of the battle for a long time without the shelter of the sea, generally is so deeply furrowed, that little of the old shape remains. A cone, for instance, is grooved and fluted into steep peaks and ridges which meet at the highest point where water falls. The mountain is weathered, and becomes a rain-mark, unless it dives under water for protection. The shape is like Λ.

The mark which a river engraves on a country-side, is like a flat branch. Rain-pools are leaves and buds, rills are twigs, and rivulets branches which spring from a stem whose roots are in the delta at the sea.

The plan, at first, is a repetition of the forms of the letters V and Y, in which straight lines meet at various angles. But as the slope gets less, straight lines curve, and the stream winds in the plain like the letter S.

Any wide landscape seen from a high mountain, any well executed map or model, shews these characters which fluid engraves upon solid. They recur in every quarter of the globe, in every continent, field, or gutter, and could be read anywhere.

The section of a gorge dug by a torrent is angular, like V ; or the sides are perpendicular, like U ; on a gentle slope the section of a river bed is curved ‿ ; and the curve gets flatter as the river spreads and winds in a shallower bed, on a smaller slope. The section of the Λ is a convex curve ⌒, fluted by numerous river-beds. It is a mark of deposition, not denudation.

The whole of these familiar forms result from the movements of flowing water, and these result from the force which drags water towards the earth's centre ; and from the resistance of the crust which impedes the movement, changes its direction, and stops it at last in some rock basin.

The seed from which a river grows is a rain-drop. A drop of rain falls perpendicularly in a calm on a flat stone, and spreads every way. It strikes, rebounds, splashes, and scatters. If water is poured upon level glass, it spreads every way. The form is a star *

The force which moved fluid towards the horizontal plane is turned aside by resistance, and the water is pushed sideways, at right angles to its original direction of movement ⊥.

Ink, dropped on box-wood, obeys the law, and draws its own shape for the engraver.

FIG. 22.

As drops diverge, so showers spread from a mountain-top, and rivers part from a watershed.

Water flowing in any open channel rebounds from side to side, and from the bottom ; so a river wears its rocky bed

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irregularly, but on system. Resistance on the right bank reflects the stream towards the left, and there it digs a hollow, and swings back. Resistance at the bottom throws the stream upwards ; but only to fall again after drawing a convex curve. Where the water falls, it digs a concave hole, from which it rebounds again ; and so the river wears its bed according to force and resistance, and in curves. On a steep slope, zigzag movements are small in proportion to the fall ; the water hits the side of the trench at a small angle, and rebounds at one still smaller. So the mountain torrent works most at the bottom, where it hews out rock pools ; leaping from step to step, through deep ravines, in foaming cascades.

The Ruikan Foss in Southern Norway is a good specimen of river work.

The rock, over which a considerable stream now falls, is a coarse sandstone or conglomerate. The upper valley is a rounded hollow, at the bottom of which the river has dug a shallow trench. The upper hollow ends in a steep slope ; and the lower valley, like the upper, is a rounded curved rock-groove, through which the river meanders ; but the bottom of the groove is covered with beds of gravel. Both these glens, the slope, and the surrounding hills, bear marks of ice ; so the river did not hew out the glens ; but it has dug a narrow trench in the slope, and it is sorting the debris in the lower glen. The notch in the slope is 700 feet deep ; and rounded water-marks are clearly seen on the steep walls of the gorge, from top to bottom. The fall is working rapidly up stream ; digging at the bottom of the pool, at the foot of the rock ; undermining, sawing, and working back into the slope. It leaps out of the pool with a wild roar ; the bed of the stream is cumbered with enormous stones. Where undermined cliffs have fallen, long banks of talus slope down

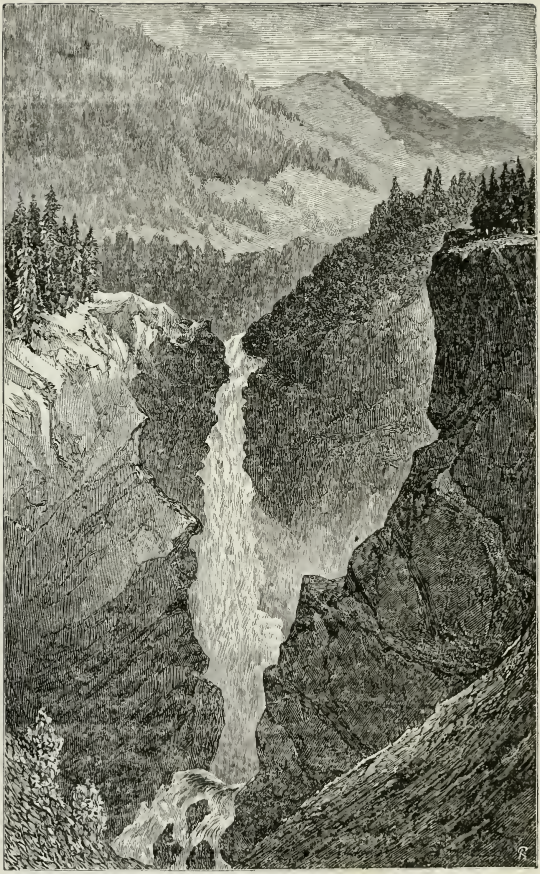

Fig. 22.

to the water's edge, ready to be swept away, and sorted lower down. The tool, the mark, and the chips, are together; and the power of the engine is displayed in the work.

On one point it is possible to lie on a long flat stone, look over, and drop pebbles from the outspread hands, 700 feet down into the gorge.

If a fall of undermined rock chokes the stream in this big ditch, there will be a deep lake in the slope between the glens. The water will fall harmlessly into it, and the rate of wearing and scene of action will change. The water will work most below the dam, till it is removed, and then the lake will disappear, and the river will begin at the bottom of the old fall again. But the sides of the trench will be angular where fractured, or smoothed where water-worn; the torrent-mark will continue like the letter U ploughed out of the bottom of the curved glen ‿. It will always be an angle L dug out of a slope.

The Vöring Foss in the Hardanger Fjord is another notable specimen of river-work of this class.

A large stream flows from snowy mountains, amongst which a few glaciers still nestle. It flows over an ice-ground plateau, in which it has worn a shallow bed; but when it reaches the sloping side of the lower valley, the stream plunges suddenly sheer down about a thousand feet, into a black chasm, so deep and narrow that the fall can only be seen by looking straight down at the pool.* Great clouds of spray dash out, and whirl up, rebounding, and driven by a strong wind caused by the fall. The spray collects on the hill-side, and streams down the rocks in miniature falls, which are blown up again. So the air in the gorge is filled with clouds of spray, and the pool is generally invisible. About

* By dropping stones, and timing their fall, the height was made 1100 feet.

FIG. 23. THE POLISHED GLEN, EIGHT MILES BELOW THE VÖRING PASS.

a Torrent cutting through and obliterating the ice-mark. *b* Ice-polished hill. *c* Birches, small pines, berries, fine turfs upon ice-polished rocks, with boulders and perched blocks. *d* River which has not obliterated the old marks upon rock points in it. The bed is chiefly composed of boulders of large size. Water, dirty, comes from a glacier.

noon, when the sun is clear, a traveller craning over the edge sees three parts of a rainbow about a black shadow with luminous edges ; a ghost of himself, wading through white clouds, which whirl and drift down the gorge like boiling mist.

It is impossible to sketch a hole of this sort ; but the mark which the river is hewing out in the hill-side is one which could not well be mistaken for any other tool-mark. It is the same as the mark at the Ruikan Fall, L.

The valley into which the river leaps bears other marks, which are as easy to read when the tool which makes them has been seen at work. The glen was scooped out ; but rivers are only cutting through and wearing out traces of ice. The river-mark is more than a thousand feet deep, but it is a mere scratch on the side of the glen in which the river flows.

Another famous Scandinavian fall is Tann Foss in Jemptlan.

It is near the watershed of the country, and the frontier between Norway and Sweden, on the road between Trondhjem and Sundsvall, between 63° and 64° N. lat. It is not a fall in a river ; there is no rapid above it. The water of placid narrows at the end of a quiet lake suddenly tumbles over a slate cliff, and becomes a quiet lake again, when it escapes from a boiling pool. The fall is 120 feet high without a break. The cliff over which it leaps is sharp, and its structure is clearly shewn where the broken horizontal beds project into the foam. In the very middle of the fall, level with the upper lake, is a square block of dark slate, which has resisted wear and tear at the edge. It is called the Chest. It is told that a bear, in trying to cross the narrows above the fall, got carried down and landed on the Chest. There was no escape ; so, in the extremity of his dismay, the bear screeched fearfully. A man heard him, and taking a most unfair advantage, pelted the

brute till he sprang over the fall, and drowned himself in despair.

Peasant proprietors still pay a nominal tax for a right to gather drowned elks and other game at this fall; for the smooth narrows tempt creatures to swim over, and many used to be drowned like the bear, when game was abundant.

From the top of Areskutan, a neighbouring mountain, which is some 3000 feet higher than the lakes, and 4000 above the sea, the work of this northern Niagara is seen to be a mere notch chipped out of the edge of a long terraced step, which runs along the hill sides, north and south, for many miles. It seems to be one of the many contour lines which coincide in general direction with the coast of the Gulf of Bothnia. The rock basin, which is a lake on the upper step, overflows; and the waste, which is about equal in volume to the Thames at Windsor, must have slid down the terraced rock into the lower basin at first. It has dug an angle now; but it has dug less than a hundred yards into the slate, for the original slope is entire elsewhere. It cannot dig much deeper than the water-level of the lower basin, for the water guards rock.

From this northern Rhigi, a vast expanse of country is seen on a clear day; and it has the characteristic shape of ice-ground rocks. The district is one great undulating slope of gray rock, green forest, meadow, and corn land; with conical peaks, rising here and there, and with silver lakes shining in their rough stone setting everywhere. One white snow-flake, a speck ten miles off, shews where water is foam, and a river is grinding rock at Tann Foss.

On a calm, clear evening, in September 1850, the wide landscape was very beautiful, and figures in it, and sounds in the still air harmonized well with the scene. A wild call

blown from a birch-bark tube rose up from a village at the foot of the hill, and then far below, as it seemed, almost under foot, tiny cows, and sheep, and goats, came slowly dropping, one by one, out of the forest into the road. Their bells tinkled as they went streaming after a bevy of girls, poking their noses into their hands for salt, lowing, bleating, and capering homeward to be milked and housed.

Close at hand a family of Röjoxa (*garulus infausta*) with their bright burnt-sienna wings, chattered and fluttered amongst green and yellow birches; and high overhead rose the peak, white with the first snow of winter, but rosy with the glow of sunset.

The denudation of rocks in this district is conspicuous, and the amount is enormous. It is plain that rivers and weathering will not account for the shape of Sweden. It is equally plain that other engines have worked here.

On the watershed, not far from Tann Foss, at the roadside—at a height which Robert Chambers estimates at 2000 feet—the clearest marks of glacial action are still perfectly fresh on rocks, in spite of weather and rivers. These marks prove that ice travelled over the hills from N.E. to S.W., at 2000 feet above the present sea level, at the place where streams now part and run to the Baltic and to the Atlantic.

It is an established geological fact that Scandinavia is rising from the sea. It is proved by marks made on stones in the Baltic, and watched since 1731, and by other marks.

It is evident that the hill-tops must have risen first, so the highest fall must be the oldest. Tann Foss, working at 1000 feet above the sea, has worked longer than Trollhattan, at about 307 feet; and the ice-mark at 2000 feet is older than the river-mark at Tann Foss, if it was made floating ice.

At the famous fall of Trollhattan on the Götha Elf, a

green river as large as the Thames at London, the waste of a great inland sea, and the drainage of a large tract of mountain and forest, escapes from a rock-basin, over a shoulder of rock, and slides down a rock-groove for about three miles. It rolls over the edge unbroken, like a great sea-wave, and slides down for twenty or thirty yards before it is streaked with foam. Below the rapids, the river meanders through a plain of boulders and drift, which partly fills the rock-groove. The plain fades into the sea, and rounded islands of rock, of the same pattern as the hills on shore, gradually decrease in height and size, till they become sunken rocks, and disappear at last under the Kattegat.

A good Tornea rapid is almost as grand as Trollhattan.

The striking feature of the place is the absence of river-marks. Denudation, worked by water, is insignificant. There is no section, no cliff, no step L worn in the slope. Trollhattan is a slide, not a fall. It is but a baby in geological time.

The country is well known to the writer; it is well described by Robert Chambers in the Edinburgh Journal, N. S., 1849.

From Stockholm to Göteborg, from Malmö to Christiania, glens, mounds, and hills, are ice-ground rocks of one pattern. Speaking generally, ridges and hollows, rock-grooves and river courses, rock basins, and lakes large and small, stretch N.E. and S.W.; and in many places striæ are fresh on the rocks, and point the same way.

At Christiania serpulæ adhere to rocks which are now 186 feet above the sea-level. When these shells lived where their mortal remains are found, the sea was over the rock.

At Udevalla, further south, a bed of sea-shells is found in a bank of gravel about 200 feet above the sea.

At Sarpsborg sea-plants have been found twenty miles inland, and at a level of 450 feet.*

But a sea 500 feet deeper would join the gulf of Bothnia, the Wettern and Wenern, the Kattegat, Skagerrack, and the German Ocean; sink Denmark, drown most of southern Scandinavia, abolish Trollhattan, and stop the war.

So Trollhattan only became a water slide, and began to grind rocks about the time when sea-shells and plants died for want of sea-water at Sarpsborg, Udevalla, and Christiania.

The river-mark is a measure of time, for the fact is established that this river began to slide when the lip of the rock-basin rose above the sea-level.

In Glen Fyne, in Scotland, are similar gorges dug by mountain-torrents in the sides of rounded hills.

The Eagle's Fall, above Ardkinglas, is not less than 300 feet high, and it has dug a wild, precipitous gash like the bed of the Vöring Foss; but the gash is scarcely seen from the valley below, which was scooped out by some other engine.

There is scarce a glen or rounded hill in Scotland which has not some modern river-work upon its steep sides, to contrast with wider, deeper, and older marks of denudation. There are numerous marks which prove beyond dispute that Scotland has risen from the sea, and that many of her waterfalls were born after the death of shells which are buried on hill-sides.

Farther north, about lat. 66° in Lulea Lappmark, is a fall which is famous all over the district, but which no Englishman has yet described. The Lapps call it Njoammel Saskas, or the hare's leap, because a hare can spring over a large river where it has dug a trench in solid rock.

* For details, see Chambers. The papers are very true and amusing pictures of Scandinavian travel, and geologically valuable.

Still further north, about lat. 70°, a large river which drains the great Enare Träsk, leaps down a fall in a narrow gorge which it has sawn through rocks. The country retains marks of glaciation over five degrees of latitude, between the Polar Basin and the Gulf of Bothnia.

All the large Swedish rivers, without exception, have one character ; they have done very little denudation since they began to saw through ice-ground rocks ; and what they have done is work of one pattern, more or less advanced, and most advanced at the highest level.

If the value of the unit could be found, the amount of river-work done might be measured from the ice-ground surface, and dimensions converted into geological time.

In Iceland, where streams work on igneous rock, the torrent carves the same pattern. At Melar, in the north, a small river leaps down a steep hill-side. It has made a succession of falls, with deep rock pools and rock pits. The rock is bedded trap, traversed by whin dykes, but the pattern of the river-bed is the same as in Welsh slate.

At the Devil's Bridge near Aberystwith a stream has sawed a groove in blue slate. It is ninety feet deep, and about six wide. The smooth water-worn surface is fresh from top to bottom on both sides of the groove, and at the bottom, in the bed of the stream, there is no joint or fracture to be seen. The whole is a river-mark, a trench sawn by running water straight down into the slope of compact slate which some other denuding agent wore out before the river began. The rivulet has but ploughed a groove at the bottom of a curve ; it has turned V into Y. River-marks are the same everywhere, and this is the mark of a mountain torrent L.

But drift and sea-shells have been found on Welsh hills at a height which would sink the hills at the Devil's Bridge

far under the sea, and all Wales is ice-ground. So this torrent, like the rest, had a beginning, and from that the begining of the groove must date.

The highest fall in Europe is that of Gaverni, in the Pyrenees. In descending the pass which leads from Spain into France, it is seen about four miles up a valley to the right. It is amongst the wildest of rocks and mountains, and there does not seem to be a tree within miles of it. In September 1842 new fallen snow reached down to the verge of the cliff, and early frosts kept the stream low. The fall seemed little more than a white thread on the dark rock face, but the water fell unbroken to the bottom except at one spot where it touched. In this it is unlike the Staubach in Switzerland, which, though lower, reaches the bottom as a shower of spray. The river at Gaverni is of considerable size, but the river-work is as nothing to the glen which some graving tool had sculptured before the river began to fall over the cliff.

High up in the Pyrenees are tiny glaciers, and the glens bear the marks of old ice.

Rivers have done similar work in Spain.

At Ronda, a small stream, which was almost dry in June 1842, runs through a trench hewn in sandstone. It is a strange water-worn Barranco cumbered with big stones, amongst which Spanish washerwomen do their best to rinse clothes. The sides are so steep that the river bed can only be reached at a few places. It is so narrow that a small bridge, with a single Moorish arch, joins the two sides. Emerging from this narrow groove, the water leaps down several ∟ steps cut in the sandstone rift, and through the cliff; it passes under the famous Ronda Bridge, turns several mills, and finally winds off through a lower plain, marking its course with verdure. The town is entered from the upper plain, and

this great cliff and chasm are so little seen that three seedy travellers spent a hot day in a venta a hundred yards from the great bridge, voting Washington Irving's description of the place to be a sheer invention. It is, in fact, one of the strangest places in Europe—a town built on a kind of rocky island on a cliff which a mountain stream has sawed off from a raised plain, with a broken edge.

Some other tool must have carved the Spanish hills, and at Grenada snow and ice still glitter above the hot plain, on the peaks of the Sierra Nevada. In the plains are beds of clay, which look very like ice-work.

In the Morea it is the same. The beds of torrents are grooves with steep sides; the glens through which the rivers flow are wide rounded hollows, and on high mountains near Cape Matapan and above Sparta, snow-wreaths still out-last summer heats.

In the Alps, where glaciers abound, rivers often run long courses, beneath ice roofs. They do the work of rivers loaded with ice-floats, and the glaciers work beside the rivers, which flow with them in rock-grooves.

Old marks of larger glaciers are found in large rounded glens, on the banks of brawling streams, which are sawing narrow trenches at the bottom of every glen. A good collection of photographs will best shew these forms, and they are common now-a-days.

In Iceland, where glaciers are far larger than Alpine glaciers, many rivers and their marks are peculiar.

Enormous tracts are covered with vast snow-heaps and glaciers, and though the surface of this upper system of beds is tolerably even, the next series below it—the shattered igneous rocks upon which the glaciers rest—must have a surface of

hill and dale like neighbouring districts where the upper series is absent.

The water series deposited from air is fusible at ordinary temperatures, and it is constantly melting, if it is constantly growing from above. In summer, the surface melts, because a hot sun shines down upon it. The undermost layers are always melting slowly, because the ground is warm. When the earth-light shines out; when a volcanic eruption bursts forth under the snow; when the earth's internal heat radiates upwards more than usual, the snow turns to water and steam. The water flies back to the clouds, or sinks as far as it can, through snow, névé ice, and shattered lava. It flows down hill like other water, gathers in glens and valleys, bursts through passes under ice and lava roofs, and comes to light at last a full-grown river.

Large rivers are hidden throughout long courses, and burst out of ice-caves to fall into the sea after a daylight course of a few miles.

The rivers which drain the country which lies under Myrdals Jökull, and the Vatna Jökull, are of this kind.

The glaciers approach the sea, and their drainage is in proportion to their great size and nature. A mass of frozen water as wide as Yorkshire, and many thousands of feet thick when exposed to a hot sun; or when a flood of lava spouts up into it, sends down streams of muddy water, larger than rivers which flow from tracts of equal area elsewhere.

Many Icelandic rivers are in fact as broad as they are long, and run their whole daylight course over a delta.

These are always difficult to ford. Travellers pass them guided by men who know the district, mounted upon ponies used to wading, which are called "water-horses." A string of ponies, loose or loaded with baggage and riders, are tied head

and tail; and the train, led by the water-horse, crosses over the delta, up one side, and down the other; wading, sinking, scrambling, sometimes even swimming; sometimes on dry sand-banks, fording for a distance of several miles. Sometimes the river-bed has ice upon it under water. When the horses tread on one side, the stream gets under the upper edge of the broken ice, and great plates rise up and turn over and slap down, as if to crush the rider. Sometimes the leading horse sinks up to his girths in a quicksand, and it takes a cool head and a skilled guide to know what to do in riding over such an unusual ridge of country. The plan of the trail is Λ, the section ⌒.

In spring these broad fords are impassable. The water is too deep and strong even for Icelandic ponies to stem; and it is cumbered by great blocks of ice, which fall from the glacier, and float out to sea—no creature could live in such a torrent.

The bed of these subglacial rivers must be like the beds of other rivers, but their banks must be very different. In the hollow glens through which they now flow, will be traces of denudation of two kinds, if the ice melts. Marks will shew the wearing of rocks, by a river loaded with ice-floats, mud, and stones, and also the work of heavy land ice, which a change of climate may cause to vanish altogether from this region.

When an eruption takes place water-floods do marvellous work in a very short time, for the rate of denudation changes. Farms are obliterated; houses, cattle, land-marks, men, and their works, are swept away like a heap of rubbish, and the sea-bed is filled near the shore with large banks and heaps of debris, sorted by water, in water.

If ice were gone, volcanos extinct, eruptions forgotten, and the sea-bottom raised higher, it would be hard to account for

hills of debris which skirt some parts of the Icelandic coast, and which seem to have been formed in this way.

They are monuments of fire and frost, denudation and deposition, and they must contain records of sea and land, confusedly mingled, though packed in layers.

In Greenland and in Spitzbergen, according to the descriptions of travellers who have visited these regions, subglacial rivers find their way into the sea without shewing their dirty faces in daylight anywhere. A sea discoloured for miles is the only symptom of the stream which must be sawing rocks under ice as it does in the open air.

The beds of such streams can only be got at by inference, but the inference is plain.

From Greenland to Iceland, from Iceland to Scandinavia, thence to the British Isles, and to Cape Matapan, there is one connected series of cause and effect. The engine is working at one place, the marks are at another, but engines and marks are side by side at many places, and the marks of rivers are plain everywhere.

North and south, east and west, European river-marks are alike, and bear witness to the fact that rivers have done very little geological grinding since they began to flow down European rocks.

In many places in Iceland rivers are subterranean. The drainage waters of large tracts of country sink bodily into the riven porous earth, and not a drop is to be seen on the surface. On Hecla and the lava plains to the north there is no water in summer, but clear cold streams burst out at a place called the springs, near the foot of Hecla. Hot springs burst out at many places, and the plains which lie between the sea and cliffs of igneous rock, all round the island, are bogs which rival the worst in Connemara. There is hardly

any water to be found about Skjaldbreið. There is no river of any size to feed the lake at Thingvalla, but a very large river runs out of the lake.

What the beds of these underground streams may be like is not easy to guess, but probably they resemble underground rivers elsewhere, and some of these may be got at.

In Park mine, near Wrexham, the course of a subterranean river was cut in looking for lead. It can be got at by scrambling, and it is a curious place. A large cavern is water-marked from top to bottom, and old sand-beaches in passages mark a water-level fifty or sixty feet above the stream. The stone is drilled into the most fantastic shapes—oval windows, peep holes through which candles glimmer and water shines; handles to grip, peaks and pillars are common, but there is no straight line or flat plane or acute angle, except where stones have fallen; and fallen stones remain where they fell. The rock is mountain limestone, cupped by millstone-grit; and rain-water, which contains carbonic acid, melts limestone, slowly, as water melts salt. In the bed of the stream are pebbles washed from a distance. A clear murmuring brook can be followed for a great way up stream; down stream it plunges into a hole, and disappears with a roar. It breaks into Minera mine lower down, and where all the water goes at last no one seems to know or care, so that it is got rid of. In some of these underground worlds beds of silicious fossil shells are washed out of the lime, and look like shells piled on a beach. No human hands could dig them from their tombs as water does.

In limestone all over the world caves with subterranean rivers are common.

In Yorkshire are many. In the Alps, streams leap from holes in steep cliffs. Near Trieste a large stream flows into a

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26. For press with a few corrections

cave in a hill-side, and ten miles off a stream of the same size runs out of another cave. One pool is seen in the famous Addlesberg cavern, which has now been explored for many miles. It was known for three miles in 1841. It is an old river-mark filling with lime; a wonderful grotto, hung with glittering white festoons and pendants, and paved with white marble, which rain-water extracts from the hill through which it strains, and leaves in the cave when it gets to air and evaporates.

But the pool, with its strange creatures, the bed where water flows, is like a pool in the free air, and it is worn like the river bed in Park Mine. River-marks under the earth are like river-marks on the surface, when they can be got at; so, probably, river-marks under lava are like those of other Icelandic rivers.

On small slopes sidelong movements are greater in proportion to fall. The resistance is greatest at the bottom, and the downward movement is more easily reflected as the fall decreases. A hill-stream works most at the sides, where there is least resistance. The undermined rock slides, falls, and breaks; the bed of the stream is choked with fallen debris; there are many rapids and pools, but few falls; and the river-bed curves like the curving stream which makes it. But the shape of the trench depends on the fracture of the rock through which the river has made a way.

On a gentle slope the fall is less, and resistance the same. The stream is pushed on rather than dragged down, and it swings from side to side. It works as it moves, wearing the banks more than the bed.

There are many windings in a plain, few deep pools, and a smooth bed; there is smooth water and bad fishing; and

the work done by the river is chiefly the sorting of chips brought down from rock-grooves in the hills.

Every Etonian knows how streams work in their beds; for rowing and swimming teach the lesson.

The Thames flows eastward on a gentle slope, and does

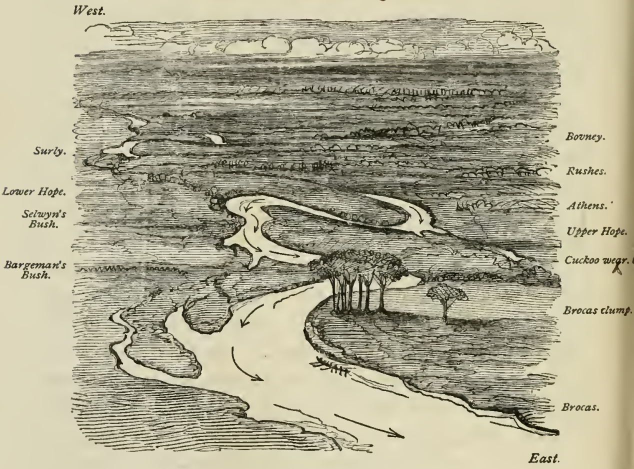

Fig. 25. The Thames.
Sketched from the top of the Round Tower, Windsor, 1862.

not trace a straight line, but winds like a snake through the green fields.

From "the Rushes" to "Upper Hope" the river curves very slightly southwards, and the depth is tolerably even on both sides. But it is greatest on the northern side, which is the outside of the curve, where the water moves fastest. There the bank is steep, the bottom clear, and the stream rapid. On the south side there is a shelving bank, a muddy bottom, and

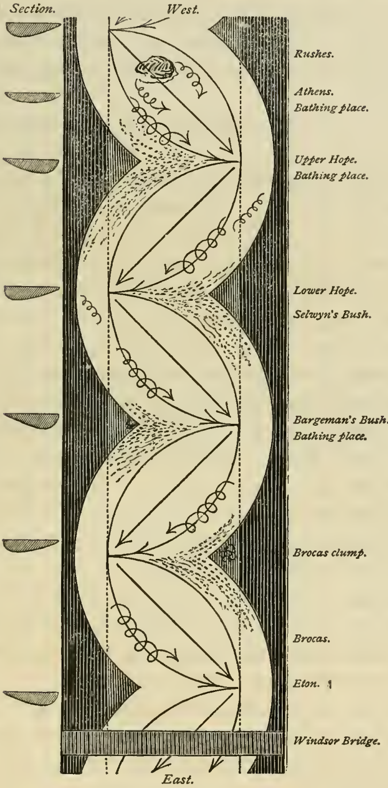

Fig. 26. Diagram to illustrate the movements of Water between the Rushes and Windsor.

dead water. So boats rowing up stream keep the southern bank, and brush the northern on their way down.

The water is swinging eastwards round a point somewhere to the south; the river is working northwards along the circumference of the curve, and writing part of the letter S.

At Upper Hope the main stream has dug into the northern bank so far as to make the curve shorter. It strikes harder upon a higher bank, undermines it more, and rebounds faster to the other side, which it reaches at Lower Hope.

Boats ascending cross the stream at Lower Hope, brush the willow bushes with their oars, and scrape the gravel to keep in the dead water near the southern bank. But on the way back they cross the bay at Upper Hope, hug the northern bank, and shoot down with a rapid stream.

The river flows south and works east between the Hopes, and it swings round a point on the west.

At Lower Hope, the main stream shoots over to the southern bank, which it undermines; and thence it rebounds, swinging on the outside of a gentle curve, about some point to the north, and circling in miniature whirlpools as it slides along the steep clay bank; till it swings away, and across to the "Brocas" at Bargeman's Bush.*

Ascending boats cross at Bargeman's, and hug the northern bank as far as Lower Hope, keeping the inside of the curve, where there is dead water, and a muddy bottom; and when they return they keep in the stream.

Between Lower Hope and Bargeman's Bush the river is working southwards, away from the northern point about which it circles; it is writing the other half of the letter S;

* Now demolished.

and from the round tower at Windsor, the whole silver letter is seen upon its emerald ground.

From Bargeman's Bush to Brocas clump the stream digs into the northern bank, and curves about a southern point. And so the Thames swings from side to side throughout its whole course. It is always gnawing into its banks northwards and southwards as it flows east; but there is scarce a rock to be seen in the river. The valley of the Thames is half-full of chips, for some other engine had hollowed the valley, and filled it with drift and gravel before the river began to dig.

The Thames is a type of streams flowing on a gentle slope; and ocean-currents swing between their banks on the same plan. The rain which streams along the roadway on Windsor bridge after a shower; the Thames, the Oxerá on its lava bed, the smallest and the biggest, the oldest and the newest streams, all dig on one principle, and do similar work. River steamers, canoes, boats, and boatmen; Indians, Lapps, and fish, all work up stream on the same plan as an Eton Funny.

The sculler or swimmer who knows the stream has the best chance in a race, and gets on best in strange lands and waters. The geologist who tries to understand the work of large currents may learn a lesson from small streams.

Salmon-fishers must study the nature of rivers, or they will have sorry sport. Fish haunt particular parts of their domains, for good reasons; and he who knows the reasons knows where to look for fish. They cannot rest in strong currents, so they avoid them; unless there be nice stones or rocks at the bottom, to give shelter from the water gale. They do not like to rest in shallows, for they cannot there be hid from their foes in the air. In dead water there is mud, and no supply of fresh eatables drifting about ; and a salmon is an aristocrat who hates ploughing in dirt, and likes to have his dinner brought to him in a clean place. So fish hang about pools where the water is rough and deep enough to hide them ; and they choose particular spots, where there is stream to bring game, but not too much for the gentleman's comfort.

A salmon likes to have a cool breeze of clear, fresh, well-aired water blowing in his face ; and he rests in his nook poised on his fins, like a gull, or a hawk, or an osprey, floating head to wind behind a cliff, high in the air. And there he puffs, and champs his white jaws, and rolls his unwinking eyes, and wags his broad tail, till something worth having appears. Then the doser awakes ; and, with a sudden rush, the glittering silver sportsman dashes out, open-mouthed, with every fin spread like a fan, and every muscle tight and quivering ; and when he has snapped his hooked jaws upon some nice morsel, he glides back into his place, and waits for more. If he has taken a sham fly, with a sharp hook in its tail, strike home when he turns. If he has missed, give him a rest, and try again.

An old fly-fisher knows the look of places where fish abide, even in strange rivers, for surface-forms indicate submerged obstructions. In his own ground, he knows every corner of every pool, every shallow and hole, stone and eddy in it. So river-marks are familiar to fishermen, who are always watching the flow of water, and the work which it does ; and the sportsman who knows most gets most sport. A still-net-fisher plants his snares in the way of travelling fish, and chooses his station by the run of the stream. Nets and spearing stages set in the Tana and Torneå are planted by Lapps and Quains in the way of ascending boats. Fish and boatmen strive to avoid the strongest stream, and cross at the same places. Fishermen know the stream, and the shape of its bed, by waves on the surface. The work of the river depends on its movements, so the nets mark out the run of the stream.

Floating bodies follow the stream, and shew its movements. If floats carve marks, they shew the course of the stream which moved the floats.

It used to be a time-honoured Eton custom for the long boats to muster once or twice in the spring, row up to the Rushes, and drift down, while the crews sang.

The captain in the "Tenoar," five or six "Eights," some "Sixes" and "Fours," and all the "Funnies" and double and single scullers that could get up in time, joined the fleet, and lay on their oars in a thick cluster; while some musical "wet bob" chanted verses, and the whole of the crews roared the chorus. A favourite performance was—

Rule Britannia,
Britannia rules the waves,
Britons, never, never, never, never, never, will be slaves.

It was a grand song; but Old Father Thames would not be ruled. He never would carry Britannia's sons directly home, or keep their boats in their stations, or even follow his own curved bed. At first, boats to the north forged ahead, and swung their sterns to the bank; those to the south hung back, the long boats whirled slowly round, and bumped and jostled as they floated. The concert was varied by cries of "Paddle on easy"—"Pull round, bow"—"Back-water, stroke"—or "Bow, side oars in the water."

But when the musical squadron had passed the bathing-place at Athens, and had reached Upper Hope, where the stream runs full tilt at the bank, the crews had to row to avoid shipwreck.

The first part of the concert ended with a thundering rattle of oars in the rollocks by way of applause; nearly a hundred oars dipped into the water, and the captain's word was "Paddle on easy to Lower Hope." There it was, "Bow side, paddle hard," and "pull round."

Then the concert began again. The brown swarm gathered into a cluster, and covered the whole breadth of the stream; while "George Barnwell," Black-eyed Susan," "God save the Queen," and similar lays, were performed with the usual applause, and under the same difficulties.

But on this reach the movements were reversed.

The northern boats hung back, the southern drifted ahead, and the long boats slewed round against the sun.

It was "Pull round, stroke side—backwater, bow," for the sterns were always trying to pass the bows, by scraping against the southern bank, while shoving the bows across the river into dead water.

The water whirled as it flowed, and it whirled the floating boats. It turned them with the sun, from left to right—east, south, west, north; with the hands of a watch, where the river curved, sunwise, eastwards, and about a southern point; from the Rushes to Lower Hope. But small whirlpools on that reach turned the other way, on the outside of the curve, because the bank holds the water back. The boats turned against the hands of a watch and widershins where the river curved eastward, and about a northern point, between Lower Hope and Bargemans; and there small whirlpools and floats of froth revolve, sunwise, under the high bank.

By watching these, similar movements on a larger scale may be understood. Corrie Bhreacan and the Maelstrom are but larger whirlpools in a larger stream, and circular storms revolve on the same principle as a whirlpool in a mill race.

What boats tell about movements in a stream is tested by swimming in it. Many a hot summer hour pleasantly spent in the cool Thames; many a long swim from the Rushes to the Brocas, and from bank to bank at every bathing station; long dives in the pools—have made this bit of river-bed familiar to all bathing Etonians.

Elsewhere they find that which is true of one stream to be true of all.

That which is true of boats and swimmers is true of other floating bodies; of trees and ships, ice-floes, icebergs, and clouds.

In Scandinavia are vast forests, in which a harvest of so-called "Norway deals" is reaped.

The reapers live in the open air for months at a time, and brave great hardship, and some danger; for pines often grow in chinks, in the face of high rocks, where it is impossible to get at them without a rope.

Hardy Norsemen and Swedes fell the pines, hew off the branches, and roll and drag the trunks to the nearest water. Once launched, the logs find their own way to saw-mills; and sometimes they drift about in lakes and roll in streams for several years before they arrive.

Many get water-logged and sink; and these may be seen strewed in hundreds upon the bottom, far down in clear green lakes.

Many get stranded in the mountain gorges, and span the torrent like bridges; others get planted like masts amongst the boulders; others sail into quiet bays, and rest side by side upon soft mud.

But in spring, when the floods are up, another class of woodmen follow the logs, and drive on the lingerers.

They launch the bridges and masts and stranded rafts, help them through the lakes, and push them into the stream ; and so from every twig on the branching river, floats gather as the river gathers on its way to the sea.

Sometimes great piles of timber get stranded, jammed, and entangled upon a shallow, near the head of a narrow rapid ; and then it is no easy or safe employment to start them.

Men armed with axes, levers, and long slender boat-hooks, shoot down in crazy boats, and clamber over slippery stones and rocks to the float ; where they wade and crawl about amongst the trees, to the danger of life and limb. They work with might and main at the base of the stack ; hacking, dragging, and pushing, till the whole mound gives way, and rolls and slides, rumbling and crashing, into the torrent, where it scatters and rushes onwards.

It is a sight worth seeing ; the power of a float, moved by water, begins to tell, and denudation is seen in progress.

The brown shoal of trees rush like living things into the white water, and charge full tilt, end on, straight at the first curve in the bank. There is a hard bump and a vehement jostle ; for there are no crews to paddle and steer these floats. The dashing sound of raging water is varied by the deep musical notes of the battle between wood and stone. Water pushes wood, tree urges tree, till logs turn over, and whirl round, and rise up out of the water, and sometimes even snap and splinter like dry reeds.

The rock is broken and crushed and dinted at the water-line by a whole fleet of battering-rams, and the square ends of logs are rounded ; so both combatants retain marks of the strife.

The movements of ice are the same.

At one mill at Christiansand, 70,000 trees thus floated down are sawn up every year; and there are many other mills in the town ; so the work done upon rock by floating timber is on a considerable scale.

The work done by river-ice is greater, but similar. The rocks are worn at the water-line, and undermined, and when they fall, there remains a perpendicular or jagged broken bank.

About ten miles from the town, at Vigelund, at another large saw-mill, there is a fall in the Torisdals river, where the lateral and vertical whirling of flowing water, and its action upon floats and rocks, is well seen.

Above the fall it has been found necessary to protect the rock from floating bodies, so as to preserve the run of the stream. It threatened to alter its course, and leave the mill dry, for the rock was wearing rapidly.

It is a good salmon station, and a tempting spot for a sketcher to watch in summer.

At every moment some new arrival comes sailing down the rapid, pitches over the fall, and dives into a foaming green pool, where hundreds of other logs are revolving, and whirling about each other in creamy froth. The new comer first takes a header, and dives to some unknown depth ; but presently he shoots up in the midst of the pool, rolls over and over, and shakes himself till he finds his level ; and then he joins the dance.

There is first a slow sober glissade eastwards, across the stream, to a rock which bears the mark of many a hard blow ; there is a shuffle, a concussion, and a retreat, followed by a pirouette sunwise, and a sidelong sweep northwards, up stream towards the fall. Then comes a vehement whirling over and over; or if the tree gets his head under the fall, there is a somersault, like a performance in the Halling dance. That is followed by a rush sideways and westward, where there is a long fit of setting to partners under the lee of a big rock. Then comes a simultaneous rush southwards, towards the rapid which leads to sea, and some logs escape and depart; but the rest appear to be seized by some freak, and away they all slide eastwards again across the stream to have another bout with the old battered pudding-stone rock below the saw-mill. And so for hours and days logs whirl one way—in this case against the sun—below the fall, and they dash against the rounded walls of the pool, leaving their mark.

Lower down, near the sea, is a long flat reach between high rounded cliffs; and there these mountaineers, floating on to be sawn up, form themselves into a solemn funeral procession which extends for miles.

But the curve of this stream of floats is always greater than the curve of the river's bed; for the water is slowly swinging from side to side as it flows, and the floats shew the course of the stream, and its whirling eddies. Many marks which remain in rocks in this great valley are clearly not marks of this wearing agency. They were neither made by trees nor by river ice.

A practised swimmer who knows what he is about, and leaps head foremost down a small cascade, is carried downwards with great rapidity, and is then shot upwards to the surface, a long way down stream, where he can swim safely to land.

It is pleasant thus to dash through water like a fish; to feel the eddies and the tickling air bubbles, and to hear the many sounds of the gurgling river. It is pleasant on a summer's day to dive through a cascade, and sit behind the water screen, and watch the flickering light amongst swarms of summer flies which there abide ; but the swimmer who gets out of the run of the water may fare ill, for he drifts round like a log, and if he struggles with the power which is stronger than he ; he may whirl till he sinks, or knocks his head against a stone and drowns.

But the diver learns to know the movements of water beneath the surface, and the surface forms which indicate them ; and he can apply his knowledge elsewhere.

A geologist who wants to know how rivers work upon their beds may profit by the experience of boatmen, fishermen, lumberers, and swimmers ; for he must learn the movements of fluids, before he can safely pronounce upon work done by them.

As fluids move in curves, marks which they make are curved also ; and as water works very slowly, and follows every inequality, water-marks are fine and smooth, though irregular. The finished work is like the polish which a carpenter gives to a surface with his hand, after he has formed it and smoothed it with rougher tools.

Projecting angles in the bed of a stream are polished and rounded, but they are not rubbed off.

Rock-pools, and all water-worn hollows retain irregularities. Sometimes deep round holes are drilled in hard rocks, below falls, and on the sea-shore ; but these are not simply water-marks. They are marks which water makes by moving solids, and the tools used are often left in holes made with them. Rock-pits often contain round stones, sand, and water.

A river, then, is always working slowly downwards and up stream, changing a V into Y, by digging trenches, drilling holes, and undermining rocks over which it flows ; and an ocean-stream works on the same principle.

But marks which flowing water engraves upon rock during a man's whole life are as nothing.

The Oxerá has not deepened its bed two feet since the history of Iceland began. The Thames has not changed its course since Magna Charta was signed, though the Thames works on gravel. What rivers and seas have done is not matter of observation but of inference for short-lived men.

Still water may be set to sculpture soft materials, and the touch and the work done may then be compared with similar work on any scale or material done anywhere during any period of time. Having found a power, it may be set to work.

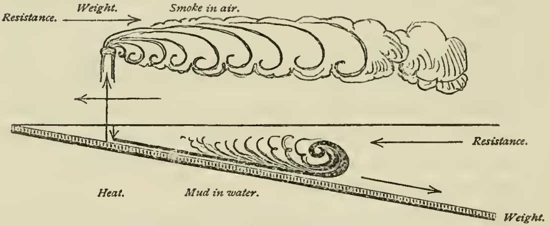

Fig. 27. Vertical Eddies in Air and Water.

The tank figured above shews how streams move vertically.

Let a sheet of glass be sloped in clear water, and drop ink, milk, or water charged with pipeclay upon the upper edge of the glass. The heavy fluid sinks, and rolls slowly down the slope, through the clear still fluid. The upper edge of the stream curls and rolls back, and every movement is clearly seen. When a breeze passes a fixed chimney, or when a steamer moves through a calm, the same forms and eddies are seen in smoke. Wherever a moving fluid passes through fluid at rest, there are similar vertical eddies ; and though they are invisible they often leave their marks.

Horizontal eddies are seen behind every stick in a stream. The woodcut is from a sketch made in London. The square stands for a post, the lines and arrows shew the paths described by bubbles floating on the Thames. But the laws

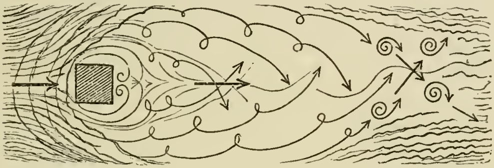

FIG. 28. HORIZONTAL EDDIES IN RUNNING WATER.

which controlled the movements of these tiny floats and streams would hold good though the post were an island, the stream an ocean-current, and the floats ice-floes. Where such floats leave marks they are drawn on a similar plan.

There are vertical and horizontal eddies, whirlpools, and whirlwinds, in the atmosphere and in the ocean ; and all streams and moving floats flow and move on the same principles.

Similar curves appear in a tea-cup when stirred with a spoon, in a mill-stream, and in the Thames ; they are seen in a strait, from a hill-top, where a rapid tide is flowing amongst an archipelago of rocky islands ; they are described by a stream of molten iron ; their tracks are on ancient hills.

There are eddies in streams moving through fluid at rest, or past pebble, post, rock, island, point, or sunken continent ; in air moving past a chimney, a volcano, an ice-peak ; or rolling north and south from pole to pole.

But the movements of all streams may be learned by studying the run of water in rivers ; and stream-marks may be learned from working models.

The following simple experiments will imitate river-marks :—

1. Mix fine pipeclay in water, and place a sheet of glass at the bottom of the vessel which contains the mixture. After a few minutes raise the glass slowly out of the water, and there remains a film of wet clay upon plane glass. Slope the glass to let water drain slowly off, and in half an hour the clay on the glass will be marked by flowing water as clay is marked by streams in the great valley which stretches seawards between Hecla and Eyafjalla, or similar alluvial plains elsewhere. Water clears channels on glass, and leaves clay islands ; and the resulting forms are those which are seen from the high ground whence Gunnar looked upon his favourite glen, and where he sleeps in his cairn. They are the same everywhere : the plane glass is a plan of a plain through which a stream meanders.

2. Vary the experiment by pouring thicker mud into clear water, to represent a quiet lake or sea into which a river falls. The descending current is seen whirling clay-clouds into beautiful curves, as it pushes through the clear still water ; but when the movement has ceased, the glass at the bottom is covered with a thin even layer of clay. Raise and slope the glass at various angles, and river-forms of various curvatures re-appear.

3. Slope a square foot of glass, and pour fine mud over it, till the glass is covered with a pretty thick stratum of even consistency. Stick a lump of clay at one corner, and let clear water, and water coloured with brown ochre, drip slowly upon it.

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See page 137. 26.

Flowing water digs out channels and colours them; and the resulting forms are those which mark the great boggy plains which surround the igneous rocks of Iceland; and similar plains elsewhere.

The model is like a map. The work of centuries of slow action on one scale, is done in miniature in half an hour; time and quantity differ, but mechanical forces, materials, movements, and resulting forms are the same.

4. Build a heap of clay on a garden walk, and pour water upon it; or throw clay upon the roof of a house where rain may fall upon it—and the work of denudation will soon begin naturally upon miniature plains of mud, deposited in hollows on the ground, but washed from the roof. The larger the experiment the longer is the time; but the tool-marks of all streams are alike.

5. Change the course of a rivulet—turn it loose in a dry field, or on a sea-beach—and watch its proceedings day by day. When it digs a new course in a bed of compact stiff clay, all the marks which water leaves upon solid rock will be copied in miniature in a week.

Time extends as quantity grows; but the miniature work having been seen in progress, like work can be referred to its cause whatever the quantity may be.

Denudation, the wearing away of solids which do not fuse at temperatures which now prevail at the earth's surface, is caused by certain definite movements—upward, sideways, and downward—in gases and fluids which do not permanently solidify at these temperatures.

The movements result from the action of radiating and converging forces, which, by moving gases and fluids, wear away and destroy previously existing solid forms, and construct others.

The moving forces appear to be heat and weight; so the marks made by weathering and rivers are their marks.

Till the contrary is shewn, it may be assumed that like results have followed from the action of these two mechanical forces ever since they first began to move gases and fluids, and wherever there was a solid to be worn by rivers and floats.

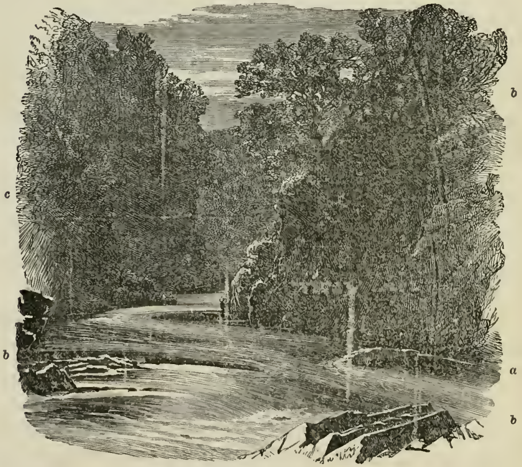

Fig. 29. A SALMON CAST IN THE FINDHORN. Photographed 1858.

A river writing the letter S, and cutting a U-groove in old stratified rocks. *a*, The place where he lies. *b*, Smooth water-worn rock. *c*, Cliffs undermined and fractured.

CHAPTER XI.

DENUDATION—FROST-MARKS—WEATHERING.

It has been shewn above, and it is familiarly known, that water, in freezing and crystallizing—in changing from a fluid to a solid—increases in bulk, and exerts a force which reacts on other substances. Because ice is abundant on the earth's surface, it is a geological engine; as it has the same qualities everywhere, its action may be learned from small experiments.

A glass jar, on which rust had been deposited from a solution, was scoured clean in a hard frost. Ice crystals formed next to the glass, which was next to the cold air; and the crystals thrust themselves in between the two solids, and so thrust them apart. The solid rust was driven inwards, leaving an angular pattern of clean glass, picked out with lines of brown powder.

This was neither the force of heat, nor that of weight; but attraction and repulsion of some kind, which acted on matter when heat and weight had placed it, and prepared it for crystallization. It is a force which seems to act differently on every substance which takes the form of a crystal; for crystals are of many shapes, and their study is a separate branch of science.

They have this in common—they all grow larger by additions from without; so they result from forces which move particles towards a centre, and pack them about a point or axis, and in particular forms. They form in fluids and disperse in solids at certain temperatures.

It seems to be this packing which reacts on other substances; and so the force of crystallization acts like a wedge.

The shape of a portmanteau changes when it is stuffed.

If a corked bottle filled with water is exposed to frost, the glass bursts when the water freezes; for the water particles are differently packed in the crystal ball.

A strong glass bottle uncorked does not always burst when water in it freezes solid; but ice is squeezed out of the neck by the pressure within. In either case, more room is wanted, and forcibly taken, by the forces which pack fluid water into solid ice crystals at 32°.

When ice formed in glass moulds is closely examined, it is found to contain air, curiously packed in hollow chambers.

Their shapes are seen through glass and ice, and they bear reference to the centre and the circumference of the vessel which contains the system.

In a spherical glass bottle air-chambers in ice radiate from a common centre; the thickest end is inwards, the outer end tapers off to a point, and the inner end bends upwards. They are like shoals of silver tadpoles retreating from the cold.

In ice formed on the flat sides of a glass tank or a tin mould, air chambers have the same general form, and point their heads away from the outer surface, where ice crystals first began to form. At the corners they point down or up. On the top they point downwards.

So water-particles attract each other and repel air. The solid packs into an angular form, and the gas is squeezed out into curved shapes, which are distorted spheres, for free bubbles are spherical.

In pond-ice, or sea-ice, or ice on a puddle, these air-chambers are nearly vertical; they radiate from the earth's centre. They are made by gases driven inwards by crystallization, driven down by cold; struggling upwards because they are lighter than ice, and resisting pressure because the freezing point of air is not the same as the freezing point of water. The "specific heat" of air radiates outwards from every bubble, and resists compression.

In every solid crust of ice there are weak points, where chambers open a way inwards towards the water, which is shut up and squeezed by the crust, and tends to escape.

Where a hole has been bored through ice, water rises; and when the ice is horizontal and the frost hard, a solid mound forms on the top of the ice plain.

Beneath the mound is a conical hollow, in which water and air gather; and as freezing and squeezing go on, the mended hole is apt to burst, as the weakest point in the ice-crust.

All these changes of form result from the well-known fact, that solid water is bigger and lighter than fluid water, and in this it resembles other materials. Iron swells as it cools in the mould; cools first outside, and squeezes imprisoned gases into moulds, which resemble air-chambers in ice.

A pound of water still weighs a pound when frozen. A pound of melted iron is no heavier when it has crystallized and taken the form of a mould; but both take more room in packing. As grains of solid lead take more room than they do when melted; as an ounce of lead filings cannot be packed cold into a bullet-mould which casts an ounce ball; so, perhaps, crystallization is the arrangement of invisible solid particles. But in any case it is an active mechanical force, which does geological work.

It crumbles earth. Ice which forms in a damp gravel walk rises up, and lifts stones. In dragging particles into their place the packing force squeezes the ice-wedge under the gravel, and the ground is "blown up by the frost." Small stones are found perched upon crystal pillars of various forms.

In clay, cold first turns a clod to stone veined with crystal; and then heat crumbles it to powder, when it melts the ice.

When ice has formed on fine sand or clay, the surface retains casts of the ice crystals, and these may be copied by sprinkling dry plaster of Paris into the water, when part of the solid has thawed. It is a case of "pseudo-morphism."

In crystallizing, water drags other substances into forms which do not belong to them; and this is true of other crystals. The force is one which works two ways. It drags in matter to build a shape; and as the shape grows it thrusts extraneous matter away. So crystallization attracts and repels.

On a larger scale this force moves and splits stones and rocks, and so this crystal tool works denudation.

In Scotland the silence of a still frosty night is sometimes broken by loud sharp reports, followed by the hoarse rumble of stones falling from mountain peaks. The fresh tool-mark of the ice-wedge, and the fallen chips, are found on many a steep hillside and rocky glen, when autumn brings Southerns to their shooting quarters. Melted ice then trickles slowly down as a bright varnish of water on the broken stone.

Rain-water sinks into every open chink; and when it freezes, the crystal wedge shoves great rocks from their base.

The tool-mark is angular; a fracture, whose shape depends on the nature of the rock which is broken. The finished work is to be seen in high mountains, whose tops are riven peaks, and whose sides lie shivered where they fell.

On the shoulder of Hecla are numerous blocks of porous stone which split easily along planes of bedding or cleavage; and they shew this action of frost. Amongst the loose black volcanic dust which seems to form great part of the hill, these blocks shew light on a dark ground, and are conspicuous. Some are entire, and have rounded outlines; others are split up into thin flags. These often retain their relative positions, but they have been moved away from each other, and they stand up in the dust like a pile of slates set on edge. It would be as easy to replace them, as it would be to reconstruct a block of slate, newly split by a slater at Baillechaolais.

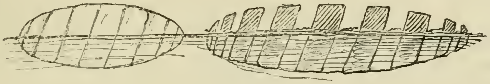

FIG. 30.

With a knowledge of the ways of English ice, it is easy to understand that water, after soaking into the joints, split the stone when the sharp frost of this lofty region in a high latitude drove the ice-wedge home. The next thaw wet the dust, and the next frost turned it to an expanding stone, and forced the slates apart. The next dry wind blew volcanic dust into the openings, and the next shower of snow covered it with a layer of water dust, ready to be melted and frozen. And so heat and cold have split and sorted enough of slabs to roof a hill-side in Iceland.

It would be easy to name a dozen hills in Scotland where slaty rocks have been split and sorted after the same fashion. The names of the hills often describe them, as "Gray flags," "Speckled slabs;" and they are truly described, for the names were given by men who lived on the hills, and knew the stones.

These are frost-marks. The ice-wedge chisels out cliffs and rugged peaks ; it makes clear sections and sharp angular fractures ; the touch could never be confounded with the smooth groove dug out by a river, or by any other grinding engine.

Amongst peaks which are conspicuous examples of this kind of denudation, the following may be named :—The Aiguilles about Mont Blanc, which are so steep as to be free from snow and tourists in all weathers ; the Schreckhorn and Finsteraarhorn in the Alps ; a few of the highest Scandinavian mountains ; Sneehættan ; the mountains called Skagastol Tinderne, which stand up like pyramids and jagged points from 8000 to 9000 feet above the sea, and far above the Fjeld ; a few of the highest mountains in Swedish Lapland, which contrast with plateaus and lower hills about them ; a few of the highest hills in Scotland, especially the Cobbler (Beinn Copach) in Argyleshire, and hills in Wester Ross ; in Skye, Mull, Rum, Arran, and other islands ; nearly all the high tops which face the Atlantic, on the Norwegian coast, north of Bergen, but only the high tops ; nearly all the high islands which protect the Norwegian coast, and make the passage to Hammerfest a pleasant sail in a landlocked sea. the Lofotens have been likened to shark's teeth, saws, and other spiked instruments. A few solitary peaks in Iceland rise through swelling mounds of snow, but peaks are rare in Iceland. The woodcut will best explain what is meant by weathered peaks.

It is copied from a sketch made in June 1852 from the deck of a Norwegian steamer at Svolvær in the Lofotens. The place is a station for catching and curing cod. The split bodies of the slain are dried upon low ice-ground rocks, and hang in festoons and fringes from sticks. Those which are dried on the rock are "clipfisk," the others "stockfisk." In the foreground a native is represented moving about on water skates (vand skidor). The peaks and the low rocks contrast here, as elsewhere on the Norwegian coast; their forms are characteristic of quarrying and polishing; of glacial denudation and weathering.*

* In this and in following cuts an attempt is made to explain by marginal notes the meaning of symbols used in the text to express certain rock-forms. A river delta Δ, Y's, and forks V, are familiar expressions; Λ is but another symbol of a natural form which is characteristic of weathering. ⊐ Λ

Fig. 31. Svolvær. June 11, 1852.

The angle Λ which the sides of various high peaks make with the horizon, are easily measured on Photographs. The following are a few examples aiguille du Dru 69° Le Geant taken from Montanvert 69 Le Mont Cervin 64° Terminal moraine 32 Dry snow heaps about 32. Mont Blanc snow dome 37°

CHAPTER XII.

DENUDATION—FROST-MARKS—LAND-ICE, ALPS.

WHEN river-marks and weather-marks have been learned, it plainly appears that many rock-grooves hollowed out of the earth's solid crust were neither hollowed by streams like those which now flow in them nor quarried with ice-wedges.

The rivers at Galway, Inver, Belfast, Ballyshannon, and Derry, in Ireland; the Araidh at Inveraray, the Clyde and Forth, the Tyne and Tay, the Awe and Spey, the Ness and Lochy, the Conon and Carron, the Shin and Laxford, and many others, in Scotland, Wales, and England, have only sawn small ruts in large rock-grooves, which hold rivers and sea-lochs into which they flow. Rivers did not scoop out the valley of the Götha; the Wenern and Wettern lakes in Sweden; Gulbrandsdal, Sætarsdal, the Hardanger and Sogne Fjords, Romsdal, and similar deep trenches cut through rocks in southern Norway. A stream flows from Skagastol's peaks, but the hollow in which it flows is not a river-mark.

Contrast the shape of the peaks in the woodcut with the rounded form of the hollow which makes the middle distance, and with the trench dug by the Ruikanfoss (Fig. 22, p. 98.) These forms are tool-marks of weathering rivers and ice.

Below these riven peaks, which are from 8000 to 9000 feet above the sea-level, are tiny snow wreaths. In the glen are old ice-marks. The form of the glen and the ice-marks are repeated down to the head of the Sogne Fjord; they may be followed for a hundred miles, past Bergen, over the islands, and out to sea ; and in some of the feeders of these great sea-lochs large glaciers still survive.

Further north, the Alten, Tana, Torneå, Umeå, and other rivers of northern Scandinavia, are sawing rock, but they did not hollow out the big rock-grooves in which they flow. Glens and hills are rounded and ice-ground, and only the highest peaks and sea-cliffs are weathered.

Frost mark ∧. Weathered peaks and talus of snow, and stones chipped from the peaks.

Land ice-mark ◡. Glen apparently worn by a glacier.
Land ice-mark ⌒. "Mammillated" rocks in the glen.
River-marks L V U Y *cut by the fall and stream at the bottom of the ice-ground glen ◡.*

FIG. 32. SKAGASTOL TINDERNE. Sept. 1, 1857.

The Laxá did not make Laxdal and Breidfjord by wearing the igneous rocks of Iceland, but they are worn. If river-marks are plain in all these glens, other older marks are fresh on the worn stone surface. They are marks of land and sea ice.

The tool-marks of rivers and weather cover a small space.

All over the north, at least as far south as the Himalayas; on hill-tops, and on cols 9000 feet above the present sea-level; in glens, and even under water as far down as rocks can be seen or felt, marks remain which are ice-marks. Weather and water are but wearing out these older tool-marks.

One who looks at these for the first time, who sees knobs of gray stone peering through vegetation; washed by streams, or sea waves; laid bare in a drain, or under turf; or near a large town, is apt to attribute the marks to any cause but the right one. The scratch was made by a wheel, or a plough, or a hobnailed shoe, or a stone moved by a flood, or a flood moving over a stone. It is the mark of a landslip, or the rock was so created. But one who has seen ice at work cannot mistake the touch of this graving-tool. Still the great majority of Englishmen do not yet understand what a glacier is like, or what ice can do; and many professed geologists will not believe in the plainest old ice-marks.

The rocks are shaped like a broken stone which has been rubbed with sand and a soft pad. Angles are ground, fractured surfaces are smoothed but not wholly obliterated, and sand-marks shew the direction in which the grinding pad was moved by the force used to move it. The stone is roughly polished; so is most part of the northern hemisphere in high latitudes.

In order to learn the meaning of a rock inscription, the character must be learned. In order to understand the marks of a graving-engine, the engine must, if possible, be seen to work; so the first step to the comprehension of ice-marks ought to be the first of a journey to visit some place where the hard ice-edge of the atmospheric denuding engine touches stone; as it does in the Alps.

The following is a greenhorn's account of his first introduction to mountain ice, some twenty years ago, when greenhorns and philosophers knew less about glacial action. As one who remembers learning to read can best describe how he learned his alphabet, a few extracts from old journals may yet be of interest. The writer of the journal was on his way northwards and upwards from warm regions to cold, having travelled from Cape Matapan, Sparta, and Patras, to Trieste and Venice, and thence across the plain to the Lago di Garda. He was bound for the top of the Stelvio, and the head of the lake of Como, and he wrote :—

"19*th August* 1841.—What a difference there is between travelling amongst romantic mountains and plodding over a plain ; the very rivers in one case seem to grow dull and lazy ; in the other they leap and bound from rock to rock, as if they too enjoyed the forests and mountains which they adorn.

"The fresh morning air seemed to send health and vigour through every vein. I felt as if I could catch a chamois. . .

"At Mareme halted and took a cast in the river. It was a thick glacier stream, brawling amongst the stones *which it had carried there in winter,* and I got nothing for my pains but a deal of admiration from all the idle vagabonds in the town.

"One fellow who spoke Italian advised me to put some lead on my line as the river was rapid. I am not a bait-fisher. . . .

"The ascent is not steep but continuous. The Adige, now a roaring torrent, rushed down by the side of the road, and the mountains began to be tipped with snow. The grapes too began to be less and less ripe, and about Laitsh the hay harvest was only now going on.

"It is curious thus to follow the harvest. At Athens, nearly four months ago, in the end of April, they were cutting the barley ; at Pola and about Trieste, they were doing the same ; at Laibach and Idria they were making hay; and here they are at it again, while the crops are nearly all green.

"At Latsch I saw a glacier for the first time in my life. Were it not for a kind of cloudlike appearance about it from its transparency, I should have taken it for a large snow wreath.

"Farther up larger ones came in sight, and the mountains, clothed with pines to the very rocks, are much wilder ; but still I was disappointed. The mountains to the left were grand ; but they were Alps, and they ought to have been grander.

"Near Prad, which lies in the entrance of a valley which branches off from the Adige, the snow-covered peaks of the Stelvio came in sight. It was getting dark, and it was no easy matter to distinguish them from the background of clouds. . . .

"*Friday, 20th August*—The road lay by the side of a roaring burn, and was a continued ascent, but still gradual.

"After about an hour we came in sight of the snowy peaks of the Stelvio, and mounting a hill a little further on, the first glacier burst upon our sight.

"One could hardly fancy the impossibility of walking upon it ;* indeed, even with the spy-glass, the cracks and clefts seemed insignificant ; but at last, by comparing one of the smallest rifts with a fir-tree which grew near it, I contrived to accustom my mind to the vastness of the surrounding scenery. The road leaves the banks of the river, and winds in zigzags up the face of the hill. I took the short cut several times, and was rewarded for my pains by numbers of Alpine strawberries and raspberries, which grew at the foot of the pines. Every turn of the road now brought some new peak into view, and glaciers, seen nearer, began to disclose the

* Much insisted upon by a cautious companion.

ruggedness of their surfaces; but still what I saw and what I had read seemed quite irreconcilable.

"At last, just below the Boscho, the road passed close to the bottom of the Matatsch; and leaving my companion to read Paul and Virginia in the carriage, I scrambled down the bank, and across the river, fully intending to ascend the glacier for some distance. What was my surprise to find that which I took for a coating of snow to be nothing but the rough surface of blue hard ice!

"Without a hatchet, I could as easily have ascended the sky as the glacier. I poked my stick into the holes, looked wistfully at the steep smooth surface of the sloping wall of ice, scrambled up some *debris brought down by the glacier-stream*, and slid down again, carrying a small avalanche with me; and then, as I could not get up, I just went back again.

"I was only gone fifteen minutes, so near is this glacier to the road. In former years, I believe, it came a good deal lower down; but now it is retiring again to its old limit.*

"At Boscho we ate bread and cheese, and proceeded.

"The villanous mists had come down on the top of the Ortles Spitz, and we could not see the whole at once, but what we did see was grand. Such wild pathless crags and enormous glaciers I had no previous idea of.

"By the way, I never saw a description of a glacier that conveyed the smallest idea of its general appearance. I had a confused notion that it was a mass of ice broken into the most fantastic forms, but that this mass should fill up a valley

* The bed from which this glacier has retired is a mass of clay and angular blocks of stone, beaten and pressed down flat in the centre, but surrounded by a boundary ridge. It looks as if the ice had been thrust forward, and had then melted away, leaving the clay which the ice contains, as a bare red hollow amongst trees and grass.

I had no idea. I rather thought it covered the tops of mountains. Now the Manatsch Spitz was in the midst of ice, and tapers up to the clouds, as black as nature made it.

"The road from Boscho to the top of the pass is a marvellous piece of engineering. It is carried up an almost perpendicular ascent, so gradually, that a carriage might gallop up the whole way. It is also protected in the middle by strong galleries of wood placed at the same angle as the hill-side, so that any substance falling down is shot past, and the traveller mounts safely under cover. The extreme height is 9272 feet, being 800 higher than the perpetual snow-line, according to Murray.*

"At Santa Maria, a short way down, we halted and dined, and I determined to stop all night, and try for a chamois in the morning. . . . .

"This is my first day really in the Alps, and the Stelvio and the Ortles Spitz are no mean specimens. If I was disappointed yesterday, I was delighted to-day; and I feel ——'s mountain mania gradually coming on. . . .

"This house is new and consequently somewhat damp; it is but little below the top of the pass, and there is the highest permanent human habitation in Europe. Except the workmen at the house above, I shall probably sleep as high this night as any one in Europe. What a place it must be in winter! Patches of snow even now surround it, and the stunted grass has that yellow green colour, which it always wears when newly freed from snow in spring. I am far above fir trees; and in fact a more desolate misty abode I cannot imagine.

"The inhabitants, like all the Tyrolese whom I have yet seen, are a rosy-cheeked wholesome-looking set. There are

* Rocks at this level, *on this col*, are rounded, not sharp weathered points.

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For press
a few letters

two children running about the house, perfect pictures of health; one, an urchin of fifteen months (so says his mother), speaks German and Italian.

"My chasseur made his appearance about seven, in his working dress. He is a handsome little active fellow of nineteen or twenty, and from the talk I had with him, seems to prefer the mountains to working on the road. His eye sparkled as he told me of his success last Sunday, and he looks like his work. I am to start at four, weather permitting. It is now raining like Old Scratch, and as thick as porridge.

"*Saturday*, 21*st August.*—Rose in the dark, breakfasted, and off by four.

"At this early hour, the mountain mists had not risen, and the peaks shewing against the clear cold sky, seemed almost close at hand. About a mile down my guide left me, to go in search of his rifle, and I mounted the hill to the right as far as a peak of rock, which we appointed as a rendezvous. Here I sat down, and swept the surrounding hills with my glass, in search of game, but without success.

"It was very enjoyable to sit basking in the rays of the newly risen sun, and *watch the wreaths of mist as they gradually rose from the valleys, and crept lazily along the mountain sides, till they finally rested upon the snowy tops.** It was very beautiful, but not good for my hunting.

"My guide now made his appearance, blowing like Boreas with the exertion of running to be in time; and after stopping for a moment to examine his rifle, we started. The plan of operations seemed at first to be the same as deer-stalking. He walked warily along, peeping over the hill shoulders, till we came to a spot from which he pointed out a green patch

* See above, p. 26, Local winds.

on an opposite scaur, where he and his friend killed two chamois last year. There was a wild cliff above, and a ruckle of loose stones below it, ending in a precipice, which fell sheer down almost to the Adda, the roar of which came up faintly to our ears from the depths of the valley below. One of them approached at each side of this slope, and two out of three chamois fell.

"We examined the whole face of the scaur, and, as I imagined, we had done with it, when to my horror I found that this ruckle of loose stones was to be our road. It was unpleasant, but the game was follow my leader, and on we went. The slope was very great, and at every step a small avalanche of stones went rattling and bounding down to the edge of the precipice, where they disappeared. The noise I should fancy, was enough to frighten all the chamois in the Alps; but my guide knew best. It was about the hardest work I ever had, and was rough training after a six months' rest, and a fever; and worse than all, there were no chamois to be seen. Tracks there were in plenty, and, at the far end of the scaur, quite fresh. I firmly believe the beasts had fled at our noisy approach.

"At last, after the hardest scramble I ever remember to have had, we got out at the top of a wild crag on a mule-path leading from some iron-mines to a furnace, and I recovered my nearly broken wind. Here we set to rolling great stones down the hill. It is a favourite pastime of mine; I got the fancy from a keeper. It was glorious to see these great lumbering fellows go hurtling down the brae, scattering the little ones before them, and then with one big bound leap over the cliff in a cloud of dust.

"A canny old shepherd sat upon an opposite bank, watching our proceedings. I suppose he thought we were daft."

And so the rest of a day's scramble is described.

"It was now well on in the day; I was not fresh, and the next chance of a chamois was on the other side of a wild rocky mountain, that towered above our heads; so, putting our best foot foremost, we legged away down a sheep-path to a place where our burn joins a larger one, which comes from the west. Here the fir-trees began, and we walked on amongst them, till we got opposite to a very remarkable cataract. The situation is beautiful: on all sides rise the wildest of crags, with lofty pines clothing the steep banks at their feet, and between these nearer hills one gets a glimpse of the distant snowy Alps.

"The cataract itself rushes out of a hole high up in the face of a cliff, and falls at one shoot fifty feet into a dark and boiling pool. The water for a wonder is as clear as crystal, and from the little height upon which I stood, I could almost have counted the pebbles in the bed of the stream. We stopped for some time, admiring, and feasting upon wortleberries and strawberries; and then, fearing a shower, set off again for Bormio.

"The distance is not great, and I walked in to the bath-house, amidst exclamations of 'Ecco il cacciatore' from all the idlers at the door. My guide, it seems, is a regular poacher, who will not pay for a licence to shoot, and walks the hills in defiance of guardians. As we came down, he took the lock off his rifle, unscrewed the nipple, and handed both to me, with his powder-horn. Then with his dismantled gun he walked past a fierce man in green, whom we met in the road, looking innocence personified.

"I cannot well account for the fact, that on the ground on which I was there was little or no snow. On the opposite side of the valley there were even glaciers, extending much lower than we were ; and on the north side of the pass, the snow-line was thousands of feet lower down. I understand it not.*

"The baths of Bormio are medicinal, and rush out of the rock at the temperature of $93\frac{1}{2}°$ R.

* * * * *

"22*d.*—Off at seven in a pour of rain. I was lucky in my day yesterday. The road lies by the side of the Adda all the way, and as we descended it was like coming into a new country.

"From bare rocks we came to pines, and then to chestnuts, mulberries, and vineyards, with all varieties of grain that grow in the different climates through which we passed. In some places the scenery was beautiful. The rocks, which towered high above the road, were covered with pines to the very top, and shewed like pictures in a magic lantern through clouds of mist, which now hid and now revealed their weather-beaten peaks. The valley lower down is full of villages, and it was amusing to watch the variety of costumes, as the peasant lads and lasses passed on their way to churches perched high on hills amongst the wood. Asthma cannot be a common ailment.

"At Tirano we dined, and I sallied forth to look at the people who were coming out of church. Every third woman had a goitre ; some were enormous. The men were not so bad, or their collars hid them ; but lots of men were deformed by these hideous swellings. Is it caused by air or water? The circulation here seems pretty free, and the water is the same which passes Bormio ; yet there was not one goitre above for ten here.

* The reason is plain : the sun shines most on the southern slope, and snow lasts longest near large snow-heaps.

"From Tirano to Sondrio the descent is gradual, between hills clothed to the top with forests of chestnut, and at the foot with trellissed vineyards; and through the side valleys we could now and then catch sight of snow-peaks, half hidden by mists, and contrasting with the rich greens below.

"Sondrio is surrounded by vineyards and gardens, and stands at the junction of the Malana and Adda, and goitres abound. . . .

"*Monday* 23*d.*—Still following the Adda most of the day. The valley is now much wider, and marshy in places from the smaller slope. The effects are evident in the sallow faces and stunted forms of the people. At Morbegno in particular, my companion was very eloquent; and, in truth, he had numerous varieties of deformity to lecture upon. Of dwarfs there was no lack; crooked eyes, goitres, and crooked legs, were fearfully abundant; and the name comes from *morbo,* disease.

"Our night's resting-place was Colico, a neat little port on the banks of the beautiful lake of Como.

"The water looked so blue and clear that I could not resist a dip, and accordingly in I went, to the great delight of a lot of boys and one woman, who with perfect composure took a position at the foot of a tree, and watched all my proceedings. . . . And so down the banks of Como to Milan.

"*Wednesday* 25*th.*—The road is as flat as a bowling-green, and the country, like the rest of Lombardy which we have seen, is a large field of Indian corn, planted with mulberries and acacias and poplars, from whose branches vines swing in festoons. Here and there comes a patch of millet, oats, and other grain. It is a contrast to the top of the Stelvio."

The raw hand, unused to ice and its marks, saw and remembers the legible characters which a departed race of giant glaciers have inscribed upon rocks in every glen in the Alps.

He could neither read the inscription nor understand the language of ice. But he had begun in a school which has turned out a class of eminent men, to whom ice-marks are familiar as letters on a page. Many books have been written about glaciers; and many more are coming. The learned dispute about details; the unlearned take sides. Bits of rock, with ice-marks upon them, are now stored in museums; shop-windows are filled with photographs of Alpine scenery; an Alpine club has been founded, and it has published books; but in spite of all these highroads to knowledge, not one man in ten understands what an ice-mark is, or knows more than the writer of the journal knew of this subject.

A second lesson was learned from the Grimsel.

Near the top, bare granite rocks support but a scanty vegetation. The path itself in many places runs over rounded tables of rock, in which steps are cut for the feet of the mules. There is no ice in the glen so far down, but these ice-marks are like those which extend from the Stelvio to Milan. The muddy river which flows at the bottom of the glen has done little work since the last of the big glaciers struck work and retired.

"*Tuesday*, 14*th September* 1841.—Started at a quarter to six, accompanied by Nauspaumer with a bag of eatables, and led by a chamois-hunter. We followed the course of the Aar for about a couple of miles, and then, turning to the left, scrambled along the face of a mountain. After some hours of slipping and stumbling, we found ourselves at the foot of the Oberaar glacier, where we halted, and loaded our rifles, and spied the country.

"My guide now turned to the right, and ascended the valley, slanting up the mountain, peeping cautiously over rocks, treading lightly on loose stones, and speaking in whispers. Chamois tracks were numerous, and some quite fresh. Far off, on the other side of the valley, my sharp-eyed guide had spied a mark in the snow. He said it was the pass of a chamois, and that we should probably find him higher up. This work went on for several hours. We had got very high up ; the glacier was spread like a model at our feet, and I was meditating the ascent of a neighbouring peak, when my eye caught something moving below. It was a fine chamois making his way carefully along the ice ; and in a moment we were all down flat and mute as flounders. With my glass I could watch every movement the brute made, and my heart was in my mouth with keenness. The hunter, with joy sparkling in his sharp eyes, declared that he was going quite right, and we had the satisfaction of seeing him stop and feed at the first rock he came to. Setting Nauspaumer to keep watch, we drank 'Fuil air an sgian,' and started for stalking in earnest.

"The place which the chamois had chosen for his mid-day halt was a rock sprinkled with tufts of nice green grass, and fronted by ice. It was a perfect chamois' paradise. We scrambled across a small broken glacier, which was rather kittle ; mounted a very steep snow-wreath, which would have stopped me at any other moment ; and when we got fairly above the rock, we began the old work of peeping and creeping over the stones.

"At last we found him ;—he was quietly chewing the cud on a green bank some hundred and twenty yards below me ; and he was looking out over the glacier as if studying its nature.

"I thought he was much further off ; put up the long sight ; fired as steadily as I could, and the ball knocked up the dirt a good foot over him. Up sprang the beast, off went the second barrel, and away he scudded like the wind. Mustering all the semblance of German at my command, I turned to the hunter and said, 'Schootz me.'

"There never was such a tailoring shot, and I never was in such a stew. I walked back very crest-fallen along the surface of the glacier, which is here as firm and safe as a road, took a shot at a stone at the same distance as the chamois and smashed it to bits. Took a header into the "dead sea," a black lake behind the inn, which cooled me effectually; told everybody I met what a mess I had made, and got to bed after twelve hours of hard walking.

"My hunter is a regular artist. He mounted the Jungfrau the other day with Forbes, and he says that he gave the Professor four fair shots at chamois, all of which he missed. The 'stag fever' is epidemic here. He stalked like an old sportsman, and I took a great liking to him, though his only lingo is that horrid German.

"15*th.*—Started at half-past five. Porters, blankets, and grub, and three young fellows who mean to join me, were to follow later. We took the same path as yesterday till we reached the Unteraar glacier, then, instead of turning to the left, we went straight on up the glen on the ice for four hours. The first six miles one might easily take for dry ground.

"There is nothing to be seen but one vast plain of loose stones. Sometimes these rise into ridges, and the biggest are always uppermost. The last hour was over crisp ice, down which torrents of clear water brawled in blue channels till they vanished into some hole or cranny with a roar like thunder.

"I threw big stones into some of these 'moulins,' and could hear them rattling from side to side to an enormous depth. The colour of these pits is a beautiful deep blue. The water which thus runs in clear, comes out milk-white below the glacier, and it does not clear till it has passed through several lakes. It is not quite clear even at Rotterdam.

"At last we reached our night's quarters. A Swiss professor has been living here for more than a month, and only went away last week. He has been digging a hole to try the depth of the ice, and the shelter used by his men is to be our bed-room.*

"The large Lauteraar and Finsteraarhorn glaciers meet here, and their enormous moraines joined, yet clearly distinguishable, run together down the Unteraar glacier, and no doubt these form the plain of stones below. At the very top of this moraine, on a ridge some forty feet higher than the surface of the glacier elsewhere, stands an enormous block of granite, from under which the ice has so melted as to leave a kind of vault with an ice floor and a granite roof.† Taking advantage of this, the Professor and his men have built up a low wall which keeps out the cold wind in some measure. We spread out some hay which was left in this den, left our extra traps, and started for the mountains. We took the right-hand side of the valley at the foot of the Wetterhorn because, having a southern exposure, there is less snow. The opposite bank of the glacier is formed by the cliffs and talus of the Schreckhorn; and there was not a bare bit of ground on the

* The party must have been Agassiz, Guyot, Desor, and their visitor Forbes. The results of their experiments were published. Agassiz, *Etudes sur les Glaciers*, with an atlas of excellent drawings, Neuchatel 1840; Forbes, *Travels through the Alps of Savoy*, Edinburgh 1843; Agassiz, *Systeme Glaciaire*, &c., Paris 1847; Forbes, *Norway and its Glaciers Visited in* 1851, Edinburgh 1853.

† This stone was figured by Agassiz, and the glacier carefully mapped, sounded, and tested in many ways. The stone is slowly floating down on the ice-river. One very like it is in Connemara; see below.

whole of it except where the rocks were too steep for snow to rest.

" It was the deuce and all scrambling over these rocks. They were much worse than any I have yet been in ; and the worst of it is that they are not firm. They often break in the hand, and crush beneath the foot. Old Nauspaumer did not like it at all. He had my rifle to carry, and was always craning when we got to a bad place. There were marmots in plenty, whistling like curlews in all directions, and there were plenty of tracks of chamois, but we could see none.

" At one place we stopped to rest after crossing a snow-wreath, and from our peak we were watching an old marmot. His head and whiskers were peering from under a stone, and he seemed to be ruminating over his own private affairs, for he never stirred an inch. We were disturbed by a loud noise, and turning round I saw two or three great blocks of stone go rattling and bounding down the identical snow-wreath which we had just crossed with some difficulty.

" These went to the glacier, and they went like cannon-balls.

" The chance of a chamois was now small, so putting up my rifle, I blazed at a marmot, who was sitting on a stone. I missed him, but the noise made the gentleman with the whiskers poke his head a little further out, and the second bullet went through his pate. Down he rolled head over heels on the grass below his door. He may have been about 100 yards off, and straight down. It took us nearly half an hour to get round to the place. We walked on carelessly after this, thinking the shot would have scared everything. The hunter was first, and on walking round a point, he started four chamois which were feeding. Off they set, and halted in a cluster on the top of a rock to gaze. I rushed back for my rifle, fired both barrels, the guide fired his, and the chamois galloped over the snow like the wind. I watched them with the glass for more than two miles, and nothing seemed to stop them. At last the leader put his nose down, and pulled up at a suspicious place, then wheeling short round they scampered off in another direction, and soon after disappeared in a great black shadow. They were 400 yards off when we fired, so there was no shame in missing them.

"We now got down to the foot of the rocks, and slid down a snow-wreath, holding back with our poles. It was like flying. Old Nauspaumar, being exceedingly pleased with his performance, got quite cocky, and forgot where he was going. He marched over a place which was evidently unsafe, and I was opening my mouth to warn him when the snow gave way and down he sank in a crevasse. Luckily he caught hold of the edge and scrambled out, or his life and my best rifle would have ended together. The bottom of the place was far out of sight, and it made one's flesh creep to look in and think of the fate which the old goose had so narrowly escaped.

"The surface here is generally firm enough for a coach and six, but it is desperately hard walking. The upper parts of these glaciers consist of loose snow; the sun had melted this during the day, and now there was a thin crust of ice on the top, through which we broke at every step, sousing our feet into a cold bath below. Further down it was all right, and we stepped out for our stone house, from which came yoddling and screaming and all sorts of noises.

"My comrades admired the marmot, bewailed the miss and my wet feet, and we sat down to a supper of cold meat. It was welcome after twelve hours of hard work. One of the party is a Russian and a dandy, another a Dane, and the best of the lot is a little German who speaks French. They have two guides and a porter ; I have a guide and a hunter ; so nine of us crept under the stone after supper, and lay like herrings in a barrel on one hay bed. I soon slept, but about midnight I was roused by giggling and German all about me. I asked my neighbour what it was about, and found that the Russ had suddenly remembered that it was a fête at home, and he was bewailing his hard fate. He was contrasting an ice pillow in Switzerland with the brilliant ball at home. I laughed and fell asleep again in spite of the cold, which was intense. The professor had left a great gap between his wall and the stone ; there was bare ice within a foot of my nose ; never was a poor gentleman in a worse lodging.

" *Thursday* 16*th.*—Got breakfast over and started at six, with a cloudless morning and a prospect of fine weather. Yesterday we followed the Lunteraar nearly to the source. Today we took the left branch, walking up the Finsteraarhorn glacier between the Schreckhorn and Finsteraarhorn. We went yoddling and shouting to rouse the echoes, and they returned the noise. My little German bedfellow had nearly finished his travels. I chose a bit of firm ice, and performed Jackytar and the double shuffle to warm my feet. The Prussian followed suit with a German 'curcuddie,' but his ground was ill chosen. I pushed him off, or he certainly would have broken the snow bridge on which he was dancing ; a stick went through the crust easily, and the depth was fearful. There is no danger in these covered cracks ; the snow, being newer than the rest, is whiter and cleaner, and by poking a stick into it, the strength is easily tested. After a fall of snow it is dangerous to walk alone, for all is white and even.

" We reached the top of our branch glacier in two hours, and sat down in the snow to strengthen our nerves with something short. Before us was a snow talus, half snow half ice, sloping at a steep angle, 32° or more, from the top of the ridge which joins the Schreckhorn to the Finsteraarhorn. It might be about 1000 feet higher than the glacier, and up this we had to go. The hunter who carried the axe made me a sign, and walking quietly away, I followed him as far as I could without help, and then trod in steps which he cut for me in the hard snow. The rest were tied together, and followed like a string of malefactors. Thanks to my hunter I was first up, and drunk success to the Schreckhorn and long life to old Scotland in a cup of kirchenwasser. We were now very high, the snow on the col was white and unsullied, and high above us rose the Schreckhorn, as yet untrodden by man. Had it not been for heavy clouds which were rising behind us I should have tried, for it looked easy. The hunter pointed at the clouds and shook his head ; so I bowed to the man who had scaled the Jungfrau, and gave it up. It poured before night.*

(So here, at a high col (11,000 feet), the rocks are weathered, not ground ; all the peaks and ridges that we saw were sharp, angular, jagged, fractured rocks, shivered and split ; and the loose fallen stones were of the same pattern.)

"Now came the descent on the other side. It was not nice going, but by following my hunter I got down, and the rest followed us. We scrambled down several broken scaurs, and halted at the top of a snow slope. It seemed to slant down several thousands of feet till it reached the level of the Grindlewald glacier. I funked desperately, but there was nothing for it but follow my leader ; so, planting my feet together,

* In 1857 this peak was mounted by Mr. Anderson. The account is very interesting. In 1852 the Strahlek was crossed by Mr. J. Ball (*Peaks, Passes, and Glaciers*, 1859). He makes the angle 60°.

and holding the pole behind, I let myself go and glided down about 300 yards. Here was a bare rock, so we dug the points of our sticks into the snow, stopped the coach, and sat down to watch the others. They looked like pigmies craning over the edge. First came the German, and reached the first stone all right; then came the Dane, who lost his footing, and performed the rest of the journey on his foundation; last came the Russ, who fell flat on his back, and lost his stick and his hat. He might have lost his life also but for a lucky stone which brought him up. He was too much shaken to try again, so two men took him under the arms for the rest of the way. The hunter cut snooks, cheered, made himself into a tripod again, and started. I followed as best I could, and reached the bottom hot, but charmed with this new method of travelling. The dandy came in terribly dilapidated; his face was pale, his hands skinned in trying to hold back, his shirt-bands were torn, the heels of his Wellingtons had gone to one side, and his knees shook. So we all sat down and ate and drank vigorously.

(Sliding is pleasant, but sometimes it is disastrous. On the 28th February 1864 a fatal accident happened in the Vallais.* A party moved a whole snow-slope, which slid with them, and two were killed in the avalanche. My father, about 1819, slipped at the top of a snow slope in Switzerland. He had no stick, but he tried to stop himself with the stock of his gun. It broke short off, and the ramrod went through his thigh. It turned him over, and he went down head foremost and senseless. A mass of snow gathered before him and stopped him at last, above some ice crags. If he had gone other ten yards I should never have seen the Alps. He was found by his servant and the

* *Times*, March 17.

guides, with his hair frozen, and unconscious. They brought him round with kirchenwasser, and helped him home; and months afterwards bits of cloth were taken out of the wound which the ramrod had made.)

"The view from the top of the pass was magnificent. On one side were the Eiger, the Jungfrau, the Monch and other peaks, the highest in the Oberland; behind us were the Finsteraarhorn and the Schreckhorn; below us lay the Grindlewald glacier, broken into every possible shape, and and looking like some blue loch; on the other side was the sea of ice, up which we had toiled in the morning. From the sides of the Eiger great avalanches poured. One took ten minutes in falling. The noise which it made, though many miles away from us, was like loud continuous thunder, or the roar of a heavy surf beating on a west-country strand. It looked like a stream of rolling white dust pouring in cataracts over the dark rocks, but when we got near the place a cone of broken ice like a cairn of chalk had covered several acres of the glacier.

"After our halt we followed the edge of the Grindlewald glacier, descending rocks, climbing over moraines, and leaping chasms, till we reached a path which led to the Inn. Here it began to rain, and for the next three hours it poured. My town-bred comrades were fairly done. The Russ and the German each had a guide to support him; and the Dane, with the heels of his boots where heels had never been, limped on alone. We walked into Grindlewald at four, and they went to bed and stayed there. After dinner I gave my hunter his dues, and a hearty squeeze of the hand, and we parted as brother sportsmen part, when one pays well, and the other is a willing, active, honest fellow, fond of his work and easily pleased."

In these few days a good deal of the ice-world and its ways had been seen and learned.

A third lesson was taken at Chamouni, and though that ground has since become pretty familiar, a first impression of the Col de Geant may still have some interest, if only for those who remember with pleasure the pleasant stories of poor Albert Smith.

" *Tuesday*, 28*th September* 1841—Chamouni.—Got under weigh at four, with a guide and a chamois-hunter. The first a tall, strapping, handsome man ; the other little, but active and strong as a mule. We walked straight up the steep hills to the south, and reached the last tree in about two hours and a half, the time allowed being three and a half. Here we halted, loaded our rifles, and began stalking. We were before the sun, so our chance was good ; but nothing did we see, but a covey of ptarmigan, which ran about close to our feet. I would not fire for fear of disturbing the larger game.

" We had now got to the foot of the Aiguille du Midi, and the impossibility of mounting was evident. Sunday's new-fallen snow had found no resting-place on the cliffs. The spot in which we most expected to find chamois was empty, and without a trace ; so turning towards the Mer de Glace, we scrambled along at the foot of the aiguilles, crossing several small glaciers on our way. After a stiff pull amongst loose stones, we got to the foot of the Aiguille de Dru, immediately above the Montanvert. Here we fed and began to descend. It is the worst place I have yet been in. The granite blocks, amongst which we were obliged to make our way, were enormous, and thrown one on the other in the most fantastic heaps and pyramids, like a cairn. Now and then we came to small snow-wreaths, and slid down ; at other places we had to leap from block to block, or crawl under the big stones. (The

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revise returned & sent April 7. 64.

rocks at the end of the Mull of Ceantire, close to the sea level, are disposed like this talus of the High Alps.) I nearly got a bad hurt at one place. The spike of the alpenstock, now nearly worn away, failed to act as drag in sliding down a patch of snow. I could not stop, but came bump against a stone at the bottom, instead of halting within a foot of it, which is the right thing to do. There was no harm done. We got safely to the heap of debris at the bottom, and having marked a marmot from above, we stationed ourselves to watch for him. I waited for an hour and a half in vain; then calling the hunter, we scrambled down a difficult ravine, called the Third Chimney, and found ourselves on the moraine. We got to the Montanvert at about half-past three; and, leaving the hunter, I walked down to Chamouni, firing ball at the little birds in the forest. Bagged two tomtits, and carried their headless remains to my quarters, in lieu of the promised chamois. Going for thirteen hours; saw one marmot and some hoof-tracks."

(This country is a specimen of weathering on the large scale. The ice-wedge quarries granite from the aiguilles, and the blocks form talus-heaps; but these bear no proportion to the work done, for the chips are carried away. They fall upon a moving base.)

"*Wednesday, 29th September.*—Off at four, and reached the Montanvert by sunrise. Took a small boy to carry my rifle, but he was so blown at the half-way fountain that I gave him a dram and sent him home as unfit for service. The hunter was up and waiting for me, so after breakfast we started. There is a path for some distance along the moraine, and this we followed as far as it went. After this we took to the ice, and walked along till we reached the rocks of Tacul. The sun did not shine on the place, so we did not pause to reconnoitre. Keeping to the ice we turned to the left, and continued on for about an hour, till we got below some aiguilles, on the top of which chamois had been seen yesterday by a party who had gone to the Jardin. Here we lay down on the stones of the moraine, and took a long survey with the glasses, but without success. We now turned back, mounted the Rochers de Tacul at one end, and walked on towards our night's quarters, looking cautiously over the ridges as we went.

"I wanted to go to the top, as it was getting late, and I thought the beasts would have gone up from their feeding-ground; but the hunter said we had a long day before us, and advised the lower beat. As the learner I submitted, but I was right. We had not gone many hundred yards from the place where we held our council, when my stalker spied a chamois trotting up hill, and in a few moments four others followed. They appeared from behind a rock, about two shots off; and as they were not much frightened, we lay perfectly still and watched. They had seen us, for I could hear their shrill warning whistle ringing sharply amongst the crags, and echoing from all sides. They were lost, and we were beat. If we had gone above we might have got a shot; now we might as well follow an eagle. After this we trudged on with a faint hope that there might be more on the ground; and we found plenty of fresh tracks, but no beasts. We saw one on the opposite side of the Mer de Glace through our telescopes; but he was in a very difficult place, and it was too late to follow him.

"As our men had now arrived, and we were close to the rock where we were to sleep, we came down and helped to gather rhododendrons and juniper for the fire.

"The last place we looked into for chamois was somewhat dangerous. We had to pass below a small glacier, and as the sun's rays struck powerfully the stones on the surface were loosened and rolled continually down, the large ones driving the little ones and threatening destruction to everything in the way. We scuttled over the rubbish heaps as fast as we could, and I was not sorry to be out of the run of the stone avalanches. A rock or a cliff, so as it be sound, is to be passed by the help of a steady head and eye; but a falling stone stops to ask no questions, and woe betide the man whom it hits on its way down hill."

(This was the second halt of a quarried stone. Dropped from a peak, it became part of a talus-heap resting on ice, and this heap by stretching became a lateral moraine as the glacier moved. Dropped from the end of the small glacier, the stone became part of a terminal moraine; and in this case it was also part of a talus-heap which formed part of the lateral moraine of a larger glacier. We were in a fork of the Mer de Glace, and two lateral moraines met at the junction and floated off side by side in the middle, till they fell at last into the valley of Chamouni, and formed part of the terminal moraine of the Mer de Glace there. The terminal moraine is the delta of the ice-river; the medial moraine is like a float of logs in the Rhine, or the float above mentioned, p. 123. Good Swiss photographs now abound.)

"My guides had brought lots of blankets, provisions, and wine; so, after supping, we all lay down with our feet to the blaze, and I for one was sound asleep before my head had been many minutes on its stone pillow.

"*Thursday*, 30*th*.—Awakened by the chasseur, who wanted my shoes to put in spikes. Seeing that the moon was just setting, and that there would be no daylight for a couple of hours, I poked my feet into a bag, wrapped my capote closer about me, and slept. I was rousted out again at about half-past four, and finding there was no help for it, I unrolled myself and gave a shake by way of washing. We ate a crust of bread and started just as the first gray dawn was beginning to appear. The boy who brought the blankets made up the fire and sat down to watch our progress; and we were a queer lot to look at certainly.

"We soon reached the broken ice, and began to scramble in earnest. It was difficult enough, but by dint of nails, and an occasional step cut with the axe, we got on swimmingly nearly to the top. But here came a stopper.

"The ice of all these glaciers seems to advance continually towards the valleys. When, therefore, this enormous mass, perhaps two hundred feet thick or more, comes to a precipice in its bed, it first cracks from side to side, and then falls over, breaking into cliffs and chasms, and forming the most fantastic towers and pinnacles. The motion is of course imperceptible to the eye, but its effects are manifest in weekly changes and hourly falls of enormous blocks of ice at the lower part of the ice-slide. Where fragments are small it is possible, though difficult to walk, but at the top, where the masses have not yet passed over the edge of the rock, the whole glacier is sometimes split from one side to the other, making a wall of hard blue ice sixty or seventy feet high. This is a wall to be climbed by those who are below, a sunk fence to be got over by those who are above; such a ditch and wall were now before us, and how to pass them was the puzzle. We clambered up one heap—a bit of a fallen wall—and could see that if this danger was passed our future progress was easy. So we fell to hunting for a passage. The guides dispersed, and appeared every now and then perched on the top of some ice-crag and peering over into the cracks, but for a long time all was in vain. The men got keen, and spoke patois; and one sentence, which meant 'No passage this way,' became familiar by repetition. We all began to think that we must return, for the sun was up and the danger of ice-falls thereby greatly increased. At last one cheery shout proclaimed a find, and we all gathered round the man to hold our council. A great block of ice had fallen out of the cliff under which we stood, and it made a bridge over the chasm below. By passing over this it seemed that we might climb the breach and gain the upper level. We leaped down to the bridge, crossed it one by one, and hauled ourselves up the slope on the other side by sticking our hands into every chink. Several chasms were now passed, and we were up, threading our way amongst the torn ice, which splits before it breaks and falls. Most of these cracks are too wide to leap, we had to wind about, sometimes on a strip not a foot broad, sometimes leaping the narrowest ditches. At last we got to a moulin—a hole into which a stream of running water fell—and here we halted for breakfast. It had taken us three hours to reach this place, and the distance could not be much more than an English mile, for we heard the boy at the Tacul shout when we got to the top of the last cliff."

(The general slope of this ice-slide is about the same as the slope of the water-slide at Trollhattan, p. 103. If the rock beneath the ice were laid bare it would probably resemble the rocks in the middle distance of fig. 23, p. 101, for similar ice-ground slopes abound elsewhere. The lava at Thingvalla, in Iceland, near the edge of the big rift, has split into forms which closely resemble ice-crevasses.)

"Breakfast over we went on. As a lot of new snow had fallen, the first precaution was to rope the party. The leader was about three yards from the rest, and went cautiously, poking his stick into every suspicious place, and tucking it under his arm when he ventured to cross an uncertain bridge. We followed, holding back with sticks pointed in front of us when the leader seemed in danger of popping into a hole. This was no unnecessary caution, for though I was in the middle I slipped in to the thigh more than once, and my comrades were not more fortunate. At noon we got to the top, and fairly cut the giant's throat. At this place, which is nothing but a bare rock peering through the snow, Saussure lived for eighteen days and nights, making experiments. His followers had gathered a goodly heap of rock-crystal, and had left about a waggon-load on the site of their tent, but all the best had been carried off, so I left the pile. All below us was calm, for light clouds of gray mist crept slowly along the mountain sides, or hung becalmed in some deep glen ; but above us, on the shoulder of Mont Blanc, the "tourments" kept whisking dry snow up into the air like clouds of smoke or spindrift. Suddenly one of these blasts paid us a passing visit, and nearly swept us from our perch. The squall half blinded us with snow, and seizing my poor green veil, carried it away up the hills and out of sight in a moment." (Here were local winds, the offspring of a hot sun, a snow-clad mountain tract, bare black heated aiguilles, and hot plains and glens.)

"The view was splendid. Below us waved a sea of mountains reaching to the horizon and capped with snow ; to our left was the giant's peak, and past one shoulder peeped Monte Rosa, a great mass of glittering snow, dwarfed by the distance to a model toy. To the right was Mont Blanc, clear to the highest peak; and at our feet lay the town and baths of Cormayeur, and Italy. We finished our wine, stowed the bottles amongst the other crystal, and scrambled on. It was rather ticklish work, but not so bad as the glacier. We had to make our way on the very edge of a ridge of stone, from both sides of which deep snow-drifts slanted down to glaciers. In some places the new-fallen snow was so deep as to cover all difficulties, and feet slipped between large loose stones, to the great detriment of shins and ankles. I wanted to slide, having learned the art; but the guides would not hear of such a thing. Slowly and surely we scrambled down to smoother ground, and the first turf on the southern slope. Took a shot at a chamois galloping at a distance of nearly a quarter of a mile, in hopes that he might be frightened into breaking his neck, but he only ran the faster. 'If I had a pair of legs like him,' said the guide, 'I would go faster than I do.' We got to Cormayeur at five."

(The top of this col amongst the glaciers of Mont Blanc is not ice-ground. It is not a firm, solid, smooth, rounded rock, like rocks which are under the glaciers, near the glaciers, far below the lowest of modern Alpine glaciers, and in all glens where land-ice has been. The ridge-stone is riven by ice-wedges; the snow-shed is either a weathered peak, on which snow-flakes fall lightly, or a ridge of peaks like the teeth of a saw. Fallen snow may press heavily on such a place, but there is no ice-slide to grind and polish.

Blocks are quarried, they are angular, and they pack themselves into the shape which fallen rubbish assumes—a cairn. A heap leans against the cliff from which it fell, and rests there, for the only wearing agents are rain-drops and snow-flakes, water-rills, ice-wedges, and the winds; the snow which falls on the knife-edge slides off and becomes a snow slope above a "ruckle o' stanes." But if the snow heap is large enough to crush its base it becomes a mechanical force to move the cairn, and it moves *under* the snow; *over* the rock.)

These are some of the steps on this ladder to learning; in this storehouse of facts; this workshop of frost.

In pursuit of chamois and trout, the scholar had seen the highest cliffs crumbling and falling away to leave peaks. He had seen angular stones falling, rolling, wearing their angles off, to make sand; gathering in heaps, and resting upon narrow shelves. He had seen the base of talus-heaps of stones and snow, coincident with the edge of a step, or resting on the bottom of a valley. He had seen valleys filled with moving ice, upon which talus-heaps became moraines. He had followed ice rivers up from delta to watershed, and down from snow-shed to terminal moraine. He had unconsciously followed the track of old glaciers from the Stelvio to Milan, and from the Col de Géant to Turin.

The first glacier was silent and still: it was slowly melting. So, for the new hand, it was a torrent which brought down the rubbish, and a muddy river which had rolled down the boulders, amongst which trout would not rise. Even philosophers had not then found out Swiss moraines in the plains of Lombardy and Germany.

The scholar was "green." In 1864 work obviously done by ice has been attributed to rivers by men who rank as geologists; and those who point out ice-marks, which they have learned to understand, are sometimes called "ice-mad," by men who have only seen pond-ice. The rounded surfaces which are conspicuous in all Southern Alpine glens, and grooves which are cut sharp and clear on the shores of every Scotch sea-loch, convey no meaning till a glacier has been seen to move, or till the lesson of land-ice has been learned on trust.

Whoever has ground a stone knows how he made marks upon it, and can recognise like marks. When he has seen water turned into an engine which crushes stones to powder, and "grinds mountains like mole-hills," he knows the touch of the solid edge of the revolving tool which works geological denudation with land-ice.

The chief things wanted are time, opportunity, and travel. Glaciers are not within every-day experience at home in England, but they are in the Alps.*

* A paper by Professor Ramsay, separately printed in 1862, and first published in the Quarterly Journal of the Geological Society, August 1862, gives a map which embodies the result of much modern study of old ice-marks. On this it is shewn that chips hewn from the Alps are spread far and wide, beyond the Rhine in one direction, and far down into Lombardy on the other. They have been carried from Mont Blanc and his neighbours, over the Lake of Geneva, on to the top of the Jura Mountains, and the prevailing explanation is that these stones were carried by land-ice.

In Lyell's *Antiquity of Man*, 1863, this subject is fully treated. At page 689 of Jukes' *Manual of Geology*, 1862, the transport of the Jura blocks is attributed to icebergs floating in a sea which washed the base of the Alps. Many older geological works treat this ice question. All who have studied it agree that glaciers were much larger since glens assumed their present general form in the Alps.

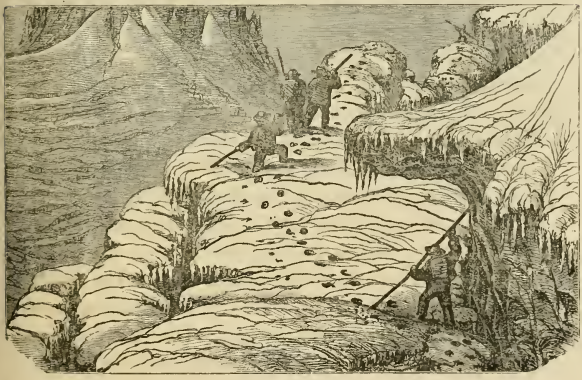


FIG. 33. AN ICE SLIDE.
From a pen and ink etching made soon after crossing the Col de Géant, September 30, 1841.

CHAPTER XIII.

DENUDATION 5—FROST-MARKS 3—LAND-ICE 2—SYMBOLS AND MODELS.

THE lesson learned from the Alps was that a glacier is ice moving from a watershed downwards towards the sea, at various rates, according to slope, pressure, and temperature.

A rain-drop is the seed from which a river grows, a cloud is the pod from which it is shed. A drop which falls vertically on a horizontal plane radiates (Fig. , p. 96); and streams part from the highest stone on a weathered peak. A snow-flake is the seed from which a glacier grows, and it falls from the same branch as the drop. When a white downy snow-flake comes whirling through still air, and settles upon a cold flat stone, it rests there unbroken. Those which follow take the same course till they are stopped, and they cover the base with a conical heap at last. Familiar letters have been used to express river-marks. Ice engraves the water-alphabet in larger letters on the same ground.

Let the dot • stand for a drop; **|** for its downward course; **⊥** for its horizontal course, when it falls on a flat stone; **L** for the notch dug in a hill side by the first leap down hill; * for the next splash; **L** for the next fall, upon the next base **O**. Then **V** will stand for the section of a valley dug by the river in a hill, or for the plan of river forks; **U** for a steep sided drain; **Y** for a valley with a trench dug at the bottom, or the plan of a fork; **L** gives the next downward step which water cuts in slopes on its way to the plain **___.**

S ‿ mean plan and section of a river and its bed (see page 114); Δ ⌒ plan and section of the delta; —— • means the water-line, and a full stop for the travels of a drop, driven down by weight from a cloud to the sea. That is the water alphabet of the symbols used above, which are intended to express natural forms by forms familiar as A B C.

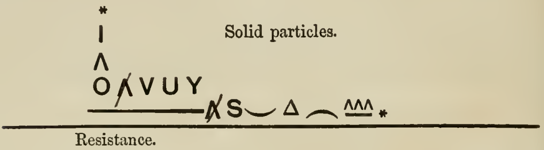
Weight.

•
I Fluid particles.
⊥
L
*
—
O L V U Y
————L S ‿ Δ ⌒ —— •

In like manner let a star * stand for a snow-flake; I for its course; Λ for a mountain peak; O for its base; then the symbol Λ may be used to express a conical or pyramidal mountain whose form results from weathering and falling. Then Λ (not L) is the shape which results from wearing by snow falls. Avalanches do not dig straight down. They do not undermine as a waterfall does. They slide, and make rounded slopes ⌒\, not steps L. Where they fall they rest, and form a talus-heap, whose angle with the horizon is about 32°. See page .

The glacier flows from the base, and slides down the slope; it wears a wide bed ‿, or a wide drain U, it joins other glaciers like a river V Y. Like a river it winds S, and has a delta Δ. Rocks over which it moves are rounded hills or groves ⌒ or ‿. If it gets to the sea the snow-flake * becomes part of an iceberg, and the debris is a moraine of conical talus-heaps ΛΛΛ.

Weight drives it down. Resistance stops it. In one case fluid particles flow; in the other, solid particles move and mark the ice-alphabet on rocks.



At 32° fresh water ceases to be fluid and becomes a solid which, bulk for bulk, is lighter than water; but it is heavier than air. At some distance from the earth's centre—generally far above the sea-level, but sometimes below it—a temperature of 32° exists at all seasons and in all latitudes. The average line is marked on high mountains by spots of snow. In winter the cold shell comes down, in summer it rises; but the perpetual snow-line is somewhere on every spoke of the wheel. At the Equator the line is about 15,000 feet above the sea; at Yakutsk it is 382 feet under ground; at the North Pole the mean annual temperature at the surface is calculated to be 13° below zero, so the perpetual ice-line must be still deeper there. From weight, and from this disposition of temperature, glacial movements and their marks result, and these may be imitated. Vapour and minute drops of water, when driven or carried above this shell of temperature, freeze into angular and other shapes, and become snow and hail, hoar-frost and rime. Solid water in this form may float in air for a time, but the heavy solid must fall at last. When it falls on ground which projects above the perpetual snow-line, frozen water continues solid, and it obeys the laws which govern other solid particles. When the base of a heap rests in fluid, it sinks or floats according to its specific weight, shape, and dimensions. If ice floats, it moves like other floating bodies. Snow, hail, and other broken bits of unmelted water, roll and slide like sand, gravel, broken stones, or such materials. The snow-shower which falls upon a weathered peak forms a cone or pyramid upon the narrow base, and when the base has reached the verge of the cliff, the point of the Δ splits the falling stream, and makes the talus-heap Λ at the foot of the cliff.

The tops of the highest snow mountains appear to be snow-heaps of this form. Drawings of the Himalayas represent them as sharp snowy peaks, resting upon rocky cliffs. If snow never melted, it would everywhere be packed in conical heaps like volcanic dust. A snow angle of 32° on the horizon expresses a temperature of 32° (p. 85).

At some distance from the earth's centre, below the line of 32°, solid water does melt, and therefore large snow-heaps are not conical when the base is low down. Snow-cones rest upon melting bases. The frozen peak tends to sink in out of the cold, and its weight pushes out the warmer base and sides, and so drives the heap down hill into the warmth; where it melts and moves faster. Mont Blanc and other high tops in Switzerland, Norway, and Iceland, are dome-shaped. Long snow ridges like Langjökull (Fig. , p.) are not angular like a house-top, but hog-backed. The snow spire or ridge-tile crushes the roof, and the walls bulge.

When the rumble of wheels becomes a muffled sound, and the earth is white with fresh snow, hostile armies bombard each other with snowballs. The soft downy crystals are kneaded together, and become tough, firm, spherical missiles, in which state they are like névé. When they are wetted and frozen they are like glacier ice. When one of these, badly aimed at a passenger, hits a wall, it changes form, and sticks.

The force which drove it is turned aside ; one end is flattened and spreads like a white star * ; the other stands up like a minature snow mountain Δ. But the snowball, like the snow mountain, sticks together, because it is at a welding heat.

Because the welding heat of ice is 32°, crushed ice mends. A large mass subjected to heavy pressure may be squeezed into any mould. To use the modern word, glaciers "regelate." The base of the snow-mound shoved down by the top of the heap is crushed into hollows, and pushed down into glens. If it moves faster than it melts, the glacier passes under the snow-line, and it may be launched in the sea at last.

It is not absolutely necessary to visit a glacier in order to comprehend this movement. If the law is universal, snowballs and small experiments serve for illustrations, and good photographs shew the natural forms in miniature.

EXPERIMENT.

(1.) The talus-cone Λ, or the angle ⋏, may be made of any materials. Let two heaps of dry sand be made by pouring sand through a funnel upon a tray. According to the shape of the fragments, so is the angle of the heap ; but the sides generally make an angle of 32° with the horizon, and that is the angle of talus-heaps, cairns, and scaurs everywhere. If water is dropped on one of the sand-heaps, it loosens the mass, and the cone sinks down and spreads out and takes a rounded form ⁀. That is the outline of many hills in the north. (Fig. .)

(2.) Make similar heaps with dry salt or sugar, and the cone which is wetted becomes a dome as the base melts and yields to pressure.

(3.) Make the piles of snow or pounded ice, and they will both change, as they melt side by side in warm air.

(4.) Make a pile of wax dust on a metal tray, and warm the base. The lowest of the angular fragments are next the greatest heat, and furthest from the perpetual *wax*-line, so the base of the cone melts. The fragments lose their angular shape, and their hold upon each other below; weight presses down the upper fragments which are not softened, and the dome ⌒ is produced from the cone Λ. If the heat is continued till the heap is melted, the cone becomes a plane; Λ sinks down; ⊥ becomes ——•; as in the case of a water stream. The cone of wax, partly fluid partly solid, freezing above, melting below, obeys the laws of heat and weight; and the mass sinks like a pile of wet sand, sugar, salt, or melting snow.

By regulating the heat, and adding wax dust, the top of a heap near its welding heat (150°), may be kept at the same distance from the tray. But if waste or supply be in excess, the heap sinks or grows. It must be the same with snow-heaps of any size, when temperature is less than 32° at the top of a hill, and more than 32° at the base.

(5.) To shew that "regelation" is not peculiar to ice and wax, but a quality common to many substances, heat a block of solder in an iron tray. At a particular temperature the hard metal softens. The block may then be crushed, and kneaded into any shape, though the upper surface continues tough and brittle, tears and breaks. The structure continues to be crystalline and granular; but the mass is plastic, like the ice of a glacier. If it cools, it freezes hard; if it warms, it melts and runs like any other fluid; but so long as the welding heat is preserved in solder, it "regelates" like ice.

Like hot solder, water is ductile at or about its freezing point, and iron welds about the freezing point of iron. One substance regelates at 32°, another about 3000°; but both weld when their melting surfaces are pressed together.

(6.) To give the experiments a more definite meaning, make conical heaps of plaster of Paris on a wet base, and the plaster will set in the conical form of volcanic mountains. Throw on dry sand, and wash it down, and the sand will take the shape of talus-heaps and plains of dust, which surround Etna, Hecla, Snæfell, and other high volcanoes. Pour on salt and sugar, and the same forms will result. Pile on snow, and the heap will melt and settle about the base of the model as water. When the water has found its place, cover the toy with wax dust, and light a lamp beneath one heap.

The wax cone sinks when the mound is warm, as snow melts on Hecla where the ground is warm to the hand. The heap which covers the cold cone keeps its shape, as ice-cones do on Snæfell where the ground is cold. If wax be added the cones rise, if heat be increased they sink; as the top of Hecla rises in winter, and falls when the snow melts in summer.

As the operation goes on, fluid wax runs from the base, sinks into loose sand, flows over the surface, and under it through sand, and over the plaster foundation of the model, down to the water-level. The half-melted stream digs as it flows. It pushes through the sand and makes hollows in it like the Manatsch glacier (p.). It carries hard wax floating upon the surface, and when it gets to the water and freezes the hardened wax-stream floats, like ice in the polar sea.

It carries sand, and contains air bubbles; it is a frozen conglomerate as glacier-ice is.

Reduce the heat and the model works slowly; turn on the gas and it works fast. Stop the supply of wax and keep up the heat till the stream has passed away from the surface,

Munich 29.
April 7.

and the tracks of the half-frozen stream which moved over the sand sunk into it, and flowed away ; the tool-mark of the wax-engine will be found in the path which it made and followed from the peak Λ to the water-line —.

Let the water go, and it will carry off the wax floats ΔΛΛ . Take the wax conglomerate, break it and pile it on the tray once more, heat it to the melting-point of wax, and the heap will take a new shape. The melted wax becomes a plane as water does ; the sand, freed from the cement which bound it, takes the conical form of moraines and rubbish-heaps shed from melting glaciers, and stranded ice-bergs.

FIG. 34.

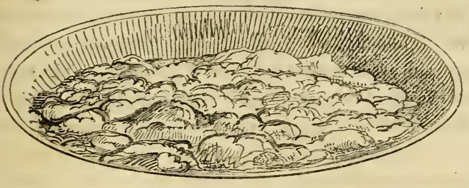


FIG. 35.

It is the form of hills of loose rubbish which rest upon ice-polished rocks, on lofty plateaux, all over the north of

Scandinavia, in Scotland, Iceland, and elsewhere, in positions which appear inexplicable, without the aid of floating ice.

The woodcuts are from drawings traced with a pencil upon the glass of a camera obscura. The instrument was aimed at a frying-pan. Fig. 34 shews a mass of wax and sand confusedly heaped together.

Fig. 35 the same mass sorted by melting the wax over a lamp.

In the one case the fractured masses had no definite shape; in the other they had become dome-shaped heaps of rubbish, and they were sorted by weight and heat.

The frying-pan and its contents were aimed at land-ice, whose movements are but modifications of flowing and sliding, melting and freezing.

The snow which fell on the top of the Schreckhorn was a cone. The avalanche which fell upon the glacier (p. 159) was a talus-heap. The water which was a freezing marsh of snow and ice upon the glacier (p. 155) when the sun had set behind a hill, had soaked through and wet snow, hail, ice, sand, stones, mud, and boulders. At night it became a solid mass, and bound the whole into a stratified bed of fusible conglomerate. The water which fell into the moulin, and ran out of the ice-cave, melted the base of the heap under which it flowed. When the sun set the supply was cut off, the sliding decreased, and the water froze. When a chink filled with water froze at night, the ice-wedge pushed the sliding mass and stretched it; when it was crushed into a hollow it "regelated" and mended, and water made the cement.

From peak to delta, the moving mass of ice plum-pudding stone, growing above and wasting below, slides bodily over the earth, making hollows and filling them; rasping the rocks over which it moves; undermining its banks like a flowing river; carrying stones like a stream of floats; and floating away with a cargo of broken stones when the frozen conglomerate is lighter than its bulk of lake or sea water, and is launched from the rock slip on which it was built.

The Alps are easily reached, and these simple experiments may illustrate the movements of land-ice.

CHAPTER XIV.

DENUDATION 6—FROST-MARKS 4—LAND-ICE 3—SOUTHERN NORWAY—CONE.

THE powers which move land-ice are weight and heat, and models moved by these forces do similar work on a small scale.

There are various forms in which ice moves, and the tool-marks of this part of the denuding engine are various, lik river-marks. There are many rasps and gouges in a tool-chest, and many kinds of land-ice in the world.

The model above described consisted of various parts.

1. A fusible cone of loose solid particles Λ ; a talus-hea dropped from above, which changed into a dome-shape mound ⌒ when warmed.

2. A half-melted stream of wax which flowed from th base, slid over sand, and marked out a groove in it ‿.

3. A stream of floats, which were pushed into water, an carried away by it.

It has now to be shewn that like systems exist in natur and form part of a revolving atmospheric system which sculp-tures mountain-forms.

Before examining tool-marks, the tools ought to be unde stood, and the conical heap comes first in order.

The opposite coast of Norway is very easily reached fro England. A small conical glacier is to be found near Berge at the head of the Sogne Fjord. It is constantly changin

Fig. 36. Supedledals Iis Bræ in Fjærlands Fjord. September 9, 1857.

from dome to cone, and from cone to dome, as it rises and sinks; it works fast, and on a hot day it teaches more about glaciers than any specimen known to the writer. A pilgrimage to see it in 1857 is thus described in a traveller's rough journal:

"*Sept.* 7.—Started from Fjærland Fjord, with a man to carry my traps, distance about 40 miles. No one about this place seems to know whether it is or is not possible to get over the mountains, but my man knows part of the way, and the map has a track marked upon it. The porter said he had often travelled with Englishmen, and he seems to be a kind of idle, poaching, good-for-nothing character, so we got on famously. On our way we met a pretty girl, who asked my man if a certain old woman was at home. She, as it turned out, is a witch, and the lassie was going to consult her about some one who was in America. The man told her not to believe such nonsense, but she said the Kona had done good once before, and she went her way to the spæwife at Hafsö. I got another man who said he knew another bit of the way, and we started in a boat, and rowed over a very pretty lake. His sister had epileptic fits. I shewed them my pedometer, and other wonders, and the girl asked if I, who knew so many things, could cure her?

"'If I were well again,' she said, 'I would not care if I were as poor as a bird.'

"Poor girl, I could do nothing for her. I could only tell her to avoid being alone, and that the illness was not dangerous. I hope I told the truth, but I have my doubts. There were several pelting showers this day, and I got my feet well wetted in bogs after we landed. We walked over a pretty steep hill, and got to a sætar, where a smiling maiden with a brown face gave us a splendid feast of sour milk, and exclaimed, at a gift of fivepence, 'I sprang 7 Reiper;' but my gun was in the cover, so I shot none. When we left the sætar we descended into the Sognedal valley, passing from gray rock and lichens into mountain pastures and birch woods. We came down at last to a road, beside a pretty river of clear water, the first I have seen for some days.

"My guide had come wrong. We are much too far down the glen, so there was nothing for it but to put on the steam, and walk up the road to the lower end of a large lake, at the upper end of which was the place I wanted to reach :—Sælseng. It was a long way to walk, and it was getting late when we arrived. No men were to be seen; but on the other side of the water we spied a black dog perched upon a boulder; so we fell to shouting, Lars! Lars! having learned that an individual of that name abode there; and presently Lars poked up his red night-cap, and after some palaver, he and a friend pushed out a leaky boat, and pulled over. The rain was pattering down, but this could not be helped, so I got on board, and my guide set off to walk ten miles over the Fjeld. The whole of this country is ice-polished, but the glaciers are out of sight. This second guide was another sporting character addicted to fishing and shooting; and he told me that he had once been attacked by an eagle, which flew at him, and flapped about his ears, till he thought he would have been killed. He drove the bird away at last with a stick.

"The change in the language, as one goes from glen to glen, is very curious. A cow here is 'Nout,' as in Scotland; to walk, is 'Tootla,' toddle. The sætar girl, and the guide who live about seven miles apart, have different dialects, at least so they said; and in this they are like the natives of all mountainous districts, from the Yorkshire dales to the Antipodes.

"The new crew rowed merrily up the lake, in which trout were plunging in shoals. I baled and smoked, and answered the usual questions. I am generally taken for an Eastlander, or a German landscape painter; and when I announce my country, there is always an exclamation of wonder, and a shaking of heads. At about dark, my men stopped, and walked me up to a house, where lived a man who knew the way to Fjærland. He did not look up to my back-load of traps: but there was no other man to be got for love or money, as I was told; so I had to content myself with him. I got some potatoes, and Fladt brod and cold water, and then turned into a hay-loft; for I have had enough of peasant beds.

"I thought I was to have a quiet night, and began to change my stockings in the dark on the hay floor, when I heard a lot of voices chattering close to me.

"'Have I company?' said I.

"'O yes, we are three,' said a girl's voice from amongst the hay.

"'And do you not sleep in the house?' quoth I.

"'No; we always sleep in the hay in summer,' said another female treble, 'because of the fleas.'

"Pleasant lookout for me! There was no help for it. It was raining cats and dogs outside, so I put on a waterproof for a nightgown, and tumbled in amongst the family; and presently I heard them groaning, and kicking, and catching fleas all round me. I had something to do in the same line myself before long; but I had walked twenty miles over the Fjeld with my gun and a heavy knapsack; and in spite of fleas and family, I was soon fast asleep.

"*Tuesday 8th.*—I was awakened before daylight by an authoritative male voice, shouting 'Martha!' and by the kicks, and plunges, and exclamations of Martha aforesaid, who only grunted 'Ney! ney!' and rolled about in the hay like a sleepy hedgehog.

"I rolled out of my nest, looked at the weather, and as there was a glimmer of dawn, I used it to select a spot as distant from my neighbours as possible, and went to sleep again. But I was hardly asleep when my guide poked me up to say it was time to be moving.

"I was as loth to rise as Martha had been; but I gave a vigorous plunge, and stood on the floor, and looked about me.

"I found I had been sleeping in a regular nest of them, big and little. Their lairs were all about in the hay, and Martha, dimly visible, was still fast asleep, with a sheep-skin rolled about her. She may have been about ten years old.

"Another girl now came out, and raked Martha out of the hay with a rake; and having seen that operation performed, I too went into the house, took same cold potatoes, and colder water, for breakfast, and started at half-past five.

"The weather looked threatening, but it might hold up, and the hills were clear of mist.

"A horse bound for a sætar, took my traps so far; and we, in light marching order, followed up a wild glen, and past some mountain lakes.

"High above us, *glaciers clung to the hill sides:* and as we went, the birches grew thinner and lower. We were getting above vegetation, and into the snow once more. At one place, my guide, an old fellow of sixty-five, shewed me where a bear had killed a cow about ten days before. I was half inclined to turn back and try for him, but the rain and the fleas were too much for me, and we plodded on to the sætar, where our traps were waiting. Here was a troop of sætar maidens, but so different from some whom I have seen in the central districts, that they might have been of a different country; ugly, unkempt, dirty damsels, with a draggled petticoat, and a sackcloth shirt for clothing; their sætars without even a stool to sit upon.

"An old woman volunteered to carry some of my traps to the next sætar, and we went on, making six miles of steep glen. Here we stopped, and had a feast of milk and some cold meat, which I had brought with me from Roneidet; and then the sætar girl took my fishing basket, and we went right up to the top of the Fjeld, and the snow. My gun and knapsack felt heavy before I got to the top; but I am getting into good walking trim, and the day was cool, and we reached the top all fresh, though it was a stiff brae.

"The girl was so exceedingly ugly, that I longed to take her portrait. She had an enormously swelled face, and hair of such an odd colour and texture, that I asked for a lock. It was like the tail of a roan horse. She was a wonderful girl to walk. Her bare legs were a mass of strings and sinews, and as she walked up the steep hill, she knitted a stocking without seeming to breathe hard. On the top we parted; my old man shouldered the whole of his load, and we descended into a deep glen, that ran right down to the fjord of Fjærland.

"From this place, the views of the distant rounded mountains with snow domes, and snow wreaths, and glaciers streaming from their sides, was very fine. But what pleased me still more, was the sight of a lot of ptarmigan. I killed two, and might have killed more; but the weather looked threatening, and I did not like to stay longer among the stones. The old man was delighted. He chuckled and crowed like a cock grouse when I killed the birds.

"The descent was by no means easy. It was very steep, and the ground was composed of perfectly bare loose stones.

"I suppose they have not been clear of snow for many years ; for the people tell me that they have never seen the Fjeld so clear. It was difficult to keep one's balance with a back-load and a gun, but we got down safe to the head of the glen, and sat down to smoke and feed and ruminate. The gray rocks, the burn, and the gray sky, were so like Scotland, and old times, that I could almost fancy myself at home again. After a rest we marched on to a sætar, where we got some milk, and found a man with a wounded hand, who was going our way with a back-load of cheese ; he was going over the Fjord, so we joined him. The sætar-path was nearly as bad as the Fjeld ; our new comrade was bare-footed, but he got on as fast as we did.

"When we got down to the birches we found people gathering leaves, and mowing grass for their cattle. They told me I should find no one at the house, and they had no time to row me to my destination, but I trusted to my one-handed man, and went on. The houses when we reached them were empty, but we passed on to the shore, and found a boat on the strand. The owner was behind talking to some friends, so I paid my old guide and sat down in solitude to smoke and dream. We had walked sixteen miles, and over a high pass ; I had a good load, and my man had a very heavy one ; but he set off home at once, overjoyed with about three shillings.

"The lame man now came, and we rowed over the Fjord to a place where the priest sleeps when he comes to preach, and where a lot of painters had lived for some time this summer. There was not a living soul about the place when we arrived, so I got in through a window and took possession of the priest's room. As it grew dark people came tumbling in from the woods where they had been working, and we had a party round the fire at one of the houses. I could not understand half they said, for I had now got into a fresh dialect; but I fancied my hostess was a witch or a doctress, for men purchased mysterious oil from a bottle, which was carefully weighed; and one pretty girl had a long earnest conversation about some one who had been sick, and who was now "frisk." There was an air of mystery about my hostess, in addition to the general odour of cormorants that pervaded her dwelling. Presently the door opened, and the husband, with a wet bag and a creel of live fish, tumbled in; and there we all sat with our faces lighted up by the wood fire, chattering like a flock of gulls; while a little girl, who woke up at the noise, kept screaming like a young cormorant from its nest, "Moor, gie me fisk." When supper was ready we supped, and I turned into the hay-loft as usual, but this time I was alone.

"*Wednesday, 9th.*—Called before dawn by my host, who was in a desperate hurry to be off to the woods, for the morning was fine. He had no time to prepare food for me, but his two boys would row me to the end of the Fjord, and I might get something there. I told him to leave some cold potatoes and went to sleep for another hour. At dawn I was up and off to the river; and when I came back I found the house with my two boys, the cold potatoes, and the little girl with towzy locks, whom I had heard screaming for fish the night before.

"Rowed about two English miles to the head of the Fjord; told the boys to meet me at half-past twelve, and walked five miles and a half up the glen to the glacier. The glen is beautiful. The bottom of it is flat, and cultivated; and the yellow corn on poles, green birches, and neat cottages, made pictures at every step. There was a pretty tumbling burn by the way side, and hills like sugar loaves rose steep on either side. Between these the edge of the great snow plateau could be seen glittering here and there in its setting of bare rock, and down the side of the valley the glacier which I had come to see streamed like a great snow brae. The sun shone brightly on the highest part of it, and there it glistened like a sapphire. It was beautiful. When I got to the foot of the ice, I scrambled over the moraine, and made a sketch opposite to the ice-cave from which the river issues. It was a dark blue cavern, with dripping roof and walls.

"The surface of the hard ice above was like a frozen sea, but sprinkled with debris from the rocks.

"There was a great precipice of bare rock above the lower glacier, and above that the glittering blue ice hung in the most fantastic peaks and spires. Each time the hot sun shone upon this broken edge, from behind drifting clouds, great wedges of ice came thundering down the rocks, broke to powder, and formed a fresh layer on a white cone.

"These avalanches looked like clouds of white dust, but I had heard the roar of their fall six miles off, out on the Fjord. Every now and then the glacier below which I was sitting gave a kind of groan, as it took a start down hill. (It was melting below, and growing at the top like the pile of wax in the model.) Altogether it was unlike anything I have seen, and it was the best practical lesson I ever had in the ways of glaciers.

"Conical heaps that have puzzled me elsewhere, were explained here, for they were in preparation before my eyes.

"The snow in melting gathers into rivers on the surface of the ice. These scoop out channels into which they sweep loose stones, which fall on the ice from the rocks above ; and then the stream shoots out the stones, as one might pour sugar from a scoop, or lead washings from a buddle.

"The glacier in course of time retires or melts away; the heaps of stones get overgrown with moss and trees, and there remain conical hills of gravel of a particular shape. Other glaciers do likewise, but this one is on a great slope, works more rapidly, and in a hot day the whole process of glacial action is seen in an hour.

"There was a heap of loose stones ten feet high within ten feet of the ice; and above it was the scoop from which it had been shot, and the great ice brae itself, of similar form shot from the rocks. Similar bare stony heaps were near, some with moss growing on the stones; further off were older heaps, with scattered trees and thin grass; and close to these was a thick birch wood, growing upon a still older moraine, while the sides of the glen were crumbling piecemeal upon the ice, and the high glacier itself was falling in icy dust over the crags." (The ice-cone was melting, spreading, slipping, grinding, groaning, and polishing rocks, as other ice-cones have done for ages at some former period over the whole of Scandinavia, as glaciers are now spreading and sliding on high plateaux above the Sogne Fjord, in Iceland, and in Switzerland.)

But my feet were wet, and it was precious cold sitting there sketching and speculating, and time was up, so I gathered up my goods and walked back to the shore again. A hundred yards from the ice the climate was that of another region, and about 400 yards off there was a field of ripe corn, and a very hot sun, which caused all the movement in air and water, and all the polishing on these rocks.

The form of a terminal moraine dropped in air is then a repetition of the conical rubbish-heap shewn in the woodcut, which may be copied by pouring sugar out of a scoop.

Supedledals glacier is a standard form to which to refer larger heaps Λ.

The seed is dust; the spray of an ice cataract which falls from an ice-cliff, and forms a conical heap of talus, which rests against the rock. In the woodcut the conical form is shewn white on a dark background, which is scoured by the falling iee.

The glacier on which these avalanches fall continually would mount up to the upper level in a few days, if the base of the cone did not melt. Numerous streams trickle down the rocks from the upper ice and wet the base; it is close to the sea-level, in a glen where corn ripens, and where a hot sun shines, so the base melts and the cone sinks in, and the glacier spreads out like wax in the model, or a snow-ball on the wall.

In every direction it pushes out, and where it pushes it grinds with all the force of a mass of blue ice, which covers about a square mile of ground, and is about 1500 feet high. If the ice-cliff behind the rubbish-heap is compared to a graving tool, its ploughing action is manifest. Marks made by it must radiate from the notch in the hills from which the avalanches fall. Rubbish-heaps shed from it must surround the base in ramparts of conical mounds. The movement may be seen and heard, and old tool-marks are to be seen on rocks beside the moving ice.

Further south, about the Hardanger Fjord, are other conical glaciers. One heap is constantly falling over a cliff, but it melts almost as fast as it falls.

If the climate of this region gets warmer from any cause, the Fjærland glacier will dwindle. If the climate cools, the Hardanger specimen will grow, and Supedledals will rise to the upper fjeld, and perhaps stretch down to the sea.

The principle on which the engine works is the same as that of the wax toy. It is the same in a snow slide from a house-top, in the avalanche which falls in the Alps, in the glacier drawn in the woodcut, and the same laws govern the movements of larger heaps which fall from the sky, and spread their bases over great tracts of country.

Supedledals glacier is a small local ice system, detached from the larger system, whose broken edge is seen against the blue sky above it.

From the Col de Geant a wide view of the Alpine local system is got. It has been mapped and described by able pens, and it consists of a series of high centres, from which ice streams radiate, as rivers do from Highland hills. In Scandinavia and in Iceland the principle is the same. The dimensions and details of the engine differ; but wherever there is a mountain or mountain-chain high enough to pierce the shell of temperature which freezes water, there the solid edge of the water-wheel comes down and grinds rock. Snow falls, a heap forms, river glaciers stream from the base, and the grinding work done is the tool-mark of land-ice driven by heat and weight. The marks of this tool are stars or portions of stars, or marks like rafters in a roof when the system is on a ridge.

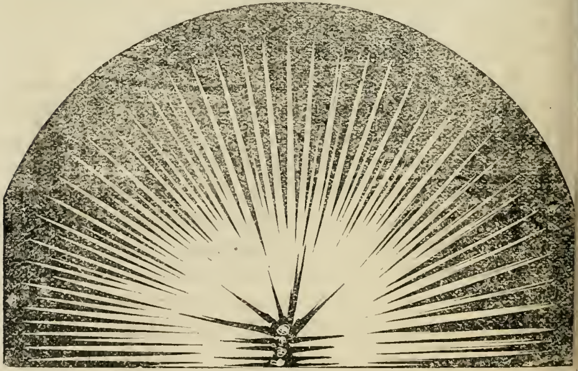


FIG. 37.

CHAPTER XV.

DENUDATION 7—FROST-MARKS 5—LAND-ICE 4—SOUTHERN NORWAY—RIVER-GLACIERS.

THE next ice-tool is the "River-glacier." It is the equivalent of the stream in the wax model, and large specimens abound in the Alps. For example, the dome of Mont Blanc, 14,760 feet high, with a temperature of 26°, is a high cold centre from which glaciers slide into hollows, and diverge, like flowing rivers. Of these, the Mer de Glace is the biggest and best known; and the rest of the system which springs from Mont Blanc is familiar to Alpine travellers.

Justedals glaciers, in the Bergen district, are nearer to England, and good specimens. They are less known, so the following extract from a journal of a trip to visit them is quoted:—*

"*Wednesday, Sept. 2d* 1857.—Landed at Roneidet about three, and after getting food from its hospitable inhabitants, set off at four with a boy, and a horse to carry my goods up the Justedal.

"The track follows the river, winding up a deep narrow gorge between enormous rocky hills. Here and there is a

* These Bergen glaciers were visited, described, and sketched by Forbes (*Norway and its Glaciers visited in* 1851; Edinburgh, 1853). The work should be consulted for a scientific account of these and other natural features of Norway. It is satisfactory to find that sketches made on the spot by different hands resemble each other in their main features. See Fig. , and lithographs by Forbes.

stony plain, the debris of a glacier, overgrown with trees; but distant views there were none. I had to walk hard to save daylight. At the end of twelve long miles by pedometer, I found myself at a farm, and as I walked up I heard a fiddle. I thought that promised fun, so walked in and asked for quarters. I found four or five tall strapping young fellows—the best grown men I have seen in Norway—and a girl to match, sitting about a long table listening to the music, while the girl brushed her long frowsy locks with a carding comb. There was a general promise of fleas about the place, but I tucked my trousers into my socks, according to the old plan first learned in Greece, and sat me down with the family. It was dark outside, but a bright fire and a single candle lit up the wild unkempt heads nodding to the music.

"I asked for old Norsk ditties, and got several. Presently a vast supper of porridge was produced, and the fiddle paused, while I smoked my pipe.

"Supper over, the fiddle began again. Presently one of the young giants in leather breeches sprang on the floor, seized the giantess who made the porridge, and began a polska. He trotted round the room, holding her hand, while she toddled after him. Presently the girl was spun round and round like a teetotum, shewing such powerful understanding that I marvelled; and then she was seized round the waist, and they both twirled together. Then they ambled about as before, then they had another fit of spinning till they were tired; and then another giant took the floor alone, and performed the Halling dance.

"It was an odd performance, more like tumbling than anything else, and when it was over they inquired if I could do anything.

"The music was something like reel time, so I took the floor, and performed sundry reel steps, amidst the most flattering exclamations—'That karl can use his feet.' 'It is not the first time thou hast danced.' 'That was supple,' and so on.

"So encouraged I performed 'Jacky-Tar,' blushed modestly, and retired to bed. I had my doubts of the couch, for it was in the family store-room, where winter garments were hung, so turned in all standing, and tried to sleep; but it was quite hopeless. There was a regular hailstorm of starving fleas pattering down upon my face from the winter clothing, creeping about my feet, and getting through my armour everywhere. I stood it for some time, but at last I jumped up, gathered my wraps, and marched out of doors. I believe they would have picked my bones before morning if I had stayed in the bed. I found a barn, open at both ends, with some straw, and there camped. Presently the moon rose over a lofty hill, and I began to rejoice in the agreeable change, and to enjoy the view; but for me there was no rest that night. I had a whole colony with me, and they were industrious fleas. I got up twice, stripped, and shook my clothes; but it was all in vain. No sooner laid down than they began to dance polskas, hallings, and reels, up and down my arms and legs. At last I fell asleep in spite of them.

"*Thursday, Sept. 3d.*—I was hardly asleep when an old fellow awoke me. I was sleeping across the barn door, and he wanted to begin his work, as it was daybreak. I was too sleepy to stir, so he rummaged about amongst the straw and departed; but he was soon back again with my host, exclaiming, that this 'fremande karl' was a 'frisk person,' because he was sleeping out, but that he must go away from there. They stirred me up, and shewed me to a hay-shed, so I took my plaid once more and flitted.

"There was a grand lot of dry hay, and I was about to throw myself upon it, when I perceived a dog curled up in a nest; the next step was almost into the mouth of my boy, who was sound asleep, and covered with hay; the next I found a vacant corner for myself, and took it, when, to my wonder, up sprang the dancing giantess, over whom I must have walked. She shook her long elf locks, gaped horridly, and departed; and I went really to sleep at last.

"At seven I was stirred up once more, fed on potatoes and cold water, and departed. As soon as I got to a river I bathed, and routed the hostile army.

"Walked seven English miles to the priest's house, and seven more to the great glacier. I was very tired for want of sleep, and took a snooze in a field by the way. It was very hot, the way was steep, but very beautiful. The valley is narrow, shut in by grand steep rocky mountains, with firs and birches growing in crannies in the rock. Here and there one gets a view of still higher hills beyond. The rocks below, and to a great height, are all smoothed and polished.

"I had some thick milk at one cottage, and at the glacier-foot I found a newly-made wooden house, in which was a clean loft to sleep in. The owner, a cheery old woman, had milk and potatoes in abundance, and was kind and hospitable to the 'wayfaring man.' She gave me some clean hay, and when I had made a nest for myself, I made a sketch of the glacier.

"It is the finest I have seen in Norway, and is worthy of Switzerland. It comes streaming down a great valley to the left, down to the houses and corn-fields, like a frozen torrent winding through the glen. It seemed about an English mile wide, and some five or six long; it makes three great bends, and as I saw it half in light, half in purple shadow, in its

FIG. 36. JUSTEDAL IS BRÆ AND RIVER. SOGNE FJORD, Sept. 3, 1857.

setting of bright rock, it looked glorious. A frail wooden bridge spans the clay-coloured torrent that flows from the glacier, and herds of goats and cows were passing back and forwards to the sætar to be milked. Each beast as it came walked up to look at me. An old white bull stared at me gravely for ten minutes; he was within a yard, and once I thought he meant to give me a poke with his stumpy horns, so I shyed a stick at him; whereon he switched his tail, gave a grunt, and marched off with slow dignity.

"When the sun had set, it got very cold, and I was glad to have a drink of milk and turn in.

"My hostess took me for the head of a road-surveying party, who have been marking out a post-road, to replace the horse-track in this valley.

"*Friday, Sept. 4th.*—Up at seven, and into the river, which was like ice. Breakfast was 'greasy porridge' made of oatmeal and cream, with a lump of butter in it, as cooked for priests and people whom they wish to treat well.

"I could not manage it, so drank some sweet milk and set off with a boy of twelve, and a little black dog, for a high point right above the house. I wanted to see the high ground from which the glacier comes. I never had such a climb in my life. I could not stand upon the slippery grass in many places, and was forced to take my shoes off. Even then I slid back occasionally. The rocks were overgrown with blaeberries, strawberries, and berries of many sorts; the air was perfumed with them; and we feasted as we went. The heat was like India. The black dog panted, and lolled out his tongue, and lay down on the grass; and I was glad to rest every now and then and look down upon the roofs of the houses. At last we got above the trees, and then above the grass, and the footing on the bare stones was better. We climbed on to a large stone, which I had made out with my glass from the houses below, and which was my point; but here we could see nothing for another pitch of bare broken rock with patches of snow, which lay behind the stone.

"My boy and I sat down, and lunched on bread and cheese, and snow water; and then up we went once more, climbing by a goat's road over the rocks.

"It was well worth all the trouble. I never saw so wild and desolate a scene.

"To the west was the grand rolling plateau of snow from which the glaciers slide. It was glittering in the bright sun with one great steep snow-capped rocky mountain rising in the midst. The rocks about me were nearly as white as the snow itself, with dark patches here and there, where moss and lichen had found space to grow.

"To the south was the valley which I had followed from the sea, with a great glacier-river thundering down it, and here and there on hill-sides, and perched in shelves, I could make out distant mountain sætars. With my old comrade the glass, I could see cows and goats clustering about the little wooden houses; but with the naked eye nothing was visible from my perch, but a few patches of greener vegetation, sky, snow, and barren rocks.

"Far away to the east, hardly to be seen without the glass, were the Skagastol peaks, which I left on Tuesday—seven great mountains peering over the hills on the other side of the valley. Fig. 32, p. 139.

"To the north, at the head of the valley, was the Fjeld as it exists in Norway—a great rolling plateau, a wilderness of stones, rocks, snow-wreaths, lichens, and desolation.

"I sat on the highest rock I could find for an hour, gazing and dreaming as one must dream when so placed. I can neither explain nor express the pleasure which it gives me to sit thus perched on a rocky point, high above the visible world, and glower and dream alone ; but here I had my fill of mountains and solitude. I left my perch with regret at last, and scrambled down to the big stone. There I took the distance of the house with my telescope, and made it about three and a half miles. I had made it four and a half by pedometer, and I think I must have gone up 5000 feet. It cost me four hours and a half.

"On the way down we found a snow-slope, which we could walk upon, and got down famously for some distance. When we left the snow, we got to ptarmigan ground, and the dog put up several. I shot one, and then took to beating about for more. I saw a lot, and killed three, to the intense joy of Thugu, the boy, who kept exclaiming—

"'Ney ! ney ! he shoots in the air ! Ney ! ney ! ney !'

"I was not sorry, for I thought of dinner.

"A little lower down we got into very bad walking—great rounded slopes of rock, where a goat could hardly stand, and where we could not stand at all. We were forced to coast about, seeking for grassy places to rest our feet upon, and for trees to hold on by, and then we were out of the shooting-ground. Then we got lower down, to places where grass had been mown, and leaves gathered in for the cattle. Then we reached the corn-land ; and, last of all, we got to the horse-track ; and, when we got there, most English paths would have been as turnpike roads to it. But it was a turnpike to us after our climb, and we stepped out merrily to the house, which we reached at seven.

"We were ten hours walking eleven and a half miles by pedometer.

"I had eaten but little food for some days, and I was not going to trust my spoil to the old woman to ruin ; so I took my birds to a log, plucked a couple, cut them up, washed them, and set them to boil with a lot of potatoes in a large black pot. The result, eaten in the dark, was such a feast as aldermen never taste, and cannot imagine; and the pipe and the sound sleep in the hay that followed were as good in their own way as the feast."

This "River-glacier" is a stream of half-melted ice and half-frozen water flowing from the base of a snow dome in a hollow trench. It is freezing and thawing, hardening and melting, shrinking and stretching ; but it is always sliding down in a rocky glen, which it grinds continually. The rate varies in summer and winter; the hotter it is, the faster the ice moves; but there is no rest, though the movement is imperceptible here. When ice gets down to the warm regions which underlie the upper regions of cold; when it passes far enough under the line of 32°, the "River-glacier" melts and becomes a glacier-river. The water, heavy with mud, runs off to the sea, with a load of chips scraped out of the rock-groove by the ice ; and, when it has dropped that load, water rises from the sea as vapour, and flies back to the hill-top to add to the snow-heap, and help to shove on the heavy ice-rasp, which makes the solid edge of this graving wheel.

But each river-glacier is part of a complete local system.

The glacier at Fjærland (p. 181) falls from the edge of a snow-plateau; the glaciers in Justedal flow from it; the dome, Fig.   , is the centre of the system, as Mont Blanc is the centre of a local system in the Alps.

This Norwegian heap is twenty miles wide, forty long; the top is 6440 Norsk feet above the present sea-level, and one part of it nearly reaches the coast at Fjærland. The whole is a local system, whose source is in the clouds, and whose base rests on a rock-plateau, which is wearing away to the amount of the mud carried to sea by the rivers.

Fjærlands glacier is a young system dropped by the large one ; as some sea-creatures multiply by dividing themselves into little bits. Having seen it move, a glance shews how the parent heap is moving. The Justedal River-glacier (p.) is winding like its glacier-river, as shewn in the foreground of the woodcut (Fig.) ; or like the Thames at Windsor (p. 114) ; or like the Findhorn (p. 130).

It cannot be seen to move, but it is easy to see how it is moving. It is swinging from side to side, rebounding from bank to bank, eddying in the lee of projecting points, sweeping round bays. It is rasping its bed ; undermining, undercutting, and breaking down its rocky banks. Like a river, it is flowing, though slowly ; and its movements are guided by the shape of the bed which it wears in the rock.

The Fjærland glacier is like a waterfall ;—like Tann Foss, falling from one lake into another (p. 102). The Justedal glacier is like a water-slide rolling down a slope ;—like Trollhattan (p. 103). Ink-drops (p. 96), snow-flakes, conical snow-heaps, rounded ice-domes, winding ice-streams, and glacier-rivers, all move for the same reason—they are dragged down by weight, and press each other on.

As water-streams carry floats of ice, logs, boats, sticks, and froth, while they roll mud, clay, sand, gravel, and stones ; so ice-streams carry floats, and push and roll sunken materials. Large rocks which fall from cliffs are ranged in lines on the ice, as logs are ranged by a Norwegian river (p. 124), or a fleet of boats by the Thames (p. 119). But ice being water in another condition, the glacier contains what water holds suspended.

It is a conglomerate of air, sand, mud, stones, and frozen water like the frozen wax (p. 176).

So in moving through a rock-groove, this heavy, flexible, viscous rasp grates and grinds, breaks and crushes, thrusts, rolls, and drags anything that comes in the way. If water flows round a sunken stone on a warm day, it becomes a vice at night ; it clasps the stone, binds it to the moving mass, and grinds it against the rock like an iron in a wooden plane. If the tool is not strong enough to crush a rock, it is flexible, and the weight behind pushes it over ; if it is broken, it mends itself. Wherever it goes the ice-tool grinds ; it works broken stones into polished boulders, boulders into mud, fractured rocks into roches moutonneés, and mountain-glens into rounded, polished, striated rock-grooves, whose general section is a curve $\smile$. When the ice melts floating chips are left in the groove, in their order.

This is at best a very imperfect description of a glacier ; the science of the matter will be found elsewhere, in works written by men who have made the subject their special study.

These differ on some points of detail, but all agree that glaciers move and mark rocks.

The lesson learned from these Norwegian glaciers is that a local land-ice system consists of a number of revolving water systems, which rise up from warm regions, move in the air, fall on cold solid rock, slide and flow from it ; carving hollows on hill-sides, and leaving tracks everywhere on the downward path, which leads water back to the sea from a block of high land.

The river-glacier is part of the system; it is a graving tool; and it does notable work near Bergen.

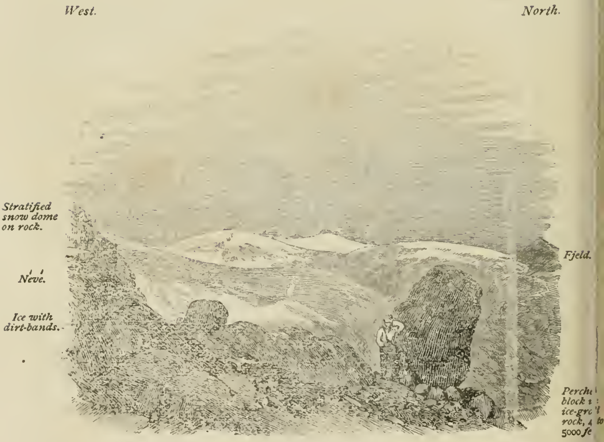


FIG. 37. KAABE, AND PART OF THE GREAT SNOW PLATEAU ABOVE JUSTEDAL. Sept. 4, 1857.

CHAPTER XVI.

DENUDATION 8—FROST-MARKS 6—LAND-ICE 5—NORWAY—LOCAL SYSTEM.

FROM the movements of land-ice it is easy to learn the direction of tool-marks which result from the movement.

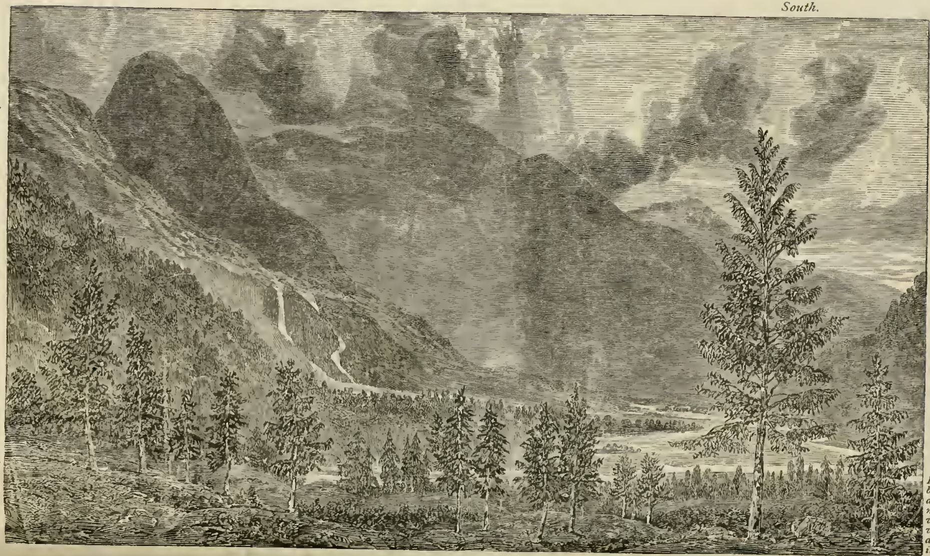
In Justedal, as elsewhere, marks are conspicuous under and near the ice. Rocks are rounded, smoothed, and grooved; and because the grooves are the tracks and ruts of the ice-sledge, they all lead various ways back to the watershed. From the source of the glacier—from the highest point from Kaabe—lines must radiate to the sea, through every glen which holds part of the drainage of the ice-field. The mark of the local land-ice system is a star *, or some other radiating figure; or a herring-bone pattern, on a ridge. Where ice has made its mark, and melted, the shape of an old local system may be learned from old rock inscriptions carved by it, and from stranded chips.

Large as this Norwegian local system now is, it was larger.

Old work done by Justedal ice is seen in the glen through which it flows. Close above the ice a higher ice-level is marked on the rocks by a lighter line, where even lichens have failed to grow. The woodcut (p.) shews the line, but in nature it is conspicuous. That line marks a recent change of climate, as surely as the scale of a registering thermometer marks temperature. But that line marks a small change; it is but one degree.

South.

Hills about 5000 *feet.* Polish d rocks and perched blocks at the level of the stone, p.



Low ground. Small trees, berries, lichens. Perched blocks, drift, and boulders on rounded tables of rock.

River-bed boulders and old moraines, washed, water-worn, and sorted in water.

FIG. 38. JUSTEDAL, LOOKING AWAY FROM THE GLACIER TOWARDS THE SOGNE FJORD. Sept. 5, 1847.

Older marks shew a lower temperature and far larger glaciers in this glen. In the woodcut (to the left) is a point of rounded bare rock, which proves, by its shape, that the ice flowed over it. It is a "tor;" but the ice was far deeper. Far up on hill-sides, as in Fig. , p. , great stones are perched upon rounded tables of rock, and high up and low down, on the sides and on the bottom of the glen, horizontal grooves and scratches point from the hills out to sea. These cross the run of streams which now flow from the hills into the glen where the ice is. Nearer to the sea where branch glens join a larger stem, and ice becomes a river, Justedal bears the same marks up to 4000 or 5000 feet, and these extend for thirty miles to the fjord. Every hill is rounded, and great stones hang poised where they were stranded by land-ice, or by ice-floats. The bottom of the valley, all the way to the sea, is strewed with drift, with clay, gravel, and boulders, arranged in the form of moraines which have been washed out of shape. Here are chips, tool-marks, and the tool at work; and these strange hill-forms are the sculpture. It is plain that rivers and weather have done little since ice left these glens.

But this is not all. These same marks extend down the Sogne Fjord for a hundred miles. From the Sgagastol peaks (p. 139), 8000 to 9000 feet high, from the Fille Fjeld (p.), from the highest ground, through every branch glen and fjord, down to the outermost island in the firth, these tool-marks can be traced upon rocks *in situ*. So the local system, whose centre is Bodal's Kaabe, and whose base covers about 800 square miles, is but a sorry descendant of a bigger race.

There were, as it seems, old Norwegian river-glaciers in this district, which were as long as the largest of the Norwegian fjords, which slid out to sea a hundred miles from their birthplace on the Fjeld; and when icebergs were thus launched here, the slips were set for Shetland.

Amongst the stones left at home by this particular Sogne Fjord glacier, are large rounded blocks of granite. If ice-floats were freighted with such stones, they should remain somewhere to tell the story of their voyage, and mark a sea-level; if the sea was higher on any other coast where the icebergs were wrecked.

Hardanger.

Where there is one local ice-system, more generally flourish in the same neighbourhood.

In the Hardanger, south of the Sogne Fjord is a large snow-heap, called the Folge Fond. It stands on a high rock plateau, nearly surrounded by deep fjords. At Bondhuus, a steep glacier flows down from the Fond to within five miles of the sea.

The river which escapes from it runs into a lake, which is dammed up by enormous boulders. The lake drains through these, and the water brawls out near the shore clear as crystal, and ice cold. The woodcut is from one of several sketches made on the spot. The boat which ferried Forbes to the foot of the glacier had sunk, so the time told off for inspecting the ice was spent in sketching.

The movements of this glacier cannot be seen, but the form shews that it moves like a steep water slide. Lines cross from side to side, and curve and wind less than they do in the glacier page , where the slope is less.

The ice-mark in this case is plain. A mountain-torrent, cuts angles; V L; this glacier wears curves ⌣ ⌞, and when it was bigger, it shaped the middle distance beyond the green lake into a big curve, at the bottom of which the river is now beginning to saw.

But here, as in the Sogne Fjord, is evidence of glaciers far larger than any which survive in Europe.

When the steep hills are scaled in any part of the Hardanger Fjord they are found to bear the same marks from top to bottom, from one end of the fjord to the other.

The woodcuts may give some notion of the form.

At Söndhord (see map) are small glaciers.

The Vöring Foss is below Söndhord at a line which crosses the river. Fig. , page , was sketched from G in the direction marked by the arrow.

Fig. (Bondhuus glacier) was sketched from (1) ; Fig. was sketched from a point (2) high above the fjord on the way down from the Folge Fond, which is rudely shewn by the curved lines about the letter S.

Fig. 39.

The river which drains the glacier of Bondhuus enters

FIG. 40. BONDHUUS LAKE AND GLACIER, LOOKING SOUTH-EAST—HARDANGER. August 13, 1857.
From a point about three miles from the sea, lat. about 60° N.

the fjord to the left of the cut (Fig.), behind a tall birch tree. The calm fjord was marked by curved streams of water or wind flowing up the hollow groove, and hanging on its sides. Wind and tide are at work; they have not yet worn out the tool-marks of ice which abound near the shore; but they have quarried a few cliffs, to shew what a sea-mark is. In the flats are plains of clay and drift, and the bottom of the fjord is strewed with glacial debris wherever it can be reached; and close to the water's edge is a terrace under water. Unless the old ice which made these marks was afloat at a high level, the Hardanger glacier was more than a hundred miles long, as deep as the hollow in which the fjord now ebbs and flows, and when launched, the floats started south-westwards for Scotland; for this slip aims about the firths of Forth and Tay.

This tract of country is frequented by bears, red-deer, roe, fallow-deer, reindeer; and elk, as it is said.

Of the bears many tales are told.

A boatman told, as, of his own knowledge, that a man who lived at a house high up on the mountains went up after a flock of sheep one morning.

"His flock came to him, as flocks do in Norway; but they came in a vast hurry pursued by a big bear. The man stood up valiantly, and the bear did the same.

"The man hit the bear over the nose with a big stick, and Bruin gripped him. He tore him badly, but the man had presence of mind enough to sham death, and the brute left him badly mauled. He got home, and he had recovered."

Here is another bear story from the Sogne Fjord.

"A man walked up the mountains one day after his sheep, and high up he fell in with a young bear. He hit him over the head with a stone and stunned him; but he had time to squall before he fainted. The squall brought the whole family to his aid. There were father and mother, two year-olds, and a well-grown baby ; and they all fell upon the man at once. They knocked him down, bit him, clawed him, and rolled him about ; but the man shammed death, and after a time, the bears left him. When he thought the coast was clear, he rose and made for home ; but the five bears were at hand, and chased him. He ran as best he could, and ended by tumbling over a rock on to a ledge, where he lay stunned. The rock was low, the shelf was narrow, and below it was a cliff.

"The bears dared not venture to leap down, so they stretched out their black paws, and growled over the wounded man. The biggest of them could just reach the man's head, and he clawed it so vigorously that he scalped him, and the ill-treated shepherd fainted. When he recovered the bears were gone, so he scrambled up and ran to the nearest house.

"He was doctored, and he recovered ; and the doctor who cured him told the tale to a Norwegian gentleman, who retailed it at Bergen, September 10th, 1857."

Even here, with glaciers about them, perched boulders seem to be strange and supernatural. Here is a boatman's account of an "erratic" :—

"On that rock (a high peak in the Hardanger, about seven miles away) sat a warrior ; on the other side of the Fjord lived a witch whom he wanted to marry ; she refused, so he cast a stone at her, which she saw coming, and avoided. The stone is there yet, and the distance is more than a Norsk mile."

Here too the ice-world is mysterious. A boatman declared that his mother, when a girl, had seen a flock of mysterious cows near the Folge Fond at Yiggra Stola. They vanished and they were "Huldra Beasto." According to peasants, under the Folge Fond are seven parishes, which were overwhelmed for wickedness. The church bells may still be heard ringing on certain holy days.

So ice and its works seem strange even to men who are familiar with glaciers; and large wild animals, men, and their works, can and do exist together with land-ice in Norway.

The country at the end of the Hardanger is thus described :—

"At Eids Fjord got a small boy to help to carry some of my traps, and walked up to the lake. It is the wildest tarn I ever saw, with sides perpendicular and impassable. One half of the mountains were in bright sunshine, the other in dark blue shadow. The water comes from Normand's jökelen, and as glacier-water it is light green. I got a boat, and my boy rowed me to the upper end, about three miles, to Garatun. I sent him with my sleeping gear to a house, and put up my rod and fished the river which runs in at the end. It was thick with snow-water, but I killed a five-pound sea-trout, and raised four more fish. I gave it up about eight. The river which runs out is a capital fishing station, but it was occupied.

"The place I slept at is a cluster of houses built on a plain, which was evidently formed by some old world glacier at the bottom of a lake (or the sea). It is all cultivated, and as flat as my hand. It is quite shut in by enormous rocks, with trees clinging in their cracks, and it is about the wildest hole I ever was in. The people are like Finns; dark-haired, dark-eyed, grave, queer-looking mortals; standing in attitudes that reminded me of the Tana people. My host was a Finn all over, but a good sort of chap. He and his brother had been to Finnmark for reindeer. They bought a herd, and travelled for eight weeks over the snow. They made about 300 dollars by their venture. I slept in the loft amongst the household gear, and spent the evening at the house door, surrounded by the whole population ; all jawing, smoking, spitting, and wondering ; and I for one enjoying the party.

"18*th.*—Up early ; carried nothing ; ate cold salmon and fladbrod, and set off for the Vöring. The way lies along the river, up a wild gorge. Every here and there it leads up a stair of rough flat stones, or over a ridge of ice-polished rock. The river is crossed by bridges, frail and shaky to a degree (p. 101). Two pine logs are set up at each side of the river, and on these logs rest two long trees. Planks cross these, and through the openings the water can be seen tumbling over great boulders underneath. There is not a shadow of a hand-rail, and when one walks fast, the whole structure shakes and sways about as if it must come down. About five miles up the river the road turns to the right, and goes about 1500 feet up a very steep face. The way is a stone stair winding about amongst the debris of the higher rocks. And yet it is up this road and over these bridges that people ride to the Foss. After this steep pitch the Fjeld is reached. It is a great waving plain, with birches and muirs, covered with multiberries (cloudberries), and through this run streaks of bare rounded rock, on one of which is the path.

" In the soft earth I tracked an English shoe, and presently saw two men going the wrong way, about a quarter of a mile ahead. I hailed them, put them right, and we joined company. We visited the Fos, and together returned to Eide. (The Fos and its mark are described, p. 99.)

Söndhord is near the watershed of Southern Norway, and glaciers are seen at the head of the glen.

A day's walk leads to a glen, whose waters pass Kongsberg and run south to the Skagerrak. A remnant of the ice-engine is at this centre; another little bit of it is left at Bondhuus (Fig.); and at the mouth of the Hardanger Fjord are some of the tool-marks of old Scandinavian ice. It was launched for Scotland, and it shaped the Scandinavian rocks which are figured in the woodcut below, for the ruts can be traced from Söndhord down to the sea.

FIG. 41. A SHORT BRANCH AND PART OF THE MAIN HARDANGER FJORD, NEAR BONDHUUS.
From a point about 2000 feet above the sea, looking N.W. to a rocky point where the main glacier, which begun about Söndhord, joined this branch.

CHAPTER XVII.

DENUDATION 9—FROST-MARKS 7—LAND-ICE 6—WESTERN SCANDINAVIA—OLD LOCAL SYSTEMS.

These two local ice-systems placed far south, and opposite to Scotland, with their old marks beside them, are good samples of Scandinavian glacial denudation, and they are easily visited. With the lesson taught by Fjærland fresh in the mind, each Norwegian fjord is found to contain like marks.

If the Sogne and Hardanger Fjords contained big glaciers, the snow-heaps which fed them must have been large in proportion, according to fair induction; and in fact, everywhere in Southern Norway, the tracks of a large local system do appear. The land is low at the col between Romsdal and Gulbrandsdal; and these two glens cut the south-western point of Norway from the main block of high land which forms the peninsula. Rivers which part at this col run west to Molde, and south to Sarpsborg, below Christiania. If there be any truth in ice-marks, two vast glaciers, or two sets of icebergs, followed the run of these two rivers and one of the streams now drains a large tract of eastern Norway.

From the high western block of land, glaciers flowed every way, diverging as rivers now diverge. Where Christiansand stands, at the mouth of Sætarsdal, a stream of ice entered the Skagerrak. Sætarsdal, as its name implies, is the mountain pasture-land of the low country.

In the autumn, the cattle are driven down in great droves.

"At the mouth of the glen, I walked down with the Procurator of the district to see what he called a 'drift.' I thought it was a raft, and was surprised to find some forty cows and a couple of hundred sheep and goats waiting to be ferried over a broad river. They were driven down to a sandy point, with logs stranded upon it, and a wooded hillock rising behind. There they stood, huddled together, bleating and lowing, and switching their tails in the calm water. The goats perched themselves on the logs, and men stood amongst them; while a flat ferry-boat, with a load of 'smaa creatur,'* was slowly rowing from the land. It was calm, and the hills had now begun to be worth looking at; the light was good, so the drift made a very pretty picture so far.

"The Procurator had bought a cow, some one else a goat; and these two were to remain behind. Boat-load after boat-load of small cattle were pitched and tossed in, and ferried over; and the poor sold goat was left alone bleating lamentably. Then the cows were driven down to the water's edge; three or four were put into the boat; and, amidst loud shouts of 'keesa, keesa,' away went the herd over the still river, snorting and blowing. Some went up stream, some down; but all tried to lay their noses on their neighbours' backs, and the boat had hard work to keep order. One obstinate cow was hauled over by the horns; but all landed safe and sound at last; and they walked deliberately up the opposite bank, cropping grass and lowing as if they were used to swimming two hundred yards.

At another station I met a party of drovers with 650 beasts. They were dressed in native costume. "All clothes in this

* Small cattle—*i.e.*, sheep and goats.

glen have an upward tendency which it is hard to account for. In all other countries people have waists, more or less, short or long: here they have none. Men fasten the waistbands of their trousers round their necks, and put their arms out of the pockets. Waistcoats are put on like neckcloths, and the general effect is that of Mr. Nobody, as drawn by Cruikshank. The women, in like manner, fasten their petticoats round their necks; but they forgot to lengthen them when the fashion came in, consequently their coats are kilted like those of Leezy Lindsay in the old song. They wear many different colours, each skirt appearing under its neighbour; and the whole lot turn up at the edge, so that the outline of a belle is a concave curve, instead of the usual convex contour."

Sætarsdal is now a wide pastoral glen; but every rock in it is ice-ground for a distance of 112 English miles, as far as the road extends north.

The upper valley is a miniature copy of one of the Bergen rock-grooves.

"At Valle, after passing through a wild narrow pass between bare rocks of great height, the glen widens into a broad green strath, dotted with stones as big as houses, set in the velvet turf as if planted there on purpose. The houses are built of vast logs as big as three modern Norwegian fir trees. Their corners are carved posts, their roofs project, there are galleries and carved door-frames, and all about them is old, dark-brown, and strange."

"At the road side stood a tall, well-shaped, straight-limbed, pretty girl, with a plaid thrown over her shoulders, and her head rolled in a large shawl. She wore a jacket about six inches long, and a waistcoat to match. She had silver breast buckles, bits of red worsted embroidery here and there, and several petticoats of various colours, the longest of which just reached the knee. She had a magnificent pair of garters, with bright silver buckles, and as neat a pair of legs as Taglioni, cased in blue worsted hose. As she stood knitting behind a little fir tree, she was the very picture of a wild mountain milk-maid. She vanished like one of her own kids when she found that she had been seen."

This is said to be the oldest glen in Norway; the language is mixed with strange words, some of which sound like Welsh and Breton. It is said that Scotch colonists were planted here after a plague had thinned the natives. Old as this human history is, older ice-marks are perfectly fresh in Sætarsdal, and sea-shells yet stick to rocks above the level of the king's palace at Christiania. But this level would sink most of the flat land in Southern Norway, and leave bare rocks above the sea here where bare hills now are.

Christiansand stands upon ice-ground rocks. All the islands for miles out to sea, are roches moutonneés, peering above the waves. "The road leads inland through a wild pass, with hills on either side, with dark pines growing in chinks in the gray rock. The bottom of this pass is filled with a plain of boulders and sand, which look as if ice had dropped them yesterday." But near this district, as shewn above, p. 104, at Sarpsborg, Christiania, and Uddevalla, the sea stood higher, and these low boulder plains look like ice-chips packed in water.

A good mountaineer can walk in a few days from Valle, where waters run south; to the head of the Hardanger, or to Bukke Fjord, whose waters run west and south-west.

It is an easy drive from the Hardanger to the Sogne, where the water runs west; and a stout walker can march in a day from sætars at the head of the Sogne, below the Sgagastol peaks, east to sætars in Gulbrandsdal, or to other glens which run east and south, north and west. A good road crosses the Fille Fjeld from another branch of the Sogne Fjord, to Christiania. It passes the watershed of this district, and crosses the head waters of many southern rivers. In short, nearly all the rivers in Southern Norway rise within about sixty miles of each other.

From this watershed rivers of water or ice must have flowed ever since the highest peak was above water.

Where glens meet, there ice-marks part. Though snow melts on the fjeld in summer now, Southern Norway certainly was the base of one big local ice-system, which helped to carve out the star of glens and fjords through which rain-water now flows to the sea. In these are deep rock-basins, which hold long narrow lakes, and salt lochs. When the glaciers were launched, the slips were set for Denmark, and for Great Britain; and the German Ocean must have been full of Scandinavian icebergs, loaded with boulders quarried about the Fille Fjeld.

A glance at a good map will shew that all the drainage of this wide tract of high land pours into a sea, which is bounded on the west by the British Isles.

A local ice-system, with its centre on the highest land, and its river-glaciers in every glen, would spread from the Fille Fjeld and Sgagastol (p.), because rivers do now. The eastern drainage is caught in Gulbrandsdal, and runs past Christiania into the Skagarrak.

Westwards and northwards, water is caught in the grooves which open towards Shetland and Eastern Scotland. Southwards, rivers enter the basin of the North Sea, and they all flow in ice-ground glens. The area drained in this direction is about equal to the British Isles.

But these waters are joined by all the drainage of Sweden and Finland, whose rivers enter the Baltic, and thereby enter the German Ocean.

Following the southern coast-road from Christiania, every glen, hill, fjord, and island, bears marks of ice moving seaward. The marks are not confined to glens; on the coast-road from Christiansand to Stavanger it is the same. "There are no glaciers, but the whole country looks as if it had just begun to change from bare rock to vegetation. In some districts rocks are mostly granite; in others they are slaty" (gneiss and slate). "The hills are all rounded at the top, and ice-polished. The glens run about north and south; and in many places their sides are nearly precipitous; but on every flat ledge, and in every crack, their grows a bunch of trees, with fern, heather, blaeberries and raspberries at their roots."

"In every bit of flat land there is a corn-field; and on August 6th, 1857, the harvest had begun. But the main features in the landscapes are gray rock and blue water—ice-marks and melted ice.

The present state of this land is a strange contrast to the scene which the ice-marks conjure up. From the utter solitudes and desolation of the ice-world which is at Justedal, and was on hills above Christiansand, the present appears like a magical change. From ice, rein-deer, elk, and bears, we get down to a smiling land.

"In the evening light this country is very beautiful. After a long day, after scrambling up a long weary hill, in a vehicle like a small blue boat upon yellow wheels, we came to a brow. At our feet was a lake stretching away for miles and miles; islands, and points, and ranges of hills beyond, were reflected in the bright shining water, and everything was rosy and golden in the sunlight. Dark firs on each side made the distance look all the brighter. It was a quiet, solitary, warm, beautiful landscape.

"I got out, and sat down by the roadside to sketch, while the horse and the boy went on, and grazed contentedly on grass and raspberries. When they were gone, I might have been in the backwoods of North America, for all I could see of humankind. The air was calm; beautiful butterflies—summer-fowl, as they call them in Norway; strange little birds, that I had never seen before, flitted about; and the great black woodpecker yelled in the forest. I had a gun, but I let them live on, and enjoy themselves as I was doing."

In every bit of flat land (that is to say, nearly in every glen), there is cultivation.

The Lyndals river flows through a wide open strath, with fine green velvet turf, moorland, and birch trees, where there is no corn. "The trees and the peat-reek smelt so sweet in the warm rain, and the place looked so like old Scotland, and my second love Lappland, that I halted to try for a fish. Pulled up at the station, and got the old master to lend me a fresh horse, and go with me to the highest pool. We had no right to fish, but nevertheless we poached together in the rain till dark. Hooked one small grilse, but lost him."

The low country in Southern Norway is very like a Highland glen. The glens are rock-grooves; the plains drift; and the rivers are only sorting ice-chips in ice-grooves. After Flekke Fjord, the hills recede from the coast, and the Stavanger road is flat and uninteresting.

Here is a sea view of the country:—

"*Sept.* 11*th*, 1857.—At Stavanger we stopped for the night. I landed at sunset and walked up to the cathedral, and to a windmill, from which there is a fine view over a perfect labyrinth of low rocky islets, and to the distant mountains about

Bukke Fjord. The town in the foreground, with the ships' masts and the watch-tower rising against the gray eastern sky, made a very pretty picture. The cathedral is Gothic, built of stone, and dilapidated. There is nothing very remarkable about it, but that it is 900 years old, and one of the two stone cathedrals of Norway.

"When we went on board again it was dead calm. The moon was peeping out from behind some dark clouds close to the old watch-tower; stars were twinkling here and there; lights were glimmering from the windows on both sides of the narrow harbour, and every light was doubled by the calm dark sea. Every boat that shot out to our steamer left a trail of sparks that glittered in the water like diamonds, glowed, and died away.

"Presently a fine deep voice, high above us, began to chaunt the hour, and a psalm, from the watch-tower; and then from all parts of the town, at different distances, the watchmen chaunted the response. It made a beautiful scene, this sleeping town; and the voice of its guardians was a grand solemn chorus rising on the still night-air. Stayed on deck gazing, listening, dreaming, and whistling old tunes, till near midnight, and then turned in.

"*Sept.* 12*th.*—Awoke nearly suffocated; the steward had shut my port-hole, and there was not a chink in the ship open for ventilation. Got air as soon as possible, and found that we were steaming south-east along a low flat coast, with distant mountains shewing beyond a plain. The road runs along this flat, which is said to be without interest. It is like the Campagna of Rome without the ruins. The distant hills are quite as fine as the Italian mountains, and the foreground quite as flat and ugly.

"The coast is a wild one. It was a fine morning, but there was a little sea on, and towards noon it clouded over, and blew from the south. We called at Eggersund and Flekke Fjord, and ran for the night into Farsund.

"The scenery in this part of Norway is very peculiar, and differs entirely from the northern coast. About the Arctic Circle hills are jagged peaks. Seen from a distance these hills appear to slope down gradually to the sea, with a rough rounded outline. There are few peaks to notice; but when the ship comes near the coast, there are intricate passages and long fjords winding in and out amongst the hills in the most extraordinary fashion. Farsund is one of these queer land-locked holes. We were tossing about in the open sea off Lyster at six, when the pilot on the bridge held up his hand, and we charged stem on right into a nest of breakers and black rocks. (Many of these rocks are of the pattern of the Devonshire tors.) We turned and twisted, and wound our way amongst these, passing within ten yards of the stones. Then we twirled round a rocky point, and steamed at a hill. At last we twisted sharp round another rock, got behind the hill, or through it, and found ourselves in a rock pool, where we anchored within twenty yards of a flourishing little red wooden town. It is built upon perfectly bare rocks, with hardly a blade of grass in sight."

Here is another coast view of this part of the world:—

"After a rough voyage from Hull, we made the Naze, and coasted along to Christiania.

"*Tuesday, June* 10*th*, 1851.—The wind veered round to the north in the night, and at the Naas, which we reached early, the tossing was worse than ever. By breakfast time we had shot round, and by the time we were off Christiansand, it was nearly calm. Here we landed a passenger by putting him and his goods into a very pretty pilot-boat with brown sails.

"The coast was in sight all day, a rough rocky foreground, backed by forests, and far away a snow-peak or two glittering in the sun, which shone out warm and bright. The sick passengers came crawling out of their dens, looking wo-begone; but on the way to recovery. A youth with a Glengary bonnet, and a Lochawe-side terrier, began to shout for whisky ; and in a short time the crew were all alive, steaming up Christiania Fjord.

"The evening effects were very beautiful. Great masses of white cloud went rolling up the dark hills from the coast, with dark blue showers falling from their ragged edges, while numberless white sails were dotted about in all directions.

"Ships of all rigs were working down the Skagerrak, hugging the Norwegian shore to gain the tide, which there runs south-westward at a considerable rate.

"At the mouth of the fjord, a custom-house officer came on board, looked at our papers, and departed. He was a big heavy man, and when he got into his cockleshell of a boat, he looked as if he were sitting on the water." Got into Christiania at 1 A.M. on the 11th, having made the run of about six hundred miles in seventy-two hours.

So if there were ice-floats in the Skagerrak they would move along the coast south-westwards ; if these carried stone cargoes they would be shipped for the coast from which we had sailed.

From Christiania we went to Bergen, falling in with a large party of students at Krokleven, which we reached as the sun was setting. "Here the main body of horses, carriages, and drivers were assembled. A regular army of Norwegian ponies were tethered in rows in the open air, while their owners chattered and smoked, and drank beer about the little inn. Lots of pedestrian students were lounging about the door, and the place was a Babel of tongues. We walked down to look at the Queen's View. It was magnificent: lake, forest, mountain, and river stretched away to the horizon, a distance of about seventy miles, and a warm twilight western sky shewed the distant peaks as clearly as if they were cut against it. A wild deep gorge was in front, and far below us were the station at Sundvolden, and the quiet lake, with a pigmy boat stealing silently over the glassy surface. Near it were some white tents with long tables laid for to-morrow's breakfast, and far away, gleaming against a dark hill, a large watch-fire blazed where the main body of Swedish students were now supping."

At this season the high watershed is a contrast to the low coast-line. The glacial period is hovering over it, with white snow-wings, ready to pounce with ice-claws on the old perch.

"*June* 14*th.*—In these high glens, with the snow just off the ground, there is no proper food for the half-starved, wretched horses. They are sorry cattle at this time of year.

"Drove on; up the Fille Fjeld to Nystuen, and got in by eight. For the last part of the way the road was still covered with old snow-drifts, two or three feet deep. Lemens were running about in all directions, and the way-side was strewed with the carcases of the slain. By the station was a frozen lake of winter snow and ice, with a patch of clear water here and there, and tracks of sledges still clear on the melting surface, which here makes the winter road. The wind was piercing cold, so I was glad to get indoors, dine on reindeer venison and potatoes, and toast my numbed hands.

"15*th.*—Up at seven; very fine. Walked up to the top of a high precipitous hill to see the view. We walked up in an hour, and it was a good stiff pull. The first part of the way was over grassy land with rocks peeping through, and small thickets of willow. It should be a grand place for Reiper. Patches of snow lay on the ground all the way, but on the top it was everywhere very deep. The sun had melted the surface crust, so we sank in three or four feet in the drifts. The lemens were in scores. They kept running about on the snow, and taking refuge under it when Bob or his master chanced to come near them. Every now and then there was a grand chivey. A little brown yellow beast appeared at a distance, and off went Bob in hot pursuit, kicking up the snow and barking with keenness. The lemens always fled at first, but when overtaken they turned and sat up on their short tails, chattering and spitting, and shewing desperate fight. The battles always ended in a crunch from Bob's jaws, and twenty lemens died. As for Bob, his travels nearly ended here, for a large eagle, which had been soaring above us, suddenly stooped at the dog who was coursing a lemen in hot haste. The bird passed within a few yards of my comrade, Bob's master, with beak and claws down; but he missed, and rose again, and hung above us wheeling as before.

"The view was fine and very extensive; to the south was Solens Tinde, the highest point on this range. It was a snowy peak rising from a wide snowy plateau, through which a few rocks were only now beginning to shew their backs. To the north were the Hörurgerne and Jotun Fjelds, a sea of wild peaks and jagged cliffs like the teeth of a saw (see p. , Fig.). To the east was the glen up which we had come, with a few snow-hills showing in the extreme distance. To the west was a confused mass of snow, lakes, and rocks, amongst which the telescope made out the reindeer which belong to the inn. Our guide told us that an Englishman had bought seven or eight last year. Came to the conclusion that they now inhabit the Zoological Gardens, and said I had seen them.

The man asked tenderly after their health and pitied them, 'poor things without any snow.'

"We sat on the top a full hour basking. This is a snow world, and a wonderful change in one week from the smoke and dust and heat of London." By autumn this tract is almost clear of snow. The glaciers are further west beyond the jagged mountains; but the plateau of the Fille Fjeld is as high as the Folge Fond, and further inland.

One is a picture of utter desolation; the other picture was pleasant to look upon, for the annual glacial period was taking flight.

"Our Sunday dinner was duck and potatoes. The girls were busy at their toilette by the lake-side. They let down masses of magnificent hair, that streamed all about them below their waists. They combed it, and washed it carefully; and rolled it up with red tape bands, and twisted the rope round their heads. Our boy sat on a stone beside them, laughing and chatting, and splashing their faces. The old landlady, with her queer white two-horned Sunday cap, sat at the door reading a big Norsk Bible, and peering out over her spectacles at the boys and girls. She, too, enjoyed the warm sunshine; and we agreed that Nystuen was a pleasant place for a Sunday halt, on a fine June day."

One stage further on, the road dives into a glen which is ice-ground from end to end; and grooves at the top point for the mouth of the Sogne Fjord and Shetland.

"The glen from Mariestuen to Hæg is magnificent. The road winds along beside a rapid little stream, growing bigger at every turn. In some places it is rather dangerous driving. At Hæg all the world were at home; so I produced a black, convex mirror, and had the whole household about me in a minute. There were about two dozen of all ages—some pretty, and all very picturesque—climbing over the stairs, and peeping over each other's shoulders, and scrambling for a peep at their own delighted faces. Married women wore a white cap with two peaks like horns; girls had their hair bound up in red tape, and twisted round their heads like a turban. They wore jackets with full sleeves, short full petticoats, and stockings of all colours. Shirts, shoes, and fingers, glittered with studs, buckles, and filagree rings of silver."

And so down to Ljusne.

"The glen is one of the wildest I ever saw; the road extraordinary. At times it passes under enormous overhanging stones, all waterworn, as if the river had flowed far higher up; at others, it crosses the stream on shaky wooden bridges; then, to avoid some cliff, it winds up hill, meandering about amongst large fallen stones. At one of these places I sat in my carriole and dropped a stone over the edge about three hundred feet down into the river. The people, as I have often remarked in other countries, are far less healthy at the foot of the glen than they are high up amongst the hills."

And so the road and the journal lead down to Lærdalsören, on the Sogne Fjord, close to the glacier district above described, chap. xiv. xv.

The fjord *was* filled with ice. It *is now* a sea-loch, and the way to Bergen lies by a water stage.

"*Monday, June 16th.*—Got under weigh at eleven. Our boat was a large one, with a big square sail. Our two carrioles were hoisted up, one in the bow, with the shafts sticking out like a brace of bowsprits; the other at the stern, with the shafts the other way. We had a crew of five; and, at the last moment, a passenger asked leave to join. We were eight men, two carriages, and Bob; and our boat was within six inches of the water. It had come on to blow very hard, and lots of natives came to see the start. Everybody chattered as we went off, and advice flew after us as long as we were within earshot. The squalls were fearful. When they came whistling down the glen and fell upon the water; the spindrift flew like mist, and our boat whizzed and sang through the boil. Waves curled up behind us, and broke close to the stern post. Three men sat together on the after thwart, two to haul down the sail, and one to hoist and steer; and they, as well as the passengers and the two who sat forward, were chewing hard. When the squalls came, they all rolled their quids, and chewed harder, and grinned and chattered like a flock of gulls in a gale.

"Down came the tall sail in a moment; and, when the worst was over, up it went, with more chattering: and then we spun over the crisp blue fjord till the next blast fell off the hills. With our top hamper and very little ballast, it was more exciting than safe.

" By the time we had reached the mouth of the Gudvangen Fjord, it had fallen dead calm, and the sun shone brightly. This is the wildest bit of scenery I have ever seen. The mountains are almost perpendicular; in many places they are cliffs. Here and there a salmon-fishery overhangs the water. A large flat net is hung from fir booms, and a man perched on a high stage sits like a spider in his web, holding strings ready to haul when anything passes. Dotted about on green spots at the foot of the cliffs, are tiny little wooden cottages, like toy boxes. As we passed them, rowing steadily over the smooth glassy water, we could see cows gathering in from birch woods, which cling in every chink and cranny; they came tinkling their bells, as they shook the flies from their ears, and whisked their tails.

"Thrushes were singing sweetly, and cuckoos were sounding their notes high up amongst the rocks. At one place a girl, dressed in the costume of Bergen, stood upon the top of a great stone, and called her flock about her with that wild plaintive tone which seems to belong to all mountaineers. All the way up, wherever there was grass, and footing, white goats clambered about, and stared at us as we passed beneath them on the black deep water. They rattled down loose stones, which plunged into the water beside us. At every fresh turn, waterfalls seemed to come from the clouds, for there was no higher ground in sight. Some fell direct into the sea from a cliff. One above the inn is said to be 2000 feet high."

From the end of this branch, the road passes over a high ridge, and down through other fjords to Bergen.

Thence steamers run to Stavanger and Molde, through land-locked sounds, amongst scenery which rivals the finest in Switzerland.

Once for all, the whole country is ice-ground, except where weather, rivers, and waves have obliterated the marks. The glacial period has been lifted, but it hangs in the air like a tent of cloud.

From the Fille Fjeld, Hardanger, and Hörungerne, from the watershed down to Bergen on one side ; to Gulbrandsdal, and Christiania, Romsdal, and Molde on the other; from Christiania round the coast to Molde again, there are tracks of one local glacier system. It spread from Gulbrandsdal to the Atlantic; from Romsdal near lat. 63° N. to Lindesnæs, lat. 58° N.

It covered an oval patch on the globe about the shape of Ireland, and the size of England, which corresponds to the latitudes of the Farö Islands, Orkney and Shetland, and Scotland to the Moray Firth.

The points about which the ellipse can be drawn on the map are the Hardanger and Hörungerne, the highest mountains at the head of the largest fjords in Southern Norway.

Here comes in a map.

CHAPTER XVIII.

DENUDATION 10—FROST-MARKS 8—LAND-ICE 7—SOUTHERN SCANDINAVIA—OLD LOCAL SYSTEM.

If Western Norway, opposite to the Farö Isles, and to Northern Scotland as far south as Inverness, now contains local glacier systems, and was formerly covered by one large local system, which still hovers over it; then the high ridge of land which forms the Scandinavian peninsula, and extends from the North Cape to Lindes Næs, ought to have been covered at the same time.

If there is a star of ice-marks on the oval block which forms Southern Norway, there ought to be a herring-bone pattern on the long ridge which stretches north-east and south-west between 58° and 71° 10′ N. lat. To travel round this block, and cross it at various points, is to be convinced that the back-bone of Scandinavia, like the ridge of a house in winter, once sent off snow slides to the Gulf of Bothnia and to the Atlantic through every hollow.

Take the next block of the peninsula.

About lat. 64° the country is traversed by a road which leads from Trondhjem to Sundsvall. It is the last of its kind, and the most northern pass in the world.

The col is about 2000 feet high at most. If a line is drawn from this pass to Sundsvall, and south about Sweden to Christiania ; up Gulbrandsdal, down Romsdal, and round the coast up to the col once more ; this oval will surround a tract as large as Great Britain, and similiarly placed on a meridian.

If the sea were up to the level of the northern pass, where ice-marks point north-east and south-west, in lat. 64°, as shown above (p. 103); and if the submergence were general in this part of the world, there would remain two groups of islands within the two districts, which now form Southern Scandinavia.

At a level of 1000 feet there would be one long island stretching from the Wenern See far up into Finnmark, with the Bergen hills as islands to the west.

It has been shown above (p. 104), that ice-marks about Götheborg, and the general features of the low country which lies below the southern end of this hill country, shew glacial movements from north-east to south-west, and shells prove that the sea was up to 500 feet at least. But if the sea were up to 500 feet, and the low hills of Southern Sweden were submerged or awash, the Baltic current which now sweeps along the southern coast of Norway (p.), would have room to flow from Gefle in Sweden direct to Lindes Næs.

If, when this low tract was sunk, neighbouring hills were covered with glaciers, and the North Sea cumbered with icebergs, these would float over Dalecarlia, south-westward, past Norwegian hills which are seen to the north in passing through the Göther Canal.

The watershed of this district would still be the highest ground, which is about the Dovre Fjeld and Röraas, in Norway.

The highest mountains are Sneehætten (7500), and the Rundene, and they are within sight of each other. A glance at a good map of Sweden, say Brandenberg's, shews the watershed from which rivers diverge ; and most of them flow from the neighbourhood of these mountains, south-east and south; and all these drain into the Skagarrack at last.

The highest mountains about the watershed are weathered peaks, like those figured above (pp. 137, 139).

Sneehættan has several sharp points, with slopes of talus and snow slopes at the base. It stands up from the fjeld like a ruined pyramid, and several neighbouring hills have similar forms.

If the sea were up to the base of these hills, they would be copies of islands which stud the coast of Norway.

The Rundene are steep cones like Λ. The fjeld and all lower hills have rounded tops ⌒ : all glens are hollow curves like Highland corries ◡.

The tract is well known. The main road from Christiania to Trondhjem passes over the Dovre Fjeld. Forbes went up Sneehætten in 1851; Chambers described the road in 1849. In August 1849, the writer started from Jerkin in pursuit of reindeer, with a comrade, whose journals were printed in 1852. The place is described in Murray's Hand-Book for 1848, Route 26, and there still older descriptions are quoted.

Sneehætten is a weathered peak with a great corrie at the foot, which some traveller calls a "crater;" a careful study of it with a telescope, and a walk to the foot of the snow, failed to discover anything but frost-marks on old slaty rocks. At the foot of the corrie is a hut built by reindeer-hunters for shelter—it stands on a moraine, and is made of slabs. Of this place the printed journal says:—

"It was about one o'clock before we started for the search, and our first beat was up a long tract of low moor to the foot of Sneehætten. At times up to our ankles in mud and water, and obliged to take shelter from the mountain showers under some large stone. At the foot of Sneehætten, we turned up to the right on to higher ground, and came back over rough stony bases of mountains. For eight hours, we had been walking over most impracticable ground, to say nothing of a fourteen miles' walk in the morning, and all we had seen was a blue hare and a few tracks. It was not, however, till we were at the foot of the ridge on which the 'Smaahuus' stands, *some* 200 *feet above the moor*, and had to climb up it, that I became aware that legs like mine would refuse the office of carrying their load if urged too far; in fact they were fairly tired out."*

The "ridge" is a moraine, like the ridge on the Aar glacier, and the corrie is like those figured, pp. 137, 139, and like hundreds of corries in the Scotch Highlands. The burn flows over boulders. The fjeld is about 3000 to 3500 feet above the sea. Sneehætten rises above it like one of the peaks of the High Alps seen from a high level, or like one of the Scotch hills seen from the coast. It is 7714 feet high according to Murray, and a hill so well known is not worth a woodcut. Here is a likeness of the neighbourhood from a manuscript journal.

"*August 4th*, 1849.—The mist had risen, and the sun shining on some of the distant peaks promised a fine day; so we started right up the hills to the west, intending to get the wind of the glen, and return to our house by four. —— was rather pumped at the first hill; and indeed it was a stiff one; but he is very plucky, and would not give in. We waited for him two or three times, and took a good hour to reach the top. There we were forced to go slower, for to lose each other would not do in such a mist as we entered. I have

* Notes from a Traveller's Journal. G. Woodfall and Son, London, 1852. Printed for private circulation.

seldom seen a denser cloud; and when we got on the snow and looked round, it seemed like walking in air, for nothing was to be seen in any direction. We cursed the mist, and turned over the shoulder to the head of the glen to the west, hoping that the mist might be higher on that side. On the way we fell in with the tracks of two deer quite fresh, and following them, we descended till we left the clouds, and then sat down to spy the corrie. Nothing appeared, so we crossed and mounted the opposite face. Here —— began to flag, and on coming up he took advice, and went back down the glen alone." (This glen joins the one which comes from the foot of Sneehætten, and like it is a wide rounded groove very much ice-ground. A lake is at the lower end, and the rocks about it are so polished as to be almost impassable.)

"Ion Eriksen and I, having devoured our respective luncheons, went on to the top of the ridge, and the sun being now very bright and warm, we could see famously for many miles. Nothing was visible but peaks, and snow, and reindeer moss, and three small snow birds that whistled and chirped and fluttered about in the sunlight, merry as crickets. I sat and watched them lazily for some minutes, and then gave it up as a bad job, and took the way to Jerkin. We had a long snow slope to descend right towards the sun, and in front of us rose a mass of broken stones and rocks in deep shadow. Here it would have puzzled a lynx to see a haystack; and here, of course, were the only deer we found. We, on the snow, must have loomed large and black as elephants. So the ren—a hind and calf—set off, and we first saw them half a mile away, racing over the snow towards the mountains which we had left in the morning. I took a long look at them through the glass, and shut it with a slap that savoured of an execration. The old one had small horns just sprouting; she ran fast, with an action of much power but little grace, and she smelt at the snow now and then as if in search of foes. She was certainly not so pretty as a red-deer, but I should have liked well to have a shot at her despite of her sex and her family.

"We now got into a deep picturesque gorge with a beautiful sheet of clear green water at the bottom. We followed it to within about two miles of our late lodgings—the hut; saw ——— with the glass, packing; and then walked down to Grönbakken, and up the hill back to Jerkin. The old lady came to my room and slapped my bare legs, which had turned red from sun and mosquitoes; then holding up her hands the worthy woman departed, exclaiming, 'Gud bevare, til gaa so naaked!' The benighted mortals had never seen a kilt."

In 1852, in June and August, the writer crossed and recrossed the Dovre Fjeld. In September 1851 he travelled from Trondhjem round the coast to Molde, and up Romsdal, where he spent two days upon the watershed to the west of Sneehætten, returning thence by Gulbrandsdal to Christiania.

Before the glacial theory had grown to its present shape, the strange appearance of this fjeld had been noticed.

Mr. Laing says, "The most extraordinary feature of this mountain tract is that the surface of the Fell and of Sneehætten to its summit is covered with, or more properly is composed of, rounded masses of gneiss and granite, from the size of a man's head to that of the hull of a ship. These loose-rolled masses are covered with soil in some places; in others they are bare, *just as they were left by the torrents, which must have rounded them and deposited them in this region.*"*

This is a true picture of the fjeld, so far as it has been

* Quoted by Murray. See *Handbook for Northern Europe*, 1848, part i. p. 224.

Journal of a Residence in Norway by Samuel Laing Lond 1836 - page 53 explored. With the top of Sneehætten acquaintance has not yet been made.

With a glacial theory forming or formed, no one can see this country without recognising the tool-marks of ice. Starting from one set of corries at the foot of Sneehætten, one connected series of ice-marks can be followed down to the mouth of the Sundalls Fjord, which the coast road crosses in lat. 65° N., at a point a hundred miles from the snowshed. Starting from the southern corries, a set of marks lead down to a low watershed, whence two large rivers part ; one flows west to Romsdal, the other south through Gulbrandsdal to the Christiania Fjord, and these two used to flow out of the same lake in Romsdal. (It is drained now—1864.)

The Romsdal Fjord is one of the finest in Norway. The view from Molde alone is worth the journey.

At Veblung Næs the fjord ends, and the glen begins. To the north are a series of weathered peaks, broken beds of rock, which dip about north away from the famous Romsdalshorn. It is an obelisk of granite about 4000 feet high, and the snow which slides off it falls sheer down into the valley.

The only adventurous traveller who has tried to scale the horn, went on till a ledge of rock ran to nothing. He wrote an account of his adventure, and tore it up ; but he made a lot of photographs in this glen, which remain. From below, the main difficulty seems to be the smoothness of the steep rock on the only practicable side. Where snow cannot rest, the foot of man is apt to slide, as all climbers know.

On the south side of the glen are a set of slaty cliffs, which dip south, away from the horn. These are several thousand feet high, and they are weathered into the most fantastic peaks. One point is called Martin Luther, the row are called Troll Tinderne (witch peaks), and Brude Följe, (the bride's following). The glen is a great fault, with an anteclinal axis, and an upthrow of granite in the crack. But since the world's crust was bent and broken, the glen has been full of ice.

The breadth from cliff to cliff may be about two miles; the space between is filled with a series of flat steps, which are made of sand and boulders. Many of these are of enormous size.

In some places big stones are piled in mounds and ridges, amongst which firs, birches, willow, and alders grow.

The bottom of the rift is filled with stranded ice-chips.

Looking down the valley, the course of the ice is marked so clearly, that it is impossible to misunderstand the record. Where the stream ran against the bank in a bay, the cliffs are deeply scored to a height of about 1000 feet; where the ice turned sharp round the foot of the horn, the marks are fresh. Talus-heaps which have crumbled from weathered peaks above, and a small drain washed through boulder-heaps below, are the marks made by weathering and rivers; and they are insignificant beside these ice-marks, though the Roma is a splendid salmon stream.

The only place in the British Isles which can be likened to Romsdal, is Loch Corrie Uisge in Skye, and it is but a small copy of this wild gorge. From a small lake close to Fokstuen, which is about 3000 feet above the present sea-level, a stream runs to the Glommen, passes Kongs Vinger, and enters the Skagarrak. It is joined by a stream, which starts from a lake near Röraas, and from hills near Röraas water runs to Elfdal, to Hudiksvalla, to Gefle, and to Trollhattan.

From Tann Foss (p. 101) to Elfdal a cross road skirts the western side of the block of high land from which all these great rivers diverge.

Sent April 28/54.
and Returned

In September 1850 the writer drove along this line sketching and scribbling to keep himself company. The country is all of one pattern, the patterns described above (p. 102). The only place in the British Isles that has ever called up a vision of this district is the pass between Lough Conn and Lough Cullen in Ireland.

The people are worth going to see.

"*September* 22*d*, 1850.—Meant to have stopped all day (at Finstuga), but there was nothing to eat but potatoes and cold water, so drove on. My first boy was dressed in full Dahl costume, and was a good-looking good-humoured fellow. Like the rest of his countrymen he sings as he talks, and he is a regular Swedish Scotchman. At the first station all the people were asleep; they yawned fearfully, and had a dram all round before they would move for horses. Dined at Arvet. All the people in full Sunday fig, and splendid fellows they were. There were clean-limbed, well-made men, and pretty women with the true Dahl singing voice, which is music to my ear. They stared at me as if I had been a wild beast. The men wear blue stockings and jackets, with leather breeches and square cut waistcoats. Some had the everlasting leather apron, but some were without it. One pretty little woman had a large leathern knapsack on her back, which, as I supposed, was filled with something to eat. Presently she turned her head and addressed the contents with 'Er du waukin du?'

"Down came the bundle, and out of it came a rosy-cheeked baby with large blue eyes, dressed in full Dahl costume. In all my wanderings I have never seen a more picturesque set of people.

"The Gästgiver was drunk as an owl, so passed myself off as a travelling tailor from Scotland. No one had ever heard of the place, and some one asked if it did not belong to Danemark.

"Drove one stage more to Skattungebyn, because it was 'a poor place in the mountains,' and I guessed that the folk would be worth studying. Made a good hit for once.

"Two carriages now joined me filled with swells who had been to a wedding; and when our cavalcade drove in to the town, the whole parish, in full fig, had gathered to see us. One of the party was the parson of Mora, and they had come to see him.

"It was worth a journey to Sweden only to see that gathering. The old fellows with their clean white breeches and their yellow aprons crowded about us: their long hair and red caps, blue stockings and birch-bark shoes, were perfect: very pretty fair blue-eyed girls and bright-eyed boys, each a picture, climbed up the railings and peered over the heads of the old men; and the landlord, himself a study, trotted about with his merry face, shaking hands with every body in turn, and talking the most incomprehensible of Dahlska. The priest told me that it was very rare for a traveller to come that road at all.

"The swells being gone, I ordered some porridge, and took possession of *the* room, intending to be quiet, but I had reckoned without my host. First one old picture, and then another, walked in, and after saluting me, gravely seated itself; and so they filled the room, to my delight.

"We were soon as thick as thieves, and I had to answer a string of questions.

"Were we Christians in England? Had we schools? Had we Bibles?

"For answer I produced mine, and for many minutes there were loud exclamations of wonder at the beauty of the book, and the unintelligible language. Then we had to read a bit to hear what it was like, and then an old fellow read the same bit in Swedish to compare the two. Next they set to play on a queer square instrument with one string which lay on the table, but as no one was good at it a girl was summoned. She was neat and trim as a Sunday maiden could be, fresh and rosy; her jacket was of sheepskin, beautifully dressed, with fringes of white curly wool round the wrists and skirt; her petticoat was blue, and like a crimped collar; her stockings were red, and her shoes of the true Dahl pattern—the upper leather embroidered, and with a large flap like a Highland brogue; the sole of birch bark, two inches thick, with a small square peg in the middle of the foot instead of a heel. With her psalmodicon on a rough deal table, with a single candle shining on her earnest face, with old long-haired wrinkled faces and twinkling eyes all about her, and a background of brown wood, she looked like a Dutch picture come to life. The lassie had a sweet voice and sang well.

"At last my party broke up, and wishing me a hearty good-night all round, they thanked me for my agreeable company with great politeness, and left me to repose in sheepskin sheets.

"24*th.*—Drove to Garlung and Elfdal, the famous porphyry work. The people at the work have been making a sarcophagus for Karl Johan for six years, and they have a year's work before them. It is a magnificent thing, and gives some idea of Egyptian works. When a plain sarcophagus keeps ten men, with three storeys of machinery, and a big water-wheel, polishing for seven years; an obelisk must have taken a long time to make."

There is no porphyry quarry at this place. The stones are big boulders stranded at the base of the hills at the mouth of a glen, which opens on Seljan lake ; and thence to the sea there is little fall. Sea-shells at Uddevalla are nearly as far above the sea-level as Elfdal, and sea-shells are found seventy miles inland. After fifteen days of coasting round these hills, the impression that the sea had been over the plains of Sweden was confirmed. Looking back from Mora, the rock-groove which runs up to the watershed, near Svaku Fjeld, is seen to be lined with flat-topped terraced slopes; and these are made of sand and boulders, through which some engine has scooped out a way which the river follows.

The old Swedish king's bones now rest in a wandering block, which ice quarried and carried to Elfdal, to be polished by men.

But where is the quarry?

What say the ice-marks? From Oregrund to Upsala, Chambers found ice-marks running N. and S. by compass; that is to say, we found tracks of ice moving down the Baltic coast. Between Upsala and Stockholm the coast-marks run N.N.E., S.S.W.

From Stockholm to Götheborg, the highest level is only 307 feet above the sea, and shells are near the watershed.

At Eknæs striæ point S.W.

All along the road from Götheborg to Frederikstadt striæ point N.E. and S.W.* In short, the striæ for a great distance point from the Baltic basin over Sweden at England.

Working north, Gulbransdal is terraced to a level, which is higher than the col which divides it from Romsdal. Romsdal is terraced also. These strange contour lines may be followed round the coast to Trondhjem, and every fjord has remnants of "parallel roads" and "terraces of erosion," which mark various sea-levels up to the foot of the pass on

* Chambers' *Edinburgh Journal*, vol. xiii., New Series.

the top of which ice-marks at 2000 feet point N.E. and S.W. in lat. 64° ; as they do at the other end of the ridge in lat. 59° in the country near Götheborg.

In low lands, as at the mouth of Sætarsdal (p. 219), clay and boulders are everywhere packed in rock basins, and on hill-sides, in the form of banks, terraces, and wide plains, through which hog-backed rocks rise up all scored and weathered, but ground into shape by some engine.

There are few moraines with conical heaps low down. If a curved rampart crosses a glen at a low level, mounds in it are rounded domes like the forms shown, p. 177, Fig. 33, not sharp cones, whose sides make an angle of 32° with the horizon (p. 181). In the Gulf of Bothnia thousands of dome-shaped heaps of boulders rise in the sea, as circular islands clad with fir-trees. On shore, in the plains of Sweden, similar heaps and long ridges of gravel and stones would be islands and points, if the sea were over the plains of drift in which they stand. At sea and on shore ice-ground rocks peer above water and rise amongst waving corn, with large stones balancing on their backs.

The parallel roads of Glenroy have given occasion to much controversy; the terraces of Scandinavia surround the whole peninsula, and these mark a sea-level high enough to cut South-Western Norway from the main ridge, and to cut the main ridge in two at lat. 64.

All this looks like the packing of ice-chips at the bottom of the sea in which shells lived; and the evidence is confirmed by other testimony. It has been proved experimentally, that the Swedish coast is rising or the sea falling at Löfgrund on the Baltic side.

A rock was marked at the sea-level in 1731, by a Swede named Rudman. In 1834 Lyell found the mark two feet seven inches above water, and made a fresh mark. In 1849, Chambers found Lyell's mark six inches above the water-line.

It seems plain that this district and the last described were, like Greenland, large islands covered with snow and local glacier systems, and that ice-floats moved south-westward, when the sea was at various high levels from 2000 down to 500 feet. On one side of the Atlantic local ice-systems and the sea hide work in progress; on the other the engine has left the work bare.

It has yet to be shewn why climate has thus changed place, and why ice moved from N.E. to S.W. when this land was low. Unless these rock inscriptions can be deciphered, there seems no clue to this mystery; but greater puzzles have been solved.

Taking the Fjærland glacier as a small working sample of a local ice-system easily visited, and easily understood, the larger system from which it falls is comprehensible; and neighbouring systems are found to work on one plan. Starting from marks which are under moving ice, near Bergen, they lead to a large local system in Southern Norway, and to one still larger, which covered the southern half of the peninsula, below lat. 64°, and cumbered the Baltic and the North Sea with floating ice. The very same forces, heat and weight, move these land-ice systems now that they are little; and moved them when they were big. The same forces moved the wax model in the old tea-tray; for these two natural powers seem to obey laws, which make them apply to air, water, and land-ice—to wax, and it may be to all matter.

This heading is wrong
Chapter 19

CHAPTER XX.

DENUDATION 12—FROST-MARKS 10—LAND-ICE 9—NORTHERN SCANDINAVIA 1—OLD LOCAL SYSTEM 4.

The lesson taught by these two blocks of high land in Southern Scandinavia is, that two kinds of ice-marks remain on this part of the northern hemisphere. There are marks of local ice-systems which radiated from the watershed. There are also marks on watersheds and high passes; and on lower lands, at 3000, 2000, and 500 feet, which do not radiate from any watershed, but point N.E. and S.W., or thereby.

Take the northern block of the peninsula, and the same thing appears.

Starting from lat. 64° N., no road crosses the hills, but several passes are used, chiefly in winter. One of these is at Bodö, another at Tromsö, another at Alten. Steamers ply regularly along the western coast from Trondhjem to Hammerfest, and run occasionally to the Waranger Fjord, passing round the North Cape.

On the other side a good road coasts the Gulf of Bothnia as far as Haparanda, and steamers ply thence regularly to Stockholm, crossing to the Russian side occasionally. From the Baltic it is easy to work up to the watershed on any of the large rivers in boats.

The Norwegian coast of this block has been described by many tourists; the glacial phenomena were seen by Forbes.*

* Norway and its Glaciers.

Here are a few first impressions :—

"*8th August* 1849.—The coast during the day not very remarkable ; passed the Vigten islands ; north of these is Lekö, where some Norsk king lies buried with his fleet and crew.

"*9th.*—Scenery improving all day ; passed Torget, an island with a large hole through it near the top ; it is big enough for a ship to sail through, but far above the present water-line. It is said that this cave is strewed with sea sand. Passed Helgeland, and landed a hospitable young Norwegian returning from his travels. Passed the mountains called the Seven Sisters, which were hid in mist.

"Passed the Hestman, a strange island on the Arctic Circle; it has some likeness to a bearded horseman with a long cloak, riding through the sea. The story goes that this was a knight from whom a lady fled ; he shot an arrow after her, which went through Torget and knocked her head off in Lekö. Her remains and the arrow were changed to stone, and are shewn in Lekö.

"The horseman is weathered slate; the horse's ears are points which overhang a cliff; the slope of cloak corresponds to the dip of the beds.

"Onö at sunset was magnificent ; the shape put me in mind of Mont St. Michael in Normandy.

"Got to Bodö in the night. The scenery all day very fine ; lofty peaks rising from the sea, and low islands interspersed landwards, a succession of mountains with patches of snow on their sides, and long fjords running up amongst them.

(Opposite to this place is Quickjok in Sweden.)

"*10th.*—Till two P.M. fishing, shooting, and sketching in Bodö.

"Steamed through a very narrow passage full of eider-ducks close to Skaadstind, and crossed to the Lofotens. The view of the peak behind us at 9.30 was quite magnificent."

This hill has been sketched several times in passing up and down this coast. It is a cliff on the north side, and a very steep slope on the other. At a guess it must be 4000 feet high. The ridge is several miles long, and like a knife-edge. It is a case of upheaval and weathering on a great scale.

"The Lofotens are a succession of needles rising one behind the other. They are like the aiguilles of Mont Blanc, or the Cuchullin Hills in Skye. Here is the best fishing ground in Norway. They fish in open boats all winter, and as it is pitch dark it must be cold dreary work (see Fig. , p.).

"In these islands, lat. 68° to 70°, corn ripens, so the climate is not severe. It is said that seed corn is sent down to Bergen, about lat. 60°.

"11*th.*—Cruising all night amongst the islands, calling at various stations. When we rose we were near the place where we went to bed. Steaming all day amongst islands. Scenery less grand, but still very fine.

"12*th.*—Tromsö. The captain went shooting.

"At this station the steamer stops for a day, so this island has been explored. It is low, and ice-ground. Beds of shells were found at a considerable height above the present sea-level in digging drains. The low grounds are terraces of boulders, and ridges of rock. Visited a Lapp encampment in Tromsödal, and sketched the tribe. In the evening the sound was alive with seath (cole-fish). Numbers of boats were fishing, but they did not understand the white fly, and seemed to catch little.

"13*th.*—Scenery all day very fine. Glaciers on the hills; fine bold peaks, shewing in all directions bare savage mountains, as wild as the High Alps, with the sea at their feet.

Quiranger Fjord, where we dropped the Amptman, was a magnificent piece of wild grandeur.

"14*th.*—Got to Kaa Fjord, and found Robert Chambers. Visited the mines, which are chiefly open galleries cut under the rock. Ice four feet thick made the floor, and men were busy picking it out." (This was the only symptom of cold; the weather was warm as spring in England.)

"After dinner Chambers proposed a walk to measure one of the terraces. We started accordingly, taking a passage to Oskar Næs in a boat which was going to Bosekaap. Some of the boatmen were Quains. I took an oar, and pulled with an old man against a boy, a Norskman, and a Quain; and we soon got into the swing, shouting and trying which side could pull the other round. I had the bow oar, so kept the old boat under control, to the wonderment of the adversaries. At last my ally, the old Quain, smashed his oar, upon which the Norwegians abused him for a Quain and a lubber, and we paddled ashore. These fellows are so like a set of Highland boatmen that it is hard to fancy them anything else. Chambers now began his operations. All this coast is supposed to have risen from the sea at some distant period, and the vestiges of raised beaches are found in all the quiet fjords. These are lofty terraces of detritus lying over rocks polished as if by glaciers. The striæ on these are most beautifully marked. The terraces rise in steps one above the other, and with a very slight slope towards the ocean from the heads of the fjords. Sometimes a long point juts out into the centre of the inlet; sometimes it is a bay that is filled with large heaps of rounded stone. But in almost every case the terrace on one side has a corresponding groove on the other, and when the sun shines brightly they look like works of art.

"My fancy is that they have been the moraines of enormous glaciers, which at some former period filled all the valleys; that these glaciers, after polishing the rocks in their course, have, from some unexplained cause, melted away, leaving enormous heaps of stones, as we see them now in Switzerland and elsewhere. Stones so deposited lie over polishings, and so do the Alten terraces. The next operation is not so easily understood. The points which jut out into Alten Fjord are evidently portions of a much larger mass which filled the whole valley,* and it seems clear that the terraces on their sides must have been sea-beaches at different times. The land, therefore, must have risen; but what can have dug out the portion now filled by the sea? Where it has all gone is to me incomprehensible. I shall wait till I get the paper which Chambers is to write.

"The method of measuring is ingenious enough; a spirit-level with a looking-glass in the middle, and a pair of sights, is all the apparatus. He knows the height from his heel to his eye; stands at high-water, takes some stone or stick above him at the level of his eye, and walks up to it. From this point he starts again, and so on to the top; by multiplying the distance from eye to heel by the number of trials, he gets a pretty correct measure.

"We tried several terraces, and walked back through a scattered wood of Scotch firs growing amongst large loose stones, along the side of the fjord to Kaafjord. It was a pretty walk, and my companion was most agreeable, full of anecdote, chatty, and good-humoured. He had been wandering about for some weeks exploring the fjords, and had met with some queer adventures. Once his telescope, during some complicated land-surveying, lighted upon a reindeer;

* This seems to be an error. A better explanation of the terraces is attempted below.

once he encountered a big buck on a narrow terrace. The deer stopped and stared, the philosopher did the same, and had it in his mind to move his instruments and make room, in case he should get the worst of a fight. But just as he had decided on a move, the deer ran up the hill, made a circuit, and returned to the terrace, his road. One fancy is to play Scotch tunes on a flute to the deer, and the seals, and the Lapps, in the quiet still twilight of a northern night, and dream of the wonder which the melodies rouse. The musician was a good one, and the idea romantic. We returned to tea by daylight, and went to bed by twilight at eleven. The peculiar mild light of these summer nights is delightful. Everything looks so still and quiet, and the outlines of the mountains cut so clear against the warm sky. It is different from anything I ever saw before, and most enjoyable."

In 1851, June 24, a fall near Trondhjem was sketched; on the 26th a careful sketch was made at Alstahong, at the foot of the Seven Sisters. The high tops are weathered; lower hills ice-ground to a great height. On the 25th the "Horseman" was sketched for the second time; on the 27th, Skaadstind; on the 28th, Hindö; on the 29th, Lapps at Tromsö; on the 2d of July, Hammerfest, the most northern town in the world; was visited and sketched.

In August the same coast was seen for the third time.

In 1852, June 8, the same fall on the Nid was drawn again; on the 10th, Torghætten; on the 11th, Skaadstind and Svolvær (p. 137); on the 12th, Tromsö at midnight.

"The sea was calm; the air still and warm; the sky to the south one bright luminous haze of purple and yellow; the hills and snow-wreaths glowed with that strange rosy fire of which Alpine travellers rave when they have once seen the sun rise from some mountain bivouac. The level northern rays

FIG. 00.

threw long blue shadows on the quiet sound, and the sleepy chatter of a stray gull, or the dash of a big fish rolling after a little one, were the only sounds that broke the silence. As the sun sailed along the northern horizon the shadows moved, but the colours remained; sunset glow deepened till it reached its depth; then rosy sunrise gradually faded into the bright light of a summer day. Poets have 'hailed the smiling morn whose rosy fingers ope the gates of day.' Here the gates of day are open for six weeks."

In August the same voyage was made for the fifth time.

"The climate is charming. The air is balmy and the sea land-locked. The life of a Norwegian steamer is the landsman's notion of a sailor's occupation, which according to the old story is to 'sit and let the wind blow you along.' There is no summer mist, or storm, or snow, or ice, on this coast of the Atlantic. It is a warm sunny region with a long summer day of six weeks. Every house has some attempt at gardening. At Tromsö the consul planted some Jerusalem artichokes with other plants in a field, and could not make out what on earth they were when two grew up. Every living-room is a greenhouse. In the windows, geraniums, cacti, myrtles, and suchlike foreigners, bloom and flourish under careful tending. The favourite ornament on tombs are bright flowers.

Nothing can be more different from the common notion of arctic regions. Here is life in Hammerfest, between 70° and 71° N.

"1851, *July 1st.*—Took my sketching materials, and wandered about the hills to the north of the town. Snow lay in patches close to the water's edge, but spring flowers were sprouting in every sheltered nook where they had room to grow. Close to the town is a large bank of stones and gravel some fifty feet high, evidently an old sea-beach. Behind this is a lake from which a small stream flows through an opening in the mound. On this stands a flour-mill, which was grinding as I passed, and in it a salmon-trap is fixed. The town has no road. It stands on a point in an island beside a famous harbour. The roads were full of vessels of many nations, the largest number Russians. These were odd-looking three-masted craft, with high bowsprits and a cross-yard, rigged like old pictures of English men-of-war. The houses are all of wood, as usual, and they are ranged in rows with some likeness to streets. On the gravel bank are lots of turf houses, the dwellings of fisher Lapps. Bearded Russians, Englishmen, Swedes, Germans, Quains, Finns, Lapps, and Portuguese, were lounging about doors, smoking, and chattering all manner of tongues. Boat-loads of dried cod and seath were being tossed into warehouses. They seemed to be as hard as sticks, but every boy had a bit in his pocket, and, as he ran about or played, he crunched off little splinters and sucked them, as an English child might suck toffee. On every available corner hung strings of dried and drying fish, and the bottom of the sea and the beach were chiefly made of back-bones. Sheep, cows, and goats, wandered about under festoons of cod, picking up odd bits, and munching with vast relish. Even on the house-tops goats were perched, browsing on grass which flourishes where barren tiles usually are. Smells were rank and rife. To add to the general odour of dried fish, several establishments were boiling train and cod-liver oil. It is a queer place altogether.

"About bedtime, a couple of Germans came in and insisted on treating me to champagne. A Norsk doctor joined, and we sat up till midnight, and toasted the midnight sun, which was still shining brightly in at the windows at one in the morning, when we went to bed.

"In winter it is another affair. Fuel is scarce and dear; cows are fed on cods' heads and horse-dung; and the island is smothered in snow. But, even in winter, the sea never freezes here."

The corresponding climate on the opposite coast of the Atlantic is more than twenty degrees further south.

That is the present state of the Norwegian coast of Finmark; ice-marks tell of a very different climate which has passed away.

The views held by Chambers before his visit to Alten in 1849 are published.*

In this book the author proves the existence of a series of ancient sea-margins in the British Isles, which maintain their horizontality round the islands, and correspond pretty well to similar terraces in Scandinavia and North America. He argues that they may have resulted from a subsidence of a sea-bottom, and a consequent general sinking of the sea-level everywhere; in short, from a general approach of the water-line towards the earth's centre, by a sinking in of a great part of the ocean.

This is a larger change than the raising up of a portion of the earth's crust in one place, and a corresponding depression elsewhere, without any general change in the earth's diameter which a general sinking of the sea implies.

Views which Chambers held after his visit are also published in a series of entertaining papers.† The notions with which the writer set off from Alten in 1849 are given above (p.). The lesson which he learned then, and the way in which it was learned, may have some interest for those who may not wish to travel so far.

* Chambers *On Ancient Sea-Margins.* Edinburgh, 1848.

† Edinburgh Journal.

Sent   Returned for Press May 4. 64

The country where Russia, Sweden, and Norway join; the tracts about the Tana and Alten; the head waters of the Torneå and Luleå; the mountains of Swedish Lapland, and low lands to the north and north-west of the Gulf of Bothnia, from the North Cape of Norway, nearly to Umeå in Sweden, correspond in latitude to inaccessible ice, which now blocks up the sea-coast of Greenland opposite to Iceland. If ever the sea was up to the base of hills in Scandinavia, there may also have been an ice-block about mountains which correspond to the coast-line near which the block now is.

The writer first acquired the notion of a Baltic current from what he saw in Northern Scandinavia during four long summer holidays spent in wandering amongst the places above named.

In July 1849 he started from Hull for Hamburgh, crossed thence to Copenhagen, via Lubek and Malmö, steamed to Götheborg, drove south to Falkenburgh, and back to Götheborg, whence he steamed to Christiania. Thence he drove up Gulbrandsdal, and over the Dovre Fjeld to Trondhjem, whence he steamed to Alten. On the last day of August two comrades set off to walk over the mountains to Sweden, and the following extracts describe part of the district which corresponds to the great ice-block off Greenland, between Jan Mayen and Iceland.

"*Friday, August* 31*st*, was our last day at Alten. Mrs. M. walked over to see the last of us. I walked over to make my bow to the old Foged, and to get his autograph on my passport; and, by 1.45, we were ready to start. T., with a Norsk doctor, had returned from Hammerfest, and they had gone on to Yoraholm, where we were to meet them, and have a farewell dinner with C., the Foged, and his son.

"Ula, from whom we had hired baggage horses, came

Look back to Trent R. P24b

down with his cart to take the baggage part of the way; and my comrade mounted a horse. I began as I meant to finish —I shouldered my gun, and walked to C.'s quarters in an hour.

"There we had an Alten dinner—mutton and milk, beer, porter, and biscuits. Plates, cups, and knives were scarce, but our pockets and flasks supplied the want; and biscuits made plates, which we, like the pious Æneas, devoured. A glass of unwonted wine made us all as jolly as princes.

"In the meantime our three steeds were getting into harness; and a precious job it seemed to be. My 'solid leather' portmanteau could not be managed at all. They stuck it up on the top of a saddle; they hung it on one side; and when it would ride nowhere, they wanted to cut it in two. I thought of a Spanish mule, which had carried it with three times as much, and the driver perched on the top of the heap, and refused my consent; so it was finally swathed in a quaint pannier of twisted birch roots, and balanced with something which made the horse-load about 150 pounds, and the packing was ended.

"Abraham Mothka, the Lapp guide, took the bridle of one horse; the one-eyed Ula, the best boatman in the river, took another; and we started.

"T. and his lot took boat for Veena. C. ferried us over the Yoraholm river, walked to the Steugles, and fished home; and we set off through the forest.

"We were a curious lot certainly.

"First marched Abraham, a little, wiry, wrinkled, sandy-haired man, with a scrubby beard, dressed in a reindeer cap, turned up with blue. His body was draped in a mangy reindeer pesk; a thing like a shirt, made fast about the waist with a girdle, from which dangled a knife. His legs were clad in a pair of yellow comagas, stuffed with grass ; and on his back he bore about thirty pounds of smoked salmon. The tails of the fish wagged and flapped like a couple of fins, one on each side, as he trudged steadily on, with a short black wooden pipe in his cheek.

"He was the picture of a savage. His father was a Quain and his mother a Lapp ; he gets drunk when he can, and knows the country by day or night, in summer or winter, for hundreds of miles, whether he is drunk or sober. He leant far forward, trod on his heels, and shuffled over the ground at a very deceptive pace.

"Then came a horse with a couple of Quain panniers, swathing a lot of deerskins for beds, a prog basket, a bottle-holder, and my rod, which stuck out over the beast's head like a bowsprit.

"Then came my comrade, T., in a razeed brigand's hat, shading a pair of blacking-brush moustaches and an unshorn chin, his shoulders covered with the tails of an old mackintosh sewn into a cape, and the rest of his rig seedy but civilised.

"Then came a second horse with a light load, intended as a resource in case any one broke down.

"Then came Ula, with one eye out, but the other as sharp as his nose and his temper. His dress was a black leathern cap, with a peak-gray woollen jacket, waistcoat, and loose leggings, over which came a pair of the everlasting long comagas.

"Then came the third horse, and then a traveller in an old kilt jacket, an old pair of rent trousers, a hat stuck round with feathers and flies, and a gun for pot-shooting.

"T.'s dog, Fan, wriggled her stump of a tail, and ran backwards and forwards, stopping every now and then to fight a lemen or smell out a mouse; and there was a procession worthy of the backwoods.

"I soon got tired of the pace, so pushed on, and found my way to Veena, after a four hours' march from Yoraholm. By 10.30 P.M. we were at our old trade, brewing toddy and coffee, boiling salmon and reindeer ham, and putting it out of sight.

"Dinner over, we sallied out of the log-hut to breathe the cool evening air; and I shall never forget the scene.

"Veena is surrounded by a flourishing wood of tall graceful birches, amongst which tower the blackened skeletons of a forest of dead pines. They are blasted, withered, gaunt ruins of trees, drilled by woodpeckers and boring insects, overgrown with moss, half barked, wild, and picturesque at all times; but now at the foot of the wildest of the lot our pet savage Abraham had kindled a fire with the entire root of another fallen pine. The flame, crackling and roaring, crept and climbed from root to root, and flew off with a fountain of sparks into the blue sky; while the fire lit up pines and birches, and even the lofty rocks above them, till they glowed again. In the brightest light of all lay Abo himself, stretched at his ease on a pile of branches, and round him in every possible attitude of lazy rest lay the tired boatmen. Some shaded their brown faces from the glare while they watched Abo's bonfire; others were sound asleep; and one with a pipe in his cheek sat staring fixedly at a salmon which was broiling on a stick for supper. Even old M., though not an admirer of nature, exclaimed, 'How very beautiful!' and we agreed that we wished we had all been born and bred savages.

"This promised well for our expedition, so we returned to our den with light hearts, had a pipe, and at one in the morning rolled ourselves upon the boarded floor, and were soon fast as churches. Walked five hours.

"*September* 1*st.*—I began the morning by slaying a brace of ducks on a pond near the hut. Then came the usual toilet by the river, then breakfast and a pipe, and then, at 9.30, after skaking of hands, we parted from our kind friends and hospitable entertainers. May they be lucky as long as they live, for they are a jolly good-tempered set of hearty Englishmen. I was sorry to part even with the wooden walls of old Veena, and spent some time in touching up my name on the log which bears the signature of so many wandering fishermen.

"The way was a very badly marked path, leading up a glen to the south of Sara Rapids, through woods of birch and pine. The loaded horses went slowly in such ground, so we beat about with the dog for game.

"I heard some reiper* scolding at a weazel which I saw amongst the trees, but nothing else was seen or heard till we cleared the wood. Here we fell in with the winter track. On every side were marks of reindeer travellers. Remnants of polks, bleached deer-horns, the ashes of bivouacs, bones, and scraps of rag fluttering on stumps; but road or path there was none, for their road is the winter's snow, and of that there was not a remnant left.

"By noon we were fairly out of the wood, and then our guides called a halt to let the horses feed, for there is no more grass fit for grazing for many miles.

"We unloaded at the side of a pretty little burn, knocked up a fire with some planks which were bleaching on the hill-side; and whilst the men plucked and roasted the ducks, T. slept, and I sketched, while the mosquitoes dined.

"What a plague these brutes must be in summer. Even now

* *Reiper*, willow grouse. A bird which, in size, shape, voice, and habits, closely resembles the Scotch grouse. In summer the plumage is gray and brown, in winter white. Commonly sold in London.

they were a confirmed nuisance ; and the curious thing is that the higher up and further north you get, the worse they are.

"By three the ducks were eaten, so T. mounted the spare horse, and I trudged on ahead up a long hill till I reached the mist. Then thinking of Clerk's adventure* in this region, I waited for Abo.

"His Norsk is bad, so is mine, so we conversed little ; but I admired the quaint little figure trudging steadily on, without ever seeming to doubt for one instant which way to turn.

"We were now fairly out on the fjeld, and there was not a bush for a land-mark ; the mist was thick as porridge, and the ground seemed to be repeated at every hundred yards.

"There were gray mist, gray moss, gray stones, and gray rocks, all of one pattern, with here and there a bit of soft marsh, covered with dwarf mountain rhododendron, dwarf birch, shrubs, and multiber. Occasionally a golden plover flew screaming into the mist as we approached his domains, and now and then enormous white owls appeared like mountain ghosts, screeched at us, and vanished.

"Lemens were everywhere. They ran round stones as we passed, hardly deigning to hide or enter their holes. Even when they did go to ground, their heads were out again in an instant to stare at us ; and if Fan, or her masters, or even a horse, came too near, the little brutes began to squeak, and dance, and spit, like perfect furies. I am sure I might have killed hundreds, but because the world is wide I left them in peace. Not so their foes the owls ; I tried to bag one, but in vain. Either they were too strong, or the mist deceived me as to distance, or I was too keen and missed them, for I killed none.

* A very long story about a Norwegian who lost his way on this mountain, and was nearly starved.

"Once the mist lifted and showed us a glimpse of the distant country; and a more dreary, desolate, cheerless waste would be hard to find. * There were lakes and stones, rock and deer moss, as far as the eye could reach, without a hill, almost without a marked feature to impress it on the memory; and yet I see it now as I saw it then.—A gray sea of rounded rocks; a flock of wild geese sailing overhead below the mist; and a large white owl, as big as an eagle, perched like a milestone upon a great block in the foreground; horses and men looking damp and shiny, and clouds of smoke rising from hides, jackets, and newly-lit pipes.

"The mist closed in again as thick as ever in a short time. I fired at the owl on the boulder, and he vanished; so we plodded on to Salavuoma.

"Just at dark, about an English mile from our resting-place, we came upon a colony of fjeld rev—mountain foxes. They had drilled a sand-hill as full of holes as a rabbit-warren. Our first notice of their presence was a sharp angry yelp from a little fellow perched as sentinel on the top; he was answered from all sides, and in a moment they had all scampered home and were out of sight. I crept stealthily up to the spot, peered over as quietly as I could, and spied a pair of sharp ears against the sky. The owner was evidently listening, and my gun was up in a moment, but the ears were under ground before I could fire. I could hear the brute yelping and snarling under ground with three or four others. I waited for a long time in hopes that one would venture to peep out, but they continued their subterranean music till I left them in despair. They seemed about the size of small terriers, and looked grey in the dusk.

* It is exactly like the high country near Rejkiavik, except that the stones are volcanic in Iceland.

"We found the human family who are paid for living at Salavuoma, sitting over a fire. They were dressed like Lapps, in deerskin pesks and leggings, with well-stuffed comagas on their feet. Men and women were smoking after their supper ; one jolly fat old woman, with bare legs, rose to welcome us, lighted some slips of birch bark for lack of bedroom candles, and in ten minutes a roaring fire was blazing in the guest-room, while we were busy about coffee and a stew. A large bowl of goat's milk was added, but neither of us could master it, so we brewed some toddy instead, and turned in for the night. Walked ten hours, distance said to be four Norsk miles, twenty-eight English.

"*September 2d.*—Mist thick again. T. very anxious to get on ; so despite of the mist and the day we started. Provender getting low, so we were forced to carry guns. The old woman had some splendid char and trout for her own breakfast, and it seems that they live chiefly on fish and goat's milk. They were dirty, fat, long-haired, lazy, and something worse ; men and women dressed alike, each armed with big toller knife. The house is built of logs, and has a but and a ben. It lies in a sort of scattered wood of scrubby birch, amongst a wilderness of moss, lakes, burns, and multiberry moors. The people are paid by Government to live there, and in winter they have no lack of company, for the road is much travelled, but in summer they rarely see a strange human being.

Started 8.30, riding for the first two hours, Fan fighting lemens and I making observations with my compass, and hoping for a shot at something good to eat.

"The whole country hereabouts is intersected by ridges of water-worn stones running about north and south. On these grow birch trees, and between them the ground is boggy, overgrown with multiberries, swineberries (cranberries), and mountain rhododendron. Wherever the rock shows, it is rounded and worn, and big wandering blocks of gray stone lie scattered in all directions.

"Lakes meet one at every turn, and without Abraham it would be hard to get on. Abo never doubted, but pounded on through bog and mire, and over mountain, in mist and sunshine, without a pause. Now he would point at a large lake and say, 'That is the winter way;' and then he would curse the bogs, and grin, and set off again. He is the queerest mortl I have seen.*

"We lunched in rain on the shore of a lake under an extempore tent made of luggage and plaids, birch trees, and fishing-rods, and then trudged on again to the Mars Elv, which we reached at 5.30. Here the men wanted to halt and camp, but T. insisted on pushing for a hut at Bingasjerre. I was neuter, and at last T. carried his point. We forded the river, and a horse sprained his fetlock so badly that he had to be unloaded. Then the men had to take off their boots, and stuff them with dry grass. So we lost a good hour. In the sand were fresh tracks of two reindeer. Our way now led along the foot of a considerable hill, through a bank of brushwood, in which every tree was a shower-bath. We were drenched like drowned rats in no time. To our left lay an enormous tract of flat moor, almost too soft for a man, and impassable for a horse. Evening mists floated over it like a silver gauze, showing distant hills and lakes to hide them the next moment. It was like the shifting of scenes in a theatre

* "We proceeded over a slightly undulating country, the lower parts being generally more or less swampy and multebær muir, and passed on our route several moraines running north and south. The stones were large, and loosely huddled together, proving almost conclusively, were other proofs wanting, that the whole country over which we were now walking had been at some period buried by glaciers."—*Traveller's Journal*, p. 137.

or dissolving views. It was very beautiful, but looked very unwholesome, and it was not comfortable. We plodded on thus till dark, when we struck off to the left, men growling all the time, and I beginning to wish I had taken part in the debate at the river. Then we got amongst a lot of rocks, which ended in a precipice. Then into a wood of birches growing on the side of a very steep hill, where the poor horses went tumbling about like drunken men. Then we got into a lake, and waded round a big stone. Then we got into a river, which we forded; and finally into a dense thicket of willow, which reached to my nose, and finished the drenching of everything. The thicket passed, the lame horse tumbled back on his haunches into the river, but we pulled him up again, and in ten minutes more reached Bingåsjerve.

"My comrade had all along expected to find a roaring fire and a welcome; but there was no one here, so we marched in and took possession of everything we wanted. First, we made a fire, then a stew, and we rolled ourselves upon the floor at one in the morning.

"I don't know that I was ever much more knocked up, and I was somewhat wroth with my chum for saying that it was all the fault of Abo. I held my tongue till I had smoked a pipe, and then the wrath went off with the smoke, and we slept side by side in peace and harmony. Walked during eleven and a half hours, distance said to be six Norsk miles, about forty-two English. Pace good, hardly four miles all the time, but sometimes fully that."

"Start 8.30 A.M., halt 11 P.M.

"3*d*.—'Chi va piano va sano chi va sano va lontano chi va forte va al a morte,' say the Italians; "More hurry worse speed," say we. One horse was so lame that he could not stir, so we had to stop all day.

"The weather was very fine, and the place pretty. I spent most of the time in vain attempts to catch fish with the fly. The men took a boat and a net in the evening, and rowed out to try their luck.

"It is curious thus to find a house deserted in the midst of a wilderness—doors open, and everything lying about as if the people had gone for a walk. Nets upon poles beside the door, the boat made fast to a stake, deerskins on the bed, some mouldy tea-leaves in a cracked tea-pot; a Finsk Bible on a shelf with a page turned down; in short, the whole tenement as the tenant left it in spring, and as he hopes to find it in autumn. It speaks well for the wandering Lapps, and for the solitude of the place.

"It is strange to find so few wild creatures in such a country. The lakes seem made for wildfowl, and there are hardly any; even the lemens begin to get scarce, and the owls have vanished altogether. Even the fish do not show, and the landscape gives a feeling of the most perfect solitude and repose. Except our party, and the mosquitoes, there was not a living creature seen all day.

"After stewing and devouring our solitary reiper, which I shot yesterday, we lay down early, intending to leave the horse to the wolves, if he did not mend by morning. By daylight our last night's path seems so dangerous, that it is a mercy we did not break our own legs or necks.

"*September 4th*, 1849.—Nearly disabled this morning by a mosquito. The men were up before daylight to drag their net, and came back by four with some sik and röding. The first I had never seen before. He is a very pretty gray fish, something like a herring, with a leather mouth and large scales. He will not take the fly, but the people catch numbers in still nets, and salt them for winter store.

"Off at 6 A.M., and got as far as the river, which we had crossed in the dark when we arrived. Here the baggage had to be sorted, so it was seven before we were fairly under weigh. We now struck upon hard ground, and walked along merrily. The day was splendid, bright, and clear, and every now and then we fell in with coveys of reiper, which helped to keep us moving. The horses kept a straight line, now floundering in a bog, now scrambling up a rock, but without any serious mishap. At one place, indeed, they all three stuck fast, and we had to unload, and carry the traps ourselves for a hundred yards or so. At one we halted, made a famous fire, and a stew of three reiper, which were delicious. At three we started again, and having got the line from Abraham, T. and I with Fan walked on ahead looking for game.

"The country all this time was a succession of low flat ridges, or rather slopes, covered with reindeer moss, with valleys between, in which birches grew. Every here and there came a bog covered with berries; and lakes were in every direction. In the far distance, to the eastward, a few naked hills and some patches of snow were visible. The general character of the landscape was flat and ugly.

"When the cavalry came up T. mounted, and we held on till we came to a splendid view from the top of the highest hill we had come to. Our destination, Kantokeino, was in the distance; at our feet, a green forest of birches; and as far as the eye could reach, northward and eastward, the same rolling sea of gray moss-clad rocks, birches, lakes, bogs, and stones.

"Then came a bad bog, which we got over with difficulty; and then came night. The horses began to flag; their master growled; and then we came to a birch wood and a river.

Kautokeino had been seen, so T. wanted to go on. Ula wanted to stop, so did Abo; it was a fine night, and I had no wish for another scramble in the dark, so I voted, and turned the scale. The place seemed made for a camp, so I declared my intention of stopping there with the horses. T. would go on to the houses with Abo, but Abo was of a different opinion. He explained that the ford was up to his breast, and that he could not swim; and, by the time the river had been examined and the argument finished, we had a fire lighted and a shelter made. It looked snug, so T. joined our party. A deerskin on the ground, a gaff-stick for a ridge-pole, and a plaid, made a tent; a roaring fire and a brew of coffee, and a reiper roasted in his feathers, a jorum of hot punch and a long jaw, kept us well employed till past eleven; and then we drew on our sleeping boots, put on great-coats, crept into our nests, and slept like tops. Once I awoke, being too hot, and found that Abo had piled up a bonfire. He was grinning at me through the smoke. We grinned mutually for some time, then I took an observation of my comrade's long legs, which projected from his shelter in a highly picturesque fashion; and then I rolled over again and slept till seven. I would not give such travelling for the best down bed in Windsor.

"Killed ten reiper, one widgeon, one diver. Walked during thirteen hours—pace good—distance not stated; but not so hard a day as the last.

"*September 5th.*—Up at 7, warm as a pie. Blew up the fire, made coffee and a stew, and were ready for a start at 9.15. Ula was in a bad humour, so I jawed him, and he came round.

"The ford was only up to our knees, but the men were too busy about their own garments to mind the horses, so two of them made up the stream. I caught one, and saved my portmanteau from a ducking; but I could not manage the other. In he went, deeper and deeper, while the men roared and cursed. At last, the packs were fairly in the water and the brute afloat. Then, with a rush and a plunge, he emerged, dripping like a water-horse, and toddled off in search of grass. The rest followed, and the men ran after them, swearing in many languages, while we were left on the river bank. They soon came back, and we proceeded.

"Our way now lay through a wood of well-grown birches growing upon sand-hills. There were paths and tracks, and here and there patches of bare sand, where we could see the tracks of men, and dogs, and cows. Here, too, we found the track of the army of lemens which we had met on the fjeld, They seemed to have marched in a compact body, following the beaten path where there was one, and taking the best road everywhere. Here and there lay the body of a defunct straggler, to prove that the tracks were really what they seemed; but there was not a live lemen to be seen anywhere. What odd little brutes these are! They march as if by agreement from some unknown eastern point, and invade Norway like a swarm of locusts. They swim rivers, climb hills, burrow holes everywhere, and gnaw and nibble everything till they reach the sea. Even then they strike out westward, for the islands get full of them. At last they disappear as mysteriously as they came. No one knows whence they come or where they go; but every two or three years they arrive in shoals as I saw them, and after a time they vanish.

"The first lemen I ever saw was at Bosekaap, in 1849. Late one evening, when night was beginning to show, my host and I were smoking about the doors, while a dog was running about near the house. Suddenly we heard a scrimmage near an outhouse, the barking of the dog, and the sharp angry chattering note of some other creature. My host exclaimed, 'The lemens are come,' ran off to the scene of action, and came back panting with a yellow animal like a marmot, but no bigger than a small rat. From that day whenever we went into the woods we found lemens, and smaller black creatures like short-tailed mice. They swim rivers, and trout eat them, for I have several times cut freshly-swallowed lemens and mice out of trout which took my flies in the Alten.

"In 1851, June 14 and 15, I fell in with the same or another swarm on the flanks and the top of the Fille Fjeld, by the road-side, and on and under snow, above Nystuen, about ten degrees of latitude farther south than Alten. The people were killing them and selling their skins, and the wayside was strewed with carcases slain by dogs and men. A terrier was of our party, and there was a grand hunt (see page 227).

"In September of the same year, a man who sat behind my carriole, near Trondhjem, about four degrees further north, told me that a swarm of lemens had been there. He added that they fell from the clouds, and that he had seen them fall; but on coming to particulars it seemed that after a heavy shower had fallen, he found live lemens in his field. Either one swarm had thus passed southwards along the fjeld and the sea-coast, from Kantokeino to Bergen, from lat. 70° to 60°, between September 1849 and June 1851, or there were many swarms wandering about in the wilds, and descending upon farmers unexpectedly as if they came from the clouds. They had certainly walked from Kantokeino westward to the fjeld and Alten in August and September 1849. In all my Scandinavian wanderings I have never seen another lemen on mountain or plain. (A great deal has been written about these strange little brutes, and their migrations, for which works on natural history may be consulted.)

"In the sand we also found the tracks of foxes and, as we thought, of wolves. A large eagle flapped lazily past us out of shot. We saw some cat-owls like those which we had seen at Alten and on the fjeld. A few curlews, and some ducks and geese on the river, made up our list of live-stock.

"The Alten river which we met here is more a chain of lakes. No stream is apparent, and it is nearly an English mile wide in some places. The banks are sandy, and clothed with birch and the eternal gray moss.

"We reached Kautokeino at 11.30, unloaded on the river bank, and were ferried over in a boat by Rout, the Swedish merchant, who is established here. Kantokeino is a colony of Lapps and Quains, and the village consists of a church and about a hundred detached wooden huts.

"The parson and his flock, except a few old men and children, had migrated for the summer. Some were at the sea-fishing, others on the lakes and the fjeld. Rout had been Clerk's foreman, and had set up for himself here as handlesmand. His house was burned some time ago, but it rose from its ashes fairer than ever, and a very pretty little wife had been brought in to adorn it. She came from Tromsö, and did not seem much to like her banishment. She spoke of her former dwelling and her friends as a London lady might if fate had married her to a wild Highlander, and the contrast between Mrs. Rout and her neighbours was more striking, though she came from an island once supposed to be the limit of the habitable globe, and the head-quarters of northern witchcraft.

"She had a famous dinner preparing for us. T. went up stairs and slept, while I washed my gun and saw to the prog-

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basket. For dinner there were roast wild goose, jam, French beans, and a bottomless meat-pie, wine and liquor; rum and silver spoons and forks to eat with. The lady as usual handed her dishes, and ate as if by sufferance. That Norwegian custom I like the least, but when done by pretty women with grace and good will, it is but a mark of hospitality. Dinner over, we all bowed and said 'Tak for mad.' The host said, 'Thanks for your agreeable company;' and then we put the chairs against the wall, shook hands, and fell to work upon pipes and *palaver*.

"The men were baking for themselves outside; and a lean hungry tribe of dogs were working at my prog-basket. They opened it; stole a goose; upset the pepper; and were deep in a jar of butter, when they were discovered and driven away. Tried to buy a silver brooch, with the old double heart pattern; but the old lady who owned it said it was not hers, and would not part with it.

"In winter, this place is full of people. Many have herds of deer, which scrape their food on the neighbouring hills; others have cows, which are housed all winter, and fed on hay. The place is the resort of merchants who come to the north for skins. These traders make their journeys in polks, drawn by deer; and sleep at stations which are kept up for them. The long night of six months is 'the season' at Kautokeino.

"Another such route from Tromsö to the Gulf is equally frequented by Swedes in winter; and these are the only regular passes between Norway and Sweden, till Trondhjem is reached. Frozen game, butter, eggs, milk, and cheese, are carried from Sweden to Alten. Pesks, 'comagas, and English merchandise; copper kettles, pewter dram-bottles, and crockery, are carried from Alten stores, and distributed amongst the borderers by traders like Rout. In summer it is rare to meet travellers; for the country is hard to pass, and there is nothing to tempt them.

"With many bows to Madame, and thanks to Rout, we paid for what we had bought, crossed the river, and started at 5.15.

(Some years afterwards, the Quains murdered this poor fellow. A quarrel had began about selling brandy, and Mrs. Rout was insulted. The trader was killed in his house, and Magnus Clerk walked over the fjeld and rescued the lady. Some years later, after a long trial, a Quain was condemned, a scaffold was set up at Alten, and the murderer beheaded.)

"The weather, to my eye, looked threatening. I had that feeling which men share with wild animals before a storm. It is a kind of dread, and wish to hurry on to shelter, which I have often felt, and never knew to fail. I can fancy that it is the instinct which urges sea-birds to fly screaming inland, long before a gale begins, turning and twisting as they go. I had the feeling, and it proved a true warning.

"A very handsome old man, with a head like a saint by Spagnoletto, watched our departure. I gave him some skillings, and he prophesied good weather; but that was gratitude.

"We started, and followed a sort of footpath amongst the birches, over a low ridge of hills.

"We went first, looking for game; and having to wait at one place, the cavalry overtook us. Ula informed me that he had lost the brandy-keg. Now, this had been newly filled, and our friends were noted topers; so I suspected roguery. 'You go back and find it,' said I, 'and I will go on with Abo.'

"'But,' said Ula, 'I don't know the way.'

"'Then go to Kautokeino, and get a guide.'

"'But I have no money,' quoth Ula.

"'Then I will lend you some, and take it off your pay.'

"'Will you wait a moment,' said Ula, 'and I will go back? it can't be far;' and so we waited.

"Those who hide can find; and, in a few minutes, Ula came shouting with the keg under his arm. I said nothing; but Ula was sulky as a bear with a sore head for the rest of the day.

"Now came the rain which I had been looking for. It came from the south-west like a second deluge. Hills, trees, and lakes vanished as the storm swept up towards us, and the wind roared and whistled about our ears, while the rushing sound of falling rain came nearer and nearer. It came at last in buckets-full, and we began to talk of returning. Pluck had it at last, so we donned our waterproofs and went on. Abo marched first, leading a horse, then came T. with a branch to drive the steed. Then came the lame one, followed by me. Then came the third horse with our one-eyed attendant, swearing that we would kill his cattle; but no one heeded him, for we knew he would keep up for fear of losing his way. And so we got on, heads down, and stepping out four and a half miles to the hour at least. Fan picked up a wand three feet long, and carried it for more than ten minutes, as if she wanted to help to drive on; and so we carried on till dark, when we got to the Alten again, and forded it, and found the hut in the dark.

"The river bank was clean, but the weather was wild. Mortana was dirty, but dry; so we made the best of it and entered. The master and his wife were in a sort of bed in one corner, and turned out all standing to welcome their guests. The old woman soon after went out, and I found her nest in a hay-shed next morning.

"The man, with his red elf locks, wild and dishevelled, standing out like a glory round his head, sat glaring like a wild beast, with scared sleepy eyes; and from another lair in another corner two half-grown human creatures, boys or girls, stared with equal wonder. From a pile of furs upon the floor peered the heads of two or three sleeping children, and some unseen dogs growled from some dark hiding-place.

"At last the sleepy master rose from his seat on the bed and kicked the dogs into the rain to cool their tempers I own I did not fancy such close quarters.

"There was no help for it, so we hung up our wet garments on the rafters, boiled the kettle, and spread our deerskins upon the clay floor close to the babies. Abo pulled off his wet pesk, and rolled in amongst the two nondescripts. Ula lay down as he was on the bare mud floor. The red-headed master gaped fearfully, and rolled backwards into his den amongst the deerskins. T. doused the glim, and all was silent in the house at Mortana.

Walked during six hours, distance said to be three miles, twenty-two English.

"*September 6th.*—Rose from my lair at six, stepped over Ula, and went out to reconnoitre. It looked bad, so returned to my deerskin. Presently the family began their toilette.

"First the master kicked off the deerskins, and turned his legs out of his box, then he scratched his head and lit a pipe, and scratched again all over and round about, and then the operation was ended, for he rose and went out.

"Then Ula got off the floor and scratched himself, and he was ready.

"Then Abo and his two bed-fellows tumbled out somehow, and yawned, and stretched, and scratched themselves all over; then they slipped their deerskin shirts over their heads, and stuck knives into their girdles, and looked as fresh as if they had washed.

"Then all hands began stuffing comagas with grass, and I thought it time to move. In a few minutes we too had shaken ourselves, and rolled up our beds, and were busy about our breakfast.

"My little neighbour, the child, was now pulled out by an old woman, and the little wretch looked so pretty with its bright eyes and its miniature fur dress, that I gave it a lump of sugar, and sketched it while T. boiled the kettle. At 10.30 it got a little better, so we packed up and set off. This is a regular reindeer station. The red-haired man gets forty dollars, and what travellers choose to give him; he spends the summer in catching sik and char; and for agriculture, he has a field of turnips about six yards square, at the end of his house. He has cows, and is a half-tamed savage, but still wild enough. He speaks Finsk and Lapp. We parted good friends and shook hands affectionately.

"Our way now led us over stony ridges covered with birch, and through hollows in which there were numerous lakes. At one of these our men halted and began grubbing in a heap of turf. I demanded an explanation, and was told that they had bought some sik. Abo, grinning like a baboon, with his mouth and hands full of fish, presently rose out of a cellar made of sticks and bark, covered with sods, in which about thirty small barrels of fish were stowed. Ula was soon as busy as the other; and both pronounced the fish excellent. I tasted, it and thought it abominable, if not disgusting. There was a boat and a pile of nets at the place, and a rude shelter full of fish-bones, and smelling strongly of Lapps or cormorants. About a mile off is another lake where there is another establishment, and where our landlord has twice as many barrels of salt fish.

"Killed three reiper on this march. My comrade was nearly lost at one place. I was ahead looking for game; he was behind, and the men did not remark his absence. At last the horses got bogged, and I turned to help, and found we were a man short. All hands lit pipes and sat down, and then we shouted in chorus. I really began to think our friend was lost in earnest, when Fan came tearing up, full speed. She looked in my face, wriggled her haunches, for she had no tail to wag, and ran off again as fast as she came.

"Presently a distant shout announced the man, who came up rather fagged. He had gone off the track into the brush after a bird, and got fairly bewildered. He was going to try back for the fish-hut, when he found our tracks.

"Far as the eye could reach there was not a distinguishing feature in the landscape. Ridge followed ridge, each a repetition of the last; round boulders, rounded rocks carpeted with gray moss; birch trees, all stunted and twisted by gales and snows, made a labyrinth with endless lakes and green bogs overgrown with berries. A slender track, faintly marked at best, and continually lost, was the only evidence of human habitation in the whole day's journey. The wind was cold, and the rain threatened to return as snow, so my chum might have fared ill if he had not found us.

"Late in the day we came to a long downward slope, from the top of which we could see a long way in every direction. In front, S.E., was a wide plain with curious round hills here and there, marks more distinct than any we have yet seen. The air was clear, and the gray landscape looked pretty in the evening light.

"Then we came to a long stretch of wood, in which was a stone with a mark like a footprint, about which Abo told me a long story in a jargon of Norsk and Lapp. I could not understand him, so I said, Ya, ya; and on we splashed through mire and brushwood to Suajerve.

"The moon had risen before we got in, and a sharp frost had cleared the air. We were glad to get housed. Many reiper were rising about us, but we could not see them.

"At nine we got to our quarters. This place is on a horseshoe lake, famous for fish, and belongs to a rich Finn. He has lots of cows and sheep, and is rather a swell. We walked into his house, as usual, without a word; turned the horses loose to shift for themselves, dragged the luggage under cover, walked up to the fire and lit our pipes.

"We were in a large room in a log-house. In one corner was a weaving-loom and a heap of undressed deerskins. A fireplace of stone, with a kind of extinguisher of masonry for a chimney, was in another angle; and a bench ran all round, which served for table, seat, shelf, and everything. A loose stool or two completed the furniture. On one of these, with the red firelight streaming on his thoughtful face, sat the old man; behind him stood an old crone, with a parchment face, churning; and above their heads, and up the chimney, and on it, hung festoons of half-dried sik, stockings, mittens, comagas, and other damp gear. A door near me led to a dairy and milk-house; and several heaps on the floor proved, by snoring, that they were alive and human. We made ourselves at home in a few minues, selected our own corners on the floor, lit our candles, cooked and supped; and we soon made stepping-stones for dogs which prowled about amongst the sleepers. Abo, Ula, and a fat frowsy girl, kept jawing on for a long time; but I could not understand Finsk, so went to sleep.

" Walking during eight and a half hours; pace less than four miles an hour.

" Killed three reiper. We are beginning to descend from the highest ground, but there has been no marked elevation since we left the valley near Alten.

" *September 7th.*—Awoke very cold at 5; went out and found it snowing and blowing like mad, so turned in again and went to sleep. Turned out again at 8, and watched the family toilette. The master, who was a very good-looking old fellow, emerged from behind the weaving-loom, and proceeded to read a very large Finsk Bible, which lay in a window. The old woman of the churn appeared from a heap of skins in the same quarter. Several men and boys arose yawning from different parts of the floor; and the fat damsel, who had talked so much over night, after rolling and gaping a good deal, got up too, and proceeded to rub her hair back with her hands, and tighten the string of her woollen petticoat. The deerskins were then kicked anyhow under the bench, which disturbed the dogs, who got up and shook themselves; and then we shook ourselves, packed our traps, and all hands made ready for breakfast.

" We had fresh sik, and they were good; our men had the same; and when breakfast was over we offered them a dram, which they refused.

" Meantime the old man had set to reading aloud from the big Bible; and for the first time I heard Finsk well. It was a sonorous, grand language, full of broad vowels and soft consonants, every second word a dactyl. I could almost fancy it ancient Greek, with its diphthongs.

" No one seemed to attend, or to stop from working. The reading over, I sketched Abo, while Ula and the fat damsel began again. I fancied I could gather the drift of this palaver; and I was right. On arriving, I had served out a dram, and in the morning I had offered another; and now it appeared that the household were teetotallers, and grievously shocked. The damsel took up the talking, and told our men their destination, and ours. The old fellow had read us a chapter, and Ula and Abo looked like whipped schoolboys, and our hosts grave and sulky.

"By 11.30 we got under way. The hills behind us were quite white, and snow kept falling in large single feathery flakes; there was about an inch of snow everywhere, and the wind was very cold. I thought our men would have a rough time of it on the way home; but Abo laughed, and swore he would sleep out that night rather than face the inhabitants of Suajerve. He would as soon sleep in a snow-wreath as a down bed, I know, so my pity was wasted.

"The country this day was all sandhills and rocky ridges, with lakes, burns, and gray reindeer moss, as far as the eye could reach northwards and eastwards. There were rounded rocks and great rounded boulders, but we were descending slowly now; and stunted firs showed that we were leaving the fjeld at last. The first got more numerous, and the scattered birches closer together, as we got on; and by 6 we had reached the river Muonio, opposite Karasoando.

"Tall, well-grown, long-haired men, dressed in gray woollen jackets, loose leggings, and comagas, came over and ferried us to Sweden from Russia. Our horses stayed on the bank; our men came with us to interpret and get paid; and so ended our walk.

"We were actually going for 60 hours, and the distance is said to be 28 Norsk, or about 200 English miles. The pace and the time agree tolerably with the calculation.

"The journey may be done by an easier route. Boats can be poled up the Alten to the falls, and dragged for a short distance, then by 'sticking' up past Kautokeino and Mortana, a chain of lakes with a few portages leads all the way to the Muonio river by water."

(A similar route leads up the Tana to a chain of lakes which communicate with the head waters of the Kemi river. It is therefore possible to travel in a boat nearly all the way from the North Sea, and from the Arctic Ocean to the Gulf of Bothnia, by several routes.

In 1851, I conversed with a man who had actually travelled from sea to sea with a boat, which he and his comrades dragged over one low neck of land, about an English mile wide.

All the portages are over low necks of land, which separate adjoining lakes, and there is no high ground all the way.

The winter tracks follow lakes and rivers, for flat ice makes a good road.

There are better summer horse-routes than ours; but there are no houses in that direction, and without a tent it was a risk to take the bare hills so late in the year.)

"The Torneå boats were objects of much curiosity, as we were now to travel in them.

"The bow rises about three feet from the water, and is very sharp; the boat gets rapidly broader and lower, for about five feet, to the place where the first rower sits upon the bottom boards, and works two broad paddles. These work in crutches made of knees, and are fastened with loops of twisted birch root. The boat then tapers rapidly aft, and ends in a sharp stern rising like the bow, but not so much. Close aft sits a second rower, who works another pair of sculls; and right aft, in the very stern, the steersman stands up and works a broad spade-handled paddle in a loop of birch root.

"For working up stream there are light fir-poles which are used by three men, or two, or one; all pushing on one side and keeping stroke.

"The length of a boat may be thirty feet, the greatest width about five, and all of them were furnished with Swedish 'lysters' for spearing salmon, and an iron grate for holding a fire of logs and birch bark over the bow.

"The river was about as broad as the Thames at Richmond, with a good stream of deep clear water, which promised well for rapids on the journey of 300 miles which lay between us and the sea.

"We were now fairly in a country where signs alone were of use, and I do not know that I ever found myself in such a condition, and without an interpreter. Spanish, Portuguese, Italian, and French, are all so like Latin or each other; German, Danish, Norsk, and Swedish, are so like broad Scotch, that from the first, words can be recognised, and the drift of a conversation guessed; but here the only language was Finsk, which bears no likeness to any I had then heard, so we were posed. Many a hearty laugh we had and caused before evening. At last we caught an old woman who, under our inspection, plucked some of our game, and boiled it in a large iron pot half full of new potatoes. About 8 came a man who had been working all day at his farm, and who spoke some Swedish; and through him we got on famously.

"The river banks are low and sandy, covered with stunted forest, except where the land has been cleared for farming. The crops, chiefly barley, were being carried home. The sheaves were hung upon tall racks made of fir-trees, and the ears were turned to the sun.

"The night was frosty and beautifully clear."

(The coast of Greenland, on the opposite shores of the Atlantic, in the same latitude, is still a blank on the latest maps. On the one side are farms ; on the other, mountains of ice. There must be a cause for such a difference.)

"*Saturday, 8th.*—Our intention being to get to Muonioniska, rose early and started at 6. The morning was magnificent, but very cold ; stubble, sand, corn, trees, everything was glittering in the sunshine, as if powdered with diamonds ; and the pools were covered with ice a quarter of an inch thick.

"Our boat was manned by three large sturdy men, dressed in blue woollen, with mittens to keep their fingers warm; and we seated ourselves upon our traps in the middle of the boat, wrapped in plaids and great-coats, with guns ready for pot-shooting.

"We could not talk to our men, so we gave them some baccy and grinned, and talked to each other," (and our subject of conversation was ice and glaciers. I had been striving to persuade my comrade that all the rocks of the country bore marks of ice, and he was sceptical. I was trying to make what I had just seen agree with the appearance of Swiss rocks, and with the work of Swiss glaciers, and I could not. The big glacier tracts of Iceland, of which I then knew nothing, and the local systems of Southern Norway, which I had not then seen, would have helped the argument.)

"The river for some ten miles or so was unchanged. There were low banks, low islands, firs and birches, and here and there a slight stream, unworthy of the name of rapid.

"Our men pulled well and fast, changing now and then, till we reached a station, where we landed. We were to change boat and crew, but knew nothing about our fate for want of a tongue. I had managed to learn to ask for milk, and to count; so we got a drink, paid our men, and at 10.30 started, shouting "Huaste," good-bye. Our new steersman was a very fine man, six feet high at least—a straight-limbed fellow as one could wish to see; he was quiet and grave, and reminded me strongly of an old Scot.

"Half the village—well-dressed comfortable folk—came down to see us go, and shouted 'huaste' in chorus.

"No one had warned us of what we were now coming to. The broad placid stream which we had been following changed all at once, and in a few minutes we were in a Torneå rapid.

"The banks changed their character also, and for some miles there was a constant succession of rocks, and pools, and whirling eddies, that seemed made for fishing.

"Our men seemed to know what they were about so well that there was no reason to fear shipwreck; but to pass some of the places which we now whisked through without good boatmen would be certain destruction.

"Our first leap was down a regular waterfall, about four feet high; and then, shooting down at railway speed—the men pulling like racers—we had to thread our way amongst large stones, breakers, and whirling pools that looked impassable. Our quiet steersman was a study. His face lighted up with the excitement; his eyes glared and sparkled; his long hair floated backward; his mouth opened slightly; and then his lips were compressed, and the teeth set, when he had taken his line and meant to keep it. He plied his paddle with strength and skill, and every attitude showed off his well-knit frame. The others worked hard and silently, watching the steerer's eye, and ready to help him at the slightest sign. It was evidently no child's play, and they were no children. I sketched the steersman in one place, and we agreed that we were safe in his hands; so we smoked our pipes and held our tongues to give the men fair play.

"That rapid alone was worth the journey.

Fig. 00.

"That night we were obliged to stop short of our point, for night fell, and we could not shoot rapids in the dark.

* * * *

"The character of the river-banks to-day was not picturesque. The country was low, and covered with forests of birch and fir, that seemed endless. There were rocks occasionally, and gray moss seemed the covering of the ground. The river-bed between the rapids was generally sandy, with large boulders here and there. In the rapids the ground is a pile of enormous stones all rounded; they are ten or twelve feet in diameter, and at times much more. They are about the size of hayricks and hay-cocks in a hay-field; and they are like those which are scattered about on the fjeld.

"These rise high, or barely reach the surface, betraying their position in the stream by a curl on the water; or they lie out of sight, and barely raise a wave.

"The steersman has to avoid them all, while the boat is kept going hard—all down a rapid stream, so as to keep steerage way.

"I calculated that we had gone about fifty miles in the twelve hours.

"*September 9th.*—Rose at 6, and found a white world; snow a foot deep, and more falling; wind blowing hard, and a very uninviting temperature. * * *

"After breakfast our host smoked his pipe and read his Finsk Bible; and his wife, having put the house in order, and having actually washed the dishes, sat down beside her husband. There was an air of Sunday quiet about them all that put me strongly in mind of the Highlands; and their marked features, brown faces, and bony hands, their coarse woollen garments and long hair, called up visions of covenanters as painters love to depict them.

"At 11 it got finer, so we started, wrapped in all the clothes we could muster.

"It was soon evident why our men would not go on in the dark. Rapids were bad and numerous. The first came at 11.38, and was succeeded by a magnificent pool. The second came at 12, with a still finer pool below it. A third was reached at 12.15, which we got down in ten minutes. I should think it was two English miles long, and it was very dangerous, though not so beautiful as yesterday's rapids. Looking back from below, the river seemed a mass of broken white water amongst a steep pile of rounded stones.

"Then came a long stretch of broad still water, to a place called (I think) Oolicola Muonio; and then we came to Muonioniska itself.

"This town is half in Russia, half in Sweden; contains a church, a merchant's house, and a lot of excellent wooden houses. It is less a town than a cluster of detached farm-houses, each with farm-steading, corn-rack, and offices. The better sort are painted red, the rest are gray from the weathering of the bare wood.

"Here we were hospitably entertained by the merchant's wife, who, amongst her numerous merits, was able to understand my bad Norsk.

"The outer door was open, and no one visible. I walked in, took off my battered hat, and knocked modestly at the first door I could see. A pretty, well-dressed woman, with a child in her arms, came out, and looked for an explanation.

"'Fru Fostrom?' said I, looking insinuating. 'Ya,' said the lady. 'Herr Rout told me to ask if I might sleep a night at your house.' 'Why not?' quoth the lady; and in a very short time we were in a house where we could sleep like princes on down beds instead of the floor.

"Where else but in the north would people stand such proceedings? Two queer-looking, travel-stained, unkempt, unintelligible foreigners ask for lodgings, at the house of the topping lady of the place, and the answer is 'Why not?'

"*September* 10*th*.—Rose early from the first beds we have slept in for ten days; had a famous breakfast; left a lot of flies for Forstrom, and departed.

"Our new crew of three had to break their way through ice, in a creek below the house. They were engaged to take us all the way to Torneå; and one spoke a little English, which was truly English in kind. With them came a hard-featured, sharp-looking fellow, who was to steer us down the famous Aiomboika Foss. He is supposed to be the only man that can do it, and receives a tax of about two shillings English for conducting boats that require his services. It is possible to walk, but we wanted to see the fun. The morning had been very fine, but by 1.30 P.M., when we started, the hills had vanished in mist, and there was a drizzling rain, which promised to get worse, and kept its word. As soon as we were seated the men shoved off, and, after a little splashing in ice, we got to the open river. The new boat was like the last, but rough fir-boards were fastened to the sides to resist the heavy water.

"The famous steersman, looking placid, chewed a quid, and took his place and the paddle, without taking off his mittens. Behind him, peering over his shoulder, was the youngest of our crew. The old bird was teaching the young idea how to shoot the rapids. At first our progress was much the same as before—the men pulled hard, and the boat went fast; our steerer chewed his quid, and guided the boat with the skill of a London cabman in a crowd. I should have thought twice about steering even there, but it was evident that we were only at the beginning. The banks grew wilder, and rocks here and there replaced the rounded boulders which had hitherto been the principal feature of the river-bed. Presently our friend began to roll his eyes, and grip the spade-handle of his steering paddle; and the roar of the water ahead told of something coming.

"I raised my head to look, and was ordered to lie down, and not hide the view; so down I went, but I could still see that we were rushing, end on, at a ridge of black stones that reached half over the river, and that the whole of the stream was dancing and tossing like a mill-race past the end of the bank. There was broken water, like a heavy surf, right up to a steep broken rock on the Swedish side. We seemed to be rushing to certain destruction; but just as we seemed to be rushing into the race, a turn of the wrist cleared the outermost boulder by a few inches, and we shot round a corner into a splendid pool. It was done with the most perfect neatness and composure; but a few inches one way or the other would have given us a hard swim.

"The steerer now seemed to explain to his pupil all about this point, and how to pass it; and then he condescended to take off his mittens.

"The next shoot he had to go further into the stream. We were drenched, the boat was half filled with water, and then, as there was worse to come, we rowed to the Russian bank, and baled and shook our feathers.

"I never have seen such glorious pools for fishing, and I cannot fancy better sport than to hook big fish in such noble water; but if salmon will take here, he who takes them must be provided with good tackle, and know how to use it.*

"We had not much time to look about us. The river had gathered force and speed for the last six miles, and here it made a final leap. The river bed made a bend below us, and the whole body of water dashed with a roar like thunder right against a perpendicular rock, some 20 or 30 feet high. There were bad stones on the shallow side; it seemed quite impracticable. Our pilot only grasped his paddle the tighter, and set his teeth, and off we went. It was grand, but somewhat terrible, to feel the frail boat whirl round as we entered

* Much against my will, I have been driven to believe that Bothnia salmon will not take the fly.

the stream; but it was worse when we got fairly into it, and dashed at the wall of rock. We were covered with spray in an instant. No one spoke, and no one could have heard for the noise. On we rushed over the waves, nearer and nearer, faster and faster towards the bank—the high bow slapping hard into the waves; but skill and coolness were at the helm. An eddy seemed to throw us bodily off from the rock into the tail of the stream, and the steersman knew all about it. The old boat writhed and cracked from stem to stern, and pitched headlong into the waves, till I thought she must part or founder. The man in the bow was nearly upset by a wave, which jumped on his back; and he nearly cut a crab; but the pilot was working his paddle with might and main, and we shot into a great boiling black pool safe, but well ducked. I know nothing grander than such a torrent, unless it be the rolling Atlantic, and nothing gives me such an idea of irresistible force as Atlantic waves after a storm.

"The rest of the rapid was bad enough, but all hands seemed to think it child's play. I would have stared at the notion of shooting down such a place a month ago; now we thought nothing of it.

"We made the last shoot at 2.45. We had made about seven miles in less than an hour, including stoppages to bale.

"I paid the river guardian, shook his hand heartily, and, with a volley of 'huastes,' we parted.

"It was cold, wet, and miserable; but our men pulled well, and we chatted merrily as we glided down a smooth stream. My comrade had shot the rapids of the Nile, and declared that these were as fine, and that the smallness of our boat made them seem much finer. I don't know what I might think of the stream from the shore, but from our boat I thought it magnificent, and I was glad that I had come to see the Torneå, for I thought I had found out new fishing-quarters. (See woodcut, p. .)

"For the rest of this day's journey there was little variety; the river was wide and smooth, the banks low and covered with forest, unless cleared for a farm.

"*September* 11*th*.—The country much the same. At two, the sun being hot and the day fine, we determined to dine on the bank; so, sending a man for some milk and potatoes, we spread a towel on a flat boulder, and fished out all our stores. We had cold boiled dun-diver, barley-cakes, and rum; butter in an old tin pot, pepper, and salt. Potatoes came soon, all hot, and bursting from their jackets, and delicious milk arrived in a great silver goblet. We stared, and fell to discussing the natives. They are dirty, and never seem to go to bed; they have plenty to eat, and seem to be sober and industrious; they have silver spoons and forks, and silver tankards, corn and cattle, and good dwellings; and so we determined to inspect this farm in Russian Lapland—this palace of the silver vase. Having washed our own tin cans and cracked tea-cups, we scaled the river-bank, and walked up to a log-house.

"The farm-yard was full of people. Half-way up the corn-rack were sundry women and girls hanging up sheaves of yellow corn, which a long-haired boy had just brought in from the field on a rough sledge, drawn by a young bull. A woman was standing in a doorway looking on, and two or three men of the very wildest and dirtiest exterior were grouped about smoking.

"One of these might have stood for a portrait of ugliness. He was a smith, short and brawny, with bandy legs half-hid by a leathern apron, and feet that looked enormous in well-stuffed comagas. His arms were bare, and folded on his breast. His head was enormous, his hair a flaming red, eight or nine inches long, and it stood out on end like the sun's rays on a sign-post. His eyes glittered under shaggy red eyebrows, and his grimy unshaven face made him look like a fiend in a pantomime. I made him a bow, and a speech in Norsk; and we were staring at each other, when the boy came breathless from the field exclaiming in Finsk.

"A fine fat reindeer stag came trotting familiarly after him, and the white bull with a sledge-load of barley followed. The natives seemed to be as much astonished as we were. The smith seized the deer by the horn, and felt his ribs as a butcher feels a calf. The deer submitted quietly, but presently he gave a loud sneeze, broke through our circle, and trotted off to rub noses with the bull. All hands now began to chatter at once, hands were laid upon knives, and I rather wished that I had met the deer where I could have had a quiet chance at him myself. But the beast took a new freak, tossed his head, sneezed again, and went off at a long trot round a corner into the forest whence he came. He was the only tame deer I saw in Lapland this time. He was lower than a stag, with sturdy legs, and a long compact body; he was fat as butter, and his horns nearly full grown, with the velvet still on.

"I shall not easily forget that group. The red smith holding the deer's horn and a long knife, the white bull and the yellow corn, some black dogs, a lot of girls with keen eyes glancing down from the rack, and the dark pine forest and blue sky behind.

"We rowed on till night. The river banks the same, low and covered with birch, fir, and gray moss; few pools, and no rapids. At our halting-place we joined the true Torneå, which comes from the west, and is larger than our branch.

"*September* 12*th.*—Cold. Tried hard for a salmon in a magnificent pool. None would come. Stayed all day at a farmhouse, drying clothes and cultivating the natives.

"*September* 14*th.*—Passed a range of rounded hills feathered to the top with fir and birch forest. There were fine pools and some slight rapids here. At twelve we reached Gatilogoski rapid. It is magnificent. The throat of the pool is very rocky, narrow, and deep. I could have thrown a stone over it. In the middle the river gets wider, and the boat shoots into glorious boiling pools, with still casts made for salmon. Near the tail the river divides. The smaller branch takes a leap of ten or twelve feet; the main stream thunders down with a terrific roar, and in the middle rises in waves ten feet high at least. Our boat slipped down near the side, scraping salmon stages from which the Finns spear great numbers of running fish. We got down safe and sound, but well drenched as usual. At 1.50 we landed the pilot of the rapid, and I tried a cast for a salmon, but in vain. From this rapid the river is smooth and broad for a long way.

"*September* 15*th.*—The river is like a great lake three miles wide. At 10.30 we reached Matagoski, the last and largest rapid. The whole river, which had a good stream where three miles wide, pours, with the speed of a mill-race, through a gap in a rock step 300 yards wide. The throat of the pool is like the escape of the Ness from Loch Ness, but everything about it is magnified except the hills. It was frightful to look back at some of the places we passed. The rapid is about five miles long. About as much water as flows past Bonn runs like a mill-race most of the way, amongst boulders of the usual pattern.

"The steersman was very old, and sent us slap over one big stone, but we slid quietly into the river on the other side, and were none the worse. That night we got to Haparanda, close to the Gulf of Bothnia, and found ourselves at the end of a road which leads to Stockholm. The cost of boat and three men for five days, drink-money and all, was sixty-five rix-dollars. How long it took them to get back I know not."

The country, then, from the fjeld to the Gulf, is a series of broad flats and short steep declivities; and these last seem to consist of worn rock and boulders of very large size. By the time Haparanda was reached, I had formed the idea that the Gulf itself was the bed of an old glacier.

"*September* 17*th.*—Bought an old trap like a gig; and, next day, 18th, set off to post to Sundsvall. There is a journal of the whole trip, but the following extracts will suffice:—

"Calix elv. Road good, country flat, birch and pine forests growing in sand, amongst enormous boulders. Here and there are polished surfaces, with striæ marking the course of the glaciers, which did it all."

"20*th.*—Crossed the Luleå."

"21*st.*—First part of the way over a sandy country, strewed with boulders, with a tree here and there. Pass Piteå."

"22*d.*—Start 7.45. Road through pretty forest scenery with hills and lakes, the latter full of ducks; passed a good river. At 10.30 came to Bureå, a pretty little salmon stream. The stone moss all through this country is quite beautiful; one sort especially. It grows in curved wave-like forms, which spread from a centre like waves from a stone thrown into still water. Each circle as it widens is beautifully shaded from white to dark brown. The woods are carpeted with numerous berries—red, black, and blue, strawberry, lingon, blaeberry, and multiberry in the soft ground. The tables of rock are constant, and so are the wandering masses which have been left there by some ancient glacier at a former period of the world.

"The striæ on these tables are strongly marked. Here the direction is S.E. by S., and on consulting the map and comparing my observations all along this journey, I find the striæ nearly parallel to the course of the rivers.

"Halted at Gumboad.

"*Monday*, 24*th*.—Crossed the Umeå.

"*Tuesday*, 25*th*.—Here the striæ are nearly north and south. They do not run parallel to the river, but cross it at an angle of 45°.

"*Friday*, 28*th*.—Arrive at Sundsvall."

This drive was about 320 English miles, the boat trip from Muonioniska was above 200; so this part of the trip cost two men about £9 each for travelling post more than 700 miles, and for living and lodging during 19 days.

At Sundsvall we reached the end of the road, which was taken as the southern boundary of this northern block of the Scandinavian peninsula.

Here we took the steamer for Stockholm. We sailed with a party of students returning to Upsala, and we used to land at night when the steamer stopped, and march arm in arm through the forest, singing choruses, in procession. From Stockholm went to Norköping to visit a friend, crossed Southern Sweden through the Götha Canal, and got back to Götheborg on the 23d of October, having travelled in three months round Scandinavia for the first time.

"On the 26th arrived at Copenhagen, and started for Wismar. Got back to London November 2d, having started July 1st."

FIG. 00. . P. 292

A still reach on the Torneå looking NW
Distant, rounded hills — near, a range
Sept 14 1849. Dinner
Rapid; Foreground
Boulders. Middle distance
ice Plain of drift with reindeer moss berries fir trees and Birches.
and Big boulders. and ice ground rocks are
common on ~~everywhere scattered over~~ the plain;
on the river bank the boulders are
washed out

CHAPTER XX.

DENUDATION 12—FROST-MARKS 10—LAND-ICE 9—NORTHERN SCANDINAVIA 2—OLD LOCAL SYSTEMS 4.

THE tract described in the last chapter teaches that the watershed, about lat. 70° N., from which five great rivers part, is ice-ground and strewed with wandering stones.

These are packed in mounds and long ridges or plains, fill rock basins, and are scattered broadcast over the land, as perched blocks. The cliffs of the Norwegian coast give a section of the rocks, and show that the surface form of the watershed results not from upheaval in the centre, but from some wearing action. The surface generally bears no relation to dip and fracture.

The Alten, Tana, Tyaljok, Kemi, and Torneå, rise close together; a section drawn south from sea to sea would give a low rounded curve ⌒, four degrees of latitude long, and less than 2000 feet high.

This estimate, made from a knowledge of three of the rivers named, is confirmed by Von Buch, who used a barometer, and makes the greatest height about 1500 feet.

According to measurements given in Murray's *Handbook for Northern Europe* (part i., route 34, p. 243, 1848), the altitudes are—Kautokeino, 834 feet; Jedeckejaure, 1378. The watershed (if this be correct) is less than 1400 feet, and further east the isthmus is known to be still lower.

With Swiss glaciers uppermost in the mental picture-gallery, the first impression left was that land-ice had followed the course of the Scandinavian rivers, and that the Gulf of Bothnia was the estuary in which the eastern side of the system combined to form one great land glacier, which filled the Baltic. This theory assumed a state of things which exists nowhere in the world, and it was soon abandoned as untenable.

A very full and very amusing account of the country in summer was published by a French lady,* who accompanied her husband to Spitzbergen with the French scientific exploring expedition. This party took high ground to the right as far as Kautokeino. The fjeld was—

"Semée de pierres, petites polies de forme sphérique," which, as the lady says, "avaient été roulées par les eaux." The high fjeld is "Une plaine pierreuse." "La Laponie n'a que deux aspects; les plaines pierreuses et les plaines boueuses." "Ce pays a du être temoin d'etranges bouleversements de cataclysms violent; car nous rencontrions souvent des monceaux de pierres rondes et blanches comme des œfs monstreux; c'étaient évidement les galets gigantesque de quelque torrent diluvien. Ces pierres avait souvent la circonference d'une roue de voiture; quelle force avait il fallu pour les polir comme des boules de marbre!" (p. 233). This carries the boulders far higher than the watershed of the isthmus.

No one who knows this tract can read the French lady's account of it without admiring the accuracy of her description, and the determination which carried a woman through such a country in such weather.

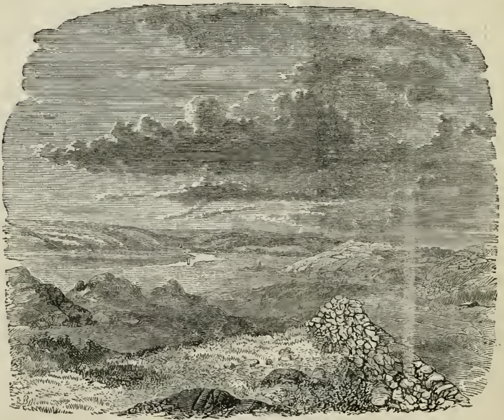
It is plain that ice had something to do with this denudation of rock and deposition of stones upon the watershed of

* *Voyage d'une Femme au Spitzberg*, par Mme. Léonie d'Aunet. Paris, 1854.

Lapland. It remains to be seen whether land or sea ice did most of the work.

At Easter, 1850, walked round the Land's End of England with a knapsack and sketch-book.

In June, set off for the Baltic to try for salmon in the Swedish rivers. Steamed to Christiania, and thence south to Götheborg. *



Striæ.
A rock-groove ⌣ partially filled with a plain of drift, through which the river winds.
Hills ice-ground ⌢ and striated.

Fig. 00. Valley of the Götha, looking about north 15° east. July 14, 1849.

"The entrance is a wild place. There are thousands of rocky islands all alike; and when the shore is reached the hills are of the very same shape as the islands.

"Instead of a blue sea, hollows between the rounded rocky

~~Foot note~~. *. For description of this country see below Chapter.

hills contain flat plains of boulders, clay, and sand, upon which a sea of green corn now waves. Passed through the canal for the second time; sketching.

"Trollhattan is described above (p. 104). It is a large water-slide, and rocks beside it are striated. Large lakes, through which the steamer passes, are full of great stones; some of which are balanced upon the backs of rocks, and rise above water; others are piled in heaps, which form circular islands, long mounds, and long shallow channels, through which the steamer is guided by poles stuck up for beacons.

"The Wenern Lake is the third largest in Europe, and it is not picturesque in any way. But, nevertheless, a number of sketches were made in passing.

"At Söderköping, where the canal gets to the Baltic, is an establishment for the cold-water cure. Near the town is a high rock, overgrown as usual with firs, and carpeted with fine grassy turf. Here, according to the captain, patients are sent to take air-baths in the dress of our first parents. 'The country people at first thought it was the old devil, but now they have got used to it.'"

The glacial period then has passed away from this part of Sweden, but all the rocks seen were of ice-ground forms, and land glaciers will not account for them.

Any good map will show that all the chief rock-basins and rock-grooves in Sweden, between lat. 60° and 56° N.; all the chief lakes, and chains of lakes, and most of the large rivers, and main roads (which are made in hollows), point N.E. and N.N.E., up into the Baltic; and at the isthmus which cuts the Baltic from the polar basin. Nothing here points at the hills.

The shape of the Baltic; its coast-forms—fjords and islands—are copies of the lakes. There are the same rocks, the same circular islands, the same low hills, fading away into a blue sea; in which the same reeds fringe a tideless coast. The map shows the same physical geography. The shapes of Gottland and Oland are like the Wenern and Wettern lakes; the main coast-lines from Stockholm to Carlskrona cut meridians diagonally, as the lakes do. These lines have reference not to the hills, but to the coast (p. 232).

At Stockholm oaks flourish on ice-ground rocks; and porphyry boulders from Elfdal are set up as polished vases in a beautiful park, with gardens and green grass; ice-grooves abound, and do not point at the nearest hills.

The coast up to Umeå is a copy of the coast below Stockholm; it has the same appearance, and the same trend. Many islands in the gulf are piles of boulders, half in half out of water; and all the rocks, without exception, are like low islands on the opposite Norwegian coast, which are all of one pattern ⌒.

From Umeå went some distance up the river to fish. Caught no salmon, but saw plenty caught in traps. Found the same kind of country so far—low rocks covered with pines, long ridges following the coast-line. Where these cross the river there is a fos; generally at the low end of a lake, or of a long reach of still water. The lakes in this tract all point at the hills, but there are few ridges of high land which run parallel to these streams and canals. This part of Sweden is like a vast amphitheatre, with streams pouring down its broad steps. There are two distinct forms of denudation.

A geological map of Europe makes the Scandinavian peninsula consist chiefly of old stratified rocks, gneiss, etc., which dip N. and N.W. under newer beds, which thus form the high grounds. Hills, hollows, and steps, which characterise the Swedish side, coincide generally with the strike.

Two books laid flat on a table may represent a geological series. Their pages coincide while they are flat. If one, with a map of Norway in the middle, is tilted and sloped towards the north-west, the disturbed volume represents an upheaved series and a big fault. In order to get to the map, and express the shape of Sweden, the solid angle of the sloping book must be cut or rasped, or carved away. If this be done, the worn edges of the leaves will coincide with the chief hills and coast-lines, and with the strike. The paper destroyed represents the amount of denudation; and Scandinavian drift, in like manner, represents destruction of rock-beds in Scandinavia, or elsewhere. It is not river-work. If it were, the river-courses would be expressed by filing notches with a triangular file, and the river-banks would everywhere give sections from page 1 to the lowest page, which they do not.

On the 25th of July, crossed the Gulf to Wasa in Finland.

"The country and the people on the Russian side seem to be identical with Sweden and Swedes. Lakes, trees, rocks, and large wandering stones characterise both sides, and the dress and language are the same. Met a girl riding man-fashion upon a bare-backed horse, her hair streaming out behind her from under a black silk handkerchief. Took her for a Tartar or Cossack, for she was riding furiously in a cloud of dust. Shouted at her to stop, but she only grinned, and rode all the faster, trying to look shy as she passed.

"Could not find striæ that indicated the direction in which ice had last moved over these rocks. But the grinding-engine did not seem to have moved from the opposite mountains of Scandinavia. (See woodcut, p. .)

Returned to Umeå, and steamed to Luleå; from which town set off for Jockmok, and Quickjok, and the fjeld, armed with rod, gun, and sketch-book. It was a queer solitary life, but good fun.

"One morning I was roused by many voices, and found a whole bevy of lumberers round my fishing-rod. Some of them I had seen before, and they were now going down the river with a float of tar-barrels, so I saluted them politely, and in five minutes my acquaintance and half a dozen more walked into the room where I had been sleeping on the boards, and began to stare like startled wild beasts. They were soon tamed, and proposed to accompany me to the river to see the rod work. As I caught nothing, said I was going to bathe. My friends said it would be highly diverting to see the gentleman swim. I begged them to retire, and promised to gratify their wish forthwith, and thereupon the whole lot sat down on a log at a little distance, and modestly turned their faces the other way, while I disrobed.

"When ready, I gave a great yell, and took an Eton header off a big stone; kicked up my heels, and swam in every odd way I could think of, till I had enough. When dried and dressed again, the spokesman advanced and made a neat little speech, thanking me for the pleasure I had given them by the performance. Then they took up their gear and departed, and I packed up my goods and jolted off in a cart through a sandy track in the forest.

"Another day, while sitting alone at the door of a sleeping-tent on the beach of a river, a dozen of those fellows—each with a great lever on his shoulder, wild, long-haired, and picturesque, sprang from a boat, marched up, and crowded round me, staring in my face as if I had been a stuffed curiosity set up for their inspection. After chattering and peering about and touching everything, they departed, saying that Englishmen had 'flera saker mitche pengar,' many goods and much cash.

" Another night we camped in an island in the Luleå.

" It was a large heap of rolled stones with fir trees on the top, and a low flat spit of green grassy land, running out on the sheltered side of the mound (down stream). Among the trees was a large ant-hill. The men cut themselves a shelter of pine branches, and lit a fire. I made a bed of pine boughs, and spread a waterproof sheet over some arched wands for a roof. There was no real night, and the air was not cold. My crew had to flit, for they had camped in a highroad which the ants had made, to get at a rotten willow trunk which lay mouldering on the spit of grass land. In the morning there were dozens of them standing on a coat which was left in the path. They were poking about in great wonder and seeming anger, feeling and flourishing their antennæ, and rearing, as if they wanted to find and fight the monster who had blocked up the road to their woodyard. The men had a colony in their clothes when we embarked."

The first portage on this river is at Råbäk.

" Here I found a little, clean, rosy-faced, light-haired Lapp, with an older fellow in leather trousers, who was seated on a keg, amidst ropes and raft gear of sorts. I liked their looks, so opened negotiations as to entering my service. To look dignified, I took my seat on the keg, and they sat cross-legged on the ground in front. They seemed to take time to consider, so I took time, and smoked gravely during pauses. It cost no small effort to keep from laughing; but the upshot was, that Marcus Stenman engaged to follow me anywhere for a rixdollar per day, and the other helped to row as far as he was going for about a penny an English mile."

With a man of all work who spoke Swedish and Lapp, knew the whole river, and had travelled with an English sportsman before, the way was easy.

Above this first portage, the country is characteristic of Sweden.

"The river at first was very broad; the hills highish, rounded, and covered with forest, which sloped evenly down to the river-bank. There the trees sloped over, till many lay flat on the water, dead and dying. Many islands in the river were covered with similar forest. The breadth varied from three English miles, to four hundred yards. Passed lots of boats, and some large rafts of wood and tar-barrels floating down to the sea. The men who managed it had a fire, and some were sleeping about it, while others guided the float." At the portages, the barrels are rolled overland, planks are hauled, and the raft is re-made below each foss.

The Umeå, Luleå, Torneå, and Kemi, and most of the rivers which enter the Gulf in this region, have portages at nearly equal distances from the coast; and the rapids are alike. They are all water-slides, like Trollhattan. At a height which nearly corresponds to the upper water-level of these first falls, the river-banks are often flat-topped terraces of boulders and clay, which, like those at Alten and Mora, rest on ice-ground rocks. On the Umeå river these terraces are conspicuous features in sketches made on the spot, and never retouched. At Bratby, Pengforss, Fellforss, Norreforss, and elsewhere, these terraces of drift are conspicuous; and when the river is left, the top of the terrace becomes a wide forest plain, bounded by low rocky hills.

In like manner, three of these large rivers, and probably many others, have a second water-slide about the same distance above the first; and the falls are about equal, and of one pattern.

The second portage on the Luleå is at Laxholmen, and it is a beautiful place.

"*August 4th*, 1850.—After a swim in the river, returned to the house, and waited till 12 in hopes of breakfast; being very hungry, but too blate to ask my host for food. Lit the pipe of resignation, and sat on the door-step reading and writing; while the master, without his coat, sat on the grass with his wife and children, playing with the little ones. It was more like Italy than Lappland close to the Arctic Circle. Despairing of food, shouldered my sketching gear, and walked to the upper foss.

"The river-bank is a pile of enormous boulders, and the bed of the river seemed to be full of them. They could be seen through the bright clear deep water, and rows of them broke the surface into tiny waves. Where the main stream came down, it thundered and roared; but it was only an exaggeration of a Highland burn tumbling over a gravel-heap. Firs and birches, and a picturesque salmon-trap, made a beautiful picture. While sketching busily, crouched amongst the stones, a couple of fishing hawks came sailing up stream. One of them pounced on a large sik, and flew with it to the shore. On seeing me, he dropped the fish within ten yards; and I took possession of the prize still alive. The mosquitoes were biting like mad all the time. About 7, saw the salmon-traps lifted, and about twenty large fish, from forty to sixteen pounds, taken out. There is a beautiful pool just under the cruive; so I returned home through the forest in great hopes of sport. If I fail again, I shall give up Swedish salmon as incorrigible.

"*5th*.—Raining in the morning; at 8, started; and by 9 had three trout (one, three, four pounds) and a great lot of large greyling. Raised one large fish that might possibly be a salmon. While eating a breakfast, caught and cooked on the spot, the salmon-fishers came and drew their trap. There were twenty enormous clean salmon, some of which had just entered the basket; they were fresh and active, while the others were dead or half drowned by the stream. They must have passed under my fly. It was a day made for fishing; and I am no greenhorn at this work. It seems to be true that Swedish salmon will not rise to the fly; but it is a curious fact in natural history that had to be proved. After breakfast, the sun came out; so put on a cast of small flies, and killed fifty greyling in an hour and a half. My host came down, and I treated him to fresh fish in return for a cold salmon's head, which he gave me for dinner yesterday. Walked down to the island, got a boat, and killed a lot of large greyling; hauled them out two, sometimes three at a time; but no salmon would look at any fly. Walked up to the pool again, and had a pipe and a brew of coffee, and fished my best with salmon-flies made by the best artist in London. Left my rod and went back to sleep at the house, having killed a hundred and eleven greyling and four trout, weighing sixty-five pounds.

"*6th.*—Worked the pools all day with every dodge I knew. Had two rods in a boat; one spinning a small fish while the boat rowed backwards and forwards, dropping slowly down; the other casting. No salmon would take anything, but everything took greyling. They managed to hook themselves on the largest salmon-fly, and even on spinning tackle with a small greyling on it for bait.

"The average daily take of salmon now is about forty fish; and the smallest I have seen was sixteen pounds; many were over forty pounds, bright as silver, and beautiful for shape and colour. They are boiled, packed in kegs, and sent off to the coast."

(This warm sunny spot is a contrast to the coast of Greenland in the same latitude; but the rocks upon which washed boulders are piled beside this river are all ice-ground.)

"Above this foss is a long reach of still water; beyond that a long portage, over which it pleased Marcus that we should walk. From Wuolderim we walked five English miles to Payarim with a couple of porters, one of whom was a very pretty girl. From Payarim, walked eleven miles to Wartsatis. The baggage train on this stage was a white bull led by an old woman in a red cap, green petticoat, and boots, with a load strapped on her shoulders; a boy in leather leggings followed to beat the white bull; and I brought up the rear laughing at their strange figures, winding through the forest, and stumbling over branches and stumps.

In this walk we got pretty high at one place, and found boulders and sand on ice-ground rock, with forest everywhere.

The next stage was Jockmok, a Lapp manse.*

The country is much the same for another day's journey to Randijaur, and there the mountains come in sight at Nyby. "I never saw anything to equal the quantity of mosquitoes that were playing on the water. The sun had set, but the snowy hills showed clear and cloudless against the yellow evening sky, the lake was like glass, and the near forest told dark and clear against the blue distance. A solitary boat was returning from the cow-milking, leaving a yellow wake in the dark shadow under the near hills. Got a drink of milk, and turned

* Of Laplanders and their "*Raindears*," of their magical drums and bags full of demons, of their magical arrows, and other strange matters, a curious account is given in "The History of Lapland, written by John Scheffer, professor of law and rhetoric at Upsal in Sweden, at the Theater in Oxford, MDCLXXIV., and are to be sold by George West and Amos Curtein."

According to this author Jockmok was a holy place in heathen times, and the neighbourhood abounded in places of worship. If so, the present occupants said nothing about this subject.

in to a hay-loft to sleep. It was a little square log-hut, not much bigger than a four-poster. Through the open door I saw my host set off to spear greyling; and presently the birch fire at the bow of his boat glanced red and glowed on the still water, as he glided out into the dark twilight. It was very beautiful.

"13*th.*—Bathed as usual. The water gets colder every day as we get nearer to the hills. My host had a famous fishing in the short arctic night.

"Day piping hot; hills still about sixty miles off, but perfectly clear, and plainly seen."

The form of these mountains contrasts with the low country in the most remarkable manner. They are jagged peaks of the Λ pattern, but all the near hills and hollows are moutonnées ⌒ ⌣.

Quickjok is another priest's house, which was reached on the 14th. It is close to the foot of the high range which makes the back-bone of Scandinavia.

On the other side of the range is Bodö (p. 248), and the hills and islands are alike.

The Luleå river is smaller than the Torneå, but like it the stream spreads out into long wide lakes, and slides down rock-steps. Up to the hill range the country is alike on the Torneå and Luleå, at Umeå, at Sundsvall and Åreskutan, at Elfdal and Upsala, at Stockholm and Götheborg, at Söderköping, Malmö, and Falkenberg.

Sweden is a series of wide drift terraces, almost flat, which rest in hollows in ice-ground rocks. Low hills and ridges rise in the drift as ice-ground rocks rise in the sea off Götheborg.

Up to a certain height the shape of the high hills continues to be rounded; above that level are cliffs and peaks, upon which a few patches of snow survive the summer. The glen, at the mouth of which the manse and church stand, is half filled with a great terraced heap of clay and boulders.

There are no glaciers in the valleys, but there is a large snow-field somewhere, near to which Lapps repair in summer to get quit of flies which torment their deer. Quickjok seems to stand on a moraine, and the plains are marshes.

The highest drift terrace is broad, and runs along the base of steep hills and inland cliffs on the Swedish side; on the Norwegian side the cliffs rise from the sea, and narrow terraces are left in the sheltered corners only. The fjeld-top, at 3000 feet, here as elsewhere, is a rolling plateau strewed with big stones, and covered with a scanty vegetation.

Life at Quickjok close to the Arctic Circle is very like life in the Highlands of Scotland in summer. In winter it is very different, for the cold is severe, and the snow deep; but, like all mountaineers, the natives love their country dearly.

"*Friday*, 24*th*.—No Lapps appeared, so went to the river and bathed, and then went out duck-shooting with the clocker and the parson, and Marcus, in two boats; Gueppe (the dog) following in his own four-oar.

"The whole valley is one maze of narrow canals winding through the forest, with clay banks thickly clad with grass, willow, and birch. At times it was difficult to shove the boat through them. Every here and there these canals open out into shallow lakes, overgrown with long grass; and into these the clocker and I plunged, wading up to our waists, and blazing away at the ducks as they rose. Gueppe, in the meantime, who hunted entirely on his own account, plunged about near us, barking loudly when he could not get near birds which he found. He is a sharp-nosed brute, like a dark brown fox, with a bushy tail curled tightly over his back, and he looks as unlike a water-dog as possible. He swims like a fish all the same. Returned to the manse with twenty-three ducks, of which I killed fifteen, Gueppe three, and the parson and his clerk the rest. Their gun was a marvellous tool. There were teal, widgeon, pintail, and a brown duck which I did not know. There were also a tail and leg which seemed to belong to a widgeon, but Gueppe ate the rest. It was so warm that I left my coat in the boat; the clocker wore neither shoes nor coat, and though wet for many hours, we were quite warm all day. In the evening, while busily drawing with one hand, and rubbing my midge-bitten face with the other, I was startled by the sudden appearance of the Lapp cow-general, with his flock of sheep at his heels. The wretch had tied a handkerchief over his ears to keep off the flies, and with his long mountain-pole on his shoulder, and his strange tattered garments fluttering about his quaint limbs, he looked the savage genius of the place.

"Patches of snow were on the hill-sides, but this is not the popular view of life in Lapland.

"*Saturday, 25th.*—Heavy rain all day. For something to do, sketched the clerk's daughter, who was a very pretty Swedish maiden. In the evening the parson told me his early history. How he lost his father when quite a child, and how his mother, 'like a sea-bird with her young, flitted to the coast to Piteå.' How, when he went to college, he struggled with poverty; and how at last, having vanquished all difficulties, he returned to his native valley a priest. 'And when I saw the hills again that I remembered so well, and the peaks that I had not seen for so many years, I don't know how I felt,' said the worthy man, 'but I began to greet' (grota)."

The natives are a strange race. They were coming down from their summer haunts at this season, and we went

August 1850 Quickjock in Swedish Lappland.

to visit them on the way to a famous fall and iron mountain, which we never reached.

The last discovery, April 1864, which bears on the antiquity of man, proves that tribes, which once lived in caves in Southern France, fed on large reindeer. Their bone implements have been found, and some are in the British Museum. The ashes of their fires remain; the debris of their meals are there—the bones of reindeer, cracked to get at the marrow, sucked, and then thrown to be gnawed by dogs. As these facts bear upon climate, the ways of living Lapps have some geological interest.

According to Whalenberg, a famous Swedish naturalist quoted by Von Buch, the level at which a mean annual temperature of 34° prevails limits the growth of plants fit for reindeer pasture, so that Lapp camps are seldom found above this line. If so, the old temperature in France was not lower than 34° when the old inhabitants ate reindeer venison.

According to the same author, a mean temperature, estimated at $32\frac{2}{3}$°, now prevails at a height of 4100 feet near Quickjok. A little further west, on the Norwegian side, 3100 feet is the level at which only a few spots of rock peer through snow in summer. Two thousand feet higher, at an estimated mean temperature of 30°, a very few lichens grow.*

The low limit of the fjeld Finns is the sea-level, about the North Cape. In Sweden the deer only come down in winter. There is plenty of moss pasture near the sea, but a certain fly drives deer and men to the snow. Further south, wild reindeer keep on the high tops, about Romsdal. Tame deer are kept as far south as Bergen, but they do not flourish in that wet climate, and they are kept on the high fjeld.

* Von Buch's *Travels*, 308.

They never come down to the sea or to rich grass pasture, but seem to prefer cold, and moss which grows in cold regions. If the French deer were of the same nature, their existence proves a cold climate in France.

There were plenty of them, for they were eaten in large numbers. They could not flourish without plenty of moss. Moss does not grow abundantly without cold. The presence of reindeer seems to indicate a mean temperature of 36° instead of 55°—the climate of Jockmok in central France. There must be a reason for a late change in temperature. Whatever the past may have been, this is a sketch from the life, of a tribe of herdsmen whose herds are deer, whose châlets are tents, and whose summer and winter pastures are never far from snow. A similar tribe may have come down from the snows of the Alps and Pyrenees.*

"By the time we got up to the kotas, we had passed through some sharp showers. The Lapps had now arrived, and a tent was pitched beside the conical hut. In the kota I found a dirty old woman and a lot of dirty children sitting round a fire made in the middle of a ring of stones, and looking very picturesque in the half light that streamed down through the chimney. There was a heap of gear and human creatures, iron pots and wooden bowls, dogs and deerskins, piled in admirable confusion; and the mother was engaged in a hunt amongst the tangled locks of the youngest of her brood. Not liking this neighbourhood, went out and made my own shelter, and got on a greatcoat, for it was cold and misty and comfortless after the warm glen. Tried the tent, and found a very fine-looking Lapp woman sitting on a heap of deerskins, serving out coffee and reindeer cream to the clocker

* Reindeers do live without moss in the present climate of London at the Zoological Gardens, but they are prisoners.

with a quaint silver spoon. She had silver bracelets and a couple of silver rings ; and altogether, with her black hair and dark brown eyes glancing in the firelight, she looked eastern and magnificent. Set to work with the paint-box instanter, but she would not sit still for a moment, and it was almost dark. Gave it up, and went out amongst the deer, which had gathered round the camp to be milked. There were about six hundred in the herd, and some old stags were quite magnificent. One had fourteen points on one brow antler, and about forty in all. He looked quite colossal in the evening mist. A small imp of a boy, about three feet high, and a child just able to toddle, were wandering about amongst the deer. The boy was amusing himself by catching the largest stags with a lasso, to pull the loose velvet from their antlers. He never missed his throw, and when he had the noose round the beast's neck, it was grand to see him set his heels on the ground, and haul himself in, hand over hand, till he got the noose round the stag's nose. Then he had him safe and quiet, with the nose and neck tied together, and then they posed for a picture of savage life. The small imp was practising on the calves and hinds, and screaming at them in emulation of the bigger brother. He kept kicking the big stags which lay on the ground with the most perfect familiarity. After I got packed into my nest, the whole herd almost walked over me. I heard their heels clicking beside my head, as they went grunting like a herd of swine. A Lapp followed, shouting a deep guttural Ho! at intervals, and several dogs followed yelping at his heels. It was a queer feeling to lie there on the bare hill-side, and hear the rushing sound of their feet sweep through the low scrubby brush, and gradually fade away as they trotted off to the sound of Ho! Presently came the patter of rain, and the sough of a rushing wind that shook the willow-bushes, and swept moaning over the hill. My low shelter was warm and dry, and I slept soundly.

"27*th.*—Awakened by hearing the Lapps chattering; poked my head out and found everything wrapped in thick mist. Pulled my head in again to brood over my ill luck, and gather courage for a plunge into air. Rolled out at last and scrambled into a kota, where I found Marcus smoking as usual. All the children were scrambling about their mother, who was getting ready for milking the deer. Got some food, packed up, and talked about this unattainable place, Autsik. No one who was at home could find the way in such a mist; so there was nothing for it but to wait for clear weather, or the father of the family, who was away. Watched the day's proceedings till the mist changed into heavy rain; when I pitched my tent again to keep a dry bed. Spent the day in sketching and studying Lapps.

"The rain came through the tent, and in the hut it was impossible even to sit on the ground without bending forward. The children would look over my shoulder, to my terror, so sketching was not easy. There were five dogs, three children, the old woman, Marcus, and myself; and all day long, the handsome lady from next door, and her husband, and a couple of quaint mangy-looking old fellows, kept popping in to see how the stranger got on. The kota itself was a cone of birch sticks and green turf, about seven feet high; and twelve or fourteen in diameter. It was close quarters, but the scene was worth the discomfort. No one seemed to care a rap for rain, or fear colds, more than the deer. Breakfast consisted of milk and cheese and boiled fish; and whenever any dish had been used the old dame carefully wiped it out with her crooked forefinger, and then licked the finger and every attainable place in the dish itself. It was wonderful to see her dexterity, and to hear her talk while she polished the dish. When one of the children spilt some milk on its deerskin dress, it was all gathered and licked up with the same tongue which found time to scold the offender.

"Dinner was reindeer's flesh boiled. The children cracked the bones on the stones after they had polished the outside; and they sucked up the marrow; then the dogs, who had not dared to steal, were called in their turn, and got the scraps. Wooden bowls were set apart for the dogs. There was an extra meal after dinner on the arrival of papa, who came dripping like a river-god, with a supply of bread, butter, and salt fish, stowed in a leathern bag. This was evidently an unusual treat, so it was all consumed. The father was a fine man for a Lapp, forty years old, and five feet high; he had walked fourteen miles in a deluge, but he only wrung his tall conical blue cap to keep the water from trickling down his nose; and then he sat down to watch his children enjoy the feast, while a brother and a young girl, who came with him, joined our circle. We were decidedly too thick, so I went next door. There I found nobody at home but a black dog. Seated myself on a heap of deerskins to have a quiet pipe, and was startled by a loud Lapp exclamation, which came from an old fellow on whom I had sat. Got up laughing, and made Marcus brew coffee for all hands.

"The tent was about as big as the kota, made of striped stuff, so coarse that I could almost see through it, as through a veil.

"It was patched here and there, and smoked brown near the top. It did not touch the ground anywhere, and at the smallest disturbance three dogs plunged out barking. They popped in when the row was over, and curled themselves up amongst the gear. The door was a canvas slip, like a boat's jib, with cross-sticks fastened to it; and it was to windward, so that it could not blow open. No one could come in without stooping, kneeling, and turning sideways, and I constantly stuck fast when I tried. The canvas was stretched by poles, which were joined at the top with considerable skill. This dwelling amounts to a large umbrella, for it gives little shelter from the wind. The life must be healthy; red blood was glowing under the brown skins of old and young, and they were bright-eyed, clear, healthy, flat-nosed, square-headed, black-haired, merry beings. The owners of the tent were married in winter, and had lots of gear, silver ornaments, bone contrivances, one of which was for weaving coloured woollen bands; baskets of ingenious shapes, very well made, of birch and fir roots variously coloured. They all wore long knives, and the newly-married couple smoked and drank coffee at intervals all day.

"Slept in my own tent, nevertheless, and heard the rain pattering close to my nose, while the wind shook the wands till I thought the cover would fly off to Norway.

"*28th.*—Cold, wet, and nasty weather. Found the Lapps getting up, the old woman licking the dishes for breakfast, the father smoking while putting on the shoes of his youngest child. He first spread out a hatful of fine hay made from a particular kind of grass, and then he tossed it on the stones beside the fire till it was perfectly dry. Then the boy was seized by the leg and laid on his back, while foot and hay were crammed and stuffed into a miniature Lapp shoe. It was a work of some difficulty to make all fit nicely, and bind it all neatly round the leg and the leather leggings. They made a good group, the father and son, and a black puppy that would nibble the boy's rosy cheeks as he lay sprawling on the ground.

"After breakfast, gave up my trip to this fall, as the weather seemed fairly broken. Got under weigh at 12 in a fair blink, and walked a little to one side of my train, admiring. There were two Lapps and the man from Niavvi, with my goods on their backs; and a picturesque old volunteer with a birch-bark knapsack strapped on the top of his deer-skin shirt. We soon picked up a boy with a milk-barrel slung on his back, and each of us carried a long pole. We marched single file over the fjeld, plodding through bog and muir till we got to a second camp. Here were two tents and a portable larder pitched under a high rock for shelter, with the first of the birch trees close beside them for fire; a burn brawling past, for water; and distant peeps of forest and lake, low hills and flat plains, peering through the edge of the mist, for a landscape.

"All our party laid down their loads, and one by one they slid into the largest tent. I followed, and sat down, and said, 'Puarist,' and lit my pipe like the rest. There were about a dozen of all ages seated round the fire besides our party. The tent was far larger than those which I had seen. The people were clean and well dressed, and they were enjoying a cup of coffee all round when we came in. The cream was served out with a silver spoon by a young lady, who carefully licked it, and tucked it into a bag which hung round her neck like a necklace. That done, she went on weaving a very pretty basket-work bottle. Another really pretty woman, with large dark eyes, sat in a corner making a garment of some sort, while a miniature Lapp, with its arms round her neck, peeped over her shoulder, and one a size larger stood beside her and stared. There was no time to draw, so took a mental picture, bid them Te-at-ast-ain, and slid out as we came. The whole of the black pack plunged out by their own way, and barked at us. The missus, sliding out after us, went to her travelling store—a bundle of clothes on a triangle of poles—took out some dainty, and gave it to the boy with a kiss. We took the same open order, and marched down hill to the old route.

"These Swedish Lapps are small of stature, very hardy, good sturdy walkers, utterly careless about wind and weather. They are curious, but not so curious as the Swedes. They are not free with their goods; they are not hospitable. No Lapp ever offered me milk or coffee when he helped himself. They gave what I asked for, and I paid; but other hill-folk offer their best to the stranger."

After a pretty long experience of Lapps elsewhere, and after reading the accounts of other travellers, this first impression has been confirmed. No Lapp has ever offered me so much as a scrap of food, or a drop of milk; but every Lapp I know was ready to sell anything, and greedy for silver, which is hoarded and hidden under ground.

"From this place dropped down to Luleå, where the usual life of a hard-drinking northern town seems to go on. Thence steamed to Sundsvall with a strange mixed crew—a Swede, Whalenberg, who had spent seven years in South Africa; a German butterfly-hunter from Berlin, who had been up to Quickjok before me; and many other travellers and travelled men.

"At Sundsvall found a 'Tivoli,' fireworks, and a balloon-ascent; and a young bear chained in a gentleman's yard, making eyes at chickens. Drove up to the fjeld opposite Trondhjem, to the region of bears, elk, Lapps, and snow-drifts; and then south along the hills to Elfdal, through a region of squatters beginning to clear and till the forest. From Elfdal, near which place Lapps and reindeer still roam on the watershed, drove through a flat tilled country with a history, to Upsala, with its university and its tombs of Odin, which are piles of old glacial drift.* They are near the end of a ridge of boulders, of which mention is made by Sir C. Lyell, and in the ridge are sea-shells.

"From Stockholm steamed to Luleå; travelled to Hamburg and to Rendsburg, then the seat of war. Found boulders in flat clay lands but little raised above the sea, men ploughing, and troops hutting themselves for winter."

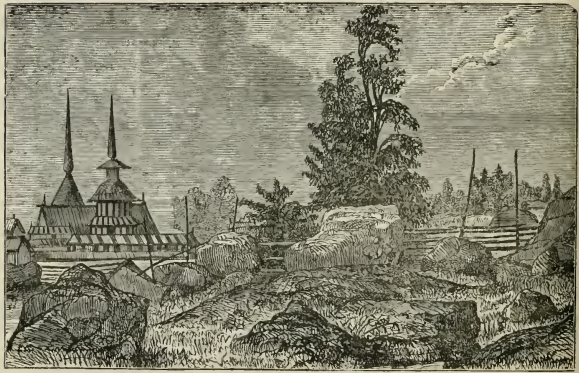
Returned to England *viâ* Hamburg, Dusseldorf, Amsterdam, and Rotterdam, and left glacial mud, which may have come from Switzerland, floating in the Rhine. After thus crossing the trough in which the Baltic lies, at six different points; after travelling round the whole peninsula, and crossing the isthmus; after taking a peep at the Russian side, fishing and copying rock-forms everywhere, a glacial theory had formed insensibly. Either the hills of Sweden had been covered with land glaciers, which made one big glacier in the Baltic; or the hills were so covered, and the sea was up to their bases, and loaded with ice-floats, which moved down the Baltic over Southern Sweden, and into the German Ocean. In any case numerous ice-grooves point across the rivers and along the coast-line, instead of pointing up at the mountains, which they would do if made by glaciers like those in the Alps.

It was plain that the whole peninsula bore marks of glacial denudation and deposition.

If an ice-laden ocean-current made these marks, then still further north, marks of submergence ought to be found upon the isthmus. Good salmon-fishing and a new country were

* The mounds were explored by boring a passage into the centre; and some remains were found which show that they are also monuments of human art.

to be found near the Tana, at a distance from the high grounds; it remained to be seen what manner of country lay next the polar basin.



Boulders and roches moutonnées. Hay-fields and corn-land beside a highroad.

FIG. 49. WASA, IN FINLAND. July 24, 1850.

CHAPTER XXI.

DENUDATION 13—FROST-MARKS 11—LAND-ICE 10—FLOATS—NORTHERN SCANDINAVIA 3.

Sir Charles Lyell says*—"If it be true that delivery be the first, second, and third requisite in a popular orator, it is no less certain that to travel is of first, second, and third importance to those who desire to originate just and comprehensive views concerning the structure of our globe."

But powers of locomotion and comprehension, and human life, are limited quantities. No one man can travel everywhere, and understand everything; and few can travel so much at ease as to have time to observe and note things which come within the range of their limited faculties. For that reason, books of travel are magazines from which those who have travelled the same road may often gather facts to add to their own store.

A naturalist's account of Northern Scandinavia was written by Leopold Von Buch.† He travelled in Scandinavia in 1806, 1807, 1808, and crossed in September 1807 from Alten to Torneå. He walked and boated; his luggage carried overland by reindeer and men. He took the mountain way over Nuppivari to Kautokeino.

According to his measurements, Nuppivari, where the

* Principles of Geology, 1853; ninth edition.

† Travels, etc., translated by John Black, with Notes by Jameson. London, 1813.

French lady found boulders (p.), is 2655 feet above the level of the sea; Kautokeino, on the Alten, 834; the watershed, 1500; Enontekis on the Swedish side, 1069. At the watershed, the nearest lands of equal height now are Spitzbergen to the north, the Ural Mountains to the east, and Greenland to the west.

At the beginning of his work, Von Buch mentions the discovery of sea-plants (*Fucus sacharinus: sostera, etc.*) in peat-mosses, near Berlin, and Drontheim; small boulders of red and gray granite between Hamburg and the Baltic; granite boulders in Denmark; large blocks in Pomerania, Mecklenburg, and the northern parts of the Mark of Brandenburg; and wastes of sand in Mecklenburg. Throughout his work he mentions boulders, and refers to beds of shells on shore, and to a rise of land in Scandinavia generally. Of boulders on the watershed north of the Gulf of Bothnia he says little; but at Palajoensu on the Torneå, at about 1000 feet above the Baltic, he noticed "a large and remarkable block of gray coarse granular zircon syenite with angular cavities, as at Christiania." He adds, "If it has come thus far, the formation cannot be at a great distance. . . . It is singular that it should appear so high and so insulated."

The rock of this country he calls gneiss. At other places lower down and along the Swedish coast he specifies erratic blocks of limestone, clay-slate, etc.; but he always assumed that these belonged to the neighbourhood.

He was surprised to find pleasant autumn weather at Torneå in September, and to learn that firm snow was not expected till the end of October. He fell in with Whalenberg, who, like Linnæus, crossed from Bodö to Quickjok, and had spent the summer in exploring Sulitjelma and the glaciers near it. He had seen Switzerland himself. On the Gulf he heard on all sides of the sinking of the water-level and of means taken to fix the rate at which land is rising.

"Near to Uddevalla a singular skiarry (shorn, cut, reef-like) country again appeared. Rocks intersected in such a way as if large floods had penetrated through them" (p. 407.)

How strange it now seems that a good traveller—a pupil of Werner, an able mineralogist and botanist, and a man of keen observation, should notice and yet overlook so much that seems to hang so well together.

He saw, but does not seem to have noticed, ice-marks which are as fresh as if the glacial period dated from last winter.

A learned traveller,* Dr. Thomas Thomson, says of this district—"The country round Gottenburgh is the most singular that I ever saw. It consists of low precipitous ridges of rocks, running in various directions, and quite naked. The highest which I measured was 310 feet high. These ridges are separated from each other by valleys about a mile wide. The rocks are all gneiss, with large beds of felspar and horn-blende."

The same author describes a terraced mountain which he visited on his way east to Stockholm. The high sea-mark makes another link in the chain of evidence.

A traveller, who takes pains to inform his readers that he was not scientific, published an account of this part of Southern Scandinavia in 1826.†

The country, near Uddevalla, thus appeared to one who was chiefly concerned with men and manners, but who used his pencil also :—

"The scenery exhibited a rugged and gigantic grandeur similar to the tumultuous waves of the mighty deep; as if heaved up into billows by some extraordinary convulsion of

* *Travels in Sweden*, 1812. By Thomas Thomson.

† *Travels*, etc. By William Rae Wilson.

nature. I could almost have imagined that at one time they had been a limpid ocean, and when tossed into the highest fury by tempests had suddenly become solid, and fixed for ever in the wild and, I may say, angry form these now assumed."

These rock-waves are, in fact, deep furrows carved in bedded rocks, gneiss, etc., which dip regularly towards the west and north-west (Von Buch, p. 21). Of boulders on the Swedish side of this tract, Mr. Wilson says—"Much of the soil was rocky, and the huge pieces of stone scattered about as if they had been dropped from the sky, or thrown out of volcanic craters."

Von Buch compares them to fallen towers and lava-streams. Haussman, whom he quotes, says of Smoland—"The blocks lie above one another like rocks; the whole province is covered with them."

"If," says Von Buch, "we succeed in connecting all the facts relating to the spreading of boulder-stones in the north, in the order of cause and effect, light will be thrown on a number of similar phenomena in other parts of the earth, and we shall thus be enabled to ascend to the general causes which concurred in producing all these different phenomena, perhaps at the same period."

This was looking ahead, and pointing out the way.

In a note on Von Buch, Jameson states that he had picked up specimens of zircon syenite in Galloway. This particular rock Von Buch found *in situ* near Christiania, and he had found it as a perched block in Lappmark. Hitherto it has not been found as a fixture in the British Isles. A mere salmon-fisher and pot-hunter, wandering to satisfy a strong tendency to move; who only noticed stones and rock-forms which were picturesque, or too conspicuous to be overlooked; who had no theory to support, and gathered a knowledge of ice-marks as he gathered his food by the way; knew nothing of zircon syenite. But Von Buch, the mineralogist, noticed a boulder of this stone near the watershed of Lapland, raised 1000 feet above the Baltic; and Jameson, the Scotch professor, found another block on the eastern coast of Scotland.

These three points—Lapland, Christiania, and Galloway—are put "en rapport" by these erratics. "How got they there?" No one has yet endeavoured to show that stones float by themselves; it would take a marvellous stream to roll stones from Scandinavia to Scotland; but Scandinavian stones have wandered there, and the source may be in Lapland.*

Scotch erratics were noticed by a French geologist, who travelled to Staffa in 1784.† This writer had a theory, and to it he referred what he saw in Scotland.

At page 107, vol. ii., the author says—"As we drew near Torloisk (in Mull), at the distance of about three miles from the castle, we came to some mountains entirely volcanic, at least 250 toises high. It excited my astonishment as I passed along their summit to observe some large blocks of granite rolled and partly rounded, detached from each other, and resting on volcanic matter, to which however they did not adhere, having been evidently transported hither by the effect of some convulsion."

In striving to account for these foreign stones, the author suggests that volcanoes had ejected the granite from deep-seated quarries; or that the hill-tops were under water, when the granite was rolled by currents to hill-tops in Mull.

* For a description of ice-marks in Scandinavia, see Chambers' *Edin. Journal*, New Series, 1849. Gottenburg is described, No. 307, p. 307; the route to Christiania in No. 308.

† *Travels in England, Scotland, and the Hebrides*, etc. etc. etc. Translated from the French of B. Faujas Saint-Fond, Member of the National Institute, and Professor of Geology in the Museum of Natural History at Paris. London 1799.

But a current strong enough to *roll* zircon syenite from Lapland, or even from Christiania to Galloway, and up hill; and stones strong enough to withstand rolling so far, without being ground to powder; are things foreign to human experience.

Another thought seems to have occurred to the French Vulcanist. At pp. 214, 215, he mentions large blocks and trains of "lava" upon sandstone, near Largo and Kirkcaldy. These he compares to similar trains in Vivarais, one of which is twenty miles long, and four or five miles wide.

But even lava-streams will not explain the transport of the Norwegian rock zircon syenite; and it would take a big volcano to throw stones so far.

The evidence of a geologist, who saw igneous action everywhere, is strong when it bears upon glacial action. The evidence of the school of Werner, who saw aqueous action and deposition from solution in every rock, from granite to obsidian, is equally strong when it supports modern geology, which looks to the present state of things in the world, for an explanation of phenomena on the world's surface.

In short, a modern glacialist may cull facts from naturalists, Neptunists, Vulcanists, and idlers, who recorded what they saw; and thus call up an array of impartial dead witnesses to support his own evidence.

Drawn on by an amusing old book of travels, it is easy to scale mountains, and cross the sea in an arm-chair; to visit the dead, share in their feasts, and watch their ways, with a buried traveller for guide. To an Englishman, the Scotch travels of Saint-Fond, in 1784, offer a series of entertaining sketches of men and rocks, landscapes and figures, dress, houses, and country in the West Highlands, as they appeared to a polished Frenchman, who was full of ready-made theories about manners and customs, as well as rocks. His own portrait, as he draws himself, waiting at Oban for a big boat, to follow his comrades, who had crossed the sound in a little one, and pestered to death by a polite piper, who would play one horrible tune in his honour, every night and all night long, is a gem worthy of a place in any library. The portrait of the smith's house at Dalmally is a likeness of many houses now. The zircon syenite boulder is a link which joins Scotland to Northern Scandinavia. Von Buch and Saint-Fond join the present to the past.

One warm picture of Lapland has been sketched above (chap. xix.) A picture of the same country in a glacial period is given in another old book of travels.*

The author with a large party, two of whom were ladies, travelled first with reindeer, afterwards with horse-sledges, from Bosekop to Torneå. They started on the 6th of December, and took four days to reach Kautokeino; on the 19th they got to Muonioniska, on the 23d to Torneå.

The usual time occupied by merchants at this season is ten days.

The temperature was often 16° below zero. The conspicuous features in the landscapes described and depicted, are snow, ice, mist, storm, and darkness; a few tree-tops, and a very few bare cliffs; an occasional herd of tame deer, and wild Lapps; an occasional story of a bear, or wolf, or fox, or rumours of reiper caught in snares; make up the sum of vegetable and animal life noticed in crossing Finmark. It is a snow world in winter.

The travellers racing with their strange drunken half-

* *A Winter in Lapland and Sweden, with various Observations relative to Finmark and its Inhabitants made during a residence at Hammerfest, near the North Cape*, by Arthur de Capell Brooke. John Murray, 1826.

savage guides; their rolls and tumbles in the snow and other adventures, make the foreground in this white panorama. They were the most conspicuous objects in this snow desert in its annual glacial period, which rises and falls with the rising and sinking of the sun in the sky.

The most northern river, the Alten, was the only unfrozen stream crossed in this journey. As far as Sundsvall, the Gulf and the larger Swedish rivers, mentioned above, (chaps. xviii. and xix.,) were all frozen, so that land and water were used indifferently as roads. An occasional ship or boat, frozen into the white plain, served to remind the Englishman that he was at sea in a sledge. The temperature was often 14° below zero. At Stockholm everything was frozen; at Götheborg, on the 13th of February, the packet was reached by walking over ice, and after sailing and anchoring lower down, they were forced to weigh and put to sea for fear of being beset and frozen in for months.

In May, Von Buch crossed the largest lake in Norway on foot, walking in water a foot deep; he walked on the top of melting ice, followed by a horse and sledge with which he did not quite like to trust the ice. Soon after, at the high watershed of the Dovre, described above (chap. xviii.) he could not see the ground for snow, and his dress was like that of an Esquimaux. June on the Fille Fjeld watershed, 2343 feet high,* is described above.

In spring, when the annual glacial period is passing from Scandinavia, the country is almost impassable everywhere. The ground is frozen above, and wet below; the water-crust is weak and bends, and the traveller and his traps sink into iced mud, or drop through ice into chilled water. Rivers are swollen to floods, rills become rivers, and sweep down stones which no

* According to Von Buch.

summer flood has strength to move. Ice-rafts which formed about stones in autumn, float; they are lifted up, and piled one upon the other, and dashed against rocks and sunken stones, like the logs above described (chap. x.) Stones frozen into a conglomerate of ice and sand float down the rivers to the fjords, on and in ice-rafts; and when the ice melts, these stones sink, and stop. Thus from every watershed, down every glen, stones float, when the thaw begins in Scandinavia, after the annual glacial period of winter in the north.

The weight of the stones, the size of the rafts, the distance to which they float, and the direction which they take, depend upon climate, streams, watersheds, tides, and ocean currents. The quantity of work done depends on the engine, and the amount of power applied. Any English mill-stream will do for illustration. The ice which forms near the bank holds pebbles and sand; and when the thaw comes with a flood, the miniature boulders float a stage down stream, and make their marks.

The Thames makes larger rafts and carries larger stones. In 1864 ice was packed to a thickness of three or four feet, about bridges in London; and it contained things picked up on the shore and dropped on the ice, which floated up and down with the tide on and in small ice-rafts.

The Tana river, which is not so large as the Thames, makes larger floats, because more cold is set to work to build the floats. On the 21st of June 1852, a few blocks of ice, three feet thick, were melting rapidly on a gravel bank at the mouth of the Tana, and they contained sand and small stones. It was stated that large stones were brought down by the river-ice; and that the course of the stream over the delta had been changed in a few years, so as to injure the salmon-fishing by stopping the run of the stream in one direction.

The delta which this river is thus rapidly forming, with the help of ice-floats, is a terrace in the sea. From deep blue water in Tana fjord, a boat suddenly shoots into light-green water, through which, on a calm day, the sandy bottom can be seen clearly. Further on the water shoals suddenly, the sand is like a rampart seven or eight feet high, with three or four feet of water flowing over the flat top, and driving sand over the edge. When the ice-rafts come down, they bring gravel and stones; and these may be seen amongst the sand on these terraced drift-plains, forming under water at the end of a stream which carries ice-floats. Many of the stones in the water are of considerable size, far larger than stones which are found on the most exposed sea-beaches, where the largest Atlantic waves have the longest fetch and greatest power; and yet this Tana fjord is sheltered by high rocky hills.

The carrying-engine is floating ice, and a stronger engine of the same kind would carry larger stones.

The direction of transport is in each case the direction in which water flows. The Glommen flows out of a lake on the Dovre Fjeld, and runs 4575 feet down to the sea, whence a current flows along the coast of Norway towards Hull. Any float would move from the watershed of Norway to Lindes Næs, if not to England, by this route.

The dimensions of the stones moved, depend on the size of the ice-engine. The Glommen is no bigger than a mill-stream where it rises, so it can only carry small stones from the watershed now; it is larger than the Thames, or the Tana lower down, and the climate is cold, so the Glommen has more power when it gets to the sea; but if a few grains of sand from the watershed, or a few pebbles and boulders of larger size picked up lower down, reach the sea-level now; the float melts, and the sea-current alone has no power to carry stones to Hull, without ships or rafts. The movements and dimensions of these engines depend on climate, and if climate is cold, this engine is strong. A stone dropped from Bodals Kaabe falls on a sledge which carries it down to the sea. If the sea were cold enough, the Fjærland glacier would be launched and able to carry its freight in any direction, which the ocean-stream followed, to any spot whose climate was warm enough to sink the ship. If glaciers in Scandinavia were as large as the Unteraar glacier (p. 152), then a stone as big as the largest block on the Swiss glacier might fall from Sneehættan, slide down the Driva groove, and sail off in the Atlantic. The transport of large blocks depends on climate and current. If hills pierce the cold shell, or if it comes down upon the sea, glaciers like those in the Alps may reach the sea and carry blocks. On the watersheds of Norway are blocks, which are not derived from neighbouring peaks, and which no mere water-streams could carry or roll. Sneehattan is mica slate; and stones in old moraines near it are slaty; but the whole of the fjeld near this mountain is strewed with great stones which are not slaty but round, and some at least are granite. No river, even with ice-floats, no glacier were it the largest known, could carry these stones to these spots. But ice-marks seem to prove that ice crossed over the ridge of Scandinavia at various passes. It passed south-westwards over Sweden above Götheborg, near lat. 58°, at a level now 500 feet or more above the sea, where mountain-terraces and beds of sea-shells rest on the polished rocks. It also passed south-westwards over Sweden and Norway about Tann Foss, near lat. 64°, at a height of 2000 feet. It seems to have passed westwards and south-westwards over Finnmark, about Kautekeino, etc., near lat. 70°, at a level of about 1500 or 2000 feet above the present sea. The witnesses who state these facts had no bias. Chambers, who " agreed with Agassiz," says, in 1849 (p. 329), ... " how such a glacial sheet was originated, and how it could move across the whole irregular face of a large country, up hill and down hill, maintaining over wide provinces one direction, I think it would be difficult to explain." The writer of the journal quoted in chap. xix., etc., who walked over Finnmark in 1849, encumbered with a land-ice theory learned in the Alps in 1841, was equally unable to make his ice-theory fit sea-ice marks, which he saw and hopes to see again. It has been shown that the peninsula is rising from the sea; if it were down at the level of high boulders, and the cold shell of climate lowered simultaneously, sea-currents might carry ice-floats of any size in any direction over the fjeld, and the ocean-stream with its ice-floats would account for boulders of the actual size. The marks upon Scandinavia seem to shew, that the glacial period in that country coincided with high sea-marks; and that the cold diminished after the land had risen, or the sea had fallen to a certain level, which is now marked on the hills by terraces and horizontal grooves.

The next step is a further attempt to show what some of these marks are like.

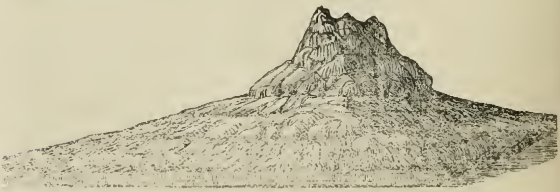


Fig. 50. Plaster of Paris Model. Page 338. Contrived to imitate the formation of terraces of loose materials on a slope, under water, near the surface, while the water-line is gradually sinking.

CHAPTER XXII.

DENUDATION 14—FROST-MARKS 12—LAND-ICE 11—FLOATS 2—TERRACES—NORTHERN SCANDINAVIA 4.

THE first step is to show by some familiar example what a terrace is. When the tide has ebbed so as to leave a sand-bank awash, but surrounded, the low sandy island often wears away between wind and water. Rippling waves dig at the sea-level, a sand-cliff forms and falls, and a talus heap spreads under water beneath it, taking a particular shape. When the tide ebbs lower, the first terrace rises. The top is almost flat, and the side makes an angle with the lower plane, which depends on the material sorted in water, by water.

Where a sea beats upon an island it wears a notch in rock, and makes a rock-cliff, with a stone talus, and a beach, on a terrace of shingle.

In the Isle of Wight, for instance, the sea is cutting a shelf in a hill of chalk, which is about 300 feet high at Freshwater. Below the lighthouse at the Needles, a beach made of rounded blue flint pebbles stands on a floor of chalk; above the shelf is a wall of white chalk with the fractured surface of the cliff fresh; below the shelf is the sea, with a terrace of pebbles, and a talus of fragments, quarried from the cliff. On the rock-shelf is the beach of shingle, and at low tide it is terraced.

The surface of the worn shelf is not like the broken chalk cliff. When closely examined it is found to be smooth and round, and pitted with small dints; and the rolled stones which are packed on the shelf bear similar marks. Wherever there is an exposed rocky coast, similar notches are at the sea-level; and at Scratchels Bay, in the Isle of Wight, the beginning of a sea-cave may be seen also. This sea-mark is like the letter L; a cliff rising above a worn plain, like a wall above a floor.

When the tide ebbs, or when a river shrinks in its bed, the water makes a series of like marks, which may be likened to stairs. These go by the name of storm-beaches on the sea coast; and they have been called raised beaches on a larger scale. They are found in high mountains.

In winter the Oxerá in Iceland is frozen; and in spring when ice breaks up, and snow melts, the stream swells and brings down ice and black sand. It does that which the Arctic Current is doing close at hand. In both cases running water wears rock; partly by rolling and running, partly by carrying floats loaded with heavier solids. When the stream shrinks in its bed, land rises because water falls; but the same action must have gone on if Scandinavia were pushed up in a frozen sea. The little river leaves sloping banks of loose sand, partly rolled, partly ice-borne, partly blown by winds; and these wet sand-banks rest upon the smooth sloping lava surface, which running water, moving sand, and floating ice, have been wearing and smoothing for centuries. In July 1862, in a pool above the fall at Thingvalla, where the water is constantly rippling and flowing one way, a hollow in a sandbank of this description was found to be surrounded by seven regular terraces, with flat tops and sloping sides. They were a few inches high, but perfect models of the Alten "terraces," and Scotch "raised beaches."

The process by which these miniature terraces were formed, illustrates larger formations of the same pattern, and may be imitated in any puddle or mill-stream.

As the water fell, a sloping bank of loose materials deposited under water upon the rock gradually rose to the surface. Waves upon the surface of the pool washed sand from the sloping rock, and left occasional stones like perched blocks; while the top of the sandbank was formed into a plain like the top of a terrace.

As the water fell, the first plain dried, and waves undermined the bank between wind and water, leaving a shelf and a sloping talus, and spreading out a second plain under water. As the river continued to fall, the process was repeated; and an eighth terrace was forming below the seventh, when the pool was visited. Probably the next flood swept the rock bare. In this case the sand was not evenly spread about the rock-pool. The terraces were not remnants of an ancient stratified water formation, the rest of which had been washed away; they were simply marks of a changing water-level, a series of talus-heaps washed off the rock, on which the stream had piled a heap of loose materials when it was higher. Each terrace did not mark a sudden fall of water or rise of land; it was a result produced by a gradual fall of the water-level. A series of larger terraces, raised beaches, and such-like sea-marks on hill-sides, do not prove alternate periods of movement and rest; a series results from the regular fall of every ebb, and from the shrinking of every stream.

In Scandinavia they may have resulted from the movements of water, and of land-ice, and coast-ice which together swept and carried stones to the sea, and shot the rubbish along the coast. Waves alone will not account for the Scandinavian terraces. A new agent comes into play where the sea freezes.

When frozen rivers rise and sink in their beds, or when the sea is frozen is northern firths, ice raised by the flood is lowered by the ebb, and part of it sticks to the shore about high-water mark. The strength of this lever is measured by the strength of the ice; the engine which works it is the tide, and that wheel in the great engine is worked by forces which move worlds. The "ice-foot" does little work in England where ice is thin, sea-ice very rare; but it will serve for illustration, as a plaster model helps to explain the shape of a terrace. In Scandinavia the ice-foot has but little power, but it does some notable work in the Baltic. But if the tale told by other ice-marks be true, then ice in Scandinavia was once a powerful lever, strong enough to lift and lower the stones of which terraces are made.

It is easy to make terraces, and see how the form grows.

Into any deep vessel pour a heap of dry plaster of Paris from a funnel. It will take the form of a cone Λ. Pour water into the vessel till it covers the cone, and the heap will spread at the base. Now run the water off slowly, and keep the surface in motion while the level sinks. The rising mound will be terraced; the plaster island surrounded by contour lines, which are water-marks. When the plaster sets, it is a model of many islands, for example, the Isle of Man, which is surrounded by contour lines of terraces.

The way in which chips are packed in moving water, and forms which beds of silt assume, may be seen upon a larger scale in the lochs of Western Scotland. Whatever power the unfrozen ocean may now have, is there exerted to the fullest extent by the Atlantic; and the sandbanks and boulder heaps which form in and about the sea which divides Scotland from Ireland are of larger proportions.

The materials of which these banks are composed, would make large tracts of sedimentary rock if hardened ; or wide tracts of land, if raised above water. The movements of the strong currents which flow backwards and forwards over these banks are well known, and soundings give the contour of the sea-bottom.

It is impossible to get sections of these submarine beds : the tide ebbs and flows in a rapid stream twenty or thirty miles wide, and forty fathoms deep in the outer channel. But the same tide ebbs and flows in straits and narrow sea lochs, and these minor currents arrange silt in shallow water on the same principle. In calm sunny weather, the whole proceedings may be watched from a boat, for the water is beautifully clear amongst the Scotch islands.

The same tides also ebb and flow, rise and fall, at the end of lochs, and move over beds which are covered and bare at high and low water. This debateable land is accessible ; and sections of the strata are laid bare by rivers, which cut through the sand when the tide ebbs. The strands are much frequented for various purposes, and their nature is familiarly known. In winter, flat punts navigate the rising tide in pursuit of ducks, and in summer to spear flounders. The sands are frequented at low tide for like reasons. Men come to dig for cockles, and lugworms, and sand eels ; and to shoot birds which feed along the ebb. So the changes which take place on the surface, the form of sea-work, the formation of beds of silt beneath the upper surface, and the movements which produce these changes, all come to be known to those who frequent the strand.

In calm weather, the flood-tide rises quietly, because it is working up hill. The water makes little disturbance at the bottom, and moves chiefly at the top. It seems to creep up the wet sloping sand, and even ripple-marks remain uninjured. Shoals of flounders and mullet creep up with the water, shrimps and other creatures caper about as thick as summer flies, gulls are busy, and ducks and geese trumpet and sound their notes of triumph and contentment as they fight and feast, and follow the flood. But when the whole flat is covered, no perceptible change has taken place in the silt bed. It is different when the ebb begins to fall outside. Then a fluid wedge of some square miles of water, from an inch to twelve feet thick or more, begins to slide bodily down the beach, and the whole surface is moved from the high to low water-line. The fish seem to know what is about to take place, and there is a regular stampedo of retreating flounders soon after the ebb begins. Most of them get off safe ; but every tide some lingering glutton who has stayed to gobble up an extra lug-worm is caught, and patters out his life upon dry sand, or is caught and eaten up by some other glutton.

The thin edge of the wedge produces little change, for the shallow water moves quietly.

Deeper water raises the sand into ripple-marks, for the water, as it flows, rises and falls over obstructions, and digs hollows behind ridges, which it makes. So the general surface of a bed of sand where the tide ebbs and flows becomes a ripple-marked sloping plain between high and low water, and the shape of the ripple-mark records the direction of the stream. The plain is strewed with debris of various kinds. There are shells, living and dead ; sea weeds, feathers, dead birds, fish, land plants, drift-wood from the ocean and from the land ; leaves ; black peat dust which settles in the trough of ripple-marks on white sand ; dust and dry sand which the wind blows over the wet sand. There are tracks of all the creatures which move about upon the surface and under it; men, horses, cows, sheep, deer, hares, rabbits, rats, mice, eagles, swans, crows, gulls, waders, linnets, flounders, crabs, shrimps, worms, mollusks. All these, and many more, may be tracked upon a single highland strand amongst the tracks of waves.

But a short distance outside low water-mark, there is always a steep bank over which the retreating water drops the sand which it sweeps from the beach. The water forms a terrace, whose top is the strand, and whose side is a talus of fallen sand dropped under water.

The ebb which flows over this bank falls upon the bottom outside, digs a trench below the rampart, and raises a bank which throws the retreating water upwards, and so causes a peculiar swirl upon the surface. The water so raised, when it falls again, digs another hollow, and raises another heap, and another greasy swirl appears upon the surface to show that the current is rising from the bottom again; and so the zigzag movement between the surface and the bottom, which produced ripple-marks at one depth, produces larger mounds and hollows of the same pattern in deeper water.

The larger, deeper, and swifter currents, which move outside, are marked by large swirls, which prove that water is acting in the same way upon large banks in the main channels through which the tide flows. When a "race" is watched from a hill, or a ship's mast, on a fine day, it is easy thus to trace the outline of banks which lie far below the surface, where cod and turbot delight to dwell, and where herrings become the prey of solan geese. Soundings and fishing-lines test these conclusions.

Mounds which the ebb makes in shallow water become permanent. Sea grass (*sostera*) springs up at the bottom, arrests the moving sand, and impedes the flow of water. Shells burrow about the roots of this green sea-meadow, like snails in a hay-field; mussels weave themselves into a living mat, and hold the mound fast. Then all the endless forms of animal and vegetable life which fill these sea-lochs take their position upon the newly-formed land under the waves; and the bottom of the loch retains its outline till some great storm breaks it up.

But if this sea-bottom now rise, the peculiar form which it has taken will long endure to tell where water ebbed and flowed; it will last till some other mechanical force disturbs this packing of silt upon rock-shelves.

It often happens in these sea-lochs that bits of turf come down with the rivers, and get stranded on the beach. Grasses sometimes take root, and so anchor the turf in the sand. There it remains, a small green island in a barren waste. It is like a sea-plant, or a stone under water in a current laden with silt. It is sometimes covered, sometimes bare, but whether it is under water or air, it is always ready with a net of roots and blades spread out to catch dust or mud, moved by wind or water. The stranded turf gathers and grows larger, and its crop of sea-grass flourishes and spreads, and gathers more sand and mud, till at last a grassy mound is only covered by the highest tides. But each of these disturbs the sand which the growing net is ever ready to catch; so at last the bank becomes a low hummocky plain full of holes, the result of the action of water and the growth of plants—a counterpart of the growth of land which is going on under water in the loch, and in the channel outside. This is "silting up." The writer watched the growth of a bank of this kind for many years, and this was the manner of its growth.

But close to this bank, on dry land, was a terrace of gravel of the pattern of the sand terrace, under water, in the loch; and further inland were other larger terraces of coarser gravel;

all of the same shape and pattern, and all packed upon rock-shelves. These are called raised beaches.

But if the rocky foundation upon which these terraces of shingle all rest were at a level which would account for these sea-forms, then great ridges of bigger stones, and of a different pattern, packed on the hills, would be explained. These last are like boulders which gather on sea-beaches on exposed parts of the coast; and they would again be exposed in their present position if the land were to sink so far as to change low lands into sounds, with beaches of shingle, gravel, and sand.

Scotch estuaries are then filling up by the deposition of silt, and the growth of plants; but the form of the arrangement of similar materials about Scotch lochs seems to place it beyond doubt that land has risen very considerably in Western Scotland. Shells prove the rise. Above the sea-level, at various heights, are beds of sea-shells in sea-sand beneath peat mosses; but beside terraces of gravel, and ridges of boulders, which can hardly be distinguished from those over which the tide now ebbs and flows.

But these Scotch terraces, like the Scandinavian terraces, rest upon ice-ground rocks; and there are great beds of large stones, and single boulders, perched high up in Scotch hills, as in Norway. The terraces were all formed after ice-grooves were made, and the last Scotch glacial period seems to have ended with the rise of land, which lifted the highest terrace out of water.

These are familiar examples of marks which show an existing sea-level :—L shelves cut in rock, and terraces of chips packed under water. The arrangement of old chips in Scotland and Lapland may be compared with this modern sea-work. The ice-lever will be mentioned below.

"In 1851, *June* 17*th*, started for the north; crossed from Hull to Christiania, drove over the Fille Fjeld to Bergen, and steamed to Hammerfest, intending to go to Spitzbergen or to the Tana. At Hammerfest (see p.) found that a yacht party had started for Spitzbergen, and had been driven back by impassable ice and heavy weather; so gave up a scheme for that bout, returned to Alten, and crossed the fjeld to the Tana, to fish for salmon instead of walrus." The following are condensed extracts of a journal which was then kept with tolerable regularity:—

"*July* 7*th*.—At 9 got under weigh from Bosekaap, and overtook the luggage horses at Elvebaken. Our guide, the Lapp Lændsmand of Karasjok, was a very intelligent little fellow, who spoke Norsk well, and who was delighted to teach odd scraps of his own language. We marched ahead, my new comrade following upon his third horse, carrying his gun. I did not carry mine, for I was told to expect a fifty miles' walk, and I was out of condition.

"After passing a couple of small rivers, we mounted about 1500 feet through a picturesque wood, growing amongst large stones and rocks, to the fjeld. At the first patch of snow, the guide, who, like the rest of us, was streaming with perspiration, stooped, made a hole in a snow-wreath with his hand and drank snow-water greedily. Thinking he knew best, followed his example, and felt much better for a delicious drink. Our way now led over the same hill which I had passed in 1849, on a memorable bear expedition.

"It is all ice-ground and strewed with boulders. The direction of movement on this top was from the north-eastward, for the broken side of the rocks was towards us as we walked.

"The views, looking back to the Kaafjord Mountains, were very fine. The wind was cold on the top, and we had a pretty smart shower, followed by a little mist, in the midst of which we took to shooting golden plover. The weather soon cleared, and we got to Rogijauri, a small lake, where we halted for two hours to dine, and let the horses graze upon a patch of grass which flourishes there—distance, twenty-seven miles by guide's reckoning; thirteen by pedometer. Off at 5.40. Heard some reiper calling, and saw a skeleton tent with winter stores, left by the Fjeld Finns. These little wandering mortals are all at the sea-coast, to save their deer from an insect which in summer stings them in the nose. My guide told me that the deer would go of their own accord if they were not taken; and in Sweden I had been told that the deer go to the snow in summer for the same reason. Here, in the latitude of Jan Mayen, there are no snow-tracts in summer.

"Marched on through mist again, taking an occasional shot with H.'s gun at golden plover, reiper, and ducks. H. took a shot at his pointer, who coursed everything that rose; and Chance, howling, vanished in the fog. We never saw him again till we got back to Alten, where we found him in excellent health and spirits. To see his tail go down when he heard his master's voice once more, was a proof that pointers can remember.

"The country here was as dreary as well could be. H. said it was worse than the Arabian deserts. Great piles of washed stone lay in ridges, which stretched for miles. There was hardly reindeer moss on the bare ground—nothing for an animal to graze on; but still, on close inspection, there was a harvest of small mountain flowerets springing up. The snow had just melted, and some patches still remained.

"About 10 the sun broke out for a moment, and showed us some high snow-capped mountains to the left (north).

They peered through the mist, and vanished, and soon after we began to descend into a valley full of dwarf willow. Here was a colony of mountain foxes, but the inhabitants were not to be seen. The grass upon their domicile was like a bit of an English hay-field. The mosquitoes now began to come about us in myriads, and by the time we got to Boiobaske, at 1 in the morning, we were followed by a thick cloud of blood-thirsty living creatures. We pitched our tents beside a little burn, had some tea, and turned in at 2.50.

" Going twelve hours; thirty miles by pedometer; fifty-one by the guide's reckoning.

" Miles in this country are Peneculam (dog's bark), as far as a dog can be heard to bark in still weather.* I am inclined to believe my pedometer, for distance, time, and pace, agree so far.

" *July 8th.*—Got into the burn and lay down in the water, and after this bath felt quite fresh. I had galled my heel yesterday, and was tired when I lay down. Once I awoke, and thought it was raining, but found that the noise was caused by midges rattling against the top of the tent, driven before a slight breeze. The poor brutes of horses were thickly covered as by a gray blanket; I never saw such swarms. Up at 11 A.M., off at 12.40, and walked over the fjeld to a bare place where we called a halt for two hours. Thence on to a rising ground from which there was a grand view, back to the Kaafjord Hills, and over a big lake, Jesjauri, which empties itself into the Tana and the Arctic Ocean. Crossed a few bogs, but small ones.

" At one place, where the ground was paved with a mass of loose boulders, and where I had some difficulty in picking my own steps, the cavalcade looked very picturesque. The little

* Dogs do bark in Lapland for all that has been said on the subject.

guide in his quaint blue frock with the many-coloured facings, his square pillow of a cap, brown leggings and bags of shoes, stood on the top of a large stone, with his long brown hair floating behind him in the breeze ; while he pointed the way with a long birch pole which served him for a walking-stick. The other men were scattered about amongst the stones, hauling at bridles, and talking Quainish to the horses ; and the beasts stepped carefully and slowly from stone to stone like goats ; while H. and I, perched upon a high rock, watched them with astonishment. (These stones were rounded, and most of them of very large size.)

" From this point we crossed the most barren desolate country I ever saw ; but it was flat and firm, and we got on famously. At midnight, we halted in a Scotch mist, and pitched beside a small lake upon a fine smooth turf in a pretty little rocky glen. Made a fire for smoke in the tent-door, and sat watching the men seated round it, while we drank tea and smoked. It was a pretty scene. Twenty-one miles by pedometer ; thirty-five by guide.

" *July 9th.*—Rained heavily. I slept in H.'s tent to let the men get under cover, and all morning the rain kept sprinkling my face through the canvass. Slept soundly nevertheless till noon, when we got up. Because it was still raining, went out to fish in the lake ; killed twenty-four grey-ling about one pound in a very short time ; stewed, boiled, and fried for all hands ; and at 3.40 P.M. packed up, and set off because it got fair. There is no such thing as night here at this season.

" The country to-day very like Sutherland. Conical hills in the distance were glittering in the sunlight which shone upon the hoary shining reindeer moss ; lakes were everywhere, and the near ground was brown moss and peat covered with low willow brush. The shadows of clouds chased each other over this wide landscape; and barren as it was, it looked very pretty and very like a Scotch moor in spring.

"Halt at the first house we have seen. It is a mountain station for winter travelling, kept by an old Fjeld Finn and his wife, who get forty dollars a year and provide travellers with wood, water, and shelter. The old fellow had a brown face wrinkled like scorched parchment, a gray beard half grown, and clothing composed of deerskin, cloth, and sacking made up into the semblance of a pesk. His hair was long, and his head-gear a blue cap trimmed with mangy fur. His wife was nearly as strange as he was, and her head-gear was the Tana cap, which is like the shape of an ancient Greek helmet. A foundation of solid birch-wood is covered with scraps of cloth and ribbon of many colours, carefully arranged, and sewn together as artfully as a Paris bonnet; but the thread is sinew.

"Reached Karasjok summer farm and the Tana at 3 in the morning.

"The country for the last part of the way getting prettier; the wide glens were clothed with high birch brush, occasional firs, mountain ash, and other trees; while the Tana was to be seen winding through this green woodland, backed by the gray fjeld.

There were lots of birds flying about. Whimbrel and plover screamed and whistled at us while we passed, and we killed several. Saw a whimbrel light on a tree, which seemed a circumstance worthy of note. Twenty-one miles by pedometer; twenty-eight by the guide's account."

This fjeld, which is the high ground at the northern extremity of Europe, and cut off from the rest of Scandinavia by the valley of the Alten, is a rolling plateau raised about

2000 feet above the present sea-level. The rock is scantily covered with soil, and in summer it is free of snow, so the form of rocks is clearly seen.

There is a steep side to the westward, and a general slope towards the Tana basin on the east. The steep western side is deeply furrowed by rocky glens, which have the form of glens in which glaciers are found ⌣, and which retain marks of sliding ice (see cut, p.   ).

The high lands are ground also ⌒; and rounded boulders are thickly strewed over the whole country—singly, in ridges, and in closely-packed masses. The whole land bears these sea-marks.

A few isolated hills rise above this upper level, and these are generally conical or rounded Λ ⌒. Steep jagged peaks, cliffs, sharp ridges, and broken rocks are rare, except at the sea, where cliffs are visibly crumbling and falling down.

But if all this tract were now sunk to the level of erratics on watersheds—say 2000 feet only—then the Arctic Ocean would be joined to the Gulf of Bothnia, and Scandinavia would be a long island crossing the Arctic Circle, as ancient geographers supposed.

If in a map of the northern hemisphere the circle 50° N. be likened to the tire of a wheel, with meridians for spokes, and the pole for an axle, then the mountains of Scandinavia cross spoke 20° E. diagonally from N.E. to S.W.

The high coast of Greenland crosses 20° W. in nearly the same direction.

In Eastern Asia similar ranges of high land cross meridians from 180° to 120° E.; and 60° E. nearly coincides with the Ural Mountains, which have a counterpart in the high coast of Western Greenland, about 60° W.

Of all the great mountain-chains in these northern high latitudes, only one trends from N.W. to S.E.; all the rest trend from N.E. to S.W. like spokes set awry.

If Scandinavia were a long island, instead of a peninsula, it would be placed on the world as the opposite coast of Greenland is now placed; and it would be exposed to the same currents if it were similarly placed.

At page 28 is a diagram which shows how winds move over sunken land; it is fair to infer that the sea would move in similar curves if it were deep enough. On the coast of Greenland a cold arctic current now describes a diagonal curve along the Eastern Greenland coast, and there a glacial period now prevails. If the cold water, in flowing S. or S.W. (see p. , Fig. , etc.) split upon the northern end of Scandinavia instead of the northern end of Greenland, there would, as it seems, be an arctic current and a glacial period at 20° E. instead of 20° W.

But if a Baltic arctic current flowed down towards England, the Greenland arctic current is an engine which is sufficient to account for denudation and transport of chips to a vast amount, and it is an existing cause fairly to be admitted into any argument.

In order to prove this Baltic current, the first step is to show that the isthmus at the head of the Gulf was in fact under water during a glacial period, and boulders, perched blocks, osar, kames, and ice-marks, which are not marks of land-ice, seem to prove that this isthmus was under water.

The lowest sea-mark in a rising series must always be the plainest, because it rose last. The highest must be hardest to recognise, because it rose first, and is the most weather-beaten, by causes which operate on shore. So marks of elevation near the shore are the best for illustration.

The elevation of land in Scandinavia has been demonstrated, but only after a controversy which brought out the facts. These are stated with great clearness in the 30th chapter of the 9th edition of Lyell's *Principles of Geology*, and many of them are referred to in *The Antiquity of Man*. The following are places where shells have been found :—

	Feet.
Kured, attached to rock (Lyell) . . .	100
Uddevalla, beds of shells and shells adhering to rock	200
Trollhattan, in digging the canal, about .	200
Northern borders of the *Wenern See*, near Lake Rogvarpen, fifty miles from the sea . .	200
Southern shores of the *Malar*, seventy miles from the sea	?
Södertelje	100
Stockholm	?
Upsala	100
Gefle	?
Sarpsborg, twenty miles inland . . .	450
Christiania, adhering to rock . . .	186
Drontheim, and its neighbourhood . .	?
Bodö, about	50
Tromsö, under the town, about . . .	50
North of Norway, according to Strons, 400 ; south-east coast, according to Keilhau, 600.	

Terraces, perched blocks, and such forms, are associated with sea-shells at the present sea-level, and as high as 450 and 600 feet. If the same forms count as sea-marks where shells have not yet been sought or found, they mark a level of 2000 feet at least.

Shelves at about and below 150 feet are seen from the steamer, and can be traced round the head of the Tana Fjord on both sides of the river. According to Chambers, who measured them, three conspicuous marks on the bluff at Quain Clubbe are 56, 65, 155 feet above the sea. There is a terrace of erosion at Trondhjem 522 feet high. Terraces in Gulbrandsdal are still higher. If sandy flats be the flat tops of terraces, they rise to the watershed of Lapland, and boulders are perched on the highest land in this tract.

From July 9th to August 14th, 1851, we explored the Tana river, and fished. On the 15th we embarked in an open boat with a big lug-sail, and started from the river mouth with a crew of three fishermen. We sailed outside, round the North Cape, and got to Hammerfest on the 19th, after a rough voyage. On the 21st we sailed again in a smaller boat, and reached Alten on the 26th.

In June 1862 this country was again visited with another comrade. We drove and steamed along the usual route to Hammerfest; sailed thence in a fishing-boat; passed inside the island, whose northern point is the North Cape; crossed the isthmus at Hopseidet, inside the peninsula which makes the most northern fast-land in Europe, Nordkyn. We landed at the mouth of the Tana, fished up to Karasjok, and walked back seventy-three miles by pedometer, over the fjeld to Alten, whence we returned to Trondhjem, and made several trips about the south-western fjords. During these two northern trips we lived in the open air, sleeping in tents, or open boats, or under a bush, and feeding chiefly on fish and game, coffee and biscuits. We questioned the wandering inhabitants about their country, and like them wandered from place to place, fishing and shooting wherever there was a chance of sport. We explored one big northern river, worked up small rivers, visited lakes, climbed hills, scrambled through woods and bogs, and landed on points and islands in the fjords and straits through which we passed.

Thus, from personal knowledge or trustworthy accounts, the general features of a large tract of bare rocky country to the north and west of the Gulf of Bothnia, between 66° and

71° N. latitude, and 20° to 30° E. longitude, came to be familiarly known. It bears marks of ice and sea-marks.*

In the same latitude, on the coast of Greenland, is a country so blocked with land and sea-ice, that the coast has rarely been visited, and great part has been left blank in the Admiralty chart of 1859. Further west is the tract where the north-west passage is barred by perpetual ice.

In Scandinavia the climate is peculiar. In June, July, August, and September—especially during six weeks, when the sun is up all night—whenever the sky is clear, the heat in the day is excessive, and the nights are like summer evenings. But when north and east winds blow, and the sky is covered; when the sun dips under the sea horizon, or even hides behind a hill, the temperature and climate change suddenly. A fisherman sometimes discovers that his flies are caked with clear ice, like flies in amber; and a traveller upon the high ground, who has been sweltering in tropical heat in a glen, often meets a hill wind that seems to chill the very bones. Nothing but a reindeer frock and smart walking will keep out the cold, which is always lurking near these warm northern lands. It is clear that a small change would bring a glacial period from the north-east, where Jack Frost lies in wait ready to pounce, and seize all Scandinavia with his icy claws.

If the barrier of land which now shuts out the Arctic Ocean were sunk, the enemy's ice-fleet might sail down the Baltic, and so re-capture Scandinavia, and perhaps the British Islands; by icing the sea, and shutting out the sun with a flying army of clouds.

* According to the opinion of Celsius, and the statements of ancient geographers, Scandinavia was an island after the time of Pliny and before the ninth century.—*Lyell*, p. 52.

It seems to be almost certain that this dam was raised from the bottom of an icy sea, which once flowed over the highest of these hill-tops. The marked features of the isthmus, from watershed to sea-level, are rounded hills, rocks, and boulders. On the high fjeld, the long mounds, which in Sweden are called "osar," abound. These are long mounds of clay and stones, which run through bogs and over plains; like dams, dykes, and raised roads, which are constructed on Holland, and other low wet countries. In shape and size these resemble some "medial moraines," which may be seen in glaciers in Switzerland, and large stones are sometimes perched on them. These are water-marks. At p. 239, *Antiquity of Man*, 1863, Sir C. Lyell describes a mound of this kind, which he examined in 1834 near Upsala. On the top were huge erratics; within, the mound was made of stratified gravel and sand, with beds of shells, 100 feet above the present sea-level.

These are chips; the tool-marks tell the same tale. In whatever direction strata may dip in this Lapp tract, the upper edge of the fracture has been ground away by some force which seems to have worked across the end of the mountain-chain.

The Swedish side is terraced. Rivers flow smoothly for a day's journey, and then rush down to a lower step. On the Norwegian side the Alten and Tana are flat, sandy, and sluggish in the upper reaches, and rapid only at a few stations.

Drift-beds all seem to rest upon a foundation of worn rocks. These peep through sands, raise their dark heads in mid stream, and rise high above the woods in gray moss-clad hill-tops.

Some northern river deltas are great flats of sand overgrown with brush, and almost impassable from bogs and old river-courses. These are terraces in rock-grooves. They end

FIG. 00. GRASS-GROWN TERRACES OF DRIFT AT QUAIN CLUBBE. August 24, 1851.

under water in steep sandbanks, which are always creeping out into the fjords, and blocking up river channels.

On the landward side they are bounded by steep terraces made of big boulders, sand, and gravel.

These older steps can be traced at various elevations far up into glens in the north, and at the other extremity of the country in Southern Sweden.

These are flat-topped terraces, and their steep sides make nearly the same angle with the horizon everywhere.

They are generally overgrown with grass and brush, and hollows on the top are often bogs in which marsh plants flourish, berries abound, and reiper congregate.

Where the general slope of the rocky foundation is small, the terraces are broad and far apart. They surround the river-basin like vast irregular steps in an amphitheatre ; but because of their size, the system can only be well seen where a wide view is got, and under favourable effects of light and shadow. They rise high—how high is uncertain. On the Western Norwegian side, where the hills are steep and exposed, the steps are narrow, broken, and irregular. Many terraces are often so crowded together at the end of a fjord, or in a bay at one side, as to seem works of human skill.

The terraces near Quain Clubbe are good examples, but there are many better. They are regular as terraces at Castle Kennedy in Galloway.

Where the rounded hills are too steep for boulders to rest upon rock, as in the case of the bluff at Quain Clubbe, the rock surface is notched and broken at various levels, which correspond to the level of drift terraces in neighbouring hollows. These seem to indicate an ancient sea-level, a line where waves and drift-ice broke the surface which older ice had made.

Where a hill is exposed to the western or northern sea, there are no terraces; and the face often retains none of these marks. Instead there is a cliff washed and undermined by waves, or protected at the base by a talus of angular fragments which constantly fall from the rock, wear away, and roll upon the beach.

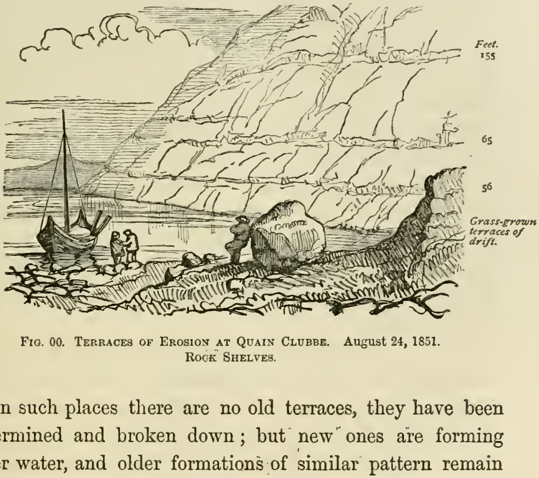


Fig. 00. Terraces of Erosion at Quain Clubbe. August 24, 1851.
Rock Shelves.

In such places there are no old terraces, they have been undermined and broken down; but new ones are forming under water, and older formations of similar pattern remain near them in sheltered nooks. They are seen from the deck of the steamer a long way south on the Scandinavian coast, and they are common in Scotland on many watersheds.

Where a mountain burn has broken through a series, as shown in the cut, their structure is seen, and they all appear to consist of rolled stones, piled upon a foundation of sloping rock which often bears marks of ice.

In Northern Scandinavia these stones, taken singly, have the same forms on the fjeld-top, and in the sea. Taken collectively, they form long points, osar, bars, ridges, terraces, and beaches of the same pattern, on the fjeld ; in bogs, in deltas, in glens, in shallow sea-bays ; at the end and in the midst of deep fjords, and even under water so far as can be ascertained. But boulders which rest upon hill-tops are rough and weathered, while those which form terraces near the sea are more like smooth rolled stones upon the beach.

The "parallel roads" and "muir chlach" (stone seas) of the Western Islands of Scotland resemble the Scandinavian terraces ; but the scale differs widely. Boulders in Finmark are larger than Scotch boulders ; Scandinavian terraces extend for hundreds of miles ; on the Swedish side, stones and terraces, banks and mounds, are still larger ; they seem to surround the whole country with great ramparts.

All these shapes seem to be results of similar action on different scales ; but the engine which is still working between Spitzbergen and Newfoundland is big enough to account for the biggest.

This record seems to prove that Northern Scandinavia rose from the sea, that the peninsula was an island, washed like Greenland by an arctic current, and like Greenland smothered in land-ice, because of ice-floats in the sea.

In Lyell's *Principles of Geology*, a map shows portions of Europe, which have been under water in late geological periods ; as proved by evidence which cannot be disputed—such as the discovery of sea-plants and sea-shells buried in drift on shore. The dark water-line might be carried from 40° E. to 20° E.—from the shores of the White Sea to Kautokeino—if there be any truth in marks which are counted as sea-marks in the plains of Sweden. A pedestrian, intent on his dinner and his journey, has no time to dig for shells ;

but sea-shells will no doubt be found on the ridge when they are sought.

If from Scandinavia we pass to the neighbourhood of the Greenland current, the same marks appear in low grounds in Iceland, Greenland, and North America. All these stream-marks and ice-marks occur in profusion.

In Scandinavia the rise of land has to be proved step by step, slowly and painfully. Near Iceland islands rise and sink, and their appearance and disappearance is recorded.

Close to Iceland is the Arctic Current, and beyond it a glacial period in full operation as far south as Cornwall. Whenever these marked forms on the watershed of the Scandinavian isthmus and on the watershed of Southern Sweden, are repeated—as they are on many watersheds in the British Isles—it seems fair and reasonable to attribute them to a working-engine which is big enough to account for the tool-marks, the chips, and the perching, if only dry land were within reach of the ocean-current, and the ice-floats, and levers.

CHAPTER XXIII.

DENUDATION 15—FROST-MARKS 13—LAND-ICE 12—ARCTIC CURRENT 1—FLOATS 3—SPITZBERGEN, ETC.

Some years ago, a wandering sportsman who was seeking for wild reindeer on the mountains which hem in Romsdal fell in with a spoor which recorded a tragedy. At one place on the wide, stony, gray fjeld, a broad hill-side was covered with a white sheet of last year's snow. Where the stones ended, at the edge of the snow, was the spoor ; and it was followed down hill. At first it was hard to make it out. A train of creatures rushing furiously had trodden the same path, and stamped out footprints ; but gradually the tracks grew clearer. Here were the large deep footprints of a big splay-footed deer ; the toes wide-spread, and the feet far apart. Here a big heavy stag had turned off alone, galloping with all his might. Further on, another reindeer had branched off and fled ; and so the spoor branched and spread, and showed where a herd of deer had fled and scattered. At last there remained the plain spoor of a large and small set of hoofs, and the seal of eight great paws. An unsought spoor had been found, and it marked out a straight line of blue dots in the white snow. It was easy to read that record. Down the hill the wild hunt had swept furiously ; the prints were deep ; the spaces wide ; and bits of sparkling crisp snow were scattered on the smooth glittering crust. The pace was killing. Presently the line of dots took a sharp turn and split; and there a tuft of deer's hair, and a deep dint in the snow, marked the spot where four big paws ran the string of the bow; and four little hoofs went off alone. Where the four big hoofs and eight great paws met again, was another big dint, and the spoor was lost in a mass of confusion. Two wolves had coursed a herd of reindeer; they had singled out a hind and calf; the leading wolf had turned and caught the hind, and had pulled her down; the other had run the string of the bow to help; there was a struggle for life, and the calf had escaped alone. Lower down were more tufts of hair, reddened snow, scraps of torn skin, flesh, sinews, and picked bones—denudation worked by wolves' teeth—and a large surface was beaten, and trodden, and strewed with chips. From this spot eight paws had stamped two lines, side by side, for a short distance; and two great, round, gorged, hairy bodies, had pressed their shapes into the snow twice within a hundred yards. The wolves had eaten up the deer, and had eaten so much that they could hardly walk off with the extra load; so they had grounded in the snow; they had stopped to rest and lick their lips. At last the spoor went off the snow towards the rough woods in Romsdal, and there was end of the record.

Short of seeing the hunt nothing could tell the story so clearly as this spoor, because the marks were known. Short of seeing ice floating along hill-sides, and over hill-tops, nothing can tell their story so well as ice-tracks. But the tracks must first be learned, and the way of the creature studied. For one who has never seen the tracks of deer, wolves, and ice, there is no record; for one who knows something of the nature of air, water, and beasts, tracks are plain everywhere on snow and rocks.

If a sportsman wants to know whence the creature which made the spoor came, he must run from toe to heel—from effect to cause—backwards. If he wants to catch the creature, he must follow from heel to toe—from cause to effect—forwards. The way to catch the wolves was to beat the woods in which they had their den.

The den of Jack Frost is in the north, so the cover to beat for the reason of his old tracks, lies northwards or upwards to the place where Jack Frost lives ; or southwards and downwards, after his two cubs land-ice and ice-floats.

In order to account for some of the marks which are found upon Scandinavian hills and watersheds an engine of large size must be found ; and one is to be seen at work very near the North Cape.

If nothing is known of a river, it is best to explore it from delta to source. From a model in a tea-tray (chap. xiii.) land-ice and its marks have been tracked up hill from Bergen, through Western and Northern Scandinavia : but in following the track of land-ice from sea to cloud, the spoor of larger game was crossed in the mist. The way to escape from mist is to follow running water ; the following pages follow the Arctic Current. The path lies down hill from snowshed and glaciers to the sea, and to a general polar system, which consists of land-ice and ice-floats moving southwards, at the sea-level.

Part of one arm of the sea-monster, whose spoor was crossed in Scandinavia, may be followed and watched ; part of the polar ice-engine may be seen to work denudation at Bear Island. No man has ever seen the whole system, but by the help of ships, books, and maps, it is possible to learn something of the plan of the engine which made the marks—of the ways of the creature which made the spoor.

Almost due north from the North Cape lie a cluster of islands called Spitzbergen.* The distance is about as far as from Hammerfest to Torneå; from Torneå to Sundsvall; from Sundsvall to Götheborg; from Hamburg to Hull; or from Aberdeen to London. This cluster of islands passes 80° N.; and this land, within ten degrees of the North Pole, is visited every year by crews of hardy Norskmen, in small crazy vessels, which sail about July from Hammerfest, from Bergen, and from Christiania. These vessels return in autumn, laden with the spoils of the ice-world. They bring trophies of sea-horses, seals, bears, and reindeer, eider-down, and such like commodities; and with these, odours which must be smelt to be understood. They do not amalgamate like other evil smells, but seem to fly about the streets of Hammerfest singly or in flocks; for they can be distinguished and recognised when they enter a house, as they are wont to do at all hours of the day and night. Norsk merchants occasionally join these expeditions for the love of sport and adventure. One who lived near the North Cape, and who was at Bergen in 1857, said that "he had been up further north than Parry in one very fine open year." They spent one winter fast in the ice near Spitzbergen, and when the summer thaw came, ice vanished, and they got far away to a country where walrusses abounded, and which he called Gillies Land. They pushed

* Views of Bear Island and the Coast of Spitzbergen are given by Scoresby, *Arctic Regions.*

A volume published by the Hakluyt Society in 1855 contains much curious information about Spitzbergen and Greenland, and gives references to works from which the history of arctic discovery in these and other regions may be learned.

A list of 68 arctic voyages, from the ninth century to 1827, is given in the narrative of Sir John Ross, of his discovery of the Northern Magnetic Pole, etc. etc., in 1829, 1830, 1831, 1833. Published, 1835.

A list of papers, relative to the search for John Franklin, etc. etc., is given in a late index to Parliamentary papers.

on a long way, and finally returned all safe to Hammerfest. He believed he had been very near the North Pole, but he took no observations. He spoke like a man who meant to tell the truth, but he may have said the thing which is not.

In July 1827, Parry had got within eight degrees of the North Pole. He had only to walk as far as from London to Thurso, but he was walking upon the sea ; the ice was bad, the surface rough, wet, and sloppy ; and as he walked northwards, the crust floated southwards. The attempt was abandoned, but the gallant sailor who made it thought it possible to succeed by wintering in Spitzbergen, and starting earlier in spring.

Whether the sea is open or frozen about the North Pole is an open question. According to one theory, there is an opening which communicates with the interior of the earth ; but that theory stands upon nothing, and cannot be disproved.

In June 1851, an English party in a yacht tried to reach Spitzbergen from Hammerfest and failed.

They met great fields of ice moving south, and tried to get round the southern end by sailing west. After running nearly a hundred miles along the ice without finding any opening they gave it up, and sailed eastwards to the Tana. In the same latitude, but in different longitudes, there was very different weather. To the west, in the longitude of Hamburg, and about the latitude of the North Cape, sea-ice was floating southwards ; snow was falling ; there were heavy gales, thick fogs, frost, and very cold disagreeable winter weather.

To the east, on the fjeld, about as far off as the Isle of Wight is from Galway, or Hamburg from Inverness, was the weather above described (chap. xxii). On one side was winter in June, colder than any English December ; on the other fine hot June weather, bright sunshine, clear sky, balmy breezes, cows, pasture, milk, berries, good salmon-fishing, and civilized men with excellent houses and gardens. In these various southern flowers, roots, and herbs managed to grow. In the houses were plants from the south of Europe, and close to the North Cape, a sleepy parrot lived in a cage for many years.

On the 20th of August in the same year, 1851, the writer, after sailing round the North Cape in an open fishing-boat without suffering cold, or encountering danger, boarded a Spitzbergen walrus-boat at Hammerfest, which had just returned loaded with odorous trophies. They sailed in June after the yacht, and got to Spitzbergen without difficulty. The ice-fleet had gone south with a heavy lading of cold, shrouded in mist, and followed by winter and storm. The walrus-boat was decked ; not much larger than an English trawler, with a den below in which three or four men could stow by crouching. The stench of oil, blubber, and very high animal remains of sorts, was only to be equalled by one of the cod-liver establishments on shore. The greasy bloodstained craft was not tempting, and to sail in her for sport seemed less agreeable than salmon-fishing with Lapps. Without a yacht a Spitzbergen trip was not tempting, and yachts cost money.

The men said that they had been to the furthest point in Spitzbergen that had ever been reached by man ; that the ice which stopped the yacht in June was Spitzbergen coast-ice breaking up earlier than usual ; and that the coast had been clearer that year, than it had been within the memory of the oldest fishers. These men described how they harpooned the walrus, and played him like a salmon, and how he sometimes fought for his life.

An old Hammerfest sailor, who had been much in Spitzbergen, confirmed their stories, and the account given by a Norsk merchant who, in 1848, went to Spitzbergen from Alten in a small schooner. Reindeer, they said, were numerous, and so unused to men that they ran great distances to stare at a red shirt or a cap, or any unusual object. Instead of stalking, some of the hunters used to lie down, stick the red cap on one foot, and "make manœuvres." The deer soon find out the danger, and get as wild and shy as deer elsewhere. "White bears abound, and are as easily speared and about as dangerous as a pig." They are very different from their brown relatives in Norway; for the men who despise, or affect to despise, white bears, speak with great respect of "Nalle." In 1856, the writer was prevented from joining a yacht party in a voyage to Spitzbergen, and he has never had another chance.

In 1856, Lord Dufferin reached Spitzbergen in an English yacht; and in 1858 and 1859, James Lamont followed with his comrades. These gentlemen have published accounts of their adventures; and they very clearly and forcibly describe the appearance of sea and land at Spitzbergen, Jan Mayen, and Iceland. Part of the coast of Greenland, which corresponds in latitude to the open sea between Hammerfest and Spitzbergen, is described in two works by Scoresby.

These four books were written by men who could well describe what they saw. One was in search of whales and discoveries, the others in search of sport; and all three sought adventure. The last had glacial theories and the origin of species in his mind; so his descriptions have a special bearing on ice and ice-marks.

After sailing in open water from Hammerfest north to Bear Island, Lord Dufferin's yacht, the "Foam," encountered a barrier of packed ice fast to the shore, like

English ice frozen round a stone. The edge of this float ran east and west as far as the eye could reach. By sailing west, and turning north whenever a bay in the ice gave a chance, the "Foam" got to English Bay on the 6th of August, after knocking about for eleven days.

Ice-floats then hang about rocky islands which come in their way; and if ever these islands become hills, there will be a mark at the old water-level. A worn shattered notch must be chopped out between wind and water, by waves and ice, which are continually hacking and sawing at one place in the stone.

Here, at the outset, is an engine at work, hewing marks like those which are seen at Quain Clubbe (p.).

The French lady above mentioned saw this island clear of ice, for the floats had not parted from their northern moorings so early in the year. To her the coast seemed like a giant fortification undermined by waves, and pierced here and there by arches; an amphitheatre with steps perfectly regular, with a large audience of sea-birds in the reserved seats. The interior of the island was a plain of melting snow, with runlets of water flowing over it, like white ribbons of silk laid upon white velvet.

The island is surrounded by reefs and shoals. It is composed of beds of stratified sandstone, lime with fossils, and coal; and in due time the upper beds will be shorn off, and the lower beds ground smooth, if the polar ice continues to saw between wind and water.

If the island rises, it will be like numerous islands on the coast of Norway, a hill in a plain. It will be like a broad-brimmed hat trimmed with snow-velvet and watered ribbon; like an island at Christiansand, or the "Dutchman's Cap" off Mull in winter.

FIG. 00. ENGLISH BAY, SPITZBERGEN.—*Letters from High Latitudes*, p. 300.

The word-pictures show the work of sea-ice.

The woodcut represents a land-glacier on the slips, ready to become an iceberg. It is filling up the whole of a valley, nine or ten miles wide in the widest part, and descending with one continuous incline for about thirty miles to the sea, sweeping like a torrent round the roots of an isolated clump of hills, entering the sea, and ending in a cliff about 120 feet high.

The ground on the left is described as low, flat, black moss, about half a mile wide, with tracks of reindeer and other animals; and dead men: the beach is strewed with drift trees and wreck. The ridges and peaks are described as jagged like a saw, split and crumbled by the frost, about 1500 feet high, and very steep. In the extreme distance were mountains peering above the surface of the ice, and they, too, are peaks—not domes.

When the rest of the forms described are so faithfully rendered, the talus-heap at the foot of the cliff, and the worn rock or rounded moraine below the ice, can be recognised.

The peaks and talus-heaps are of the Λ pattern, the rock in the way of the glacier is rounded ⌒. The flowing ice has the sweep of a river S, and the grooves which it makes in the rock-groove ⌣ must be S also.

By the author's permission this picture is copied from part of a cut in Lord Dufferin's book.* It shows part of the local glacier system of Spitzbergen, which is sliding into the sea, and drifting southwards and westwards, together with the polar ice which Parry found drifting southwards at the highest latitude ever reached.

From Parry's point, as from a source, a stream of ice floats; and it washes an ice-bound coast at Spitzbergen.

* Letters from High Latitudes; London, 1857.

Take Lamont's description of the coast about 77° N (p. 136).*

"We were still a few miles north of Black Point, and opposite a glacier extending into the sea. Like all the other coast glaciers, with few exceptions, it is only an arm or branch of that vast body of solid ice which occupies all the interior of the country, and which, like an enormous centipede, extends its hundred legs down nearly every valley to the sea on both sides of the islands.

"There are three glaciers on this part of the coast, between Black Point and Ryk Yse Islands. The two southmost ones are not of any great size, or in any way remarkable; they each have a sea-front of about three miles, and protrude into the water for one and a half or two miles in regular semicircular arcs.

"The third or northmost of these three glaciers is one of the largest and most remarkakle in Spitzbergen, or perhaps in all the world. It has a seaward face of thirty or thirty-two English miles,† and protrudes in three great sweeping arcs for at least five miles beyond the coast-line. It has a precipitous and inaccessible cliff of ice all along its face, varying from twenty to one hundred feet in height: pieces from the size of a church downwards are constantly becoming detached from this icy precipice, and tumble into the sea with a terrific roar and splash, and of course render it highly dangerous to go near the base in a boat.

"The surrounding sea is always filled with these fragments of all sizes and shapes, and many of them I have observed carrying large quantities of clay and stones imbedded in them.

"This great glacier is in three divisions; the northern and southern divisions are each quite smooth and glassy; but the piece in the centre is broken up, and rough and jagged to a degree that is quite indescribable. At a little distance it exactly resembles a great forest of pine-trees thickly covered with snow.

"This part of the glacier must have undergone some disturbance, arising either from its sliding over a rocky bed, or from its being forced through a narrow ravine in the underlying hills. Whatever the disturbing cause may be, it is actively at work still, because we frequently

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* Seasons with Sea-Horses.

† About the dimensions of the glacier which faces Sprenge Sandr in Iceland, and which is a marvellous object to look upon, though it is not in the sea.

saw enormous slices of the smooth division split up and cave in towards the disrupted part; and there is a constant succession of tremendous booming reports, exactly resembling loud and prolonged thunder, proceeding from these cracks, and from the whole of the rough part of the glacier in general.

"I have questioned men who have frequented the Spitzbergen seas for as many as twenty summers, and they all say that this glacier has always presented the same appearance since they first saw it."

Spitzbergen land-ice is then a copy of Swiss and Norwegian land-ice; and the whole system radiates from the highest land, but the glaciers work far out to sea. They push along the bottom under water, till they get out of their depth, and then they break off and swim. The system or cluster of systems is perched on land, whose area is about equal to that of Iceland or Ireland, or the block of land in Southern Scandinavia described in chapter xvii. The particular foot of the "Centipede" described by Lamont, may be likened to a sheet of coarse sand-paper; it is flat and pliable, a sheet of wet ice with sand and stones frozen into it. But it is broader, bigger, and heavier, than all the buildings in London and its suburbs; and it has been sliding over wet gritty rocks in the same direction for twenty years, and probably for as many centuries. According to the earliest accounts of Spitzbergen, the climate was much the same when the land was discovered in 1596 by Barentz. If such an engine were planted in the London Basin, and set to grind chalk, it would leave a notable groove. The spoor of the ice-centipede must be conspicuous; but the star-fish which stretches from the North Pole to Cape Race, and thrusts its arms through Behring's Straits and Baffin's Sea, is bigger than the Spitzbergen centipede.

Of the hind claw of his ice-monster, Lamont says (p. 138), "Of course this glacier has no visible terminal moraine above water, but it may possibly have some connection with an extensive submarine bank which lies opposite the whole length of the front of the glacier, and extends for fifteen or twenty miles to sea. The soundings on this bank may average fifteen fathoms, with a bottom of bluish clay; it is a very favourite resort of the seal and the walrus, particularly the latter, for which I am led to suppose that the bank produces in unusual numbers the molluscæ on which they feed."

Of another glacier, it is said (p. 144), "A terminal moraine made entirely of mud extends like a rampart along the centre front of a small glacier, at a distance of about two miles." The glacier slopes into the sea, which was partially frozen on the surface; but the mound had evidently been raised by the great and immediate pressure of the glacier.

So Spitzbergen land-ice digs grooves and packs chips under water, as an English coal-barge does when it slides off a mud bank in the Thames.

English ice may be seen to do similar work on a small scale, and melted wax will so pack sand in a tea-tray. But in Spitzbergen the land-ice floats away after it has done its work at home, and the first thing it does is to breed a cold sea-fog, and local storms.

The English yacht found it so in June 1851. Lord Dufferin found the fog everywhere beside the ice in 1856. Scoresby found it lower down. Lamont says (p. 46), "I imagine that these prodigious masses of ice generate the fogs, which, it is notorious, are much more prevalent here than on the west side of the country." In every Spitzbergen landscape, by whomsoever drawn, fogs are notable features.

Like a crab, a flounder, or an ink-fish, which knocks up a cloud over-head while burrowing into sand or gravel under water, the polar ice-star condenses a cloud of mist and snow-crystals to hide in the dark from its foe the bright warm sun.

The cold fog was the only thing which seemed to daunt the Parisian dame, who ventured so far.

The ice-raft, thus built and launched, sets off at a rapid pace, with its awning of gray cloud spread, and the next thing it does is cool air, sea, and climate. When sailors dread icebergs thirty degrees further south, their best safeguard is a thermometer. An instrument has been constructed to ascertain the direction in which this cold danger lies. It consists of a reflector, with a delicate thermometer in the focus, and by turning it in azimuth, the coldest point on the horizon is detected. The presence of ice affects a thermometer at several miles; and the larger the quantity the greater is the cold. In approaching the ice-floats winter is approached; on leaving them winter is left behind.

The faster the floats travel the further they carry their own climate. The shock of a blow, and the mark made on a rock, must depend on the direction of movement, weight, and velocity of the hard body moved.

The pace of an Alpine glacier, according to Forbes, and the best authorities, is four feet in twenty-four hours at the utmost. Incidentally, Lamont gives the pace of the ice-float and its direction.

"Two bull walruses hove in sight, floating rapidly by, asleep on a cake of ice. The current was carrying the ice past the island at the rate of five miles an hour, from north-east to south-west."

So a maximum velocity of two inches an hour grows to 316,800 inches per hour.

At page 127, Lamont mentions a small float of from sixteen to twenty square miles, moving in one almost unbroken sheet down a fjord, with a tide which was running "very hard indeed." At page 125, similar ice-rafts, laden with large stones, are mentioned. At 165, the rate of the Arctic Current amongst the Thousand Isles is estimated at "seven or eight miles an hour." On one occasion, six men pulling their best could not move the boat ahead at Black Point.

So the power of a glacier on shore is nothing to the power of the same glacier afloat.

Of the moving stream of ice-floats, many pictures have been drawn by able hands; but no one seems to have considered the system as one great denuding engine.

The brave little Frenchwoman who went to Magdalena Bay with Gaimard, and who compared rills of water flowing over snow to wedding millinery, compared the ice-floats to sparkling jewels.

Old Martens, in his *Voyage to Spitzbergen* in 1671, says, that "the fairest blew that can be seen is in the cracks of these ice hills." One piece was "curiously worked and carved, as it were, by the sea like a church, with arched windows and pillars, the doors and windows hung full of icicles on the inside thereof, the delicatest blew that can be imagined." Others were of "other figures," "round and four-square tables, with round and blew pillars underneath: the tables was very plain and smooth at the top, and white with the snow; at the sides hung down a great many icicles close to one another like a fringed tablecloth; I believe that near forty men might have sat about it. I have seen of these tables with one foot, and with two or three pillars, and abundance of seales swarm about. The dishes that furnished this table were a piece of ice like an horse's head and a swan; I doubt they were but salt." The old Hamburgher was surely very cold and hungry when he wrote thus of churches and tables in the ice.*

* Old translation, 1694, from F. Marten's *Voyage to Spitzbergen.* Republished by the Hakluyt Society, 1855; originally dedicated to Samuel Pepys.

Off Jan Mayen, Lord Dufferin—Irish gentlemen, artist, sportsman, and sailor—saw diamonds and silver argosies—a knight on horseback clad in sapphire mail, a white plume above his casque—a cathedral window with shafts of chrysophras, new powdered by a snow-storm—a smooth sheer cliff of lapis lazuli—a banyan tree, with roots descending from its branches, and a foliage as delicate as the efflorescence of molten metal—a fiery dragon in scales of emerald—" or anything you please."

The British tars who sailed with Ross were pleased to see "the familiar emblem of a public house"—the lion and the unicorn—and the broad shield of England, adrift in the sea off Cape Farewell. The French sailors who sailed with Prince Napoleon saw ice, and danced the cancan. Lamont—the Scotch gentleman, sportsman, naturalist, and geologist—saw ice mushrooms and centipedes, caverns and crystal vaults, and noted geological facts into the bargain ; for which he deserves special thanks, which are hereby tendered by a traveller, who thinks he sees an ice-engine in a tea-tray. At page 150, Lamont says—

"The vast accumulation of ice in the Spitzbergen seas consists partly of flat tabular slabs of all sizes, from that of an acre downwards, which have composed part of the winter's growth on the shallow bays and gulfs of the coast, and partly of rough irregular masses which have become detached from the ice-cliffs of the glaciers.

"Some of these latter I have observed to be carrying large stones—which, by the way, I have frequently mistaken for seals—and very many of them are charged with such quantities of dark-coloured mud or clay, that the sea is in places sometimes discoloured for many miles around by their washings.

"This was one of the finest and warmest days I ever knew in Spitzbergen ; the thermometer was 55° in the cabin, and in the sun it was actually hot. The summer's warmth has had a perceptible effect upon the ice, much of which we observed to be undermined, and honeycombed or 'rotten' as the sailors call it; it always seems to decay fastest 'between wind and water,' so that enormous caverns get excavated in the sides of the bergs.

"Nothing can exceed the beauty of these crystal vaults, which sometimes appear of a deep ultramarine blue, and at others of an emerald green colour. They look as if they were the fitting abodes of mermaids and all sorts of sea-monsters, but practically no animal ever goes into them. The water dashing in and out through these icy caves and tunnels makes a sonorous but rather monotonous and melancholy sound. In moderately calm weather many of these excavated bergs assume the form of gigantic mushrooms, and all sorts of fantastic shapes, but directly a breeze of wind comes they break up into little pieces."

When an iceberg thus capsizes or breaks up, the cargo of mud and stones goes to the bottom; it must there take the shape which rubbish takes on being shot over a pier. The breakwaters at Plymouth and off Portland were so constructed, and their shape is a standard for rubbish-heaps shot from ice.

This is a case in which a working model may be instructive.

A plate of ice loaded with sand and loose stones must drop its load in the same way, whatever the dimensions may be. In a small plate the ice gradually melts, and mounds of sand form themselves into conical heaps on the wet surface. But as the ice-raft melts it loses the power of floatation, and it becomes lopsided; one edge sinks, and the flat surface becomes a sloping plain. It slopes more and more as the ice melts, till the slope becomes so great that the deck-load slips and rolls to one side, and sinks the sunken edge still more. Then the mounds slip and become avalanches, slide overboard, sink to the bottom, and become mounds there. But while rubbish is thus shot one way the float shoots in the opposite direction, and the rest of the deck-load is washed overboard as the raft slips through the water. Ice relieved from weight bobs up like a board and shoots off edgeways, because there is least resistance in that direction. When rubbish-heaps are thus shot eastward, flat ice shoots westward, and the rubbish at the bottom is deposited as a mound with a tail stretching westward. The mound may be conical, or a long ridge.

Big snowballs rolled about in a garden, watered, kneaded, and frozen, are like miniature glaciers, in that they consist of air, ice, stones, earth, and sand. Set afloat in a glass tank they are like miniature icebergs.

After a night's frost has hardened the surface into a thin crust, so as to fix the floats to the sides of the tank, and join them together by a flat ice-raft; the system is a miniature copy of the ice whose upper surface is described by arctic voyagers. There are "berg" and "floe," and where the ice is broken, there are "packs" and "hummocks;" and the whole is fast in the "coast" in a narrow space, as in sea or strait, or bay or lake. The glass gives a section of the solid crust and fluid core, and of the loose deposit which falls when the solid melts. The copy is a working model.

According to the stone-load so is the depth at which bergs swim. Of one mass, six inches deep, half an inch was above water, or $\frac{1}{12}$. Of one five inches deep, half an inch was in the air, or $\frac{1}{10}$. Of one three inches deep, four-tenths of an inch rose, or 1 to $7\frac{1}{2}$. If this proportion is made to fit the dimensions of small icebergs, one 600 feet thick would show 50 feet; 500 feet would show the same; and 300 feet, 40.

The visible height of an iceberg is no certain measure of its size. One may be almost pure ice, and float as glacier-ice floats in sea-water; another may be so freighted as to sink; or it may float so as to ground at any depth. Moreover, the shape of the lump affects its height. In one case a sharp peak may rise high, in another a blunt end may be uppermost.

In these floating masses the centre of gravity is not a fixture. It is constantly changing.

When a heavy stone or a mass of rubbish falls from the end of one spoke in the wheel, that side becomes lighter; it rises, and the wheel turns round. The system rolls in the water till it recovers equilibrium. Icebergs constantly roll over, and this seems to be a sufficient reason. The woodcut was drawn from a model which was made as described and worked in this way.

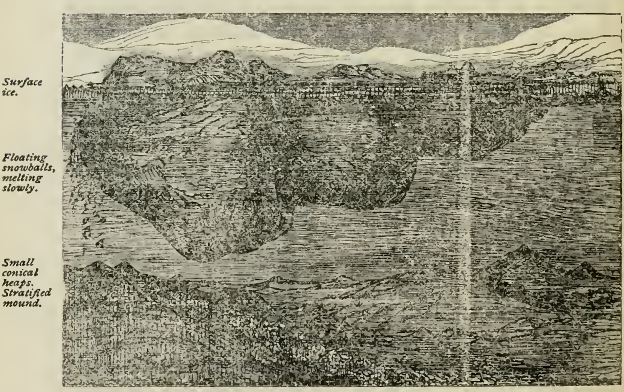

FIG. 00.

On these and similar movements the shape and structure of rubbish-heaps dropped from ice on a sea-bottom must depend. The glass tank shows the structure of such mounds, and it coincides with the structure of mounds of drift which occur in ice-ground countries like Scandinavia and the British Isles. The glass gives a section of the rubbish-heap which fell through water from floating ice, and it shows that the mound is roughly stratified. The coarsest and heaviest materials win the race to the bottom, and the rest follow and fall upon them. The mound is conical, and a section of it shows beds of various materials, packed in conical layers. Gravel goes straight to the bottom, sand follows, fine river-mud hangs in still water for days, but mud settles at last, and it forms the highest layer. In a stream such mud would travel far.

The original shape of an iceberg does not affect the shape of the mound which it leaves when it melts.

The woodcut was drawn from a model contrived to illustrate this point, and ascertain experimentally what shape frozen rubbish-heaps would take in water.

A lot of various materials—fine mud brought from the river Zambesi in Africa, sand of many kinds, and stones of various sizes—were turned into a large dish with water on a winter's day; and when the lump was frozen, it was placed in a glass tank full of water, and watched while it thawed. There was more cargo than ice could lift, so the mass sank.

As the ice-cement became water, the silt crumbled and fell. The angular mass became rounded, and took all manner of strange forms. The rotting ice grew honeycombed; and like glacier-ice at the lower end, it was covered with sliding dirt. Slowly and by degrees the ice vanished, and in its place a rounded hillock of definite form loomed through a yellow fog of suspended mud which hung about it, and floated in water-clouds for several days. The mud was thickest in the coldest water; thermometers marked 36° below, 39° above, when the air was more than 40°.

The heap thus formed against a glass wall (see cut) was conical; but many cones had united to form one heap, and the top was rounded off. The section was exceedingly complicated, but it was easy to understand the process by which loose silt had assumed this contorted form. The heaviest silt sunk fastest, the lightest came over all like a bed of snow; but each fall made a separate system, and these beds mingled and interlaced. The form thus obtained must be like the reality, for the experiment is but a copy of nature. The dimensions differ widely. In all books about these northern regions, and all accounts which have been gleaned from men

FIG. 00. MELTED ICE. MELTING.

who have frequented these seas, it is said that icebergs and floes—pack and new ice—form islands as big as an English county in winter; and north of Spitzbergen, the winter ice-field is supposed to equal the area of North America, unless there be an open polar sea behind the ice-floats.

Lamont says—"After the end of August, the Arctic Current entirely overcomes the remnant of the Gulf Stream which has been struggling with it, so far successfully as to modify its blighting influence on Spitzbergen during the preceding months; and the polar ice, aided by the increasing cold, comes down in such quantities as to defy the efforts of the now vanquished Gulf Stream to dissolve it. It rapidly sweeps round the coast . . . . and Spitzbergen is enveloped for the winter."

In spring, the pendulum swings the other way. The ice breaks up and floats towards Jan Mayen, coasting along the ice which is sliding off Greenland.

As in the case of land-ice, so in Spitzbergen old marks abound on shore which suggest the marine engine which made them.

Of the glaciers, Lamont says (p. 109)—"It is wonderful to observe how insignificant even mountains of solid rock are compared to the enormous power of glacial action! They appear to melt and crumble into dust and mud like mole-hills, in the gigantic grasp of the 'ice-rivers.'"

At another place, he speaks of a deep trench crossing a plain of debris on shore, and its appearance suggested that a heavy floating iceberg had ploughed through the plain while it was under water.

As land-ice digs and grinds on shore here as elsewhere, so firth-ice, moved by the tide, wears the coast and the bottom of hollows partially filled by the sea. As floats work on this scale in firths and sounds whose dimensions equal Norwegian firths and Scotch lochs; so larger floats, worked by the Arctic Current, must plough mud and grind rock where they run aground.

Whatever the direction of the movement may be, the mark made must coincide with it. The glacier-grooves lead to the watershed, the firth-ice grooves lead to the glacier foot; the grooves made by floats in the ocean-current must coincide with the run of the stream, and here it runs from north-east to south-west. So the tracks lead to the Pole.

In Spitzbergen, as in Scandinavia, is evidence of a recent change in the sea-level.

Drift-wood and whale skeletons are found high up on hill-sides, amongst moss and rock; reindeer and reiper, foxes and travellers, walk about on an old sea-bottom where walrusses browsed, and where the drift-ice of the Arctic Current ran aground and left its spoor.

With his wits about him, and ice-floats at hand, the sportsman, who could see rocks and game, writes—

> "The surface of these rocks was much smoothed and polished, as if by the passage over them of much heavy ice in bygone times. . . . There was not a particle of vegetation to be seen, and the aspect of the country was bleak and sterile, and gloomy beyond description" (p. 148).
>
> "This island, as well as all the other off-lying islets and skerries on the south, south-east, and south-west of Spitzbergen (I do not include Hope Island) is composed of a rough, coarse-grained trap rock, which in places imperfectly assumes the columnar shape. These columns seem very much shaken, as if ready to fall to pieces, and the tops of the columns, as well as all the corners and protuberances, are much worn and rounded, as if they had been half made into boulders already. They no doubt are so, for thousands of boulders, quite smooth and rounded, and formed of the same rock, half cover the islands. These are mostly of an average size of about a cubic foot, and very seldom exceed two feet and a half in diameter. They are curiously packed and levelled in some places, as if they had been roughly made into a causeway for walking on by human agency. This singular appearance I conceive to have been given to them by enormous icebergs grazing over and resting on the islands ere yet they became dry land, and acting on the boulders like a roller on a gravel walk."

Amongst these "travelled ice-born blocks" were boulders of granite and limestone, which came with the ice; and worm-eaten drifted pines, with their roots, which grew in Europe, Asia, or America, and landed in Spitzbergen after floating half round the world with the Arctic Current or the Gulf Stream.

The most northern rock known—the shore from which Parry set off—is granite; a bit of it may have travelled to the place where the tree left the shore, if it grew on the Rocky Mountains, and put to sea at New Orleans.

If there be such a thing as development, human philosophers, who rose from apes and hope to become angels, can neither fly like gulls, dive like seals, nor burrow like moles now; but during their brief stay in this bodily half-way house, men can join facts to frame new ideas, and see with mental eyes.

Beneath the mass of solid water, which now forms the winter crust of the solid and fluid world about Spitzbergen, lie beds of a stone which once flowed like water, and like it crystallized and froze when it cooled. Stratified beds of snow, which rose from the sea and fell from the air, rest on stratified beds of sandstone which fell through water upon beds which are coal, and were land plants. Underneath these are beds of igneous rocks; frozen stones which sunlight cannot melt, but which were melted under the earth, nevertheless. In Spitzbergen, within ten degrees of the North Pole, are beds of sandstone, limestone, and shale; coal-seams, whin-dykes, hills of columnar basalt, and granite hills; and somewhere under all these some mighty force is heaving and swelling upwards, lifting the islands, as a whale lifts a shell on his rough hide, when he rises to blow off the steam in the Arctic Current amongst the ice-floats.

CHAPTER XXIV.

DENUDATION 16—FROST-MARKS 14—LAND-ICE 13—ARCTIC CURRENT 2—FLOATS 4—GREENLAND, ETC.

GOOD descriptions of land and sea ice are given in the quaint old book quoted above (p. 374). In 1671 old Martens described what he saw, nearly two hundred years ago—ships, waves, meteors, snow-crystals, sea-ice; birds, beasts, and fish, and how to catch them. A great deal has been added by later writers, but very little of this account has been contradicted. The same engines which Lamont describes have been at work for 200 years at least in Spitzbergen.

The best-known book, and perhaps the best which treats of arctic ice, is Scoresby's first volume.* It contains, in a condensed form, the experience of a shrewd, scientific, practical observer, who had made seventeen voyages to the Spitzbergen or "Greenland whale-fishery;" and who seems, also, to have read all that had then been written about his subject. Many suggestions made by Scoresby have been followed, many of his predictions have been fulfilled. The sea does really pass round North America; the north-west passage exists, and it is in fact useless: he held that the polar basin was a frozen sea; and there is still every reason to believe that he was right: the Arctic Sea is still unexplored, though men have been striving to pass through it ever since A.D. 1500.

* *An Account of the Arctic Regions, with a History and Description of the Northern Whale-fishery.* By W. Scoresby junr., F.R.S.E. Edinburgh, 1820.

The highest latitude reached by Scoresby was 18° 30′. Parry got to 82° 40′. One sailed to the edge of a floating crust of ice; the other found the ice-crust on which he walked floating south-west. Early Dutch whale-fishers assert that they sailed to 82° and 83°, even to 89° 30′. In 1856 a Norwegian asserted that he had sailed nearly to the Pole (see p.). When Scoresby reached 81° 30′ he found an opening which extended east and west; beyond 8° west and 19° east longitude. A similar crack might lead north to the Pole, for the polar ice seems to be a floating crust. The ice which breaks from the edge and comes past Spitzbergen is sea-ice, not land-ice launched into the sea.

All round the arctic basin, between 70° and 80°, sea-ice sticks to the brim, except about the North Cape of Norway, where the Gulf Stream runs in towards the N.E., and keeps the coast clear. From Nova Zembla to Bear Island and Spitzbergen, the warm stream is bounded on the north by a broken crust, which is working towards the south-west. The "north-east passage," and the transpolar passage, are as useless as the "north-west passage," and for the same reason—the sea is blocked by a broken moving float.

Between the shore-ice and the sea-ice; between the lip of the basin, and the central floats; the sea is occasionally open. Kane found open water to the north of Greenland in 81° 20′. Scoresby sailed in open water in 81° 30′. Barentz saw open water, got to Nova Zembla, and perished on his way back. Wrangell saw what he called a wide illimitable ocean from Siberian ice.

It seems that the main body of north polar ice is a brittle fusible crust; a moveable solid floating on a liquid base about 2000 miles in diameter; raised above the sea-level from four to fifty feet; revolving with the earth; free to move. It mends and grows in winter; the edges break in spring, and the splinters run aground on the coast and move off towards the south-west, through the widest opening in the edge of the basin which holds the polar sea. A prevailing current flows from the north-eastern point of Russia westwards, and in the Spitzbergen Sea flows out of the polar basin from north-east to south-west, during nine months in the year, if not all the year round. It moves at a varying rate of from five to twenty miles per day, and sometimes much faster near land (p.). It carries a vast quantity of ice as far as Cape Farewell, round Cape Farewell up to Disko, down to Newfoundland, and even to lat. 40°. The crust annually carried south-west by this one ocean-river, and melted in the south by the sun, is calculated to cover an area of 20,000 square leagues.

The fragments give some idea of the nature of the central mass.

The ice-floats in the Spitzbergen seas consist chiefly of "field-ice," "floes," and other varieties.

The "fields" cover an area of several hundred square miles; they are a hundred miles long, thirty miles in diameter. They rise from four to six feet above the water, and sink ten, fifteen, twenty feet. Before July these floating districts are covered with beds of snow from a foot to a fathom in depth. When the sun has power, the snow melts, and the surface is wet, and covered with lakes and pools of fresh water. The white plain is so compact and even that "a coach" might drive over the ice, but the plain is varied by strange hills and peaks. Hummocks of blue ice—thirty, forty, fifty feet high are raised by pressure. Bits of crushed ice are turned on edge; great ridges and piles of ice are formed above; and "calves" are thrust under; so the depth of field-ice is often more than fifty feet. Fifty feet is as high as the front of a London street. Field-ice floats with one part above to eight below water, according to Scoresby's experiments. Fresh-water ice is so hard as to "inflict a wound like glass;" it is so clear that lenses were made of it, which melted lead, lit pipes, and burned the sailors' fingers, to their great delight.

Incidentally it appears that ice which is fixed to the shore, and drift-ice, is often covered with mud and gravel. When a swell comes, land-ice breaks adrift; fields break, and become floes; and these, when still more broken, change into loose and close "pack." When the weather is warm, the "pack" gets rotten; when the freezing-point is passed, the frozen water sinks to the sea-level, and the stones go to the bottom.

When the freezing-point is passed in the downward scale, ice rises from the sea.

A mass of loose crystals, which are called "sludge," form, float, and join. If the sea is rough, the growth takes a form which is common in pools in English rivers; the sea is covered with circular slabs with upturned edges, which jostle and grind till they too join and form larger cakes. When these unite, they form a rude ice-pavement of marine glass mosaic. When the sea is calm, the growth goes on smoothly from below. The rule of flotation holds good; "bay-ice" lifts one-ninth of its bulk above the sea, and joins pack to pack, and floe to field, with new flat water glass cement.

To these mended flats, with projecting edges, are joined bergs, which slide from the land; and on this crust a sheet of snow is thickly spread, which adds size and weight. There seems no limit to this growth but the constant waste. The "small" icebergs about Spitzbergen are sometimes 1000 yards in circumference, and 200 feet in thickness. So the ice-plane has stone points about 180 feet deep at least. On the opposite side of Greenland bergs are 600 feet under water, 1500, 1800 feet thick ; 480 feet out of water ; three or four miles in circumference. According to their shape $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, or $\frac{1}{7}$ is visible. They are like cliffs of chalk or gray marble streaked with blue and emerald green, and with darker colours caused by strata of earth, gravel, and sand. The banks of Newfoundland are often crowded with them, and some reach lat. 40°. At $\frac{1}{7}$ of 1800 feet above water, a stone in an iceberg might touch in 1543 feet.

The motion of icebergs and heavy ice is not much affected by the wind. When light drift is flying before a gale, and dancing on the waves, the iceberg seems to plough through it like a fixed rock, or a moving island crashing through ice ; but it is only a heavy float moving in the current, or stranded on the solid ground.

Information as to the denuding work of this ice-engine can be gathered from old accounts of arctic voyages only by searching for pictures, and for facts mentioned incidentally, and by drawing conclusions. Geology is but a well-grown infant science after all.

Scoresby looked on the icebergs which Lamont and Dufferin describe, as puny specimens of their class. Of land-ice work in Spitzbergen, Lamont first gave an estimate (p.) ; but if hills "crumble in the grasp of ice-rivers" on shore, the same engines must work faster when they go adrift.

Of Spitzbergen, Bear Island, and Jan Mayen, Scoresby gives excellent descriptions and comprehensible drawings. From these and from other authorities it appears that most of the high peaks are like the aiguilles of Mont Blanc ; they are pyramidal, conical, or pointed ; weathered peaks of the Λ pattern, with the structure of the rock picked out in lines of snow. This bare high ground consists of newly fractured rocks, and fallen fragments; and the tool which quarries the rock is the ice-wedge of frost. When the full power is on in winter, stones, rocks, and wood rive and split with loud reports. The stones so quarried follow the same downward path as alpine stones (chap. xii.) or Norwegian stones (chap. xiv. xv. xvi.) The hills are frost-marks, the peaks and glens tool-marks of land-ice. Snow-slides, névé, and glaciers, fill every hollow and corrie; we know now that they carry the quarried stones, and that rocks "crumble in their grasp." Incidentally, it appears that the glaciers are riven and crevassed, and like Swiss glaciers; for a sailor tumbled in and was only saved by his elbows.

The launching is described. The ice-cliff awash in the shallow sea, and the broken glacier adrift with its moraine in the Arctic Current, are so described as to call up pictures of the real thing which the writers saw; but nothing is said directly of the work which such an engine must do, when it goes afloat and moves with great velocity.

According to Scoresby, the Spitzbergen drift moved S.W. 100 miles in a month; 120 miles in 9 days; 182 miles in 13 days; 420 miles at 8½ per day. In 1777 a whole fleet of 9 Dutch whalers were caught on the 22d of June. They first drifted within sight of the Greenland coast about lat. 75½° N. By the 24th Iceland was in sight; by the beginning of October they had drifted to lat. 64°; and on the 11th the last ship was overwhelmed by the ice, and sank. Between 300 and 400 men were driven to the ice. On 30th of October they separated; the greater part took to the shore and tried to travel, while the rest floated on a field of ice to Statern Hook, where they took to their boats. A hundred and forty reached the Danish settlements, on the west of Greenland, near Cape

Farewell ; 200 died. The ship which lasted longest drifted from lat. 78° or 80°, to 62° southwards ; westwards from 5° or 6° E., to about 40° W. long. ; or about 1300 miles S., 43 W., in 103 days, at 12 miles a day.

The Arctic Current, with its floats, is an established fact, and its power at sea is formidable. As Scoresby says, "A body of more than 10,000 millions of tons in weight meeting with resistance when in motion, produces consequences which it is scarcely possible to conceive." But what is a single field to this stream of fields and bergs, in which a fleet of nine ships and their hardy crews were helpless as a swarm of ants adrift upon touchwood in frosty weather.

The thrust of ice upon ice, the thundering crash of iceberg against iceberg ; the power which crushes a ship like a hazlenut, with a substance which cuts like glass, mingled with sand, earth, gravel, and stones, and is 1500 feet deep, is surely an engine strong enough to work denudation on a large scale.

It everywhere appears incidentally that ice grounds on reefs and shoals, and sometimes it hangs for years near one place ; and the deepest ice carries cutting stone points, and sand for polishing the work. For the best of the old voyagers ice at sea was a terrible ship-destroying engine ; but so far they do not seem to have thought much of the consequences of the collision between hard water and hard stones on shore or under fluid water.

Ice-floats both on the eastern and western coasts of Greenland, from the highest known latitudes down to the Arctic Circle, appear to be of similar dimensions, and to have worked for centuries.

The earliest voyagers found ice-floats. About A.D. 986, a certain Icelander, named Thorgils, went to Greenland to join Eirik the Red, the discovever. An Icelandic saga tells the story of his voyage; and he found a land teeming with snowy Jöklen, and a bay surrounded by ice mountains in which the ship was wrecked. Then comes a long tale of suffering and disaster, with portents and marvels; and through this strange old saga there looms a cold picture of savage desolation—a glacier on land, frozen seas near the shore, floating ice on the sea horizon. When they sailed south in a new-built ship, at last they sailed between Jökulls on land, and ice-floats at sea. They had to lift their boat over ice; they found a broken-legged bear struggling in ice. In short, they found Greenland a thousand years ago like Greenland now. There is, however, some evidence of a sudden change in the climate of these regions within historic times. From the end of the tenth century, the Scandinavian colony founded by Eirik the Red grew and flourished, in spite of ice, till the end of the thirteenth. Then came a change for the worse. The last bishop was unable to reach the land for ice; and Eirik the Red found what he called a green land. What became of the colony is unknown; what the interior of Greenland may now be like is inferred. It seems to be a snow-heap, with green spots round the edge—a land upon which the banished Scandinavian glacial period has made a settlement by the help of the ice-fleet.

From Spitzbergen to Jan Mayen the current, laden with ice-floats, curves south-westward; it is from 100 to 150 miles wide. Near the shore are "insets" and "offsets" and local tides, which vary the direction; but along the coast of Greenland, from Spitzbergen to Iceland, the current moves like a still river-pool, with lines of froth curving and whirling as they float.

In 1784 ships in lat. 63° opposite to Iceland were beaten back by ice fifty miles from the coast. It is still, 1864, a problem whether the colony died of the black death or starvation; were slain by savages or survived to found a race of savage Scandinavians, who still people the unknown coast of Eastern Greenland; but ruins about Cape Farewell seem to prove that the old colonists perished.

In 1822 Scoresby sailed from Liverpool in search of whales and the colony; and a very interesting account of his voyage was published.* It was an adventurous voyage of discovery made by a keen observer well used to ice. He sailed north to 80°, and worked down the coast from Gale Hawkesland 75° nearly to 69°—the latitudes of Hammerfest, Alten, the Loffodens, etc., in Norway. About 80° the ice-floes were twenty to fifty feet thick in the open sea, and to the north was a floating continent. In lat. 74° Scoresby drove his good ship westward for a hundred miles through heavy ice to the coast. Along the eastern bounds of the stream was open water. In the stream, where ice had crushed ice, great broken plates were piled one above the other, till packs and hummocks rose thirty or forty feet. At the rate of $\frac{1}{9}$, this ice was about 270 or 360 feet thick, like bits of the chalk-cliffs of England adrift in the North Sea. Floes eight, ten, twenty, and thirty miles in diameter, moving S.W. at the rate of a mile an hour, or seven or eight miles in a day, were common about 70°, but near the land these masses stop and stick fast on the ground.

The coasts sketched by Scoresby show steep cliffs; something very like a volcanic cone, and glaciers in every hollow. The hills vary from 6000 feet to low lands, and their general height is about 3000 feet. Tke sea near the coast was open, but near the land great icebergs were set in ice-floats, like

* *Journal of Voyage to the Northern Whale Fishery*, William Scoresby, Edinburgh 1822.

stakes in a raft or irons in a plane. Those described were 100 and 150 feet high, so they were about 800 or 900 and 1200 or 1350 feet thick, according to their flotation, and many were aground.

If hard heavy solids, whose area is about 900 square miles, move a mile an hour, with rough points scraping the sea-bottom 1000 feet or 1500 feet down; the graving-tools which the Arctic Current moves south-west must leave deep tracks about lat. 71°, which corresponds to the North Cape of Norway, and the fjeld about Alten and Tana, above described (chaps. xix. xx. xxi.)

The land which Scoresby describes consists of strange weathered peaks, cones, and pyramids, and of low, rounded, "uninteresting" islands. They were uninteresting then, because the effect of glacier-work had not been recognised in 1822. The low lands seem to be "ice-tors" with "perched blocks." "Rathbone Island," in 70° 40′, had an insulated peak jutting into the sea, with a rock on the summit resembling the ruins of an old castle (p. 179). There was little snow on the steep hills, large tracts of rounded hills were bare; but there were very large glaciers in the glens and lochs. The heat on a sunny day was oppressive; plants and insects abounded; there were the bones of reindeer and other large creatures; hares and birds were shot; and there were many traces of men, huts, ashes, implements, and graves. Amongst rocks of the coal formation and beds of coal were boulders of granite and gneiss, and these were seen on floating ice.

In lat. 69° was a chain of large floating icebergs thirty miles long. There were about 500 adrift. Some were loaded with stones, and contained strata of earth and stones. One was covered as high as a ship's mast by the freight of glacial debris, so as almost to hide the ice. Another was calculated to weigh forty-five millions of tons. At fifty miles from the shore soundings were got in 1142 feet; so for fifty miles every projecting rock under water is liable to be grooved by the passage of floating islands of ice conglomerate as large as Arthur's Seat frozen into Mid-Lothian, and sailing south-west; except where local tides and cross straits vary the course.

For Scoresby's vivid description of the perils braved in this voyage, his book must be read.

On the 23d of August the "Baffin" off Greenland was between two great floes, which were rolling their edges against each other like a pair of crushing rollers, and they threatened to crack the good ship like a nut. About the same season, and in the same latitude, the writer sailed round the North Cape of Norway in a fishing-boat, without suffering danger, discomfort, or cold; he was out for two nights, and, except a few patches of snow on the hills, there was no sign of frost.

The coast which Scoresby left unexplored is still a blank on the last Admiralty chart.

Eastern Greenland then is as habitable as Sweden, so far as the sun's heat is concerned; but the climate is spoiled by a current of cold water. Ice excepted, the eastern coast described is like that of Scandinavia and Western Iceland. Is this Greenland "ice period" to be attributed to a general cooling of the earth; to some great astronomical change; or simply to ocean-currents?

In these latitudes, horizontal ice-grooves are made on the sides of fjords, at the sea-level on both sides; and in all depths to 1500 feet at least. At greater depths, the bottom may be covered with undisturbed loose drift, while the sides are bare stone scraped and polished. If Greenland were to rise 2000 feet, and banish its climate, it is easy to comprehend that two sorts of marks would remain. Horizontal marks for a height of 1500 feet; made by sea-ice, and having reference to the old coast-line; to tides and currents:—sloping marks made by land-glaciers sliding down the glens. One set would be conspicuous on hill-tops which had risen and on promontories which had become hill-shoulders; the other in glens which had held glaciers ending in fjords.

According to Scoresby's theory, the northern part of Greenland is a cluster of islands; if so they must be marked on the same principle.

A sound is supposed to communicate with Baffin's Bay, about lat. 70°, because an inset was there detected on the east coast, and because an outset exists about Jacob's Bight on the western coast. According to natives, whales killed on the east have drifted through to the west. This channel, if it exists now, is blocked by ice. The Esquimeaux have a tradition that the channel was open, and fear that it will open again, so as to let the east coast natives, whom they call savages, pass to their side. In any case, the land about the latitude of Hammerfest is closed, so that the questions of land or sea, strait or glen, remain open; but the whole coast must be ice-ground.

Of the interior of the country, nothing is certainly known down to lat. 60.° From specimens of rock taken from the east coast, and from icebergs near it, the country above 70° includes granites, gneiss, clay-slates, "primitive transition and secondary rocks," greenstones, syenites, and rocks of the coal formation; bituminous shale, slate coal, trap, porphyry, brown coal, etc.

In the geological notice of 1822, there is no mention of denudation by ice. Though many old geologists had then noticed ice-marks in the British Isles, the bearing of arctic phenomena upon these marks appears to have been overlooked.

At the end of Parry's *Voyages*, 1821-22-23-24-25, is a geological summary by Jameson.

Under the head of alluvial rocks he says—

"No extensive deposits of alluvial rocks were met with. The most striking objects under this head are outliers or boulders, or fragments of rocks spread over the surface of some of the islands. The surface of Igloolik, a limestone island, is strewed with blocks of primitive rocks ; the island of Neerlo Nakto, which is principally composed of limestone, is also strewed over with primitive blocks or boulders ; and in Amherst Island, in which greywacke and greywacke slate are almost the only rocks, rolled masses or boulders of granite, gneiss, and quartz rock are not uncommon."

This geologist mentions that water in the form of snow and ice abounds, and asserts that the boulders prove the passage of water over the land; but he does not mention glaciers and icebergs as transporting and denuding agents. It appears, however, that large perched blocks abound about Port Bowen and Cape York near the coast, and up to a height of 400 feet. They are numerous on hill-sides near Prince Regent's Inlet, but from fourteen to sixteen miles inland they are smaller and rare. The nearest known fixed rocks of the same kind were 100 miles away in many cases.

It further appears that coal-beds prove the former existence of a climate fit for trees, which cannot grow anywhere near the same latitudes now.

In Franklin's *Travels to the Shores of the Polar Sea*, 1819-20-21-22-55-26-27, are numerous passages which forcibly describe the appearance and work of heavy ice.

At page 143, vol. ii., is a drawing, by Back, of a stranded berg : on it they remarked large heaps of gravel fifteen feet above the surface of the reef, "which must have been caused by the pressure of the ice."

At page 256, vol. ii., ice-floats in latitude 68° 32′ N. are described. They grounded in fifty-four feet of water, and rose five or six feet above the surface. They were drifting in a tide which ran three or four miles an hour, and they rolled horizontally along the coast, as a wheel rolls vertically along a road. Their sudden collision reminded the party of the poet's description of Scylla and Carybdis. A boat was caught between a floe and a piece that lay aground; it was lifted out of the water, and seriously damaged.

It is evident that a mechanical force sufficient to lift and crush a boat and a fleet of ships, might also lift and crush an equal weight of any material of equal strength. As a wheel crushes small stones, and makes a rut, so an ice-raft rolling on a coast must also crush stones and make ruts. Horizontally, all rollers work on one plan.

These volumes contain a simple narrative of gallant exploits performed during years of hardship, endurance, and steady toil; they are very interesting, and very instructive. In the geological notice at the end all the usual marks of glacial action—rounded rocks, boulders, etc.—are well described; but no mention is made of ice as a geological engine. In the geognostical observations these passages occur:—

"With regard to the large rolled blocks which are so plentifully scattered over the surface of some countries, and which have been considered to have been deposited by the waters of the flood, we have no remarks of moment to make."

* * * *

With regard to the large blocks which are strewed over "barren ground," it is said—"Their angular forms, and their resting-places, often on the very summit of hills, militate against their having travelled from a great distance."

The eminent discoverers whose names are familiar to all who admire daring and endurance, travelled before geology had taken the shape which it now wears; but their accounts of North America show a country "like Sweden," with all the usual marks of ice and ice-floats.

In the geological notes attached to Banks's *Journey to the Mouth of the Great Fish River*, 1833-34-35, there is no mention of ice as a geological agent, though drawings and descriptions in the narrative show a country strewed with granite, boulders, and beds of sand; salt plains, and other marks, which suggested an old sea flowing over these northern regions of North America.

Every book about arctic travel describes an engine of enormous power busily working upon the coast.

The western coast of Greenland is like the eastern.

In Ross's *Voyage to Baffin's Bay*, a coast is described in latitudes which correspond to those of the open sea between Spitzbergen and the North Cape. *August* 17*th*, 1819.—The ship was amongst bergs, which were aground in 300 feet, in a current moving a knot an hour. The sea-bottom was there exposed to the force of a graving-tool as high as Shakespeare's Cliff at Dover, driven by a stream as strong as the tide in the English Strait. Lat. 76° 12½′, long. 69° 54′ W. The coast was a succession of high cliffs, beyond which snowy mountains appeared; and every inlet was filled with glaciers, some extending far out to sea.

Here is an August Greenland landscape, to compare with one in Spitzbergen or Norway:—

"While the moon was in sight, she had the appearance of following the sun round the horizon; and while these bodies were passing in azimuth along the tops of the mountains, the snow which covered them, and which naturally had a yellow tinge, had the lustre of gold; and the reflection of these upon the sky introduced a rich green tint, so delicately beautiful as to surpass description. On the other hand, the rays of the sun, darting over the tops of the mountains, came in contact with the icebergs, which appeared like as many edifices of silver, adorned with precious stones of every variety."

Lat. 75° 25′ N. At the head of Baffin's Bay, now promoted to be a sea, were vast numbers of very large icebergs, most of which were aground in 250 fathoms (1500 feet). The velocity of the tide was half a mile an hour. Each valley held its glacier; each fjord was a great rock-slip, with icebergs ready to be sent adrift, sliding seawards to join the floats. The sea is like one great glacier, whose crevasses are lanes of clear water, which open and close, mend and break; while the mass drifts continually on its way to the region where ice melts in sunlight.

Of the coast of Greenland—in lat. 75° 25′ N., long. 60° 36′ W., Ross says, *July 24th*—"We were now twelve miles from the land, which was everywhere covered with ice, except a few places near the shore, where the sharp top of a rock appeared occasionally piercing through it; the interior being an entire smooth but high mass of ice."

The ships were beset in floating ice; but here was the névé from which the bergs came. Soundings were got in 1884 ft.; bottom, mud and stones; temperature of mud, 32°; and of water at the surface, 34°; air, 55°; sun obscured.

The inhabitants of this region, according to Ross, supposed their own people to be the only inhabitants of the universe, and the rest of the world to be ice. They inquired whether the Englishmen and their ships came from the sun or moon, and generally they were amphibious, copper-coloured, corpulent, ignorant mortals, dressed in skins, who walked chiefly on frozen water, and only trod upon bare ground occasionally in summer.

In latitude 72° 30′, the corresponding sea to that which washes the Norwegian coast about the North Cape, they passed through a third barrier of large icebergs, which were aground, in vast numbers, in 63 and 100 fathoms (378 and 600 feet). In lat. 70° 54′, on the coast which corresponds to Alten in Norway (in June 29th), the whole sea was cumbered with ice drifting fast in a calm—the large bits grounding, the small bits helping to drive them on.

The prospect from the masthead was interminable ice, melting and breaking up.

In lat. 68° 10′, which corresponds to West Fjord, in Norway, on the 9th of June, Ross landed on an iceberg which was aground near two small islands. The natives said that it had been there since last year. Various stones, and a stratum of gravel, were found in it, and several rare birds were shot. The tide ran about half a mile an hour, the ebb southwards. From marks on this grounded float it appeared that the water had been higher, so it had run aground. Here was sea-ice doing glacier-work, for a year at least, grinding slowly north or south, if it moved with the tide, and dropping its cargo where it lay.

The whole coast about Disko, near the latitude of Tromsö, was frozen in, and the sea was thick with heavy ice, swinging up and down, north and south, with the tide, and moving with the ocean-current. There were flat pieces of pack-ice, "full as large as half an acre, drawing from five to ten fathoms;" ice-planes, fifty to sixty feet deep, smoothing sunken rocks so far under water. There were icebergs afloat and aground in a tide running a knot and a half an hour; hard points working at all depths, from 1500 to the surface, according to their several dimensions; and they all worked up and down the channel in which like engines have floated with the tide and current ever since the days of Eirik the Red and Thorgill. The lithographs of remarkable icebergs in 70° 45′ N. make the ice-cliffs seven times the height of the ship's masts; but lithographers were, and still are, apt to improve original sketches, and to put life into dull landscapes. One of these ice-mountains to which the ship was moored suddenly got afloat, and was carried with great rapidity to the west; it soon grounded again. By taking a mental dive, it is easy to see the result of the bump and scrape which must have resulted from this movement, though it was but a step in this endless dance of ice-islands. On this voyage Ross saw his first iceberg on the 26th of May, in lat. 58° 34′ N., long. 51° W. It was off Cape Farewell, in the latitude of Götheborg, Christiansand, and Inverness, Skye and North Uist. It appeared to be 40 feet high and 1000 long, 360 feet thick; or about as big as a slice of the cliffs above Portrigh in Skye.

About the Arctic Circle 66° 22′, on the 7th of June, icebergs were seen which may have been somewhere about 2275, or even 2900 feet thick. They were 1200 long, 325 feet high. At one-ninth this berg would touch at 2600 feet: at one-seventh in 1850.

There are many islands on the corresponding Norwegian coast which are about these dimensions above water. If the Norwegian islands were grinding the Norwegian coast, they would do notable work in a thousand years. "At 9, seeing fixed ice from the masthead extending from the land, we hauled to the northward by compass—that is, making a west course—and steered between the grounded icebergs among packs and streams of ice. One of the icebergs was 300 feet high, and 1200 feet in length: a torrent of water was running down its side."

So the western coast of Greenland, which corresponds to the western coast of Norway, is continually worn by floats which work at all depths between 2000 feet and the surface. They are grinding in shallows, and filling up deep hollows with drift sorted in water. The eastern and western coasts, according to Scoresby and Ross, are alike so far.

Modern arctic explorers had the works of the exponents of glacial action to refer to, and their works give direct information as to ice-work.

Kane, in his account of his arctic explorations in 1853-54-55, gives picturesque descriptions and good engravings of ice and ice-work. He compares Greenland glaciers, in the latitudes of Spitzbergen, with Swiss glaciers; and refers to well-known works published between 1840 and 1850. For a striking picture of land-ice of enormous dimensions, Kane's descriptions of the great Humboldt glacier should be read. This sea-face is an ice-cliff 300 feet high, and it joins Greenland to America. It is a great table-land of ice sliding into the sea and over islands, and there breaking into icebergs, which must touch in 2000 feet. Amongst these the wild Esqumeaux and their dogs hunt bears upon the ice-crust.

The carrying power of bergs, and their birthplaces, are equally well described; and to these another tool is added by Kane.

The sea-ice which forms about lat. 79° is of the pattern described by Martens, Scoresby, and others, but of still larger dimensions. Ice-floes are forty feet thick; pack-ice sixty feet high. Bay-ice is so hard and sharp that it cuts through boats like a saw; all ice is so hard that it is aptly compared to granite. For protection the boats were covered with tin. In the Clyde, near Glasgow, young ice so wears iron steamers that they are forced to stop when the river freezes. The strange ringing, tinkling, crunching, clattering sound of small plates of broken ice adrift in a stream, may be heard even in Scotland occasionally. From this miniature "pack," it is easy to rise to the larger drift which Kane so well describes. Here is the same rolling engine which Scoresby and Franklin also describe :—

> " I had hardly got back to my boat before a gale struck us from the north-west, and a floe, taking upon a tongue of ice about a mile to the north of us, began to swing upon it like a pivot, and close slowly in upon our narrow resting-place. At first our own floe also was driven before the wind ; but in a little while it encountered the stationary ice at the foot of the very rock itself. On the instant, the wildest imaginable ruin rose around us. The men sprang mechanically each one to his station, bearing back the boats and stores ; but I gave up for the moment all hope of our escape. It was not a nip such as is familiar to arctic navigating ; but the whole platform where we stood, and for hundreds of yards on every side of us, crumbled and crushed and piled and tossed itself madly under the pressure." All this " in the midst of a clamour utterly indescribable, through which the braying of a thousand trumpets could no more have been heard than the voice of a man."

That was the big engine ; but the very same scene was enacted upon the Serpentine, when a thaw in 1864 set miniature floes adrift : they made marks in the gravel along the shore.

The geological engine, to which Kane calls special attention, is one which may also be seen at home. The ice-foot of the far north is but a folio copy of stranded ice frozen on the shore of every tidal stream during every English frost ; but a winter temperature of 70° below zero writes ice-records on thick slabs. Bergs 300 feet high, and probably more than 2000 thick ; fjelds, floes, and pack forty and sixty feet thick, frozen into one raft, hard as granite, and reaching from shore to shore, is an engine of vast weight ; and it is moved by tides which have the whole power of the ocean behind them.

The saw, which is hard enough to cut iron in motion, is hard enough to cut stone when it moves ; and this saw is of large dimensions. It is saw, crushing-roller, lever, and shears combined.

Falling with every ebb, the raft, which covers a strait about the size of the Irish Channel, grounds, and the edge breaks. The flood lifts it, the frost mends it, and water cements the beach into one solid mass. Ice-wedges shower down new stones from cliffs overhead ; small glaciers hurl down moraines ; Jack Frost shakes his bag of snow-feathers, and they gather and slide and fall upon the shelf. The ice-piers grow from beneath, and the raft tends to prize up the wall ; and so at last the winter's cold and the force of the tide build a terrace—a broad flat road, somewhat higher than high-water mark, and with a steep broken face towards the sea. The dimensions described by Kane are about equal to the Liverpool quays and landing-stages ; and a like wall is built round the coast of Greenland, round Spitzbergen, round great part of the polar basin, and wherever there is ice in a tideway, and cold enough to make water-cement.

This ice-foot is described as a geological engine, almost equal to a glacier in power. Where built by a tidal wave of thirteen feet, it is twenty feet high. It grows in winter ; encroaches on the floes ; drives a ship and her ice-dock gradually away from the land. It is a machine able to move stones seawards at a slow rate. The woodcuts show a white wall, studded with large stones. It is an ordinary beach and talus-heap, packed and moved by the cold end of the caloric and gravitation engine of the world.

In spring, great slices of this ice-wall break off and move seawards, where the beach may be seen in the ice-raft. When the rafts break up, they sail south with the current, and the wandering beaches depart with them, and sail till they sink. If a slice of sea-beach breaks adrift from the floe which helps to float it, and sinks where water is warmer than the freezing-point—for instance in the mud above mentioned—the wandering beach, freed from its ice-bonds, would become a ridge of stones, sand, clay, and other ice-chips, like "osar" and "kames," which are found in Scandinavia.

If the ice-foot melts on the ice-rubbed slope, at the sea-level, where it is built, it will become a drift-terrace, of the pattern which is so common on the shores of Greenland at higher levels.

Kane's drawings, and the cuts (p.), seem to represent the engine at work in Greenland, and tool-marks and chips in Northern Scandinavia.

At page 81, vol. ii., Kane uses these same marks to fix an old sea-level. He counted forty-one distinct ledges, or shelves of terrace, rising 480 feet above the present sea in Northern Greenland; and at 1100 feet was a syenite boulder, perched on coarse sandstone. By these, and other marks, a rise in the north is fixed—in Norway, Spitzbergen, Greenland, and the Wellington Channel; and apparently the same marks are found throughout North America. In Southern Greenland, according to the best authorities, land is sinking.

Rising and sinking of land, on a vast scale, goes on at the source of the arctic currents, which so chill the climates of other lands.

The temperature of the ice-crust is arranged in layers, like the temperature of the rest of the crusts which make up the surface of the globe.

In the air the warmest layer is below. In mid-winter, in lat. 78° 50′, Kane found minus 30° at the surface of ice, minus 8° at two feet, plus 2° at four feet, plus 26° at eight feet, and fluid water below. The warmest layer of water is below when the whole column is near the freezing-point; the mud was 32°.

The glaciers yielded an uninterrupted flow of fresh water throughout the year; so a temperature of 32° is buried in ice, where air was as cold as minus 70°, and the mean of the year minus 5°.

Still lower, under sedimentary beds of limestone and sandstone, is a temperature which boils water; for there are hot springs in Greenland: and lower still, there has been a heat sufficient to melt greenstone, lava, and basalt.

Under all the snow and ice, and all the crusts of sedimentary and igneous rocks, some power is raising one end of this island, and lowering the other, as the tide lifts and lowers the ice-crust in the sea.

These are some of the facts which have been gleaned from the works of men who were travellers; indeed, the merit of collecting them is theirs.

The object here aimed at, is to show that these facts hang together; that all the mechanics of geology belong to one engine; and that the Arctic Current is but a small part of it.

Following the curve of the stream from the point where Scoresby left it, take Lord Dufferin's vivid description of it about a hundred miles from the Greenland coast—p. 202, *Letters from High Latitudes.*

"It was shortly after this that, as I was standing in the main rigging peering out over the smooth blue surface of the sea, a white twinkling point of light caught my eye about a couple of miles off the port bow, which the telescope soon resolved into a solitary isle of ice, dancing and dipping in the sunlight. As you may suppose, the news brought everybody upon deck, and when, almost immediately afterwards, a string of other pieces, glittering like a diamond necklace, hove in sight, the excitement was extreme."

And then follows a picturesque description of a fresh, vivid, first impression, expressed in simple language by a well-educated gentleman, who appreciates beauty and fun, can face danger, and write English.

The island of Jan Mayen is about the latitude of the North Cape of Norway, where there are old ice-marks in plenty but Jan Mayen often has "ice all round."*

" Behind that veil of mist," writes Lord Dufferin, " I know must lie Jan Mayen."

" A few minutes more, and slowly, silently, in a manner you could take no count of, its dusky hem first deepened to a violet tinge, then, gradually lifting, displayed a long line of coast, in reality but the roots of Beerenberg, dyed of the darkest purple ; while, obedient to a common impulse, the clouds that wrapt its summit gently disengaged themselves, and left the mountain standing in all the magnificence of his 6870 feet, girdled by a single zone of pearly vapour, from underneath whose floating folds seven enormous glaciers rolled down into the sea ! Nature seemed to have turned scene-shifter, so artfully were the phases of this glorious spectacle successively developed.

" Although, by reason of our having hit upon its side, instead of its narrow end, the outline of Mount Beerenberg appeared to us more like a sugar-loaf than a spire—broader at the base and rounder at the top than I had imagined—in size, colour, and effect, it far surpassed anything I had anticipated. The glaciers were quite an unexpected element of beauty.

" Imagine a mighty river, of as great a volume as the Thames, started down the side of a mountain, bursting over every impediment, whirled into a thousand eddies, tumbling and raging on from ledge to ledge, in quivering cataracts of foam ; then suddenly struck rigid by a power so instantaneous in its action that even the froth and fleeting wreaths of spray have stiffened to the immutability of sculpture. Unless you had seen it, it would be almost impossible to conceive the strangeness of the

* P. 213, Letters from High Latitudes.

contrast between the actual tranquillity of these silent crystal rivers, and the violent descending energy impressed upon their exterior. You must remember, too, that all this is upon a scale of such prodigious magnitude that when we succeeded subsequently in approaching the spot, where, with a leap like that of Niagara, one of these glaciers plunges down into the sea—the eye, no longer able to take in its fluviatile character, was content to rest in simple astonishment at what then appeared a lucent precipice of gray green ice, rising to the height of several hundred feet above the masts of the vessel."

This masterly word-picture is taken from a distance at which the grandeur of the entire local system could be seen and understood by one able to appreciate it; but the island in the Arctic Current is but a rubbish-heap in the stream.

It is a slumbering volcano, rising in the midst of a current which is wearing it down. It is stopping floats and gathering drift, like Bear Island. Every big stone does as much in every freezing stream, but this island gathers floating ice in a solid rampart which sometimes stretches northwards and southwards for hundreds of miles. Floats gather up stream on the weather side, strike, and stop; and down stream in the lee of the mountain, they whirl round in the eddy out of the stream into the shelter, and freeze again. Sometimes the whole fleet departs and the coast is clear.

The snow-clad ridge is a condenser thrust from below far up into polar and equatorial currents of air, to catch aqueous vapour on its way north, and so it distils glaciers and icebergs of its own, from clouds and mists which cold icy seas condense from chilled air. Jan Mayen has a local system of glacial action, but it is in a general system of far greater size. A stranded turf gathers a heap of snow while the stream flows past it, and so does Greenland between the arctic currents.

For all the cold Jan Mayen is a heap which once burned and glowed. "The base is a network of trap dykes, which shoot in every direction through the scoriæ and conglommerate of which the cliff seemed to be composed.*

Scoresby found one crater smoking.

Probably there are floods of molten lava still seething beneath the crust of hardened rock, on which stands the mountain with its outer crust of hardened water, and the cold fluid sea with its ice-crust sailing back to the place whence icebergs flew as clouds.

If this mountain were freed from all its coverings of mist, snow, ice, and water, and left bare like hills near the North Cape of Norway, the marks left by moving ice upon solid rock would register the direction of movements, and prove the existence of forces which now cause them.

The Norwegian hills seem to record the passage of an arctic current. If this island becomes a mountain in the midst of a fjeld there will certainly remain a system of ice-marks to record the facts.

One system of grooves radiating from the top, dug out of the sides of the cone by local icebergs, will record the movements of the local system whose centre of motion is the watershed of this small district. Like evidence will record the movements of the system whose centre of motion is the North Pole. Horizontal grooves on the ends and sides of the island will record the passage of floats which strike the coast, and these may extend from forty or fifty feet above high-water mark, to 360 or 450 below low-water mark—for these are the dimensions of the floats described. There may be scratches, grooves, and glens at any depth, short of the extreme limit at which Greenland icebergs ground; and that has been stated at 2000 feet at least.

* Letters from High Latitudes.

The direction of marks made by floats must coincide with that of the movement. The diagram (p. 127) will serve for illustration, and any bridge will show the movements of floats in a stream. In this case the floats move south-west, strike the north-eastern end of a long ridge, and gather at the south-western end in the eddy; and they rise and fall with the tide. The shape of the island is a long ridge, with the longest axis pointing up stream N.E.

The greatest force is applied at the north-eastern end, and most frequently and continuously within ten or twelve feet of high and low water mark, and along the sides. So the engine tends to shave off the stone which projects above the sea. There must be a worn shelving bottom and a notch worn in the hill, at the foot of a cliff which is constantly undercut by ice-saws, and crushed by rollers.

Few stones can rest in shallow water at this end, or at the sides; but if any stones are wrecked on the end of the ice-pack, they may sink at the weather end where water is too deep for ice to get at them. At the south-western end, where the pack hangs in the lee, the rock must be ground; but it cannot be shorn and ground and shaved off in the same fashion at the sheltered end; and loose stones may there rest, unless winter ice picks them up and carries them off. If this island rises, and the climate changes to the Norwegian scale, it will be a fluted cone, with terraced sides, and with piles of stones dropped in the lee. The sea-marks will be as plain as the marks of seven great glaciers which Dufferin and Scoresby describe and depict.

If the sea-bottom and the island rise together, the shape of the Norwegian fjeld will be copied.

At the top are weathered peaks of the Λ pattern, with terraced sides and grooves and shelves of the L pattern to mark the old sea-level. North-east and south-west will be the stone cargoes of wrecked floes. Round the hill will be moraines shed by the glaciers ; and stones may be scattered in any direction, for light ice drifts with the wind.

The sunken plain above which this cone now rises is at the outer edge of the ice-stream, and is probably strewed with light drift, sand, clay, and occasional stones. If it rises above the sea, and is washed and furrowed by new-born rivers, these will start from the ridge Λ; follow the course of the glaciers in the grooves U ; fall over the steps L; and then follow the run of the ocean-current north-east or south-west; for the ocean-stream must furrow its bed like any other stream.

In the bed of the glacier U the water-stream will cut its own mark V Y. In the edge of the old L shelf a fall will work backwards. In the bed of the ice-slide ⟍ it will dig a notch L. But when the rain-stream gets to the land, which is now under the sea, it may find hollows made by the ocean-river; and so the course of the new river and the form of lakes and islands will mark out the course of the old ocean-current which shaped the sea-bottom, and marked the shores.

As air-streams bearing clouds flow over mountains and drop loads of snow and hail, so ocean-streams now flow over these sunken lands, and drop their loads of stone and sand from ice-floats. Where the air is chilled the water-load falls; where the water is warmed it drops the load which it gathered where it fell on shore.

There will be two separate sets of marks about Jan Mayen, if the sea-bottom rises—marks of "weathering and land-ice ;" and marks of "sea-ice" and waves; tool-marks, chiselled, scored, sawn, and hacked ; scratched, rubbed, and broken out of the rock—marks of denudation. There will also be marks of deposition, "perched blocks" dropped somewhere on hill or hollow; "glacial drift," "boulder clay" made of washings and stray stones; "osar" and "kames," long ridges and points like those which are found in every dry river-bed; and wandering beaches dropped by the ice-foot; "trains" of stones dropped from a moving iceberg, and marking its course from N.E. to S.W.; "motes," "duns," mounds of rubbish shot bodily into the sea from a passing or stranded berg; "moraines" formed under water, as well as "moraines" formed at the end of glaciers which do not reach the sea.

The bed of the sea at low tide will show the shape of the land under the waves about Jan Mayen. Streams do similar work on various scales. To learn the way in which denudation and deposition go on near the Arctic Current, between Spitzbergen and Iceland, it is but necessary to study nature and books at home, travel with open eyes, and think.

CHAPTER XXV.

DENUDATION 17—FROST-MARKS 15—LAND-ICE 14—ARCTIC CURRENT 3—FLOATS 5—ICELAND.

CLOSE to the stream which has been followed thus far on its south-west course, lies Iceland. It is about the latitudes of Torneå, Quickjok, and Bodö; Archangel, Wasa, Umeå, Trondhjem, Tann Foss, and other places mentioned above. It is a block of land as large as Ireland; the Gulf Stream runs foul of it, and the Arctic Current passes it on the west. It is a good station for watching the effects of ocean-currents on climate.

Iceland is easily accessible; steamers now run from the Firth of Forth in a week, and in summer the voyage is easy and pleasant. The first striking feature is the unusual outline of the hill country.

The first land made is the Öræfa. It is a mountain 6241 Danish feet high, and the highest land in the island. From a distance of sixty miles, it is clearly seen on a fine day, and the shape is that of a great white dome. It is the snowshed of a local glacier system called the Vatna Jökull, whose base is as large as Yorkshire. River-glaciers which flow from it are seen to the right in crossing Sprenge Sandr northwards. On that side they flow out of hollows between strange black peaks and volcanic cones; for the works of fire and frost, of denudation, deposition, and upheaval, are mixed in this desolate tract.

The system rests upon active volcanoes, for smoke and fire broke out amongst the ice in 1862. The smoke was seen by a party of Icelanders, who tried to cross this great frozen sea of land-ice ; but they were forced to abandon their attempt, for they found no grass for their horses within many miles of the snow-field. They described the place where they turned as a desert of stones and black ashes, wet and frozen, with a great rolling white sea of snow and névé, stretching to the horizon before them. It is said that this snow-tract has been crossed and recrossed on horseback. In 1861 an attempt to scale

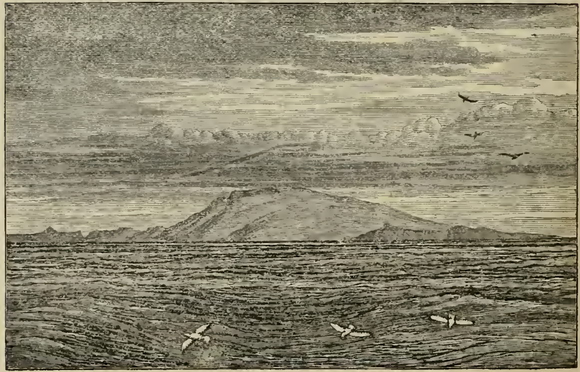

FIG. . ÖRÆFA. July 52, 1862—Morning.

the Öræfa was made by Mr. Holland, who published an account of his trip through Iceland in the book of the Alpine Club.* The eastern and the northern side of the mountains, and the skirts of glaciers which flow from it in that direction, were seen by Mr. Holland from the eastern coast, and they are seen from Krabla in the north.

As the steamer nears the coast, the snow-dome is seen to rest upon a foundation of dark rocks, which would seem to be sharp peaks from the coast below them. Low volcanic cones, and small hills, whose shape is characteristic of the action of fire, fringe the Öræfa, and can be made out with a good telescope. The woodcut is from a sketch made under favourable circumstances; and the form was carefully copied more than once, as the steamer approached and passed to the west. This system is a great snow-dome, like that on Mont Blanc, but planted on a lower base, in a higher latitude. It is far larger than anything of the kind in Europe.

It was seen at 4 A.M. on the 25th of July, at a distance which the sailors estimated at more than sixty miles; and in passing to the westward, it kept the same general form for an angular distance of about 45°. The snow-dome shone in the warm yellow light of the newly-risen sun, and seemed to sparkle on the dark blue sea horizon. Above it, hung a cloud-map of the cold country; the tent of vapour which the glacial period in this tract was weaving in the damp air of the warm Gulf Stream. Other clouds hung in the clear, calm, hard, bright morning sky, to show where other snow-systems were still hidden under the rolling swell of the "Spanish waves;" and soft-looking, downy, long-winged sea-birds, swung through the air, almost touching the spray of the steamer's bows, as she plunged on her way to Iceland.

The pattern is the same as that of the snowshed on Bodals Kaabe (Fig. 39, p. 204).

As the steamer works on to the northwards, more hills of the same pattern rise. Fig. , p. 416, was sketched from a distance estimated at about forty miles. The cluster of snowy domes which thus rise to the west of the Vatna Jökull, and to the east of Hecla, cover a district of hidden fire. Small black specks on the snow are seen to be the edges of smothered craters when a powerful glass is brought to bear upon them ; the coast-line is a succession of small cones and craters. Skaptafells Sysla, the district thus covered with snow-domes, was the scene of one of the most famous of modern volcanic eruptions. A mass of matter, calculated to be equal in dimensions to Mont Blanc, was ejected from the mountain; great glens were filled to the brim with lava, the sea was cumbered with rubbish, the air was thick with volcanic dust, and the face of the country was changed. But for all that, Eyjafyalla, Myrdalls Jökull, and the rest of the cluster of domes now

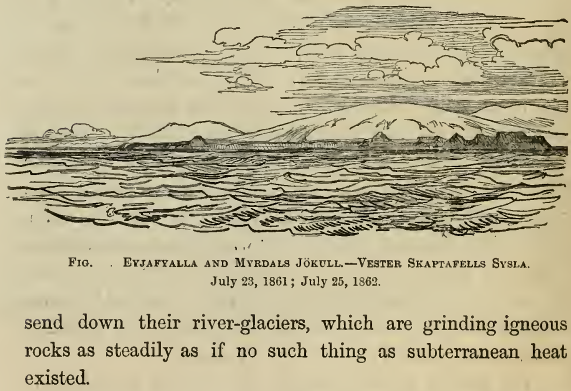

FIG. . EYJAFYALLA AND MYRDALS JÖKULL.—VESTER SKAPTAFELLS SYSLA. July 23, 1861; July 25, 1862.

send down their river-glaciers, which are grinding igneous rocks as steadily as if no such thing as subterranean heat existed.

As the sun rose and the steamer advanced, the air seemed to thicken and the hills to recede; the clear sky was left behind, and the gray sky rose. The tent of cloud seemed lower, and its rugged edges hung fluttering about the high tops, drifting slowly along, and casting blue shadows on the white world beneath. Right ahead, to the west, was the clear hard sea-horizon, with a line of bright sky, against which rock and cloud, hill and island, rose as the vessel went panting on in the bright warm sun of noon.

At sunset the strange volcanic shapes of the Westmanna Islands glowed astern, as if they were still red-hot, and the western sky and the calm sea and the hills ahead were one blaze of orange and purple, and gold and fire. Myriads of birds screamed in the warm summer air of the northern night, and Britons and Danes and Icelanders sat round a bowl of punch, and sang till their throats were sore.

As the steamer thus coasts along on a fine clear calm day, the mountains pass in review. The great snow domes of the Öræfa, Eyafjalla, and Myrdals Jökull are seen to be stratified snow-heaps which have broken away in places round the edge, leaving tall cliffs of bedded snow. The glass shows the section, and it consists of a white snow formation resting on a dark brown igneous formation of a similar shape. It is like the Irish coast, near the Giant's Causeway, where beds of chalk and beds of trap are in contact. But the snow is pushing on over the edge of the rock, and it breaks and pushes the broken edge down hill. Beneath these compound cliffs are talus-heaps of snow and stone.

From the lower edge of this upper region stream long slender spurs of blue ice, discoloured with dirt, moraines, and volcanic dust. These are about ten miles long and one wide, or in that apparent proportion. They are true glaciers broken and fissured and laid in hollows, and some of them nearly reach the sea. Without a good glass they might pass for dirty snow-wreaths, but they are as big as many Swiss glaciers, and have a larger névé.

The coast-line is a plain of mud and sand at the foot of an old cliff, an L shelf dug in the hills of bedded igneous rock by sea-waves. On the low plain are farms and cattle, above the cliffs there is little grass to be seen. Between the cliff and the snow-line is a wide desolate belt of stone and sand, lava and ashes, over which three or four ice-rivers stream. At Solheimer one of these, after a straight course of some ten or twelve miles, tumbles through a gap in the cliff, and becomes a conical glacier like that of Fjærland, resting on a broad sea-beach. There it changes into a muddy river, which spreads till it is nearly as broad as it is long. The terminal moraine of this glacier is the delta of the river; the glacier itself is a cover for running water; so the work done partakes of the nature of Moraine, River Delta, and Sea-beach.

In passing thus along the coast on a bright clear day with an excellent map and a good telescope, these great local ice-systems are as plainly seen as models; their shapes can be copied and their movements understood. Their work; the marks which they are engraving and the chips which they are making, carrying, and packing, are as easy to understand as are their forms.

After passing the Westmanna Eyjar these ice-domes are left behind. They give place to a wide open strath, in the midst of which rises the cone of Hekla.

There are no glaciers upon it, but the crater was full of hard snow on the 10th of August 1861. Late in the summer there is no snow, for the ground is hot at the top. The névé had formed ice-bridges by melting below, and the sun was melting it above. The snow was sinking rapidly into the cone of hot ashes, and it was hard to find enough of water to drink. A certain subterranean temperature coincides with a glacial period, and with glaciers reaching to the shore on the south and south-eastern coasts; but a higher subterranean temperature melts the ice on Hekla.

The scene of the Njäl Saga is one vast plain of sand and mud, washed down by streams of water, and packed in the sea. It is Sea-beach, Delta, Moraine, and Cinder-heap in one.

By following rivers which enter the sea near Hekla, a way leads north-east over the island, and that watershed is clear of snow in summer. It seems to be a pile of drift.

The next and last glacier-system on the south coast is at Snæfell. It is a cone of ice poured over a cone of lava and ashes, and set upon the end of a long peninsula. Fig. 18, p. 85, was sketched from Reykjavik, and it shows the form. These glaciers must date from the last eruption of the volcano; so their work would give a measure of time, if the date of the eruption were known.

In the centre of the island are several large local systems. Hofs Jökull is to the west of the Öræfa, and to the left in passing north-east over Sprengisandr. It is a great cluster of rounded snow-domes, from which broad ice-floods sweep every way. There is nothing of the kind in the Alps. One of these broad sheets, Arnarfells Jökull faces the Sprengisandr for thirty miles. A few dark rock-peaks stand up near the edge, and the ice splits above, laps round the base, and joins below, like water flowing round a stone in a fall.

These rocks seem to be remnants of bedded trap strata, the rest of which have been ground away by this white sea of ice. They resemble hills in Sutherland, which are quoted as examples of extensive denudation; and one black rock in particular is exceedingly like Suilbheinn. According to the Icelandic meaning, the name is descriptive, for Sul means pillar. The marks which this kind of glacier makes must radiate from the snowshed like the marks in the diagram, p. 192. Lang Jökull, further west, is another system of this kind—ice poured over a long ridge and hiding it completely;

but the snow-surface is varied by hill and dale, and the snow-cover breaks here and there to show black broken cliffs upon which the white snow-beds rest.

Ok Jökull is a dome of snow on a base of bedded igneous rock. Eyriks Jökull is of the same pattern, but it is smaller than the rest, easily seen and understood, and a good type of a local ice-system at work.

It consists of snow, névé, and ice ; dome and stream.

Here is a description of it copied from a clever pamphlet called, *A Tour Twenty Years Ago*, by Umbra.*

The next day was the most momentous in all our journey. It was put to long debate whether we should attempt the ascent of Eyriks Jökul, a mountain which had never been ascended by foreigner or Icelander. The reasons assigned in favour of going up were various.

M'Diarmid, being by nature and constitution a sort of Spartan, was in favour of anything that entailed fatigue or endurance. Another said Eyriks Jökul was the Key of Iceland, and it would redound to our glory. A third remarked that it would be a jolly lark. Mr. X—— was decidedly adverse to going up. He observed that in case we met glaciers, we had no ropes and no hatchet, and he made some incoherent remarks about a mountain in Mexico. As Umbra, I was ready to go or stay. At last it was resolved by a large majority to make the attempt ; but what with bathing and breakfasting and debating and preparing, half the day was consumed, and it was eleven o'clock when we started. We then rode as quickly as we could up the valley, having constantly to ford the river, and in two hours we came in full sight of that monster Eyrik Jökul. His appearance and shape are peculiar : a scarped perpendicular jet-black precipice, surmounted by a dome of snow—the latter, seen from below, like the back of a great fish, or the convex surface of a dessert spoon. For another hour we rode over the rough debris of lava, enlivening the way by killing two unfortunate wild swans whose wings had not grown enough to fly, and who foolishly deserted their native waters to run up the rocks, where they fell an easy prey. At one spot it seemed our progress must be stopped, as we came

* London, 1863.

to a torrent that ran through steep rocky banks, and we in vain searched for a place to cross. At last we all dismounted, and our horses one by one were made to leap down a place which would shock the nerves of a goat. To my surprise, they none of them broke their legs, and after witnessing this feat I could believe anything of Iceland ponies. We left our ponies at the foot of the precipice. We had reconnoitred the hill pretty well, and ascertained that this was the only spot where the ascent of the precipice was practicable. At it we went—the heat was now intense—the loose lava crumbled under our feet; but after an hour the cliff was scaled.

There was now before us a level plain—which of course had been invisible from below—of snow and lava mixed, a mile and a half in extent; and above rose the great snowy dome. The level plain we soon walked across, and stopped ten minutes to lunch. And then commenced that dreadful climb, "il modo ancor m' offende," the recollection of it is still grievous to me; no glacier, no crevasses, no danger, no excitement, but sheer hard fatigue. The snow, instead of being frozen hard as we anticipated, so soft and crumbling that at every step we were plunged into it up to our knees. On we went, still up, up, up, occasionally changing the leader in front, in order that others might follow in his footprints—still up, up, up; and that horrid dome, the top of which always seemed near, but which after long hours seemed no whit nearer. Still up, up, up, till at last the resolution of some failed and they announced their resolve to return.

And now it seemed that the ascent of the Key of Iceland was to be abandoned; for M'Diarmid alone, who though just then the most tired of all, yet loving fatigue for fatigue's sake, was still indomitable—M'Diarmid alone seemed averse to giving it up, when Mr. X ——, who was considered the most sluggish of the party, and was just then lying exhausted on the snow, got on his legs and made us a speech! First, he premised that he had been strongly against the attempt, but having begun, it was our duty as citizens of the Great British Empire to go on with it. Secondly, he begged to observe that he had stood two contested elections, which was much more trying than the ascent of any mountain. Thirdly, he made reference to a mountain in Mexico with an unpronounceable name; and he concluded by saying that after having been up the latter, before he would give in to this Iceland excrescence (for so he contemptuously termed the magnificent Eyriks

Jökul) he would rather, on an important division, go into the wrong lobby.

At the close of this unexpected oration our party divided; M'Diarmid, Mr. X——, and the poetic Digwell, pursued their upward way, and in the course of another hour succeeded in reaching the top of the dome, which they described as being a large plateau some miles in extent; but I did not make out that they saw much more than ourselves, who commenced the descent, which was fatiguing enough. We had, however, the consolation of a splendid view. To the left, and lower than where we stood, were the glaciers of Long Jökul, Blafell Jökul, Gelt Jökul—mountains which from below had seemed as high as Eyriks Jökul itself. Range on range of distant hills loomed in the far distance, while northwards stretched a plain studded with innumerable lakes, sparkling like cairngorms in the orange light of the setting sun; while, still beyond, a broad gleam of glory revealed to us the vicinity of the Arctic Sea. What illusive enchantment will not light throw on objects most cheerless in themselves! As seen by that gorgeous sunset the region below us seemed like the realm of fairyland; yet when we came to know it better it was nothing but a wilderness, dreary, waste, and barren. I might make comparisons about all this, and say how hope may dress the dullest condition of life in the liveliest colours, how the deceitful hues vanish, and so on. I might do this, but I will not. It is not the speciality of Umbra to moralize; besides, it is the truer philosophy to enjoy what is bright and sunny while it lasts.

One remark I made as we descended. The shadows thrown on the snow were so blue, that in some places it seemed as though indigo had been spilt on the surface. Once or twice I stopped to make sure it was shadow, and not blue rock. I had often observed before the blueness of shadows on snow, but never had before seen it near so marked, which I suppose may be ascribed to the clearness of the atmosphere. The moon had now risen; at the foot of the snow we re-united the divided parties, and all proceeded together till we reached our horses.

We rode home in three hours, as quickly as the nature of the ground would permit; and the moon having disappeared, it required some care to pick our way in the dark. I can remember now how picturesque appeared the leading horsemen, splashing through the frequent fords. There was nothing very picturesque in my friends themselves—Englishmen in shooting-coats. But by that uncertain light, now lost to view, now emerging from shadow, they seemed worthy of being mounted brigands painted by Wouvermans. Even so does partial darkness in some cases, as excess of light in others, enhance the effect.

We arrived at our tent at twelve : our expedition had taken exactly thirteen hours in all. We supped. The Key of Iceland had been scaled. That night we slept well.

At a place which is higher than the cloudy layer of atmosphere in which the average temperature is 32°, a high plateau whose area may be about 30 square miles, forms a high centre on which the supply of frozen water which falls equals or exceeds the waste which melts.

The snow-heap is a cold mass which cools air and condenses vapour in it ; so it lasts and grows by robbing warm air of heat and water; by dragging down currents of cold damp air from higher regions; by condensing mist and gathering clouds, which shield the snow-heap from the sun till they fall upon it. Hekla, which is clear of snow, is often clear of mist when neighbouring snowy mountains are invisible. Snæfell is noted for fogs and rain. Bergen, near the ice, is called the washpot of Norway ; it rains and snows in the Alps when the sun shines in Lombardy, France, and Germany. Eyriks Jökull is seldom clear, for cold breeds cold, and snow begets snow. After a day of rain the top of this snow-heap is powdered with water-crystals. Winds blow the water-dust from exposed places, and it falls in the shelter, and fills up holes. In clear calm weather the feathery snow melts and becomes a bed of fine loose water-gravel, composed of lumps of clear ice, which form by melting and freezing. During the greatest heat this upper layer is wet and loose; when the sun sets it forms a crust.

Each drop of water, every rounded surface of ice, is a lens which brings sunlight to a focus, and so water-drops and ice-lenses help to melt the heap irregularly when the sun shines. But on these high tops in Iceland, the sun shines all night at midsummer. When the crust is wet and loose, about noon on a fine day, walking on high snow-mountains is hard work everywhere. The loose damp surface, nearly frozen and yet almost melted, partially supports a man; but when the weight is on one foot the névé yields like fine gravel on a wet beach, or dry peat-dust on the top of a bog. Down goes the foot to the knee or further, and it has to be dragged out of the hole for the next step. In order to rise six inches at a stride, the body has to be lifted two feet or more, and when that is done it falls again with a grievous jerk. The leader has this work to do, the next in the line has easier work, and each follower finds the snow at the bottom of the hole grow firmer like a kneaded snowball.

When the surface is in this state, surface water is filtering through it, but it freezes in the shade below. In the early morning, after a hot day and a cold night, mountain-climbing is easy; the upper layer is crisp and strong, and all is gain where the foot neither sinks nor slides. The upper névé on the Öræfa and Eyriks Jökull was like wet sand, which is sandstone in frost, and a quicksand at other times.

If sugar be sifted on one place, it forms a conical heap. Snow which would form a conical mountain here presses with vast force on its base, and till it consolidates the peak tends to sink in and shove out the sides. So these Icelandic and Norwegian snow-heaps are domes.

The lower part of the dome is like a well kneaded snowball, watered and frozen, but thawing on a warm base. The weight above kneads it, water sinking in wets it, and it is in a region where frost is the rule; but it stands on the lid of a boiler. Water which sinks through névé flows over ice beneath it, and forms water-springs. Like rain-water, which trickles through gravel and flows out when it comes to rock, springs of snow-water rise about the foot of the dome and névé, and these water-pools rest upon hard blue ice.

If heat is strongest pools grow, multiply, and overflow; and streams join and fill lakes and rivers; so glacier-streams are in flood at various hours according to the distance from the mountains. At the head of the Lago de Guarda, where there is a famous trout-fishery, the snow-flood comes down in the evening. Near Hekla the spate in the Markarfljöt is about noon on a fine day. The difference is to be accounted for by the distance from the snow-heaps, and the rate at which water flows; the cause of the flood is sunlight, and its power may be seen in rills which flow from every snow-dome. When the sun sets, pools cease to form above, and rivers shrink in the plains soon after dark.

The plan of this local system is like the letter Q. The dome is the O, the tail is a tiny river-glacier pointing north-east, ϙ.

The woodcut is taken partly from a sketch made from the saddle, at a distance of about forty miles, at the point shown; the map is copied from Gunlaugson's. Plan and elevation together show the shape and position of this local system. The plan of the plateau is angular and irregular, the elevation shows a high plain with cliff and talus surrounded by a snow-dome. Snæfell is 5808 Danish feet high; Eyriks Jökull has not been measured, but it is about as high; it is nearly surrounded by lava-floods, which flowed out of other mountains. From the top Snæfell, Hekla, Myrdals Jökull, perhaps the Öræfa; hills about Fyafjörd in the north, and Bardastrand on the west—places about 200 miles apart—were seen on the 6th of August 1862, and the plain below looked much the same as it did to Umbra twenty years ago.

From this lofty centre lower snow-domes like Ok Jökull,

Plan and Elevation.

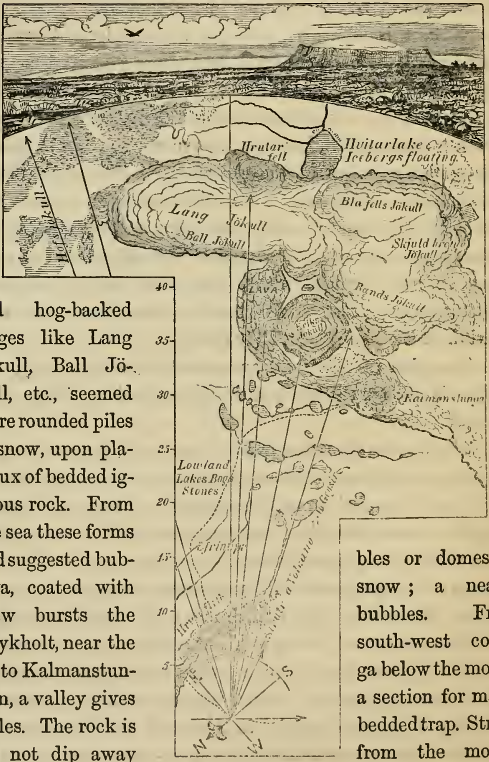

Fig. .

and hog-backed ridges like Lang Jökull, Ball Jökull, etc., seemed mere rounded piles of snow, upon plateaux of bedded igneous rock. From the sea these forms had suggested bub- bles or domes of lava, coated with snow ; a nearer view bursts the bubbles. From Reykholt, near the south-west coast, up to Kalmanstun- ga below the moun- tain, a valley gives a section for many miles. The rock is bedded trap. Strata do not dip away from the moun- tains as they would if they were sources from which the rocks flowed ; they dip regularly at a small angle towards the mountains, but the slope of the country is the other way. So even here, in the workshop of fire, some denuding force has cut diagonally over the angle of the broken crust.

On all these low hills are signs of glacial denudation ; but the marks are so covered with lava and other volcanic debris, that their meaning is very obscure. One thing is plain—though numerous faults, dykes, and veins traverse these strata, there was no upheaval by the dome-shaped mountains, and hog-backed ridges, whose structure is partly hidden by snow-domes. These mountains are remnants of a wide tract which has been largely denuded, worn away, and partly destroyed by some external force.

The escarpment of Eyriks Jökull gives a clear section, and it shows horizontal layers of bedded igneous rock, like courses of masonry. The lower strata are friable beds of white sandy tuff, and fine ashes, which show minute false bedding. They contain small black glassy crystals, and large dark-coloured cinders arranged like flints in chalk-beds. From the structure of these lower beds the foundation is easily undermined. Small streams, which have dug down to the white tuff, have dug U ravines with vertical broken sides, in which the structure of the rock is clearly seen. No sign of Surtrbrand, or any other organic form, was discovered. The steep slope is a talus of loose rubbish, angle 32°. The cliff above it is igneous rock laid in horizontal beds, and broken. The beds split and break horizontally and vertically, so they weather into angular blocks ; but nevertheless rounded stones are strewed about the base of this slope. On the top of the cliff a plain of rock a mile wide, on the south-western side of the dome, is strewed with rounded boulders, loose angular stones, and half melted snow-wreaths ; and there is no sign of recent igneous action on any part of it. On this plain stands the snow-dome. It is snow at the top, névé lower down, ice at the bottom ; and water-springs flow out over the ice, form rills which flow over the plain, fall over the cliff, and help to undermine it on their way to the sea. Waving dark lines, which fringe the base of the snow-dome, and which were supposed to be lava, are in fact a scolloped pattern of morraines ; loose piles of subangular blocks of dark-coloured igneous rock, like the big stones which strew the plains below the dome.

Either these are quarried by the base of the dome, and thrust upwards and outwards, or they were dropped on this table-land, for there is nothing above them from which they could fall.

It is manifest that the weight of this dome of hardened slush must tend to thrust its crushed foundation outwards, as in the case of ink dropped on paper (p. 96), or a snowball thrown at a door (p.). But as the greatest resistance is where the base is widest, the downward pressure ought to be reflected, so as to thrust out stones at the weakest point, somewhere between the top and the base, where the moraines appear. If this dome were gone there would probably remain a star of striæ with a waving fringe of moraines, like those which strew the plain.

If the system were on the North Pole, this radiating force would push southwards along all meridians, and push furthest where resistance was least. If a like system were on the South Pole, it would push opposite ways. As the sun is to the south of Eyriks Jökull during most of the time that it is above the horizon, the dome slopes most towards the south, and it approaches the cliff at the north-eastern side. There—in a hollow sheltered from the sun, and from the warm south-west

FIG. 00. EYRIKS JÖKULL, FROM SURTSHELLR, looking about East. August 7, 1862.

wind, exposed to the north, where the sun appears at midnight once or twice in the year, and to the cold of Lang Jökull; in a place well fitted for an ice-house—the snow-dome thrusts out a small river-glacier. Its position is shown on the map (p. 426).

It is like other river-glaciers. If it started from the North Pole, this tail would grow down some meridian at first. It now lies in a cold nook exposed to the cold north-east wind, and it is digging a trench to contrast with water-work on the other side. The ice-system here ends on a stone plain which flowed round this mountain, after the talus-heap had formed, and long after the cliff had been torn, broken, or chipped out of a larger plain by some denuding agent.

If ever there were systems of this kind on the poles, or if they exist now, and change place on some system, their present and past movements must in some measure depend on those of the revolving world; and their old marks must either radiate along meridians or cross them if the tail of the Q grows any way but south, or north.

If these rock-devouring glacial systems are to be likened to living things, local systems in Iceland are like star-fish clinging to bait, or clustering on stones. There are many small ones, but the biggest are those above named.

In Iceland the marks of Frost are on a vast scale, but they are mingled with the work of Fire. These denuding and upheaving forces are working natural engines—air, water, ice, and steam, side by side—and their marks are mingled. Marks made by glaciers upon igneous rock are the same as those which are made by land-ice in Norway and Switzerland, on rocks of all kinds; but the chips are different. Here ice-ground glens are partially filled with lava; water-worn boulders, pebbles, and sand, are smothered under sand which fell from the air; great stones have been cast through the air and rest amongst glacial rubbish. Snow is often blackened with ashes; ashes are whitewashed with snow; water flows under the lava, and there freezes and forms subterranean glaciers. Glacier-rivers carry fine mud, which glaciers grind; but it is mixed with volcanic dust, sulphur, cinders, sticks, and all things which rain can wash from such a land into the sea. The sea-beach is strewed with lava and arctic shells; American drift timber, mahogany, strange sea-weeds of great size; "horse-eyes" from the West Indies; dead puffins from the Arctic Ocean; fish-bones and seals, and sometimes the Arctic Current brings an ice-fleet; it may be freighted with stones and mud picked up at Spitzbergen, Jan Mayen, or Greenland. The surface of this land is a stone standard by which to read geological hieroglyphics elsewhere.

Snæfell, the mountain shown in the plan and elevation at page 85, seen from a distance of sixty miles from a ship's deck at Reykjavik, often seems to be a conical golden island on the horizon, cutting sharp and clear against a warm evening sky, glowing with all the splendour of an arctic night. On a bright clear morning, it tells white against the cold blue sky, like a tall cutter yacht with white sails. At this distance, it seems to be a snow-cone Λ in the sea.

It is a cone streaming with radiating glaciers, which descend to within a thousand feet of the sea now. It was an island like Jan Mayen, because old marks on the low slopes record that glaciers reached to the verge of the cliffs at Stapi.

The volcanic cone stands upon a plain of basalt. The "Dutchman's Cap," with its white cover, has a broad dark brim, which ends in a range of low cliffs.

These make the "Staffa" of Iceland; or rather, Staffa is the "Stapi" of the Hebrides. The cliffs are breaking away;

the waves are hewing out strange stacks, pillars, and caves; they are mining and blowing up the roof of the mines with compressed air; and the chips hewn from this strange sea-cliff—this L shelf at the sea-level—furnish boulders and sand for beaches. Here are plain sea-marks; rock-shelf and chips; a cliff and beach; under water the sea shoals gradually, and the bottom is bare lava and black sand. Sea-work going on below explains old marks above.

In riding along the verge of the land-cliff, a series of ice-grooves are crossed. The bare slope of rock which makes the brim of the hat is like a strange brown mosaic, half-polished, and broken. The cliff shows ranges of basaltic columns, with the upper ends ground away. The marks record that the basaltic mosaic work was in fact polished by ice. Now comes the question, What kind of ice? Land ice or sea ice, or both? and that question is answered by the ice-marks.

All the grooves, for a distance of several miles, converge upon a hollow, from which a small stream of water flows; and when a cloud is on the hill, it seems to fall from the clouds over a cliff. The rays of the star—the spokes of the wheel—aim at the groove ‿ in the shelf L.

But this cliff is a repetition of the sea-cliff only raised a step; and here and there are beds of rolled stones and sand, which are identical with those on the beach, and in the sea. No shell was found in the few minutes that could be spared for a search; but a more perfect sample of a raised sea-bottom would be hard to find. The brim of the hat is a raised sea-mark, and the cliff which bounds this plain is a second sea-mark—a second shelf—a copy of the cliff below. Three steps may be traced from Snæfell to Borgar Fjord; and there are many smaller steps where the low land is wide. But there are other marks over the neck of the

Read by.

J Kendall. —

F Leveson Gower. —

The Duke of Argyll.

Feb & March. 1864.

Kenneth Mackenzie

Experiment

Capter 1. to Page 128

The point to be
brought out is that
there are two forces
which work natural
engines, to wit. Weight
and heat —

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and return with remarks.
as soon as may be. —

CHAPTER I.

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CHAPTER I.

CINDER HEAPS.

A CERTAIN hardy English traveller, in excellent health and spirits, returning from Iceland, with the appetite of a hunter, and the condition of a race-horse; declared to his shipmates that the country was "not worth seeing." "It was nothing," he said, "but a big cinder heap, as interesting as the dust hills at Wolverhampton, and not a whit more fertile."

The traveller's description, though *not* complimentary, was pretty accurate.

Volcanic products are very like furnace refuse, and all Iceland is volcanic; but cinder heaps, great and small, are worth sifting, for they throw light upon each other, and on dark subjects. Slag, Lava, and Trap, were all melted stone, and they are equally products of heat.

Even in a cinder heap there is much to be learned.

One branch of geology may be studied at a foundry where stones are melted; but something is first wanted to bridge over the gulf which separates a rill of slag from a lava flood; and a visit to Iceland supplies the want.

One great steam-engine must be seen at work before the ways of steam can be learned from a kettle; but when it is understood that steam power is limited only by the size of the engine and the amount of heat applied as force, then models, drawings, descriptions, or even traces of work done by natural steam-engines, are comprehensible.

So it is on the large scale.

The tool marks of natural heat must be seen in a large volcanic country, before the action of tame heat working at home on a small scale can be identified with volcanic action.

Earth heat has done great work in Iceland. The country whose bare barren surface has recently been altered by two mechanical forces, which upheave and grind down the crust of the world, teaches principles on which geology is founded; and when the lesson is learned, the scholar sees that a smelting house, a rubbish heap, a frying-pan, and the kettle, all shew the action and the effect of the same forces working on a smaller scale.

Iceland is a "cinder heap," but it is a very large one; and the lesson which it teaches is well worth the cost. Hecla may only be one large valve in a great caloric engine; but it is not too large to be seen, and it is well worth looking at. The two forces which have been set to shape the outer surface of the crust of our globe, if not the globe itself, are now employed in busily finishing an island as large as Ireland. They have worked and are working within such narrow bounds, that their work can be seen as a whole; but on such a vast scale that the performance of still greater tasks by the same agents can be understood. These twin giants, Fire and Frost, Heat and Cold, are as busy near Hecla as at Wolverhampton or Coatbridge, and their work is alike at home and abroad.

They move steam, the atmosphere, and the ocean, and things moved by them; they melt and freeze gas, water and slag, lava and metal, and move things moved by them; they shape clouds in the air, plates of slag, mounds in lava, and great mountains on the earth; they have upheaved and depressed Iceland, Norway, and Scotland; they have altered the whole surface of the globe, and its upper crust, so far as it is

explored; and they may have done still greater things, if they were the servants employed to do the work.

So a traveller, surrounded by mountains of ice and cinders, may be driven by the work before him to think of the agents employed to do it, and of him who set them their tasks, who said "Let there be light, and there was light," in the dawn of time.

In furnaces and volcanoes, in models and steam engines, in cinder heaps and in Iceland, in art and nature, certain mechanical forces work, and movements and forms produced by them are alike on all scales.

The tool marks of fire and frost may be learned in their workshop, and they may be set to work at home.

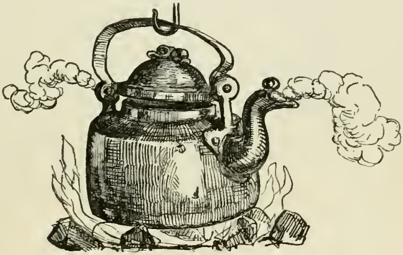

FIG. 1. PORTRAIT OF AN OLD FRIEND AND PRECEPTOR.

CHAPTER II.

HOME GEOLOGY.

A HOME student of geology is forced to take a great deal upon trust, and has often to work sorely against the grain. He may understand the teaching of practised men, and believe what he is told; but he cannot be familiar with the irresistible power of natural forces, whose power he has only seen displayed upon some pigmy scale.

A landsman who has only seen a puddle in a storm, has no clear notion of the Atlantic in a gale; and so it is with a man who has never been far from home.

He may have been familiar all his life with the form of some great mountain covered with rich soil, grass, heather, trees, and yellow corn in summer; sprinkled with snow, and glittering with icicles in winter. He is taught that the rounded form which he has known from his childhood, and which has never changed within the memory of man, is due to the wearing of floods of water, or of fields of ice.

But no home-bred Englishman has ever seen any power in action which seems strong enough for the work described as denudation.

The rivulets which trickle down the mountain could not have done work of the kind if they had worked as they do now for countless ages. They do not make rounded shoulders; they cut deep furrows on smooth hill-sides.

Burns meet in quiet lakes which mirror swelling hills on either side of some great glen, along which a river

winds to the sea; but the shape of the glen bears no resemblance to that of the small transverse furrows which rivulets make, or to the winding river bed at the bottom of the glen.

If scooped out, it is clear that the main glen was made with some coarser tool; and that the hill was rounded by something different from streams of rain water.

The great glen which crosses Scotland at the Caledonian Canal never could be hollowed by streams like those which have furrowed the long, smooth, steep hill-sides which make its southern boundary.

Ben Wyvis, and hills like it, were not rounded by streams like those which flow from their sides, and furrow them.

A little scratch on a rounded smooth rock which peeps through heather on the steep side of a burn, is shewn triumphantly to prove how an enormous glacier, now replaced by a little winter icicle, once filled up the glen, overspread a whole tract of country, and ground its way slowly downwards, bearing earth and stones on its surface, as leaves and sticks float down a river to the sea. Green hillocks, from which loose stones are now dug to gravel the roads, are pointed out at the mouth of the glen to mark the spot where a local glacier once ended; and the student is told that ice carried stones overland from the mountains, and left them in heaps when it melted, like piles of floating rubbish stranded by some winter spate.

It is said that ice and cold water ground down the hills and scooped out the glens, and left water-worn moraines behind them, because there is an ice-mark on the rock.

A man may believe it all vaguely, but he cannot realize it if there is nothing like a glacier within his experience.

The face of a peasant who is told for the first time that ice rounded the hill-tops where his sheep feed, is a study.

But glaciers and cold rain-water alone will not account

for many great glens, because of their peculiar forms; and there are ice-marks which no mere land-glacier could make.

It may be that a man has lived all his life beside some great stone fixed in a rich plain, buried in an old wood, or perched upon a hill-top. He may have seen it gray with lichen, or green and brown with moss and fern, or sparkling in the sun like a great jewel when powdered with hoar-frost.

It has been an "earth-fast stone" ever since he can remember; it looks as if it never could be moved from its place; perhaps tradition tells that some ancient giant hurled it at his foes. The teacher declares that it is a "wandering block" which first broke off and rolled down from a mountain hundreds of miles beyond the limit of vision, in some far distant country; and then sailed over the ocean on an ice-raft, and finally sank to the bottom, where it lies.

The tradition seems far more probable. It is just as likely that another stone of the same kind should now come sailing on a cloud, and plump down amongst the hens in the barnyard, for there is no sea near the stone, and the nearest sea has no ice-rafts.

It is vain to point at an ice-groove on the tip-top of a high hill, and then assure a canny Scotchman that like marks are to be found upon many similar isolated hill-tops, in the British isles and elsewhere; that all these high grooves seem to bear some relation to each other, and that they were all made by ice-floats while sailing over the hills, and dropping cargoes of clay and stones in the sea, to make land for farmers to plough on shore. It is contrary to the evidence of the senses. The sea is far away, hills are high and steadfast; and many ice-grooves are but faintly marked now.

It is vain to point at illegible characters on the stone or on geological maps, and try to explain how it must all have

happened long ago. It is not easy to expel old ideas and take in a new stock ; and so the usual first-fruits of an explanation of a fire-mark or a frost-mark is a look of incredulity or contempt.

A geological student is taught that mountain-chains were ocean beds, that continents were groups of islands, that islands are sunken mountains, that hills pop up their heads, and dive down again like seals ; that if some glens are grooves, some are rifts in the earth's broken crust ; that the land has waves, and that the sea is comparatively at rest ; but he never sees any of these changes happen.

He is assured that the cold, solid, gray rock, from which an old moss-grown tower has watched for centuries over generations of actors in the world's history was once white hot, and rose up through the sands of the sea ; that a quarry was a sand bank, and a stone in it a drifted log. But no rocks, hot or cold, ever rise now in neighbouring seas, nor do sand banks and forests turn to stone and coal.

He knows that it is the nature and habit of all the rocks and stones that he has ever seen, to fall as fast and as far as they can, and then lie still. He is taught that rocks and stones move about, float in water, and fly through the air, and have done so time out of mind.

By vigorous submission to authority, or by hard thinking, a man may bring himself to believe that these are truths, not waking dreams of book-learned men, or travellers' tales ; but it is no light labour for simple men who have never seen fire and frost at heavy work, to take it all in.

A certain venerable professor of natural history was in the habit of taking a walk round Arthur's Seat once a year with his class at his heels ; and it was his custom to pause beneath certain basaltic columns, and gather his flock about him to

pick up crumbs of knowledge, and hear the yearly open-air Edinburgh lecture on geology.

In these days—some twenty years ago—there was no "Queen's Drive," but there was some fine green turf near the rocks, and on one of these occasions a bevy of Edinburgh wives and lasses had chosen the spot for a bleaching green.

"What the diel's a' thae folk doin' there?" said one cummer.

"Oh, it's a daft chiel gien them a lectur aboot Samson's ribs," said another.

And then they laughed a mocking chorus, and fell to work again at their wet napery.

Not all the professors in Edinburgh, not even Sir Roderick himself, could have persuaded the washerwomen that Samson's ribs had been pumped up hot out of the earth, or had ever been anything but solid rocks since the world was first created.

This hard crust of experience must be quarried through before knowledge can reach the understanding of home-bred men, for daily experience seems to contradict what they are taught.

But daily experience really agrees with geological teaching, for the mechanical action of natural force is always the same, though it varies in degree; and this is felt and understood when cold has been seen battling in earnest with heat.

A man begins to feel that cold is a mighty engine when he has seen a glacier, and heard it. When he has seen it move with acres of stones and gravel on its surface, and launch cargoes upon ice-rafts, to sail wherever the wind may blow them. He has learned a new alphabet when he has seen polished rocks under and near moving ice, and grooves and scratches freshly gouged out by stones in the ice. He

gains a new view of an old ridge of gravel, when he sees a conical mound of loose rubbish newly shot from a groove in blue ice, by a snow rivulet, and the end of a glacier fringed by ramparts of such mounds. Thenceforth he knows a "terminal moraine." He begins to understand how a clay field may have come from some neighbouring glen or distant country, when he has seen a thick, white, muddy river, smelling of sulphur, bursting out of an ice cave, tearing through heaps of debris, and busily engaged in spoiling a delta of its own building to make another lower down, or to freight an iceberg.

When he has seen all these movements and changes, these tools and their marks—and they are all to be seen in Iceland, Norway, and Switzerland—it is easy to believe that similar work was similarly done by the agency of cold and weight elsewhere.

Then the action of large masses of ice, and great floods of water, which hew out rock forms, and carry and arrange banks, mounds, and plains of drift, clay, and boulders, is recognised in the sliding of a plate of ice upon the bank of a rivulet, or in the miniature work of a mill stream on a frosty day. Having learned the alphabet and the living language, he can decipher the rock inscriptions of old ice.

So, when a man has seen one smoking volcano, with its lava floods and cinder heaps still warm beneath snow and ice, and the curl that once played upon a river of melted stone as sharp and clear upon a rock as the curl upon the glacier river beside it, his ideas about steadfast and eternal hills are changed. When he has seen stones, sand, and ashes, that once rose up, repelled by heat, and flew through the air in defiance of gravitation, now strewed on the ground where they fell, because the laws of attraction were the strongest in the end, he gains another new experience, and recognises a

force opposed to gravitation, which meets him at every turn.

When he has seen the workshop of heat and cold, he learns to know the tool marks of the two giant slaves wherever he finds their work, and he finds it everywhere when the lesson has been well learned.

The heat of a volcano is but the same force which works a furnace and a steam-engine ; the same forms result from its action, and he sees them in familiar hills, in cinder heaps, and everywhere. When the natural heat of the earth has been seen to hurl clods and stones, drops and jets of water, steam and smoke, far away from the earth's surface, to move freely for a time in obedience to laws which govern the movements of planets and earthly projectiles, it ceases to be an effort to realize the fact that heat, cold, and gravitation, are forces which together move projectiles in well-defined paths within the bounds of our world, and it may be beyond them.

A man becomes familiar with these, his fellow-servants, when he has eaten food cooked by nature's fire, and has slept on a turf bed warmed by mother earth. As he lights his morning pipe through a lens, with fire direct from the sun, beside a pool of water boiled by fire in the earth, and watches distant ice mountains through condensing steam, and thinks whence all the water came, how it was moved, and by what forces, a traveller must realize that these useful giants who can turn their hands to so many things, great and small, do not confine their labours wholly to this world.

He sees that heat boils a kettle, a steam boiler, a geyser, and a volcano ; lifts water at the equator to drop it at the poles ; and will hand a cigar light from his quarters in the sun, to a friend on earth who knows his ways.

He knows that cold cools the tea, and stops the engine, seals up the hot spring and the volcano, shakes down snow to

grind the mountain which the other raised. Cold arrests the motion which heat started: he knows that cold puts a man's pipe out when the time is come.

An Englishman seldom thinks of heat and cold as natural mechanical forces, though he sees their work everywhere.

An Icelander who lives within sight of Hecla may have seen the top of a mountain larger than Ben Nevis, red hot; with a stream of melted stone, as broad as the Thames at London, flowing down its sides.

The stream is there now, though frozen, hard, cold, and dark. Every year he sees water fall, flow, and freeze, and hang on the slope as lava does. There is snow upon lava now, and ice in caves beneath it.

He sees steam and boiling water burst up and spout from the earth, and condense, and fall, and flow into still lakes, freeze hard, and split; and he can understand that the great shattered plain of stone on which he lives was liquid, and rose, flowed, froze, and split, like the water.

He knows that lava boils over, froths and freezes outside Hecla; so he can understand how bigger streams boiled up elsewhere, before his ancestors came to the land.

A traveller who has gained a part of this Icelandic experience can apply it at home, and recognise past glacial and igneous action in forms which remain to tell their origin to those who can understand their meaning.

So a trip to Iceland is worth its cost.

The rugged features of nature are hidden or veiled in fertile lands; in the cold barren north they are clearly seen, and stern though they be, they are well worth contemplation.

The desolate country is one of the grandest in the world, though the prevailing feature in its landscapes may be dust and ashes.

Atmospheric circulation, water falling and flowing, fluid and solid; sliding glaciers, freezing seas, ice rafts floating, rocks wearing, sediment falling to form new beds, "denudation," and "deposition:"—downward movements from the action of cold and weight:—

Rising land, hot springs, intruded rocks, lava, boiling, rising, flowing, and freezing; volcanic projectiles rising, freezing, and falling in air; upheaval of land, upward movements in gas, fluid and solid, caused by heat:—

Demolition and reconstruction by natural forces,—are not all within daily experience at home.

Therefore, teaching and experience may seem to differ, but they really agree; for natural agents work everywhere in the same way, and the form of their work is alike at home and abroad, on the smallest and on the largest visible scale. The same powers work in a kettle, and in the Great Geyser; both boil, and sometimes they boil over.

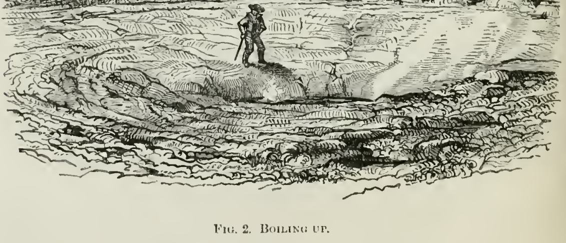

FIG. 2. BOILING UP.
Tube and Basin of the Great Geyser, after an Eruption, 1862.

CHAPTER III.

GEOLOGY.

Geology teaches generally that great changes have taken place on the surface of the earth, and it seems to point back to some distant time when a crust first cooled about a molten interior.

But there is nothing like a molten surface within common experience. The world with which we are familiar is green and smiling, and the old rugged crust is buried far out of sight, or worn away. It takes skilled eyes to read the lessons of our rocks. In Iceland nearly the whole surface has been fused; it is warm still in many places, and most of the rocks are bare, so he who rides reads.

The modern geologist generally works slowly but surely downwards through the outer crust of sedimentary rocks which have settled layer upon layer above each other, and about the cooled surface of the first crust, whose formation is assumed in the meantime. From sedimentary beds he digs out the shapes of creatures and plants that once lived, and he marks off the layers in which they are found, and knows their order, and their fragments, by these forms of buried plants, shells, and skeletons.

The thickness of this outer shell is measured along its broken upturned edges, and it is calculated how long it may have cost air, water, and ice—the gaseous fluid and solid matters which now move about upon the earth's surface—to grind down mountains at a given rate, and so produce, transport, and arrange enough of mud, sand, gravel, and boulders to make up sedimentary beds whose thickness is known.

The time is estimated during which the formation of these rocks lasted ; while plants grew, withered, died, fell, and accumulated, and became peat beds and coal fields; and while races of creatures lived, died, and were buried and turned to stone.

Each step so gained seems to rest upon a pile of facts as hard as the fossils themselves, each link in the chain is firmly joined to its fellow, and geology has become a science. But the rate of action may have varied in former times. The whole chain of reasoning in this direction, proves at least the endurance and activity of one mechanical force, which still acts towards the earth's centre.

The formation of sedimentary rocks under water, and the transport of their materials from a higher to a lower level, are facts which prove that the force which causes an apple to fall has acted in the same direction ever since it first moved silt : whatever the rate of action may have been.

There is not much to be learned in this branch of geology in Iceland. There are few sedimentary rocks, and very few fossils ; but of the present activity of the weight-force which must have acted upon the original crust of the earth, there are striking examples.

Falling water has not yet smoothed the shattered, wrinkled surface of the lava ; the sediment which it washes off and carries has not yet buried the rough outer crust ; but water and ice are busily grinding igneous rocks to make others, and they have ground and buried many surfaces which were bare and wrinkled at first.

There are few sedimentary rocks yet formed, but they are forming everywhere upon igneous rocks, so there is much to be learned about the past, from that which now takes place in Iceland.

But gravitation is only one of the mechanical forces which

act at the earth's surface, and denudation and deposition are but one-half of geology.

At every step there is evidence of a force opposed to gravitation, which has counteracted the downward movement of sediment.

The rain which washed down materials enough to make known beds of rock, would have washed all the land into the sea long ago, and ocean currents would have levelled the bottom, had not land been raised above water by a force sufficient to balance weight.

No apple could ever have fallen from a tree unless the tree had first grown ; water could not fall from clouds unless it were first raised from the earth ; and stones could not fall from mountains unless mountains were raised above the plain. There could be no new sedimentary rocks unless mountains were raised up as fast as they are ground down. If there has been denudation, there has also been upheaval of the surface.

A second mechanical force is recognized in all modern geology ; it has helped to model the outer crust of the earth, and it is still very active in Iceland.

Heat helps to raise trees upon which apples grow, and the ground on which they fall ; it acts upwards ; weight acts downwards, and the action of the earth's heat is seen in hot springs, in volcanic eruptions, and in their work all over Iceland.

Heat drives matter away from the centre, gravitation drags it back.

Heat expands that which contracts when cold. Hot particles repel, cold ones attract, each other.

So heat raised up hills from which sediment falls ; it shatters the earth's crust, and heaves up the broken fragments, and thrusts up molten matter through openings so made ; it raised up islands, and continents, and sea bottoms,

and is raising them slowly still; it hurls projectiles away from the earth's surface, and it has probably worked in the same direction from the beginning.

And this mighty force is manifest within a week's sail of the English coast; where its activity is often forgotten till some earthquake startles a sleeping town.

It seems impossible to visit Iceland and deny the importance of internal heat as a geological agent, or to revisit old haunts without recognizing traces of extinct volcanic action everywhere.

To ride over lava and gaze into craters is to gain fresh knowledge, and learn new tool marks. It is like visiting some asteroid still warm from nature's laboratory, or to read an early chapter in this world's history.

If any stones be preachers, surely these are eloquent.

Modern geology, then, treats of sedimentary and of igneous rocks; it recognizes the activity of two mechanical forces, which act in opposite directions, upward and downward, from and towards a centre, in radiating and converging lines; and Iceland is peculiarly fitted for studying the effects of both.

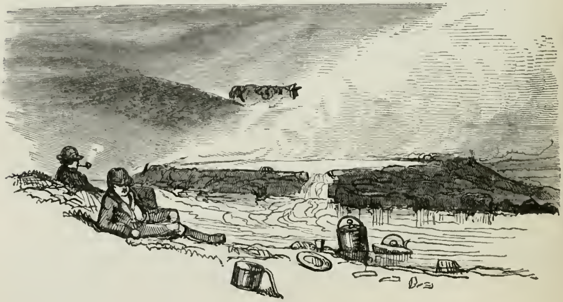

Fig. 3. Nature and Art.
Northern Iceland.—Badstua, near the Uxahver, 1861.

CHAPTER IV.

FORM.

Visible objects of all kinds are known by their forms, by their outlines, and by their internal structure, as well as by colour, weight, and chemical composition : and form has this advantage—it can be used as a test where others cannot be applied.

Fossils, for example, are known to have been plants, shells, or bones, only because of their outward forms and internal structure.

Organized forms indicate previous orderly movements, and forces which produced them ; and the former activity of vital and mechanical forces which now arrange the component parts of living plants and animals is proved by form ; when colour, weight, and chemical composition differ from those of any living thing.

A knowledge of form is very important to the student of extinct life.

So it is to students of other branches of geology.

The rounded shape of a pebble tells that a stone was rolled till its angles were ground away, wherever it may now rest. It is the same whether it is found in a stream, on a beach, in a dry bed of loose gravel, or in a hard rock ; in a deep mine, on a hill top, or buried in lava and ashes. The form of a water-worn pebble of any material cannot well be mistaken when the tool-mark is learned.

An ice-ground stone differs from one that is simply water worn.

There are many degrees of wearing, and many varieties of gravel and rolled stones ; and a skilled eye can distinguish them.

The outlines tell part of the story ; internal structure tells more of it.

A bit of water-worn bottle-glass, for instance, shews by its structure that it is glass, which was artificially fused before it was broken and rolled ; and its fracture, and the shape of chambers in it, shew the direction in which heat, cold, and human skill worked on tough glass while cooling and passing from fluidity to hardness—from heat to coldness.

The glass may be a pebble in a sea-beach, so far as outward form and position are concerned ; but internal structure tells of the agency of man, and the action of heat and cold.

A jasper pebble, a bit of rolled obsidian or agate, or calcedony, all of which break like glass, tell their history too. Because of its outward form the stone has been rolled in water, or ice-ground ; because of its internal structure it has been heated to fusion, or perhaps to sublimation.

A broken bottle proves the former existence of men.

A scratched jasper pebble picked up in a field near the Clyde, means previous aqueous and glacial action where there is now dry land ; and volcanic action at the place whence the jasper was moved, before it became a pebble.

If a square block of jasper is found on some neighbouring hill, it points to a possible place from which the pebble may have started ; and if a vein of jasper is there found *in situ* it points out the site of an eruption, though there may be no other record of it.

So a fragment of rolled brick, a slate pebble, a limestone

boulder, and a bit of water-worn chalk, all have something to tell about forces which moved their particles.

Brick, though rolled, is easily known to be manufactured brick, and it tells of a bed of clay somewhere on shore, of the labour of men, and of the action of a certain temperature artificially applied to bake, without fusing, clay and sand. It may be part of a delta now, but a brick is human work.

Slate, sandstone, and limestone, though rolled pebbles, tell of the fracture and wearing of old beds of stone, of old denudation, and of deposition of silt to form new beds; of some action which changed silt to stone, and of the breaking and wearing of these new beds. A pebble of metamorphic clay-slate or marble may tell of a heat sufficient to bake without fusing clay and lime; and the materials tell of still older changes which formed and packed the minute fragments of which the rocks consisted before they were baked hard.

The minutest visible grain of sand has a well-marked form of its own, which tells a separate story.

But because these inorganic forms are as well marked as those of plants, shells, and bones, they prove the past action of mechanical forces as clearly as fossil shells do the action of vital force.

The form of sand tells of motion in gas or fluid as clearly as a fish-bone records swimming in water; and if sand and a fish-bone are found together in the same place, they tell of mechanical and vital forces acting much as they now do, and in water, cold enough for fish to live in.

These separate inorganic forms, then, give much information. But other forms tell their story with equal clearness.

A dry river delta tells as clearly of flowing water and moving silt, as a shell does of the life and death of a living creature. It is a water-mark.

The minute delta which forms in a gutter during a shower, is the result of flowing water ; so is the delta of the Nile, or the moving delta which is creeping seawards, out of valleys about Hecla ; or a fossil delta of any size, anywhere.

They differ, but their general form is the same ; and though all big rivers were dried up, their former existence might be known from their work, if but one flowing rill survived to explain the way in which silt is packed at a river mouth.

Size is of no importance when movements and forces, from which natural forms result, are known. The forces can be inferred, if only the forms can be recognised.

Distance does not affect the test by outward form.

A tree is known though it grows on some inaccessible cliff, and the vital vegetable force is inferred from the shape of the tree.

A river delta is recognised from a hill top, though it may be far away.

If there were a large delta or river-bed upon the moon's surface, it could be recognized there as easily as upon the earth, for it has a conspicuous shape. It is a tool-mark. No Δ is to be seen in the moon ; no forks and meanderings ; no V, no Y, no S. There are no clouds there from which rain can fall. There can neither be river nor tree, like earthly trees and rivers, on the moon's surface, because familiar water and air forms are absent.

But fixed, solid forms are there. It is known how similar forms are produced in this world. So it is fair to conclude that these lunar shapes, these O craters, also resulted from a combined action of heat, cold, and weight, which did their work, and have now ceased to work on that surface, though still active here.

Visible forms then, whether accessible or not, mean

previous movements, forces which caused them, and a temperature sufficient to make the movements possible in the material moved; and similar natural forms, wherever they may be, probably indicate similar action and agents, movements and forces.

A delta is a water-mark; a round crater a fire-mark; and every force which acts on a surface makes a tool-mark which may be learned.

Each mark is like a letter. It has a form and a meaning, but only for those who learn to read.

To learn the character, the language, and the meaning of inscriptions sculptured on the world by fire and frost is worth some trouble. The geological alphabet—the first lesson to be learned is—Form.

FIG. 4. AN EASTERN SYMBOL.

CHAPTER V.

ATMOSPHERIC FORMS.

If ever there was a time when the solid surface of our world was a newly-formed hot crust of stone, there must have been an atmosphere about it, whatever its composition may have been; for our gases and fluids, air and water, only expand by heat.

Movements in any gaseous shell must have resembled those which now take place in the air from the action of heat, cold, and gravitation, whatever the surface-temperature may have been; and these atmospheric movements surely left marks upon the solid crust from the beginning, because they do now.

We have but to look above us to read some of the ancient characters, which are and have been written in air, and to learn their meaning. They are forms which reveal forces. On a calm clear summer evening, after a thunder shower, when the setting sun is near the horizon, and the wind is still, great masses of vapour often pile themselves up into fantastic shapes which can only be seen in profile from a distance. They are easily drawn, and easily photographed. Those to the eastward shine like snow in the evening sunlight, and their shapes are clearly defined by light and shadow. Those to the west are dark, or edged with brilliant light, and their outlines cut sharply against the western sky.

Such clouds float steadily in the air; they are unaltered by

wind; but when they are closely watched, they are seen to change their forms at every instant.

There are magazines of force within them and without, and changing forms point out the directions in which these forces act.

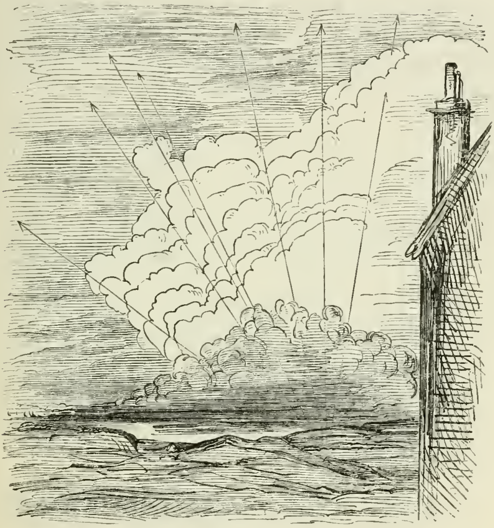

FIG. 5. DIAGRAM TO SHEW THE GROWTH OF A CLOUD.

The outlines were traced with a pencil on the ground glass of a camera obscura, at short intervals, on a still, bright, hot evening.

Whoever has been enveloped in a mountain mist or a city fog, knows that a cloud is commonly made up of minute floating spheres of water, and these are moved about by currents of air, which are moved by some force.

These liquid spheres form at one place and disperse at another, according to the temperature and humidity of the air about them; but while they exist as drops in clouds they collect and scatter, and move according to movements of the air in which they float. Clouds are but fleeting characters written in air; but while they endure, they tell their story by their form and by their movements. In order to see these cloud-forms, and note changes which take place in them, they must be far off, for clouds are of enormous bulk.

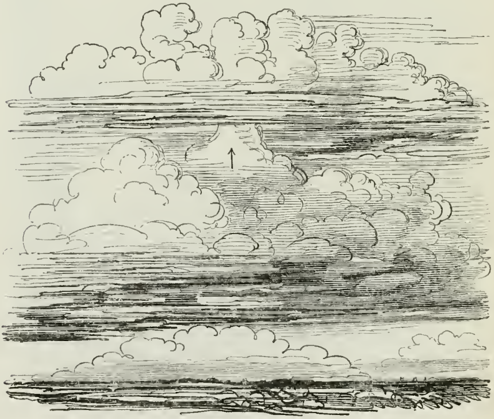

FIG. 6. "CUMULI." SKETCHED FROM A RAILWAY TRAIN.

"Cumulus" clouds which form above London are higher than the Alps, and, like Alps, they must be seen from a distance before the eye can take them in. But when they are seen, under favourable circumstances, their movements tell of upward and downward currents in air—of expansion

and contraction in particular regions—of currents which are analogous to those which move up and down, and sideways, in boiling water.

The lower edge of a distant cloud is often nearly a straight line; it is, in fact, the outline of the under side of part of a dome of vapour, forming at a certain distance above the earth's convex surface. The upper side is a heap of great rolling mounds which are constantly moving, swelling, and shrinking; rising and falling.

As warm currents of air rise through the vapour, rolling clouds expand upwards, and change from rounded domes to conical piles, and they flow over, and spread out upon the higher layer of atmosphere through which they have been

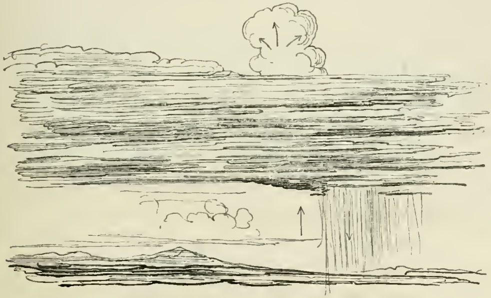

Fig. 7. Rising and Falling.

thrust, taking the shapes of mountains. So long as the sun warms the cloud, or the earth beneath it, the upward expanding motion continues. But when the sun disappears below the horizon, the action grows less, and the movement is reversed.

The great boiling mass ceases to boil; and settles down into layers of even thickness. The "Cumulus" becomes a "Stratus,"

or perhaps a cold wet current of air joins company with the cloud; drops grow larger and heavier, and the whole fabric tumbles down as a heavy shower. Then the "Cumulus" is a "Nimbus," and the source of a flowing stream.

It is the same whether the growth and decay of such clouds be watched from below or from above.

At sea there are no mountains to interfere with winds which blow along the surface of the water; so clouds, if they change their form, alter because of forces within them.

Thus, off the Orkney Islands, with a strong north-westerly breeze below, a distant mass of cloud on the southern horizon was seen to move so as to indicate upward and downward currents moving within the system of air which moved eastwards along the sea. The clouds also shewed higher currents moving in various directions. Steep conical peaks rose up out of flat clouds, which moved with the wind towards the south-east; more and more followed, rising till there were rounded domes; and these in their turn spread out and flowed over, and broke up into detached masses, which drifted away before upper currents. But the cloud spread to windward as well as to leeward, eastward and westward from its own centre of movement. It contained a radiating force.

When the upper sides of clouds are seen from a high mountain, the same forms appear.

From the top of the Rhigi, before sunrise, the Swiss lakes may often be traced among the mountains. Each is covered with a canopy of gray cloud, beyond which there stretches a frozen sea of mountain peaks cutting clearly against the rosy sky. Distant detached hills to the northward stand up like blue islands in lakes of gray mist, resting becalmed upon wide plains. But when the sun rises motion begins. The stratum of flat mist rises up, and heaves, and the gray plain

becomes a troubled moving sea of rounded hills of vapour, all bright and shaded, and glittering in the morning light. As the day wears on these rounded masses separate, break up, and creep along the glens and hill-sides, rising as they go, and by noon piles of rounded white cumulus clouds are peering over the tops of the highest mountains, or covering them. Later in the day a traveller in a valley may find himself drenched by heavy rain, while one upon a higher level, or in the plain, is rejoicing in bright sunshine. But if a wet pedestrian ascends an outlying mountain like the Faulhorn, he may pass through the falling shower into the cloud of little floating drops, and so through gray mist into bright sunshine and clear air. He may see the mist creeping up the glens, because the sun is warming the hills, and rain is condensing about the cold snow.

This engine is worked by fire and frost.

Shortly before sunset, on such a day, the lookout from such a spot is very beautiful. The great snowy Alps glitter in the bright light and clear frosty air, and seem to be close at hand, till some distant thundering noise calls attention to a few rolling grains of white dust. Then the real distance is measured by the help of the grand sound of a falling avalanche, and the giants assume their true proportions.

The sea of cloud which surges against the mountain a few hundred feet below the peak, changes its shape at every moment, as currents of air rise from glens below. The atmosphere is all in motion, though there may be no general horizontal movement at a particular spot and time.

But, when the sun sets, this local motion gradually decreases, and cold moon-beams may play upon a quiet stagnant silvery ocean of gray cloud resting becalmed upon hill and plain, or creeping slowly upon still water.

We live in a sea of boiling air, and when its local movements are made visible by clouds; heat, cold, and gravitation—radiating and converging forces—are seen at work in the atmosphere.

Force is revealed by form.

On these forces and on these movements depend all atmospheric changes and the science of meteorology, which treats of them.

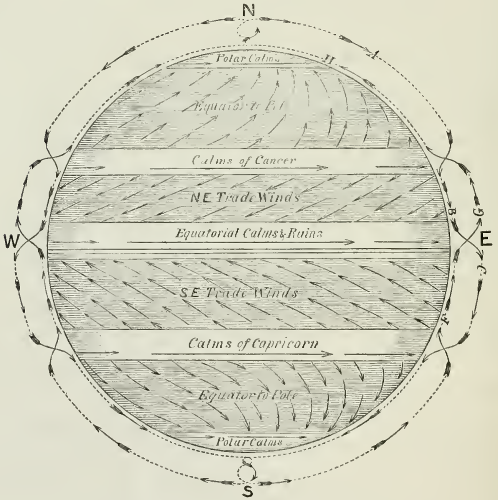

FIG. 8. DIAGRAM OF THE WINDS, BY LIEUT. MAURY, U.S.N.

"Abstracts of Meteorological Observations, etc.," edited by Lieut.-Col. James. London: Eyre and Spottiswoode, 1855.

CHAPTER VI.

METEOROLOGY.

THE modern science of meteorology is founded upon upward and downward movements in the whole atmosphere.

All storms have been traced to the movements of two great currents in each hemisphere, which move like local currents, and for the same reason. These are north-east or north polar, south-west or equatorial, in the northern hemisphere; south-east or south polar, north-west or equatorial, in the southern hemisphere.

These great currents are attributed to upward and downward movements:—to the rising of light warm air near the equator, and to the falling of heavier colder air at the poles. Atmospheric movements then, whether large or small, general or local, are attributed to the action of heat, cold, and weight. But these simple movements are modified by the earth's rotation and by change of weight.

A cold heavy current of air, moving southwards from the north pole towards the equator, moves also towards the west along the earth's surface. It appears as a north-easterly wind, and it gathers heat and loses weight as it moves.

The equator is a larger circle than any other which is described by a point on the earth's surface about the earth's axis, and its parts move through a larger space in a given time.

A mass of air moving southward from a small revolving circle near the north pole, and also moving eastward together

with that part of the earth from which it sets out, lags behind a point upon a larger circle which is nearer to the equator, and is revolving eastward with greater speed.

So a north wind becomes a north-easter. A point on the edge of a disc, ten miles from the north pole, travels round the axis, a distance of about sixty miles, in twenty-four hours : it moves about as fast as a man walks : but a point on the disc, whose edge is the equator, moves eastwards more than a thousand miles in an hour.

So a north wind moving southward over Scotland, and eastward at the rate of Iceland, is passed by a Scotch tree as a man walking eastward is passed by an express train. A polar wind is a north-easter in the northern hemisphere, and a south-easter south of the equator, because air lags behind earth and sea when moving from smaller to larger circles. But the polar wind does not blow furiously, because air is dragged round and gains easterly motion as it gathers heat and loses weight on its way to the equator.

For a like reason, an equatorial calm, which sets off along a meridian, and blows from large to small circles, becomes a westerly wind. It plays the part of the railway train, and overtakes the crawling tree which grows on the British Isles. It bends trees, but does not always tear them up by the roots, because it is held back by friction.

The warm light equatorial south wind blows because air expands, and loses weight, and rises ; it becomes a south-west wind because the earth turns eastwards.

The prevailing direction of the wind in the British Isles is about south-west, and trees proclaim the fact by form.

In Wistman's Wood, near Dartmoor Prison, at an elevation of about 1200 feet above the sea, a curious stunted scrub of gnarled oak, said to be "as old as the creation,"

shews that the prevailing wind has been south-west since the oaks were acorns.

The strange old trees stretch out their twisted, tangled, moss-grown, fern-clad arms towards the north-east, and bend their hoary trunks in the same direction, as if seeking shelter. But on the hill above them, a great boulder, as big as a house, proves that some force stronger than the wind has acted in the contrary direction, *towards* the south-west. The stone has been pushed from its place, and rests on the hill side.

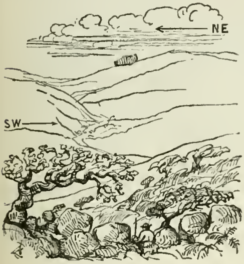

FIG. 9. OLD TREES AND BOULDERS. Wistman's Wood, Dartmoor.

Wherever a tree grows on the western coast of Ireland it bows its head to the north-east. Every exposed Welsh tree bends towards the dawn.

Every exposed tree on the west coast of Scotland seems to be driven by a furious wind on the calmest day. About Edinburgh it is the same. On the east coast, on North Berwick Law, an old thorn tree streams towards the north-east, and every tree in that neighbourhood that dares to peep over a wall, straightway assumes the form of an old broom, and points eastward.

At Dalwhinny there is something almost ludicrous in the stormy look of a whole wood of fir trees which point their fingers down Strathspey, and bend their trunks as if yielding to a furious gale.

In Scotch islands, at least as far north as Orkney, it is still the same. Trees are vanes, and no other wind-gauge is wanted to shew that the atmosphere has a habit of rushing

past the British Isles from west to east on its way north. If the true bearings of exposed trees were taken and mapped, a wind chart might be added to the physical atlas.

But though there are prevailing winds, and a general atmospheric system of movement; the easterly and westerly, heavy and light, cold and warm, polar and equatorial streams, which cross meridians in travelling north and south, one above the other; get entangled and whirl round as rotatory storms. On one side of the equator the storms revolve one way, on the other they whirl in the opposite direction, as whirlpools do when a stream flows into still water; or when streams cross or meet; under bridges and behind posts.

The meteorological department of the Board of Trade have a hard task, though an able leader, when they try to forecast winds. But for all that, the strongest wind that presses on British trees goes towards the north-east.

At places where winds meet and mingle, currents flowing in opposite directions neutralize and roll over, and whirl about each other; and so whirlwinds, circular storms, calms, and partial winds of every strength and direction, occur; though light and heavy currents keep their places, and surface winds are almost constant in some latitudes.

When opposite currents are flowing, clouds betray them by form, and they are commonly seen.

When a strong south-wester is driving in a flock of detached clouds from the sea, the clouds transform themselves as they fly.

The wind drags along the surface.

The under side of the cloud drags also and stretches backwards, but the upper side is pushed forwards and rolls over like a curling wave. There may be a strong breeze below, but a gale higher up; and higher still clouds may be spread

out on calm ripple-marked plains, where currents are passing each other, and rolling up the clouds between them into mackerel sky.

Fig. 10.

All these forms do but indicate movements which result from the action of two forces ; one radiating from a centre, the other converging towards it, and the science of meteorology is founded upon these two forces and on their action, above the earth's surface, in the air.

Air is constantly moving up, and down, and sideways, above water and solid ground. Meteorology attempts to explain the movements, and the moving forces are heat and weight.

The main facts were known to men when the first chapter of Ecclesiastes was written, as Maury points out in his writings.

"5. The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.

"6. The wind goeth toward the south, and turneth about unto the north : it whirleth about continually; and the wind returneth again according to his circuits.

"7. All the rivers run into the sea ; yet the sea is not full :

unto the place from whence the rivers come, thither they return again."

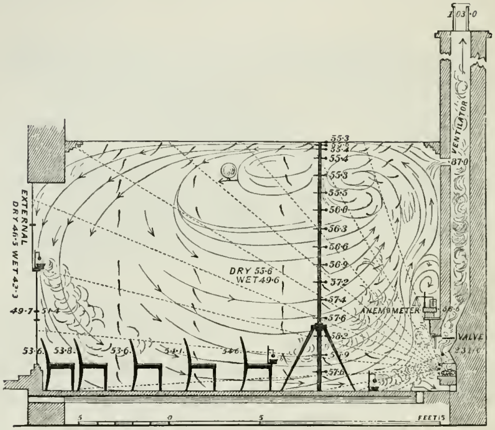

FIG. 11. DIAGRAM OF DRAUGHTS IN A ROOM.

Section of a large room, shewing the positions and mean amount of deflection of silk vanes; temperature shewn by thermometers; force of upward current at the mantlepiece in grains per square foot; moving fumes; balloon; radiation from fire; and the direction in which air circulated under these conditions.

From the "Report on Warming and Ventilation of Dwellings," 320, Sess. 2, 1857.

CHAPTER VII.

AIR.

A CAUSE is found by working up stream—by creeping along any one spoke of a wheel towards the centre. The effects of a known cause are got at by working the other way. Starting from cloud forms, heat is reached. If heat be a mechanical power which moves the atmosphere, forms like clouds should be found at the outer end of shorter spokes in the same wheel.

If a principle be established, many phenomena can be traced to it. In meteorology, as in all sciences, a result is reached by observation of facts, but experiment is the final test of theory, however formed.

A power may be used when found.

If great and small atmospheric currents flow, for the reasons given, and heat and gravitation are radiating and converging forces by which air is moved, then any quantity of air, great or small, ought to be moved in the same way and by the same forces. And so it is wherever the experiment is tried.

Air in a conservatory may be taken to represent an atmosphere. The ground is warm, the roof is cold, and the general mass of air cannot escape beyond certain limits.

If one part of the floor is hotter than the rest, cold currents converge, and fall and flow towards that spot, absorb heat there, and rise like warm fountains to the roof. Thence warm

currents radiate in all directions, and flow towards the cold sides of the building, away from the warm region, and as they move above, they part with the heat which they acquired below. The smoke of a few charges of gunpowder, burned upon the floor of a hot-house, makes the currents visible, and the experiment always gives a like result, because it is founded upon a general law which affects air.

Air expands and rises when heated, contracts and falls when cooled, and moves sideways to find its own level, or escape pressure.

Air within a cottage, with a fire on the floor, obeys the law, and clouds of peat-smoke float overhead, and roll in emulation of clouds in the sky, while small storms blow amongst the plenishing on the clay floor. There is good fresh air in poor huts.

Air in a cave moves in the very same way for the same reason. When a fire is lighted at the extreme end, smoke rises to the cold roof, but it speedily cools and falls again, and returns along the cold floor to the fire, which set air and carbon in motion. It takes some time for heat to force smoke to the cave's mouth, because the hot air which carries it is cooled by cold air in the cave. So revolving systems of radiating and converging currents move in opposite directions, above and below; while men near the fire sneeze and cough, and are lost in clouds of rolling peat-reek. But as the air of the cave warms, the system moving within it enlarges its sphere. The smoke gets nearer and nearer to the door, and finally two regular currents are established. A warm stream flows outwards along the roof, bearing smoke and glowing in the firelight; and a cold chilly draught of pure, clear, fresh air creeps along the floor towards the bivouac. Because they breathe pure air, cottagers, gipsies, and travellers seldom wheeze.

A sail or some other screen makes all snug, and then a wanderer may stretch himself at ease on his bed of heather or leaves, and watch forms in the smoke, and rapid steady movements, which fire, kindled by a spark, keeps up in air, so long as fire gives off heat-force.

It is the same in a cubic foot of air confined under a glass shade. The movements may be seen by the help of smoke ; or delicate vanes made with gold leaf, will point towards the fire and the window, the hottest and coldest spots which can influence air in a room.

Polar and equatorial currents are found under a glass shade when they are sought, and they blow even in close cellars.

Perhaps the largest mass of air enclosed artificially is at the Sydenham Crystal Palace, and there draughts and warm currents are in proportion to the size of the building.

At one end a high temperature is preserved for the benefit of tropical plants, birds, and fish, but the rest of the building is kept cool.

According to theory, there should be a warm moist current flowing along the roof from the warm tropical regions, and a cold dry current flowing along the floor towards them ; but if there were, the temperature within would be too evenly spread by the air. To keep temperature off the balance, the currents were arrested, but they assert their presence nevertheless, and shew pressure by form.

The tropic which divided the torrid zone of the Crystal Palace from more temperate regions was at first a great canvas screen, and its form betrayed the invisible forces which pressed upon it. It bulged outwards *above*, like the topsail of a big ship, and inwards *below* like the mainsail of a first-rate taken aback. The imprisoned breezes could have driven big ships

and large balloons, waves and clouds, east and west, for the sails tugged hard above and below.

A visitor passing the tropics below, passed the door with a cold fair wind behind him, but one who attempted to enter by the upper gallery was met by a strong, damp, warm, head wind. Heat expanded the air, weight squeezed it, and air pushed the canvas, two ways at once.

Thermometers shewed that the lower current was cold and dry, but the upper warm and moist, and the outer glass in the tropical region streamed and dripped with condensed vapour, which light hot expanded air had absorbed.

So, in the Crystal Palace at Sydenham, are tropical and polar currents, and local winds ; evaporation and condensation ; as well as specimens, models, and copies of most of the world's productions, old and new, living and dead.

The principle on which these currents of air move is worth learning, for it may be turned to practical use.

Without oxygen any animal dies ; without fresh air constantly supplied it suffers for want of oxygen ; and these sufferings are in proportion to the absence of oxygen from the air which is breathed, or to the presence of something hurtful in it. Men die for want of air under water. That they often suffer in dwellings for want of fresh air is notorious ; but few ever think why they suffer in mines, or in rooms. Every breath drawn by every living creature is a chemical operation, in performing which oxygen is taken away from nitrogen, and carbonic acid added to it. Within a given time a set of lungs will absorb so much of the oxygen in a certain limited quantity of air, as to leave a spoiled mixture of air, nitrogen, carbonic acid, and exhalations ; a mixture which stops the play of lungs, stills the beating of hearts, and quenches fire as effectually as a like volume of water.

If any one is cruel enough to try the experiment, let him put a mouse on a plate under a tumbler, oil the edge of the glass, and watch the result. The mouse, unless relieved, will certainly drown himself in his own breath. But men and women, for want of knowledge, voluntarily subject themselves every day to sufferings which are the same in kind, though less in degree. The evil is glaring, and the results are but too well known; the difficulty is to find out the best remedy, and to persuade the patients to take it. Anything is blamed rather than invisible air, and every smoke doctor and engineer has a special nostrum of his own for keeping out "draughts," while persuading fresh air to come where it can be breathed. The plan is called by a long name, and when tried it often fails. Surely it is wisest to teach that fresh air is necessary, and foul air hurtful; to shew why air moves, and leave men to apply the knowledge, and help themselves. Air driven by heat moves exactly as water does in a boiling kettle. Hot air, or hot water, is lighter, bulk for bulk, than cold air or cold water, at a certain pressure; and the cold heavy fluid will flow towards the hottest place, and the warm lighter fluid will flow from it as certainly as winds blow and rivers flow, and for the same reason.

There is nothing simpler than "ventilation," if the principle is known and the law of nature obeyed.

Air under the earth obeys the same laws which govern air in the free atmosphere.

In coal mines ventilation is carried out artificially, but according to natural laws, by heating air in one shaft, and letting cold air sink down another; or by dividing a single shaft, and lighting a fire on one side. By partitions, doors, screens, and brattices, the downward current, set up by gravitation, is made to flow where it is wanted, to dilute and

carry off noxious gases, and supply the means of existence to miners, horses, lamps, and fires, which cannot breathe and burn without oxygen. In some mines air is thus moved a distance of thirty miles, at a steady rate, and more heat moves it faster. A ton of coals burned in a day boils up a breeze. Burned in an hour, the fuel drives an upward gale which blows out candles in rushing down to the furnace.

The system is good, and it only fails when ill carried out, or when the machinery breaks down.

In cold metalliferous mines, driven into hill sides, and out at the top, like those of Yorkshire; where the so-called system of natural ventilation prevails; currents of air move different ways under ground when the outer air is in different states of heat and pressure.

Changes in weight, which move mercury in a barometer, also move columns of cold air shut up in vertical shafts.

Changes of temperature, which affect fluids in a thermometer and in the free atmosphere, also affect air shut up in big tubes and chambers of rock.

Shafts and levels, pits and galleries, mines and chimneys, are but barometers and thermometers on a large scale.

So it happens that when air within one of these mines is colder and heavier than the air outside, a current flows along the adit and out into the glen below, as water does; and it draws air down into shafts at the hill top. Because the air within is heavy and runs out, the upper air falls in after it to fill the void.

When the air outside is cold and heavy, and the air within warmer and lighter, the current is reversed. Light air rises out of the highest shaft like smoke from a chimney, while heavy air flows in below, as water would if the glens were flooded.

In either case, there is sufficient movement to change air in most parts of a mine, with openings at high and low levels.

If barometric pressure is removed outside, the air within expands, and so escapes till the balance of pressure is restored. If there be noxious gas in chinks in rock, or in coal, it escapes most when the barometer is low.

If pressure is added, the confined air is compressed, and the outer air enters till the vacant space is filled.

When a strong wind is blowing outside, it acts upon air within a mine, sucking it out of a shaft as the current passes over it; and driving it in when the wind blows upon the entrance to a level.

But in certain states of pressure and temperature there must be stagnation in a mine, as there are calms at the surface, and on these occasions men are driven from their work.

When no one is able to predict which way the current will flow at any time or place, it is impossible to direct it.

Thus it happens that close ends abound in nooks and corners of mines, in spite of "windy kings," "windylators," "fans," and "water-blasts;" engines which substitute muscular force, water and steam power, for nature's power—heat.

Men are often driven from their work and choked out of mines for days by changes in the weather, when a fire would remedy the evil; though strong fires are burning to waste beside most mines. "Lead miners are as good as barometers" for their neighbours, but nevertheless they and their class generally, seem to be convinced that "weather ventilation" is the best of systems for them, and that fires are only fitted for coal mines where fuel is cheap.

In deep hot mines like those of Idria and Cornwall, where the natural heat of the earth is felt—at a depth of 1800 feet below the surface—in hot lodes, and hot rocks, where tem-

perature rises to 90° and 100°—there is true "natural ventilation," which only needs direction to secure good air. But even in such mines men often trust to nature while working against natural laws.

In one hot Cornish mine everything went wrong at "the end," till a great storm made a commotion in the atmosphere, which reached the hot levels below. The currents changed, and since that time they have constantly and steadily followed their own paths, and all goes well. The men suffer from heat, but they breathe good air—for the natural heat of the earth ventilates the mine.

In all cold mines where atmospheric ventilation prevails, there are "close ends," "poor air," "cold damp," "carbonic acid," and other evils, which cause sickness and excessive mortality, while engine fires are burning to waste at the surface near most of them.

"Levels" which are open at one end and closed at the other; where work is going on, ventilate themselves, though slowly and imperfectly, on the general principle. They are like long low caves, 7 feet high and sometimes 300 feet long, and men and candles heat the inner end. There is consequently a light warm column of air at one end, six or seven feet high, while at the other is an equal column of colder and heavier air, which presses upon and displaces the other. Heat forces out a wedge of air along the roof, while weight forces in a wedge of purer air along the floor. When a shot has been fired, the smoke is seen rolling slowly out in thick volumes along the roof, while there is little or none below. In an hour or in many hours the smoke is gone, and in time it will be found rising out of some shaft, if followed. But smoke often hangs for days in close ends, because men and candles are weak caloric engines.

If a regular and constant current, however slow, passed through a mine, down one shaft and up another, which would be the case if an upcast shaft were joined to an engine furnace-door; then brattices and trap-doors would turn the current into any corner, however distant, and so miners would suffer less from bad air if they used power which they throw away.

In dwelling-houses it is the same. Heat and weight cause movement in air everywhere, but the simple law is often forgotten, unknown, or misunderstood. So it happens that contrivances meant to promote ventilation impede movement in air.

To warm a room is easy. Every savage who kindles fire knows the art. It is only requisite to burn enough of fuel to warm a hut; and a leaky hut ventilates itself.

Fuel burned on the floor of a cave or hut, in an open fire-place or a closed stove, in a mine, a lamp, or candle, or in any other contrivance, is a source of heat, and that is power which may be used or wasted.

The fire radiates directly to all places to which straight lines can be drawn from it; indirectly wherever rays of heat can be reflected or refracted, and the radiated heat is absorbed and given off by everything within its reach, in proportion to the supply. The fire is to things in a room what the sun is to the outer world; but a room is a small world, and, unlike a hut, it is nearly air-tight.

To change the air in dwellings with chimneys and doors, or in mines, it is only necessary to put right fires in right places, and let air follow its natural course. To ventilate close rooms air-holes must first be made.

Fire acts mechanically by expanding air about it, and every separate object which is warmed by radiant heat and is warmer than air in contact with it, gives heat to air, both by contact and by radiation; expands it, and so moves it. Cur-

rents, like those which are caused by natural heat in the atmosphere, circulate in dwellings because heat is set free, reflected, and refracted. But fresh air cannot get in if " draughts" are kept out.

There is a general system of currents which radiate upwards, away from the hottest place in a room—be it fire, or stove, or heated pipe—and which converge downwards and move towards it, after the spreading currents have carried heat to the coldest places, and have left it there. There are miniature radiating and converging equatorial and polar currents in every room, as in every mine, and ventilators should use them.

There are small local systems which circulate about every candle, or heated chair or footstool, stove, or living creature, in a human dwelling, mine, or other closed space. These are as eddy winds, land and sea breezes, domestic whirlwinds, and family storms ; and their progress may be watched in graceful curves which form in clouds rising from peat fires, pastiles, tobacco pipes, newly extinguished candles, matches, powder, steaming tea-cups, or the kettle.

To warm and ventilate, it is only necessary to burn fuel, and direct the currents of air, which must move somewhere.

Let the window of a warm room be partially opened above and below, and let threads, ribbons, grass, feathers, or any other light material, be hung in the openings to act as vanes. It will be shewn that light air is escaping above, with a charge of heat taken from things in the room ; that heavy air is entering below to be warmed, and that the air in the room is revolving as a current of water eddies in a bight. It is the case of the mine in a hill.

If the same thing is tried in a room colder than the outer air, heavy cold air flows down and falls out of the window,

as water might do ; and light warm air enters the window above, deposits a freight of heat in the room, and then follows the outward stream. In either case the movement goes on till the mechanical force is expended, till the unequal weights are balanced, and pressure and temperature the same.

A living being is a source of heat, and a cause of movement in the air of a room, a mine, or any closed or open space. The warm breath and natural heat of a man who enters a cold room and takes up a position in it, moves air and cobwebs on the ceiling, at a distance of 30 feet, in about a minute. A miner moves the air in which he works ; a mouse moves air under a glass shade ; so does a rabbit in his hole.

The smell of a newly-lighted cigar moves about 30 feet in two minutes in cold air in a room ; but the rate of motion depends upon the coldness of the room, and the energy of the smoker. The sun and a pipe are different sources of heat and power, and currents of air flow when power acts, whatever the source of it may be. But a man and a candle work on air in a large mine, as a sailor's pipe does on a calm at sea.

An elastic balloon filled with a light gas, and carefully weighted, so as barely to rest on a table, expands and ascends when placed on the floor opposite to the fire. It is like a cloud warmed by the sun. It moves along the ceiling, away from the fire, towards a window, falls where it cools, and drifts back towards the fire along the floor. It rises because it expands ; it expands because it is warmed ; and it follows the stream of air, and shews its rate and direction. It does not move of its own accord, neither do the currents which move it. They move because they are expanded and compressed, and go fast or slow in proportion to the heat used to move their weight.

The smoke of a lamp where it blackens a ceiling, shews the course of currents of air by forms in which carbon is arranged. The forms are tool marks, and the tool is air.

Ice forming on a window, and hoar frost under a door, take the shape of streams of air moving in a room and entering a house.

Silk vanes, cobwebs, or any light substances hung about any closed space, shew currents of air by form as clouds do.

Air escapes from the garret windows of a warm house, but enters the cellar door. The cause is still the same.

There is pressure where currents are impeded, as shewn by the skreen at the Crystal Palace. There is outward heat-pressure on a garret window when closed; inward weight-pressure on the lowest door, and cold air will open the door and enter, if the latch be turned on a winter's day.

When pressure is greater than resistance, as when a house burns, air, urged by strong heat and weight, shews more power; upper windows burst outwards, lower windows are crushed in, and hard glass is shattered by invisible gas.

Imprisoned air, aided by more heat, bursts iron in a mould.

The atmosphere and weight crush iron boilers when water inside is deserted by heat, and steam loses the ally, without whose aid steam is ice.

And the atmosphere, when urged by the sun, and by the earth's gravity and rotation, sometimes becomes a hurricane which sweeps away trees and houses in its resistless course.

So heat and weight are strong useful powers; good servants if bad masters; and they work with air.

Some years ago an experiment on a very large scale was made in a coal mine below the sea-level, and it affected gases of very different specific gravities.

A northern mine in full work is a strange busy scene.

At the pit-mouth fires flare and smoke; steam-engines pant, and puff, and wheeze; chains clank, wheels rattle, and waggon loads of coals rise up, rush from the pit, and crash down shoots into railway trains. There is a fearful din.

Men step on a smoky platform, and down they go like Don Giovanni and the commandatore. Down they sink rapidly; and if unused to falling, their hearts seem to rise.

If the pit be an upcast, the smoke is dense, and the air grows hot, and hotter, and hotter still, as the skip slides down the chimney. It passes the furnace vent, the air clears, and the journey ends; it may be, far below the sea-level.

At the bottom of the pit there is bustle and busy work. Shouting and grinning, black, half-naked urchins, push waggons of coals rattling over iron plates, and up they go like a puff of smoke. Sleek steaming ponies, who never see daylight, trot in with trains of waggons from distant ends, grimy postilions with lamps in their hands ride in from distant stations, with arms clasped about the necks of their steeds, and heads bent low to avoid the roof. Black railway guards crouch in their trains and grin, and clouds roll from every open mouth and nostril.

The boys always ride home from their work if they can, and sometimes they ride races.

Lights flit about, gather, and disperse. Half seen forms, —a man's head and hands, or half a face; a tobacco-pipe smoking itself; horses' heads with glittering eyes and smoking nostrils, with a figure of fun grinning out from under the mane; all the fancies of Teniers, in his wildest mood, seem to float about in the darkness.

A cluster of these visions and their lights gather and

grasp a bar; three raps are heard, and they fly smiling up the chimney after the coals and the smoke.

At the end where the work goes on, these gnomes are constantly burrowing on, and bringing down their roof. The coal foundation is picked out, and the upper coal, the old sandstone flags, and the shales above; the arched roofs of this vault, with all their loads, begin to yield and split with a strange ominous noise. "CRICK." Wooden props shoved in feel the load, and they too complain and creak. When the full strain comes on them they are crushed and riven to splinters, and the roof "roars like cannons when it is coming down."

A spoke in the world's wheel is cut through and mended with sticks; the scaffold which supported the flat arch is dug away, so the arch comes down and the sticks are crushed.

With his head touching the roof, and his feet on the floor of a mine, a collier stands under a stone column it may be 2000 feet high. A weight sufficient to squeeze him as flat as a fossil fish is coming down, and he hears it coming, but he works on and smokes placidly under the lee of his prop, rejoicing to see weight help him to quarry coals.

That is working according to natural laws. That is using a power which has been found. That is one use of weight.

Some years ago, the workings of two such coal mines near Newcastle were purposely joined. Each underground world had its own atmosphere, with its system of currents. It is important to keep the stream moving, to make it move along the face where men work, and to know the way the stream flows, in order to be able to guide it. So these black gnomes, with shining oil stars on their foreheads, and gleaming teeth and eyes, argued keenly in their separate burrows. They are a shrewd, knowing race these northern Teutonic gnomes;

they know that fire-damp or choke-damp may blow them to bits, or drown them if their atmospheric systems go wrong. They know their own interests, and generally know how to secure them. So they held high council about their winds, when their systems were approaching each other.

The pits were miles apart, but a thin block of coal divided the workings at last.

On either side stood an anxious man reading the weight-power that pressed on the coal, from the dial-plate of an aneroid barometer. That was another use for weight.

A blow demolished the wall, and the mines were successfully joined. Weight turned the scale again. The lightest column went up, the heaviest came down. The trade wind blew towards the barometer which shewed least pressure, away from that which shewed most, by standing highest; and the coal wall being gone, the barometers marked the same pressure at the same level, and regular circulation went on.

There was less pressure in one mine, because there was more heat; and the colliers poked their fires, and rejoiced in fresh air, and scorned danger overcome.

They had got the mastery over weight and heat; and the giants and the gnomes now work amicably together in their united dens under the earth.

In deep cold metal mines, where a few narrow pits all open about the same level, stagnation is the rule. So long as air inside the stone bottle with the slender necks is colder than air outside, it is heavier. There is no natural power applied to lift it, and it cannot flow out for want of fall. Like water collected in an old working, the cold, heavy mine air is a foul deep stagnant pool, which evaporates a little, overflows now and then, and swings about in its rocky bed; but it never changes like water in a river pool, because

there is no stream flowing through it. Such a mine is a contrast to one through which air moves constantly.

On a fine, warm, breezy, bright, sunny day, with the sweet breath of fields and heather hills in his nostrils, a pedestrian in search of information comes to a trap-door and a hole like a draw-well. Odours of bilge water and rotten eggs, mildew and worse things rise when the trap is lifted, and they contrast abominably with the delicate perfume of beans and hedge-rows. The pool moves when it is stirred; but when left to its own devices, the most delicate tests often fail to shew any movement at a pit mouth. Cobwebs, paper, silk, soap-bubbles, and smoke, which shew movement in the stillest room, all indicate repose at the neck of the bottle, for the unsavoury air stagnates in the cold dumb well which holds it.

If the average temperature inside be 60°, and outside 61°, there is nothing to lift the lowest stratum.

There is no rattle, no din, no movement here. A dull sleepy creaking sound comes faintly in from a big water-wheel, which is slowly turning and pumping water from a neighbouring hole. The only cheery sound about the place is the rattle of hammers and stones, where boys and girls and strong-armed women, are smashing and washing ore in sun-light and fresh air. Like bees they sing as they work cheerily. Their cheeks are ruddy, and their bright eyes dance with fun; but down in the dark well is sickness, silence, and gloom.

A distant sound is heard below; the yellow glimmer of a candle shines out of the black earth; hard breathing approaches, and the regular beat of thick-soled boots on iron staves comes slowly ticking up the pit, like the beating of a great clock. A mud-coloured man appears at

last, and he stares amazed at the stranger perched at the mouth of his den ; seated on a sollar, and watching cobwebs with a pipe in his cheek. The miner may be blue, or yellow, green, brown, orange, or almost red, but he is sure to be gaunt and pale-faced. His hair and brow are wet with toil ; his eyes blink like those of an owl in day-light; he wheezes, and he looks fairly blown. With scarce a word of greeting, he stares and passes on to the changing house; and the cobweb which he disturbed settles like a pendulum at Zero once more.

When a lot of miners who work in such mines gather amongst other folk, they are as easily distinguished as blanched celery from green leaves.

When visitors go down, guides and strangers dressed in their worst, each armed with a vile tallow dip, stuck in a ball of clay, cluster about the well, which is called the "foot way," and one after another they vanish from the upper air.

The TICK : TICK : TICK : of many feet wakes up echo, and hot breath stirs the air. For the height of a town-church, down they go into the darkness, and their steaming breath rises up like blue smoke. When daylight fails, a halt is called, and candles are lit on the ladders.

This travelling is, to say the least, uncomfortable. A man in the middle has to watch that he may not tread on the fingers next below him, and to look out for his own knuckles; to hold the sharp, cold, greasy, gritty iron rounds, and the candlestick of soft wet clay, so as to hold the grip without losing the light, or singeing his nose with the candle. He has to feel for his footing, watch for damaged or missing rounds, and generally keep his wits bright; for there may be fifty fathoms of sheer open depth at his elbow, and nothing earthly to save him if he slips or stumbles in this "foot-way."

The Col de Geant in the Alps, Eriks Jökull in Iceland,

a long day after the deer, and a day's march with a heavy pack, are easy journeys to a mining scramble through dirt, darkness, and foul air.

Like a train of Irish hodmen, slipping down from a London house, down goes the procession; and those who are unused to the work find it hard labour. The way into this Avernus is not a facile descent. In half an hour, or an hour and a half, according to pace and distance, a journey which costs minutes and seconds in a coal mine, ends at the bottom of the mine where machinery is unknown. It is the goat's track against the railway; the fox's mine against the work of human brains. It is the old story of brute force and skill, giants against dwarfs; and the clever dwarfs who circumvent the giants best get most work out of them in mines as elsewhere.

On the floor of a coal mine the footing is sure. In the other, passages are made at different levels, and they are full of pitfalls, and uneven in height and width. Tramping and splashing through mud and mire, over hard rock and piles of rubbish, the train moves off. When the level is reached, a miner leads, another brings up the rear, and strangers file off and keep their places as best they can.

"Shoot:" cries the leader, and ducks his head. The next finds the edge of a sharp ironshod trough at the level of his eyes, dives under it in his turn and passes the word; "SHOOT." It is the place where ore is shot down from upper levels into waggons, and it is a trap to break the heads of the unwary.

"Sump:" cries the leader, and the follower, with his candle flickering in his eyes, finds that he stands on a single plank, or a narrow ledge of stone, above a black abyss. In daylight, heads are apt to swim above such depths, in the dark that feeling is absent; so each in turn passes the bridge and the

word: "SUMP." It is the place where ore is sent down, or the top of an air chimney, or the mouth of a pit dug into the vein.

"Deads:" and the leader proves his descent from some burrowing ancestor, perhaps a badger, a rabbit, or a rat, by crawling up a heap of rusty stones, wriggling through a long hole, and sliding down head foremost into the passage beyond. He looks very picturesque. The soles of his boots disappear at last, and one by one the procession struggle through and take the colour of the mine from its roof and sides. And so for half a mile, or a mile or more, it is "heads!" "shoot!" "sump!" "deads!" splash, tramp; and by that time all hands are wet, hot, greasy, smoky, and muddy. The smallest hole in an air-way is the measure of the current which can pass, so deads throttle the mine.

Having driven two long caves, one above the other, so far that candles will no longer burn at the ends, and men can hardly breathe, the next step in metal-mining is to "rise" and "sink" and join the caves; to make a passage for air to move through if nature so wills. It is easier to rise than sink, for loose stones fall when blown out of the roof, but as men rise into the rock, smoke, breath, hot air, and light exhalations rise with them. Thermometers rise also to 70° and 80° though water in the level and the rock may be at 60° or 64°.

To get up to the top of a rise "stemples" are often fixed for steps. These are bars of wood on either side, and to mount is like climbing a chimney. The stones which are quarried at the top are thrown down and gather in a conical heap below. So the place is well called "a close end."

In order to get oxygen into this black hole, a small boy, whose life, like Mr. Mantelini's, is one perpetual grind, is stationed at some place where the air is thought fit for use.

With a circular fan and a leaky tube, or with a thing like a magnified squirt; by the muscular force of a young male caloric engine, with the idle nature of a boy, some air of some sort is driven to the end, and half-choked men and dim candles struggle on for life in the burrow.

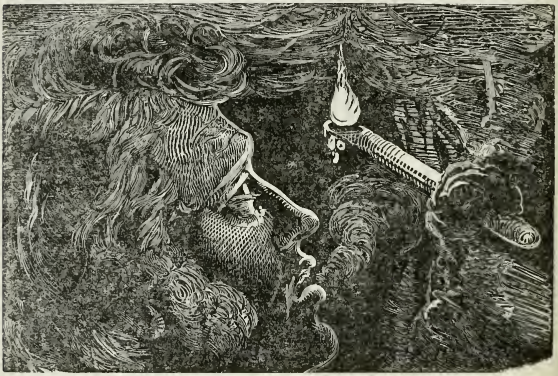

FIG. 12. Ventilating engines, commonly used at close ends in Metal Mines.

The lungs of a healthy man hold as much air as some of the squirts used, and one was expected to supply oxygen to three men and three candles.

The collier laddie who does like work, has a lamp and a book; he sits beside a door with a string in his hand, and his duty is to open the door when any one passes; to keep it shut, and keep his own eyes open at other times.

The one guides air intelligently, the other urchin drives it by weak brute force, and with bad engines. The ventilating boy engine passed, the leader dives into a rolling cloud of thick fœtid smoke. His candle turns into a nebu-

lous haze, his legs are seen wading alone after his body has disappeared, but both are found together at the end. With hands and feet on either side of the rise, in the graceful posture of a split crow, or a wild cat nailed on a kennel door ; through showers of dust and falling stones, up sprawl guides and followers with many a puff and cramp till they crowd a shaky platform at the top of the rise. It is the place where men work for hours, days, and months.

One effect of these close ends on one who is unused to them is to cause perspiration to break out freely while standing still, or sitting quietly, resting where a thermometer marks 64° or less. There is a feeling of tightness about the neck ; the chest heaves with a gasp, instead of rising steadily ; the shoulders take a share in working the bellows ; and generally there is distress, and a feeling like nightmare. Men at work in bad places pant and seem to breathe painfully ; their faces are red, or purple ; their veins swelled ; their brows wet and begrimed with soot. They seem to labour hard, though their work is not harder than quarrying stones elsewhere. In such places candles flicker and sometimes go out altogether ; no puffing or drawing will light a pipe or keep it lighted. There is no laughter, no fun ; no busy cheery clatter of active labour at close ends ; there is silent toil ; for carbonic acid is not laughing-gas.

When a sump and rise meet, where they have "holed through," the hot air in the rise flies up into the upper level, and the cold air falls in behind it. The temperature changes instantaneously and the hole clears as fast. Heat and weight have room to act, and they do the work of many boys. Fans and squirts are thrown aside, till the levels have been driven another stage.

But the foul air of an end is only diluted with less foul air if there be stagnation at outlets, where cobwebs are still.

To retrace downward steps, to return to upper air, has ever been labour and hard work. From the bottom of a deep mine, perhaps from under the sea whose waves are heard rolling stones above the roof—up perpendicular ladders, perhaps in the pumping shaft with the rods moving up and down within a few inches of his back; with foul stinging mine-water dripping on his head, and a smoky candle sputtering in front of his open mouth; edgeways through clefts, on all fours, feet foremost, head foremost, on his back, his belly, and his sides, the amateur miner follows his guide. Greasy, muddy, drenched, streaming with perspiration, with throbbing ears, giddy, tired and gasping like a fish, the man who is used to climb mountains in fresh air struggles back to it.

When daylight appears, glimmering far over head, when the trap-door is passed, the first long greedy draught of the clean pure air of heaven seems too strong. It flies to the head like brandy. Even miners who are used to such places often stagger and totter like drunken men when they come "to grass." These were the sensations of the winner of a Highland hill-race, in good condition, at the age of twenty-eight. In well-ventilated mines ordinary fatigue was the sole result of many a long scramble under ground. An ill-ventilated mine is a crying evil; air in it is slow poison; working in it shortens life; it proves ignorance, parsimony, or poverty—for ventilation is easy to intelligent men, who will learn an easy lesson.

By analysing air collected in close ends, Dr. Angus Smith has proved the existence of poisonous gases, in places where these sensations are felt. So working in these places must

be injurious. It has also been proved that mining shortens life, where ventilation is faulty.

It appears, from calculations made by Dr. Farr, immediately after the census of 1851, that Cornish miners who work where currents of air are weak and uncertain, die faster than the Cornish population who live above ground. They die faster than colliers who, in Durham and Northumberland, work in places where air is moved by the direct application of heat-power to it; where currents are strong and regular in the mines.

Foul air fills the black list faster than fire-damp and choke-damp, and all the perils which colliers brave.

The death rates between certain ages were as follows :—

Ages.	Cornish people above ground.	Northern Colliers.	Cornish men under ground.	
35 to 45	10	10	14	per 1000.
45 to 55	15	17	34	
55 to 65	24	24	63	

So the principle upon which currents of air move has been turned to practical use in northern coal pits.

A leader in the *Times* of February 4, 1864, shews the evil in dwellings.

Festiniog, in Merionethshire, has been a healthy place for many years. It stands where mountain air is pure, and natural drainage good. The people were well off, and neither intemperate nor uncleanly in their personal and domestic habits; they earned good wages, but they slept in foul air.

A new slate-quarry drew men to the district; no one had time to build; the work went on day and night; so houses, rooms, and beds, like the lodgings of Box and Cox in the

farce, were occupied continuously by successive tenants. In two low bedrooms, 8 × 6, and 12 × 6 feet, ten and twelve people were lodged. In some lodgings the beds were never vacated, nor the rooms aired, either by day or night. So fever broke out amongst the overcrowded. There were six or seven hundred cases amongst six or seven thousand people, and sixty or seventy died.

Without fresh air constantly supplied, men do suffer; but air is free to all, if they will only open their mouths and take it.

The law which governs air above the sea-level is good law under it; and governs all gases and all fluids, fire-damp and choke-damp, steam and water, as well as air. It governs air in copper-mines and in coal-pits, in houses and in the atmosphere.

Bacon was right when he wrote long ago, "IT WERE GOOD FOR MEN TO THINK OF HAVING HEALTHFUL AIR IN THEIR HOUSES" (vol. iii., 297).

There are many tool-marks which moving air leaves on the earth. It bends trees; it uses them as levers to tear up turf and stones; it blows sand; it blows waves against a coast, and the coast wears into cliffs. The atmosphere is but one part of one wheel in a vast machine; and it leaves its mark on the world which turns within it.

The moving powers are few and simple, and the forms which shew their action are easily learned from smoke, trees, snow-drifts, sand-drifts, waves, and clouds.

These have a meaning which can be read and translated; they shew movements in air by their forms. Motion shews force, and its direction; its nature is found by experiment.

Experiment proves that Heat, Cold, and Weight are forces which produce upward, lateral, and downward movements in air, and so mould forms, and wear solids.

Observation finds these forces distributed in the world so as to fulfil conditions which produce these movements in air; and that heat comes from the sun, and from the earth. So cloud-forms and air-marks shew the mechanical action of solar and terrestrial heat, and of weight, in the air. They are tool-marks.

All atmospheric movements, great and small, can be traced to one general law, which governs gases; and fluids also. But before a law can be applied, it must be well known to those who apply it; and the laws of natural ventilation are often unknown to men who try to fill houses and mines with pure air.

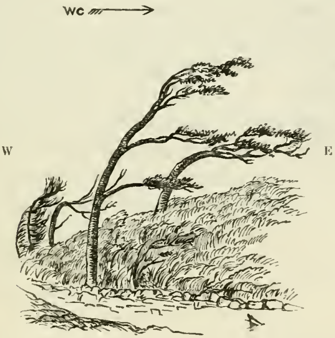

FIG. 13. BENT TREES NEAR LITTLE ORMES HEAD.
Sketched in a calm. 1863.

CHAPTER VIII.

WATER.

If heat be a force which moves all gases away from centres, then for that reason alone it is probable that heat also moves liquids, and in the same direction.

It is not necessary to begin at the dial-plate, and work through a whole train of machinery, in order to find the centre of every wheel; or to go back to the rim of each wheel to find the axle for every spoke. All British railways converge on London, but all railway journeys up to town need not begin at the furthest station. Without travelling round the world, we know that chimneys at the Antipodes smoke opposite ways, and that blacks fall towards each other, and the earth's centre.

If a natural law is known, its results follow. Powers which move the atmosphere and all gases, which radiate from, and meet at a point, bring a traveller to a large junction, from which to make a fresh start, or take a short cut, towards his object.

It is easily seen that forces which move air also move water.

Clouds whose forms betray movements in air are made up of water.

When air expands, it takes in water like a sponge; when it is lifted air lifts water. When it contracts it drops the load.

But air is expanded by heat, and contracts when cold;

so heat, weight, and air, are as hands which open and close about a wet sponge while lifting and lowering it.

In lifting air heat certainly lifts water to the highest point reached by clouds, and it carries them from the Equator to the Poles, and far above Coxwell, Glaisier, and Kunchinjunga.

But heat also acts directly on fluids. The sun's direct rays, when absorbed by water, and accumulated in it, lift it. They move water away from the centre, along a spoke, as fire drives steam out of a kettle.

In May 1857, during hot clear weather, two similar glass vessels were placed on opposite sides of a house, and filled with water. When weighed in the evening, the vessel which stood on the sunny side had lost nearly twice as much weight as the other. The sun's light, and its heat, had lifted water into the air, and the air had carried it off. But air on one side of the house could differ little from air on the other side ; so in this experiment the sun's rays drove the water out of the vessel. In the next trial, a thirsty terrier lapped up the water and spoiled the result ; but both did the work of mechanical powers.

According to Sir John Herschel, the amount of solar heat which reaches the surface of our globe would suffice to melt a crust of ice an inch thick in an hour, or evaporate a layer of water nine feet deep in the year ; if part of it were not expended in warming earth and air as well as ice and water. According to the same high authority, the actual fall of water in all shapes, and therefore the evaporation, amounts to a depth of five feet on the whole globe in each year. The sun's rays do notable work when they lift and drop such floods.*

Evaporation is a result of heat, and every experiment

* Good Words, January 1864.

shews it to be much or little in proportion to heat-power used, or weight-power removed.

It is common to fix the value of fuel by the weight of water lifted by heat set free while burning a certain weight of the fuel under a boiler. But fuel may be so burned as to spend heat-power on air instead of water.

In like manner, sun-power is differently applied at every different latitude, at every season, at every hour of the day, at every spot on the earth's surface, and the most of the rays shine into space or on other planets.

Most of the solar heat which gets to our world stops about the Equator, where the sun's rays beat directly on the ball by day, and from tropical regions most heat is radiated onwards by hot ground at night.

Least solar heat is absorbed at the Poles, where the rays glance off the slanting white surface.

So evaporation goes on most rapidly near the Equator in summer, and about noon, when the sun's rays strike into the earth, and drive water out into the air.

Though heat coming from the sun is the power which acts most conspicuously on air and water in the atmosphere, it is not the sole heat-power used, for it only penetrates a small way into the earth.

At Yakutsk, in Siberia, lat. 62° N., the earth is frozen to a depth of 382 feet. The summer sun thaws $3\frac{1}{2}$ feet of the surface, but the ice-crust is always hard lower down. If the sun were the only source of heat, this crust would be found at all depths. It is not so. Under the ice-formation is earth-heat. Temperature rises in descending: below 382 feet ice melts, and hard ice conglomerates are melted beneath the frozen crust. The mean temperature at the surface is 14°: below the ice-region it is more than 32°. But at 217 feet the

temperature of the ground is 27° ; and at 50 feet 18°. So heat is below and cold above, at Yakutsk.

On the American side, the ice-crust comes further south, but it is thinner at the same latitude. Perhaps the earth's heat comes further up from its home near the centre.

At Mackenzie River, the mean annual temperature at the surface is 25°, the ice-crust 17 feet thick, and summer melts 11 feet of the frozen surface.*

Solar evaporation goes on wherever the sun shines on water or damp ground, though at different rates; and terrestrial evaporation goes on also. Winds blow ; dew, rain, snow, and hail fall ; rivers collect and flow ; glaciers gather and slide above the earth's surface, chiefly because the side that is next the sun absorbs heat by day, which travels onwards into space by night, leaving water behind it. But rays which the earth absorbs radiate back from the earth's centre, together with rays which the earth gives off, and together they lift water and air up the spokes, as far as they have power; for radiating heat is radiating force, whatever its source may be. Solar heat is not much absorbed by smooth reflecting surfaces.

Mercury in a thermometer placed behind a mirror, exposed to sunlight, is less expanded than mercury placed behind a black board. But a thermometer, placed in the focus of a concave mirror, on a sunny day, shews that reflected heat is strong reflected force when it meets resistance. Placed in the focus of a strong lens, a spirit thermometer shews that refracted solar heat bursts a glass boiler.

A thin dark object like a leaf or a slate sinks straight down into ice on a bright day, but a thick stone protects ice, absorbs heat, and gives it off by night as the world does. For this reason large stones often stand upon raised pedestals

* Keith Johnston's Physical Atlas, etc. etc. etc.

of ice, on glaciers, while fine dust melts ice, sinks in, and is buried in ice, at night.

So in nature. Solar heat is more absorbed by land than it is by sea, because the sea is smooth ; and least of all in high latitudes, where the frozen surface slants most and reflects best ; and it penetrates little anywhere.

But when a hill-side faces the sun, and rays strike it fairly, sun-power is as strong in high as in low latitudes and levels. All arctic voyagers, mountain travellers, and æronauts, have found it so. Pitch melts on the side of ships ; men, balloons, and thermometers feel the power, and measure it. A white tent, pitched on a spit of white sand beside the Tana, lat. 70° N., became so insupportably hot about noon on a summer day in 1851, that panting inmates were forced to move it to the cool shade of a birch tree, where mosquitoes were thick and bloodthirsty. "Cuoikædne læ olla"—there are many midges, quoth a Lapp boatman ; but in the shadow of a hill there was frost.

A balloon rising through a cloud feels the sun-power, and expands with dangerous rapidity ; though transparent air above the clouds is cold as air in Arctic regions.

The power of the sun's rays to lift water depends on accumulation of heat-power ; and that depends on the nature of the substance on which the rays fall, and on the shape of the surface which they strike.

A rough black surface gathers more heat than a white one, and reflects less ; a black bulb thermometer stands higher than one with clear glass. A glass vessel, filled with black sand and water, loses more weight on a sunny day than a vessel placed beside it, and filled with white sand and water. White gun-cotton will not readily explode in the focus of a burning-glass, because it is transparent. A lens of clear ice

will transmit and condense the sun's rays, and light tinder. Clear air is little warmed by the sun's heat, which it transmits and refracts. Clear fluid absorbs more heat, but it transmits a great deal; for a glass bulb filled with spirit is a powerful burning-glass, though not so powerful as a solid ball of clear glass.

All these are questions of degree; the facts remain. The action of solar heat is directly opposed to that of weight at the earth's surface, and it lifts water when absorbed by it.

The earth's heat has a like power, and acts in the same direction.

When pressure is removed from water, placed under the bell of an air-pump, water rises from the vessel which contains it; and heat is the moving power, for water which remains cools and freezes. The heat acts upwards.

When air is cold enough, water steams up into it visibly, and heat is the moving power still; for water freezes, and vapour which evaporates turns to rain, and falls down when it parts with the heat which raised it up. Lower down, water in a dark mine steams under greater atmospheric pressure. The earth's heat lifts it, and the earth's weight drags it down when it cools. Still lower, water from a hot spring boils and spouts up, and blows off in clouds of steam; but it rains down in floods when it gets out of reach of the earth's heat which raised it. Heat in the earth lifts water at the end of every spoke where water is, but with varying force at every point on the sphere; because heat is variously impeded by various rocks.

Heat artificially set free acts in the same direction, whatever the source may be. Water rises from a kettle on a fire, and hot steam lifts a piston, or bursts the boiler.

Having found a centre from which air moves, and a power

which moves it; the movements of water are found to coincide with those of air, so far as anything is certainly known about them. Rising columns of steam move opposite ways at the antipodes, like columns of smoke or mist. Air and water circulate together in the atmosphere, and within their bounds they are moved up and down by heat and weight.

If these two forces so act on water above the sea-level, they probably act in the same way on water in the sea.

There are polar and equatorial winds; and similar ocean-currents flow in like directions unless impeded by land. When they can be seen, water-clouds are found drifting under water, and their forms repeat the story told by clouds in air.

We deal with the bottom of the air-ocean, and look up for signs of movement in it. We must look down on the sea and through waves at water-clouds.

Air rises far above the solid earth. It flows over mountains as the sea flows over sunken rocks; and its surface is out of reach. We cannot dive to the bottom of the sea; but we may look to the surface of the ocean for information as to the surface of the atmosphere, and seek at the bottom of the air-ocean to learn something about the bottom of the sea.

From the movements of air, movements in water can be inferred, when powers which move both are known; and experiments made with one fluid test theories formed about another.

It is easy to see movements in water.

The first difficulty is to get a smooth surface through which to look. On the calmest day waves disperse rays of light, and reflect them, so that a sea bottom is hardly seen, except in shallow water. A diver cannot see clearly under water; his eyes are not made to see there, and objects seem blurred and indistinct. A lump of chalk is white, but has no definite shape; a silver coin shines like light behind ground glass; the distance fades away into dark green, or blue, or black.

Smugglers of former days found a way to meet the difficulty, and their contrivance is used by seal-hunters and others. When smugglers were chased, their practice was to chain their cargo of tubs together, and sink them; taking cross bearings at the spot. Their foes used to drag hooks about at random, and sometimes they fished up the prize. The smugglers, when the coast was clear, returned and peered about with a marine telescope. A sheet of strong glass was fixed in one end of a barrel, and sunk a few inches; a man put his head into the other end, shut out the light from above, and saw clearly, because light came straight, to eyes in air, through a plane from which no light was reflected.

With this simple contrivance, fish, sea-weeds, shells, sand, stones, ripple-marks, flickering lights refracted by waves, dead seals, and brandy tubs are easily seen in four or five fathoms of clear water; and water-clouds are seen rolling below when water is thick with mud. The gazer gets a vertical view of things under him, as an aëronaut does of land and clouds beneath his car.

So far as this contrivance enables men to see the land under the waves, movements under water closely resemble movements under air. Sea-weeds, like land plants, bend before the gale; fish, like birds, keep their heads to the stream, and hang poised on their fins; mud-clouds take the shape of water-clouds in air; impede light, cast shadows, and take shapes which point out the directions in which currents flow. It is strange, at first, to hang over a boat's side, peering into a new world, and the interest grows. There is excitement in watching big fish swoop, like hawks, out of their sea-weed

forests, after a white fly sunk to the tree tops to tempt them, and the fight which follows is better fun when plainly seen.

Of late years glass tanks have been used as fish cages, and the ways of fish are better known, because they are now plainly seen in their own element.

The ways of water may be studied in the same contrivance.

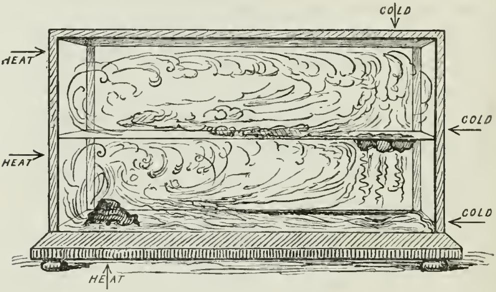

FIG. 14.

The principle might be extended. A boat with plate glass windows beneath the water line would make men and fish still better acquainted, by bringing them face to face. The man would be in the cage, and the cage might be in a salmon pool where fish are free.

If air in a hothouse be a miniature atmosphere, water in a glass tank is a working model of a sea, and heat and cold may be set to work the model engine at home.

Let one of the common fish-tanks be half filled with clear water, and placed where the sun may shine upon it.

Float a few lumps of rough ice at one end, and sink a black stone at the other; and, when the water has settled,

pour milk gently on the ice. An ounce to a gallon serves the purpose.

Milk consists of small white vesicles and a fluid, and, bulk for bulk, milk is heavier than water. So at first the white milk sinks in the clear water, and spreads upon the bottom of the tank, leaving the dark stone like a sunken rock in a muddy sea, or a mountain top peering over a low fog.

But this arrangement is unstable, because two powers are shut up in the tank with the water.

The sun warms the stone at one end, and the stone warms the water below. At the other end melting ice cools water above. Temperature is unevenly distributed, so weights are uneven, and the machine turns round.

Heavy cold streams pour down from the ice at the cold end, and flow along the bottom towards the stone, driving milk vesicles like drops of water in a gray mist.

Light warm fountains float up from the stone at the warm end, and flow along near the surface towards the ice, driving milk like wreaths of mountain mist rolling up into a summer sky from a mountain side.

The water is circulating, and every movement is shewn by milk-clouds, for the glass tank gives a vertical section of a circulating fluid system, driven by the sun's rays and by weight.

Cloud-forms are copied with marvellous fidelity in this water toy, and because the movement is very slow, they are easily seen and copied.

But the tank gives a section of air as well as water. The miniature sea has an atmosphere, and the same forces work both engines. Let a bit of smouldering paper, tinder, rope, touchwood, or any such light combustible fall on the ice-raft,

and cover the tank with a sheet of glass to keep in the smoke.

If there be small ocean-currents in the water, there are storms in the smoky air; and the systems revolve in the same direction, because the moving forces are the same. Cooled air streams down upon the floating ice, and drives gray smoke rapidly before it, drifting along the water towards the warm end, like a cold sea-fog before a north-easter.

At the warm end the mist lifts, like a sea-fog when it nears a warm shore. The smoke rises to the glass roof, spreads there and returns along the top towards the ice, whirling, streaming out, and taking the forms of fleecy summer clouds, which float high in air above the Atlantic in fine weather. "Stratus," "cumulus," "cirrus," "cirro cumulus," "comoid cirrus," and the rest of the learned tribe; "mackarel sky," "mare's tails," "Noah's arks," and vulgar popular clouds of their class; nameless cloud-forms which are the joy of an artist, and his despair when he tries to copy them; all appear drifting with streams, which various degrees of weight and heat cause to flow in air and water shut up within a cubic foot of space.

The amount of power used: the difference in temperature between the ice and the stone, moves air a great deal faster than water, because it is lighter, and there is less resistance to be overcome. It follows that winds should move faster than ocean-currents; and they do in fact.

When damp air has cooled and contracted to a certain point, it lays its load of water on any cold substance which takes in part of the charge of heat—which expanded air. Vapour is condensed. It follows the heat out of the warm air to the cold substance, and if it cannot get in, it stops on the surface, and gathers in small round drops. In the ex-

periment above described, cooled glass at the cold end of the tank stops water coming from the outer air; while the heat passes through glass and cold water to melt floating ice. Dew forms in curves on the outside, and it marks the dew-point temperature in the moving streams which cool the glass within. The curve is like a section of a river whirlpool, or a waterspout, and it coincides with the shape of the milk-clouds.

When the damp air of a room lays its load of vapour on cold glass windows in hard frost, similar curves are copied in solid ice. The dew-point temperature of the air in the room is marked out by a fog on the window, at first; then drops change to crystals, and ice-trees grow up by robbing the air which falls along the glass.

When a fire is lighted in a large room with windows encrusted with these beautiful forms, the march of the heat may be seen. As hot air rises and flows to the windows, ice begins to thaw at the top pane; crystal trees change to haze and vanish, wiped from the glass by dry air; or melted branches slide and stream down the window, dragged by weight when freed by heat. Where the fire radiates directly, the windows clear first. In corners sheltered from the rays ice lasts longest; and the lowest pane is the last to thaw and the first to fog. Heat pushes water towards the glass, away from the fire; weight pushes it towards the earth's centre. The radiating and converging forces do not part and meet at one point in a room; so the dew-point temperature is not in a regular figure. In the atmosphere, the dew-point curve has reference to the earth's centre; and vapour forms in shells about the solid earth because the two forces meet and part within the shell.

The facts shewn by experiment are confirmed by every fresh trial and observation. When temperature and weight

are unevenly disposed in fluids, it takes time to adjust the balance, but it tends to equilibrium, and to regular forms.

A warm bath is arranged in layers of various thickness, and varying temperature. When a human body is placed in it, natural observers stationed at the extremities send nerve telegraphs to head-quarters, to announce that one foot or hand is in warm or cold regions, and uncomfortable.

To prevent this evil, a bath attendant, who knows his work, stirs the water with a paddle; but much stirring hardly spreads heat evenly throughout a bath.

Near Reykjavik, in Iceland, is a hot spring from which a scalding burn escapes. French man-of-war's men, who frequent the harbour to protect French fishermen, have built a turf dam across the burn, about a quarter of a mile from the source; and they use the steaming pool as a hot swimming bath and washing establishment. The place was thus described in 1862:—

Last night we wandered along the shore to a hot spring, which rises in a small hollow about two miles from the town. We found the place, and a dam, made by French sailors in the burn, which runs from the spring. The water was about 80°; so we stripped, and plunged in, and swam about in the tepid water. The spring itself is about 170°, hot enough to cook eggs. We had none to cook; but there were plenty of egg-shells and broken bottles to shew the ways of the place.

A lot of cows were browsing on rich grass, which grows in the hollow, and some of them stood close to the spring chewing the cud thoughtfully in the steam. The setting sun threw their blue shadows on the cloud of white mist, like great long-legged ghosts of cows. It was dead calm, and very warm; and the hills, and the golden sea, and the purple islands floating in the bay, made a beautiful Claude landscape.

It was Italy in Iceland. There we lay stretched at ease on a velvet turf, and smoked, and watched the growing shadows, exclaiming, "how beautiful;" and the old cows seemed to feel as jolly as we did.

At last, when it was nearly ten o'clock at night, the cows seemed to think it time to go home to be milked. So one stepped deliberately down to the scalding burn, and smelt at it. She put one foot in, then another, and then the demure old brute sprang out on the grass, curled her tail over her back, and capered a wild dance, so utterly at variance with her former staid demeanour, that we all lay back and roared with laughter.

Next came a giddy young calf, who went through the same performance; but he, being more active, shook his scalded heels in the air in a way that was perfectly ludicrous.

The brutes, who should have known better, speedily resumed their placidity and walked away; so we got up and walked off to our floating home, where we drank tea on deck, and went to bed by daylight at midnight.

The next night was as fine, as warm and calm. Snæfell, sixty miles away at least, showed his head against a golden sky, in which clouds floated steadily, like the eider ducks and gulls floating about us on the calm water; but every now and again a strong cold blast fell down from the still sky, broke up the mirror of the sea, and then died away as suddenly as it came.

The air was in layers, the layers were of different weight and temperature, and the wind was "straight up and down," like an Irishman's hurricane.

The natural hot bath was a good illustration of a similar arrangement, and the glass tank and glass windows show the movements which result from it.

Water which stands in this hot bath is not stirred. The warm stream flows in above, and it cools by radiation as it flows to the far end, where it cools and sinks. The supply at the source is 170°, the waste at the dam is scarcely tepid, and the pool is circulating and rolling over and over because of its uneven weight. When a bather takes a header into it, he finds himself shooting through all sorts of climates. He feels summer, autumn, and winter rolling along his skin, as he shoots down. When he stands upright, he feels that temperature is packed in horizontal layers in the water about him, and that the cold layers are below. When he swims about, he finds hot and cold regions in different corners at the same level, for the heat is nowhere evenly spread. Lower down the ground may be frozen, but under all is the boiler from which the hot water rose. From this experiment with nature's thermometers, it appears that the coldest strata of water in a pond are generally below, but sometimes warm regions are below colder layers in the pond, as in air and sea.

The movements of water about to freeze are well seen in the glass tank above described.

At one corner a glass thermometer is hung with the bulb near the bottom ; at the opposite corner the stalk of a thermometer is thrust through a bung, and so placed that it can be raised or sunk without disturbing the water much. Thin ice formed in the tank floats at the surface, and a block-tin bottle filled with hot water is sunk. The heat of the water put into the bottle is 212°, the ice is 32°. On the ice, about the centre of the tank, some lamp black is painted on with a brush, one side of the tank is covered with a screen of thin paper, and then the machine is ready for action.

As the colour is at the coldest place :—on the ice, it marks the position of the coldest water when the ice begins to melt,

and the cold is easily measured with the instruments. As the hot bottle is in clear water, white paper seen through clear water marks the position of the water which is warmed. As lamp black takes many days to settle in a tumbler, it shews the movements of water, for it only moves about the tank, because water is moved by weight and temperature.

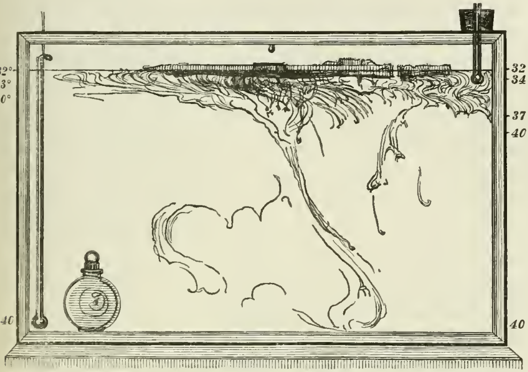

FIG. 15. FREEZING.

Ice being at the top is lightest, and its temperature is 32°. When it is melting the colour begins to move. If it is warmed by the sun, a dark revolving column sinks very slowly down. But beneath the ice are layers which contain intricate patterns of curved lines of black, which bend and wave slowly, but keep near the ice. The temperature in the coloured band is

Ice, 32°
Water, 33°
34°
37° As shewn in the woodcut.

So the coldest of these layers is the lightest, and the solid crust is lightest of all. The clear water in contact with the coloured layer is at 40°, and so is the water elsewhere in the tank, after the hot bottle has given off its charge of heat and melted the equivalent weight of ice. So water at 40° is heavier than water at 37°, and the different temperatures are drawn in black on a white ground. But water that is warmer than 40° is lighter than water at 37°.

When a water-bottle filled with hot water, coloured with lamp black, is sunk through an ice dome, without the stopper, a warm dark column rises up like the Afret whom the Arabian fisherman let out of the copper vase ; or the foul air which in cold weather rises out of a copper mine. When the water is hot, a thing like a round-headed mushroom grows rapidly out of the neck, and takes all manner of strange shapes. The head is like some monster which a painter sees in his waking dreams, a vision by Gustave Doré, for example. The stalk bends and winds through the clear water like an eel, or a black snake creeping out of its hole. When it gets to the cold region, the top spreads out like a palm tree, waving its drooping boughs, and shedding a crop of rings, and spheres, and streamers ; like fire-works in daylight. The temperature of the coloured water which rose from the bottle to the top is in this case about 44°, when clear water is 40° at the bottom and elsewhere. So of this series the warm layer is lightest.

While the bottle is hot the pace is fast, as it cools the phantom growths are nipped. When the water is almost boiling, it rises in water at 33° like smoke from a furnace chimney rising in air.

When the temperature has fallen in the bottle and spread through the tank, small jets of colour rise up and sink back into the pipe whence they rose. Their shapes are like those

of plants rising through the earth, their action is that of a boiling spring.

When all the extra charge of heat has escaped from the bottle, there is rest at the source ; the rapid action ceases, and the coloured water slowly takes its place in the tank.

On a frosty evening when there is no ice, but when ice is about to form in the tank, the water which rose out of the bottle forms an even layer above clear water, and the temperature then is 37° above, and about 40° below.

In that case the water which rose because it was warmed, stays where it cools, beyond 37°, and after that the more it cools the higher it rises, till it is 32° at the top and a floating solid.

When the hot bottle spends its force beneath a solid ice roof, thermometers mark 32°
33°
34°
35°

and the blackest layer in the series is the lowest and the warmest.

When freezing water freezes, crystals expel colour from ice, and water-currents distribute paint amongst the remaining fluid. Circulation goes on under ice, for some of the dark water which was next below the ice when it began to form is found at the bottom when all the instruments read close upon 32°, and the solid crust has formed.

Water, then, is a gas, a fluid, and a solid at different temperatures ; and the formation of one crust on one fluid illustrates the formation of other crusts.

The ice crust forms next the coldest place, and the fluid remains shut up inside.

In a tank the process can be watched, and the disposi-

tion of the crust is seen, because ice is transparent, and vertical glass walls bound ice planes through which rays pass undistorted. A plate of ice seven inches broad is more transparent edgewise, than an equal thickness of plate-glass.

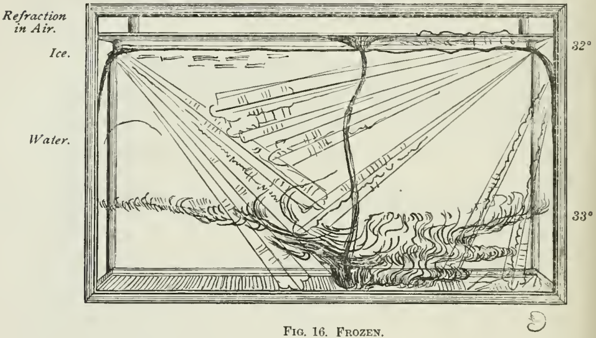

Fig. 16. Frozen.

It refracts rather less than water. On the surface, the ice is disposed in layers, whose planes coincide with those which colour shewed in freezing water. The layers are added below; they are horizontal and regular where the ice is smooth above; where the ice is rough outside, the planes of stratification within are bent and crumpled. The surface next the wall is a plane, where the layers are flat and undisturbed; it waves where the strata are bent and wrinkled.

The thickness of the upper crust varies; at corners, the angular solid is rounded off, so as to form a dome.

From these solid corners long blade-like crystals radiate at all angles from 1° to 90°. They are like spokes of wheels, whose common centres are the corners of the tank; or as

fans behind the glass, opening from the angles where three planes meet.

Each of these blades is like the back of a saw with crystal teeth growing into the water, away from the glass.

When a tank is so placed that frosty air circulates under it, ice crystals form at the bottom also, and radiate from the lower corners. The glass box is lined at last with a box of solid ice, and fluid water is shut up in a curved crystal chamber, wherein it circulates till it is frozen.

By pouring hot water on the ice, a hole is quickly bored through it. When coloured water is poured on the surface, near the hole, it is warmer than ice, however cold it may be, and it sinks through, falling like the column which rose out of the bottle, but very slowly. It strikes on the bottom and rises up again, steadily working its way through the colder water, and forming itself into crumpled layers below. A thermometer marks 33° when placed in the colour. So water at 33° is heavier than ice at 32°, and, therefore, solid ice must float in water at any temperature.

The charge of heat which a mass of fluid water contains, passes outwards ; and leaves ice where it passes through any substance which stops water but cannot stop heat.

It is the rule that cold water is heavier than warm water, but the rule does not hold good for all temperatures. At 32° fresh water is ice, at 37° and all lower temperatures it is about to become ice, and it floats on water at 40°.

At 44° it rises through water at 40°, and then it melts ice floating above.

So fresh water is heaviest about 39° at some temperature between 40° and 37°, and many other fluids appear to have a temperature of greatest density.

Salt water of the specific gravity of 1.026 freezes at 28°. At the specific gravity of 1.104 it freezes at 14°.

As steam at 212°, or as vapour at any temperature, water takes up most space, is lightest, and refracts light least. As ice at 32°, 28°, or 14°, it takes up more space than it does when fluid. As fluid, water takes up least space, and is heaviest; it has greatest density, and refracts light most.

So vapour floats on ice, and ice on water. At or about 37°, water, having got rid of extra heat, seems to begin to assume the angular shape of ice crystals. Curves become straight, waves are calmed, bends change to angles, while coloured water is freezing. The angular shape takes more room, the crystal is bigger than the cold drop, but there is no more water in it. So the crystal floats, and crystallizing water floats up next beneath crystallized ice.

From these experiments it follows that layers of water of various changing temperatures must move; and the temperatures being known, the direction of movement can be inferred.

From other experiments it appears that air and sea are in fact arranged in moving layers of various thickness, temperature, weight, and density.

On a fine summer evening when the sun is nearing a sea horizon, some of the air-shells may be seen. Rays of light are variously refracted by lenses of different densities, and the atmosphere is a great compound concave lens.

The glass of an argand burner, though transparent, appears to cut across the flame like a dark bar at the bent shoulder. Any lamp shews the effect. When the sun is near the horizon, his light slants through domes of air which surround the earth, and, like a nest of glass shades, they refract the rays more or less according to their shape and density.

The round ball is distorted. As it sinks the disc of light is bent and broken up into irregular figures. The sinking light in passing the layers darkens, but the bars are flat and stationary, so the edge of the sun appears to bend and wave, as a lamp does when the shoulder of the glass chimney is lifted or lowered. If any clouds hang about the horizon in the twilight, they too are flat, for they are the edges of thin shells of condensing vapour, which made the air dense before sunset.

Fig. 16.

These upper regions have often been explored. In Mr. Glasier's late balloon ascents, in which pluck was a very conspicuous feature, it was found that although high regions, which correspond to regions of perpetual snow on high mountains, are cold, still sensible heat decreases irregularly, and is constant at no stage on the scale. Because snow falls upon the highest mountains, water in some shape must be carried higher than 28,000 feet above the sea; and accordingly, in June 1863, cirrus clouds and a blue sky were

seen far above a balloon raised four and a half miles above England.

The temperature was 17° at the highest point reached, but far above that cold shell of air, water was packed in the form of cirrus clouds. They marked a dew point. Lower down, from 13,000 down to 10,000 feet was a deep bed where the temperature was 32° or 33°, and the air thick with vapour and frozen water. Mist, snow, and crystals of ice were floating and falling ready to be moved in any direction. The water was there in a solid form, ready to rise higher if the air rose, or to fall into lower and warmer strata, or on the earth. It was colder below, but near the surface was summer weather, and a temperature of 66°.

The arrangement was unstable. It was one to cause motion ; the heavy snow was above and the light vapour below ; the one must fall and the other rise. But if the snow came down to the region of 66° and summer weather, the earth's own heat and the extra store which the sun had given it, were ready to send the piston up again to the dew-point.

In a former ascent at Paris, a temperature of 16° was reached at a height of 23,000 feet above the ground where the temperature was 87°. The mean temperature at the ground in Nova Zembla is 17°.

It is not given to every one to mount so high with a whole battery of instruments, but it is easy to understand the arrangement of the atmosphere from models worked by heat and weight, when it is known that temperature decreases as the distance from the earth's centre increases, and that heat is disposed in layers above the ground.

Air in high regions is pressed by less weight. It is colder than air near the earth ; but like a sponge relieved from pressure, it is better able to hold water the higher it is.

There is more room in it, so to speak, and the dew-point is colder. When air at 32° was found resting on strata sensibly colder, the upper layer was still better able to hold water, because still more expanded by the heat which it had absorbed.

A stream of warm, damp air, rising because it is warmed and expanded; expanding still more as it rises; because there is less air above to squeeze it, is like a balloon; and carries great part of its load of water to high regions, where there is little sensible heat, but much heat latent.

Clouds, high snowy mountains, and balloon ascents, prove that water is somehow lifted more than 28,000 feet above the sea, and there seems nothing to stop it short of the limit at which the earth's weight and the earth's heat balance each other in their action on water.

As water evaporates spontaneously at all temperatures, and even in vacuo when the weight of the atmosphere is taken away, heat moves water one way, and weight moves it in the opposite direction. That is the working principle of the atmospheric engine, though the machinery is complex and hard to comprehend.

The depths of the sea have also been explored, though they have not been visited. Deep sea soundings have been taken; living star-fish have been brought up from a depth of 15,600 feet; the sea is fluid at the lowest depth reached; so it must obey laws which affect fluids in smaller quantities.

The sea is packed in layers like the bath, the pond, the model tank, and the atmosphere, and these all circulate for the same reason.

Let a few of the temperatures which are given in scientific works be arranged in the following shape, and the movements shewn on Mauray's diagram, page 28. On the diagram page 34°, and on the woodcuts page and and will be

found to coincide in principle and direction with the ascertained movements of ocean and air.

Fig. 17.

Fluid water being heavy at the Poles and light between the Tropics, would move like air and clouds if it were deep as the atmosphere ; and the sea does, in fact, move diagonally on meridians, where land will permit.

Water, then, is found in three conditions at different temperatures and pressures, at different distances from the earth's centre ; and the order of the arrangement above the solid crust is

	Weight and Cold.	
1	Gaseous matter,	Air and watery vapour.
2	Solid,	Ice and air.
3	Fluid,	Water and air.
	Heat.	

Two opposing forces meet at some layer of the sphere, and so work the air and the water-engines, to which geological denudation is ascribed. Characters which these engrave upon the solid earth are written with heat and weight.

But because the double engine consists of many cutting wheels, and each wheel makes a different tool-mark, rocks which bear marks of air and of water, are variously marked by the contriver of the engine, which carves hills and glens.

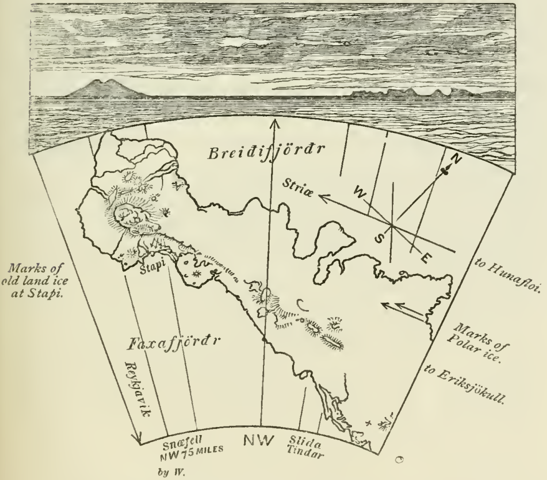

FIG. 18. PLAN AND ELEVATION.

Map and Sketch of the SNÆFELL Peninsula, opposite to Reykjavik. After sunset, June 27, 1862.

CHAPTER IX.

DENUDATION—TIME.

THERE is an ingenious device for sculpturing marble, which illustrates the working of engines which carve hills.

An artist's thought is modelled in clay, and cast in plaster of Paris. A block of marble is laid beside the solid thought, and the engine is placed between the stone and the model. Power is got out of fire and water, or water and weight, and it is passed through a train of wheels, strings, and levers, to a small cutting wheel which revolves rapidly at the end of a bar.

Let this wheel stand for a circulating atmosphere charged with water.

At the other end of the bar a point touches the model, and universal joints allow the bar to move every way. But the engine is so contrived, that if the point rises, the wheel rises as much ; if it falls, the cutting-wheel falls also, and where it touches, it cuts away marble, and makes tool-marks and a pile of chips. Gradually the artist's thought looks out of the block of stone. It bears the marks of a steam-engine worked by heat and weight, but it is a man's thought nevertheless.

Geologists have to learn the tool-marks of their trade.

Every tool makes a different mark. The cutting-wheel of the sculpturing engine cuts grooves, which the engineer could distinguish from an artist's touch, and many different wheels are used to make coarse and fine carving.

The brass wheel of a glass-cutter makes a different mark from the iron wheel, and the wooden polisher makes a different mark from a leather wheel.

A carpenter's adze cuts out a curved hollow, an axe makes a flat-sided notch, a handsaw marks straight lines and acute angles on two parallel flat sides, a circular saw draws cycloids on opposite planes. A gouge, a chisel, a rasp, a file, a centre-bit, a bradawl, a plane, a plough, a glass scraper, sandpaper, all the tools in the chest leave marks on wood which a carpenter knows. The work of a particular tool with a notch in it, of a blunt tool or a sharp tool, may be known by the mark.

A blacksmith knows the dent of a sledge-hammer from hand hammering; the groove cut with a cold chisel from the hole punched out with a square point. He has but to look at iron-work to know the tools used to fashion it, because he knows the tools and how they work.

A mason knows pointing from chiseling, dressing, and polishing; he can distinguish a stone that has been hand worked, or sawed up, from one broken out of a quarry.

A miner knows the mark of a pick from that of a jumper; the crushed surface broken by a blow, from one torn by a blast.

A goldsmith knows the touch of a graver wielded by skilled or by unskilled hands.

A wood-engraver, a shoemaker, an optician, an engineer, a tinker, a painter, a crossing-sweeper, a shoe-black—any craftsman or artist knows the tool-marks of his familiar art or mystery, or the sweep of his brush.

A geologist ought to know the tools whose marks he strives to understand.

It is taught, and it is true, that the earth's outer shell has been enormously "denuded."

So many feet of rock are wanting to complete an arch whose piers remain; the missing stones have been removed. The uppermost layer of a stone arch has been taken away, and the next course laid bare at one part of the bridge, which remains standing, though it is worn down by tracks. The crown of an arch has fallen, enough stone to make a mountain has been denuded from a particular part of the earth's crust. How the mountain was removed is to be learned from the marks of the engines used to remove it.

But unless the engines, and their modes of working, are studied, their work may be misunderstood.

It is often said that a big strath was hollowed by the river which flows in it; or that a mountain is a weathered rock which crumbled into its present form; but in many cases the river has little to do with the carving of the glen, and the weather has scarcely touched the hill since it was sculptured.

The river might have done a great deal in a long time, but if the whole land was under the sea, river-work must date from the rise of the land. If there be a sea-shell high on a hill-side, rain could not get at the rock, when the shell was buried under water; so rock-weathering, like river-work, had a beginning, if sea-shells and loose rubbish are above the worn rock.

Iceland is one of the great battle-fields of the powers of the air which grind down the earth.

It is a good place to watch the cutting wheel, the engine fire, and the smelting furnace; it is a place to see work in progress, to study the engines, and learn the tool-marks of fire and frost. Heavy work is there going on between large ocean currents. The same work is doing wherever air, vapour, ice, and water, heat and weight, are together, but the rate in

Iceland is faster than it is in countries where the heavy work is done. There also is a starting-point from which to reckon time, for the finished work of fire is wholly different from the tool-marks of the grinding engines of frost.

At the outset, it is clear that the carving engine has been long at work.

The beginning from which to reckon geological time is commonly wanting. The supposed rate of wearing by waves and of deposition by rivers, the thickness of beds deposited or destroyed within some historical period, these, or such as these, are the common measures for time. But, if ocean currents moved faster, climate altered or changed place, then work done may have taken more or less time to do than its finishing touches seem to show. There is a river-mark in Iceland from which to count time with tolerable certainty.

If the first mark of denudation was made upon an igneous surface, the cooling of the crust is a point in time from which to reckon. At Thingvalla is a river called the Oxerá, which, in ordinary weather, is about the size of an English mill-stream. The water would pass through one of the large iron pipes which carry Thames water to London. The Oxerá falls over a large cliff into a rift. There can be no doubt that the cliff over which the stream now falls, was formed by the falling away of the opposite side of the rift, and that the cliffs and the rocks in the valley were as fluid as water in the river at some time. To see the place is to be convinced of these facts. The Oxerá began to fall over this cliff, and denudation began at the edge, after the lava cooled, and after it split. There is no water-mark on the opposite cliff, so the stream most probably began to flow in its present channel when the bottom of the valley sank, and the plain became a slope.

The whole surface of this lava for many square miles is

marked by certain rope-like coils, which formed while the hot fluid was curdling, and these rise about two inches above the surface. They are fire-marks.

The water of the Oxerá has worn the stone at the edge of the cliff for a breadth of about thirty yards, at the place where water is always flowing, unless frozen ; the channel is about two feet deep, and three or four wide. Where water flows only during floods, the coils have not been worn away, but they are smoothed and worn ; and near the deep channel, the lava surface is very like that of slag which has been used to mend a road, and has been worn by traffic. Specimens are common in Lanarkshire and other iron districts.

Calculating from the angle which the sides of the rift make with each other, and with the horizon, the beds of lava may be about 600 feet thick, and it must have taken a long time to cool such a mass. As it happens, the Icelandic Parliament have met at the Logberg, on the surface of the lava, for 800 years, and there has been no great change in the valley during that time, for the ground is minutely described. At the earliest date recorded, the Oxerá fell into the rift ; a deep pool in it was the place in which wicked women were drowned ; trees grew on the lava, horses found grazing by the river side. It must have taken a long time for soil to gather after the lava had cooled. But things had arrived at this stage 800 years ago. Say that water has been wearing its stone channel for 1000 years only, and the depth from the fire-mark, the wrinkle on the lava, to the bottom of the water-mark, two feet, gives a rate of one foot of lava in five hundred years. The rate, in all probability, is far too rapid, but it gives a great age for these Icelandic rocks, and for those on which they rest.

At other spots streams have cut wide and deep channels in lavas of the same kind. The river at Godafoss, in the

north, has cut a deep channel, and has worked its way backwards for some hundreds of yards. The smoothed water-worn surface is plainly seen on cliffs far below the fall. The river is large, so it must work faster than the Oxerá ; but if one has cut 900 feet, while the other has only cut two, they cannot have begun to work at the same time. Giving one river credit for only one-third of the work done, the rate makes the age of the lava at Godafoss 150,000 years.*

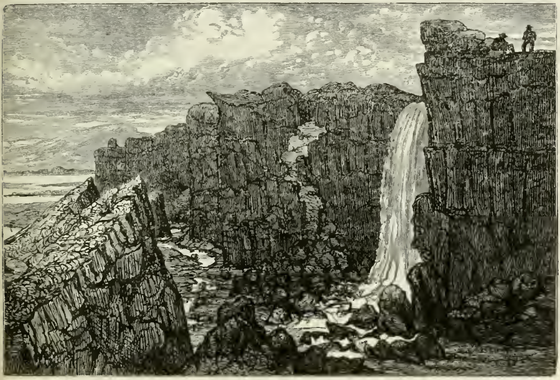

FIG. 19. ICELAND, July 30, 1862.—FALL OF THE OXERA.

But where streams do not flow on the lava about Godafoss, the wrinkles have not been worn off, so weathering has not denuded a quarter of an inch of igneous rock in that time at least.

Other Icelandic rivers have done a great deal of work. The Bruerá has drilled large pits, and it has scooped out smooth channels of considerable depth.

* 300 feet, at one foot in 500 years.

At Merkiarfoss, near Hecla, a small stream has dug out a large trench, and it has drilled the most fantastic peep-holes through a black conglomerate of ashes and stones, and this river began to work after the volcanic mountain had grown.

At Skogarfoss, a river falls over a cliff on a sea-beach, and it has dug backwards into the hill for some fifty or sixty yards. It began to dig after the sea had done its undermining, and had retired towards the horizon away from the base of the old sea-cliff. At the wearing rate the sea made the cliff 75,000 years ago.*

All these times may be wrongly calculated; they may be too short or too long; but when the last formed igneous rocks have endured so long, it is plain that the wearing of rocks to form known sedimentary beds must have gone on during ages, which it is vain to calculate. However rapid the rate may have been when the grinding-engine first began to work, it has been carving and packing chips for a very long time. The world is an old world; and sculptures on it are old inscriptions, though made with engines which are working now.

A river is a grinding-wheel in the denuding engine; a soft tool which makes a mark. Tools of the same kind are cutting and have been cutting patterns on rocks ever since water rose from the sea, fell on shore, and flowed towards the earth's centre; but each river had a beginning, and the time which has elapsed, since land rose above the sea, is too short for the work attributed to many rivers.

* 150 feet at 1 in 500 years.

CHAPTER X.

DENUDATION—RIVERS.

Before a craftsman can recognise a tool-mark, he must be familiar with the tool; before a geologist knows river-marks, he must study the ways of rivers.

Falling water proverbially wears a stone; stones wear in many ways, and at different rates; but that which the Oxerà and other Icelandic rivers have done to lava, streams must have done to rocks, from the time when the first shower fell, and the first stream began to flow. So ancient river-marks ought to be found on the oldest rocks, and these ought to resemble modern river-marks.

Clouds rise up from earth and sea. A river takes its rise in the clouds, from which drops fall. Fallen drops collect and roll from hills into hollows, and so a river grows. On the stony top of a granite mountain puddles may be seen forming during a shower. They fill from above, overflow, and so help to fill lower hollows in every rock and stone. These, in their turn, overflow and send off larger rills, which take the shortest way towards the earth's centre, and roll down the steepest slope.

Streams which flow straight down steep hill-sides must cut straight furrows, if they cut at all. Such trenches may be seen on the flanks of Icelandic volcanos, which have grown up in modern times; and on the sides of steep hills everywhere, and this river-mark always has the same general form.

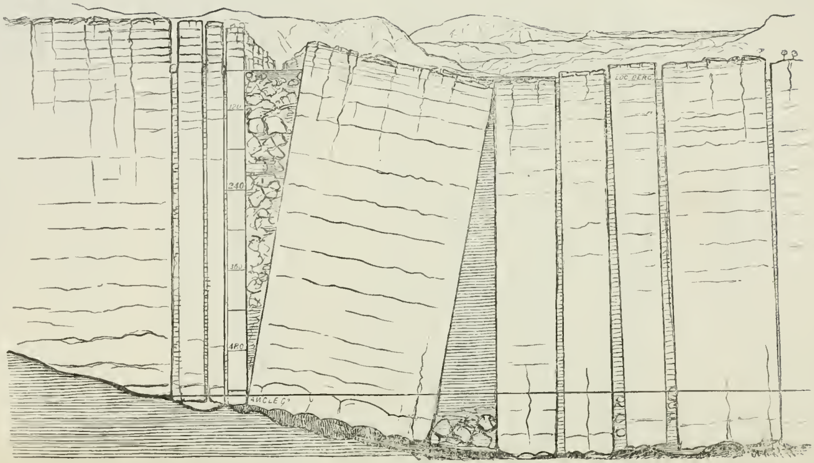

Fig. 21.

The steeper the mountain, the straighter are its gorges ; the deeper the trench dug by rain, the more rain-water tends to gather in it ; the water makes a path, and follows it, and it works faster as the work grows deeper. The mark is like V.

For this cause an ancient mountain, which has borne the brunt of the battle for a long time without the shelter of the sea, generally is so deeply furrowed, that little of the old shape remains. A cone, for instance, is grooved and fluted into steep peaks and ridges which meet at the highest point where water falls. The mountain is weathered, and becomes a rain-mark, unless it dives under water for protection. The shape is like Λ.

The mark which a river engraves on a country-side, is like a flat branch. Rain-pools are leaves and buds, rills are twigs, and rivulets branches which spring from a stem whose roots are in the delta at the sea.

The plan, at first, is a repetition of the forms of the letters V and Y, in which straight lines meet at various angles. But as the slope gets less, straight lines curve, and the stream winds in the plain like the letter S.

Any wide landscape seen from a high mountain, any well executed map or model, shews these characters which fluid engraves upon solid. They recur in every quarter of the globe, in every continent, field, or gutter, and could be read anywhere.

The section of a gorge dug by a torrent is angular, like V ; or the sides are perpendicular, like U ; on a gentle slope the section of a river bed is curved ‿ ; and the curve gets flatter as the river spreads and winds in a shallower bed, on a smaller slope. The section of the Λ is a convex curve ⌒, fluted by numerous river-beds. It is a mark of deposition, not denudation.

The whole of these familiar forms result from the movements of flowing water, and these result from the force which drags water towards the earth's centre ; and from the resistance of the crust which impedes the movement, changes its direction, and stops it at last in some rock basin.

The seed from which a river grows is a rain-drop. A drop of rain falls perpendicularly in a calm on a flat stone, and spreads every way. It strikes, rebounds, splashes, and scatters. If water is poured upon level glass, it spreads every way. The form is a star *

The force which moved fluid towards the horizontal plane is turned aside by resistance, and the water is pushed sideways, at right angles to its original direction of movement ⊥.

Ink, dropped on box-wood, obeys the law, and draws its own shape for the engraver.

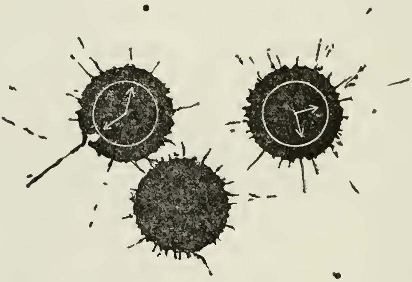

Fig. 22.

As drops diverge, so showers spread from a mountain-top, and rivers part from a watershed.

Water flowing in any open channel rebounds from side to side, and from the bottom ; so a river wears its rocky bed

irregularly, but on system. Resistance on the right bank reflects the stream towards the left, and there it digs a hollow, and swings back. Resistance at the bottom throws the stream upwards ; but only to fall again after drawing a convex curve. Where the water falls, it digs a concave hole, from which it rebounds again ; and so the river wears its bed according to force and resistance, and in curves. On a steep slope, zigzag movements are small in proportion to the fall ; the water hits the side of the trench at a small angle, and rebounds at one still smaller. So the mountain torrent works most at the bottom, where it hews out rock pools ; leaping from step to step, through deep ravines, in foaming cascades.

The Ruikan Foss in Southern Norway is a good specimen of river work.

The rock, over which a considerable stream now falls, is a coarse sandstone or conglomerate. The upper valley is a rounded hollow, at the bottom of which the river has dug a shallow trench. The upper hollow ends in a steep slope ; and the lower valley, like the upper, is a rounded curved rock-groove, through which the river meanders ; but the bottom of the groove is covered with beds of gravel. Both these glens, the slope, and the surrounding hills, bear marks of ice ; so the river did not hew out the glens ; but it has dug a narrow trench in the slope, and it is sorting the debris in the lower glen. The notch in the slope is 700 feet deep ; and rounded water-marks are clearly seen on the steep walls of the gorge, from top to bottom. The fall is working rapidly up stream ; digging at the bottom of the pool, at the foot of the rock ; undermining, sawing, and working back into the slope. It leaps out of the pool with a wild roar ; the bed of the stream is cumbered with enormous stones. Where undermined cliffs have fallen, long banks of talus slope down

Fig. 22.

to the water's edge, ready to be swept away, and sorted lower down. The tool, the mark, and the chips, are together; and the power of the engine is displayed in the work.

On one point it is possible to lie on a long flat stone, look over, and drop pebbles from the outspread hands, 700 feet down into the gorge.

If a fall of undermined rock chokes the stream in this big ditch, there will be a deep lake in the slope between the glens. The water will fall harmlessly into it, and the rate of wearing and scene of action will change. The water will work most below the dam, till it is removed, and then the lake will disappear, and the river will begin at the bottom of the old fall again. But the sides of the trench will be angular where fractured, or smoothed where water-worn; the torrent-mark will continue like the letter U ploughed out of the bottom of the curved glen ◡. It will always be an angle L dug out of a slope.

The Vöring Foss in the Hardanger Fjord is another notable specimen of river-work of this class.

A large stream flows from snowy mountains, amongst which a few glaciers still nestle. It flows over an ice-ground plateau, in which it has worn a shallow bed; but when it reaches the sloping side of the lower valley, the stream plunges suddenly sheer down about a thousand feet, into a black chasm, so deep and narrow that the fall can only be seen by looking straight down at the pool.* Great clouds of spray dash out, and whirl up, rebounding, and driven by a strong wind caused by the fall. The spray collects on the hill-side, and streams down the rocks in miniature falls, which are blown up again. So the air in the gorge is filled with clouds of spray, and the pool is generally invisible. About

* By dropping stones, and timing their fall, the height was made 1100 feet.

FIG. 23. THE POLISHED GLEN, EIGHT MILES BELOW THE VÖRING PASS.

a Torrent cutting through and obliterating the ice-mark. b Ice-polished hill. c Birches, small pines, berries, fine turfs upon ice-polished rocks, with boulders and perched blocks.

noon, when the sun is clear, a traveller craning over the edge sees three parts of a rainbow about a black shadow with luminous edges ; a ghost of himself, wading through white clouds, which whirl and drift down the gorge like boiling mist.

It is impossible to sketch a hole of this sort ; but the mark which the river is hewing out in the hill-side is one which could not well be mistaken for any other tool-mark. It is the same as the mark at the Ruikan Fall, L.

The valley into which the river leaps bears other marks, which are as easy to read when the tool which makes them has been seen at work. The glen was scooped out ; but rivers are only cutting through and wearing out traces of ice. The river-mark is more than a thousand feet deep, but it is a mere scratch on the side of the glen in which the river flows.

Another famous Scandinavian fall is Tann Foss in Jemptlan.

It is near the watershed of the country, and the frontier between Norway and Sweden, on the road between Trondhjem and Sundsvall, between 63° and 64° N. lat. It is not a fall in a river ; there is no rapid above it. The water of placid narrows at the end of a quiet lake suddenly tumbles over a slate cliff, and becomes a quiet lake again, when it escapes from a boiling pool. The fall is 120 feet high without a break. The cliff over which it leaps is sharp, and its structure is clearly shewn where the broken horizontal beds project into the foam. In the very middle of the fall, level with the upper lake, is a square block of dark slate, which has resisted wear and tear at the edge. It is called the Chest. It is told that a bear, in trying to cross the narrows above the fall, got carried down and landed on the Chest. There was no escape ; so, in the extremity of his dismay, the bear screeched fearfully. A man heard him, and taking a most unfair advantage, pelted the

brute till he sprang over the fall, and drowned himself in despair.

Peasant proprietors still pay a nominal tax for a right to gather drowned elks and other game at this fall; for the smooth narrows tempt creatures to swim over, and many used to be drowned like the bear, when game was abundant.

From the top of Areskutan, a neighbouring mountain, which is some 3000 feet higher than the lakes, and 4000 above the sea, the work of this northern Niagara is seen to be a mere notch chipped out of the edge of a long terraced step, which runs along the hill sides, north and south, for many miles. It seems to be one of the many contour lines which coincide in general direction with the coast of the Gulf of Bothnia. The rock basin, which is a lake on the upper step, overflows; and the waste, which is about equal in volume to the Thames at Windsor, must have slid down the terraced rock into the lower basin at first. It has dug an angle now; but it has dug less than a hundred yards into the slate, for the original slope is entire elsewhere. It cannot dig much deeper than the water-level of the lower basin, for the water guards rock.

From this northern Rhigi, a vast expanse of country is seen on a clear day; and it has the characteristic shape of ice-ground rocks. The district is one great undulating slope of gray rock, green forest, meadow, and corn land; with conical peaks, rising here and there, and with silver lakes shining in their rough stone setting everywhere. One white snow-flake, a speck ten miles off, shews where water is foam, and a river is grinding rock at Tann Foss.

On a calm, clear evening, in September 1850, the wide landscape was very beautiful, and figures in it, and sounds in the still air harmonized well with the scene. A wild call

blown from a birch-bark tube rose up from a village at the foot of the hill, and then far below, as it seemed, almost under foot, tiny cows, and sheep, and goats, came slowly dropping, one by one, out of the forest into the road. Their bells tinkled as they went streaming after a bevy of girls, poking their noses into their hands for salt, lowing, bleating, and capering homeward to be milked and housed.

Close at hand a family of Röjoxa (*garulus infausta*) with their bright burnt-sienna wings, chattered and fluttered amongst green and yellow birches; and high overhead rose the peak, white with the first snow of winter, but rosy with the glow of sunset.

The denudation of rocks in this district is conspicuous, and the amount is enormous. It is plain that rivers and weathering will not account for the shape of Sweden. It is equally plain that other engines have worked here.

On the watershed, not far from Tann Foss, at the road-side—at a height which Robert Chambers estimates at 2000 feet—the clearest marks of glacial action are still perfectly fresh on rocks, in spite of weather and rivers. These marks prove that ice travelled over the hills from N.E. to S.W., at 2000 feet above the present sea level, at the place where streams now part and run to the Baltic and to the Atlantic.

It is an established geological fact that Scandinavia is rising from the sea. It is proved by marks made on stones in the Baltic, and watched since 1731, and by other marks.

It is evident that the hill-tops must have risen first, so the highest fall must be the oldest. Tann Foss, working at 1000 feet above the sea, has worked longer than Trollhattan, at about 307 feet; and the ice-mark at 2000 feet is older than the river-mark at Tann Foss, if it was made floating ice.

At the famous fall of Trollhattan on the Götha Elf, a

green river as large as the Thames at London, the waste of a great inland sea, and the drainage of a large tract of mountain and forest, escapes from a rock-basin, over a shoulder of rock, and slides down a rock-groove for about three miles. It rolls over the edge unbroken, like a great sea-wave, and slides down for twenty or thirty yards before it is streaked with foam. Below the rapids, the river meanders through a plain of boulders and drift, which partly fills the rock-groove. The plain fades into the sea, and rounded islands of rock, of the same pattern as the hills on shore, gradually decrease in height and size, till they become sunken rocks, and disappear at last under the Kattegat.

A good Tornea rapid is almost as grand as Trollhattan.

The striking feature of the place is the absence of river-marks. Denudation, worked by water, is insignificant. There is no section, no cliff, no step ∟ worn in the slope. Trollhattan is a slide, not a fall. It is but a baby in geological time.

The country is well known to the writer; it is well described by Robert Chambers in the Edinburgh Journal, N. S., 1849.

From Stockholm to Göteborg, from Malmö to Christiania, glens, mounds, and hills, are ice-ground rocks of one pattern. Speaking generally, ridges and hollows, rock-grooves and river courses, rock basins, and lakes large and small, stretch N.E. and S.W.; and in many places striæ are fresh on the rocks, and point the same way.

At Christiania serpulæ adhere to rocks which are now 186 feet above the sea-level. When these shells lived where their mortal remains are found, the sea was over the rock.

At Udevalla, further south, a bed of sea-shells is found in a bank of gravel about 200 feet above the sea.

At Sarpsborg sea-plants have been found twenty miles inland, and at a level of 450 feet.*

But a sea 500 feet deeper would join the gulf of Bothnia, the Wettern and Wenern, the Kattegat, Skagerrack, and the German Ocean; sink Denmark, drown most of southern Scandinavia, abolish Trollhattan, and stop the war.

So Trollhattan only became a water slide, and began to grind rocks about the time when sea-shells and plants died for want of sea-water at Sarpsborg, Udevalla, and Christiania.

The river-mark is a measure of time, for the fact is established that this river began to slide when the lip of the rock-basin rose above the sea-level.

In Glen Fyne, in Scotland, are similar gorges dug by mountain-torrents in the sides of rounded hills.

The Eagle's Fall, above Ardkinglas, is not less than 300 feet high, and it has dug a wild, precipitous gash like the bed of the Vöring Foss; but the gash is scarcely seen from the valley below, which was scooped out by some other engine.

There is scarce a glen or rounded hill in Scotland which has not some modern river-work upon its steep sides, to contrast with wider, deeper, and older marks of denudation. There are numerous marks which prove beyond dispute that Scotland has risen from the sea, and that many of her waterfalls were born after the death of shells which are buried on hill-sides.

Farther north, about lat. 66° in Lulea Lappmark, is a fall which is famous all over the district, but which no Englishman has yet described. The Lapps call it Njoammel Saskas, or the hare's leap, because a hare can spring over a large river where it has dug a trench in solid rock.

* For details, see Chambers. The papers are very true and amusing pictures of Scandinavian travel, and geologically valuable.

Still further north, about lat. 70°, a large river which drains the great Enare Träsk, leaps down a fall in a narrow gorge which it has sawn through rocks. The country retains marks of glaciation over five degrees of latitude, between the Polar Basin and the Gulf of Bothnia.

All the large Swedish rivers, without exception, have one character ; they have done very little denudation since they began to saw through ice-ground rocks ; and what they have done is work of one pattern, more or less advanced, and most advanced at the highest level.

If the value of the unit could be found, the amount of river-work done might be measured from the ice-ground surface, and dimensions converted into geological time.

In Iceland, where streams work on igneous rock, the torrent carves the same pattern. At Melar, in the north, a small river leaps down a steep hill-side. It has made a succession of falls, with deep rock pools and rock pits. The rock is bedded trap, traversed by whin dykes, but the pattern of the river-bed is the same as in Welsh slate.

At the Devil's Bridge near Aberystwith a stream has sawed a groove in blue slate. It is ninety feet deep, and about six wide. The smooth water-worn surface is fresh from top to bottom on both sides of the groove, and at the bottom, in the bed of the stream, there is no joint or fracture to be seen. The whole is a river-mark, a trench sawn by running water straight down into the slope of compact slate which some other denuding agent wore out before the river began. The rivulet has but ploughed a groove at the bottom of a curve ; it has turned V into Y. River-marks are the same everywhere, and this is the mark of a mountain torrent L.

But drift and sea-shells have been found on Welsh hills at a height which would sink the hills at the Devil's Bridge

far under the sea, and all Wales is ice-ground. So this torrent, like the rest, had a beginning, and from that the begining of the groove must date.

The highest fall in Europe is that of Gaverni, in the Pyrenees. In descending the pass which leads from Spain into France, it is seen about four miles up a valley to the right. It is amongst the wildest of rocks and mountains, and there does not seem to be a tree within miles of it. In September 1842 new fallen snow reached down to the verge of the cliff, and early frosts kept the stream low. The fall seemed little more than a white thread on the dark rock face, but the water fell unbroken to the bottom except at one spot where it touched. In this it is unlike the Staubach in Switzerland, which, though lower, reaches the bottom as a shower of spray. The river at Gaverni is of considerable size, but the river-work is as nothing to the glen which some graving tool had sculptured before the river began to fall over the cliff.

High up in the Pyrenees are tiny glaciers, and the glens bear the marks of old ice.

Rivers have done similar work in Spain.

At Ronda, a small stream, which was almost dry in June 1842, runs through a trench hewn in sandstone. It is a strange water-worn Barranco cumbered with big stones, amongst which Spanish washerwomen do their best to rinse clothes. The sides are so steep that the river bed can only be reached at a few places. It is so narrow that a small bridge, with a single Moorish arch, joins the two sides. Emerging from this narrow groove, the water leaps down several L steps cut in the sandstone rift, and through the cliff; it passes under the famous Ronda Bridge, turns several mills, and finally winds off through a lower plain, marking its course with verdure. The town is entered from the upper plain, and

this great cliff and chasm are so little seen that three seedy travellers spent a hot day in a venta a hundred yards from the great bridge, voting Washington Irving's description of the place to be a sheer invention. It is, in fact, one of the strangest places in Europe—a town built on a kind of rocky island on a cliff which a mountain stream has sawed off from a raised plain, with a broken edge.

Some other tool must have carved the Spanish hills, and at Grenada snow and ice still glitter above the hot plain, on the peaks of the Sierra Nevada. In the plains are beds of clay, which look very like ice-work.

In the Morea it is the same. The beds of torrents are grooves with steep sides; the glens through which the rivers flow are wide rounded hollows, and on high mountains near Cape Matapan and above Sparta, snow-wreaths still out-last summer heats.

In the Alps, where glaciers abound, rivers often run long courses, beneath ice roofs. They do the work of rivers loaded with ice-floats, and the glaciers work beside the rivers, which flow with them in rock-grooves.

Old marks of larger glaciers are found in large rounded glens, on the banks of brawling streams, which are sawing narrow trenches at the bottom of every glen. A good collection of photographs will best shew these forms, and they are common now-a-days.

In Iceland, where glaciers are far larger than Alpine glaciers, many rivers and their marks are peculiar.

Enormous tracts are covered with vast snow-heaps and glaciers, and though the surface of this upper system of beds is tolerably even, the next series below it—the shattered igneous rocks upon which the glaciers rest—must have a surface of

hill and dale like neighbouring districts where the upper series is absent.

The water series deposited from air is fusible at ordinary temperatures, and it is constantly melting, if it is constantly growing from above. In summer, the surface melts, because a hot sun shines down upon it. The undermost layers are always melting slowly, because the ground is warm. When the earth-light shines out; when a volcanic eruption bursts forth under the snow; when the earth's internal heat radiates upwards more than usual, the snow turns to water and steam. The water flies back to the clouds, or sinks as far as it can, through snow, névé ice, and shattered lava. It flows down hill like other water, gathers in glens and valleys, bursts through passes under ice and lava roofs, and comes to light at last a full-grown river.

Large rivers are hidden throughout long courses, and burst out of ice-caves to fall into the sea after a daylight course of a few miles.

The rivers which drain the country which lies under Myrdals Jökull, and the Vatna Jökull, are of this kind.

The glaciers approach the sea, and their drainage is in proportion to their great size and nature. A mass of frozen water as wide as Yorkshire, and many thousands of feet thick when exposed to a hot sun; or when a flood of lava spouts up into it, sends down streams of muddy water, larger than rivers which flow from tracts of equal area elsewhere.

Many Icelandic rivers are in fact as broad as they are long, and run their whole daylight course over a delta.

These are always difficult to ford. Travellers pass them guided by men who know the district, mounted upon ponies used to wading, which are called "water-horses." A string of ponies, loose or loaded with baggage and riders, are tied head

and tail; and the train, led by the water-horse, crosses over the delta, up one side, and down the other; wading, sinking, scrambling, sometimes even swimming; sometimes on dry sand-banks, fording for a distance of several miles. Sometimes the river-bed has ice upon it under water. When the horses tread on one side, the stream gets under the upper edge of the broken ice, and great plates rise up and turn over and slap down, as if to crush the rider. Sometimes the leading horse sinks up to his girths in a quicksand, and it takes a cool head and a skilled guide to know what to do in riding over such an unusual ridge of country. The plan of the trail is Λ, the section ⌒.

In spring these broad fords are impassable. The water is too deep and strong even for Icelandic ponies to stem; and it is cumbered by great blocks of ice, which fall from the glacier, and float out to sea—no creature could live in such a torrent.

The bed of these subglacial rivers must be like the beds of other rivers, but their banks must be very different. In the hollow glens through which they now flow, will be traces of denudation of two kinds, if the ice melts. Marks will shew the wearing of rocks, by a river loaded with ice-floats, mud, and stones, and also the work of heavy land ice, which a change of climate may cause to vanish altogether from this region.

When an eruption takes place water-floods do marvellous work in a very short time, for the rate of denudation changes. Farms are obliterated; houses, cattle, land-marks, men, and their works, are swept away like a heap of rubbish, and the sea-bed is filled near the shore with large banks and heaps of debris, sorted by water, in water.

If ice were gone, volcanos extinct, eruptions forgotten, and the sea-bottom raised higher, it would be hard to account for

hills of debris which skirt some parts of the Icelandic coast, and which seem to have been formed in this way.

They are monuments of fire and frost, denudation and deposition, and they must contain records of sea and land, confusedly mingled, though packed in layers.

In Greenland and in Spitzbergen, according to the descriptions of travellers who have visited these regions, subglacial rivers find their way into the sea without shewing their dirty faces in daylight anywhere. A sea discoloured for miles is the only symptom of the stream which must be sawing rocks under ice as it does in the open air.

The beds of such streams can only be got at by inference, but the inference is plain.

From Greenland to Iceland, from Iceland to Scandinavia, thence to the British Isles, and to Cape Matapan, there is one connected series of cause and effect. The engine is working at one place, the marks are at another, but engines and marks are side by side at many places, and the marks of rivers are plain everywhere.

North and south, east and west, European river-marks are alike, and bear witness to the fact that rivers have done very little geological grinding since they began to flow down European rocks.

In many places in Iceland rivers are subterranean. The drainage waters of large tracts of country sink bodily into the riven porous earth, and not a drop is to be seen on the surface. On Hecla and the lava plains to the north there is no water in summer, but clear cold streams burst out at a place called the springs, near the foot of Hecla. Hot springs burst out at many places, and the plains which lie between the sea and cliffs of igneous rock, all round the island, are bogs which rival the worst in Connemara. There is hardly

any water to be found about Skjaldbreið. There is no river of any size to feed the lake at Thingvalla, but a very large river runs out of the lake.

What the beds of these underground streams may be like is not easy to guess, but probably they resemble underground rivers elsewhere, and some of these may be got at.

In Park mine, near Wrexham, the course of a subterranean river was cut in looking for lead. It can be got at by scrambling, and it is a curious place. A large cavern is water-marked from top to bottom, and old sand-beaches in passages mark a water-level fifty or sixty feet above the stream. The stone is drilled into the most fantastic shapes—oval windows, peep holes through which candles glimmer and water shines ; handles to grip, peaks and pillars are common, but there is no straight line or flat plane or acute angle, except where stones have fallen ; and fallen stones remain where they fell. The rock is mountain limestone, cupped by millstone-grit ; and rain-water, which contains carbonic acid, melts limestone, slowly, as water melts salt. In the bed of the stream are pebbles washed from a distance. A clear murmuring brook can be followed for a great way up stream ; down stream it plunges into a hole, and disappears with a roar. It breaks into Minera mine lower down, and where all the water goes at last no one seems to know or care, so that it is got rid of. In some of these underground worlds beds of silicious fossil shells are washed out of the lime, and look like shells piled on a beach. No human hands could dig them from their tombs as water does.

In limestone all over the world caves with subterranean rivers are common.

In Yorkshire are many. In the Alps, streams leap from holes in steep cliffs. Near Trieste a large stream flows into a

cave in a hill-side, and ten miles off a stream of the same size runs out of another cave. One pool is seen in the famous Addlesberg cavern, which has now been explored for many miles. It was known for three miles in 1841. It is an old river-mark filling with lime; a wonderful grotto, hung with glittering white festoons and pendants, and paved with white marble, which rain-water extracts from the hill through which it strains, and leaves in the cave when it gets to air and evaporates.

But the pool, with its strange creatures, the bed where water flows, is like a pool in the free air, and it is worn like the river bed in Park Mine. River-marks under the earth are like river-marks on the surface, when they can be got at; so, probably, river-marks under lava are like those of other Icelandic rivers.

On small slopes sidelong movements are greater in proportion to fall. The resistance is greatest at the bottom, and the downward movement is more easily reflected as the fall decreases. A hill-stream works most at the sides, where there is least resistance. The undermined rock slides, falls, and breaks; the bed of the stream is choked with fallen debris; there are many rapids and pools, but few falls; and the river-bed curves like the curving stream which makes it. But the shape of the trench depends on the fracture of the rock through which the river has made a way.

On a gentle slope the fall is less, and resistance the same. The stream is pushed on rather than dragged down, and it swings from side to side. It works as it moves, wearing the banks more than the bed.

There are many windings in a plain, few deep pools, and a smooth bed; there is smooth water and bad fishing; and

the work done by the river is chiefly the sorting of chips brought down from rock-grooves in the hills.

Every Etonian knows how streams work in their beds; for rowing and swimming teach the lesson.

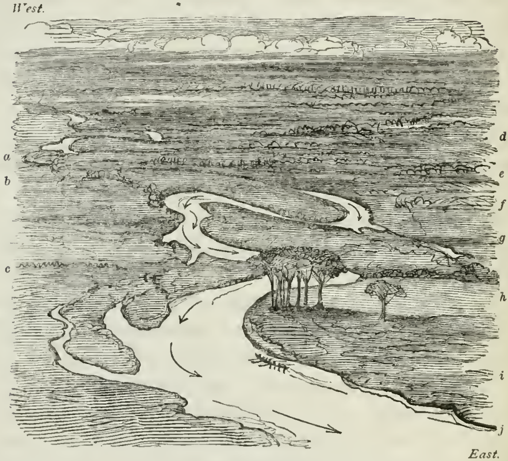

Fig. 24. THE THAMES.
Sketched from the top of the Round Tower, Windsor, 1862.

a Surly. *b* Lower Hope. *c* Bargeman's. *d* Bovney. *e* Rushes. *f* Athens. *g* Upper Hope. *h* Cuckoo wear. *i* Brocas clump, *j* Brocas.

The Thames flows eastward on a gentle slope, and does not trace a straight line, but winds like a snake through the green fields.

From "the Rushes" to "Upper Hope" the river curves very slightly southwards, and the depth is tolerably even on both sides. But it is greatest on the northern side, which is the outside of the curve, where the water moves fastest. There

the bank is steep, the bottom clear, and the stream rapid. On the south side there is a shelving bank, a muddy bottom, and dead water. So boats rowing up stream keep the southern bank, and brush the northern on their way down.

The water is swinging eastwards round a point somewhere to the south; the river is working northwards along the circumference of the curve, and writing part of the letter S.

At Upper Hope the main stream has dug into the northern bank so far as to make the curve shorter. It strikes harder upon a higher bank, undermines it more, and rebounds faster to the other side, which it reaches at Lower Hope.

Boats ascending cross the stream at Lower Hope, brush the willow bushes with their oars, and scrape the gravel to keep in the dead water near the southern bank. But on the way back they cross the bay at Upper Hope, hug the northern bank, and shoot down with a rapid stream.

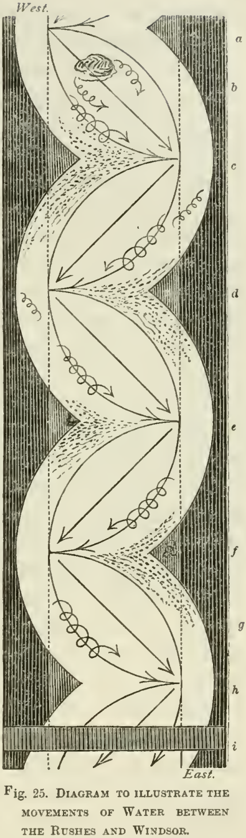

Fig. 25. Diagram to illustrate the movements of Water between the Rushes and Windsor.

a Rushes. *b* Athens. *c* Upper Hope. *d* Lower Hope. *e* Bargeman's Bush. *f* Brocas clump. *g* Brocas. *h* Eton. *i* Windsor Bridge.

The river flows south and works east between the Hopes, and it swings round a point on the west.

At Lower Hope, the main stream shoots over to the southern bank, which it undermines ; and thence it rebounds, swinging on the outside of a gentle curve, about some point to the north, and circling in miniature whirlpools as it slides along the steep clay bank ; till it swings away, and across to the "Brocas" at Bargeman's Bush.*

Ascending boats cross at Bargeman's, and hug the northern bank as far as Lower Hope, keeping the inside of the curve, where there is dead water, and a muddy bottom ; and when they return they keep in the stream.

Between Lower Hope and Bargeman's Bush the river is working southwards, away from the northern point about which it circles ; it is writing the other half of the letter **S** ; and from the round tower at Windsor, the whole silver letter is seen upon its emerald ground.

From Bargeman's Bush to Brocas clump the stream digs into the northern bank, and curves about a southern point. And so the Thames swings from side to side throughout its whole course. It is always gnawing into its banks northwards and southwards as it flows east ; but there is scarce a rock to be seen in the river. The valley of the Thames is half-full of chips, for some other engine had hollowed the valley, and filled it with drift and gravel before the river began to dig.

The Thames is a type of streams flowing on a gentle slope ; and ocean-currents swing between their banks on the same plan. The rain which streams along the roadway on Windsor bridge after a shower ; the Thames, the Oxerá on its lava bed, the smallest and the biggest, the oldest and the newest

* Now demolished.

streams, all dig on one principle, and do similar work. River steamers, canoes, boats, and boatmen ; Indians, Lapps, and fish, all work up stream on the same plan as an Eton Funny.

The sculler or swimmer who knows the stream has the best chance in a race, and gets on best in strange lands and waters. The geologist who tries to understand the work of large currents may learn a lesson from small streams.

Salmon-fishers must study the nature of rivers, or they will have sorry sport. Fish haunt particular parts of their domains, for good reasons ; and he who knows the reasons knows where to look for fish. They cannot rest in strong currents, so they avoid them ; unless there be nice stones or rocks at the bottom, to give shelter from the water gale. They do not like to rest in shallows, for they cannot there be hid from their foes in the air. In dead water there is mud, and no supply of fresh eatables drifting about ; and a salmon is an aristocrat who hates ploughing in dirt, and likes to have his dinner brought to him in a clean place. So fish hang about pools where the water is rough and deep enough to hide them ; and they choose particular spots, where there is stream to bring game, but not too much for the gentleman's comfort.

A salmon likes to have a cool breeze of clear, fresh, well-aired water blowing in his face ; and he rests in his nook poised on his fins, like a gull, or a hawk, or an osprey, floating head to wind behind a cliff, high in the air. And there he puffs, and champs his white jaws, and rolls his unwinking eyes, and wags his broad tail, till something worth having appears. Then the doser awakes ; and, with a sudden rush, the glittering silver sportsman dashes out, open-mouthed, with every fin spread like a fan, and every muscle tight and

quivering; and when he has snapped his hooked jaws upon some nice morsel, he glides back into his place, and waits for more. If he has taken a sham fly, with a sharp hook in its tail, strike home when he turns. If he has missed, give him a rest, and try again.

An old fly-fisher knows the look of places where fish abide, even in strange rivers, for surface-forms indicate submerged obstructions. In his own ground, he knows every corner of every pool, every shallow and hole, stone and eddy in it. So river-marks are familiar to fishermen, who are always watching the flow of water, and the work which it does; and the sportsman who knows most gets most sport. A still-net-fisher plants his snares in the way of travelling fish, and chooses his station by the run of the stream. Nets and spearing stages set in the Tana and Tornea are planted by Lapps and Quains in the way of ascending boats. Fish and boatmen strive to avoid the strongest stream, and cross at the same places. Fishermen know the stream, and the shape of its bed, by waves on the surface. The work of the river depends on its movements, so the nets mark out the run of the stream.

Floating bodies follow the stream, and shew its movements. If floats carve marks, they shew the course of the stream which moved the floats.

It used to be a time-honoured Eton custom for the long boats to muster once or twice in the spring, row up to the Rushes, and drift down, while the crews sang.

The captain in the "Tenoar," five or six "Eights," some "Sixes" and "Fours," and all the Funnies and double and single scullers that could get up in time, joined the fleet, and lay on their oars in a thick cluster; while some musical

"wet bob" chanted verses, and the whole of the crews roared the chorus. A favourite performance was—

Rule Britannia,
Britannia rules the waves,
Britons, never, never, never, never, never, will be slaves.

It was a grand song; but Old Father Thames would not be ruled. He never would carry Britannia's sons directly home, or keep their boats in their stations, or even follow his own curved bed. At first, boats to the north forged ahead, and swung their sterns to the bank; those to the south hung back, the long boats whirled slowly round, and bumped and jostled as they floated. The concert was varied by cries of "Paddle on easy"—"Pull round, bow"—"Back-water, stroke"—or "Bow, side oars in the water."

But when the musical squadron had passed the bathing-place at Athens, and had reached Upper Hope, where the stream runs full tilt at the bank, the crews had to row to avoid shipwreck.

The first part of the concert ended with a thundering rattle of oars in the rollocks by way of applause; nearly a hundred oars dipped into the water, and the captain's word was "Paddle on easy to Lower Hope." There it was, "Bow side, paddle hard," and "pull round."

Then the concert began again. The brown swarm gathered into a cluster, and covered the whole breadth of the stream; while "George Barnwell," Black-eyed Susan," "God save the Queen," and similar lays, were performed with the usual applause, and under the same difficulties.

But on this reach the movements were reversed.

The northern boats hung back, the southern drifted ahead, and the long boats slewed round against the sun.

It was "Pull round, stroke side—backwater, bow," for the

sterns were always trying to pass the bows, by scraping against the southern bank, while shoving the bows across the river into dead water.

The water whirled as it flowed, and it whirled the floating boats. It turned them with the sun, from left to right—east, south, west, north; with the hands of a watch, where the river curved, sunwise, eastwards, and about a southern point; from the Rushes to Lower Hope. But small whirlpools on that reach turned the other way, on the outside of the curve, because the bank holds the water back. The boats turned against the hands of a watch and widershins where the river curved eastward, and about a northern point, between Lower Hope and Bargemans; and there small whirlpools and floats of froth revolve, sunwise, under the high bank.

By watching these, similar movements on a larger scale may be understood. Corrie Bhreacan and the Maelstrom are but larger whirlpools in a larger stream, and circular storms revolve on the same principle as a whirlpool in a mill race.

What boats tell about movements in a stream is tested by swimming in it. Many a hot summer hour pleasantly spent in the cool Thames; many a long swim from the Rushes to the Brocas, and from bank to bank at every bathing station; long dives in the pools—have made this bit of river-bed familiar to all bathing Etonians.

Elsewhere they find that which is true of one stream to be true of all.

That which is true of boats and swimmers is true of other floating bodies; of trees and ships, ice-floes, icebergs, and clouds.

In Scandinavia are vast forests, in which a harvest of so-called "Norway deals" is reaped.

The reapers live in the open air for months at a time, and

brave great hardship, and some danger; for pines often grow in chinks, in the face of high rocks, where it is impossible to get at them without a rope.

Hardy Norsemen and Swedes fell the pines, hew off the branches, and roll and drag the trunks to the nearest water. Once launched, the logs find their own way to saw-mills; and sometimes they drift about in lakes and roll in streams for several years before they arrive.

Many get water-logged and sink; and these may be seen strewed in hundreds upon the bottom, far down in clear green lakes.

Many get stranded in the mountain gorges, and span the torrent like bridges; others get planted like masts amongst the boulders; others sail into quiet bays, and rest side by side upon soft mud.

But in spring, when the floods are up, another class of woodmen follow the logs, and drive on the lingerers.

They launch the bridges and masts and stranded rafts, help them through the lakes, and push them into the stream; and so from every twig on the branching river, floats gather as the river gathers on its way to the sea.

Sometimes great piles of timber get stranded, jammed, and entangled upon a shallow, near the head of a narrow rapid; and then it is no easy or safe employment to start them.

Men armed with axes, levers, and long slender boat-hooks, shoot down in crazy boats, and clamber over slippery stones and rocks to the float; where they wade and crawl about amongst the trees, to the danger of life and limb. They work with might and main at the base of the stack; hacking, dragging, and pushing, till the whole mound gives way, and rolls and slides, rumbling and crashing, into the torrent, where it scatters and rushes onwards.

It is a sight worth seeing; the power of a float, moved by water, begins to tell, and denudation is seen in progress.

The brown shoal of trees rush like living things into the white water, and charge full tilt, end on, straight at the first curve in the bank. There is a hard bump and a vehement jostle; for there are no crews to paddle and steer these floats. The dashing sound of raging water is varied by the deep musical notes of the battle between wood and stone. Water pushes wood, tree urges tree, till logs turn over, and whirl round, and rise up out of the water, and sometimes even snap and splinter like dry reeds.

The rock is broken and crushed and dinted at the water-line by a whole fleet of battering-rams, and the square ends of logs are rounded; so both combatants retain marks of the strife.

The movements of ice are the same.

At one mill at Christiansand, 70,000 trees thus floated down are sawn up every year; and there are many other mills in the town; so the work done upon rock by floating timber is on a considerable scale.

The work done by river-ice is greater, but similar. The rocks are worn at the water-line, and undermined, and when they fall, there remains a perpendicular or jagged broken bank.

About ten miles from the town, at Vigelund, at another large saw-mill, there is a fall in the Torisdals river, where the lateral and vertical whirling of flowing water, and its action upon floats and rocks, is well seen.

Above the fall it has been found necessary to protect the rock from floating bodies, so as to preserve the run of the stream. It threatened to alter its course, and leave the mill dry, for the rock was wearing rapidly.

It is a good salmon station, and a tempting spot for a sketcher to watch in summer.

At every moment some new arrival comes sailing down the rapid, pitches over the fall, and dives into a foaming green pool, where hundreds of other logs are revolving, and whirling about each other in creamy froth. The new comer first takes a header, and dives to some unknown depth ; but presently he shoots up in the midst of the pool, rolls over and over, and shakes himself till he finds his level ; and then he joins the dance.

There is first a slow sober glissade eastwards, across the stream, to a rock which bears the mark of many a hard blow ; there is a shuffle, a concussion, and a retreat, followed by a pirouette sunwise, and a sidelong sweep northwards, up stream towards the fall. Then comes a vehement whirling over and over ; or if the tree gets his head under the fall, there is a somersault, like a performance in the Halling dance. That is followed by a rush sideways and westward, where there is a long fit of setting to partners under the lee of a big rock. Then comes a simultaneous rush southwards, towards the rapid which leads to sea, and some logs escape and depart; but the rest appear to be seized by some freak, and away they all slide eastwards again across the stream to have another bout with the old battered pudding-stone rock below the saw-mill. And so for hours and days logs whirl one way—in this case against the sun—below the fall, and they dash against the rounded walls of the pool, leaving their mark.

Lower down, near the sea, is a long flat reach between high rounded cliffs ; and there these mountaineers, floating on to be sawn up, form themselves into a solemn funeral procession which extends for miles.

But the curve of this stream of floats is always greater

than the curve of the river's bed; for the water is slowly swinging from side to side as it flows, and the floats shew the course of the stream, and its whirling eddies. Many marks which remain in rocks in this great valley are clearly not marks of this wearing agency. They were neither made by trees nor by river ice.

A practised swimmer who knows what he is about, and leaps head foremost down a small cascade, is carried downwards with great rapidity, and is then shot upwards to the surface, a long way down stream, where he can swim safely to land.

It is pleasant thus to dash through water like a fish; to feel the eddies and the tickling air bubbles, and to hear the many sounds of the gurgling river. It is pleasant on a summer's day to dive through a cascade, and sit behind the water screen, and watch the flickering light amongst swarms of summer flies which there abide; but the swimmer who gets out of the run of the water may fare ill, for he drifts round like a log, and if he struggles with the power which is stronger than he; he may whirl till he sinks, or knocks his head against a stone and drowns.

But the diver learns to know the movements of water beneath the surface, and the surface forms which indicate them; and he can apply his knowledge elsewhere.

A geologist who wants to know how rivers work upon their beds may profit by the experience of boatmen, fishermen, lumberers, and swimmers; for he must learn the movements of fluids, before he can safely pronounce upon work done by them.

As fluids move in curves, marks which they make are curved also; and as water works very slowly, and follows every inequality, water-marks are fine and smooth, though irregular.

The finished work is like the polish which a carpenter gives to a surface with his hand, after he has formed it and smoothed it with rougher tools.

Projecting angles in the bed of a stream are polished and rounded, but they are not rubbed off.

Rock-pools, and all water-worn hollows retain irregularities. Sometimes deep round holes are drilled in hard rocks, below falls, and on the sea-shore; but these are not simply water-marks. They are marks which water makes by moving solids, and the tools used are often left in holes made with them. Rock-pits often contain round stones, sand, and water.

A river, then, is always working slowly downwards and up stream, changing a **V** into **Y**, by digging trenches, drilling holes, and undermining rocks over which it flows; and an ocean-stream works on the same principle.

But marks which flowing water engraves upon rock during a man's whole life are as nothing.

The Oxerá has not deepened its bed two feet since the history of Iceland began. The Thames has not changed its course since Magna Charta was signed, though the Thames works on gravel. What rivers and seas have done is not matter of observation but of inference for short-lived men.

Still water may be set to sculpture soft materials, and the touch and the work done may then be compared with similar work on any scale or material done anywhere during any period of time. Having found a power, it may be set to work.

The tank figured above shews how streams move vertically.

Let a sheet of glass be sloped in clear water, and drop ink, milk, or water charged with pipeclay upon the upper edge of the glass. The heavy fluid sinks, and rolls slowly down the

slope, through the clear still fluid. The upper edge of the stream curls and rolls back, and every movement is clearly seen. When a breeze passes a fixed chimney, or when a steamer moves through a calm, the same forms and eddies are seen in smoke. Wherever a moving fluid passes through fluid at rest, there are similar vertical eddies ; and though they are invisible they often leave their marks.

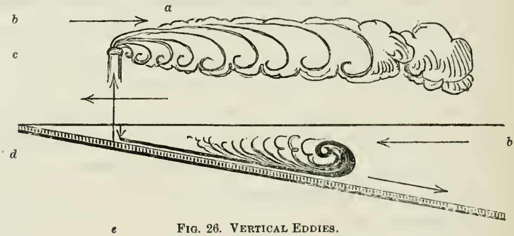

Fig. 26. Vertical Eddies.

a Weight. *b* Resistance. *c* Air. *d* Water. *e* Heat.

Horizontal eddies are seen behind every stick in a stream.

The woodcut is from a sketch made in London. The square stands for a post, the lines and arrows shew the paths described by bubbles floating on the Thames. But the laws

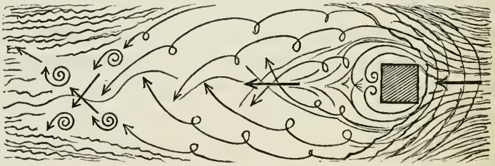

Fig. 27. Horizontal Eddies in Water.

which controlled the movements of these tiny floats and streams would hold good though the post were an island, the

stream an ocean-current, and the floats ice-floes. Where such floats leave marks they are drawn on a similar plan.

There are vertical and horizontal eddies, whirlpools, and whirlwinds, in the atmosphere and in the ocean ; and all streams and moving floats flow and move on the same principles.

Similar curves appear in a tea-cup when stirred with a spoon, in a mill-stream, and in the Thames ; they are seen in a strait, from a hill-top, where a rapid tide is flowing amongst an archipelago of rocky islands ; they are described by a stream of molten iron ; their tracks are on ancient hills.

There are eddies in streams moving through fluid at rest, or past pebble, post, rock, island, point, or sunken continent ; in air moving past a chimney, a volcano, an ice-peak ; or rolling north and south from pole to pole.

But the movements of all streams may be learned by studying the run of water in rivers ; and stream-marks may be learned from working models.

The following simple experiments will imitate river-marks :—

1. Mix fine pipeclay in water, and place a sheet of glass at the bottom of the vessel which contains the mixture. After a few minutes raise the glass slowly out of the water, and there remains a film of wet clay upon plane glass. Slope the glass to let water drain slowly off, and in half an hour the clay on the glass will be marked by flowing water as clay is marked by streams in the great valley which stretches seawards between Hecla and Eyafjalla, or similar alluvial plains elsewhere. Water clears channels on glass, and leaves clay islands ; and the resulting forms are those which are seen from the high ground whence Gunnar looked upon his favourite glen, and where he sleeps in his cairn : they are the same.

Everywhere the plane glass is a plan of a plain through which a stream meanders.

2. Vary the experiment by pouring thicker mud into clear water, to represent a quiet lake or sea into which a river falls. The descending current is seen whirling clay-clouds into beautiful curves, as it pushes through the clear still water ; but when the movement has ceased, the glass at the bottom is covered with a thin even layer of clay. Raise and slope the glass at various angles, and river-forms of various curvatures re-appear.

3. Slope a square foot of glass, and pour fine mud over it, till the glass is covered with a pretty thick stratum of even consistency. Stick a lump of clay at one corner, and let clear water, and water coloured with brown ochre, drip slowly upon it.

Flowing water digs out channels and colours them ; and the resulting forms are those which mark the great boggy plains which surround the igneous rocks of Iceland ; and similar plains elsewhere.

The model is like a map. The work of centuries of slow action on one scale, is done in miniature in half an hour ; time and quantity differ, but mechanical forces, materials, movements, and resulting forms are the same.

4. Build a heap of clay on a garden walk, and pour water upon it ; or throw clay upon the roof of a house where rain may fall upon it—and the work of denudation will soon begin naturally upon miniature plains of mud, deposited in hollows on the ground, but washed from the roof. The larger the experiment the longer is the time ; but the tool-marks of all streams are alike.

5. Change the course of a rivulet—turn it loose in a clay field, or on a sea-beach—and watch its proceedings day by day ;

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CHAPTER I.

CINDER HEAPS.

A CERTAIN hardy English traveller, in excellent health and spirits, returning from Iceland, with the appetite of a hunter, and the condition of a race-horse; declared to his shipmates that the country was "not worth seeing." "It was nothing," he said, "but a big cinder heap, as interesting as the dust hills at Wolverhampton, and not a whit more fertile."

The traveller's description, though *not* complimentary, was pretty accurate.

Volcanic products are very like furnace refuse, and all Iceland is volcanic; but cinder heaps, great and small, are worth sifting, for they throw light upon each other, and on dark subjects. Slag, Lava, and Trap, were all melted stone, and they are equally products of heat.

Even in a cinder heap there is much to be learned.

One branch of geology may be studied at a foundry where stones are melted; but something is first wanted to bridge over the gulf which separates a rill of slag from a lava flood; and a visit to Iceland supplies the want.

One great steam-engine must be seen at work before the ways of steam can be learned from a kettle; but when it is understood that steam power is limited only by the size of the engine and the amount of heat applied as force, then models, drawings, descriptions, or even traces of work done by natural steam-engines, are comprehensible.

So it is on the large scale.

The tool marks of natural heat must be seen in a large volcanic country, before the action of tame heat working at home on a small scale can be identified with volcanic action.

Earth heat has done great work in Iceland. The country whose bare barren surface has recently been altered by two mechanical forces, which upheave and grind down the crust of the world, teaches principles on which geology is founded; and when the lesson is learned, the scholar sees that a smelting house, a rubbish heap, a frying-pan, and the kettle, all shew the action and the effect of the same forces working on a smaller scale.

Iceland is a "cinder heap," but it is a very large one; and the lesson which it teaches is well worth the cost. Hecla may only be one large valve in a great caloric engine; but it is not too large to be seen, and it is well worth looking at. The two forces which have been set to shape the outer surface of the crust of our globe, if not the globe itself, are now employed in busily finishing an island as large as Ireland. They have worked and are working within such narrow bounds, that their work can be seen as a whole; but on such a vast scale that the performance of still greater tasks by the same agents can be understood. These twin giants, Fire and Frost, Heat and Cold, are as busy near Hecla as at Wolverhampton or Coatbridge, and their work is alike at home and abroad.

They move steam, the atmosphere, and the ocean, and things moved by them; they melt and freeze gas, water and slag, lava and metal, and move things moved by them; they shape clouds in the air, plates of slag, mounds in lava, and great mountains on the earth; they have upheaved and depressed Iceland, Norway, and Scotland; they have altered the whole surface of the globe, and its upper crust, so far as it is

explored; and they may have done still greater things, if they were the servants employed to do the work.

So a traveller, surrounded by mountains of ice and cinders, may be driven by the work before him to think of the agents employed to do it, and of him who set them their tasks, who said "Let there be light, and there was light," in the dawn of time.

In furnaces and volcanoes, in models and steam engines, in cinder heaps and in Iceland, in art and nature, certain mechanical forces work, and movements and forms produced by them are alike on all scales.

The tool marks of fire and frost may be learned in their workshop, and they may be set to work at home.

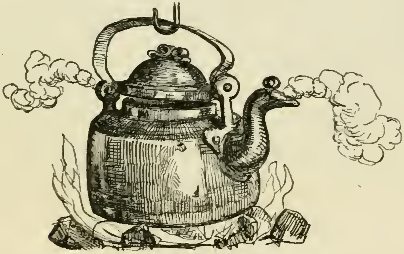

FIG. 1. PORTRAIT OF AN OLD FRIEND AND PRECEPTOR.

CHAPTER II.

HOME GEOLOGY.

A HOME student of geology is forced to take a great deal upon trust, and has often to work sorely against the grain. He may understand the teaching of practised men, and believe what he is told; but he cannot be familiar with the irresistible power of natural forces, whose power he has only seen displayed upon some pigmy scale.

A landsman who has only seen a puddle in a storm, has no clear notion of the Atlantic in a gale; and so it is with a man who has never been far from home.

He may have been familiar all his life with the form of some great mountain covered with rich soil, grass, heather, trees, and yellow corn in summer; sprinkled with snow, and glittering with icicles in winter. He is taught that the rounded form which he has known from his childhood, and which has never changed within the memory of man, is due to the wearing of floods of water, or of fields of ice.

But no home-bred Englishman has ever seen any power in action which seems strong enough for the work described as denudation.

The rivulets which trickle down the mountain could not have done work of the kind if they had worked as they do now for countless ages. They do not make rounded shoulders; they cut deep furrows on smooth hill-sides.

Burns meet in quiet lakes which mirror swelling hills on either side of some great glen, along which a river

winds to the sea; but the shape of the glen bears no resemblance to that of the small transverse furrows which rivulets make, or to the winding river bed at the bottom of the glen.

If scooped out, it is clear that the main glen was made with some coarser tool; and that the hill was rounded by something different from streams of rain water.

The great glen which crosses Scotland at the Caledonian Canal never could be hollowed by streams like those which have furrowed the long, smooth, steep hill-sides which make its southern boundary.

Ben Wyvis, and hills like it, were not rounded by streams like those which flow from their sides, and furrow them.

A little scratch on a rounded smooth rock which peeps through heather on the steep side of a burn, is shewn triumphantly to prove how an enormous glacier, now replaced by a little winter icicle, once filled up the glen, overspread a whole tract of country, and ground its way slowly downwards, bearing earth and stones on its surface, as leaves and sticks float down a river to the sea. Green hillocks, from which loose stones are now dug to gravel the roads, are pointed out at the mouth of the glen to mark the spot where a local glacier once ended; and the student is told that ice carried stones overland from the mountains, and left them in heaps when it melted, like piles of floating rubbish stranded by some winter spate.

It is said that ice and cold water ground down the hills and scooped out the glens, and left water-worn moraines behind them, because there is an ice-mark on the rock.

A man may believe it all vaguely, but he cannot realize it if there is nothing like a glacier within his experience.

The face of a peasant who is told for the first time that ice rounded the hill-tops where his sheep feed, is a study.

But glaciers and cold rain-water alone will not account

for many great glens, because of their peculiar forms; and there are ice-marks which no mere land-glacier could make.

It may be that a man has lived all his life beside some great stone fixed in a rich plain, buried in an old wood, or perched upon a hill-top. He may have seen it gray with lichen, or green and brown with moss and fern, or sparkling in the sun like a great jewel when powdered with hoar-frost.

It has been an "earth-fast stone" ever since he can remember; it looks as if it never could be moved from its place; perhaps tradition tells that some ancient giant hurled it at his foes. The teacher declares that it is a "wandering block" which first broke off and rolled down from a mountain hundreds of miles beyond the limit of vision, in some far distant country; and then sailed over the ocean on an ice-raft, and finally sank to the bottom, where it lies.

The tradition seems far more probable. It is just as likely that another stone of the same kind should now come sailing on a cloud, and plump down amongst the hens in the barnyard, for there is no sea near the stone, and the nearest sea has no ice-rafts.

It is vain to point at an ice-groove on the tip-top of a high hill, and then assure a canny Scotchman that like marks are to be found upon many similar isolated hill-tops, in the British isles and elsewhere; that all these high grooves seem to bear some relation to each other, and that they were all made by ice-floats while sailing over the hills, and dropping cargoes of clay and stones in the sea, to make land for farmers to plough on shore. It is contrary to the evidence of the senses. The sea is far away, hills are high and steadfast; and many ice-grooves are but faintly marked now.

It is vain to point at illegible characters on the stone or on geological maps, and try to explain how it must all have

happened long ago. It is not easy to expel old ideas and take in a new stock ; and so the usual first-fruits of an explanation of a fire-mark or a frost-mark is a look of incredulity or contempt.

A geological student is taught that mountain-chains were ocean beds, that continents were groups of islands, that islands are sunken mountains, that hills pop up their heads, and dive down again like seals ; that if some glens are grooves, some are rifts in the earth's broken crust ; that the land has waves, and that the sea is comparatively at rest ; but he never sees any of these changes happen.

He is assured that the cold, solid, gray rock, from which an old moss-grown tower has watched for centuries over generations of actors in the world's history was once white hot, and rose up through the sands of the sea ; that a quarry was a sand bank, and a stone in it a drifted log. But no rocks, hot or cold, ever rise now in neighbouring seas, nor do sand banks and forests turn to stone and coal.

He knows that it is the nature and habit of all the rocks and stones that he has ever seen, to fall as fast and as far as they can, and then lie still. He is taught that rocks and stones move about, float in water, and fly through the air, and have done so time out of mind.

By vigorous submission to authority, or by hard thinking, a man may bring himself to believe that these are truths, not waking dreams of book-learned men, or travellers' tales ; but it is no light labour for simple men who have never seen fire and frost at heavy work, to take it all in.

A certain venerable professor of natural history was in the habit of taking a walk round Arthur's Seat once a year with his class at his heels ; and it was his custom to pause beneath certain basaltic columns, and gather his flock about him to

pick up crumbs of knowledge, and hear the yearly open-air Edinburgh lecture on geology.

In these days—some twenty years ago—there was no "Queen's Drive," but there was some fine green turf near the rocks, and on one of these occasions a bevy of Edinburgh wives and lasses had chosen the spot for a bleaching green.

"What the diel's a' thae folk doin' there?" said one cummer.

"Oh, it's a daft chiel gien them a lectur aboot Samson's ribs," said another.

And then they laughed a mocking chorus, and fell to work again at their wet napery.

Not all the professors in Edinburgh, not even Sir Roderick himself, could have persuaded the washerwomen that Samson's ribs had been pumped up hot out of the earth, or had ever been anything but solid rocks since the world was first created.

This hard crust of experience must be quarried through before knowledge can reach the understanding of home-bred men, for daily experience seems to contradict what they are taught.

But daily experience really agrees with geological teaching, for the mechanical action of natural force is always the same, though it varies in degree; and this is felt and understood when cold has been seen battling in earnest with heat.

A man begins to feel that cold is a mighty engine when he has seen a glacier, and heard it. When he has seen it move with acres of stones and gravel on its surface, and launch cargoes upon ice-rafts, to sail wherever the wind may blow them. He has learned a new alphabet when he has seen polished rocks under and near moving ice, and grooves and scratches freshly gouged out by stones in the ice. He

gains a new view of an old ridge of gravel, when he sees a conical mound of loose rubbish newly shot from a groove in blue ice, by a snow rivulet, and the end of a glacier fringed by ramparts of such mounds. Thenceforth he knows a "terminal moraine." He begins to understand how a clay field may have come from some neighbouring glen or distant country, when he has seen a thick, white, muddy river, smelling of sulphur, bursting out of an ice cave, tearing through heaps of debris, and busily engaged in spoiling a delta of its own building to make another lower down, or to freight an iceberg.

When he has seen all these movements and changes, these tools and their marks—and they are all to be seen in Iceland, Norway, and Switzerland—it is easy to believe that similar work was similarly done by the agency of cold and weight elsewhere.

Then the action of large masses of ice, and great floods of water, which hew out rock forms, and carry and arrange banks, mounds, and plains of drift, clay, and boulders, is recognised in the sliding of a plate of ice upon the bank of a rivulet, or in the miniature work of a mill stream on a frosty day. Having learned the alphabet and the living language, he can decipher the rock inscriptions of old ice.

So, when a man has seen one smoking volcano, with its lava floods and cinder heaps still warm beneath snow and ice, and the curl that once played upon a river of melted stone as sharp and clear upon a rock as the curl upon the glacier river beside it, his ideas about steadfast and eternal hills are changed. When he has seen stones, sand, and ashes, that once rose up, repelled by heat, and flew through the air in defiance of gravitation, now strewed on the ground where they fell, because the laws of attraction were the strongest in the end, he gains another new experience, and recognises a

force opposed to gravitation, which meets him at every turn.

When he has seen the workshop of heat and cold, he learns to know the tool marks of the two giant slaves wherever he finds their work, and he finds it everywhere when the lesson has been well learned.

The heat of a volcano is but the same force which works a furnace and a steam-engine ; the same forms result from its action, and he sees them in familiar hills, in cinder heaps, and everywhere. When the natural heat of the earth has been seen to hurl clods and stones, drops and jets of water, steam and smoke, far away from the earth's surface, to move freely for a time in obedience to laws which govern the movements of planets and earthly projectiles, it ceases to be an effort to realize the fact that heat, cold, and gravitation, are forces which together move projectiles in well-defined paths within the bounds of our world, and it may be beyond them.

A man becomes familiar with these, his fellow-servants, when he has eaten food cooked by nature's fire, and has slept on a turf bed warmed by mother earth. As he lights his morning pipe through a lens, with fire direct from the sun, beside a pool of water boiled by fire in the earth, and watches distant ice mountains through condensing steam, and thinks whence all the water came, how it was moved, and by what forces, a traveller must realize that these useful giants who can turn their hands to so many things, great and small, do not confine their labours wholly to this world.

He sees that heat boils a kettle, a steam boiler, a geyser, and a volcano ; lifts water at the equator to drop it at the poles ; and will hand a cigar light from his quarters in the sun, to a friend on earth who knows his ways.

He knows that cold cools the tea, and stops the engine, seals up the hot spring and the volcano, shakes down snow to

grind the mountain which the other raised. Cold arrests the motion which heat started: he knows that cold puts a man's pipe out when the time is come.

An Englishman seldom thinks of heat and cold as natural mechanical forces, though he sees their work everywhere.

An Icelander who lives within sight of Hecla may have seen the top of a mountain larger than Ben Nevis, red hot; with a stream of melted stone, as broad as the Thames at London, flowing down its sides.

The stream is there now, though frozen, hard, cold, and dark. Every year he sees water fall, flow, and freeze, and hang on the slope as lava does. There is snow upon lava now, and ice in caves beneath it.

He sees steam and boiling water burst up and spout from the earth, and condense, and fall, and flow into still lakes, freeze hard, and split; and he can understand that the great shattered plain of stone on which he lives was liquid, and rose, flowed, froze, and split, like the water.

He knows that lava boils over, froths and freezes outside Hecla; so he can understand how bigger streams boiled up elsewhere, before his ancestors came to the land.

A traveller who has gained a part of this Icelandic experience can apply it at home, and recognise past glacial and igneous action in forms which remain to tell their origin to those who can understand their meaning.

So a trip to Iceland is worth its cost.

The rugged features of nature are hidden or veiled in fertile lands; in the cold barren north they are clearly seen, and stern though they be, they are well worth contemplation.

The desolate country is one of the grandest in the world, though the prevailing feature in its landscapes may be dust and ashes.

Atmospheric circulation, water falling and flowing, fluid and solid; sliding glaciers, freezing seas, ice rafts floating, rocks wearing, sediment falling to form new beds, "denudation," and "deposition:"—downward movements from the action of cold and weight:—

Rising land, hot springs, intruded rocks, lava, boiling, rising, flowing, and freezing; volcanic projectiles rising, freezing, and falling in air; upheaval of land, upward movements in gas, fluid and solid, caused by heat:—

Demolition and reconstruction by natural forces,—are not all within daily experience at home.

Therefore, teaching and experience may seem to differ, but they really agree; for natural agents work everywhere in the same way, and the form of their work is alike at home and abroad, on the smallest and on the largest visible scale. The same powers work in a kettle, and in the Great Geyser; both boil, and sometimes they boil over.

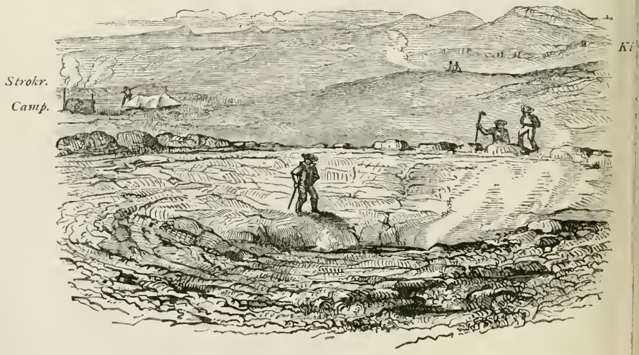

FIG. 2. BOILING UP.
Tube and Basin of the Great Geyser, after an Eruption, 1862.

CHAPTER III.

GEOLOGY.

Geology teaches generally that great changes have taken place on the surface of the earth, and it seems to point back to some distant time when a crust first cooled about a molten interior.

But there is nothing like a molten surface within common experience. The world with which we are familiar is green and smiling, and the old rugged crust is buried far out of sight, or worn away. It takes skilled eyes to read the lessons of our rocks. In Iceland nearly the whole surface has been fused ; it is warm still in many places, and most of the rocks are bare, so he who rides reads.

The modern geologist generally works slowly but surely downwards through the outer crust of sedimentary rocks which have settled layer upon layer above each other, and about the cooled surface of the first crust, whose formation is assumed in the meantime. From sedimentary beds he digs out the shapes of creatures and plants that once lived, and he marks off the layers in which they are found, and knows their order, and their fragments, by these forms of buried plants, shells, and skeletons.

The thickness of this outer shell is measured along its broken upturned edges, and it is calculated how long it may have cost air, water, and ice—the gaseous fluid and solid matters which now move about upon the earth's surface—to grind down mountains at a given rate, and so produce, transport, and arrange enough of mud, sand, gravel, and boulders to make up sedimentary beds whose thickness is known.

The time is estimated during which the formation of these rocks lasted; while plants grew, withered, died, fell, and accumulated, and became peat beds and coal fields; and while races of creatures lived, died, and were buried and turned to stone.

Each step so gained seems to rest upon a pile of facts as hard as the fossils themselves, each link in the chain is firmly joined to its fellow, and geology has become a science. But the rate of action may have varied in former times. The whole chain of reasoning in this direction, proves at least the endurance and activity of one mechanical force, which still acts towards the earth's centre.

The formation of sedimentary rocks under water, and the transport of their materials from a higher to a lower level, are facts which prove that the force which causes an apple to fall has acted in the same direction ever since it first moved silt: whatever the rate of action may have been.

There is not much to be learned in this branch of geology in Iceland. There are few sedimentary rocks, and very few fossils; but of the present activity of the weight-force which must have acted upon the original crust of the earth, there are striking examples.

Falling water has not yet smoothed the shattered, wrinkled surface of the lava; the sediment which it washes off and carries has not yet buried the rough outer crust; but water and ice are busily grinding igneous rocks to make others, and they have ground and buried many surfaces which were bare and wrinkled at first.

There are few sedimentary rocks yet formed, but they are forming everywhere upon igneous rocks, so there is much to be learned about the past, from that which now takes place in Iceland.

But gravitation is only one of the mechanical forces which

act at the earth's surface, and denudation and deposition are but one-half of geology.

At every step there is evidence of a force opposed to gravitation, which has counteracted the downward movement of sediment.

The rain which washed down materials enough to make known beds of rock, would have washed all the land into the sea long ago, and ocean currents would have levelled the bottom, had not land been raised above water by a force sufficient to balance weight.

No apple could ever have fallen from a tree unless the tree had first grown ; water could not fall from clouds unless it were first raised from the earth ; and stones could not fall from mountains unless mountains were raised above the plain. There could be no new sedimentary rocks unless mountains were raised up as fast as they are ground down. If there has been denudation, there has also been upheaval of the surface.

A second mechanical force is recognized in all modern geology ; it has helped to model the outer crust of the earth, and it is still very active in Iceland.

Heat helps to raise trees upon which apples grow, and the ground on which they fall ; it acts upwards ; weight acts downwards, and the action of the earth's heat is seen in hot springs, in volcanic eruptions, and in their work all over Iceland.

Heat drives matter away from the centre, gravitation drags it back.

Heat expands that which contracts when cold. Hot particles repel, cold ones attract, each other.

So heat raised up hills from which sediment falls ; it shatters the earth's crust, and heaves up the broken fragments, and thrusts up molten matter through openings so made ; it raised up islands, and continents, and sea bottoms,

and is raising them slowly still; it hurls projectiles away from the earth's surface, and it has probably worked in the same direction from the beginning.

And this mighty force is manifest within a week's sail of the English coast; where its activity is often forgotten till some earthquake startles a sleeping town.

It seems impossible to visit Iceland and deny the importance of internal heat as a geological agent, or to revisit old haunts without recognizing traces of extinct volcanic action everywhere.

To ride over lava and gaze into craters is to gain fresh knowledge, and learn new tool marks. It is like visiting some asteroid still warm from nature's laboratory, or to read an early chapter in this world's history.

If any stones be preachers, surely these are eloquent.

Modern geology, then, treats of sedimentary and of igneous rocks; it recognizes the activity of two mechanical forces, which act in opposite directions, upward and downward, from and towards a centre, in radiating and converging lines; and Iceland is peculiarly fitted for studying the effects of both.

FIG. 3. NATURE AND ART.
Northern Iceland.—Badstua, near the Uxahver, 1861.

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CHAPTER IV.

FORM.

VISIBLE objects of all kinds are known by their forms, by their outlines, and by their internal structure, as well as by colour, weight, and chemical composition : and form has this advantage—it can be used as a test where others cannot be applied.

Fossils, for example, are known to have been plants, shells, or bones, only because of their outward forms and internal structure.

Organized forms indicate previous orderly movements, and forces which produced them ; and the former activity of vital and mechanical forces which now arrange the component parts of living plants and animals is proved by form ; when colour, weight, and chemical composition differ from those of any living thing.

A knowledge of form is very important to the student of extinct life.

So it is to students of other branches of geology.

The rounded shape of a pebble tells that a stone was rolled till its angles were ground away, wherever it may now rest. It is the same whether it is found in a stream, on a beach, in a dry bed of loose gravel, or in a hard rock ; in a deep mine, on a hill top, or buried in lava and ashes. The form of a water-worn pebble of any material cannot well be mistaken when the tool-mark is learned.

An ice-ground stone differs from one that is simply water worn.

There are many degrees of wearing, and many varieties of gravel and rolled stones ; and a skilled eye can distinguish them.

The outlines tell part of the story ; internal structure tells more of it.

A bit of water-worn bottle-glass, for instance, shews by its structure that it is glass, which was artificially fused before it was broken and rolled ; and its fracture, and the shape of chambers in it, shew the direction in which heat, cold, and human skill worked on tough glass while cooling and passing from fluidity to hardness—from heat to coldness.

The glass may be a pebble in a sea-beach, so far as outward form and position are concerned ; but internal structure tells of the agency of man, and the action of heat and cold.

A jasper pebble, a bit of rolled obsidian or agate, or calcedony, all of which break like glass, tell their history too. Because of its outward form the stone has been rolled in water, or ice-ground ; because of its internal structure it has been heated to fusion, or perhaps to sublimation.

A broken bottle proves the former existence of men.

A scratched jasper pebble picked up in a field near the Clyde, means previous aqueous and glacial action where there is now dry land ; and volcanic action at the place whence the jasper was moved, before it became a pebble.

If a square block of jasper is found on some neighbouring hill, it points to a possible place from which the pebble may have started ; and if a vein of jasper is there found *in situ* it points out the site of an eruption, though there may be no other record of it.

So a fragment of rolled brick, a slate pebble, a limestone

boulder, and a bit of water-worn chalk, all have something to tell about forces which moved their particles.

Brick, though rolled, is easily known to be manufactured brick, and it tells of a bed of clay somewhere on shore, of the labour of men, and of the action of a certain temperature artificially applied to bake, without fusing, clay and sand. It may be part of a delta now, but a brick is human work.

Slate, sandstone, and limestone, though rolled pebbles, tell of the fracture and wearing of old beds of stone, of old denudation, and of deposition of silt to form new beds; of some action which changed silt to stone, and of the breaking and wearing of these new beds. A pebble of metamorphic clay-slate or marble may tell of a heat sufficient to bake without fusing clay and lime; and the materials tell of still older changes which formed and packed the minute fragments of which the rocks consisted before they were baked hard.

The minutest visible grain of sand has a well-marked form of its own, which tells a separate story.

But because these inorganic forms are as well marked as those of plants, shells, and bones, they prove the past action of mechanical forces as clearly as fossil shells do the action of vital force.

The form of sand tells of motion in gas or fluid as clearly as a fish-bone records swimming in water; and if sand and a fish-bone are found together in the same place, they tell of mechanical and vital forces acting much as they now do, and in water, cold enough for fish to live in.

These separate inorganic forms, then, give much information. But other forms tell their story with equal clearness.

A dry river delta tells as clearly of flowing water and moving silt, as a shell does of the life and death of a living creature. It is a water-mark.

The minute delta which forms in a gutter during a shower, is the result of flowing water ; so is the delta of the Nile, or the moving delta which is creeping seawards, out of valleys about Hecla ; or a fossil delta of any size, anywhere.

They differ, but their general form is the same ; and though all big rivers were dried up, their former existence might be known from their work, if but one flowing rill survived to explain the way in which silt is packed at a river mouth.

Size is of no importance when movements and forces, from which natural forms result, are known. The forces can be inferred, if only the forms can be recognised.

Distance does not affect the test by outward form.

A tree is known though it grows on some inaccessible cliff, and the vital vegetable force is inferred from the shape of the tree.

A river delta is recognised from a hill top, though it may be far away.

If there were a large delta or river-bed upon the moon's surface, it could be recognized there as easily as upon the earth, for it has a conspicuous shape. It is a tool-mark. No Δ is to be seen in the moon ; no forks and meanderings ; no V, no Y, no S. There are no clouds there from which rain can fall. There can neither be river nor tree, like earthly trees and rivers, on the moon's surface, because familiar water and air forms are absent.

But fixed, solid forms are there. It is known how similar forms are produced in this world. So it is fair to conclude that these lunar shapes, these O craters, also resulted from a combined action of heat, cold, and weight, which did their work, and have now ceased to work on that surface, though still active here.

Visible forms then, whether accessible or not, mean

previous movements, forces which caused them, and a temperature sufficient to make the movements possible in the material moved; and similar natural forms, wherever they may be, probably indicate similar action and agents, movements and forces.

A delta is a water-mark; a round crater a fire-mark; and every force which acts on a surface makes a tool-mark which may be learned.

Each mark is like a letter. It has a form and a meaning, but only for those who learn to read.

To learn the character, the language, and the meaning of inscriptions sculptured on the world by fire and frost is worth some trouble. The geological alphabet—the first lesson to be learned is—Form.

Fig. 4. An Eastern Symbol.

CHAPTER V.

ATMOSPHERIC FORMS.

If ever there was a time when the solid surface of our world was a newly-formed hot crust of stone, there must have been an atmosphere about it, whatever its composition may have been; for our gases and fluids, air and water, only expand by heat.

Movements in any gaseous shell must have resembled those which now take place in the air from the action of heat, cold, and gravitation, whatever the surface-temperature may have been; and these atmospheric movements surely left marks upon the solid crust from the beginning, because they do now.

We have but to look above us to read some of the ancient characters, which are and have been written in air, and to learn their meaning. They are forms which reveal forces. On a calm clear summer evening, after a thunder shower, when the setting sun is near the horizon, and the wind is still, great masses of vapour often pile themselves up into fantastic shapes which can only be seen in profile from a distance. They are easily drawn, and easily photographed. Those to the eastward shine like snow in the evening sunlight, and their shapes are clearly defined by light and shadow. Those to the west are dark, or edged with brilliant light, and their outlines cut sharply against the western sky.

Such clouds float steadily in the air; they are unaltered by

wind; but when they are closely watched, they are seen to change their forms at every instant.

There are magazines of force within them and without, and changing forms point out the directions in which these forces act.

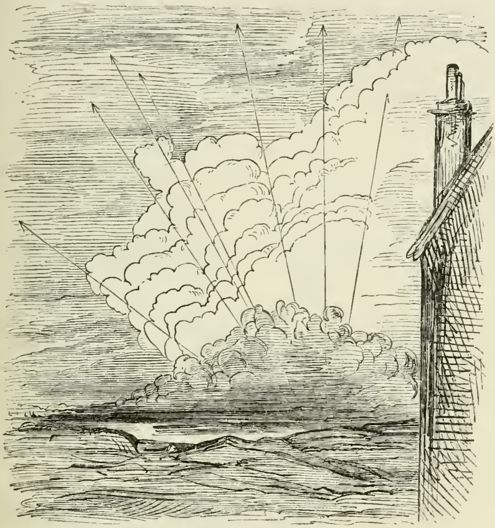

Fig. 5. Diagram to shew the Growth of a Cloud.

The outlines were traced with a pencil on the ground glass of a camera obscura, at short intervals, on a still, bright, hot evening.

Whoever has been enveloped in a mountain mist or a city fog, knows that a cloud is commonly made up of minute floating spheres of water, and these are moved about by currents of air, which are moved by some force.

These liquid spheres form at one place and disperse at another, according to the temperature and humidity of the air about them; but while they exist as drops in clouds they collect and scatter, and move according to movements of the air in which they float. Clouds are but fleeting characters written in air; but while they endure, they tell their story by their form and by their movements. In order to see these cloud-forms, and note changes which take place in them, they must be far off, for clouds are of enormous bulk.

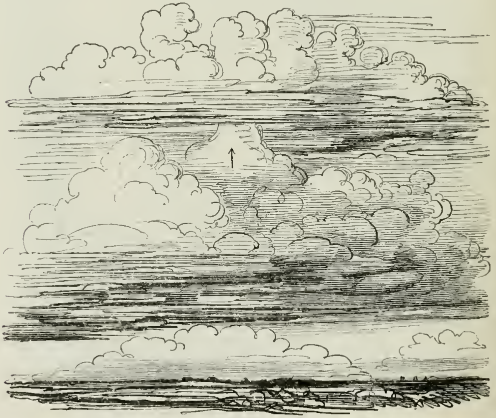

Fig. 6. "Cumuli." Sketched from a Railway Train.

"Cumulus" clouds which form above London are higher than the Alps, and, like Alps, they must be seen from a distance before the eye can take them in. But when they are seen, under favourable circumstances, their movements tell of upward and downward currents in air—of expansion

and contraction in particular regions—of currents which are analogous to those which move up and down, and sideways, in boiling water.

The lower edge of a distant cloud is often nearly a straight line; it is, in fact, the outline of the under side of part of a dome of vapour, forming at a certain distance above the earth's convex surface. The upper side is a heap of great rolling mounds which are constantly moving, swelling, and shrinking; rising and falling.

As warm currents of air rise through the vapour, rolling clouds expand upwards, and change from rounded domes to conical piles, and they flow over, and spread out upon the higher layer of atmosphere through which they have been

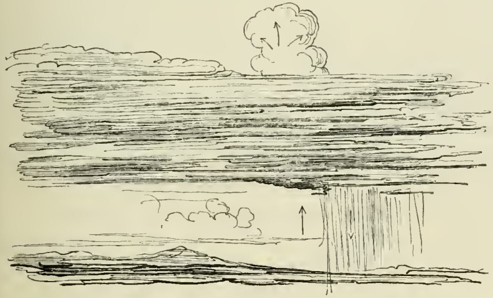

Fig. 7. Rising and Falling.

thrust, taking the shapes of mountains. So long as the sun warms the cloud, or the earth beneath it, the upward expanding motion continues. But when the sun disappears below the horizon, the action grows less, and the movement is reversed.

The great boiling mass ceases to boil; and settles down into layers of even thickness. The "Cumulus" becomes a "Stratus,"

or perhaps a cold wet current of air joins company with the cloud; drops grow larger and heavier, and the whole fabric tumbles down as a heavy shower. Then the "Cumulus" is a "Nimbus," and the source of a flowing stream.

It is the same whether the growth and decay of such clouds be watched from below or from above.

At sea there are no mountains to interfere with winds which blow along the surface of the water; so clouds, if they change their form, alter because of forces within them.

Thus, off the Orkney Islands, with a strong north-westerly breeze below, a distant mass of cloud on the southern horizon was seen to move so as to indicate upward and downward currents moving within the system of air which moved eastwards along the sea. The clouds also shewed higher currents moving in various directions. Steep conical peaks rose up out of flat clouds, which moved with the wind towards the south-east; more and more followed, rising till there were rounded domes; and these in their turn spread out and flowed over, and broke up into detached masses, which drifted away before upper currents. But the cloud spread to windward as well as to leeward, eastward and westward from its own centre of movement. It contained a radiating force.

When the upper sides of clouds are seen from a high mountain, the same forms appear.

From the top of the Rhigi, before sunrise, the Swiss lakes may often be traced among the mountains. Each is covered with a canopy of gray cloud, beyond which there stretches a frozen sea of mountain peaks cutting clearly against the rosy sky. Distant detached hills to the northward stand up like blue islands in lakes of gray mist, resting becalmed upon wide plains. But when the sun rises motion begins. The stratum of flat mist rises up, and heaves, and the gray plain

becomes a troubled moving sea of rounded hills of vapour, all bright and shaded, and glittering in the morning light. As the day wears on these rounded masses separate, break up, and creep along the glens and hill-sides, rising as they go, and by noon piles of rounded white cumulus clouds are peering over the tops of the highest mountains, or covering them. Later in the day a traveller in a valley may find himself drenched by heavy rain, while one upon a higher level, or in the plain, is rejoicing in bright sunshine. But if a wet pedestrian ascends an outlying mountain like the Faulhorn, he may pass through the falling shower into the cloud of little floating drops, and so through gray mist into bright sunshine and clear air. He may see the mist creeping up the glens, because the sun is warming the hills, and rain is condensing about the cold snow.

This engine is worked by fire and frost.

Shortly before sunset, on such a day, the lookout from such a spot is very beautiful. The great snowy Alps glitter in the bright light and clear frosty air, and seem to be close at hand, till some distant thundering noise calls attention to a few rolling grains of white dust. Then the real distance is measured by the help of the grand sound of a falling avalanche, and the giants assume their true proportions.

The sea of cloud which surges against the mountain a few hundred feet below the peak, changes its shape at every moment, as currents of air rise from glens below. The atmosphere is all in motion, though there may be no general horizontal movement at a particular spot and time.

But, when the sun sets, this local motion gradually decreases, and cold moon-beams may play upon a quiet stagnant silvery ocean of gray cloud resting becalmed upon hill and plain, or creeping slowly upon still water.

We live in a sea of boiling air, and when its local movements are made visible by clouds ; heat, cold, and gravitation —radiating and converging forces—are seen at work in the atmosphere.

Force is revealed by form.

On these forces and on these movements depend all atmospheric changes and the science of meteorology, which treats of them.

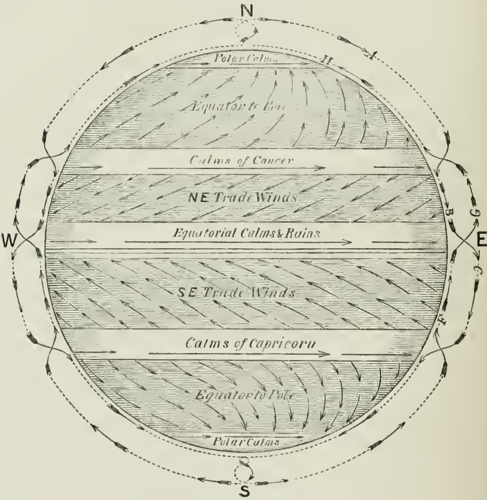

FIG. 8. DIAGRAM OF THE WINDS, BY LIEUT. MAURY, U.S.N.

"Abstracts of Meteorological Observations, etc.," edited by Lieut.-Col. James. London: Eyre and Spottiswoode, 1855.

CHAPTER VI.

METEOROLOGY.

The modern science of meteorology is founded upon upward and downward movements in the whole atmosphere.

All storms have been traced to the movements of two great currents in each hemisphere, which move like local currents, and for the same reason. These are north-east or north polar, south-west or equatorial, in the northern hemisphere; south-east or south polar, north-west or equatorial, in the southern hemisphere.

These great currents are attributed to upward and downward movements :—to the rising of light warm air near the equator, and to the falling of heavier colder air at the poles. Atmospheric movements then, whether large or small, general or local, are attributed to the action of heat, cold, and weight. But these simple movements are modified by the earth's rotation and by change of weight.

A cold heavy current of air, moving southwards from the north pole towards the equator, moves also towards the west along the earth's surface. It appears as a north-easterly wind, and it gathers heat and loses weight as it moves.

The equator is a larger circle than any other which is described by a point on the earth's surface about the earth's axis, and its parts move through a larger space in a given time.

A mass of air moving southward from a small revolving circle near the north pole, and also moving eastward together

with that part of the earth from which it sets out, lags behind a point upon a larger circle which is nearer to the equator, and is revolving eastward with greater speed.

So a north wind becomes a north-easter. A point on the edge of a disc, ten miles from the north pole, travels round the axis, a distance of about sixty miles, in twenty-four hours : it moves about as fast as a man walks : but a point on the disc, whose edge is the equator, moves eastwards more than a thousand miles in an hour.

So a north wind moving southward over Scotland, and eastward at the rate of Iceland, is passed by a Scotch tree as a man walking eastward is passed by an express train. A polar wind is a north-easter in the northern hemisphere, and a south-easter south of the equator, because air lags behind earth and sea when moving from smaller to larger circles. But the polar wind does not blow furiously, because air is dragged round and gains easterly motion as it gathers heat and loses weight on its way to the equator.

For a like reason, an equatorial calm, which sets off along a meridian, and blows from large to small circles, becomes a westerly wind. It plays the part of the railway train, and overtakes the crawling tree which grows on the British Isles. It bends trees, but does not always tear them up by the roots, because it is held back by friction.

The warm light equatorial south wind blows because air expands, and loses weight, and rises ; it becomes a south-west wind because the earth turns eastwards.

The prevailing direction of the wind in the British Isles is about south-west, and trees proclaim the fact by form.

In Wistman's Wood, near Dartmoor Prison, at an elevation of about 1200 feet above the sea, a curious stunted scrub of gnarled oak, said to be "as old as the creation,"

shews that the prevailing wind has been south-west since the oaks were acorns.

The strange old trees stretch out their twisted, tangled, moss-grown, fern-clad arms towards the north-east, and bend their hoary trunks in the same direction, as if seeking shelter.

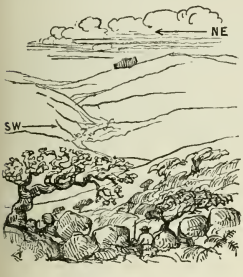

FIG. 9. OLD TREES AND BOULDERS.
Wistman's Wood, Dartmoor.

But on the hill above them, a great boulder, as big as a house, proves that some force stronger than the wind has acted in the contrary direction, *towards* the south-west. The stone has been pushed from its place, and rests on the hill side.

Wherever a tree grows on the western coast of Ireland it bows its head to the north-east. Every exposed Welsh tree bends towards the dawn.

Every exposed tree on the west coast of Scotland seems to be driven by a furious wind on the calmest day. About Edinburgh it is the same. On the east coast, on North Berwick Law, an old thorn tree streams towards the north-east, and every tree in that neighbourhood that dares to peep over a wall, straightway assumes the form of an old broom, and points eastward.

At Dalwhinny there is something almost ludicrous in the stormy look of a whole wood of fir trees which point their fingers down Strathspey, and bend their trunks as if yielding to a furious gale.

In Scotch islands, at least as far north as Orkney, it is still the same. Trees are vanes, and no other wind-gauge is wanted to shew that the atmosphere has a habit of rushing

past the British Isles from west to east on its way north. If the true bearings of exposed trees were taken and mapped, a wind chart might be added to the physical atlas.

But though there are prevailing winds, and a general atmospheric system of movement; the easterly and westerly, heavy and light, cold and warm, polar and equatorial streams, which cross meridians in travelling north and south, one above the other; get entangled and whirl round as rotatory storms. On one side of the equator the storms revolve one way, on the other they whirl in the opposite direction, as whirlpools do when a stream flows into still water; or when streams cross or meet; under bridges and behind posts.

The meteorological department of the Board of Trade have a hard task, though an able leader, when they try to forecast winds. But for all that, the strongest wind that presses on British trees goes towards the north-east.

At places where winds meet and mingle, currents flowing in opposite directions neutralize and roll over, and whirl about each other; and so whirlwinds, circular storms, calms, and partial winds of every strength and direction, occur; though light and heavy currents keep their places, and surface winds are almost constant in some latitudes.

When opposite currents are flowing, clouds betray them by form, and they are commonly seen.

When a strong south-wester is driving in a flock of detached clouds from the sea, the clouds transform themselves as they fly.

The wind drags along the surface.

The under side of the cloud drags also and stretches backwards, but the upper side is pushed forwards and rolls over like a curling wave. There may be a strong breeze below, but a gale higher up; and higher still clouds may be spread

out on calm ripple-marked plains, where currents are passing each other, and rolling up the clouds between them into mackerel sky.

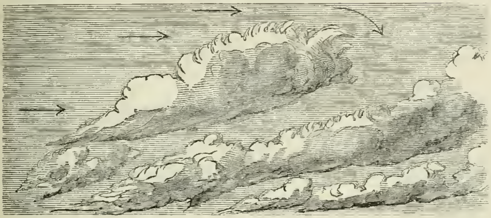

Fig. 10.

All these forms do but indicate movements which result from the action of two forces ; one radiating from a centre, the other converging towards it, and the science of meteorology is founded upon these two forces and on their action, above the earth's surface, in the air.

Air is constantly moving up, and down, and sideways, above water and solid ground. Meteorology attempts to explain the movements, and the moving forces are heat and weight.

The main facts were known to men when the first chapter of Ecclesiastes was written, as Maury points out in his writings.

"5. The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.

"6. The wind goeth toward the south, and turneth about unto the north : it whirleth about continually; and the wind returneth again according to his circuits.

"7. All the rivers run into the sea ; yet the sea is not full :

unto the place from whence the rivers come, thither they return again."

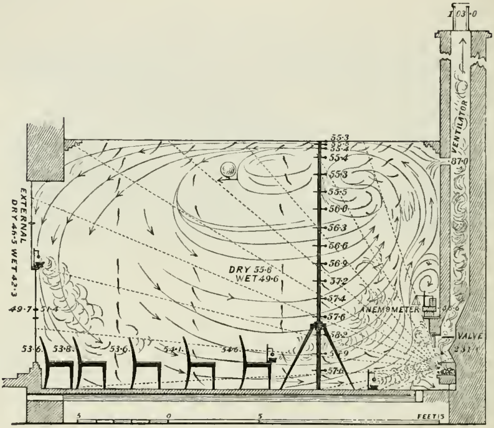

Fig. 11. Diagram of Draughts in a Room.

Section of a large room, shewing the positions and mean amount of deflection of silk vanes; temperature shewn by thermometers; force of upward current at the mantlepiece in grains per square foot; moving fumes; balloon; radiation from fire; and the direction in which air circulated under these conditions.

From the "Report on Warming and Ventilation of Dwellings," 320, Sess. 2, 1857.

CHAPTER VII.

AIR.

A CAUSE is found by working up stream—by creeping along any one spoke of a wheel towards the centre. The effects of a known cause are got at by working the other way. Starting from cloud forms, heat is reached. If heat be a mechanical power which moves the atmosphere, forms like clouds should be found at the outer end of shorter spokes in the same wheel.

If a principle be established, many phenomena can be traced to it. In meteorology, as in all sciences, a result is reached by observation of facts, but experiment is the final test of theory, however formed.

A power may be used when found.

If great and small atmospheric currents flow, for the reasons given, and heat and gravitation are radiating and converging forces by which air is moved, then any quantity of air, great or small, ought to be moved in the same way and by the same forces. And so it is wherever the experiment is tried.

Air in a conservatory may be taken to represent an atmosphere. The ground is warm, the roof is cold, and the general mass of air cannot escape beyond certain limits.

If one part of the floor is hotter than the rest, cold currents converge, and fall and flow towards that spot, absorb heat there, and rise like warm fountains to the roof. Thence warm

currents radiate in all directions, and flow towards the cold sides of the building, away from the warm region, and as they move above, they part with the heat which they acquired below. The smoke of a few charges of gunpowder, burned upon the floor of a hot-house, makes the currents visible, and the experiment always gives a like result, because it is founded upon a general law which affects air.

Air expands and rises when heated, contracts and falls when cooled, and moves sideways to find its own level, or escape pressure.

Air within a cottage, with a fire on the floor, obeys the law, and clouds of peat-smoke float overhead, and roll in emulation of clouds in the sky, while small storms blow amongst the plenishing on the clay floor. There is good fresh air in poor huts.

Air in a cave moves in the very same way for the same reason. When a fire is lighted at the extreme end, smoke rises to the cold roof, but it speedily cools and falls again, and returns along the cold floor to the fire, which set air and carbon in motion. It takes some time for heat to force smoke to the cave's mouth, because the hot air which carries it is cooled by cold air in the cave. So revolving systems of radiating and converging currents move in opposite directions, above and below; while men near the fire sneeze and cough, and are lost in clouds of rolling peat-reek. But as the air of the cave warms, the system moving within it enlarges its sphere. The smoke gets nearer and nearer to the door, and finally two regular currents are established. A warm stream flows outwards along the roof, bearing smoke and glowing in the firelight; and a cold chilly draught of pure, clear, fresh air creeps along the floor towards the bivouac. Because they breathe pure air, cottagers, gipsies, and travellers seldom wheeze.

A sail or some other screen makes all snug, and then a wanderer may stretch himself at ease on his bed of heather or leaves, and watch forms in the smoke, and rapid steady movements, which fire, kindled by a spark, keeps up in air, so long as fire gives off heat-force.

It is the same in a cubic foot of air confined under a glass shade. The movements may be seen by the help of smoke ; or delicate vanes made with gold leaf, will point towards the fire and the window, the hottest and coldest spots which can influence air in a room.

Polar and equatorial currents are found under a glass shade when they are sought, and they blow even in close cellars.

Perhaps the largest mass of air enclosed artificially is at the Sydenham Crystal Palace, and there draughts and warm currents are in proportion to the size of the building.

At one end a high temperature is preserved for the benefit of tropical plants, birds, and fish, but the rest of the building is kept cool.

According to theory, there should be a warm moist current flowing along the roof from the warm tropical regions, and a cold dry current flowing along the floor towards them ; but if there were, the temperature within would be too evenly spread by the air. To keep temperature off the balance, the currents were arrested, but they assert their presence nevertheless, and shew pressure by form.

The tropic which divided the torrid zone of the Crystal Palace from more temperate regions was at first a great canvas screen, and its form betrayed the invisible forces which pressed upon it. It bulged outwards *above,* like the topsail of a big ship, and inwards *below* like the mainsail of a first-rate taken aback. The imprisoned breezes could have driven big ships

and large balloons, waves and clouds, east and west, for the sails tugged hard above and below.

A visitor passing the tropics below, passed the door with a cold fair wind behind him, but one who attempted to enter by the upper gallery was met by a strong, damp, warm, head wind. Heat expanded the air, weight squeezed it, and air pushed the canvas, two ways at once.

Thermometers shewed that the lower current was cold and dry, but the upper warm and moist, and the outer glass in the tropical region streamed and dripped with condensed vapour, which light hot expanded air had absorbed.

So, in the Crystal Palace at Sydenham, are tropical and polar currents, and local winds ; evaporation and condensation ; as well as specimens, models, and copies of most of the world's productions, old and new, living and dead.

The principle on which these currents of air move is worth learning, for it may be turned to practical use.

Without oxygen any animal dies ; without fresh air constantly supplied it suffers for want of oxygen ; and these sufferings are in proportion to the absence of oxygen from the air which is breathed, or to the presence of something hurtful in it. Men die for want of air under water. That they often suffer in dwellings for want of fresh air is notorious ; but few ever think why they suffer in mines, or in rooms. Every breath drawn by every living creature is a chemical operation, in performing which oxygen is taken away from nitrogen, and carbonic acid added to it. Within a given time a set of lungs will absorb so much of the oxygen in a certain limited quantity of air, as to leave a spoiled mixture of air, nitrogen, carbonic acid, and exhalations ; a mixture which stops the play of lungs, stills the beating of hearts, and quenches fire as effectually as a like volume of water.

If any one is cruel enough to try the experiment, let him put a mouse on a plate under a tumbler, oil the edge of the glass, and watch the result. The mouse, unless relieved, will certainly drown himself in his own breath. But men and women, for want of knowledge, voluntarily subject themselves every day to sufferings which are the same in kind, though less in degree. The evil is glaring, and the results are but too well known; the difficulty is to find out the best remedy, and to persuade the patients to take it. Anything is blamed rather than invisible air, and every smoke doctor and engineer has a special nostrum of his own for keeping out "draughts," while persuading fresh air to come where it can be breathed. The plan is called by a long name, and when tried it often fails. Surely it is wisest to teach that fresh air is necessary, and foul air hurtful; to shew why air moves, and leave men to apply the knowledge, and help themselves. Air driven by heat moves exactly as water does in a boiling kettle. Hot air, or hot water, is lighter, bulk for bulk, than cold air or cold water, at a certain pressure; and the cold heavy fluid will flow towards the hottest place, and the warm lighter fluid will flow from it as certainly as winds blow and rivers flow, and for the same reason.

There is nothing simpler than "ventilation," if the principle is known and the law of nature obeyed.

Air under the earth obeys the same laws which govern air in the free atmosphere.

In coal mines ventilation is carried out artificially, but according to natural laws, by heating air in one shaft, and letting cold air sink down another; or by dividing a single shaft, and lighting a fire on one side. By partitions, doors, screens, and brattices, the downward current, set up by gravitation, is made to flow where it is wanted, to dilute and

carry off noxious gases, and supply the means of existence to miners, horses, lamps, and fires, which cannot breathe and burn without oxygen. In some mines air is thus moved a distance of thirty miles, at a steady rate, and more heat moves it faster. A ton of coals burned in a day boils up a breeze. Burned in an hour, the fuel drives an upward gale which blows out candles in rushing down to the furnace.

The system is good, and it only fails when ill carried out, or when the machinery breaks down.

In cold metalliferous mines, driven into hill sides, and out at the top, like those of Yorkshire; where the so-called system of natural ventilation prevails; currents of air move different ways under ground when the outer air is in different states of heat and pressure.

Changes in weight, which move mercury in a barometer, also move columns of cold air shut up in vertical shafts.

Changes of temperature, which affect fluids in a thermometer and in the free atmosphere, also affect air shut up in big tubes and chambers of rock.

Shafts and levels, pits and galleries, mines and chimneys, are but barometers and thermometers on a large scale.

So it happens that when air within one of these mines is colder and heavier than the air outside, a current flows along the adit and out into the glen below, as water does; and it draws air down into shafts at the hill top. Because the air within is heavy and runs out, the upper air falls in after it to fill the void.

When the air outside is cold and heavy, and the air within warmer and lighter, the current is reversed. Light air rises out of the highest shaft like smoke from a chimney, while heavy air flows in below, as water would if the glens were flooded.

In either case, there is sufficient movement to change air in most parts of a mine, with openings at high and low levels.

If barometric pressure is removed outside, the air within expands, and so escapes till the balance of pressure is restored. If there be noxious gas in chinks in rock, or in coal, it escapes most when the barometer is low.

If pressure is added, the confined air is compressed, and the outer air enters till the vacant space is filled.

When a strong wind is blowing outside, it acts upon air within a mine, sucking it out of a shaft as the current passes over it; and driving it in when the wind blows upon the entrance to a level.

But in certain states of pressure and temperature there must be stagnation in a mine, as there are calms at the surface, and on these occasions men are driven from their work.

When no one is able to predict which way the current will flow at any time or place, it is impossible to direct it.

Thus it happens that close ends abound in nooks and corners of mines, in spite of "windy kings," "windylators," "fans," and "water-blasts;" engines which substitute muscular force, water and steam power, for nature's power—heat.

Men are often driven from their work and choked out of mines for days by changes in the weather, when a fire would remedy the evil; though strong fires are burning to waste beside most mines. "Lead miners are as good as barometers" for their neighbours, but nevertheless they and their class generally, seem to be convinced that "weather ventilation" is the best of systems for them, and that fires are only fitted for coal mines where fuel is cheap.

In deep hot mines like those of Idria and Cornwall, where the natural heat of the earth is felt—at a depth of 1800 feet below the surface—in hot lodes, and hot rocks, where tem-

perature rises to 90° and 100°—there is true "natural ventilation," which only needs direction to secure good air. But even in such mines men often trust to nature while working against natural laws.

In one hot Cornish mine everything went wrong at "the end," till a great storm made a commotion in the atmosphere, which reached the hot levels below. The currents changed, and since that time they have constantly and steadily followed their own paths, and all goes well. The men suffer from heat, but they breathe good air—for the natural heat of the earth ventilates the mine.

In all cold mines where atmospheric ventilation prevails, there are "close ends," "poor air," "cold damp," "carbonic acid," and other evils, which cause sickness and excessive mortality, while engine fires are burning to waste at the surface near most of them.

"Levels" which are open at one end and closed at the other; where work is going on, ventilate themselves, though slowly and imperfectly, on the general principle. They are like long low caves, 7 feet high and sometimes 300 feet long, and men and candles heat the inner end. There is consequently a light warm column of air at one end, six or seven feet high, while at the other is an equal column of colder and heavier air, which presses upon and displaces the other. Heat forces out a wedge of air along the roof, while weight forces in a wedge of purer air along the floor. When a shot has been fired, the smoke is seen rolling slowly out in thick volumes along the roof, while there is little or none below. In an hour or in many hours the smoke is gone, and in time it will be found rising out of some shaft, if followed. But smoke often hangs for days in close ends, because men and candles are weak caloric engines.

If a regular and constant current, however slow, passed through a mine, down one shaft and up another, which would be the case if an upcast shaft were joined to an engine furnace-door; then brattices and trap-doors would turn the current into any corner, however distant, and so miners would suffer less from bad air if they used power which they throw away.

In dwelling-houses it is the same. Heat and weight cause movement in air everywhere, but the simple law is often forgotten, unknown, or misunderstood. So it happens that contrivances meant to promote ventilation impede movement in air.

To warm a room is easy. Every savage who kindles fire knows the art. It is only requisite to burn enough of fuel to warm a hut; and a leaky hut ventilates itself.

Fuel burned on the floor of a cave or hut, in an open fire-place or a closed stove, in a mine, a lamp, or candle, or in any other contrivance, is a source of heat, and that is power which may be used or wasted.

The fire radiates directly to all places to which straight lines can be drawn from it; indirectly wherever rays of heat can be reflected or refracted, and the radiated heat is absorbed and given off by everything within its reach, in proportion to the supply. The fire is to things in a room what the sun is to the outer world; but a room is a small world, and, unlike a hut, it is nearly air-tight.

To change the air in dwellings with chimneys and doors, or in mines, it is only necessary to put right fires in right places, and let air follow its natural course. To ventilate close rooms air-holes must first be made.

Fire acts mechanically by expanding air about it, and every separate object which is warmed by radiant heat and is warmer than air in contact with it, gives heat to air, both by contact and by radiation; expands it, and so moves it. Cur-

rents, like those which are caused by natural heat in the atmosphere, circulate in dwellings because heat is set free, reflected, and refracted. But fresh air cannot get in if " draughts" are kept out.

There is a general system of currents which radiate upwards, away from the hottest place in a room—be it fire, or stove, or heated pipe—and which converge downwards and move towards it, after the spreading currents have carried heat to the coldest places, and have left it there. There are miniature radiating and converging equatorial and polar currents in every room, as in every mine, and ventilators should use them.

There are small local systems which circulate about every candle, or heated chair or footstool, stove, or living creature, in a human dwelling, mine, or other closed space. These are as eddy winds, land and sea breezes, domestic whirlwinds, and family storms ; and their progress may be watched in graceful curves which form in clouds rising from peat fires, pastiles, tobacco pipes, newly extinguished candles, matches, powder, steaming tea-cups, or the kettle.

To warm and ventilate, it is only necessary to burn fuel, and direct the currents of air, which must move somewhere.

Let the window of a warm room be partially opened above and below, and let threads, ribbons, grass, feathers, or any other light material, be hung in the openings to act as vanes. It will be shewn that light air is escaping above, with a charge of heat taken from things in the room ; that heavy air is entering below to be warmed, and that the air in the room is revolving as a current of water eddies in a bight. It is the case of the mine in a hill.

If the same thing is tried in a room colder than the outer air, heavy cold air flows down and falls out of the window,

as water might do ; and light warm air enters the window above, deposits a freight of heat in the room, and then follows the outward stream. In either case the movement goes on till the mechanical force is expended, till the unequal weights are balanced, and pressure and temperature the same.

A living being is a source of heat, and a cause of movement in the air of a room, a mine, or any closed or open space. The warm breath and natural heat of a man who enters a cold room and takes up a position in it, moves air and cobwebs on the ceiling, at a distance of 30 feet, in about a minute. A miner moves the air in which he works ; a mouse moves air under a glass shade ; so does a rabbit in his hole.

The smell of a newly-lighted cigar moves about 30 feet in two minutes in cold air in a room ; but the rate of motion depends upon the coldness of the room, and the energy of the smoker. The sun and a pipe are different sources of heat and power, and currents of air flow when power acts, whatever the source of it may be. But a man and a candle work on air in a large mine, as a sailor's pipe does on a calm at sea.

An elastic balloon filled with a light gas, and carefully weighted, so as barely to rest on a table, expands and ascends when placed on the floor opposite to the fire. It is like a cloud warmed by the sun. It moves along the ceiling, away from the fire, towards a window, falls where it cools, and drifts back towards the fire along the floor. It rises because it expands ; it expands because it is warmed ; and it follows the stream of air, and shews its rate and direction. It does not move of its own accord, neither do the currents which move it. They move because they are expanded and compressed, and go fast or slow in proportion to the heat used to move their weight.

The smoke of a lamp where it blackens a ceiling, shews the course of currents of air by forms in which carbon is arranged. The forms are tool marks, and the tool is air.

Ice forming on a window, and hoar frost under a door, take the shape of streams of air moving in a room and entering a house.

Silk vanes, cobwebs, or any light substances hung about any closed space, shew currents of air by form as clouds do.

Air escapes from the garret windows of a warm house, but enters the cellar door. The cause is still the same.

There is pressure where currents are impeded, as shewn by the skreen at the Crystal Palace. There is outward heat-pressure on a garret window when closed; inward weight-pressure on the lowest door, and cold air will open the door and enter, if the latch be turned on a winter's day.

When pressure is greater than resistance, as when a house burns, air, urged by strong heat and weight, shews more power; upper windows burst outwards, lower windows are crushed in, and hard glass is shattered by invisible gas.

Imprisoned air, aided by more heat, bursts iron in a mould.

The atmosphere and weight crush iron boilers when water inside is deserted by heat, and steam loses the ally, without whose aid steam is ice.

And the atmosphere, when urged by the sun, and by the earth's gravity and rotation, sometimes becomes a hurricane which sweeps away trees and houses in its resistless course.

So heat and weight are strong useful powers; good servants if bad masters; and they work with air.

Some years ago an experiment on a very large scale was made in a coal mine below the sea-level, and it affected gases of very different specific gravities.

A northern mine in full work is a strange busy scene.

At the pit-mouth fires flare and smoke; steam-engines pant, and puff, and wheeze; chains clank, wheels rattle, and waggon loads of coals rise up, rush from the pit, and crash down shoots into railway trains. There is a fearful din.

Men step on a smoky platform, and down they go like Don Giovanni and the commandatore. Down they sink rapidly; and if unused to falling, their hearts seem to rise.

If the pit be an upcast, the smoke is dense, and the air grows hot, and hotter, and hotter still, as the skip slides down the chimney. It passes the furnace vent, the air clears, and the journey ends; it may be, far below the sea-level.

At the bottom of the pit there is bustle and busy work. Shouting and grinning, black, half-naked urchins, push waggons of coals rattling over iron plates, and up they go like a puff of smoke. Sleek steaming ponies, who never see daylight, trot in with trains of waggons from distant ends, grimy postilions with lamps in their hands ride in from distant stations, with arms clasped about the necks of their steeds, and heads bent low to avoid the roof. Black railway guards crouch in their trains and grin, and clouds roll from every open mouth and nostril.

The boys always ride home from their work if they can, and sometimes they ride races.

Lights flit about, gather, and disperse. Half seen forms, —a man's head and hands, or half a face; a tobacco-pipe smoking itself; horses' heads with glittering eyes and smoking nostrils, with a figure of fun grinning out from under the mane; all the fancies of Teniers, in his wildest mood, seem to float about in the darkness.

A cluster of these visions and their lights gather and

grasp a bar; three raps are heard, and they fly smiling up the chimney after the coals and the smoke.

At the end where the work goes on, these gnomes are constantly burrowing on, and bringing down their roof. The coal foundation is picked out, and the upper coal, the old sandstone flags, and the shales above; the arched roofs of this vault, with all their loads, begin to yield and split with a strange ominous noise. "CRICK." Wooden props shoved in feel the load, and they too complain and creak. When the full strain comes on them they are crushed and riven to splinters, and the roof "roars like cannons when it is coming down."

A spoke in the world's wheel is cut through and mended with sticks; the scaffold which supported the flat arch is dug away, so the arch comes down and the sticks are crushed.

With his head touching the roof, and his feet on the floor of a mine, a collier stands under a stone column it may be 2000 feet high. A weight sufficient to squeeze him as flat as a fossil fish is coming down, and he hears it coming, but he works on and smokes placidly under the lee of his prop, rejoicing to see weight help him to quarry coals.

That is working according to natural laws. That is using a power which has been found. That is one use of weight.

Some years ago, the workings of two such coal mines near Newcastle were purposely joined. Each underground world had its own atmosphere, with its system of currents. It is important to keep the stream moving, to make it move along the face where men work, and to know the way the stream flows, in order to be able to guide it. So these black gnomes, with shining oil stars on their foreheads, and gleaming teeth and eyes, argued keenly in their separate burrows. They are a shrewd, knowing race these northern Teutonic gnomes;

Fig. 5. 64
11. 64. make up slip

they know that fire-damp or choke-damp may blow them to bits, or drown them if their atmospheric systems go wrong. They know their own interests, and generally know how to secure them. So they held high council about their winds, when their systems were approaching each other.

The pits were miles apart, but a thin block of coal divided the workings at last.

On either side stood an anxious man reading the weight-power that pressed on the coal, from the dial-plate of an aneroid barometer. That was another use for weight.

A blow demolished the wall, and the mines were successfully joined. Weight turned the scale again. The lightest column went up, the heaviest came down. The trade wind blew towards the barometer which shewed least pressure, away from that which shewed most, by standing highest; and the coal wall being gone, the barometers marked the same pressure at the same level, and regular circulation went on.

There was less pressure in one mine, because there was more heat; and the colliers poked their fires, and rejoiced in fresh air, and scorned danger overcome.

They had got the mastery over weight and heat; and the giants and the gnomes now work amicably together in their united dens under the earth.

In deep cold metal mines, where a few narrow pits all open about the same level, stagnation is the rule. So long as air inside the stone bottle with the slender necks is colder than air outside, it is heavier. There is no natural power applied to lift it, and it cannot flow out for want of fall. Like water collected in an old working, the cold, heavy mine air is a foul deep stagnant pool, which evaporates a little, overflows now and then, and swings about in its rocky bed; but it never changes like water in a river pool, because

there is no stream flowing through it. Such a mine is a contrast to one through which air moves constantly.

On a fine, warm, breezy, bright, sunny day, with the sweet breath of fields and heather hills in his nostrils, a pedestrian in search of information comes to a trap-door and a hole like a draw-well. Odours of bilge water and rotten eggs, mildew and worse things rise when the trap is lifted, and they contrast abominably with the delicate perfume of beans and hedge-rows. The pool moves when it is stirred; but when left to its own devices, the most delicate tests often fail to shew any movement at a pit mouth. Cobwebs, paper, silk, soap-bubbles, and smoke, which shew movement in the stillest room, all indicate repose at the neck of the bottle, for the unsavoury air stagnates in the cold dumb well which holds it.

If the average temperature inside be 60°, and outside 61°, there is nothing to lift the lowest stratum.

There is no rattle, no din, no movement here. A dull sleepy creaking sound comes faintly in from a big water-wheel, which is slowly turning and pumping water from a neighbouring hole. The only cheery sound about the place is the rattle of hammers and stones, where boys and girls and strong-armed women, are smashing and washing ore in sun-light and fresh air. Like bees they sing as they work cheerily. Their cheeks are ruddy, and their bright eyes dance with fun; but down in the dark well is sickness, silence, and gloom.

A distant sound is heard below; the yellow glimmer of a candle shines out of the black earth; hard breathing approaches, and the regular beat of thick-soled boots on iron staves comes slowly ticking up the pit, like the beating of a great clock. A mud-coloured man appears at

last, and he stares amazed at the stranger perched at the mouth of his den; seated on a sollar, and watching cobwebs with a pipe in his cheek. The miner may be blue, or yellow, green, brown, orange, or almost red, but he is sure to be gaunt and pale-faced. His hair and brow are wet with toil; his eyes blink like those of an owl in day-light; he wheezes, and he looks fairly blown. With scarce a word of greeting, he stares and passes on to the changing house; and the cobweb which he disturbed settles like a pendulum at Zero once more.

When a lot of miners who work in such mines gather amongst other folk, they are as easily distinguished as blanched celery from green leaves.

When visitors go down, guides and strangers dressed in their worst, each armed with a vile tallow dip, stuck in a ball of clay, cluster about the well, which is called the "foot way," and one after another they vanish from the upper air.

The TICK : TICK : TICK : of many feet wakes up echo, and hot breath stirs the air. For the height of a town-church, down they go into the darkness, and their steaming breath rises up like blue smoke. When daylight fails, a halt is called, and candles are lit on the ladders.

This travelling is, to say the least, uncomfortable. A man in the middle has to watch that he may not tread on the fingers next below him, and to look out for his own knuckles; to hold the sharp, cold, greasy, gritty iron rounds, and the candlestick of soft wet clay, so as to hold the grip without losing the light, or singeing his nose with the candle. He has to feel for his footing, watch for damaged or missing rounds, and generally keep his wits bright; for there may be fifty fathoms of sheer open depth at his elbow, and nothing earthly to save him if he slips or stumbles in this "foot-way."

The Col de Geant in the Alps, Eriks Jökull in Iceland,

a long day after the deer, and a day's march with a heavy pack, are easy journeys to a mining scramble through dirt, darkness, and foul air.

Like a train of Irish hodmen, slipping down from a London house, down goes the procession; and those who are unused to the work find it hard labour. The way into this Avernus is not a facile descent. In half an hour, or an hour and a half, according to pace and distance, a journey which costs minutes and seconds in a coal mine, ends at the bottom of the mine where machinery is unknown. It is the goat's track against the railway; the fox's mine against the work of human brains. It is the old story of brute force and skill, giants against dwarfs; and the clever dwarfs who circumvent the giants best get most work out of them in mines as elsewhere.

On the floor of a coal mine the footing is sure. In the other, passages are made at different levels, and they are full of pitfalls, and uneven in height and width. Tramping and splashing through mud and mire, over hard rock and piles of rubbish, the train moves off. When the level is reached, a miner leads, another brings up the rear, and strangers file off and keep their places as best they can.

"Shoot:" cries the leader, and ducks his head. The next finds the edge of a sharp ironshod trough at the level of his eyes, dives under it in his turn and passes the word; "SHOOT." It is the place where ore is shot down from upper levels into waggons, and it is a trap to break the heads of the unwary.

"Sump:" cries the leader, and the follower, with his candle flickering in his eyes, finds that he stands on a single plank, or a narrow ledge of stone, above a black abyss. In daylight, heads are apt to swim above such depths, in the dark that feeling is absent; so each in turn passes the bridge and the

word: "SUMP." It is the place where ore is sent down, or the top of an air chimney, or the mouth of a pit dug into the vein.

"Deads:" and the leader proves his descent from some burrowing ancestor, perhaps a badger, a rabbit, or a rat, by crawling up a heap of rusty stones, wriggling through a long hole, and sliding down head foremost into the passage beyond. He looks very picturesque. The soles of his boots disappear at last, and one by one the procession struggle through and take the colour of the mine from its roof and sides. And so for half a mile, or a mile or more, it is "heads!" "shoot!" "sump!" "deads!" splash, tramp; and by that time all hands are wet, hot, greasy, smoky, and muddy. The smallest hole in an air-way is the measure of the current which can pass, so deads throttle the mine.

Having driven two long caves, one above the other, so far that candles will no longer burn at the ends, and men can hardly breathe, the next step in metal-mining is to "rise" and "sink" and join the caves; to make a passage for air to move through if nature so wills. It is easier to rise than sink, for loose stones fall when blown out of the roof, but as men rise into the rock, smoke, breath, hot air, and light exhalations rise with them. Thermometers rise also to 70° and 80° though water in the level and the rock may be at 60° or 64°.

To get up to the top of a rise "stemples" are often fixed for steps. These are bars of wood on either side, and to mount is like climbing a chimney. The stones which are quarried at the top are thrown down and gather in a conical heap below. So the place is well called "a close end."

In order to get oxygen into this black hole, a small boy, whose life, like Mr. Mantelini's, is one perpetual grind, is stationed at some place where the air is thought fit for use.

With a circular fan and a leaky tube, or with a thing like a magnified squirt; by the muscular force of a young male caloric engine, with the idle nature of a boy, some air of some sort is driven to the end, and half-choked men and dim candles struggle on for life in the burrow.

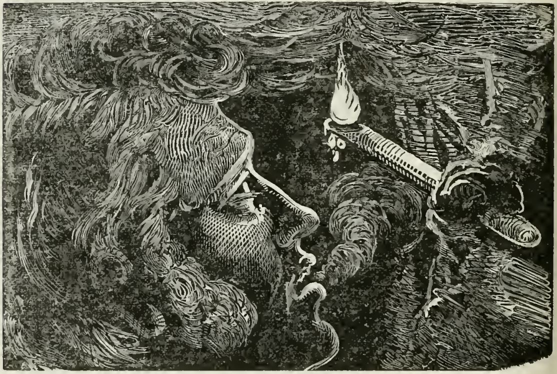

FIG. 12. Ventilating engines, commonly used at close ends in Metal Mines.

The lungs of a healthy man hold as much air as some of the squirts used, and one was expected to supply oxygen to three men and three candles.

The collier laddie who does like work, has a lamp and a book; he sits beside a door with a string in his hand, and his duty is to open the door when any one passes; to keep it shut, and keep his own eyes open at other times.

The one guides air intelligently, the other urchin drives it by weak brute force, and with bad engines. The ventilating boy engine passed, the leader dives into a rolling cloud of thick fœtid smoke. His candle turns into a nebu-

lous haze, his legs are seen wading alone after his body has disappeared, but both are found together at the end. With hands and feet on either side of the rise, in the graceful posture of a split crow, or a wild cat nailed on a kennel door; through showers of dust and falling stones, up sprawl guides and followers with many a puff and cramp till they crowd a shaky platform at the top of the rise. It is the place where men work for hours, days, and months.

One effect of these close ends on one who is unused to them is to cause perspiration to break out freely while standing still, or sitting quietly, resting where a thermometer marks 64° or less. There is a feeling of tightness about the neck; the chest heaves with a gasp, instead of rising steadily; the shoulders take a share in working the bellows; and generally there is distress, and a feeling like nightmare. Men at work in bad places pant and seem to breathe painfully; their faces are red, or purple; their veins swelled; their brows wet and begrimed with soot. They seem to labour hard, though their work is not harder than quarrying stones elsewhere. In such places candles flicker and sometimes go out altogether; no puffing or drawing will light a pipe or keep it lighted. There is no laughter, no fun; no busy cheery clatter of active labour at close ends; there is silent toil; for carbonic acid is not laughing-gas.

When a sump and rise meet, where they have "holed through," the hot air in the rise flies up into the upper level, and the cold air falls in behind it. The temperature changes instantaneously and the hole clears as fast. Heat and weight have room to act, and they do the work of many boys. Fans and squirts are thrown aside, till the levels have been driven another stage.

But the foul air of an end is only diluted with less foul air if there be stagnation at outlets, where cobwebs are still.

To retrace downward steps, to return to upper air, has ever been labour and hard work. From the bottom of a deep mine, perhaps from under the sea whose waves are heard rolling stones above the roof—up perpendicular ladders, perhaps in the pumping shaft with the rods moving up and down within a few inches of his back; with foul stinging mine-water dripping on his head, and a smoky candle sputtering in front of his open mouth; edgeways through clefts, on all fours, feet foremost, head foremost, on his back, his belly, and his sides, the amateur miner follows his guide. Greasy, muddy, drenched, streaming with perspiration, with throbbing ears, giddy, tired and gasping like a fish, the man who is used to climb mountains in fresh air struggles back to it.

When daylight appears, glimmering far over head, when the trap-door is passed, the first long greedy draught of the clean pure air of heaven seems too strong. It flies to the head like brandy. Even miners who are used to such places often stagger and totter like drunken men when they come "to grass." These were the sensations of the winner of a Highland hill-race, in good condition, at the age of twenty-eight. In well-ventilated mines ordinary fatigue was the sole result of many a long scramble under ground. An ill-ventilated mine is a crying evil; air in it is slow poison; working in it shortens life; it proves ignorance, parsimony, or poverty—for ventilation is easy to intelligent men, who will learn an easy lesson.

By analysing air collected in close ends, Dr. Angus Smith has proved the existence of poisonous gases, in places where these sensations are felt. So working in these places must

be injurious. It has also been proved that mining shortens life, where ventilation is faulty.

It appears, from calculations made by Dr. Farr, immediately after the census of 1851, that Cornish miners who work where currents of air are weak and uncertain, die faster than the Cornish population who live above ground. They die faster than colliers who, in Durham and Northumberland, work in places where air is moved by the direct application of heat-power to it; where currents are strong and regular in the mines.

Foul air fills the black list faster than fire-damp and choke-damp, and all the perils which colliers brave.

The death rates between certain ages were as follows :—

Ages.	Cornish people above ground.	Northern Colliers.	Cornish men under ground.	
35 to 45	10	10	14	per 1000.
45 to 55	15	17	34	
55 to 65	24	24	63	

So the principle upon which currents of air move has been turned to practical use in northern coal pits.

A leader in the *Times* of February 4, 1864, shews the evil in dwellings.

Festiniog, in Merionethshire, has been a healthy place for many years. It stands where mountain air is pure, and natural drainage good. The people were well off, and neither intemperate nor uncleanly in their personal and domestic habits; they earned good wages, but they slept in foul air.

A new slate-quarry drew men to the district; no one had time to build; the work went on day and night; so houses, rooms, and beds, like the lodgings of Box and Cox in the

farce, were occupied continuously by successive tenants. In two low bedrooms, 8 × 6, and 12 × 6 feet, ten and twelve people were lodged. In some lodgings the beds were never vacated, nor the rooms aired, either by day or night. So fever broke out amongst the overcrowded. There were six or seven hundred cases amongst six or seven thousand people, and sixty or seventy died.

Without fresh air constantly supplied, men do suffer; but air is free to all, if they will only open their mouths and take it.

The law which governs air above the sea-level is good law under it; and governs all gases and all fluids, fire-damp and choke-damp, steam and water, as well as air. It governs air in copper-mines and in coal-pits, in houses and in the atmosphere.

Bacon was right when he wrote long ago, "IT WERE GOOD FOR MEN TO THINK OF HAVING HEALTHFUL AIR IN THEIR HOUSES" (vol. iii., 297).

There are many tool-marks which moving air leaves on the earth. It bends trees; it uses them as levers to tear up turf and stones; it blows sand; it blows waves against a coast, and the coast wears into cliffs. The atmosphere is but one part of one wheel in a vast machine; and it leaves its mark on the world which turns within it.

The moving powers are few and simple, and the forms which shew their action are easily learned from smoke, trees, snow-drifts, sand-drifts, waves, and clouds.

These have a meaning which can be read and translated; they shew movements in air by their forms. Motion shews force, and its direction; its nature is found by experiment.

Experiment proves that Heat, Cold, and Weight are forces which produce upward, lateral, and downward movements in air, and so mould forms, and wear solids.

Observation finds these forces distributed in the world so as to fulfil conditions which produce these movements in air; and that heat comes from the sun, and from the earth. So cloud-forms and air-marks shew the mechanical action of solar and terrestrial heat, and of weight, in the air. They are tool-marks.

All atmospheric movements, great and small, can be traced to one general law, which governs gases; and fluids also. But before a law can be applied, it must be well known to those who apply it; and the laws of natural ventilation are often unknown to men who try to fill houses and mines with pure air.

Fig. 13. Bent Trees near Little Ormes Head.
Sketched in a calm. 1863.

CHAPTER VIII.

WATER.

If heat be a force which moves all gases away from centres, then for that reason alone it is probable that heat also moves liquids, and in the same direction.

It is not necessary to begin at the dial-plate, and work through a whole train of machinery, in order to find the centre of every wheel ; or to go back to the rim of each wheel to find the axle for every spoke. All British railways converge on London, but all railway journeys up to town need not begin at the furthest station. Without travelling round the world, we know that chimneys at the Antipodes smoke opposite ways, and that blacks fall towards each other, and the earth's centre.

If a natural law is known, its results follow. Powers which move the atmosphere and all gases, which radiate from, and meet at a point, bring a traveller to a large junction, from which to make a fresh start, or take a short cut, towards his object.

It is easily seen that forces which move air also move water.

Clouds whose forms betray movements in air are made up of water.

When air expands, it takes in water like a sponge ; when it is lifted air lifts water. When it contracts it drops the load.

But air is expanded by heat, and contracts when cold ;

so heat, weight, and air, are as hands which open and close about a wet sponge while lifting and lowering it.

In lifting air heat certainly lifts water to the highest point reached by clouds, and it carries them from the Equator to the Poles, and far above Coxwell, Glaisier, and Kunchinjunga.

But heat also acts directly on fluids. The sun's direct rays, when absorbed by water, and accumulated in it, lift it. They move water away from the centre, along a spoke, as fire drives steam out of a kettle.

In May 1857, during hot clear weather, two similar glass vessels were placed on opposite sides of a house, and filled with water. When weighed in the evening, the vessel which stood on the sunny side had lost nearly twice as much weight as the other. The sun's light, and its heat, had lifted water into the air, and the air had carried it off. But air on one side of the house could differ little from air on the other side ; so in this experiment the sun's rays drove the water out of the vessel. In the next trial, a thirsty terrier lapped up the water and spoiled the result ; but both did the work of mechanical powers.

According to Sir John Herschel, the amount of solar heat which reaches the surface of our globe would suffice to melt a crust of ice an inch thick in an hour, or evaporate a layer of water nine feet deep in the year ; if part of it were not expended in warming earth and air as well as ice and water. According to the same high authority, the actual fall of water in all shapes, and therefore the evaporation, amounts to a depth of five feet on the whole globe in each year. The sun's rays do notable work when they lift and drop such floods.*

Evaporation is a result of heat, and every experiment

* Good Words, January 1864.

shews it to be much or little in proportion to heat-power used, or weight-power removed.

It is common to fix the value of fuel by the weight of water lifted by heat set free while burning a certain weight of the fuel under a boiler. But fuel may be so burned as to spend heat-power on air instead of water.

In like manner, sun-power is differently applied at every different latitude, at every season, at every hour of the day, at every spot on the earth's surface, and the most of the rays shine into space or on other planets.

Most of the solar heat which gets to our world stops about the Equator, where the sun's rays beat directly on the ball by day, and from tropical regions most heat is radiated onwards by hot ground at night.

Least solar heat is absorbed at the Poles, where the rays glance off the slanting white surface.

So evaporation goes on most rapidly near the Equator in summer, and about noon, when the sun's rays strike into the earth, and drive water out into the air.

Though heat coming from the sun is the power which acts most conspicuously on air and water in the atmosphere, it is not the sole heat-power used, for it only penetrates a small way into the earth.

At Yakutsk, in Siberia, lat. 62° N., the earth is frozen to a depth of 382 feet. The summer sun thaws $3\frac{1}{2}$ feet of the surface, but the ice-crust is always hard lower down. If the sun were the only source of heat, this crust would be found at all depths. It is not so. Under the ice-formation is earth-heat. Temperature rises in descending: below 382 feet ice melts, and hard ice conglomerates are melted beneath the frozen crust. The mean temperature at the surface is 14°: below the ice-region it is more than 32°. But at 217 feet the

temperature of the ground is 27° ; and at 50 feet 18°. So heat is below and cold above, at Yakutsk.

On the American side, the ice-crust comes further south, but it is thinner at the same latitude. Perhaps the earth's heat comes further up from its home near the centre.

At Mackenzie River, the mean annual temperature at the surface is 25°, the ice-crust 17 feet thick, and summer melts 11 feet of the frozen surface.*

Solar evaporation goes on wherever the sun shines on water or damp ground, though at different rates; and terrestrial evaporation goes on also. Winds blow; dew, rain, snow, and hail fall; rivers collect and flow; glaciers gather and slide above the earth's surface, chiefly because the side that is next the sun absorbs heat by day, which travels onwards into space by night, leaving water behind it. But rays which the earth absorbs radiate back from the earth's centre, together with rays which the earth gives off, and together they lift water and air up the spokes, as far as they have power; for radiating heat is radiating force, whatever its source may be. Solar heat is not much absorbed by smooth reflecting surfaces.

Mercury in a thermometer placed behind a mirror, exposed to sunlight, is less expanded than mercury placed behind a black board. But a thermometer, placed in the focus of a concave mirror, on a sunny day, shews that reflected heat is strong reflected force when it meets resistance. Placed in the focus of a strong lens, a spirit thermometer shews that refracted solar heat bursts a glass boiler.

A thin dark object like a leaf or a slate sinks straight down into ice on a bright day, but a thick stone protects ice, absorbs heat, and gives it off by night as the world does. For this reason large stones often stand upon raised pedestals

* Keith Johnston's Physical Atlas, etc. etc. etc.

of ice, on glaciers, while fine dust melts ice, sinks in, and is buried in ice, at night.

So in nature. Solar heat is more absorbed by land than it is by sea, because the sea is smooth; and least of all in high latitudes, where the frozen surface slants most and reflects best; and it penetrates little anywhere.

But when a hill-side faces the sun, and rays strike it fairly, sun-power is as strong in high as in low latitudes and levels. All arctic voyagers, mountain travellers, and æronauts, have found it so. Pitch melts on the side of ships; men, balloons, and thermometers feel the power, and measure it. A white tent, pitched on a spit of white sand beside the Tana, lat. 70° N., became so insupportably hot about noon on a summer day in 1851, that panting inmates were forced to move it to the cool shade of a birch tree, where mosquitoes were thick and bloodthirsty. "Cuoikædne læ olla"—there are many midges, quoth a Lapp boatman; but in the shadow of a hill there was frost.

A balloon rising through a cloud feels the sun-power, and expands with dangerous rapidity; though transparent air above the clouds is cold as air in Arctic regions.

The power of the sun's rays to lift water depends on accumulation of heat-power; and that depends on the nature of the substance on which the rays fall, and on the shape of the surface which they strike.

A rough black surface gathers more heat than a white one, and reflects less; a black bulb thermometer stands higher than one with clear glass. A glass vessel, filled with black sand and water, loses more weight on a sunny day than a vessel placed beside it, and filled with white sand and water. White gun-cotton will not readily explode in the focus of a burning-glass, because it is transparent. A lens of clear ice will transmit and condense the sun's rays, and light tinder. Clear air is little warmed by the sun's heat, which it transmits and refracts. Clear fluid absorbs more heat, but it transmits a great deal ; for a glass bulb filled with spirit is a powerful burning-glass, though not so powerful as a solid ball of clear glass.

All these are questions of degree ; the facts remain. The action of solar heat is directly opposed to that of weight at the earth's surface, and it lifts water when absorbed by it.

The earth's heat has a like power, and acts in the same direction.

When pressure is removed from water, placed under the bell of an air-pump, water rises from the vessel which contains it ; and heat is the moving power, for water which remains cools and freezes. The heat acts upwards.

When air is cold enough, water steams up into it visibly, and heat is the moving power still ; for water freezes, and vapour which evaporates turns to rain, and falls down when it parts with the heat which raised it up. Lower down, water in a dark mine steams under greater atmospheric pressure. The earth's heat lifts it, and the earth's weight drags it down when it cools. Still lower, water from a hot spring boils and spouts up, and blows off in clouds of steam ; but it rains down in floods when it gets out of reach of the earth's heat which raised it. Heat in the earth lifts water at the end of every spoke where water is, but with varying force at every point on the sphere ; because heat is variously impeded by various rocks.

Heat artificially set free acts in the same direction, whatever the source may be. Water rises from a kettle on a fire, and hot steam lifts a piston, or bursts the boiler.

Having found a centre from which air moves, and a power

which moves it; the movements of water are found to coincide with those of air, so far as anything is certainly known about them. Rising columns of steam move opposite ways at the antipodes, like columns of smoke or mist. Air and water circulate together in the atmosphere, and within their bounds they are moved up and down by heat and weight.

If these two forces so act on water above the sea-level, they probably act in the same way on water in the sea.

There are polar and equatorial winds; and similar ocean-currents flow in like directions unless impeded by land. When they can be seen, water-clouds are found drifting under water, and their forms repeat the story told by clouds in air.

We deal with the bottom of the air-ocean, and look up for signs of movement in it. We must look down on the sea and through waves at water-clouds.

Air rises far above the solid earth. It flows over mountains as the sea flows over sunken rocks; and its surface is out of reach. We cannot dive to the bottom of the sea; but we may look to the surface of the ocean for information as to the surface of the atmosphere, and seek at the bottom of the air-ocean to learn something about the bottom of the sea.

From the movements of air, movements in water can be inferred, when powers which move both are known; and experiments made with one fluid test theories formed about another.

It is easy to see movements in water.

The first difficulty is to get a smooth surface through which to look. On the calmest day waves disperse rays of light, and reflect them, so that a sea bottom is hardly seen, except in shallow water. A diver cannot see clearly under water; his eyes are not made to see there, and objects seem blurred and indistinct. A lump of chalk is white, but has no

definite shape ; a silver coin shines like light behind ground glass; the distance fades away into dark green, or blue, or black.

Smugglers of former days found a way to meet the difficulty, and their contrivance is used by seal-hunters and others. When smugglers were chased, their practice was to chain their cargo of tubs together, and sink them ; taking cross bearings at the spot. Their foes used to drag hooks about at random, and sometimes they fished up the prize. The smugglers, when the coast was clear, returned and peered about with a marine telescope. A sheet of strong glass was fixed in one end of a barrel, and sunk a few inches ; a man put his head into the other end, shut out the light from above, and saw clearly, because light came straight, to eyes in air, through a plane from which no light was reflected.

With this simple contrivance, fish, sea-weeds, shells, sand, stones, ripple-marks, flickering lights refracted by waves, dead seals, and brandy tubs are easily seen in four or five fathoms of clear water; and water-clouds are seen rolling below when water is thick with mud. The gazer gets a vertical view of things under him, as an aëronaut does of land and clouds beneath his car.

So far as this contrivance enables men to see the land under the waves, movements under water closely resemble movements under air. Sea-weeds, like land plants, bend before the gale ; fish, like birds, keep their heads to the stream, and hang poised on their fins ; mud-clouds take the shape of water-clouds in air ; impede light, cast shadows, and take shapes which point out the directions in which currents flow. It is strange, at first, to hang over a boat's side, peering into a new world, and the interest grows. There is excitement in watching big fish swoop, like hawks, out of their sea-weed

forests, after a white fly sunk to the tree tops to tempt them, and the fight which follows is better fun when plainly seen.

Of late years glass tanks have been used as fish cages, and the ways of fish are better known, because they are now plainly seen in their own element.

The ways of water may be studied in the same contrivance.

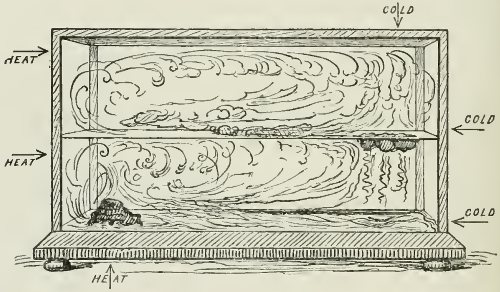

FIG. 14.

The principle might be extended. A boat with plate glass windows beneath the water line would make men and fish still better acquainted, by bringing them face to face. The man would be in the cage, and the cage might be in a salmon pool where fish are free.

If air in a hothouse be a miniature atmosphere, water in a glass tank is a working model of a sea, and heat and cold may be set to work the model engine at home.

Let one of the common fish-tanks be half filled with clear water, and placed where the sun may shine upon it.

Float a few lumps of rough ice at one end, and sink a black stone at the other; and, when the water has settled,

pour milk gently on the ice. An ounce to a gallon serves the purpose.

Milk consists of small white vesicles and a fluid, and, bulk for bulk, milk is heavier than water. So at first the white milk sinks in the clear water, and spreads upon the bottom of the tank, leaving the dark stone like a sunken rock in a muddy sea, or a mountain top peering over a low fog.

But this arrangement is unstable, because two powers are shut up in the tank with the water.

The sun warms the stone at one end, and the stone warms the water below. At the other end melting ice cools water above. Temperature is unevenly distributed, so weights are uneven, and the machine turns round.

Heavy cold streams pour down from the ice at the cold end, and flow along the bottom towards the stone, driving milk vesicles like drops of water in a gray mist.

Light warm fountains float up from the stone at the warm end, and flow along near the surface towards the ice, driving milk like wreaths of mountain mist rolling up into a summer sky from a mountain side.

The water is circulating, and every movement is shewn by milk-clouds, for the glass tank gives a vertical section of a circulating fluid system, driven by the sun's rays and by weight.

Cloud-forms are copied with marvellous fidelity in this water toy, and because the movement is very slow, they are easily seen and copied.

But the tank gives a section of air as well as water. The miniature sea has an atmosphere, and the same forces work both engines. Let a bit of smouldering paper, tinder, rope, touchwood, or any such light combustible fall on the ice-raft,

and cover the tank with a sheet of glass to keep in the smoke.

If there be small ocean-currents in the water, there are storms in the smoky air; and the systems revolve in the same direction, because the moving forces are the same. Cooled air streams down upon the floating ice, and drives gray smoke rapidly before it, drifting along the water towards the warm end, like a cold sea-fog before a north-easter.

At the warm end the mist lifts, like a sea-fog when it nears a warm shore. The smoke rises to the glass roof, spreads there and returns along the top towards the ice, whirling, streaming out, and taking the forms of fleecy summer clouds, which float high in air above the Atlantic in fine weather. "Stratus," "cumulus," "cirrus," "cirro cumulus," "comoid cirrus," and the rest of the learned tribe; "mackarel sky," "mare's tails," "Noah's arks," and vulgar popular clouds of their class; nameless cloud-forms which are the joy of an artist, and his despair when he tries to copy them; all appear drifting with streams, which various degrees of weight and heat cause to flow in air and water shut up within a cubic foot of space.

The amount of power used: the difference in temperature between the ice and the stone, moves air a great deal faster than water, because it is lighter, and there is less resistance to be overcome. It follows that winds should move faster than ocean-currents; and they do in fact.

When damp air has cooled and contracted to a certain point, it lays its load of water on any cold substance which takes in part of the charge of heat—which expanded air. Vapour is condensed. It follows the heat out of the warm air to the cold substance, and if it cannot get in, it stops on the surface, and gathers in small round drops. In the ex-

periment above described, cooled glass at the cold end of the tank stops water coming from the outer air; while the heat passes through glass and cold water to melt floating ice. Dew forms in curves on the outside, and it marks the dew-point temperature in the moving streams which cool the glass within. The curve is like a section of a river whirlpool, or a waterspout, and it coincides with the shape of the milk-clouds.

When the damp air of a room lays its load of vapour on cold glass windows in hard frost, similar curves are copied in solid ice. The dew-point temperature of the air in the room is marked out by a fog on the window, at first; then drops change to crystals, and ice-trees grow up by robbing the air which falls along the glass.

When a fire is lighted in a large room with windows encrusted with these beautiful forms, the march of the heat may be seen. As hot air rises and flows to the windows, ice begins to thaw at the top pane; crystal trees change to haze and vanish, wiped from the glass by dry air; or melted branches slide and stream down the window, dragged by weight when freed by heat. Where the fire radiates directly, the windows clear first. In corners sheltered from the rays ice lasts longest; and the lowest pane is the last to thaw and the first to fog. Heat pushes water towards the glass, away from the fire; weight pushes it towards the earth's centre. The radiating and converging forces do not part and meet at one point in a room; so the dew-point temperature is not in a regular figure. In the atmosphere, the dew-point curve has reference to the earth's centre; and vapour forms in shells about the solid earth because the two forces meet and part within the shell.

The facts shewn by experiment are confirmed by every fresh trial and observation. When temperature and weight

are unevenly disposed in fluids, it takes time to adjust the balance, but it tends to equilibrium, and to regular forms.

A warm bath is arranged in layers of various thickness, and varying temperature. When a human body is placed in it, natural observers stationed at the extremities send nerve telegraphs to head-quarters, to announce that one foot or hand is in warm or cold regions, and uncomfortable.

To prevent this evil, a bath attendant, who knows his work, stirs the water with a paddle ; but much stirring hardly spreads heat evenly throughout a bath.

Near Reykjavik, in Iceland, is a hot spring from which a scalding burn escapes. French man-of-war's men, who frequent the harbour to protect French fishermen, have built a turf dam across the burn, about a quarter of a mile from the source ; and they use the steaming pool as a hot swimming bath and washing establishment. The place was thus described in 1862 :—

Last night we wandered along the shore to a hot spring, which rises in a small hollow about two miles from the town. We found the place, and a dam, made by French sailors in the burn, which runs from the spring. The water was about 80° ; so we stripped, and plunged in, and swam about in the tepid water. The spring itself is about 170°, hot enough to cook eggs. We had none to cook ; but there were plenty of egg-shells and broken bottles to shew the ways of the place.

A lot of cows were browsing on rich grass, which grows in the hollow, and some of them stood close to the spring chewing the cud thoughtfully in the steam. The setting sun threw their blue shadows on the cloud of white mist, like great long-legged ghosts of cows. It was dead calm, and very warm ; and the hills, and the golden sea, and the purple islands floating in the bay, made a beautiful Claude landscape.

It was Italy in Iceland. There we lay stretched at ease on a velvet turf, and smoked, and watched the growing shadows, exclaiming, "how beautiful;" and the old cows seemed to feel as jolly as we did.

At last, when it was nearly ten o'clock at night, the cows seemed to think it time to go home to be milked. So one stepped deliberately down to the scalding burn, and smelt at it. She put one foot in, then another, and then the demure old brute sprang out on the grass, curled her tail over her back, and capered a wild dance, so utterly at variance with her former staid demeanour, that we all lay back and roared with laughter.

Next came a giddy young calf, who went through the same performance; but he, being more active, shook his scalded heels in the air in a way that was perfectly ludicrous.

The brutes, who should have known better, speedily resumed their placidity and walked away; so we got up and walked off to our floating home, where we drank tea on deck, and went to bed by daylight at midnight.

The next night was as fine, as warm and calm. Snæfell, sixty miles away at least, showed his head against a golden sky, in which clouds floated steadily, like the eider ducks and gulls floating about us on the calm water; but every now and again a strong cold blast fell down from the still sky, broke up the mirror of the sea, and then died away as suddenly as it came.

The air was in layers, the layers were of different weight and temperature, and the wind was "straight up and down," like an Irishman's hurricane.

The natural hot bath was a good illustration of a similar arrangement, and the glass tank and glass windows show the movements which result from it.

Water which stands in this hot bath is not stirred. The warm stream flows in above, and it cools by radiation as it flows to the far end, where it cools and sinks. The supply at the source is 170°, the waste at the dam is scarcely tepid, and the pool is circulating and rolling over and over because of its uneven weight. When a bather takes a header into it, he finds himself shooting through all sorts of climates. He feels summer, autumn, and winter rolling along his skin, as he shoots down. When he stands upright, he feels that temperature is packed in horizontal layers in the water about him, and that the cold layers are below. When he swims about, he finds hot and cold regions in different corners at the same level, for the heat is nowhere evenly spread. Lower down the ground may be frozen, but under all is the boiler from which the hot water rose. From this experiment with nature's thermometers, it appears that the coldest strata of water in a pond are generally below, but sometimes warm regions are below colder layers in the pond, as in air and sea.

The movements of water about to freeze are well seen in the glass tank above described.

At one corner a glass thermometer is hung with the bulb near the bottom ; at the opposite corner the stalk of a thermometer is thrust through a bung, and so placed that it can be raised or sunk without disturbing the water much. Thin ice formed in the tank floats at the surface, and a block-tin bottle filled with hot water is sunk. The heat of the water put into the bottle is 212°, the ice is 32°. On the ice, about the centre of the tank, some lamp black is painted on with a brush, one side of the tank is covered with a screen of thin paper, and then the machine is ready for action.

As the colour is at the coldest place :—on the ice, it marks the position of the coldest water when the ice begins to melt,

and the cold is easily measured with the instruments. As the hot bottle is in clear water, white paper seen through clear water marks the position of the water which is warmed. As lamp black takes many days to settle in a tumbler, it shews the movements of water, for it only moves about the tank, because water is moved by weight and temperature.

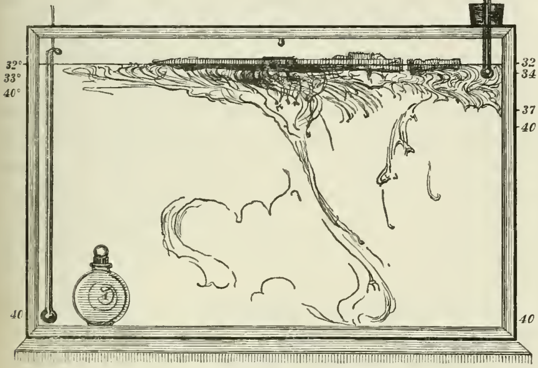

FIG. 15. FREEZING.

Ice being at the top is lightest, and its temperature is 32°. When it is melting the colour begins to move. If it is warmed by the sun, a dark revolving column sinks very slowly down. But beneath the ice are layers which contain intricate patterns of curved lines of black, which bend and wave slowly, but keep near the ice. The temperature in the coloured band is

Ice, 32°
Water, 33°
34°
37° As shewn in the woodcut.

So the coldest of these layers is the lightest, and the solid crust is lightest of all. The clear water in contact with the coloured layer is at 40°, and so is the water elsewhere in the tank, after the hot bottle has given off its charge of heat and melted the equivalent weight of ice. So water at 40° is heavier than water at 37°, and the different temperatures are drawn in black on a white ground. But water that is warmer than 40° is lighter than water at 37°.

When a water-bottle filled with hot water, coloured with lamp black, is sunk through an ice dome, without the stopper, a warm dark column rises up like the Afret whom the Arabian fisherman let out of the copper vase ; or the foul air which in cold weather rises out of a copper mine. When the water is hot, a thing like a round-headed mushroom grows rapidly out of the neck, and takes all manner of strange shapes. The head is like some monster which a painter sees in his waking dreams, a vision by Gustave Doré, for example. The stalk bends and winds through the clear water like an eel, or a black snake creeping out of its hole. When it gets to the cold region, the top spreads out like a palm tree, waving its drooping boughs, and shedding a crop of rings, and spheres, and streamers ; like fire-works in daylight. The temperature of the coloured water which rose from the bottle to the top is in this case about 44°, when clear water is 40° at the bottom and elsewhere. So of this series the warm layer is lightest.

While the bottle is hot the pace is fast, as it cools the phantom growths are nipped. When the water is almost boiling, it rises in water at 33° like smoke from a furnace chimney rising in air.

When the temperature has fallen in the bottle and spread through the tank, small jets of colour rise up and sink back into the pipe whence they rose. Their shapes are like those

of plants rising through the earth, their action is that of a boiling spring.

When all the extra charge of heat has escaped from the bottle, there is rest at the source ; the rapid action ceases, and the coloured water slowly takes its place in the tank.

On a frosty evening when there is no ice, but when ice is about to form in the tank, the water which rose out of the bottle forms an even layer above clear water, and the temperature then is 37° above, and about 40° below.

In that case the water which rose because it was warmed, stays where it cools, beyond 37°, and after that the more it cools the higher it rises, till it is 32° at the top and a floating solid.

When the hot bottle spends its force beneath a solid ice roof, thermometers mark 32°

33°

34°

35°

and the blackest layer in the series is the lowest and the warmest.

When freezing water freezes, crystals expel colour from ice, and water-currents distribute paint amongst the remaining fluid. Circulation goes on under ice, for some of the dark water which was next below the ice when it began to form is found at the bottom when all the instruments read close upon 32°, and the solid crust has formed.

Water, then, is a gas, a fluid, and a solid at different temperatures ; and the formation of one crust on one fluid illustrates the formation of other crusts.

The ice crust forms next the coldest place, and the fluid remains shut up inside.

In a tank the process can be watched, and the disposi-

tion of the crust is seen, because ice is transparent, and vertical glass walls bound ice planes through which rays pass undistorted. A plate of ice seven inches broad is more transparent edgewise, than an equal thickness of plate-glass.

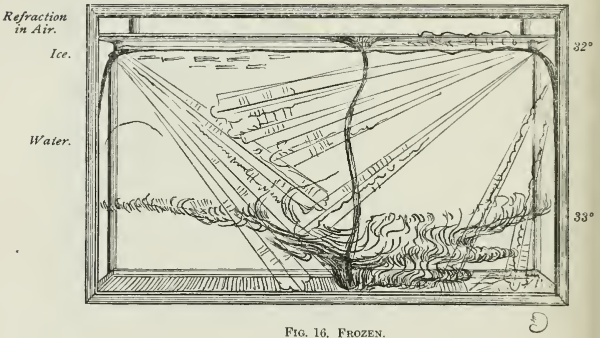

FIG. 16. FROZEN.

It refracts rather less than water. On the surface, the ice is disposed in layers, whose planes coincide with those which colour shewed in freezing water. The layers are added below; they are horizontal and regular where the ice is smooth above; where the ice is rough outside, the planes of stratification within are bent and crumpled. The surface next the wall is a plane, where the layers are flat and undisturbed; it waves where the strata are bent and wrinkled.

The thickness of the upper crust varies; at corners, the angular solid is rounded off, so as to form a dome.

From these solid corners long blade-like crystals radiate at all angles from 1° to 90°. They are like spokes of wheels, whose common centres are the corners of the tank; or as

fans behind the glass, opening from the angles where three planes meet.

Each of these blades is like the back of a saw with crystal teeth growing into the water, away from the glass.

When a tank is so placed that frosty air circulates under it, ice crystals form at the bottom also, and radiate from the lower corners. The glass box is lined at last with a box of solid ice, and fluid water is shut up in a curved crystal chamber, wherein it circulates till it is frozen.

By pouring hot water on the ice, a hole is quickly bored through it. When coloured water is poured on the surface, near the hole, it is warmer than ice, however cold it may be, and it sinks through, falling like the column which rose out of the bottle, but very slowly. It strikes on the bottom and rises up again, steadily working its way through the colder water, and forming itself into crumpled layers below. A thermometer marks 33° when placed in the colour. So water at 33° is heavier than ice at 32°, and, therefore, solid ice must float in water at any temperature.

The charge of heat which a mass of fluid water contains, passes outwards ; and leaves ice where it passes through any substance which stops water but cannot stop heat.

It is the rule that cold water is heavier than warm water, but the rule does not hold good for all temperatures. At 32° fresh water is ice, at 37° and all lower temperatures it is about to become ice, and it floats on water at 40°.

At 44° it rises through water at 40°, and then it melts ice floating above.

So fresh water is heaviest about 39° at some temperature between 40° and 37°, and many other fluids appear to have a temperature of greatest density.

Salt water of the specific gravity of 1.026 freezes at 28°. At the specific gravity of 1.104 it freezes at 14°.

As steam at 212°, or as vapour at any temperature, water takes up most space, is lightest, and refracts light least. As ice at 32°, 28°, or 14°, it takes up more space than it does when fluid. As fluid, water takes up least space, and is heaviest; it has greatest density, and refracts light most.

So vapour floats on ice, and ice on water. At or about 37°, water, having got rid of extra heat, seems to begin to assume the angular shape of ice crystals. Curves become straight, waves are calmed, bends change to angles, while coloured water is freezing. The angular shape takes more room, the crystal is bigger than the cold drop, but there is no more water in it. So the crystal floats, and crystallizing water floats up next beneath crystallized ice.

From these experiments it follows that layers of water of various changing temperatures must move; and the temperatures being known, the direction of movement can be inferred.

From other experiments it appears that air and sea are in fact arranged in moving layers of various thickness, temperature, weight, and density.

On a fine summer evening when the sun is nearing a sea horizon, some of the air-shells may be seen. Rays of light are variously refracted by lenses of different densities, and the atmosphere is a great compound concave lens.

The glass of an argand burner, though transparent, appears to cut across the flame like a dark bar at the bent shoulder. Any lamp shews the effect. When the sun is near the horizon, his light slants through domes of air which surround the earth, and, like a nest of glass shades, they refract the rays more or less according to their shape and density.

The round ball is distorted. As it sinks the disc of light is bent and broken up into irregular figures. The sinking light in passing the layers darkens, but the bars are flat and stationary, so the edge of the sun appears to bend and wave, as a lamp does when the shoulder of the glass chimney is lifted or lowered. If any clouds hang about the horizon in the twilight, they too are flat, for they are the edges of thin shells of condensing vapour, which made the air dense before sunset.

Fig. 16.

These upper regions have often been explored. In Mr. Glasier's late balloon ascents, in which pluck was a very conspicuous feature, it was found that although high regions, which correspond to regions of perpetual snow on high mountains, are cold, still sensible heat decreases irregularly, and is constant at no stage on the scale. Because snow falls upon the highest mountains, water in some shape must be carried higher than 28,000 feet above the sea; and accordingly, in June 1863, cirrus clouds and a blue sky were

seen far above a balloon raised four and a half miles above England.

The temperature was 17° at the highest point reached, but far above that cold shell of air, water was packed in the form of cirrus clouds. They marked a dew point. Lower down, from 13,000 down to 10,000 feet was a deep bed where the temperature was 32° or 33°, and the air thick with vapour and frozen water. Mist, snow, and crystals of ice were floating and falling ready to be moved in any direction. The water was there in a solid form, ready to rise higher if the air rose, or to fall into lower and warmer strata, or on the earth. It was colder below, but near the surface was summer weather, and a temperature of 66°.

The arrangement was unstable. It was one to cause motion ; the heavy snow was above and the light vapour below ; the one must fall and the other rise. But if the snow came down to the region of 66° and summer weather, the earth's own heat and the extra store which the sun had given it, were ready to send the piston up again to the dew-point.

In a former ascent at Paris, a temperature of 16° was reached at a height of 23,000 feet above the ground where the temperature was 87°. The mean temperature at the ground in Nova Zembla is 17°.

It is not given to every one to mount so high with a whole battery of instruments, but it is easy to understand the arrangement of the atmosphere from models worked by heat and weight, when it is known that temperature decreases as the distance from the earth's centre increases, and that heat is disposed in layers above the ground.

Air in high regions is pressed by less weight. It is colder than air near the earth ; but like a sponge relieved from pressure, it is better able to hold water the higher it is.

There is more room in it, so to speak, and the dew-point is colder. When air at 32° was found resting on strata sensibly colder, the upper layer was still better able to hold water, because still more expanded by the heat which it had absorbed.

A stream of warm, damp air, rising because it is warmed and expanded ; expanding still more as it rises ; because there is less air above to squeeze it, is like a balloon ; and carries great part of its load of water to high regions, where there is little sensible heat, but much heat latent.

Clouds, high snowy mountains, and balloon ascents, prove that water is somehow lifted more than 28,000 feet above the sea, and there seems nothing to stop it short of the limit at which the earth's weight and the earth's heat balance each other in their action on water.

As water evaporates spontaneously at all temperatures, and even in vacuo when the weight of the atmosphere is taken away, heat moves water one way, and weight moves it in the opposite direction. That is the working principle of the atmospheric engine, though the machinery is complex and hard to comprehend.

The depths of the sea have also been explored, though they have not been visited. Deep sea soundings have been taken ; living star-fish have been brought up from a depth of 15,600 feet ; the sea is fluid at the lowest depth reached ; so it must obey laws which affect fluids in smaller quantities.

The sea is packed in layers like the bath, the pond, the model tank, and the atmosphere, and these all circulate for the same reason.

Let a few of the temperatures which are given in scientific works be arranged in the following shape, and the movements shewn on Mauray's diagram, page 28. On the diagram page 34°, and on the woodcuts page and and will be

found to coincide in principle and direction with the ascertained movements of ocean and air.

Fig. 17.

Fluid water being heavy at the Poles and light between the Tropics, would move like air and clouds if it were deep as the atmosphere ; and the sea does, in fact, move diagonally on meridians, where land will permit.

Water, then, is found in three conditions at different temperatures and pressures, at different distances from the earth's centre ; and the order of the arrangement above the solid crust is

	Weight and Cold.	
1	Gaseous matter,	Air and watery vapour.
2	Solid,	Ice and air.
3	Fluid,	Water and air.
	Heat.	

Two opposing forces meet at some layer of the sphere, and so work the air and the water-engines, to which geological denudation is ascribed. Characters which these engrave upon the solid earth are written with heat and weight.

But because the double engine consists of many cutting wheels, and each wheel makes a different tool-mark, rocks which bear marks of air and of water, are variously marked by the contriver of the engine, which carves hills and glens.

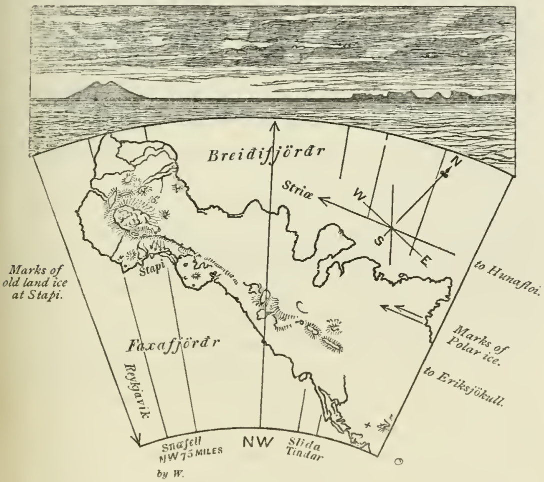

FIG. 18. PLAN AND ELEVATION.

Map and Sketch of the SNÆFELL Peninsula, opposite to Reykjavik. After sunset, June 27, 1862.

CHAPTER IX.

DENUDATION—TIME.

There is an ingenious device for sculpturing marble, which illustrates the working of engines which carve hills.

An artist's thought is modelled in clay, and cast in plaster of Paris. A block of marble is laid beside the solid thought, and the engine is placed between the stone and the model. Power is got out of fire and water, or water and weight, and it is passed through a train of wheels, strings, and levers, to a small cutting wheel which revolves rapidly at the end of a bar.

Let this wheel stand for a circulating atmosphere charged with water.

At the other end of the bar a point touches the model, and universal joints allow the bar to move every way. But the engine is so contrived, that if the point rises, the wheel rises as much ; if it falls, the cutting-wheel falls also, and where it touches, it cuts away marble, and makes tool-marks and a pile of chips. Gradually the artist's thought looks out of the block of stone. It bears the marks of a steam-engine worked by heat and weight, but it is a man's thought nevertheless.

Geologists have to learn the tool-marks of their trade.

Every tool makes a different mark. The cutting-wheel of the sculpturing engine cuts grooves, which the engineer could distinguish from an artist's touch, and many different wheels are used to make coarse and fine carving.

The brass wheel of a glass-cutter makes a different mark from the iron wheel, and the wooden polisher makes a different mark from a leather wheel.

A carpenter's adze cuts out a curved hollow, an axe makes a flat-sided notch, a handsaw marks straight lines and acute angles on two parallel flat sides, a circular saw draws cycloids on opposite planes. A gouge, a chisel, a rasp, a file, a centre-bit, a bradawl, a plane, a plough, a glass scraper, sandpaper, all the tools in the chest leave marks on wood which a carpenter knows. The work of a particular tool with a notch in it, of a blunt tool or a sharp tool, may be known by the mark.

A blacksmith knows the dent of a sledge-hammer from hand hammering; the groove cut with a cold chisel from the hole punched out with a square point. He has but to look at iron-work to know the tools used to fashion it, because he knows the tools and how they work.

A mason knows pointing from chiseling, dressing, and polishing; he can distinguish a stone that has been hand worked, or sawed up, from one broken out of a quarry.

A miner knows the mark of a pick from that of a jumper; the crushed surface broken by a blow, from one torn by a blast.

A goldsmith knows the touch of a graver wielded by skilled or by unskilled hands.

A wood-engraver, a shoemaker, an optician, an engineer, a tinker, a painter, a crossing-sweeper, a shoe-black—any craftsman or artist knows the tool-marks of his familiar art or mystery, or the sweep of his brush.

A geologist ought to know the tools whose marks he strives to understand.

It is taught, and it is true, that the earth's outer shell has been enormously "denuded."

So many feet of rock are wanting to complete an arch whose piers remain; the missing stones have been removed. The uppermost layer of a stone arch has been taken away, and the next course laid bare at one part of the bridge, which remains standing, though it is worn down by tracks. The crown of an arch has fallen, enough stone to make a mountain has been denuded from a particular part of the earth's crust. How the mountain was removed is to be learned from the marks of the engines used to remove it.

But unless the engines, and their modes of working, are studied, their work may be misunderstood.

It is often said that a big strath was hollowed by the river which flows in it; or that a mountain is a weathered rock which crumbled into its present form; but in many cases the river has little to do with the carving of the glen, and the weather has scarcely touched the hill since it was sculptured.

The river might have done a great deal in a long time, but if the whole land was under the sea, river-work must date from the rise of the land. If there be a sea-shell high on a hill-side, rain could not get at the rock, when the shell was buried under water; so rock-weathering, like river-work, had a beginning, if sea-shells and loose rubbish are above the worn rock.

Iceland is one of the great battle-fields of the powers of the air which grind down the earth.

It is a good place to watch the cutting wheel, the engine fire, and the smelting furnace; it is a place to see work in progress, to study the engines, and learn the tool-marks of fire and frost. Heavy work is there going on between large ocean currents. The same work is doing wherever air, vapour, ice, and water, heat and weight, are together, but the rate in

Iceland is faster than it is in countries where the heavy work is done. There also is a starting-point from which to reckon time, for the finished work of fire is wholly different from the tool-marks of the grinding engines of frost.

At the outset, it is clear that the carving engine has been long at work.

The beginning from which to reckon geological time is commonly wanting. The supposed rate of wearing by waves and of deposition by rivers, the thickness of beds deposited or destroyed within some historical period, these, or such as these, are the common measures for time. But, if ocean currents moved faster, climate altered or changed place, then work done may have taken more or less time to do than its finishing touches seem to show. There is a river-mark in Iceland from which to count time with tolerable certainty.

If the first mark of denudation was made upon an igneous surface, the cooling of the crust is a point in time from which to reckon. At Thingvalla is a river called the Oxerá, which, in ordinary weather, is about the size of an English mill-stream. The water would pass through one of the large iron pipes which carry Thames water to London. The Oxerá falls over a large cliff into a rift. There can be no doubt that the cliff over which the stream now falls, was formed by the falling away of the opposite side of the rift, and that the cliffs and the rocks in the valley were as fluid as water in the river at some time. To see the place is to be convinced of these facts. The Oxerá began to fall over this cliff, and denudation began at the edge, after the lava cooled, and after it split. There is no water-mark on the opposite cliff, so the stream most probably began to flow in its present channel when the bottom of the valley sank, and the plain became a slope.

The whole surface of this lava for many square miles is

marked by certain rope-like coils, which formed while the hot fluid was curdling, and these rise about two inches above the surface. They are fire-marks.

The water of the Oxerá has worn the stone at the edge of the cliff for a breadth of about thirty yards, at the place where water is always flowing, unless frozen ; the channel is about two feet deep, and three or four wide. Where water flows only during floods, the coils have not been worn away, but they are smoothed and worn ; and near the deep channel, the lava surface is very like that of slag which has been used to mend a road, and has been worn by traffic. Specimens are common in Lanarkshire and other iron districts.

Calculating from the angle which the sides of the rift make with each other, and with the horizon, the beds of lava may be about 600 feet thick, and it must have taken a long time to cool such a mass. As it happens, the Icelandic Parliament have met at the Logberg, on the surface of the lava, for 800 years, and there has been no great change in the valley during that time, for the ground is minutely described. At the earliest date recorded, the Oxerá fell into the rift ; a deep pool in it was the place in which wicked women were drowned ; trees grew on the lava, horses found grazing by the river side. It must have taken a long time for soil to gather after the lava had cooled. But things had arrived at this stage 800 years ago. Say that water has been wearing its stone channel for 1000 years only, and the depth from the fire-mark, the wrinkle on the lava, to the bottom of the water-mark, two feet, gives a rate of one foot of lava in five hundred years. The rate, in all probability, is far too rapid, but it gives a great age for these Icelandic rocks, and for those on which they rest.

At other spots streams have cut wide and deep channels in lavas of the same kind. The river at Godafoss, in the

north, has cut a deep channel, and has worked its way backwards for some hundreds of yards. The smoothed water-worn surface is plainly seen on cliffs far below the fall. The river is large, so it must work faster than the Oxerá ; but if one has cut 900 feet, while the other has only cut two, they cannot have begun to work at the same time. Giving one river credit for only one-third of the work done, the rate makes the age of the lava at Godafoss 150,000 years.*

Fig. 19. Iceland, July 30, 1862.—Fall of the Oxera.

But where streams do not flow on the lava about Godafoss, the wrinkles have not been worn off, so weathering has not denuded a quarter of an inch of igneous rock in that time at least.

Other Icelandic rivers have done a great deal of work. The Bruerá has drilled large pits, and it has scooped out smooth channels of considerable depth.

* 300 feet, at one foot in 500 years.

At Merkiarfoss, near Hecla, a small stream has dug out a large trench, and it has drilled the most fantastic peep-holes through a black conglomerate of ashes and stones, and this river began to work after the volcanic mountain had grown.

At Skogarfoss, a river falls over a cliff on a sea-beach, and it has dug backwards into the hill for some fifty or sixty yards. It began to dig after the sea had done its undermining, and had retired towards the horizon away from the base of the old sea-cliff. At the wearing rate the sea made the cliff 75,000 years ago.*

All these times may be wrongly calculated; they may be too short or too long; but when the last formed igneous rocks have endured so long, it is plain that the wearing of rocks to form known sedimentary beds must have gone on during ages, which it is vain to calculate. However rapid the rate may have been when the grinding-engine first began to work, it has been carving and packing chips for a very long time. The world is an old world; and sculptures on it are old inscriptions, though made with engines which are working now.

A river is a grinding-wheel in the denuding engine; a soft tool which makes a mark. Tools of the same kind are cutting and have been cutting patterns on rocks ever since water rose from the sea, fell on shore, and flowed towards the earth's centre; but each river had a beginning, and the time which has elapsed, since land rose above the sea, is too short for the work attributed to many rivers.

* 150 feet at 1 in 500 years.

CHAPTER X.

DENUDATION—RIVERS.

Before a craftsman can recognise a tool-mark, he must be familiar with the tool; before a geologist knows river-marks, he must study the ways of rivers.

Falling water proverbially wears a stone; stones wear in many ways, and at different rates; but that which the Oxerà and other Icelandic rivers have done to lava, streams must have done to rocks, from the time when the first shower fell, and the first stream began to flow. So ancient river-marks ought to be found on the oldest rocks, and these ought to resemble modern river-marks.

Clouds rise up from earth and sea. A river takes its rise in the clouds, from which drops fall. Fallen drops collect and roll from hills into hollows, and so a river grows. On the stony top of a granite mountain puddles may be seen forming during a shower. They fill from above, overflow, and so help to fill lower hollows in every rock and stone. These, in their turn, overflow and send off larger rills, which take the shortest way towards the earth's centre, and roll down the steepest slope.

Streams which flow straight down steep hill-sides must cut straight furrows, if they cut at all. Such trenches may be seen on the flanks of Icelandic volcanos, which have grown up in modern times; and on the sides of steep hills everywhere, and this river-mark always has the same general form.

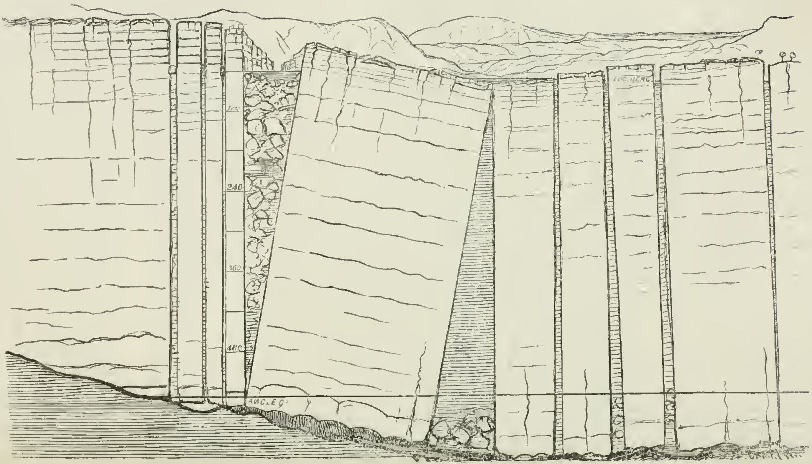

Fig. 21.

The steeper the mountain, the straighter are its gorges ; the deeper the trench dug by rain, the more rain-water tends to gather in it ; the water makes a path, and follows it, and it works faster as the work grows deeper. The mark is like **V**.

For this cause an ancient mountain, which has borne the brunt of the battle for a long time without the shelter of the sea, generally is so deeply furrowed, that little of the old shape remains. A cone, for instance, is grooved and fluted into steep peaks and ridges which meet at the highest point where water falls. The mountain is weathered, and becomes a rain-mark, unless it dives under water for protection. The shape is like **Λ**.

The mark which a river engraves on a country-side, is like a flat branch. Rain-pools are leaves and buds, rills are twigs, and rivulets branches which spring from a stem whose roots are in the delta at the sea.

The plan, at first, is a repetition of the forms of the letters **V** and **Y**, in which straight lines meet at various angles. But as the slope gets less, straight lines curve, and the stream winds in the plain like the letter **S**.

Any wide landscape seen from a high mountain, any well executed map or model, shews these characters which fluid engraves upon solid. They recur in every quarter of the globe, in every continent, field, or gutter, and could be read anywhere.

The section of a gorge dug by a torrent is angular, like **V** ; or the sides are perpendicular, like **U** ; on a gentle slope the section of a river bed is curved ‿ ; and the curve gets flatter as the river spreads and winds in a shallower bed, on a smaller slope. The section of the **Λ** is a convex curve ⌒, fluted by numerous river-beds. It is a mark of deposition, not denudation.

The whole of these familiar forms result from the movements of flowing water, and these result from the force which drags water towards the earth's centre ; and from the resistance of the crust which impedes the movement, changes its direction, and stops it at last in some rock basin.

The seed from which a river grows is a rain-drop. A drop of rain falls perpendicularly in a calm on a flat stone, and spreads every way. It strikes, rebounds, splashes, and scatters. If water is poured upon level glass, it spreads every way. The form is a star *

The force which moved fluid towards the horizontal plane is turned aside by resistance, and the water is pushed sideways, at right angles to its original direction of movement ⊥.

Ink, dropped on box-wood, obeys the law, and draws its own shape for the engraver.

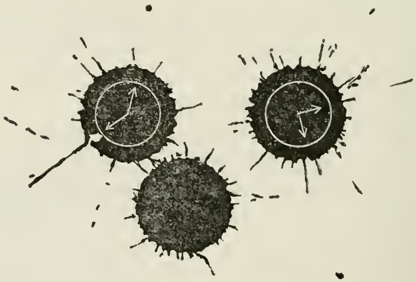

FIG. 22.

As drops diverge, so showers spread from a mountain-top, and rivers part from a watershed.

Water flowing in any open channel rebounds from side to side, and from the bottom ; so a river wears its rocky bed

irregularly, but on system. Resistance on the right bank reflects the stream towards the left, and there it digs a hollow, and swings back. Resistance at the bottom throws the stream upwards ; but only to fall again after drawing a convex curve. Where the water falls, it digs a concave hole, from which it rebounds again ; and so the river wears its bed according to force and resistance, and in curves. On a steep slope, zigzag movements are small in proportion to the fall ; the water hits the side of the trench at a small angle, and rebounds at one still smaller. So the mountain torrent works most at the bottom, where it hews out rock pools ; leaping from step to step, through deep ravines, in foaming cascades.

The Ruikan Foss in Southern Norway is a good specimen of river work.

The rock, over which a considerable stream now falls, is a coarse sandstone or conglomerate. The upper valley is a rounded hollow, at the bottom of which the river has dug a shallow trench. The upper hollow ends in a steep slope ; and the lower valley, like the upper, is a rounded curved rock-groove, through which the river meanders ; but the bottom of the groove is covered with beds of gravel. Both these glens, the slope, and the surrounding hills, bear marks of ice ; so the river did not hew out the glens ; but it has dug a narrow trench in the slope, and it is sorting the debris in the lower glen. The notch in the slope is 700 feet deep ; and rounded water-marks are clearly seen on the steep walls of the gorge, from top to bottom. The fall is working rapidly up stream ; digging at the bottom of the pool, at the foot of the rock ; undermining, sawing, and working back into the slope. It leaps out of the pool with a wild roar ; the bed of the stream is cumbered with enormous stones. Where undermined cliffs have fallen, long banks of talus slope down

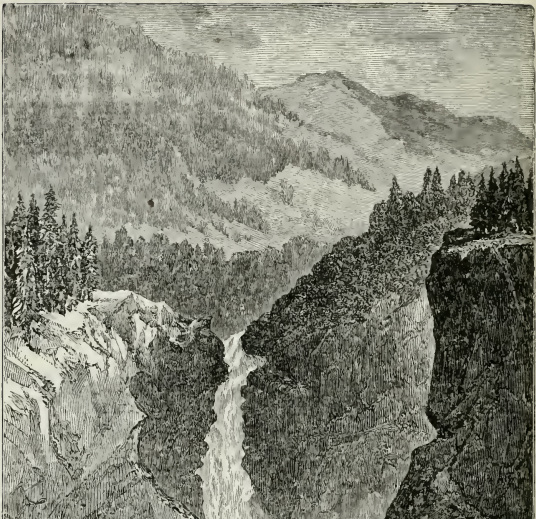

FIG. 22.

to the water's edge, ready to be swept away, and sorted lower down. The tool, the mark, and the chips, are together; and the power of the engine is displayed in the work.

On one point it is possible to lie on a long flat stone, look over, and drop pebbles from the outspread hands, 700 feet down into the gorge.

If a fall of undermined rock chokes the stream in this big ditch, there will be a deep lake in the slope between the glens. The water will fall harmlessly into it, and the rate of wearing and scene of action will change. The water will work most below the dam, till it is removed, and then the lake will disappear, and the river will begin at the bottom of the old fall again. But the sides of the trench will be angular where fractured, or smoothed where water-worn; the torrent-mark will continue like the letter U ploughed out of the bottom of the curved glen ‿. It will always be an angle L dug out of a slope.

The Vöring Foss in the Hardanger Fjord is another notable specimen of river-work of this class.

A large stream flows from snowy mountains, amongst which a few glaciers still nestle. It flows over an ice-ground plateau, in which it has worn a shallow bed; but when it reaches the sloping side of the lower valley, the stream plunges suddenly sheer down about a thousand feet, into a black chasm, so deep and narrow that the fall can only be seen by looking straight down at the pool.* Great clouds of spray dash out, and whirl up, rebounding, and driven by a strong wind caused by the fall. The spray collects on the hill-side, and streams down the rocks in miniature falls, which are blown up again. So the air in the gorge is filled with clouds of spray, and the pool is generally invisible. About

* By dropping stones, and timing their fall, the height was made 1100 feet.

Fig. 23. The Polished Glen, Eight Miles below the Vöring Pass.

a Torrent cutting through and obliterating the ice-mark. b Ice-polished hill c Birches, small pines, berries, fine turfs upon ice-polished rocks, with boulders and perched blocks.

noon, when the sun is clear, a traveller craning over the edge sees three parts of a rainbow about a black shadow with luminous edges ; a ghost of himself, wading through white clouds, which whirl and drift down the gorge like boiling mist.

It is impossible to sketch a hole of this sort ; but the mark which the river is hewing out in the hill-side is one which could not well be mistaken for any other tool-mark. It is the same as the mark at the Ruikan Fall, L.

The valley into which the river leaps bears other marks, which are as easy to read when the tool which makes them has been seen at work. The glen was scooped out ; but rivers are only cutting through and wearing out traces of ice. The river-mark is more than a thousand feet deep, but it is a mere scratch on the side of the glen in which the river flows.

Another famous Scandinavian fall is Tann Foss in Jemptlan.

It is near the watershed of the country, and the frontier between Norway and Sweden, on the road between Trondhjem and Sundsvall, between 63° and 64° N. lat. It is not a fall in a river ; there is no rapid above it. The water of placid narrows at the end of a quiet lake suddenly tumbles over a slate cliff, and becomes a quiet lake again, when it escapes from a boiling pool. The fall is 120 feet high without a break. The cliff over which it leaps is sharp, and its structure is clearly shewn where the broken horizontal beds project into the foam. In the very middle of the fall, level with the upper lake, is a square block of dark slate, which has resisted wear and tear at the edge. It is called the Chest. It is told that a bear, in trying to cross the narrows above the fall, got carried down and landed on the Chest. There was no escape ; so, in the extremity of his dismay, the bear screeched fearfully. A man heard him, and taking a most unfair advantage, pelted the

brute till he sprang over the fall, and drowned himself in despair.

Peasant proprietors still pay a nominal tax for a right to gather drowned elks and other game at this fall; for the smooth narrows tempt creatures to swim over, and many used to be drowned like the bear, when game was abundant.

From the top of Areskutan, a neighbouring mountain, which is some 3000 feet higher than the lakes, and 4000 above the sea, the work of this northern Niagara is seen to be a mere notch chipped out of the edge of a long terraced step, which runs along the hill sides, north and south, for many miles. It seems to be one of the many contour lines which coincide in general direction with the coast of the Gulf of Bothnia. The rock basin, which is a lake on the upper step, overflows; and the waste, which is about equal in volume to the Thames at Windsor, must have slid down the terraced rock into the lower basin at first. It has dug an angle now; but it has dug less than a hundred yards into the slate, for the original slope is entire elsewhere. It cannot dig much deeper than the water-level of the lower basin, for the water guards rock.

From this northern Rhigi, a vast expanse of country is seen on a clear day; and it has the characteristic shape of ice-ground rocks. The district is one great undulating slope of gray rock, green forest, meadow, and corn land; with conical peaks, rising here and there, and with silver lakes shining in their rough stone setting everywhere. One white snow-flake, a speck ten miles off, shews where water is foam, and a river is grinding rock at Tann Foss.

On a calm, clear evening, in September 1850, the wide landscape was very beautiful, and figures in it, and sounds in the still air harmonized well with the scene. A wild call

blown from a birch-bark tube rose up from a village at the foot of the hill, and then far below, as it seemed, almost under foot, tiny cows, and sheep, and goats, came slowly dropping, one by one, out of the forest into the road. Their bells tinkled as they went streaming after a bevy of girls, poking their noses into their hands for salt, lowing, bleating, and capering homeward to be milked and housed.

Close at hand a family of Röjoxa (*garulus infausta*) with their bright burnt-sienna wings, chattered and fluttered amongst green and yellow birches; and high overhead rose the peak, white with the first snow of winter, but rosy with the glow of sunset.

The denudation of rocks in this district is conspicuous, and the amount is enormous. It is plain that rivers and weathering will not account for the shape of Sweden. It is equally plain that other engines have worked here.

On the watershed, not far from Tann Foss, at the roadside—at a height which Robert Chambers estimates at 2000 feet—the clearest marks of glacial action are still perfectly fresh on rocks, in spite of weather and rivers. These marks prove that ice travelled over the hills from N.E. to S.W., at 2000 feet above the present sea level, at the place where streams now part and run to the Baltic and to the Atlantic.

It is an established geological fact that Scandinavia is rising from the sea. It is proved by marks made on stones in the Baltic, and watched since 1731, and by other marks.

It is evident that the hill-tops must have risen first, so the highest fall must be the oldest. Tann Foss, working at 1000 feet above the sea, has worked longer than Trollhattan, at about 307 feet; and the ice-mark at 2000 feet is older than the river-mark at Tann Foss, if it was made floating ice.

At the famous fall of Trollhattan on the Götha Elf, a

green river as large as the Thames at London, the waste of a great inland sea, and the drainage of a large tract of mountain and forest, escapes from a rock-basin, over a shoulder of rock, and slides down a rock-groove for about three miles. It rolls over the edge unbroken, like a great sea-wave, and slides down for twenty or thirty yards before it is streaked with foam. Below the rapids, the river meanders through a plain of boulders and drift, which partly fills the rock-groove. The plain fades into the sea, and rounded islands of rock, of the same pattern as the hills on shore, gradually decrease in height and size, till they become sunken rocks, and disappear at last under the Kattegat.

A good Tornea rapid is almost as grand as Trollhattan.

The striking feature of the place is the absence of river-marks. Denudation, worked by water, is insignificant. There is no section, no cliff, no step L worn in the slope. Trollhattan is a slide, not a fall. It is but a baby in geological time.

The country is well known to the writer; it is well described by Robert Chambers in the Edinburgh Journal, N. S., 1849.

From Stockholm to Göteborg, from Malmö to Christiania, glens, mounds, and hills, are ice-ground rocks of one pattern. Speaking generally, ridges and hollows, rock-grooves and river courses, rock basins, and lakes large and small, stretch N.E. and S.W.; and in many places striæ are fresh on the rocks, and point the same way.

At Christiania serpulæ adhere to rocks which are now 186 feet above the sea-level. When these shells lived where their mortal remains are found, the sea was over the rock.

At Udevalla, further south, a bed of sea-shells is found in a bank of gravel about 200 feet above the sea.

At Sarpsborg sea-plants have been found twenty miles inland, and at a level of 450 feet.*

But a sea 500 feet deeper would join the gulf of Bothnia, the Wettern and Wenern, the Kattegat, Skagerrack, and the German Ocean; sink Denmark, drown most of southern Scandinavia, abolish Trollhattan, and stop the war.

So Trollhattan only became a water slide, and began to grind rocks about the time when sea-shells and plants died for want of sea-water at Sarpsborg, Udevalla, and Christiania.

The river-mark is a measure of time, for the fact is established that this river began to slide when the lip of the rock-basin rose above the sea-level.

In Glen Fyne, in Scotland, are similar gorges dug by mountain-torrents in the sides of rounded hills.

The Eagle's Fall, above Ardkinglas, is not less than 300 feet high, and it has dug a wild, precipitous gash like the bed of the Vöring Foss; but the gash is scarcely seen from the valley below, which was scooped out by some other engine.

There is scarce a glen or rounded hill in Scotland which has not some modern river-work upon its steep sides, to contrast with wider, deeper, and older marks of denudation. There are numerous marks which prove beyond dispute that Scotland has risen from the sea, and that many of her waterfalls were born after the death of shells which are buried on hill-sides.

Farther north, about lat. 66° in Lulea Lappmark, is a fall which is famous all over the district, but which no Englishman has yet described. The Lapps call it Njoammel Saskas, or the hare's leap, because a hare can spring over a large river where it has dug a trench in solid rock.

* For details, see Chambers. The papers are very true and amusing pictures of Scandinavian travel, and geologically valuable.

Still further north, about lat. 70°, a large river which drains the great Enare Träsk, leaps down a fall in a narrow gorge which it has sawn through rocks. The country retains marks of glaciation over five degrees of latitude, between the Polar Basin and the Gulf of Bothnia.

All the large Swedish rivers, without exception, have one character ; they have done very little denudation since they began to saw through ice-ground rocks ; and what they have done is work of one pattern, more or less advanced, and most advanced at the highest level.

If the value of the unit could be found, the amount of river-work done might be measured from the ice-ground surface, and dimensions converted into geological time.

In Iceland, where streams work on igneous rock, the torrent carves the same pattern. At Melar, in the north, a small river leaps down a steep hill-side. It has made a succession of falls, with deep rock pools and rock pits. The rock is bedded trap, traversed by whin dykes, but the pattern of the river-bed is the same as in Welsh slate.

At the Devil's Bridge near Aberystwith a stream has sawed a groove in blue slate. It is ninety feet deep, and about six wide. The smooth water-worn surface is fresh from top to bottom on both sides of the groove, and at the bottom, in the bed of the stream, there is no joint or fracture to be seen. The whole is a river-mark, a trench sawn by running water straight down into the slope of compact slate which some other denuding agent wore out before the river began. The rivulet has but ploughed a groove at the bottom of a curve ; it has turned **V** into **Y**. River-marks are the same everywhere, and this is the mark of a mountain torrent **L**.

But drift and sea-shells have been found on Welsh hills at a height which would sink the hills at the Devil's Bridge

far under the sea, and all Wales is ice-ground. So this torrent, like the rest, had a beginning, and from that the begining of the groove must date.

The highest fall in Europe is that of Gaverni, in the Pyrenees. In descending the pass which leads from Spain into France, it is seen about four miles up a valley to the right. It is amongst the wildest of rocks and mountains, and there does not seem to be a tree within miles of it. In September 1842 new fallen snow reached down to the verge of the cliff, and early frosts kept the stream low. The fall seemed little more than a white thread on the dark rock face, but the water fell unbroken to the bottom except at one spot where it touched. In this it is unlike the Staubach in Switzerland, which, though lower, reaches the bottom as a shower of spray. The river at Gaverni is of considerable size, but the river-work is as nothing to the glen which some graving tool had sculptured before the river began to fall over the cliff.

High up in the Pyrenees are tiny glaciers, and the glens bear the marks of old ice.

Rivers have done similar work in Spain.

At Ronda, a small stream, which was almost dry in June 1842, runs through a trench hewn in sandstone. It is a strange water-worn Barranco cumbered with big stones, amongst which Spanish washerwomen do their best to rinse clothes. The sides are so steep that the river bed can only be reached at a few places. It is so narrow that a small bridge, with a single Moorish arch, joins the two sides. Emerging from this narrow groove, the water leaps down several steps cut in the sandstone rift, and through the cliff; it passes under the famous Ronda Bridge, turns several mills, and finally winds off through a lower plain, marking its course with verdure. The town is entered from the upper plain, and

this great cliff and chasm are so little seen that three seedy travellers spent a hot day in a venta a hundred yards from the great bridge, voting Washington Irving's description of the place to be a sheer invention. It is, in fact, one of the strangest places in Europe—a town built on a kind of rocky island on a cliff which a mountain stream has sawed off from a raised plain, with a broken edge.

Some other tool must have carved the Spanish hills, and at Grenada snow and ice still glitter above the hot plain, on the peaks of the Sierra Nevada. In the plains are beds of clay, which look very like ice-work.

In the Morea it is the same. The beds of torrents are grooves with steep sides ; the glens through which the rivers flow are wide rounded hollows, and on high mountains near Cape Matapan and above Sparta, snow-wreaths still out-last summer heats.

In the Alps, where glaciers abound, rivers often run long courses, beneath ice roofs. They do the work of rivers loaded with ice-floats, and the glaciers work beside the rivers, which flow with them in rock-grooves.

Old marks of larger glaciers are found in large rounded glens, on the banks of brawling streams, which are sawing narrow trenches at the bottom of every glen. A good collection of photographs will best shew these forms, and they are common now-a-days.

In Iceland, where glaciers are far larger than Alpine glaciers, many rivers and their marks are peculiar.

Enormous tracts are covered with vast snow-heaps and glaciers, and though the surface of this upper system of beds is tolerably even, the next series below it—the shattered igneous rocks upon which the glaciers rest—must have a surface of

hill and dale like neighbouring districts where the upper series is absent.

The water series deposited from air is fusible at ordinary temperatures, and it is constantly melting, if it is constantly growing from above. In summer, the surface melts, because a hot sun shines down upon it. The undermost layers are always melting slowly, because the ground is warm. When the earth-light shines out; when a volcanic eruption bursts forth under the snow; when the earth's internal heat radiates upwards more than usual, the snow turns to water and steam. The water flies back to the clouds, or sinks as far as it can, through snow, névé ice, and shattered lava. It flows down hill like other water, gathers in glens and valleys, bursts through passes under ice and lava roofs, and comes to light at last a full-grown river.

Large rivers are hidden throughout long courses, and burst out of ice-caves to fall into the sea after a daylight course of a few miles.

The rivers which drain the country which lies under Myrdals Jökull, and the Vatua Jökull, are of this kind.

The glaciers approach the sea, and their drainage is in proportion to their great size and nature. A mass of frozen water as wide as Yorkshire, and many thousands of feet thick when exposed to a hot sun; or when a flood of lava spouts up into it, sends down streams of muddy water, larger than rivers which flow from tracts of equal area elsewhere.

Many Icelandic rivers are in fact as broad as they are long, and run their whole daylight course over a delta.

These are always difficult to ford. Travellers pass them guided by men who know the district, mounted upon ponies used to wading, which are called "water-horses." A string of ponies, loose or loaded with baggage and riders, are tied head

and tail; and the train, led by the water-horse, crosses over the delta, up one side, and down the other; wading, sinking, scrambling, sometimes even swimming; sometimes on dry sand-banks, fording for a distance of several miles. Sometimes the river-bed has ice upon it under water. When the horses tread on one side, the stream gets under the upper edge of the broken ice, and great plates rise up and turn over and slap down, as if to crush the rider. Sometimes the leading horse sinks up to his girths in a quicksand, and it takes a cool head and a skilled guide to know what to do in riding over such an unusual ridge of country. The plan of the trail is Λ, the section ⌒.

In spring these broad fords are impassable. The water is too deep and strong even for Icelandic ponies to stem; and it is cumbered by great blocks of ice, which fall from the glacier, and float out to sea—no creature could live in such a torrent.

The bed of these subglacial rivers must be like the beds of other rivers, but their banks must be very different. In the hollow glens through which they now flow, will be traces of denudation of two kinds, if the ice melts. Marks will shew the wearing of rocks, by a river loaded with ice-floats, mud, and stones, and also the work of heavy land ice, which a change of climate may cause to vanish altogether from this region.

When an eruption takes place water-floods do marvellous work in a very short time, for the rate of denudation changes. Farms are obliterated; houses, cattle, land-marks, men, and their works, are swept away like a heap of rubbish, and the sea-bed is filled near the shore with large banks and heaps of debris, sorted by water, in water.

If ice were gone, volcanos extinct, eruptions forgotten, and the sea-bottom raised higher, it would be hard to account for

hills of debris which skirt some parts of the Icelandic coast, and which seem to have been formed in this way.

They are monuments of fire and frost, denudation and deposition, and they must contain records of sea and land, confusedly mingled, though packed in layers.

In Greenland and in Spitzbergen, according to the descriptions of travellers who have visited these regions, subglacial rivers find their way into the sea without shewing their dirty faces in daylight anywhere. A sea discoloured for miles is the only symptom of the stream which must be sawing rocks under ice as it does in the open air.

The beds of such streams can only be got at by inference, but the inference is plain.

From Greenland to Iceland, from Iceland to Scandinavia, thence to the British Isles, and to Cape Matapan, there is one connected series of cause and effect. The engine is working at one place, the marks are at another, but engines and marks are side by side at many places, and the marks of rivers are plain everywhere.

North and south, east and west, European river-marks are alike, and bear witness to the fact that rivers have done very little geological grinding since they began to flow down European rocks.

In many places in Iceland rivers are subterranean. The drainage waters of large tracts of country sink bodily into the riven porous earth, and not a drop is to be seen on the surface. On Hecla and the lava plains to the north there is no water in summer, but clear cold streams burst out at a place called the springs, near the foot of Hecla. Hot springs burst out at many places, and the plains which lie between the sea and cliffs of igneous rock, all round the island, are bogs which rival the worst in Connemara. There is hardly

any water to be found about Skjaldbreið. There is no river of any size to feed the lake at Thingvalla, but a very large river runs out of the lake.

What the beds of these underground streams may be like is not easy to guess, but probably they resemble underground rivers elsewhere, and some of these may be got at.

In Park mine, near Wrexham, the course of a subterranean river was cut in looking for lead. It can be got at by scrambling, and it is a curious place. A large cavern is water-marked from top to bottom, and old sand-beaches in passages mark a water-level fifty or sixty feet above the stream. The stone is drilled into the most fantastic shapes—oval windows, peep holes through which candles glimmer and water shines; handles to grip, peaks and pillars are common, but there is no straight line or flat plane or acute angle, except where stones have fallen; and fallen stones remain where they fell. The rock is mountain limestone, cupped by millstone-grit; and rain-water, which contains carbonic acid, melts limestone, slowly, as water melts salt. In the bed of the stream are pebbles washed from a distance. A clear murmuring brook can be followed for a great way up stream; down stream it plunges into a hole, and disappears with a roar. It breaks into Minera mine lower down, and where all the water goes at last no one seems to know or care, so that it is got rid of. In some of these underground worlds beds of silicious fossil shells are washed out of the lime, and look like shells piled on a beach. No human hands could dig them from their tombs as water does.

In limestone all over the world caves with subterranean rivers are common.

In Yorkshire are many. In the Alps, streams leap from holes in steep cliffs. Near Trieste a large stream flows into a

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This sheet sent back revised & altered

cave in a hill-side, and ten miles off a stream of the same size runs out of another cave. One pool is seen in the famous Addlesberg cavern, which has now been explored for many miles. It was known for three miles in 1841. It is an old river-mark filling with lime; a wonderful grotto, hung with glittering white festoons and pendants, and paved with white marble, which rain-water extracts from the hill through which it strains, and leaves in the cave when it gets to air and evaporates.

But the pool, with its strange creatures, the bed where water flows, is like a pool in the free air, and it is worn like the river bed in Park Mine. River-marks under the earth are like river-marks on the surface, when they can be got at; so, probably, river-marks under lava are like those of other Icelandic rivers.

On small slopes sidelong movements are greater in proportion to fall. The resistance is greatest at the bottom, and the downward movement is more easily reflected as the fall decreases. A hill-stream works most at the sides, where there is least resistance. The undermined rock slides, falls, and breaks; the bed of the stream is choked with fallen debris; there are many rapids and pools, but few falls; and the river-bed curves like the curving stream which makes it. But the shape of the trench depends on the fracture of the rock through which the river has made a way.

On a gentle slope the fall is less, and resistance the same. The stream is pushed on rather than dragged down, and it swings from side to side. It works as it moves, wearing the banks more than the bed.

There are many windings in a plain, few deep pools, and a smooth bed; there is smooth water and bad fishing; and

the work done by the river is chiefly the sorting of chips brought down from rock-grooves in the hills.

Every Etonian knows how streams work in their beds; for rowing and swimming teach the lesson.

Fig. 24. THE THAMES.
Sketched from the top of the Round Tower, Windsor, 1862.

a Surly. *b* Lower Hope. *c* Bargeman's. *d* Bovney. *e* Rushes. *f* Athens. *g* Upper Hope. *h* Cuckoo wear. *i* Brocas clump, *j* Brocas.

The Thames flows eastward on a gentle slope, and does not trace a straight line, but winds like a snake through the green fields.

From "the Rushes" to "Upper Hope" the river curves very slightly southwards, and the depth is tolerably even on both sides. But it is greatest on the northern side, which is the outside of the curve, where the water moves fastest. There

the bank is steep, the bottom clear, and the stream rapid. On the south side there is a shelving bank, a muddy bottom, and dead water. So boats rowing up stream keep the southern bank, and brush the northern on their way down.

The water is swinging eastwards round a point somewhere to the south; the river is working northwards along the circumference of the curve, and writing part of the letter S.

At Upper Hope the main stream has dug into the northern bank so far as to make the curve shorter. It strikes harder upon a higher bank, undermines it more, and rebounds faster to the other side, which it reaches at Lower Hope.

Boats ascending cross the stream at Lower Hope, brush the willow bushes with their oars, and scrape the gravel to keep in the dead water near the southern bank. But on the way back they cross the bay at Upper Hope, hug the northern bank, and shoot down with a rapid stream.

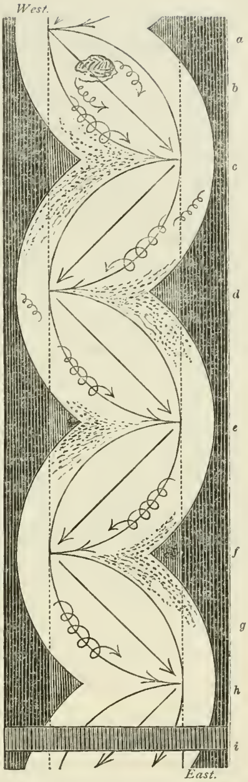

Fig. 25. Diagram to illustrate the movements of Water between the Rushes and Windsor.

a Rushes. *b* Athens. *c* Upper Hope. *d* Lower Hope. *e* Bargeman's Bush. *f* Brocas clump. *g* Brocas. *h* Eton. *i* Windsor Bridge.

The river flows south and works east between the Hopes, and it swings round a point on the west.

At Lower Hope, the main stream shoots over to the southern bank, which it undermines ; and thence it rebounds, swinging on the outside of a gentle curve, about some point to the north, and circling in miniature whirlpools as it slides along the steep clay bank ; till it swings away, and across to the "Brocas" at Bargeman's Bush.*

Ascending boats cross at Bargeman's, and hug the northern bank as far as Lower Hope, keeping the inside of the curve, where there is dead water, and a muddy bottom ; and when they return they keep in the stream.

Between Lower Hope and Bargeman's Bush the river is working southwards, away from the northern point about which it circles ; it is writing the other half of the letter S ; and from the round tower at Windsor, the whole silver letter is seen upon its emerald ground.

From Bargeman's Bush to Brocas clump the stream digs into the northern bank, and curves about a southern point. And so the Thames swings from side to side throughout its whole course. It is always gnawing into its banks northwards and southwards as it flows east ; but there is scarce a rock to be seen in the river. The valley of the Thames is half-full of chips, for some other engine had hollowed the valley, and filled it with drift and gravel before the river began to dig.

The Thames is a type of streams flowing on a gentle slope ; and ocean-currents swing between their banks on the same plan. The rain which streams along the roadway on Windsor bridge after a shower ; the Thames, the Oxerá on its lava bed, the smallest and the biggest, the oldest and the newest

* Now demolished.

streams, all dig on one principle, and do similar work. River steamers, canoes, boats, and boatmen ; Indians, Lapps, and fish, all work up stream on the same plan as an Eton Funny.

The sculler or swimmer who knows the stream has the best chance in a race, and gets on best in strange lands and waters. The geologist who tries to understand the work of large currents may learn a lesson from small streams.

Salmon-fishers must study the nature of rivers, or they will have sorry sport. Fish haunt particular parts of their domains, for good reasons ; and he who knows the reasons knows where to look for fish. They cannot rest in strong currents, so they avoid them ; unless there be nice stones or rocks at the bottom, to give shelter from the water gale. They do not like to rest in shallows, for they cannot there be hid from their foes in the air. In dead water there is mud, and no supply of fresh eatables drifting about ; and a salmon is an aristocrat who hates ploughing in dirt, and likes to have his dinner brought to him in a clean place. So fish hang about pools where the water is rough and deep enough to hide them ; and they choose particular spots, where there is stream to bring game, but not too much for the gentleman's comfort.

A salmon likes to have a cool breeze of clear, fresh, well-aired water blowing in his face ; and he rests in his nook poised on his fins, like a gull, or a hawk, or an osprey, floating head to wind behind a cliff, high in the air. And there he puffs, and champs his white jaws, and rolls his unwinking eyes, and wags his broad tail, till something worth having appears. Then the doser awakes ; and, with a sudden rush, the glittering silver sportsman dashes out, open-mouthed, with every fin spread like a fan, and every muscle tight and

quivering; and when he has snapped his hooked jaws upon some nice morsel, he glides back into his place, and waits for more. If he has taken a sham fly, with a sharp hook in its tail, strike home when he turns. If he has missed, give him a rest, and try again.

An old fly-fisher knows the look of places where fish abide, even in strange rivers, for surface-forms indicate submerged obstructions. In his own ground, he knows every corner of every pool, every shallow and hole, stone and eddy in it. So river-marks are familiar to fishermen, who are always watching the flow of water, and the work which it does; and the sportsman who knows most gets most sport. A still-net-fisher plants his snares in the way of travelling fish, and chooses his station by the run of the stream. Nets and spearing stages set in the Tana and Tornea are planted by Lapps and Quains in the way of ascending boats. Fish and boatmen strive to avoid the strongest stream, and cross at the same places. Fishermen know the stream, and the shape of its bed, by waves on the surface. The work of the river depends on its movements, so the nets mark out the run of the stream.

Floating bodies follow the stream, and shew its movements. If floats carve marks, they shew the course of the stream which moved the floats.

It used to be a time-honoured Eton custom for the long boats to muster once or twice in the spring, row up to the Rushes, and drift down, while the crews sang.

The captain in the "Tenoar," five or six "Eights," some "Sixes" and "Fours," and all the Funnies and double and single scullers that could get up in time, joined the fleet, and lay on their oars in a thick cluster; while some musical

"wet bob" chanted verses, and the whole of the crews roared the chorus. A favourite performance was—

Rule Britannia,
Britannia rules the waves,
Britons, never, never, never, never, never, will be slaves.

It was a grand song; but Old Father Thames would not be ruled. He never would carry Britannia's sons directly home, or keep their boats in their stations, or even follow his own curved bed. At first, boats to the north forged ahead, and swung their sterns to the bank; those to the south hung back, the long boats whirled slowly round, and bumped and jostled as they floated. The concert was varied by cries of "Paddle on easy"—"Pull round, bow"—"Back-water, stroke"—or "Bow, side oars in the water."

But when the musical squadron had passed the bathing-place at Athens, and had reached Upper Hope, where the stream runs full tilt at the bank, the crews had to row to avoid shipwreck.

The first part of the concert ended with a thundering rattle of oars in the rollocks by way of applause; nearly a hundred oars dipped into the water, and the captain's word was "Paddle on easy to Lower Hope." There it was, "Bow side, paddle hard," and "pull round."

Then the concert began again. The brown swarm gathered into a cluster, and covered the whole breadth of the stream; while "George Barnwell," Black-eyed Susan," "God save the Queen," and similar lays, were performed with the usual applause, and under the same difficulties.

But on this reach the movements were reversed.

The northern boats hung back, the southern drifted ahead, and the long boats slewed round against the sun.

It was "Pull round, stroke side—backwater, bow," for the

sterns were always trying to pass the bows, by scraping against the southern bank, while shoving the bows across the river into dead water.

The water whirled as it flowed, and it whirled the floating boats. It turned them with the sun, from left to right—east, south, west, north; with the hands of a watch, where the river curved, sunwise, eastwards, and about a southern point; from the Rushes to Lower Hope. But small whirlpools on that reach turned the other way, on the outside of the curve, because the bank holds the water back. The boats turned against the hands of a watch and widershins where the river curved eastward, and about a northern point, between Lower Hope and Bargemans; and there small whirlpools and floats of froth revolve, sunwise, under the high bank.

By watching these, similar movements on a larger scale may be understood. Corrie Bhreacan and the Maelstrom are but larger whirlpools in a larger stream, and circular storms revolve on the same principle as a whirlpool in a mill race.

What boats tell about movements in a stream is tested by swimming in it. Many a hot summer hour pleasantly spent in the cool Thames; many a long swim from the Rushes to the Brocas, and from bank to bank at every bathing station; long dives in the pools—have made this bit of river-bed familiar to all bathing Etonians.

Elsewhere they find that which is true of one stream to be true of all.

That which is true of boats and swimmers is true of other floating bodies; of trees and ships, ice-floes, icebergs, and clouds.

In Scandinavia are vast forests, in which a harvest of so-called "Norway deals" is reaped.

The reapers live in the open air for months at a time, and

brave great hardship, and some danger; for pines often grow in chinks, in the face of high rocks, where it is impossible to get at them without a rope.

Hardy Norsemen and Swedes fell the pines, hew off the branches, and roll and drag the trunks to the nearest water. Once launched, the logs find their own way to saw-mills; and sometimes they drift about in lakes and roll in streams for several years before they arrive.

Many get water-logged and sink; and these may be seen strewed in hundreds upon the bottom, far down in clear green lakes.

Many get stranded in the mountain gorges, and span the torrent like bridges; others get planted like masts amongst the boulders; others sail into quiet bays, and rest side by side upon soft mud.

But in spring, when the floods are up, another class of woodmen follow the logs, and drive on the lingerers.

They launch the bridges and masts and stranded rafts, help them through the lakes, and push them into the stream; and so from every twig on the branching river, floats gather as the river gathers on its way to the sea.

Sometimes great piles of timber get stranded, jammed, and entangled upon a shallow, near the head of a narrow rapid; and then it is no easy or safe employment to start them.

Men armed with axes, levers, and long slender boat-hooks, shoot down in crazy boats, and clamber over slippery stones and rocks to the float; where they wade and crawl about amongst the trees, to the danger of life and limb. They work with might and main at the base of the stack; hacking, dragging, and pushing, till the whole mound gives way, and rolls and slides, rumbling and crashing, into the torrent, where it scatters and rushes onwards.

It is a sight worth seeing; the power of a float, moved by water, begins to tell, and denudation is seen in progress.

The brown shoal of trees rush like living things into the white water, and charge full tilt, end on, straight at the first curve in the bank. There is a hard bump and a vehement jostle; for there are no crews to paddle and steer these floats. The dashing sound of raging water is varied by the deep musical notes of the battle between wood and stone. Water pushes wood, tree urges tree, till logs turn over, and whirl round, and rise up out of the water, and sometimes even snap and splinter like dry reeds.

The rock is broken and crushed and dinted at the waterline by a whole fleet of battering-rams, and the square ends of logs are rounded; so both combatants retain marks of the strife.

The movements of ice are the same.

At one mill at Christiansand, 70,000 trees thus floated down are sawn up every year; and there are many other mills in the town; so the work done upon rock by floating timber is on a considerable scale.

The work done by river-ice is greater, but similar. The rocks are worn at the water-line, and undermined, and when they fall, there remains a perpendicular or jagged broken bank.

About ten miles from the town, at Vigelund, at another large saw-mill, there is a fall in the Torisdals river, where the lateral and vertical whirling of flowing water, and its action upon floats and rocks, is well seen.

Above the fall it has been found necessary to protect the rock from floating bodies, so as to preserve the run of the stream. It threatened to alter its course, and leave the mill dry, for the rock was wearing rapidly.

It is a good salmon station, and a tempting spot for a sketcher to watch in summer.

At every moment some new arrival comes sailing down the rapid, pitches over the fall, and dives into a foaming green pool, where hundreds of other logs are revolving, and whirling about each other in creamy froth. The new comer first takes a header, and dives to some unknown depth ; but presently he shoots up in the midst of the pool, rolls over and over, and shakes himself till he finds his level ; and then he joins the dance.

There is first a slow sober glissade eastwards, across the stream, to a rock which bears the mark of many a hard blow ; there is a shuffle, a concussion, and a retreat, followed by a pirouette sunwise, and a sidelong sweep northwards, up stream towards the fall. Then comes a vehement whirling over and over ; or if the tree gets his head under the fall, there is a somersault, like a performance in the Halling dance. That is followed by a rush sideways and westward, where there is a long fit of setting to partners under the lee of a big rock. Then comes a simultaneous rush southwards, towards the rapid which leads to sea, and some logs escape and depart; but the rest appear to be seized by some freak, and away they all slide eastwards again across the stream to have another bout with the old battered pudding-stone rock below the saw-mill. And so for hours and days logs whirl one way—in this case against the sun—below the fall, and they dash against the rounded walls of the pool, leaving their mark.

Lower down, near the sea, is a long flat reach between high rounded cliffs ; and there these mountaineers, floating on to be sawn up, form themselves into a solemn funeral procession which extends for miles.

But the curve of this stream of floats is always greater

than the curve of the river's bed; for the water is slowly swinging from side to side as it flows, and the floats shew the course of the stream, and its whirling eddies. Many marks which remain in rocks in this great valley are clearly not marks of this wearing agency. They were neither made by trees nor by river ice.

A practised swimmer who knows what he is about, and leaps head foremost down a small cascade, is carried downwards with great rapidity, and is then shot upwards to the surface, a long way down stream, where he can swim safely to land.

It is pleasant thus to dash through water like a fish; to feel the eddies and the tickling air bubbles, and to hear the many sounds of the gurgling river. It is pleasant on a summer's day to dive through a cascade, and sit behind the water screen, and watch the flickering light amongst swarms of summer flies which there abide; but the swimmer who gets out of the run of the water may fare ill, for he drifts round like a log, and if he struggles with the power which is stronger than he; he may whirl till he sinks, or knocks his head against a stone and drowns.

But the diver learns to know the movements of water beneath the surface, and the surface forms which indicate them; and he can apply his knowledge elsewhere.

A geologist who wants to know how rivers work upon their beds may profit by the experience of boatmen, fishermen, lumberers, and swimmers; for he must learn the movements of fluids, before he can safely pronounce upon work done by them.

As fluids move in curves, marks which they make are curved also; and as water works very slowly, and follows every inequality, water-marks are fine and smooth, though irregular.

The finished work is like the polish which a carpenter gives to a surface with his hand, after he has formed it and smoothed it with rougher tools.

Projecting angles in the bed of a stream are polished and rounded, but they are not rubbed off.

Rock-pools, and all water-worn hollows retain irregularities. Sometimes deep round holes are drilled in hard rocks, below falls, and on the sea-shore; but these are not simply water-marks. They are marks which water makes by moving solids, and the tools used are often left in holes made with them. Rock-pits often contain round stones, sand, and water.

A river, then, is always working slowly downwards and up stream, changing a V into Y, by digging trenches, drilling holes, and undermining rocks over which it flows; and an ocean-stream works on the same principle.

But marks which flowing water engraves upon rock during a man's whole life are as nothing.

The Oxerá has not deepened its bed two feet since the history of Iceland began. The Thames has not changed its course since Magna Charta was signed, though the Thames works on gravel. What rivers and seas have done is not matter of observation but of inference for short-lived men.

Still water may be set to sculpture soft materials, and the touch and the work done may then be compared with similar work on any scale or material done anywhere during any period of time. Having found a power, it may be set to work.

The tank figured above shews how streams move vertically.

Let a sheet of glass be sloped in clear water, and drop ink, milk, or water charged with pipeclay upon the upper edge of the glass. The heavy fluid sinks, and rolls slowly down the

slope, through the clear still fluid. The upper edge of the stream curls and rolls back, and every movement is clearly seen. When a breeze passes a fixed chimney, or when a steamer moves through a calm, the same forms and eddies are seen in smoke. Wherever a moving fluid passes through fluid at rest, there are similar vertical eddies ; and though they are invisible they often leave their marks.

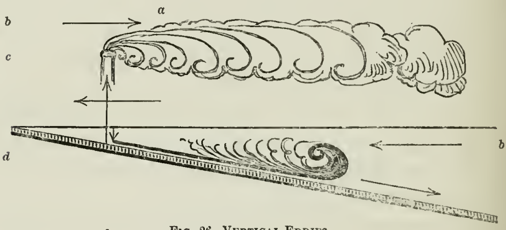

Fig. 26. Vertical Eddies.

a Weight. *b* Resistance. *c* Air. *d* Water. *e* Heat.

Horizontal eddies are seen behind every stick in a stream. The woodcut is from a sketch made in London. The square stands for a post, the lines and arrows shew the paths described by bubbles floating on the Thames. But the laws

Fig. 27. Horizontal Eddies in Water.

which controlled the movements of these tiny floats and streams would hold good though the post were an island, the

stream an ocean-current, and the floats ice-floes. Where such floats leave marks they are drawn on a similar plan.

There are vertical and horizontal eddies, whirlpools, and whirlwinds, in the atmosphere and in the ocean; and all streams and moving floats flow and move on the same principles.

Similar curves appear in a tea-cup when stirred with a spoon, in a mill-stream, and in the Thames; they are seen in a strait, from a hill-top, where a rapid tide is flowing amongst an archipelago of rocky islands; they are described by a stream of molten iron; their tracks are on ancient hills.

There are eddies in streams moving through fluid at rest, or past pebble, post, rock, island, point, or sunken continent; in air moving past a chimney, a volcano, an ice-peak; or rolling north and south from pole to pole.

But the movements of all streams may be learned by studying the run of water in rivers; and stream-marks may be learned from working models.

The following simple experiments will imitate river-marks:—

1. Mix fine pipeclay in water, and place a sheet of glass at the bottom of the vessel which contains the mixture. After a few minutes raise the glass slowly out of the water, and there remains a film of wet clay upon plane glass. Slope the glass to let water drain slowly off, and in half an hour the clay on the glass will be marked by flowing water as clay is marked by streams in the great valley which stretches seawards between Hecla and Eyafjalla, or similar alluvial plains elsewhere. Water clears channels on glass, and leaves clay islands; and the resulting forms are those which are seen from the high ground whence Gunnar looked upon his favourite glen, and where he sleeps in his cairn: they are the same.

Everywhere the plane glass is a plan of a plain through which a stream meanders.

2. Vary the experiment by pouring thicker mud into clear water, to represent a quiet lake or sea into which a river falls. The descending current is seen whirling clay-clouds into beautiful curves, as it pushes through the clear still water ; but when the movement has ceased, the glass at the bottom is covered with a thin even layer of clay. Raise and slope the glass at various angles, and river-forms of various curvatures re-appear.

3. Slope a square foot of glass, and pour fine mud over it, till the glass is covered with a pretty thick stratum of even consistency. Stick a lump of clay at one corner, and let clear water, and water coloured with brown ochre, drip slowly upon it.

Flowing water digs out channels and colours them ; and the resulting forms are those which mark the great boggy plains which surround the igneous rocks of Iceland ; and similar plains elsewhere.

The model is like a map. The work of centuries of slow action on one scale, is done in miniature in half an hour ; time and quantity differ, but mechanical forces, materials, movements, and resulting forms are the same.

4. Build a heap of clay on a garden walk, and pour water upon it ; or throw clay upon the roof of a house where rain may fall upon it—and the work of denudation will soon begin naturally upon miniature plains of mud, deposited in hollows on the ground, but washed from the roof. The larger the experiment the longer is the time ; but the tool-marks of all streams are alike.

5. Change the course of a rivulet—turn it loose in a clay field, or on a sea-beach—and watch its proceedings day by day ;

Experimental
Sheets. —
tried on the public
March 64.

CHAPTER I.

CINDER HEAPS.

A CERTAIN hardy English traveller, in excellent health and spirits, returning from Iceland, with the appetite of a hunter, and the condition of a race-horse; declared to his shipmates that the country was "not worth seeing." "It was nothing," he said, "but a big cinder heap, as interesting as the dust hills at Wolverhampton, and not a whit more fertile."

The traveller's description, though *not* complimentary, was pretty accurate.

Volcanic products are very like furnace refuse, and all Iceland is volcanic; but cinder heaps, great and small, are worth sifting, for they throw light upon each other, and on dark subjects. Slag, Lava, and Trap, were all melted stone, and they are equally products of heat.

Even in a cinder heap there is much to be learned.

One branch of geology may be studied at a foundry where stones are melted; but something is first wanted to bridge over the gulf which separates a rill of slag from a lava flood; and a visit to Iceland supplies the want.

One great steam-engine must be seen at work before the ways of steam can be learned from a kettle; but when it is understood that steam power is limited only by the size of the engine and the amount of heat applied as force, then models, drawings, descriptions, or even traces of work done by natural steam-engines, are comprehensible.

So it is on the large scale.

The tool marks of natural heat must be seen in a large volcanic country, before the action of tame heat working at home on a small scale can be identified with volcanic action.

Earth heat has done great work in Iceland. The country whose bare barren surface has recently been altered by two mechanical forces, which upheave and grind down the crust of the world, teaches principles on which geology is founded; and when the lesson is learned, the scholar sees that a smelting house, a rubbish heap, a frying-pan, and the kettle, all shew the action and the effect of the same forces working on a smaller scale.

Iceland is a "cinder heap," but it is a very large one; and the lesson which it teaches is well worth the cost. Hecla may only be one large valve in a great caloric engine; but it is not too large to be seen, and it is well worth looking at. The two forces which have been set to shape the outer surface of the crust of our globe, if not the globe itself, are now employed in busily finishing an island as large as Ireland. They have worked and are working within such narrow bounds, that their work can be seen as a whole; but on such a vast scale that the performance of still greater tasks by the same agents can be understood. These twin giants, Fire and Frost, Heat and Cold, are as busy near Hecla as at Wolverhampton or Coatbridge, and their work is alike at home and abroad.

They move steam, the atmosphere, and the ocean, and things moved by them; they melt and freeze gas, water and slag, lava and metal, and move things moved by them; they shape clouds in the air, plates of slag, mounds in lava, and great mountains on the earth; they have upheaved and depressed Iceland, Norway, and Scotland; they have altered the whole surface of the globe, and its upper crust, so far as it is

explored; and they may have done still greater things, if they were the servants employed to do the work.

So a traveller, surrounded by mountains of ice and cinders, may be driven by the work before him to think of the agents employed to do it, and of him who set them their tasks, who said "Let there be light, and there was light," in the dawn of time.

In furnaces and volcanoes, in models and steam engines, in cinder heaps and in Iceland, in art and nature, certain mechanical forces work, and movements and forms produced by them are alike on all scales.

The tool marks of fire and frost may be learned in their workshop, and they may be set to work at home.

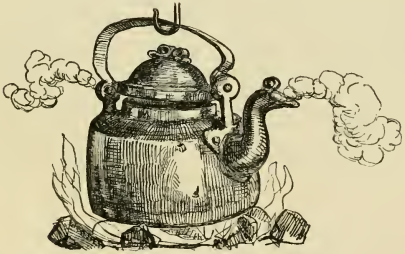

Fig. 1. Portrait of an old Friend and Preceptor.

CHAPTER II.

HOME GEOLOGY.

A HOME student of geology is forced to take a great deal upon trust, and has often to work sorely against the grain. He may understand the teaching of practised men, and believe what he is told ; but he cannot be familiar with the irresistible power of natural forces, whose power he has only seen displayed upon some pigmy scale.

A landsman who has only seen a puddle in a storm, has no clear notion of the Atlantic in a gale ; and so it is with a man who has never been far from home.

He may have been familiar all his life with the form of some great mountain covered with rich soil, grass, heather, trees, and yellow corn in summer ; sprinkled with snow, and glittering with icicles in winter. He is taught that the rounded form which he has known from his childhood, and which has never changed within the memory of man, is due to the wearing of floods of water, or of fields of ice.

But no home-bred Englishman has ever seen any power in action which seems strong enough for the work described as denudation.

The rivulets which trickle down the mountain could not have done work of the kind if they had worked as they do now for countless ages. They do not make rounded shoulders; they cut deep furrows on smooth hill-sides.

Burns meet in quiet lakes which mirror swelling hills on either side of some great glen, along which a river

winds to the sea; but the shape of the glen bears no resemblance to that of the small transverse furrows which rivulets make, or to the winding river bed at the bottom of the glen.

If scooped out, it is clear that the main glen was made with some coarser tool; and that the hill was rounded by something different from streams of rain water.

The great glen which crosses Scotland at the Caledonian Canal never could be hollowed by streams like those which have furrowed the long, smooth, steep hill-sides which make its southern boundary.

Ben Wyvis, and hills like it, were not rounded by streams like those which flow from their sides, and furrow them.

A little scratch on a rounded smooth rock which peeps through heather on the steep side of a burn, is shewn triumphantly to prove how an enormous glacier, now replaced by a little winter icicle, once filled up the glen, overspread a whole tract of country, and ground its way slowly downwards, bearing earth and stones on its surface, as leaves and sticks float down a river to the sea. Green hillocks, from which loose stones are now dug to gravel the roads, are pointed out at the mouth of the glen to mark the spot where a local glacier once ended; and the student is told that ice carried stones overland from the mountains, and left them in heaps when it melted, like piles of floating rubbish stranded by some winter spate.

It is said that ice and cold water ground down the hills and scooped out the glens, and left water-worn moraines behind them, because there is an ice-mark on the rock.

A man may believe it all vaguely, but he cannot realize it if there is nothing like a glacier within his experience.

The face of a peasant who is told for the first time that ice rounded the hill-tops where his sheep feed, is a study.

But glaciers and cold rain-water alone will not account

for many great glens, because of their peculiar forms; and there are ice-marks which no mere land-glacier could make.

It may be that a man has lived all his life beside some great stone fixed in a rich plain, buried in an old wood, or perched upon a hill-top. He may have seen it gray with lichen, or green and brown with moss and fern, or sparkling in the sun like a great jewel when powdered with hoar-frost.

It has been an "earth-fast stone" ever since he can remember; it looks as if it never could be moved from its place; perhaps tradition tells that some ancient giant hurled it at his foes. The teacher declares that it is a "wandering block" which first broke off and rolled down from a mountain hundreds of miles beyond the limit of vision, in some far distant country; and then sailed over the ocean on an ice-raft, and finally sank to the bottom, where it lies.

The tradition seems far more probable. It is just as likely that another stone of the same kind should now come sailing on a cloud, and plump down amongst the hens in the barnyard, for there is no sea near the stone, and the nearest sea has no ice-rafts.

It is vain to point at an ice-groove on the tip-top of a high hill, and then assure a canny Scotchman that like marks are to be found upon many similar isolated hill-tops, in the British isles and elsewhere; that all these high grooves seem to bear some relation to each other, and that they were all made by ice-floats while sailing over the hills, and dropping cargoes of clay and stones in the sea, to make land for farmers to plough on shore. It is contrary to the evidence of the senses. The sea is far away, hills are high and steadfast; and many ice-grooves are but faintly marked now.

It is vain to point at illegible characters on the stone or on geological maps, and try to explain how it must all have

happened long ago. It is not easy to expel old ideas and take in a new stock ; and so the usual first-fruits of an explanation of a fire-mark or a frost-mark is a look of incredulity or contempt.

A geological student is taught that mountain-chains were ocean beds, that continents were groups of islands, that islands are sunken mountains, that hills pop up their heads, and dive down again like seals ; that if some glens are grooves, some are rifts in the earth's broken crust ; that the land has waves, and that the sea is comparatively at rest ; but he never sees any of these changes happen.

He is assured that the cold, solid, gray rock, from which an old moss-grown tower has watched for centuries over generations of actors in the world's history was once white hot, and rose up through the sands of the sea ; that a quarry was a sand bank, and a stone in it a drifted log. But no rocks, hot or cold, ever rise now in neighbouring seas, nor do sand banks and forests turn to stone and coal.

He knows that it is the nature and habit of all the rocks and stones that he has ever seen, to fall as fast and as far as they can, and then lie still. He is taught that rocks and stones move about, float in water, and fly through the air, and have done so time out of mind.

By vigorous submission to authority, or by hard thinking, a man may bring himself to believe that these are truths, not waking dreams of book-learned men, or travellers' tales ; but it is no light labour for simple men who have never seen fire and frost at heavy work, to take it all in.

A certain venerable professor of natural history was in the habit of taking a walk round Arthur's Seat once a year with his class at his heels ; and it was his custom to pause beneath certain basaltic columns, and gather his flock about him to

pick up crumbs of knowledge, and hear the yearly open-air Edinburgh lecture on geology.

In these days—some twenty years ago—there was no "Queen's Drive," but there was some fine green turf near the rocks, and on one of these occasions a bevy of Edinburgh wives and lasses had chosen the spot for a bleaching green.

"What the diel's a' thae folk doin' there?" said one cummer.

"Oh, it's a daft chiel gien them a lectur aboot Samson's ribs," said another.

And then they laughed a mocking chorus, and fell to work again at their wet napery.

Not all the professors in Edinburgh, not even Sir Roderick himself, could have persuaded the washerwomen that Samson's ribs had been pumped up hot out of the earth, or had ever been anything but solid rocks since the world was first created.

This hard crust of experience must be quarried through before knowledge can reach the understanding of home-bred men, for daily experience seems to contradict what they are taught.

But daily experience really agrees with geological teaching, for the mechanical action of natural force is always the same, though it varies in degree; and this is felt and understood when cold has been seen battling in earnest with heat.

A man begins to feel that cold is a mighty engine when he has seen a glacier, and heard it. When he has seen it move with acres of stones and gravel on its surface, and launch cargoes upon ice-rafts, to sail wherever the wind may blow them. He has learned a new alphabet when he has seen polished rocks under and near moving ice, and grooves and scratches freshly gouged out by stones in the ice. He

gains a new view of an old ridge of gravel, when he sees a conical mound of loose rubbish newly shot from a groove in blue ice, by a snow rivulet, and the end of a glacier fringed by ramparts of such mounds. Thenceforth he knows a "terminal moraine." He begins to understand how a clay field may have come from some neighbouring glen or distant country, when he has seen a thick, white, muddy river, smelling of sulphur, bursting out of an ice cave, tearing through heaps of debris, and busily engaged in spoiling a delta of its own building to make another lower down, or to freight an iceberg.

When he has seen all these movements and changes, these tools and their marks—and they are all to be seen in Iceland, Norway, and Switzerland—it is easy to believe that similar work was similarly done by the agency of cold and weight elsewhere.

Then the action of large masses of ice, and great floods of water, which hew out rock forms, and carry and arrange banks, mounds, and plains of drift, clay, and boulders, is recognised in the sliding of a plate of ice upon the bank of a rivulet, or in the miniature work of a mill stream on a frosty day. Having learned the alphabet and the living language, he can decipher the rock inscriptions of old ice.

So, when a man has seen one smoking volcano, with its lava floods and cinder heaps still warm beneath snow and ice, and the curl that once played upon a river of melted stone as sharp and clear upon a rock as the curl upon the glacier river beside it, his ideas about steadfast and eternal hills are changed. When he has seen stones, sand, and ashes, that once rose up, repelled by heat, and flew through the air in defiance of gravitation, now strewed on the ground where they fell, because the laws of attraction were the strongest in the end, he gains another new experience, and recognises a

force opposed to gravitation, which meets him at every turn.

When he has seen the workshop of heat and cold, he learns to know the tool marks of the two giant slaves wherever he finds their work, and he finds it everywhere when the lesson has been well learned.

The heat of a volcano is but the same force which works a furnace and a steam-engine ; the same forms result from its action, and he sees them in familiar hills, in cinder heaps, and everywhere. When the natural heat of the earth has been seen to hurl clods and stones, drops and jets of water, steam and smoke, far away from the earth's surface, to move freely for a time in obedience to laws which govern the movements of planets and earthly projectiles, it ceases to be an effort to realize the fact that heat, cold, and gravitation, are forces which together move projectiles in well-defined paths within the bounds of our world, and it may be beyond them.

A man becomes familiar with these, his fellow-servants, when he has eaten food cooked by nature's fire, and has slept on a turf bed warmed by mother earth. As he lights his morning pipe through a lens, with fire direct from the sun, beside a pool of water boiled by fire in the earth, and watches distant ice mountains through condensing steam, and thinks whence all the water came, how it was moved, and by what forces, a traveller must realize that these useful giants who can turn their hands to so many things, great and small, do not confine their labours wholly to this world.

He sees that heat boils a kettle, a steam boiler, a geyser, and a volcano ; lifts water at the equator to drop it at the poles ; and will hand a cigar light from his quarters in the sun, to a friend on earth who knows his ways.

He knows that cold cools the tea, and stops the engine, seals up the hot spring and the volcano, shakes down snow to

grind the mountain which the other raised. Cold arrests the motion which heat started: he knows that cold puts a man's pipe out when the time is come.

An Englishman seldom thinks of heat and cold as natural mechanical forces, though he sees their work everywhere.

An Icelander who lives within sight of Hecla may have seen the top of a mountain larger than Ben Nevis, red hot; with a stream of melted stone, as broad as the Thames at London, flowing down its sides.

The stream is there now, though frozen, hard, cold, and dark. Every year he sees water fall, flow, and freeze, and hang on the slope as lava does. There is snow upon lava now, and ice in caves beneath it.

He sees steam and boiling water burst up and spout from the earth, and condense, and fall, and flow into still lakes, freeze hard, and split; and he can understand that the great shattered plain of stone on which he lives was liquid, and rose, flowed, froze, and split, like the water.

He knows that lava boils over, froths and freezes outside Hecla; so he can understand how bigger streams boiled up elsewhere, before his ancestors came to the land.

A traveller who has gained a part of this Icelandic experience can apply it at home, and recognise past glacial and igneous action in forms which remain to tell their origin to those who can understand their meaning.

So a trip to Iceland is worth its cost.

The rugged features of nature are hidden or veiled in fertile lands; in the cold barren north they are clearly seen, and stern though they be, they are well worth contemplation.

The desolate country is one of the grandest in the world, though the prevailing feature in its landscapes may be dust and ashes.

Atmospheric circulation, water falling and flowing, fluid and solid; sliding glaciers, freezing seas, ice rafts floating, rocks wearing, sediment falling to form new beds, "denudation," and "deposition:"—downward movements from the action of cold and weight:—

Rising land, hot springs, intruded rocks, lava, boiling, rising, flowing, and freezing; volcanic projectiles rising, freezing, and falling in air; upheaval of land, upward movements in gas, fluid and solid, caused by heat:—

Demolition and reconstruction by natural forces,—are not all within daily experience at home.

Therefore, teaching and experience may seem to differ, but they really agree; for natural agents work everywhere in the same way, and the form of their work is alike at home and abroad, on the smallest and on the largest visible scale. The same powers work in a kettle, and in the Great Geyser; both boil, and sometimes they boil over.

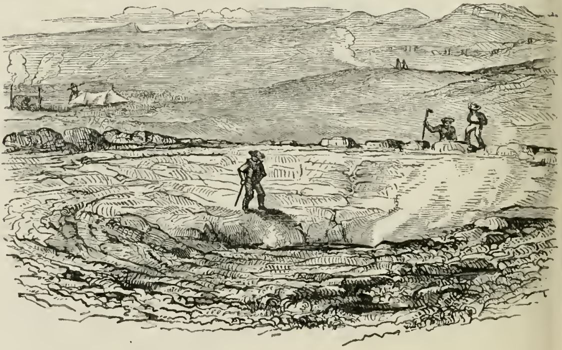

Fig. 2. Boiling up.

Tube and Basin of the Great Geyser, after an Eruption, 1862.

CHAPTER III.

GEOLOGY.

GEOLOGY teaches generally that great changes have taken place on the surface of the earth, and it seems to point back to some distant time when a crust first cooled about a molten interior.

But there is nothing like a molten surface within common experience. The world with which we are familiar is green and smiling, and the old rugged crust is buried far out of sight, or worn away. It takes skilled eyes to read the lessons of our rocks. In Iceland nearly the whole surface has been fused; it is warm still in many places, and most of the rocks are bare, so he who rides reads.

The modern geologist generally works slowly but surely downwards through the outer crust of sedimentary rocks which have settled layer upon layer above each other, and about the cooled surface of the first crust, whose formation is assumed in the meantime. From sedimentary beds he digs out the shapes of creatures and plants that once lived, and he marks off the layers in which they are found, and knows their order, and their fragments, by these forms of buried plants, shells, and skeletons.

The thickness of this outer shell is measured along its broken upturned edges, and it is calculated how long it may have cost air, water, and ice—the gaseous fluid and solid matters which now move about upon the earth's surface—to grind down mountains at a given rate, and so produce, transport, and arrange enough of mud, sand, gravel, and boulders to make up sedimentary beds whose thickness is known.

The time is estimated during which the formation of these rocks lasted; while plants grew, withered, died, fell, and accumulated, and became peat beds and coal fields; and while races of creatures lived, died, and were buried and turned to stone.

Each step so gained seems to rest upon a pile of facts as hard as the fossils themselves, each link in the chain is firmly joined to its fellow, and geology has become a science. But the rate of action may have varied in former times. The whole chain of reasoning in this direction, proves at least the endurance and activity of one mechanical force, which still acts towards the earth's centre.

The formation of sedimentary rocks under water, and the transport of their materials from a higher to a lower level, are facts which prove that the force which causes an apple to fall has acted in the same direction ever since it first moved silt: whatever the rate of action may have been.

There is not much to be learned in this branch of geology in Iceland. There are few sedimentary rocks, and very few fossils; but of the present activity of the weight-force which must have acted upon the original crust of the earth, there are striking examples.

Falling water has not yet smoothed the shattered, wrinkled surface of the lava; the sediment which it washes off and carries has not yet buried the rough outer crust; but water and ice are busily grinding igneous rocks to make others, and they have ground and buried many surfaces which were bare and wrinkled at first.

There are few sedimentary rocks yet formed, but they are forming everywhere upon igneous rocks, so there is much to be learned about the past, from that which now takes place in Iceland.

But gravitation is only one of the mechanical forces which

act at the earth's surface, and denudation and deposition are but one-half of geology.

At every step there is evidence of a force opposed to gravitation, which has counteracted the downward movement of sediment.

The rain which washed down materials enough to make known beds of rock, would have washed all the land into the sea long ago, and ocean currents would have levelled the bottom, had not land been raised above water by a force sufficient to balance weight.

No apple could ever have fallen from a tree unless the tree had first grown ; water could not fall from clouds unless it were first raised from the earth ; and stones could not fall from mountains unless mountains were raised above the plain. There could be no new sedimentary rocks unless mountains were raised up as fast as they are ground down. If there has been denudation, there has also been upheaval of the surface.

A second mechanical force is recognized in all modern geology ; it has helped to model the outer crust of the earth, and it is still very active in Iceland.

Heat helps to raise trees upon which apples grow, and the ground on which they fall ; it acts upwards ; weight acts downwards, and the action of the earth's heat is seen in hot springs, in volcanic eruptions, and in their work all over Iceland.

Heat drives matter away from the centre, gravitation drags it back.

Heat expands that which contracts when cold. Hot particles repel, cold ones attract, each other.

So heat raised up hills from which sediment falls ; it shatters the earth's crust, and heaves up the broken fragments, and thrusts up molten matter through openings so made ; it raised up islands, and continents, and sea bottoms,

and is raising them slowly still; it hurls projectiles away from the earth's surface, and it has probably worked in the same direction from the beginning.

And this mighty force is manifest within a week's sail of the English coast; where its activity is often forgotten till some earthquake startles a sleeping town.

It seems impossible to visit Iceland and deny the importance of internal heat as a geological agent, or to revisit old haunts without recognizing traces of extinct volcanic action everywhere.

To ride over lava and gaze into craters is to gain fresh knowledge, and learn new tool marks. It is like visiting some asteroid still warm from nature's laboratory, or to read an early chapter in this world's history.

If any stones be preachers, surely these are eloquent.

Modern geology, then, treats of sedimentary and of igneous rocks; it recognizes the activity of two mechanical forces, which act in opposite directions, upward and downward, from and towards a centre, in radiating and converging lines; and Iceland is peculiarly fitted for studying the effects of both.

FIG. 3. NATURE AND ART.
Northern Iceland.—Badstua, near the Uxahver, 1861.

CHAPTER IV.

FORM.

VISIBLE objects of all kinds are known by their forms, by their outlines, and by their internal structure, as well as by colour, weight, and chemical composition: and form has this advantage—it can be used as a test where others cannot be applied.

Fossils, for example, are known to have been plants, shells, or bones, only because of their outward forms and internal structure.

Organized forms indicate previous orderly movements, and forces which produced them; and the former activity of vital and mechanical forces which now arrange the component parts of living plants and animals is proved by form; when colour, weight, and chemical composition differ from those of any living thing.

A knowledge of form is very important to the student of extinct life.

So it is to students of other branches of geology.

The rounded shape of a pebble tells that a stone was rolled till its angles were ground away, wherever it may now rest. It is the same whether it is found in a stream, on a beach, in a dry bed of loose gravel, or in a hard rock; in a deep mine, on a hill top, or buried in lava and ashes. The form of a water-worn pebble of any material cannot well be mistaken when the tool-mark is learned.

An ice-ground stone differs from one that is simply water worn.

There are many degrees of wearing, and many varieties of gravel and rolled stones ; and a skilled eye can distinguish them.

The outlines tell part of the story ; internal structure tells more of it.

A bit of water-worn bottle-glass, for instance, shews by its structure that it is glass, which was artificially fused before it was broken and rolled ; and its fracture, and the shape of chambers in it, shew the direction in which heat, cold, and human skill worked on tough glass while cooling and passing from fluidity to hardness—from heat to coldness.

The glass may be a pebble in a sea-beach, so far as outward form and position are concerned ; but internal structure tells of the agency of man, and the action of heat and cold.

A jasper pebble, a bit of rolled obsidian or agate, or calcedony, all of which break like glass, tell their history too. Because of its outward form the stone has been rolled in water, or ice-ground ; because of its internal structure it has been heated to fusion, or perhaps to sublimation.

A broken bottle proves the former existence of men.

A scratched jasper pebble picked up in a field near the Clyde, means previous aqueous and glacial action where there is now dry land ; and volcanic action at the place whence the jasper was moved, before it became a pebble.

If a square block of jasper is found on some neighbouring hill, it points to a possible place from which the pebble may have started ; and if a vein of jasper is there found *in situ* it points out the site of an eruption, though there may be no other record of it.

So a fragment of rolled brick, a slate pebble, a limestone

boulder, and a bit of water-worn chalk, all have something to tell about forces which moved their particles.

Brick, though rolled, is easily known to be manufactured brick, and it tells of a bed of clay somewhere on shore, of the labour of men, and of the action of a certain temperature artificially applied to bake, without fusing, clay and sand. It may be part of a delta now, but a brick is human work.

Slate, sandstone, and limestone, though rolled pebbles, tell of the fracture and wearing of old beds of stone, of old denudation, and of deposition of silt to form new beds; of some action which changed silt to stone, and of the breaking and wearing of these new beds. A pebble of metamorphic clay-slate or marble may tell of a heat sufficient to bake without fusing clay and lime; and the materials tell of still older changes which formed and packed the minute fragments of which the rocks consisted before they were baked hard.

The minutest visible grain of sand has a well-marked form of its own, which tells a separate story.

But because these inorganic forms are as well marked as those of plants, shells, and bones, they prove the past action of mechanical forces as clearly as fossil shells do the action of vital force.

The form of sand tells of motion in gas or fluid as clearly as a fish-bone records swimming in water; and if sand and a fish-bone are found together in the same place, they tell of mechanical and vital forces acting much as they now do, and in water, cold enough for fish to live in.

These separate inorganic forms, then, give much information. But other forms tell their story with equal clearness.

A dry river delta tells as clearly of flowing water and moving silt, as a shell does of the life and death of a living creature. It is a water-mark.

The minute delta which forms in a gutter during a shower, is the result of flowing water ; so is the delta of the Nile, or the moving delta which is creeping seawards, out of valleys about Hecla ; or a fossil delta of any size, anywhere.

They differ, but their general form is the same ; and though all big rivers were dried up, their former existence might be known from their work, if but one flowing rill survived to explain the way in which silt is packed at a river mouth.

Size is of no importance when movements and forces, from which natural forms result, are known. The forces can be inferred, if only the forms can be recognised.

Distance does not affect the test by outward form.

A tree is known though it grows on some inaccessible cliff, and the vital vegetable force is inferred from the shape of the tree.

A river delta is recognised from a hill top, though it may be far away.

If there were a large delta or river-bed upon the moon's surface, it could be recognized there as easily as upon the earth, for it has a conspicuous shape. It is a tool-mark. No Δ is to be seen in the moon ; no forks and meanderings ; no V, no Y, no S. There are no clouds there from which rain can fall. There can neither be river nor tree, like earthly trees and rivers, on the moon's surface, because familiar water and air forms are absent.

But fixed, solid forms are there. It is known how similar forms are produced in this world. So it is fair to conclude that these lunar shapes, these O craters, also resulted from a combined action of heat, cold, and weight, which did their work, and have now ceased to work on that surface, though still active here.

Visible forms then, whether accessible or not, mean

previous movements, forces which caused them, and a temperature sufficient to make the movements possible in the material moved; and similar natural forms, wherever they may be, probably indicate similar action and agents, movements and forces.

A delta is a water-mark; a round crater a fire-mark; and every force which acts on a surface makes a tool-mark which may be learned.

Each mark is like a letter. It has a form and a meaning, but only for those who learn to read.

To learn the character, the language, and the meaning of inscriptions sculptured on the world by fire and frost is worth some trouble. The geological alphabet—the first lesson to be learned is—Form.

FIG. 4. AN EASTERN SYMBOL.

CHAPTER V.

ATMOSPHERIC FORMS.

If ever there was a time when the solid surface of our world was a newly-formed hot crust of stone, there must have been an atmosphere about it, whatever its composition may have been ; for our gases and fluids, air and water, only expand by heat.

Movements in any gaseous shell must have resembled those which now take place in the air from the action of heat, cold, and gravitation, whatever the surface-temperature may have been ; and these atmospheric movements surely left marks upon the solid crust from the beginning, because they do now.

We have but to look above us to read some of the ancient characters, which are and have been written in air, and to learn their meaning. They are forms which reveal forces. On a calm clear summer evening, after a thunder shower, when the setting sun is near the horizon, and the wind is still, great masses of vapour often pile themselves up into fantastic shapes which can only be seen in profile from a distance. They are easily drawn, and easily photographed. Those to the eastward shine like snow in the evening sunlight, and their shapes are clearly defined by light and shadow. Those to the west are dark, or edged with brilliant light, and their outlines cut sharply against the western sky.

Such clouds float steadily in the air ; they are unaltered by

wind; but when they are closely watched, they are seen to change their forms at every instant.

There are magazines of force within them and without, and changing forms point out the directions in which these forces act.

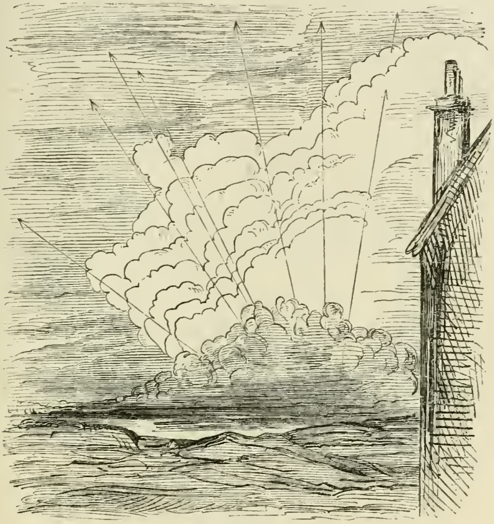

FIG. 5. DIAGRAM TO SHEW THE GROWTH OF A CLOUD.

The outlines were traced with a pencil on the ground glass of a camera obscura, at short intervals, on a still, bright, hot evening.

Whoever has been enveloped in a mountain mist or a city fog, knows that a cloud is commonly made up of minute floating spheres of water, and these are moved about by currents of air, which are moved by some force.

These liquid spheres form at one place and disperse at another, according to the temperature and humidity of the air about them; but while they exist as drops in clouds they collect and scatter, and move according to movements of the air in which they float. Clouds are but fleeting characters written in air; but while they endure, they tell their story by their form and by their movements. In order to see these cloud-forms, and note changes which take place in them, they must be far off, for clouds are of enormous bulk.

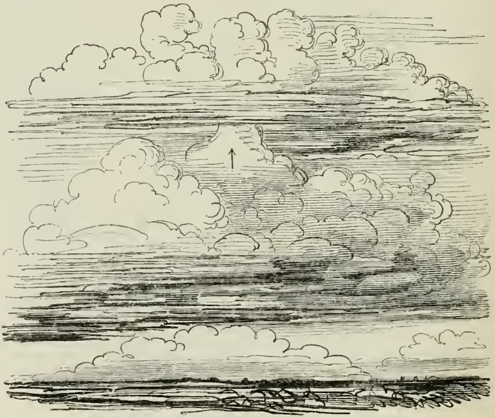

FIG. 6. "CUMULI." SKETCHED FROM A RAILWAY TRAIN.

"Cumulus" clouds which form above London are higher than the Alps, and, like Alps, they must be seen from a distance before the eye can take them in. But when they are seen, under favourable circumstances, their movements tell of upward and downward currents in air—of expansion

and contraction in particular regions—of currents which are analogous to those which move up and down, and sideways, in boiling water.

The lower edge of a distant cloud is often nearly a straight line; it is, in fact, the outline of the under side of part of a dome of vapour, forming at a certain distance above the earth's convex surface. The upper side is a heap of great rolling mounds which are constantly moving, swelling, and shrinking; rising and falling.

As warm currents of air rise through the vapour, rolling clouds expand upwards, and change from rounded domes to conical piles, and they flow over, and spread out upon the higher layer of atmosphere through which they have been

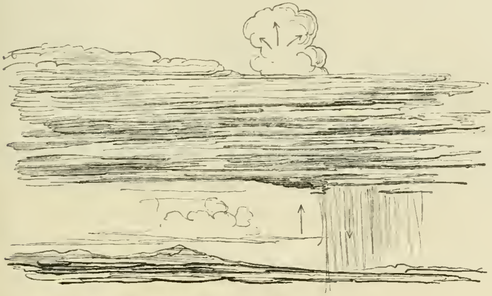

FIG. 7. RISING AND FALLING.

thrust, taking the shapes of mountains. So long as the sun warms the cloud, or the earth beneath it, the upward expanding motion continues. But when the sun disappears below the horizon, the action grows less, and the movement is reversed.

The great boiling mass ceases to boil; and settles down into layers of even thickness. The "Cumulus" becomes a "Stratus,"

or perhaps a cold wet current of air joins company with the cloud; drops grow larger and heavier, and the whole fabric tumbles down as a heavy shower. Then the "Cumulus" is a "Nimbus," and the source of a flowing stream.

It is the same whether the growth and decay of such clouds be watched from below or from above.

At sea there are no mountains to interfere with winds which blow along the surface of the water; so clouds, if they change their form, alter because of forces within them.

Thus, off the Orkney Islands, with a strong north-westerly breeze below, a distant mass of cloud on the southern horizon was seen to move so as to indicate upward and downward currents moving within the system of air which moved eastwards along the sea. The clouds also shewed higher currents moving in various directions. Steep conical peaks rose up out of flat clouds, which moved with the wind towards the south-east; more and more followed, rising till there were rounded domes; and these in their turn spread out and flowed over, and broke up into detached masses, which drifted away before upper currents. But the cloud spread to windward as well as to leeward, eastward and westward from its own centre of movement. It contained a radiating force.

When the upper sides of clouds are seen from a high mountain, the same forms appear.

From the top of the Rhigi, before sunrise, the Swiss lakes may often be traced among the mountains. Each is covered with a canopy of gray cloud, beyond which there stretches a frozen sea of mountain peaks cutting clearly against the rosy sky. Distant detached hills to the northward stand up like blue islands in lakes of gray mist, resting becalmed upon wide plains. But when the sun rises motion begins. The stratum of flat mist rises up, and heaves, and the gray plain

becomes a troubled moving sea of rounded hills of vapour, all bright and shaded, and glittering in the morning light. As the day wears on these rounded masses separate, break up, and creep along the glens and hill-sides, rising as they go, and by noon piles of rounded white cumulus clouds are peering over the tops of the highest mountains, or covering them. Later in the day a traveller in a valley may find himself drenched by heavy rain, while one upon a higher level, or in the plain, is rejoicing in bright sunshine. But if a wet pedestrian ascends an outlying mountain like the Faulhorn, he may pass through the falling shower into the cloud of little floating drops, and so through gray mist into bright sunshine and clear air. He may see the mist creeping up the glens, because the sun is warming the hills, and rain is condensing about the cold snow.

This engine is worked by fire and frost.

Shortly before sunset, on such a day, the lookout from such a spot is very beautiful. The great snowy Alps glitter in the bright light and clear frosty air, and seem to be close at hand, till some distant thundering noise calls attention to a few rolling grains of white dust. Then the real distance is measured by the help of the grand sound of a falling avalanche, and the giants assume their true proportions.

The sea of cloud which surges against the mountain a few hundred feet below the peak, changes its shape at every moment, as currents of air rise from glens below. The atmosphere is all in motion, though there may be no general horizontal movement at a particular spot and time.

But, when the sun sets, this local motion gradually decreases, and cold moon-beams may play upon a quiet stagnant silvery ocean of gray cloud resting becalmed upon hill and plain, or creeping slowly upon still water.

We live in a sea of boiling air, and when its local movements are made visible by clouds; heat, cold, and gravitation—radiating and converging forces—are seen at work in the atmosphere.

Force is revealed by form.

On these forces and on these movements depend all atmospheric changes and the science of meteorology, which treats of them.

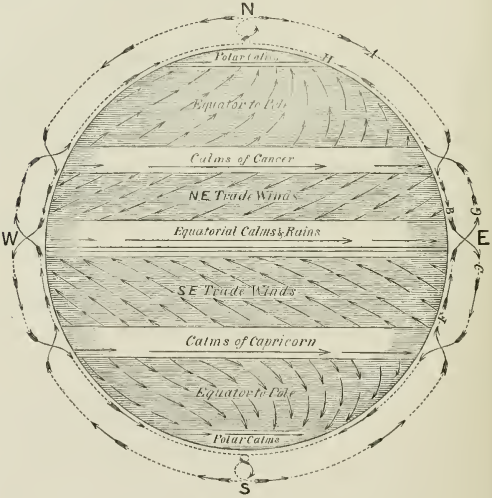

Fig. 8. Diagram of the Winds, by Lieut. Maury, U.S.N.

"Abstracts of Meteorological Observations, etc.," edited by Lieut.-Col. James. London: Eyre and Spottiswoode, 1855.

CHAPTER VI.

METEOROLOGY.

THE modern science of meteorology is founded upon upward and downward movements in the whole atmosphere.

All storms have been traced to the movements of two great currents in each hemisphere, which move like local currents, and for the same reason. These are north-east or north polar, south-west or equatorial, in the northern hemisphere; south-east or south polar, north-west or equatorial, in the southern hemisphere.

These great currents are attributed to upward and downward movements :—to the rising of light warm air near the equator, and to the falling of heavier colder air at the poles. Atmospheric movements then, whether large or small, general or local, are attributed to the action of heat, cold, and weight. But these simple movements are modified by the earth's rotation and by change of weight.

A cold heavy current of air, moving southwards from the north pole towards the equator, moves also towards the west along the earth's surface. It appears as a north-easterly wind, and it gathers heat and loses weight as it moves.

The equator is a larger circle than any other which is described by a point on the earth's surface about the earth's axis, and its parts move through a larger space in a given time.

A mass of air moving southward from a small revolving circle near the north pole, and also moving eastward together

with that part of the earth from which it sets out, lags behind a point upon a larger circle which is nearer to the equator, and is revolving eastward with greater speed.

So a north wind becomes a north-easter. A point on the edge of a disc, ten miles from the north pole, travels round the axis, a distance of about sixty miles, in twenty-four hours : it moves about as fast as a man walks : but a point on the disc, whose edge is the equator, moves eastwards more than a thousand miles in an hour.

So a north wind moving southward over Scotland, and eastward at the rate of Iceland, is passed by a Scotch tree as a man walking eastward is passed by an express train. A polar wind is a north-easter in the northern hemisphere, and a south-easter south of the equator, because air lags behind earth and sea when moving from smaller to larger circles. But the polar wind does not blow furiously, because air is dragged round and gains easterly motion as it gathers heat and loses weight on its way to the equator.

For a like reason, an equatorial calm, which sets off along a meridian, and blows from large to small circles, becomes a westerly wind. It plays the part of the railway train, and overtakes the crawling tree which grows on the British Isles. It bends trees, but does not always tear them up by the roots, because it is held back by friction.

The warm light equatorial south wind blows because air expands, and loses weight, and rises ; it becomes a south-west wind because the earth turns eastwards.

The prevailing direction of the wind in the British Isles is about south-west, and trees proclaim the fact by form.

In Wistman's Wood, near Dartmoor Prison, at an elevation of about 1200 feet above the sea, a curious stunted scrub of gnarled oak, said to be "as old as the creation,"

shews that the prevailing wind has been south-west since the oaks were acorns.

The strange old trees stretch out their twisted, tangled, moss-grown, fern-clad arms towards the north-east, and bend their hoary trunks in the same direction, as if seeking shelter. But on the hill above them, a great boulder, as big as a house, proves that some force stronger than the wind has acted in the contrary direction, *towards* the south-west. The stone has been pushed from its place, and rests on the hill side.

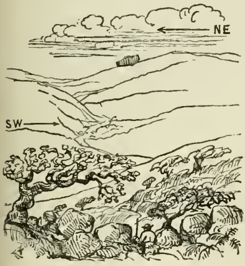

FIG. 9. OLD TREES AND BOULDERS.
Wistman's Wood, Dartmoor.

Wherever a tree grows on the western coast of Ireland it bows its head to the north-east.

Every exposed Welsh tree bends towards the dawn.

Every exposed tree on the west coast of Scotland seems to be driven by a furious wind on the calmest day. About Edinburgh it is the same. On the east coast, on North Berwick Law, an old thorn tree streams towards the north-east, and every tree in that neighbourhood that dares to peep over a wall, straightway assumes the form of an old broom, and points eastward.

At Dalwhinny there is something almost ludicrous in the stormy look of a whole wood of fir trees which point their fingers down Strathspey, and bend their trunks as if yielding to a furious gale.

In Scotch islands, at least as far north as Orkney, it is still the same. Trees are vanes, and no other wind-gauge is wanted to shew that the atmosphere has a habit of rushing

past the British Isles from west to east on its way north. If the true bearings of exposed trees were taken and mapped, a wind chart might be added to the physical atlas.

But though there are prevailing winds, and a general atmospheric system of movement ; the easterly and westerly, heavy and light, cold and warm, polar and equatorial streams, which cross meridians in travelling north and south, one above the other ; get entangled and whirl round as rotatory storms. On one side of the equator the storms revolve one way, on the other they whirl in the opposite direction, as whirlpools do when a stream flows into still water ; or when streams cross or meet ; under bridges and behind posts.

The meteorological department of the Board of Trade have a hard task, though an able leader, when they try to forecast winds. But for all that, the strongest wind that presses on British trees goes towards the north-east.

At places where winds meet and mingle, currents flowing in opposite directions neutralize and roll over, and whirl about each other ; and so whirlwinds, circular storms, calms, and partial winds of every strength and direction, occur ; though light and heavy currents keep their places, and surface winds are almost constant in some latitudes.

When opposite currents are flowing, clouds betray them by form, and they are commonly seen.

When a strong south-wester is driving in a flock of detached clouds from the sea, the clouds transform themselves as they fly.

The wind drags along the surface.

The under side of the cloud drags also and stretches backwards, but the upper side is pushed forwards and rolls over like a curling wave. There may be a strong breeze below, but a gale higher up ; and higher still clouds may be spread

out on calm ripple-marked plains, where currents are passing each other, and rolling up the clouds between them into mackerel sky.

Fig. 10.

All these forms do but indicate movements which result from the action of two forces; one radiating from a centre, the other converging towards it, and the science of meteorology is founded upon these two forces and on their action, above the earth's surface, in the air.

Air is constantly moving up, and down, and sideways, above water and solid ground. Meteorology attempts to explain the movements, and the moving forces are heat and weight.

The main facts were known to men when the first chapter of Ecclesiastes was written, as Maury points out in his writings.

"5. The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.

"6. The wind goeth toward the south, and turneth about unto the north: it whirleth about continually; and the wind returneth again according to his circuits.

"7. All the rivers run into the sea; yet the sea is not full:

unto the place from whence the rivers come, thither they return again."

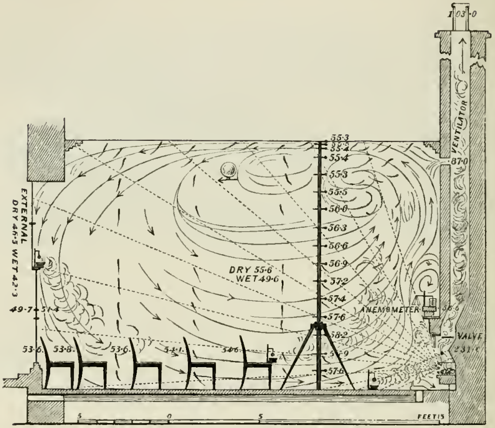

FIG. 11. DIAGRAM OF DRAUGHTS IN A ROOM.

Section of a large room, shewing the positions and mean amount of deflection of silk vanes; temperature shewn by thermometers; force of upward current at the mantlepiece in grains per square foot; moving fumes; balloon; radiation from fire; and the direction in which air circulated under these conditions.

From the "Report on Warming and Ventilation of Dwellings," 320, Sess. 2, 1857.

CHAPTER VII.

AIR.

A CAUSE is found by working up stream—by creeping along any one spoke of a wheel towards the centre. The effects of a known cause are got at by working the other way. Starting from cloud forms, heat is reached. If heat be a mechanical power which moves the atmosphere, forms like clouds should be found at the outer end of shorter spokes in the same wheel.

If a principle be established, many phenomena can be traced to it. In meteorology, as in all sciences, a result is reached by observation of facts, but experiment is the final test of theory, however formed.

A power may be used when found.

If great and small atmospheric currents flow, for the reasons given, and heat and gravitation are radiating and converging forces by which air is moved, then any quantity of air, great or small, ought to be moved in the same way and by the same forces. And so it is wherever the experiment is tried.

Air in a conservatory may be taken to represent an atmosphere. The ground is warm, the roof is cold, and the general mass of air cannot escape beyond certain limits.

If one part of the floor is hotter than the rest, cold currents converge, and fall and flow towards that spot, absorb heat there, and rise like warm fountains to the roof. Thence warm

currents radiate in all directions, and flow towards the cold sides of the building, away from the warm region, and as they move above, they part with the heat which they acquired below. The smoke of a few charges of gunpowder, burned upon the floor of a hot-house, makes the currents visible, and the experiment always gives a like result, because it is founded upon a general law which affects air.

Air expands and rises when heated, contracts and falls when cooled, and moves sideways to find its own level, or escape pressure.

Air within a cottage, with a fire on the floor, obeys the law, and clouds of peat-smoke float overhead, and roll in emulation of clouds in the sky, while small storms blow amongst the plenishing on the clay floor. There is good fresh air in poor huts.

Air in a cave moves in the very same way for the same reason. When a fire is lighted at the extreme end, smoke rises to the cold roof, but it speedily cools and falls again, and returns along the cold floor to the fire, which set air and carbon in motion. It takes some time for heat to force smoke to the cave's mouth, because the hot air which carries it is cooled by cold air in the cave. So revolving systems of radiating and converging currents move in opposite directions, above and below; while men near the fire sneeze and cough, and are lost in clouds of rolling peat-reek. But as the air of the cave warms, the system moving within it enlarges its sphere. The smoke gets nearer and nearer to the door, and finally two regular currents are established. A warm stream flows outwards along the roof, bearing smoke and glowing in the firelight; and a cold chilly draught of pure, clear, fresh air creeps along the floor towards the bivouac. Because they breathe pure air, cottagers, gipsies, and travellers seldom wheeze.

A sail or some other screen makes all snug, and then a wanderer may stretch himself at ease on his bed of heather or leaves, and watch forms in the smoke, and rapid steady movements, which fire, kindled by a spark, keeps up in air, so long as fire gives off heat-force.

It is the same in a cubic foot of air confined under a glass shade. The movements may be seen by the help of smoke ; or delicate vanes made with gold leaf, will point towards the fire and the window, the hottest and coldest spots which can influence air in a room.

Polar and equatorial currents are found under a glass shade when they are sought, and they blow even in close cellars.

Perhaps the largest mass of air enclosed artificially is at the Sydenham Crystal Palace, and there draughts and warm currents are in proportion to the size of the building.

At one end a high temperature is preserved for the benefit of tropical plants, birds, and fish, but the rest of the building is kept cool.

According to theory, there should be a warm moist current flowing along the roof from the warm tropical regions, and a cold dry current flowing along the floor towards them ; but if there were, the temperature within would be too evenly spread by the air. To keep temperature off the balance, the currents were arrested, but they assert their presence nevertheless, and shew pressure by form.

The tropic which divided the torrid zone of the Crystal Palace from more temperate regions was at first a great canvas screen, and its form betrayed the invisible forces which pressed upon it. It bulged outwards *above*, like the topsail of a big ship, and inwards *below* like the mainsail of a first-rate taken aback. The imprisoned breezes could have driven big ships

and large balloons, waves and clouds, east and west, for the sails tugged hard above and below.

A visitor passing the tropics below, passed the door with a cold fair wind behind him, but one who attempted to enter by the upper gallery was met by a strong, damp, warm, head wind. Heat expanded the air, weight squeezed it, and air pushed the canvas, two ways at once.

Thermometers shewed that the lower current was cold and dry, but the upper warm and moist, and the outer glass in the tropical region streamed and dripped with condensed vapour, which light hot expanded air had absorbed.

So, in the Crystal Palace at Sydenham, are tropical and polar currents, and local winds ; evaporation and condensation ; as well as specimens, models, and copies of most of the world's productions, old and new, living and dead.

The principle on which these currents of air move is worth learning, for it may be turned to practical use.

Without oxygen any animal dies ; without fresh air constantly supplied it suffers for want of oxygen ; and these sufferings are in proportion to the absence of oxygen from the air which is breathed, or to the presence of something hurtful in it. Men die for want of air under water. That they often suffer in dwellings for want of fresh air is notorious ; but few ever think why they suffer in mines, or in rooms. Every breath drawn by every living creature is a chemical operation, in performing which oxygen is taken away from nitrogen, and carbonic acid added to it. Within a given time a set of lungs will absorb so much of the oxygen in a certain limited quantity of air, as to leave a spoiled mixture of air, nitrogen, carbonic acid, and exhalations ; a mixture which stops the play of lungs, stills the beating of hearts, and quenches fire as effectually as a like volume of water.

If any one is cruel enough to try the experiment, let him put a mouse on a plate under a tumbler, oil the edge of the glass, and watch the result. The mouse, unless relieved, will certainly drown himself in his own breath. But men and women, for want of knowledge, voluntarily subject themselves every day to sufferings which are the same in kind, though less in degree. The evil is glaring, and the results are but too well known; the difficulty is to find out the best remedy, and to persuade the patients to take it. Anything is blamed rather than invisible air, and every smoke doctor and engineer has a special nostrum of his own for keeping out "draughts," while persuading fresh air to come where it can be breathed. The plan is called by a long name, and when tried it often fails. Surely it is wisest to teach that fresh air is necessary, and foul air hurtful; to shew why air moves, and leave men to apply the knowledge, and help themselves. Air driven by heat moves exactly as water does in a boiling kettle. Hot air, or hot water, is lighter, bulk for bulk, than cold air or cold water, at a certain pressure; and the cold heavy fluid will flow towards the hottest place, and the warm lighter fluid will flow from it as certainly as winds blow and rivers flow, and for the same reason.

There is nothing simpler than "ventilation," if the principle is known and the law of nature obeyed.

Air under the earth obeys the same laws which govern air in the free atmosphere.

In coal mines ventilation is carried out artificially, but according to natural laws, by heating air in one shaft, and letting cold air sink down another; or by dividing a single shaft, and lighting a fire on one side. By partitions, doors, screens, and brattices, the downward current, set up by gravitation, is made to flow where it is wanted, to dilute and

carry off noxious gases, and supply the means of existence to miners, horses, lamps, and fires, which cannot breathe and burn without oxygen. In some mines air is thus moved a distance of thirty miles, at a steady rate, and more heat moves it faster. A ton of coals burned in a day boils up a breeze. Burned in an hour, the fuel drives an upward gale which blows out candles in rushing down to the furnace.

The system is good, and it only fails when ill carried out, or when the machinery breaks down.

In cold metalliferous mines, driven into hill sides, and out at the top, like those of Yorkshire; where the so-called system of natural ventilation prevails; currents of air move different ways under ground when the outer air is in different states of heat and pressure.

Changes in weight, which move mercury in a barometer, also move columns of cold air shut up in vertical shafts.

Changes of temperature, which affect fluids in a thermometer and in the free atmosphere, also affect air shut up in big tubes and chambers of rock.

Shafts and levels, pits and galleries, mines and chimneys, are but barometers and thermometers on a large scale.

So it happens that when air within one of these mines is colder and heavier than the air outside, a current flows along the adit and out into the glen below, as water does; and it draws air down into shafts at the hill top. Because the air within is heavy and runs out, the upper air falls in after it to fill the void.

When the air outside is cold and heavy, and the air within warmer and lighter, the current is reversed. Light air rises out of the highest shaft like smoke from a chimney, while heavy air flows in below, as water would if the glens were flooded.

In either case, there is sufficient movement to change air in most parts of a mine, with openings at high and low levels.

If barometric pressure is removed outside, the air within expands, and so escapes till the balance of pressure is restored. If there be noxious gas in chinks in rock, or in coal, it escapes most when the barometer is low.

If pressure is added, the confined air is compressed, and the outer air enters till the vacant space is filled.

When a strong wind is blowing outside, it acts upon air within a mine, sucking it out of a shaft as the current passes over it; and driving it in when the wind blows upon the entrance to a level.

But in certain states of pressure and temperature there must be stagnation in a mine, as there are calms at the surface, and on these occasions men are driven from their work.

When no one is able to predict which way the current will flow at any time or place, it is impossible to direct it.

Thus it happens that close ends abound in nooks and corners of mines, in spite of "windy kings," "windylators," "fans," and "water-blasts;" engines which substitute muscular force, water and steam power, for nature's power—heat.

Men are often driven from their work and choked out of mines for days by changes in the weather, when a fire would remedy the evil; though strong fires are burning to waste beside most mines. "Lead miners are as good as barometers" for their neighbours, but nevertheless they and their class generally, seem to be convinced that "weather ventilation" is the best of systems for them, and that fires are only fitted for coal mines where fuel is cheap.

In deep hot mines like those of Idria and Cornwall, where the natural heat of the earth is felt—at a depth of 1800 feet below the surface—in hot lodes, and hot rocks, where tem-

perature rises to 90° and 100°—there is true "natural ventilation," which only needs direction to secure good air. But even in such mines men often trust to nature while working against natural laws.

In one hot Cornish mine everything went wrong at "the end," till a great storm made a commotion in the atmosphere, which reached the hot levels below. The currents changed, and since that time they have constantly and steadily followed their own paths, and all goes well. The men suffer from heat, but they breathe good air—for the natural heat of the earth ventilates the mine.

In all cold mines where atmospheric ventilation prevails, there are "close ends," "poor air," "cold damp," "carbonic acid," and other evils, which cause sickness and excessive mortality, while engine fires are burning to waste at the surface near most of them.

"Levels" which are open at one end and closed at the other; where work is going on, ventilate themselves, though slowly and imperfectly, on the general principle. They are like long low caves, 7 feet high and sometimes 300 feet long, and men and candles heat the inner end. There is consequently a light warm column of air at one end, six or seven feet high, while at the other is an equal column of colder and heavier air, which presses upon and displaces the other. Heat forces out a wedge of air along the roof, while weight forces in a wedge of purer air along the floor. When a shot has been fired, the smoke is seen rolling slowly out in thick volumes along the roof, while there is little or none below. In an hour or in many hours the smoke is gone, and in time it will be found rising out of some shaft, if followed. But smoke often hangs for days in close ends, because men and candles are weak caloric engines.

If a regular and constant current, however slow, passed through a mine, down one shaft and up another, which would be the case if an upcast shaft were joined to an engine furnace-door; then brattices and trap-doors would turn the current into any corner, however distant, and so miners would suffer less from bad air if they used power which they throw away.

In dwelling-houses it is the same. Heat and weight cause movement in air everywhere, but the simple law is often forgotten, unknown, or misunderstood. So it happens that contrivances meant to promote ventilation impede movement in air.

To warm a room is easy. Every savage who kindles fire knows the art. It is only requisite to burn enough of fuel to warm a hut; and a leaky hut ventilates itself.

Fuel burned on the floor of a cave or hut, in an open fire-place or a closed stove, in a mine, a lamp, or candle, or in any other contrivance, is a source of heat, and that is power which may be used or wasted.

The fire radiates directly to all places to which straight lines can be drawn from it; indirectly wherever rays of heat can be reflected or refracted, and the radiated heat is absorbed and given off by everything within its reach, in proportion to the supply. The fire is to things in a room what the sun is to the outer world; but a room is a small world, and, unlike a hut, it is nearly air-tight.

To change the air in dwellings with chimneys and doors, or in mines, it is only necessary to put right fires in right places, and let air follow its natural course. To ventilate close rooms air-holes must first be made.

Fire acts mechanically by expanding air about it, and every separate object which is warmed by radiant heat and is warmer than air in contact with it, gives heat to air, both by contact and by radiation; expands it, and so moves it. Cur-

rents, like those which are caused by natural heat in the atmosphere, circulate in dwellings because heat is set free, reflected, and refracted. But fresh air cannot get in if "draughts" are kept out.

There is a general system of currents which radiate upwards, away from the hottest place in a room—be it fire, or stove, or heated pipe—and which converge downwards and move towards it, after the spreading currents have carried heat to the coldest places, and have left it there. There are miniature radiating and converging equatorial and polar currents in every room, as in every mine, and ventilators should use them.

There are small local systems which circulate about every candle, or heated chair or footstool, stove, or living creature, in a human dwelling, mine, or other closed space. These are as eddy winds, land and sea breezes, domestic whirlwinds, and family storms; and their progress may be watched in graceful curves which form in clouds rising from peat fires, pastiles, tobacco pipes, newly extinguished candles, matches, powder, steaming tea-cups, or the kettle.

To warm and ventilate, it is only necessary to burn fuel, and direct the currents of air, which must move somewhere.

Let the window of a warm room be partially opened above and below, and let threads, ribbons, grass, feathers, or any other light material, be hung in the openings to act as vanes. It will be shewn that light air is escaping above, with a charge of heat taken from things in the room; that heavy air is entering below to be warmed, and that the air in the room is revolving as a current of water eddies in a bight. It is the case of the mine in a hill.

If the same thing is tried in a room colder than the outer air, heavy cold air flows down and falls out of the window,

as water might do; and light warm air enters the window above, deposits a freight of heat in the room, and then follows the outward stream. In either case the movement goes on till the mechanical force is expended, till the unequal weights are balanced, and pressure and temperature the same.

A living being is a source of heat, and a cause of movement in the air of a room, a mine, or any closed or open space. The warm breath and natural heat of a man who enters a cold room and takes up a position in it, moves air and cobwebs on the ceiling, at a distance of 30 feet, in about a minute. A miner moves the air in which he works; a mouse moves air under a glass shade; so does a rabbit in his hole.

The smell of a newly-lighted cigar moves about 30 feet in two minutes in cold air in a room; but the rate of motion depends upon the coldness of the room, and the energy of the smoker. The sun and a pipe are different sources of heat and power, and currents of air flow when power acts, whatever the source of it may be. But a man and a candle work on air in a large mine, as a sailor's pipe does on a calm at sea.

An elastic balloon filled with a light gas, and carefully weighted, so as barely to rest on a table, expands and ascends when placed on the floor opposite to the fire. It is like a cloud warmed by the sun. It moves along the ceiling, away from the fire, towards a window, falls where it cools, and drifts back towards the fire along the floor. It rises because it expands; it expands because it is warmed; and it follows the stream of air, and shews its rate and direction. It does not move of its own accord, neither do the currents which move it. They move because they are expanded and compressed, and go fast or slow in proportion to the heat used to move their weight.

The smoke of a lamp where it blackens a ceiling, shews the course of currents of air by forms in which carbon is arranged. The forms are tool marks, and the tool is air.

Ice forming on a window, and hoar frost under a door, take the shape of streams of air moving in a room and entering a house.

Silk vanes, cobwebs, or any light substances hung about any closed space, shew currents of air by form as clouds do.

Air escapes from the garret windows of a warm house, but enters the cellar door. The cause is still the same.

There is pressure where currents are impeded, as shewn by the skreen at the Crystal Palace. There is outward heat-pressure on a garret window when closed; inward weight-pressure on the lowest door, and cold air will open the door and enter, if the latch be turned on a winter's day.

When pressure is greater than resistance, as when a house burns, air, urged by strong heat and weight, shews more power; upper windows burst outwards, lower windows are crushed in, and hard glass is shattered by invisible gas.

Imprisoned air, aided by more heat, bursts iron in a mould.

The atmosphere and weight crush iron boilers when water inside is deserted by heat, and steam loses the ally, without whose aid steam is ice.

And the atmosphere, when urged by the sun, and by the earth's gravity and rotation, sometimes becomes a hurricane which sweeps away trees and houses in its resistless course.

So heat and weight are strong useful powers; good servants if bad masters; and they work with air.

Some years ago an experiment on a very large scale was made in a coal mine below the sea-level, and it affected gases of very different specific gravities.

A northern mine in full work is a strange busy scene.

At the pit-mouth fires flare and smoke; steam-engines pant, and puff, and wheeze; chains clank, wheels rattle, and waggon loads of coals rise up, rush from the pit, and crash down shoots into railway trains. There is a fearful din.

Men step on a smoky platform, and down they go like Don Giovanni and the commandatore. Down they sink rapidly; and if unused to falling, their hearts seem to rise.

If the pit be an upcast, the smoke is dense, and the air grows hot, and hotter, and hotter still, as the skip slides down the chimney. It passes the furnace vent, the air clears, and the journey ends; it may be, far below the sea-level.

At the bottom of the pit there is bustle and busy work. Shouting and grinning, black, half-naked urchins, push waggons of coals rattling over iron plates, and up they go like a puff of smoke. Sleek steaming ponies, who never see daylight, trot in with trains of waggons from distant ends, grimy postilions with lamps in their hands ride in from distant stations, with arms clasped about the necks of their steeds, and heads bent low to avoid the roof. Black railway guards crouch in their trains and grin, and clouds roll from every open mouth and nostril.

The boys always ride home from their work if they can, and sometimes they ride races.

Lights flit about, gather, and disperse. Half seen forms, —a man's head and hands, or half a face; a tobacco-pipe smoking itself; horses' heads with glittering eyes and smoking nostrils, with a figure of fun grinning out from under the mane; all the fancies of Teniers, in his wildest mood, seem to float about in the darkness.

A cluster of these visions and their lights gather and

grasp a bar; three raps are heard, and they fly smiling up the chimney after the coals and the smoke.

At the end where the work goes on, these gnomes are constantly burrowing on, and bringing down their roof. The coal foundation is picked out, and the upper coal, the old sandstone flags, and the shales above; the arched roofs of this vault, with all their loads, begin to yield and split with a strange ominous noise. "CRICK." Wooden props shoved in feel the load, and they too complain and creak. When the full strain comes on them they are crushed and riven to splinters, and the roof "roars like cannons when it is coming down."

A spoke in the world's wheel is cut through and mended with sticks; the scaffold which supported the flat arch is dug away, so the arch comes down and the sticks are crushed.

With his head touching the roof, and his feet on the floor of a mine, a collier stands under a stone column it may be 2000 feet high. A weight sufficient to squeeze him as flat as a fossil fish is coming down, and he hears it coming, but he works on and smokes placidly under the lee of his prop, rejoicing to see weight help him to quarry coals.

That is working according to natural laws. That is using a power which has been found. That is one use of weight.

Some years ago, the workings of two such coal mines near Newcastle were purposely joined. Each underground world had its own atmosphere, with its system of currents. It is important to keep the stream moving, to make it move along the face where men work, and to know the way the stream flows, in order to be able to guide it. So these black gnomes, with shining oil stars on their foreheads, and gleaming teeth and eyes, argued keenly in their separate burrows. They are a shrewd, knowing race these northern Teutonic gnomes;

they know that fire-damp or choke-damp may blow them to bits, or drown them if their atmospheric systems go wrong. They know their own interests, and generally know how to secure them. So they held high council about their winds, when their systems were approaching each other.

The pits were miles apart, but a thin block of coal divided the workings at last.

On either side stood an anxious man reading the weight-power that pressed on the coal, from the dial-plate of an aneroid barometer. That was another use for weight.

A blow demolished the wall, and the mines were successfully joined. Weight turned the scale again. The lightest column went up, the heaviest came down. The trade wind blew towards the barometer which shewed least pressure, away from that which shewed most, by standing highest ; and the coal wall being gone, the barometers marked the same pressure at the same level, and regular circulation went on.

There was less pressure in one mine, because there was more heat ; and the colliers poked their fires, and rejoiced in fresh air, and scorned danger overcome.

They had got the mastery over weight and heat ; and the giants and the gnomes now work amicably together in their united dens under the earth.

In deep cold metal mines, where a few narrow pits all open about the same level, stagnation is the rule. So long as air inside the stone bottle with the slender necks is colder than air outside, it is heavier. There is no natural power applied to lift it, and it cannot flow out for want of fall. Like water collected in an old working, the cold, heavy mine air is a foul deep stagnant pool, which evaporates a little, overflows now and then, and swings about in its rocky bed ; but it never changes .like water in a river pool, because

there is no stream flowing through it. Such a mine is a contrast to one through which air moves constantly.

On a fine, warm, breezy, bright, sunny day, with the sweet breath of fields and heather hills in his nostrils, a pedestrian in search of information comes to a trap-door and a hole like a draw-well. Odours of bilge water and rotten eggs, mildew and worse things rise when the trap is lifted, and they contrast abominably with the delicate perfume of beans and hedge-rows. The pool moves when it is stirred; but when left to its own devices, the most delicate tests often fail to shew any movement at a pit mouth. Cobwebs, paper, silk, soap-bubbles, and smoke, which shew movement in the stillest room, all indicate repose at the neck of the bottle, for the unsavoury air stagnates in the cold dumb well which holds it.

If the average temperature inside be 60°, and outside 61°, there is nothing to lift the lowest stratum.

There is no rattle, no din, no movement here. A dull sleepy creaking sound comes faintly in from a big waterwheel, which is slowly turning and pumping water from a neighbouring hole. The only cheery sound about the place is the rattle of hammers and stones, where boys and girls and strong-armed women, are smashing and washing ore in sun-light and fresh air. Like bees they sing as they work cheerily. Their cheeks are ruddy, and their bright eyes dance with fun; but down in the dark well is sickness, silence, and gloom.

A distant sound is heard below; the yellow glimmer of a candle shines out of the black earth; hard breathing approaches, and the regular beat of thick-soled boots on iron staves comes slowly ticking up the pit, like the beating of a great clock. A mud-coloured man appears at

last, and he stares amazed at the stranger perched at the mouth of his den; seated on a sollar, and watching cobwebs with a pipe in his cheek. The miner may be blue, or yellow, green, brown, orange, or almost red, but he is sure to be gaunt and pale-faced. His hair and brow are wet with toil; his eyes blink like those of an owl in day-light; he wheezes, and he looks fairly blown. With scarce a word of greeting, he stares and passes on to the changing house; and the cobweb which he disturbed settles like a pendulum at Zero once more.

When a lot of miners who work in such mines gather amongst other folk, they are as easily distinguished as blanched celery from green leaves.

When visitors go down, guides and strangers dressed in their worst, each armed with a vile tallow dip, stuck in a ball of clay, cluster about the well, which is called the "foot way," and one after another they vanish from the upper air.

The TICK : TICK : TICK : of many feet wakes up echo, and hot breath stirs the air. For the height of a town-church, down they go into the darkness, and their steaming breath rises up like blue smoke. When daylight fails, a halt is called, and candles are lit on the ladders.

This travelling is, to say the least, uncomfortable. A man in the middle has to watch that he may not tread on the fingers next below him, and to look out for his own knuckles; to hold the sharp, cold, greasy, gritty iron rounds, and the candlestick of soft wet clay, so as to hold the grip without losing the light, or singeing his nose with the candle. He has to feel for his footing, watch for damaged or missing rounds, and generally keep his wits bright; for there may be fifty fathoms of sheer open depth at his elbow, and nothing earthly to save him if he slips or stumbles in this "foot-way."

The Col de Geant in the Alps, Eriks Jökull in Iceland,

a long day after the deer, and a day's march with a heavy pack, are easy journeys to a mining scramble through dirt, darkness, and foul air.

Like a train of Irish hodmen, slipping down from a London house, down goes the procession ; and those who are unused to the work find it hard labour. The way into this Avernus is not a facile descent. In half an hour, or an hour and a half, according to pace and distance, a journey which costs minutes and seconds in a coal mine, ends at the bottom of the mine where machinery is unknown. It is the goat's track against the railway ; the fox's mine against the work of human brains. It is the old story of brute force and skill, giants against dwarfs ; and the clever dwarfs who circumvent the giants best get most work out of them in mines as elsewhere.

On the floor of a coal mine the footing is sure. In the other, passages are made at different levels, and they are full of pitfalls, and uneven in height and width. Tramping and splashing through mud and mire, over hard rock and piles of rubbish, the train moves off. When the level is reached, a miner leads, another brings up the rear, and strangers file off and keep their places as best they can.

"Shoot :" cries the leader, and ducks his head. The next finds the edge of a sharp ironshod trough at the level of his eyes, dives under it in his turn and passes the word ; "SHOOT." It is the place where ore is shot down from upper levels into waggons, and it is a trap to break the heads of the unwary.

"Sump :" cries the leader, and the follower, with his candle flickering in his eyes, finds that he stands on a single plank, or a narrow ledge of stone, above a black abyss. In daylight, heads are apt to swim above such depths, in the dark that feeling is absent ; so each in turn passes the bridge and the

word: "SUMP." It is the place where ore is sent down, or the top of an air chimney, or the mouth of a pit dug into the vein.

"Deads:" and the leader proves his descent from some burrowing ancestor, perhaps a badger, a rabbit, or a rat, by crawling up a heap of rusty stones, wriggling through a long hole, and sliding down head foremost into the passage beyond. He looks very picturesque. The soles of his boots disappear at last, and one by one the procession struggle through and take the colour of the mine from its roof and sides. And so for half a mile, or a mile or more, it is "heads!" "shoot!" "sump!" "deads!" splash, tramp; and by that time all hands are wet, hot, greasy, smoky, and muddy. The smallest hole in an air-way is the measure of the current which can pass, so deads throttle the mine.

Having driven two long caves, one above the other, so far that candles will no longer burn at the ends, and men can hardly breathe, the next step in metal-mining is to "rise" and "sink" and join the caves; to make a passage for air to move through if nature so wills. It is easier to rise than sink, for loose stones fall when blown out of the roof, but as men rise into the rock, smoke, breath, hot air, and light exhalations rise with them. Thermometers rise also to 70° and 80° though water in the level and the rock may be at 60° or 64°.

To get up to the top of a rise "stemples" are often fixed for steps. These are bars of wood on either side, and to mount is like climbing a chimney. The stones which are quarried at the top are thrown down and gather in a conical heap below. So the place is well called "a close end."

In order to get oxygen into this black hole, a small boy, whose life, like Mr. Mantelini's, is one perpetual grind, is stationed at some place where the air is thought fit for use.

With a circular fan and a leaky tube, or with a thing like a magnified squirt ; by the muscular force of a young male caloric engine, with the idle nature of a boy, some air of some sort is driven to the end, and half-choked men and dim candles struggle on for life in the burrow.

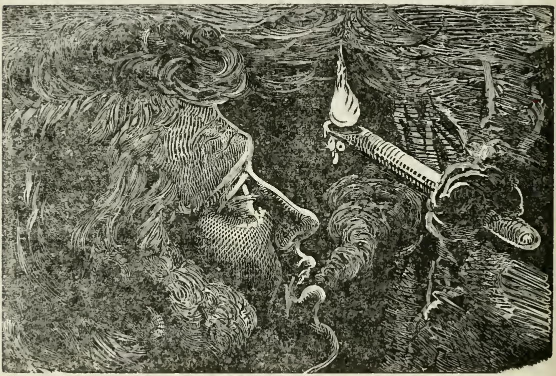

Fig. 12. Ventilating engines, commonly used at close ends in Metal Mines.

The lungs of a healthy man hold as much air as some of the squirts used, and one was expected to supply oxygen to three men and three candles.

The collier laddie who does like work, has a lamp and a book ; he sits beside a door with a string in his hand, and his duty is to open the door when any one passes ; to keep it shut, and keep his own eyes open at other times.

The one guides air intelligently, the other urchin drives it by weak brute force, and with bad engines. The ventilating boy engine passed, the leader dives into a rolling cloud of thick fœtid smoke. His candle turns into a nebu-

lous haze, his legs are seen wading alone after his body has disappeared, but both are found together at the end. With hands and feet on either side of the rise, in the graceful posture of a split crow, or a wild cat nailed on a kennel door; through showers of dust and falling stones, up sprawl guides and followers with many a puff and cramp till they crowd a shaky platform at the top of the rise. It is the place where men work for hours, days, and months.

One effect of these close ends on one who is unused to them is to cause perspiration to break out freely while standing still, or sitting quietly, resting where a thermometer marks 64° or less. There is a feeling of tightness about the neck; the chest heaves with a gasp, instead of rising steadily; the shoulders take a share in working the bellows; and generally there is distress, and a feeling like nightmare. Men at work in bad places pant and seem to breathe painfully; their faces are red, or purple; their veins swelled; their brows wet and begrimed with soot. They seem to labour hard, though their work is not harder than quarrying stones elsewhere. In such places candles flicker and sometimes go out altogether; no puffing or drawing will light a pipe or keep it lighted. There is no laughter, no fun; no busy cheery clatter of active labour at close ends; there is silent toil; for carbonic acid is not laughing-gas.

When a sump and rise meet, where they have "holed through," the hot air in the rise flies up into the upper level, and the cold air falls in behind it. The temperature changes instantaneously and the hole clears as fast. Heat and weight have room to act, and they do the work of many boys. Fans and squirts are thrown aside, till the levels have been driven another stage.

But the foul air of an end is only diluted with less foul air if there be stagnation at outlets, where cobwebs are still.

To retrace downward steps, to return to upper air, has ever been labour and hard work. From the bottom of a deep mine, perhaps from under the sea whose waves are heard rolling stones above the roof—up perpendicular ladders, perhaps in the pumping shaft with the rods moving up and down within a few inches of his back; with foul stinging mine-water dripping on his head, and a smoky candle sputtering in front of his open mouth; edgeways through clefts, on all fours, feet foremost, head foremost, on his back, his belly, and his sides, the amateur miner follows his guide. Greasy, muddy, drenched, streaming with perspiration, with throbbing ears, giddy, tired and gasping like a fish, the man who is used to climb mountains in fresh air struggles back to it.

When daylight appears, glimmering far over head, when the trap-door is passed, the first long greedy draught of the clean pure air of heaven seems too strong. It flies to the head like brandy. Even miners who are used to such places often stagger and totter like drunken men when they come "to grass." These were the sensations of the winner of a Highland hill-race, in good condition, at the age of twenty-eight. In well-ventilated mines ordinary fatigue was the sole result of many a long scramble under ground. An ill-ventilated mine is a crying evil; air in it is slow poison; working in it shortens life; it proves ignorance, parsimony, or poverty—for ventilation is easy to intelligent men, who will learn an easy lesson.

By analysing air collected in close ends, Dr. Angus Smith has proved the existence of poisonous gases, in places where these sensations are felt. So working in these places must

be injurious. It has also been proved that mining shortens life, where ventilation is faulty.

It appears, from calculations made by Dr. Farr, immediately after the census of 1851, that Cornish miners who work where currents of air are weak and uncertain, die faster than the Cornish population who live above ground. They die faster than colliers who, in Durham and Northumberland, work in places where air is moved by the direct application of heat-power to it; where currents are strong and regular in the mines.

Foul air fills the black list faster than fire-damp and choke-damp, and all the perils which colliers brave.

The death rates between certain ages were as follows :—

Ages.	Cornish people above ground.	Northern Colliers.	Cornish men under ground.	
35 to 45	10	10	14	per 1000.
45 to 55	15	17	34	
55 to 65	24	24	63	

So the principle upon which currents of air move has been turned to practical use in northern coal pits.

A leader in the *Times* of February 4, 1864, shews the evil in dwellings.

Festiniog, in Merionethshire, has been a healthy place for many years. It stands where mountain air is pure, and natural drainage good. The people were well off, and neither intemperate nor uncleanly in their personal and domestic habits; they earned good wages, but they slept in foul air.

A new slate-quarry drew men to the district; no one had time to build; the work went on day and night; so houses, rooms, and beds, like the lodgings of Box and Cox in the

farce, were occupied continuously by successive tenants. In two low bedrooms, 8 × 6, and 12 × 6 feet, ten and twelve people were lodged. In some lodgings the beds were never vacated, nor the rooms aired, either by day or night. So fever broke out amongst the overcrowded. There were six or seven hundred cases amongst six or seven thousand people, and sixty or seventy died.

Without fresh air constantly supplied, men do suffer; but air is free to all, if they will only open their mouths and take it.

The law which governs air above the sea-level is good law under it; and governs all gases and all fluids, fire-damp and choke-damp, steam and water, as well as air. It governs air in copper-mines and in coal-pits, in houses and in the atmosphere.

Bacon was right when he wrote long ago, "It were good for men to think of having healthful air in their houses" (vol. iii., 297).

There are many tool-marks which moving air leaves on the earth. It bends trees; it uses them as levers to tear up turf and stones; it blows sand; it blows waves against a coast, and the coast wears into cliffs. The atmosphere is but one part of one wheel in a vast machine; and it leaves its mark on the world which turns within it.

The moving powers are few and simple, and the forms which shew their action are easily learned from smoke, trees, snow-drifts, sand-drifts, waves, and clouds.

These have a meaning which can be read and translated; they shew movements in air by their forms. Motion shews force, and its direction; its nature is found by experiment.

Experiment proves that Heat, Cold, and Weight are forces which produce upward, lateral, and downward movements in air, and so mould forms, and wear solids.

Observation finds these forces distributed in the world so as to fulfil conditions which produce these movements in air; and that heat comes from the sun, and from the earth. So cloud-forms and air-marks shew the mechanical action of solar and terrestrial heat, and of weight, in the air. They are tool-marks.

All atmospheric movements, great and small, can be traced to one general law, which governs gases; and fluids also. But before a law can be applied, it must be well known to those who apply it; and the laws of natural ventilation are often unknown to men who try to fill houses and mines with pure air.

FIG. 13. BENT TREES NEAR LITTLE ORMES HEAD.
Sketched in a calm. 1863.

CHAPTER VIII.

WATER.

If heat be a force which moves all gases away from centres, then for that reason alone it is probable that heat also moves liquids, and in the same direction.

It is not necessary to begin at the dial-plate, and work through a whole train of machinery, in order to find the centre of every wheel; or to go back to the rim of each wheel to find the axle for every spoke. All British railways converge on London, but all railway journeys up to town need not begin at the furthest station. Without travelling round the world, we know that chimneys at the Antipodes smoke opposite ways, and that blacks fall towards each other, and the earth's centre.

If a natural law is known, its results follow. Powers which move the atmosphere and all gases, which radiate from, and meet at a point, bring a traveller to a large junction, from which to make a fresh start, or take a short cut, towards his object.

It is easily seen that forces which move air also move water.

Clouds whose forms betray movements in air are made up of water.

When air expands, it takes in water like a sponge; when it is lifted air lifts water. When it contracts it drops the load.

But air is expanded by heat, and contracts when cold;

so heat, weight, and air, are as hands which open and close about a wet sponge while lifting and lowering it.

In lifting air heat certainly lifts water to the highest point reached by clouds, and it carries them from the Equator to the Poles, and far above Coxwell, Glaisier, and Kunchinjunga.

But heat also acts directly on fluids. The sun's direct rays, when absorbed by water, and accumulated in it, lift it. They move water away from the centre, along a spoke, as fire drives steam out of a kettle.

In May 1857, during hot clear weather, two similar glass vessels were placed on opposite sides of a house, and filled with water. When weighed in the evening, the vessel which stood on the sunny side had lost nearly twice as much weight as the other. The sun's light, and its heat, had lifted water into the air, and the air had carried it off. But air on one side of the house could differ little from air on the other side; so in this experiment the sun's rays drove the water out of the vessel. In the next trial, a thirsty terrier lapped up the water and spoiled the result; but both did the work of mechanical powers.

According to Sir John Herschel, the amount of solar heat which reaches the surface of our globe would suffice to melt a crust of ice an inch thick in an hour, or evaporate a layer of water nine feet deep in the year; if part of it were not expended in warming earth and air as well as ice and water. According to the same high authority, the actual fall of water in all shapes, and therefore the evaporation, amounts to a depth of five feet on the whole globe in each year. The sun's rays do notable work when they lift and drop such floods.*

Evaporation is a result of heat, and every experiment

* Good Words, January 1864.

shews it to be much or little in proportion to heat-power used, or weight-power removed.

It is common to fix the value of fuel by the weight of water lifted by heat set free while burning a certain weight of the fuel under a boiler. But fuel may be so burned as to spend heat-power on air instead of water.

In like manner, sun-power is differently applied at every different latitude, at every season, at every hour of the day, at every spot on the earth's surface, and the most of the rays shine into space or on other planets.

Most of the solar heat which gets to our world stops about the Equator, where the sun's rays beat directly on the ball by day, and from tropical regions most heat is radiated onwards by hot ground at night.

Least solar heat is absorbed at the Poles, where the rays glance off the slanting white surface.

So evaporation goes on most rapidly near the Equator in summer, and about noon, when the sun's rays strike into the earth, and drive water out into the air.

Though heat coming from the sun is the power which acts most conspicuously on air and water in the atmosphere, it is not the sole heat-power used, for it only penetrates a small way into the earth.

At Yakutsk, in Siberia, lat. 62° N., the earth is frozen to a depth of 382 feet. The summer sun thaws $3\frac{1}{2}$ feet of the surface, but the ice-crust is always hard lower down. If the sun were the only source of heat, this crust would be found at all depths. It is not so. Under the ice-formation is earth-heat. Temperature rises in descending: below 382 feet ice melts, and hard ice conglomerates are melted beneath the frozen crust. The mean temperature at the surface is 14°: below the ice-region it is more than 32°. But at 217 feet the

temperature of the ground is 27° ; and at 50 feet 18°. So heat is below and cold above, at Yakutsk.

On the American side, the ice-crust comes further south, but it is thinner at the same latitude. Perhaps the earth's heat comes further up from its home near the centre.

At Mackenzie River, the mean annual temperature at the surface is 25°, the ice-crust 17 feet thick, and summer melts 11 feet of the frozen surface.*

Solar evaporation goes on wherever the sun shines on water or damp ground, though at different rates; and terrestrial evaporation goes on also. Winds blow ; dew, rain, snow, and hail fall; rivers collect and flow; glaciers gather and slide above the earth's surface, chiefly because the side that is next the sun absorbs heat by day, which travels onwards into space by night, leaving water behind it. But rays which the earth absorbs radiate back from the earth's centre, together with rays which the earth gives off, and together they lift water and air up the spokes, as far as they have power; for radiating heat is radiating force, whatever its source may be. Solar heat is not much absorbed by smooth reflecting surfaces.

Mercury in a thermometer placed behind a mirror, exposed to sunlight, is less expanded than mercury placed behind a black board. But a thermometer, placed in the focus of a concave mirror, on a sunny day, shews that reflected heat is strong reflected force when it meets resistance. Placed in the focus of a strong lens, a spirit thermometer shews that refracted solar heat bursts a glass boiler.

A thin dark object like a leaf or a slate sinks straight down into ice on a bright day, but a thick stone protects ice, absorbs heat, and gives it off by night as the world does. For this reason large stones often stand upon raised pedestals

* Keith Johnston's Physical Atlas, etc. etc. etc.

of ice, on glaciers, while fine dust melts ice, sinks in, and is buried in ice, at night.

So in nature. Solar heat is more absorbed by land than it is by sea, because the sea is smooth ; and least of all in high latitudes, where the frozen surface slants most and reflects best ; and it penetrates little anywhere.

But when a hill-side faces the sun, and rays strike it fairly, sun-power is as strong in high as in low latitudes and levels. All arctic voyagers, mountain travellers, and æronauts, have found it so. Pitch melts on the side of ships ; men, balloons, and thermometers feel the power, and measure it. A white tent, pitched on a spit of white sand beside the Tana, lat. 70° N., became so insupportably hot about noon on a summer day in 1851, that panting inmates were forced to move it to the cool shade of a birch tree, where mosquitoes were thick and bloodthirsty. "Cuoikædne læ olla"—there are many midges, quoth a Lapp boatman ; but in the shadow of a hill there was frost.

A balloon rising through a cloud feels the sun-power, and expands with dangerous rapidity ; though transparent air above the clouds is cold as air in Arctic regions.

The power of the sun's rays to lift water depends on accumulation of heat-power ; and that depends on the nature of the substance on which the rays fall, and on the shape of the surface which they strike.

A rough black surface gathers more heat than a white one, and reflects less ; a black bulb thermometer stands higher than one with clear glass. A glass vessel, filled with black sand and water, loses more weight on a sunny day than a vessel placed beside it, and filled with white sand and water. White gun-cotton will not readily explode in the focus of a burning-glass, because it is transparent. A lens of clear ice

will transmit and condense the sun's rays, and light tinder. Clear air is little warmed by the sun's heat, which it transmits and refracts. Clear fluid absorbs more heat, but it transmits a great deal; for a glass bulb filled with spirit is a powerful burning-glass, though not so powerful as a solid ball of clear glass.

All these are questions of degree; the facts remain. The action of solar heat is directly opposed to that of weight at the earth's surface, and it lifts water when absorbed by it.

The earth's heat has a like power, and acts in the same direction.

When pressure is removed from water, placed under the bell of an air-pump, water rises from the vessel which contains it; and heat is the moving power, for water which remains cools and freezes. The heat acts upwards.

When air is cold enough, water steams up into it visibly, and heat is the moving power still; for water freezes, and vapour which evaporates turns to rain, and falls down when it parts with the heat which raised it up. Lower down, water in a dark mine steams under greater atmospheric pressure. The earth's heat lifts it, and the earth's weight drags it down when it cools. Still lower, water from a hot spring boils and spouts up, and blows off in clouds of steam; but it rains down in floods when it gets out of reach of the earth's heat which raised it. Heat in the earth lifts water at the end of every spoke where water is, but with varying force at every point on the sphere; because heat is variously impeded by various rocks.

Heat artificially set free acts in the same direction, whatever the source may be. Water rises from a kettle on a fire, and hot steam lifts a piston, or bursts the boiler.

Having found a centre from which air moves, and a power

which moves it ; the movements of water are found to coincide with those of air, so far as anything is certainly known about them. Rising columns of steam move opposite ways at the antipodes, like columns of smoke or mist. Air and water circulate together in the atmosphere, and within their bounds they are moved up and down by heat and weight.

If these two forces so act on water above the sea-level, they probably act in the same way on water in the sea.

There are polar and equatorial winds; and similar ocean-currents flow in like directions unless impeded by land. When they can be seen, water-clouds are found drifting under water, and their forms repeat the story told by clouds in air.

We deal with the bottom of the air-ocean, and look up for signs of movement in it. We must look down on the sea and through waves at water-clouds.

Air rises far above the solid earth. It flows over mountains as the sea flows over sunken rocks ; and its surface is out of reach. We cannot dive to the bottom of the sea ; but we may look to the surface of the ocean for information as to the surface of the atmosphere, and seek at the bottom of the air-ocean to learn something about the bottom of the sea.

From the movements of air, movements in water can be inferred, when powers which move both are known ; and experiments made with one fluid test theories formed about another.

It is easy to see movements in water.

The first difficulty is to get a smooth surface through which to look. On the calmest day waves disperse rays of light, and reflect them, so that a sea bottom is hardly seen, except in shallow water. A diver cannot see clearly under water ; his eyes are not made to see there, and objects seem blurred and indistinct. A lump of chalk is white, but has no

definite shape ; a silver coin shines like light behind ground glass; the distance fades away into dark green, or blue, or black.

Smugglers of former days found a way to meet the difficulty, and their contrivance is used by seal-hunters and others. When smugglers were chased, their practice was to chain their cargo of tubs together, and sink them ; taking cross bearings at the spot. Their foes used to drag hooks about at random, and sometimes they fished up the prize. The smugglers, when the coast was clear, returned and peered about with a marine telescope. A sheet of strong glass was fixed in one end of a barrel, and sunk a few inches ; a man put his head into the other end, shut out the light from above, and saw clearly, because light came straight, to eyes in air, through a plane from which no light was reflected.

With this simple contrivance, fish, sea-weeds, shells, sand, stones, ripple-marks, flickering lights refracted by waves, dead seals, and brandy tubs are easily seen in four or five fathoms of clear water; and water-clouds are seen rolling below when water is thick with mud. The gazer gets a vertical view of things under him, as an aëronaut does of land and clouds beneath his car.

So far as this contrivance enables men to see the land under the waves, movements under water closely resemble movements under air. Sea-weeds, like land plants, bend before the gale ; fish, like birds, keep their heads to the stream, and hang poised on their fins ; mud-clouds take the shape of water-clouds in air ; impede light, cast shadows, and take shapes which point out the directions in which currents flow. It is strange, at first, to hang over a boat's side, peering into a new world, and the interest grows. There is excitement in watching big fish swoop, like hawks, out of their sea-weed

forests, after a white fly sunk to the tree tops to tempt them, and the fight which follows is better fun when plainly seen.

Of late years glass tanks have been used as fish cages, and the ways of fish are better known, because they are now plainly seen in their own element.

The ways of water may be studied in the same contrivance.

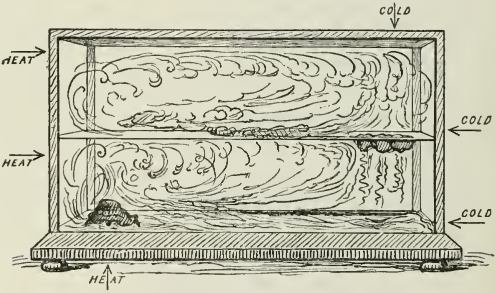

FIG. 14.

The principle might be extended. A boat with plate glass windows beneath the water line would make men and fish still better acquainted, by bringing them face to face. The man would be in the cage, and the cage might be in a salmon pool where fish are free.

If air in a hothouse be a miniature atmosphere, water in a glass tank is a working model of a sea, and heat and cold may be set to work the model engine at home.

Let one of the common fish-tanks be half filled with clear water, and placed where the sun may shine upon it.

Float a few lumps of rough ice at one end, and sink a black stone at the other; and, when the water has settled,

pour milk gently on the ice. An ounce to a gallon serves the purpose.

Milk consists of small white vesicles and a fluid, and, bulk for bulk, milk is heavier than water. So at first the white milk sinks in the clear water, and spreads upon the bottom of the tank, leaving the dark stone like a sunken rock in a muddy sea, or a mountain top peering over a low fog.

But this arrangement is unstable, because two powers are shut up in the tank with the water.

The sun warms the stone at one end, and the stone warms the water below. At the other end melting ice cools water above. Temperature is unevenly distributed, so weights are uneven, and the machine turns round.

Heavy cold streams pour down from the ice at the cold end, and flow along the bottom towards the stone, driving milk vesicles like drops of water in a gray mist.

Light warm fountains float up from the stone at the warm end, and flow along near the surface towards the ice, driving milk like wreaths of mountain mist rolling up into a summer sky from a mountain side.

The water is circulating, and every movement is shewn by milk-clouds, for the glass tank gives a vertical section of a circulating fluid system, driven by the sun's rays and by weight.

Cloud-forms are copied with marvellous fidelity in this water toy, and because the movement is very slow, they are easily seen and copied.

But the tank gives a section of air as well as water. The miniature sea has an atmosphere, and the same forces work both engines. Let a bit of smouldering paper, tinder, rope, touchwood, or any such light combustible fall on the ice-raft,

and cover the tank with a sheet of glass to keep in the smoke.

If there be small ocean-currents in the water, there are storms in the smoky air; and the systems revolve in the same direction, because the moving forces are the same. Cooled air streams down upon the floating ice, and drives gray smoke rapidly before it, drifting along the water towards the warm end, like a cold sea-fog before a north-easter.

At the warm end the mist lifts, like a sea-fog when it nears a warm shore. The smoke rises to the glass roof, spreads there and returns along the top towards the ice, whirling, streaming out, and taking the forms of fleecy summer clouds, which float high in air above the Atlantic in fine weather. "Stratus," "cumulus," "cirrus," "cirro cumulus," "comoid cirrus," and the rest of the learned tribe; "mackarel sky," "mare's tails," "Noah's arks," and vulgar popular clouds of their class; nameless cloud-forms which are the joy of an artist, and his despair when he tries to copy them; all appear drifting with streams, which various degrees of weight and heat cause to flow in air and water shut up within a cubic foot of space.

The amount of power used: the difference in temperature between the ice and the stone, moves air a great deal faster than water, because it is lighter, and there is less resistance to be overcome. It follows that winds should move faster than ocean-currents; and they do in fact.

When damp air has cooled and contracted to a certain point, it lays its load of water on any cold substance which takes in part of the charge of heat—which expanded air. Vapour is condensed. It follows the heat out of the warm air to the cold substance, and if it cannot get in, it stops on the surface, and gathers in small round drops. In the ex-

periment above described, cooled glass at the cold end of the tank stops water coming from the outer air; while the heat passes through glass and cold water to melt floating ice. Dew forms in curves on the outside, and it marks the dew-point temperature in the moving streams which cool the glass within. The curve is like a section of a river whirlpool, or a waterspout, and it coincides with the shape of the milk-clouds.

When the damp air of a room lays its load of vapour on cold glass windows in hard frost, similar curves are copied in solid ice. The dew-point temperature of the air in the room is marked out by a fog on the window, at first; then drops change to crystals, and ice-trees grow up by robbing the air which falls along the glass.

When a fire is lighted in a large room with windows encrusted with these beautiful forms, the march of the heat may be seen. As hot air rises and flows to the windows, ice begins to thaw at the top pane; crystal trees change to haze and vanish, wiped from the glass by dry air; or melted branches slide and stream down the window, dragged by weight when freed by heat. Where the fire radiates directly, the windows clear first. In corners sheltered from the rays ice lasts longest; and the lowest pane is the last to thaw and the first to fog. Heat pushes water towards the glass, away from the fire; weight pushes it towards the earth's centre. The radiating and converging forces do not part and meet at one point in a room; so the dew-point temperature is not in a regular figure. In the atmosphere, the dew-point curve has reference to the earth's centre; and vapour forms in shells about the solid earth because the two forces meet and part within the shell.

The facts shewn by experiment are confirmed by every fresh trial and observation. When temperature and weight

are unevenly disposed in fluids, it takes time to adjust the balance, but it tends to equilibrium, and to regular forms.

A warm bath is arranged in layers of various thickness, and varying temperature. When a human body is placed in it, natural observers stationed at the extremities send nerve telegraphs to head-quarters, to announce that one foot or hand is in warm or cold regions, and uncomfortable.

To prevent this evil, a bath attendant, who knows his work, stirs the water with a paddle ; but much stirring hardly spreads heat evenly throughout a bath.

Near Reykjavik, in Iceland, is a hot spring from which a scalding burn escapes. French man-of-war's men, who frequent the harbour to protect French fishermen, have built a turf dam across the burn, about a quarter of a mile from the source ; and they use the steaming pool as a hot swimming bath and washing establishment. The place was thus described in 1862 :—

Last night we wandered along the shore to a hot spring, which rises in a small hollow about two miles from the town. We found the place, and a dam, made by French sailors in the burn, which runs from the spring. The water was about 80° ; so we stripped, and plunged in, and swam about in the tepid water. The spring itself is about 170°, hot enough to cook eggs. We had none to cook ; but there were plenty of egg-shells and broken bottles to shew the ways of the place.

A lot of cows were browsing on rich grass, which grows in the hollow, and some of them stood close to the spring chewing the cud thoughtfully in the steam. The setting sun threw their blue shadows on the cloud of white mist, like great long-legged ghosts of cows. It was dead calm, and very warm ; and the hills, and the golden sea, and the purple islands floating in the bay, made a beautiful Claude landscape.

It was Italy in Iceland. There we lay stretched at ease on a velvet turf, and smoked, and watched the growing shadows, exclaiming, "how beautiful;" and the old cows seemed to feel as jolly as we did.

At last, when it was nearly ten o'clock at night, the cows seemed to think it time to go home to be milked. So one stepped deliberately down to the scalding burn, and smelt at it. She put one foot in, then another, and then the demure old brute sprang out on the grass, curled her tail over her back, and capered a wild dance, so utterly at variance with her former staid demeanour, that we all lay back and roared with laughter.

Next came a giddy young calf, who went through the same performance; but he, being more active, shook his scalded heels in the air in a way that was perfectly ludicrous.

The brutes, who should have known better, speedily resumed their placidity and walked away; so we got up and walked off to our floating home, where we drank tea on deck, and went to bed by daylight at midnight.

The next night was as fine, as warm and calm. Snæfell, sixty miles away at least, showed his head against a golden sky, in which clouds floated steadily, like the eider ducks and gulls floating about us on the calm water; but every now and again a strong cold blast fell down from the still sky, broke up the mirror of the sea, and then died away as suddenly as it came.

The air was in layers, the layers were of different weight and temperature, and the wind was "straight up and down," like an Irishman's hurricane.

The natural hot bath was a good illustration of a similar arrangement, and the glass tank and glass windows show the movements which result from it.

Water which stands in this hot bath is not stirred. The warm stream flows in above, and it cools by radiation as it flows to the far end, where it cools and sinks. The supply at the source is 170°, the waste at the dam is scarcely tepid, and the pool is circulating and rolling over and over because of its uneven weight. When a bather takes a header into it, he finds himself shooting through all sorts of climates. He feels summer, autumn, and winter rolling along his skin, as he shoots down. When he stands upright, he feels that temperature is packed in horizontal layers in the water about him, and that the cold layers are below. When he swims about, he finds hot and cold regions in different corners at the same level, for the heat is nowhere evenly spread. Lower down the ground may be frozen, but under all is the boiler from which the hot water rose. From this experiment with nature's thermometers, it appears that the coldest strata of water in a pond are generally below, but sometimes warm regions are below colder layers in the pond, as in air and sea.

The movements of water about to freeze are well seen in the glass tank above described.

At one corner a glass thermometer is hung with the bulb near the bottom ; at the opposite corner the stalk of a thermometer is thrust through a bung, and so placed that it can be raised or sunk without disturbing the water much. Thin ice formed in the tank floats at the surface, and a block-tin bottle filled with hot water is sunk. The heat of the water put into the bottle is 212°, the ice is 32°. On the ice, about the centre of the tank, some lamp black is painted on with a brush, one side of the tank is covered with a screen of thin paper, and then the machine is ready for action.

As the colour is at the coldest place :—on the ice, it marks the position of the coldest water when the ice begins to melt,

and the cold is easily measured with the instruments. As the hot bottle is in clear water, white paper seen through clear water marks the position of the water which is warmed. As lamp black takes many days to settle in a tumbler, it shews the movements of water, for it only moves about the tank, because water is moved by weight and temperature.

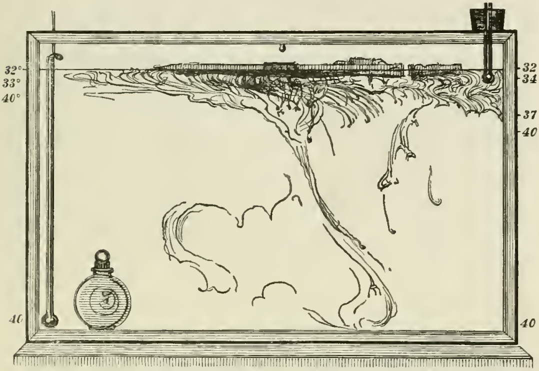

FIG. 15. FREEZING.

Ice being at the top is lightest, and its temperature is **32°**. When it is melting the colour begins to move. If it is warmed by the sun, a dark revolving column sinks very slowly down. But beneath the ice are layers which contain intricate patterns of curved lines of black, which bend and wave slowly, but keep near the ice. The temperature in the coloured band is

Ice, 32°
Water, 33°
34°
37° As shewn in the woodcut.

So the coldest of these layers is the lightest, and the solid crust is lightest of all. The clear water in contact with the coloured layer is at 40°, and so is the water elsewhere in the tank, after the hot bottle has given off its charge of heat and melted the equivalent weight of ice. So water at 40° is heavier than water at 37°, and the different temperatures are drawn in black on a white ground. But water that is warmer than 40° is lighter than water at 37°.

When a water-bottle filled with hot water, coloured with lamp black, is sunk through an ice dome, without the stopper, a warm dark column rises up like the Afret whom the Arabian fisherman let out of the copper vase ; or the foul air which in cold weather rises out of a copper mine. When the water is hot, a thing like a round-headed mushroom grows rapidly out of the neck, and takes all manner of strange shapes. The head is like some monster which a painter sees in his waking dreams, a vision by Gustave Doré, for example. The stalk bends and winds through the clear water like an eel, or a black snake creeping out of its hole. When it gets to the cold region, the top spreads out like a palm tree, waving its drooping boughs, and shedding a crop of rings, and spheres, and streamers ; like fire-works in daylight. The temperature of the coloured water which rose from the bottle to the top is in this case about 44°, when clear water is 40° at the bottom and elsewhere. So of this series the warm layer is lightest.

While the bottle is hot the pace is fast, as it cools the phantom growths are nipped. When the water is almost boiling, it rises in water at 33° like smoke from a furnace chimney rising in air.

When the temperature has fallen in the bottle and spread through the tank, small jets of colour rise up and sink back into the pipe whence they rose. Their shapes are like those

of plants rising through the earth, their action is that of a boiling spring.

When all the extra charge of heat has escaped from the bottle, there is rest at the source ; the rapid action ceases, and the coloured water slowly takes its place in the tank.

On a frosty evening when there is no ice, but when ice is about to form in the tank, the water which rose out of the bottle forms an even layer above clear water, and the temperature then is 37° above, and about 40° below.

In that case the water which rose because it was warmed, stays where it cools, beyond 37°, and after that the more it cools the higher it rises, till it is 32° at the top and a floating solid.

When the hot bottle spends its force beneath a solid ice roof, thermometers mark 32°
33°
34°
35°
and the blackest layer in the series is the lowest and the warmest.

When freezing water freezes, crystals expel colour from ice, and water-currents distribute paint amongst the remaining fluid. Circulation goes on under ice, for some of the dark water which was next below the ice when it began to form is found at the bottom when all the instruments read close upon 32°, and the solid crust has formed.

Water, then, is a gas, a fluid, and a solid at different temperatures ; and the formation of one crust on one fluid illustrates the formation of other crusts.

The ice crust forms next the coldest place, and the fluid remains shut up inside.

In a tank the process can be watched, and the disposi-

tion of the crust is seen, because ice is transparent, and vertical glass walls bound ice planes through which rays pass undistorted. A plate of ice seven inches broad is more transparent edgewise, than an equal thickness of plate-glass.

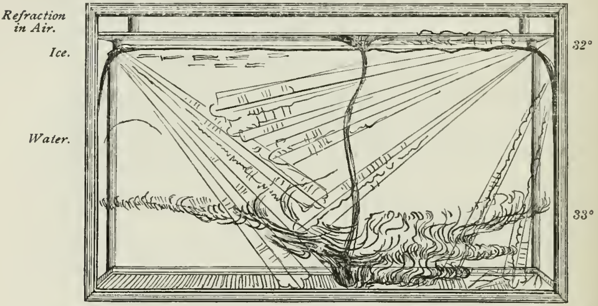

Fig. 16. Frozen.

It refracts rather less than water. On the surface, the ice is disposed in layers, whose planes coincide with those which colour shewed in freezing water. The layers are added below; they are horizontal and regular where the ice is smooth above; where the ice is rough outside, the planes of stratification within are bent and crumpled. The surface next the wall is a plane, where the layers are flat and undisturbed; it waves where the strata are bent and wrinkled.

The thickness of the upper crust varies; at corners, the angular solid is rounded off, so as to form a dome.

From these solid corners long blade-like crystals radiate at all angles from 1° to 90°. They are like spokes of wheels, whose common centres are the corners of the tank; or as

fans behind the glass, opening from the angles where three planes meet.

Each of these blades is like the back of a saw with crystal teeth growing into the water, away from the glass.

When a tank is so placed that frosty air circulates under it, ice crystals form at the bottom also, and radiate from the lower corners. The glass box is lined at last with a box of solid ice, and fluid water is shut up in a curved crystal chamber, wherein it circulates till it is frozen.

By pouring hot water on the ice, a hole is quickly bored through it. When coloured water is poured on the surface, near the hole, it is warmer than ice, however cold it may be, and it sinks through, falling like the column which rose out of the bottle, but very slowly. It strikes on the bottom and rises up again, steadily working its way through the colder water, and forming itself into crumpled layers below. A thermometer marks 33° when placed in the colour. So water at 33° is heavier than ice at 32°, and, therefore, solid ice must float in water at any temperature.

The charge of heat which a mass of fluid water contains, passes outwards; and leaves ice where it passes through any substance which stops water but cannot stop heat.

It is the rule that cold water is heavier than warm water, but the rule does not hold good for all temperatures. At 32° fresh water is ice, at 37° and all lower temperatures it is about to become ice, and it floats on water at 40°.

At 44° it rises through water at 40°, and then it melts ice floating above.

So fresh water is heaviest about 39° at some temperature between 40° and 37°, and many other fluids appear to have a temperature of greatest density.

Salt water of the specific gravity of 1.026 freezes at 28°. At the specific gravity of 1.104 it freezes at 14°.

As steam at 212°, or as vapour at any temperature, water takes up most space, is lightest, and refracts light least. As ice at 32°, 28°, or 14°, it takes up more space than it does when fluid. As fluid, water takes up least space, and is heaviest; it has greatest density, and refracts light most.

So vapour floats on ice, and ice on water. At or about 37°, water, having got rid of extra heat, seems to begin to assume the angular shape of ice crystals. Curves become straight, waves are calmed, bends change to angles, while coloured water is freezing. The angular shape takes more room, the crystal is bigger than the cold drop, but there is no more water in it. So the crystal floats, and crystallizing water floats up next beneath crystallized ice.

From these experiments it follows that layers of water of various changing temperatures must move; and the temperatures being known, the direction of movement can be inferred.

From other experiments it appears that air and sea are in fact arranged in moving layers of various thickness, temperature, weight, and density.

On a fine summer evening when the sun is nearing a sea horizon, some of the air-shells may be seen. Rays of light are variously refracted by lenses of different densities, and the atmosphere is a great compound concave lens.

The glass of an argand burner, though transparent, appears to cut across the flame like a dark bar at the bent shoulder. Any lamp shews the effect. When the sun is near the horizon, his light slants through domes of air which surround the earth, and, like a nest of glass shades, they refract the rays more or less according to their shape and density.

The round ball is distorted. As it sinks the disc of light is bent and broken up into irregular figures. The sinking light in passing the layers darkens, but the bars are flat and stationary, so the edge of the sun appears to bend and wave, as a lamp does when the shoulder of the glass chimney is lifted or lowered. If any clouds hang about the horizon in the twilight, they too are flat, for they are the edges of thin shells of condensing vapour, which made the air dense before sunset.

Fig. 16.

These upper regions have often been explored. In Mr. Glasier's late balloon ascents, in which pluck was a very conspicuous feature, it was found that although high regions, which correspond to regions of perpetual snow on high mountains, are cold, still sensible heat decreases irregularly, and is constant at no stage on the scale. Because snow falls upon the highest mountains, water in some shape must be carried higher than 28,000 feet above the sea; and accordingly, in June 1863, cirrus clouds and a blue sky were

seen far above a balloon raised four and a half miles above England.

The temperature was 17° at the highest point reached, but far above that cold shell of air, water was packed in the form of cirrus clouds. They marked a dew point. Lower down, from 13,000 down to 10,000 feet was a deep bed where the temperature was 32° or 33°, and the air thick with vapour and frozen water. Mist, snow, and crystals of ice were floating and falling ready to be moved in any direction. The water was there in a solid form, ready to rise higher if the air rose, or to fall into lower and warmer strata, or on the earth. It was colder below, but near the surface was summer weather, and a temperature of 66°.

The arrangement was unstable. It was one to cause motion ; the heavy snow was above and the light vapour below ; the one must fall and the other rise. But if the snow came down to the region of 66° and summer weather, the earth's own heat and the extra store which the sun had given it, were ready to send the piston up again to the dew-point.

In a former ascent at Paris, a temperature of 16° was reached at a height of 23,000 feet above the ground where the temperature was 87°. The mean temperature at the ground in Nova Zembla is 17°.

It is not given to every one to mount so high with a whole battery of instruments, but it is easy to understand the arrangement of the atmosphere from models worked by heat and weight, when it is known that temperature decreases as the distance from the earth's centre increases, and that heat is disposed in layers above the ground.

Air in high regions is pressed by less weight. It is colder than air near the earth ; but like a sponge relieved from pressure, it is better able to hold water the higher it is.

There is more room in it, so to speak, and the dew-point is colder. When air at 32° was found resting on strata sensibly colder, the upper layer was still better able to hold water, because still more expanded by the heat which it had absorbed.

A stream of warm, damp air, rising because it is warmed and expanded ; expanding still more as it rises ; because there is less air above to squeeze it, is like a balloon ; and carries great part of its load of water to high regions, where there is little sensible heat, but much heat latent.

Clouds, high snowy mountains, and balloon ascents, prove that water is somehow lifted more than 28,000 feet above the sea, and there seems nothing to stop it short of the limit at which the earth's weight and the earth's heat balance each other in their action on water.

As water evaporates spontaneously at all temperatures, and even in vacuo when the weight of the atmosphere is taken away, heat moves water one way, and weight moves it in the opposite direction. That is the working principle of the atmospheric engine, though the machinery is complex and hard to comprehend.

The depths of the sea have also been explored, though they have not been visited. Deep sea soundings have been taken ; living star-fish have been brought up from a depth of 15,600 feet ; the sea is fluid at the lowest depth reached ; so it must obey laws which affect fluids in smaller quantities.

The sea is packed in layers like the bath, the pond, the model tank, and the atmosphere, and these all circulate for the same reason.

Let a few of the temperatures which are given in scientific works be arranged in the following shape, and the movements shewn on Mauray's diagram, page 28. On the diagram page 34°, and on the woodcuts page and and will be

found to coincide in principle and direction with the ascertained movements of ocean and air.

Fig. 17.

Fluid water being heavy at the Poles and light between the Tropics, would move like air and clouds if it were deep as the atmosphere ; and the sea does, in fact, move diagonally on meridians, where land will permit.

Water, then, is found in three conditions at different temperatures and pressures, at different distances from the earth's centre ; and the order of the arrangement above the solid crust is

	Weight and Cold.	
1	Gaseous matter,	Air and watery vapour.
2	Solid,	Ice and air.
3	Fluid,	Water and air.
	Heat.	

Two opposing forces meet at some layer of the sphere, and so work the air and the water-engines, to which geological denudation is ascribed. Characters which these engrave upon the solid earth are written with heat and weight.

But because the double engine consists of many cutting wheels, and each wheel makes a different tool-mark, rocks which bear marks of air and of water, are variously marked by the contriver of the engine, which carves hills and glens.

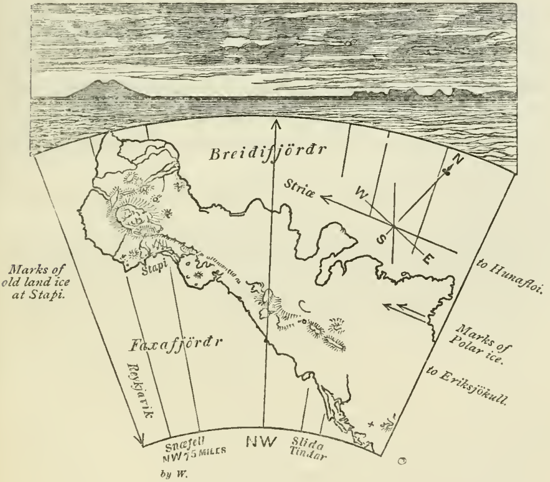

FIG. 18. PLAN AND ELEVATION.
Map and Sketch of the SNÆFELL Peninsula, opposite to Reykjavik. After sunset, June 27, 1862.

CHAPTER IX.

DENUDATION—TIME.

There is an ingenious device for sculpturing marble, which illustrates the working of engines which carve hills.

An artist's thought is modelled in clay, and cast in plaster of Paris. A block of marble is laid beside the solid thought, and the engine is placed between the stone and the model. Power is got out of fire and water, or water and weight, and it is passed through a train of wheels, strings, and levers, to a small cutting wheel which revolves rapidly at the end of a bar.

Let this wheel stand for a circulating atmosphere charged with water.

At the other end of the bar a point touches the model, and universal joints allow the bar to move every way. But the engine is so contrived, that if the point rises, the wheel rises as much ; if it falls, the cutting-wheel falls also, and where it touches, it cuts away marble, and makes tool-marks and a pile of chips. Gradually the artist's thought looks out of the block of stone. It bears the marks of a steam-engine worked by heat and weight, but it is a man's thought nevertheless.

Geologists have to learn the tool-marks of their trade.

Every tool makes a different mark. The cutting-wheel of the sculpturing engine cuts grooves, which the engineer could distinguish from an artist's touch, and many different wheels are used to make coarse and fine carving.

The brass wheel of a glass-cutter makes a different mark from the iron wheel, and the wooden polisher makes a different mark from a leather wheel.

A carpenter's adze cuts out a curved hollow, an axe makes a flat-sided notch, a handsaw marks straight lines and acute angles on two parallel flat sides, a circular saw draws cycloids on opposite planes. A gouge, a chisel, a rasp, a file, a centre-bit, a bradawl, a plane, a plough, a glass scraper, sandpaper, all the tools in the chest leave marks on wood which a carpenter knows. The work of a particular tool with a notch in it, of a blunt tool or a sharp tool, may be known by the mark.

A blacksmith knows the dent of a sledge-hammer from hand hammering; the groove cut with a cold chisel from the hole punched out with a square point. He has but to look at iron-work to know the tools used to fashion it, because he knows the tools and how they work.

A mason knows pointing from chiseling, dressing, and polishing; he can distinguish a stone that has been hand worked, or sawed up, from one broken out of a quarry.

A miner knows the mark of a pick from that of a jumper; the crushed surface broken by a blow, from one torn by a blast.

A goldsmith knows the touch of a graver wielded by skilled or by unskilled hands.

A wood-engraver, a shoemaker, an optician, an engineer, a tinker, a painter, a crossing-sweeper, a shoe-black—any craftsman or artist knows the tool-marks of his familiar art or mystery, or the sweep of his brush.

A geologist ought to know the tools whose marks he strives to understand.

It is taught, and it is true, that the earth's outer shell has been enormously "denuded."

So many feet of rock are wanting to complete an arch whose piers remain; the missing stones have been removed. The uppermost layer of a stone arch has been taken away, and the next course laid bare at one part of the bridge, which remains standing, though it is worn down by tracks. The crown of an arch has fallen, enough stone to make a mountain has been denuded from a particular part of the earth's crust. How the mountain was removed is to be learned from the marks of the engines used to remove it.

But unless the engines, and their modes of working, are studied, their work may be misunderstood.

It is often said that a big strath was hollowed by the river which flows in it; or that a mountain is a weathered rock which crumbled into its present form; but in many cases the river has little to do with the carving of the glen, and the weather has scarcely touched the hill since it was sculptured.

The river might have done a great deal in a long time, but if the whole land was under the sea, river-work must date from the rise of the land. If there be a sea-shell high on a hill-side, rain could not get at the rock, when the shell was buried under water; so rock-weathering, like river-work, had a beginning, if sea-shells and loose rubbish are above the worn rock.

Iceland is one of the great battle-fields of the powers of the air which grind down the earth.

It is a good place to watch the cutting wheel, the engine fire, and the smelting furnace; it is a place to see work in progress, to study the engines, and learn the tool-marks of fire and frost. Heavy work is there going on between large ocean currents. The same work is doing wherever air, vapour, ice, and water, heat and weight, are together, but the rate in

Iceland is faster than it is in countries where the heavy work is done. There also is a starting-point from which to reckon time, for the finished work of fire is wholly different from the tool-marks of the grinding engines of frost.

At the outset, it is clear that the carving engine has been long at work.

The beginning from which to reckon geological time is commonly wanting. The supposed rate of wearing by waves and of deposition by rivers, the thickness of beds deposited or destroyed within some historical period, these, or such as these, are the common measures for time. But, if ocean currents moved faster, climate altered or changed place, then work done may have taken more or less time to do than its finishing touches seem to show. There is a river-mark in Iceland from which to count time with tolerable certainty.

If the first mark of denudation was made upon an igneous surface, the cooling of the crust is a point in time from which to reckon. At Thingvalla is a river called the Oxerá, which, in ordinary weather, is about the size of an English mill-stream. The water would pass through one of the large iron pipes which carry Thames water to London. The Oxerá falls over a large cliff into a rift. There can be no doubt that the cliff over which the stream now falls, was formed by the falling away of the opposite side of the rift, and that the cliffs and the rocks in the valley were as fluid as water in the river at some time. To see the place is to be convinced of these facts. The Oxerá began to fall over this cliff, and denudation began at the edge, after the lava cooled, and after it split. There is no water-mark on the opposite cliff, so the stream most probably began to flow in its present channel when the bottom of the valley sank, and the plain became a slope.

The whole surface of this lava for many square miles is

marked by certain rope-like coils, which formed while the hot fluid was curdling, and these rise about two inches above the surface. They are fire-marks.

The water of the Oxerá has worn the stone at the edge of the cliff for a breadth of about thirty yards, at the place where water is always flowing, unless frozen ; the channel is about two feet deep, and three or four wide. Where water flows only during floods, the coils have not been worn away, but they are smoothed and worn ; and near the deep channel, the lava surface is very like that of slag which has been used to mend a road, and has been worn by traffic. Specimens are common in Lanarkshire and other iron districts.

Calculating from the angle which the sides of the rift make with each other, and with the horizon, the beds of lava may be about 600 feet thick, and it must have taken a long time to cool such a mass. As it happens, the Icelandic Parliament have met at the Logberg, on the surface of the lava, for 800 years, and there has been no great change in the valley during that time, for the ground is minutely described. At the earliest date recorded, the Oxerá fell into the rift ; a deep pool in it was the place in which wicked women were drowned ; trees grew on the lava, horses found grazing by the river side. It must have taken a long time for soil to gather after the lava had cooled. But things had arrived at this stage 800 years ago. Say that water has been wearing its stone channel for 1000 years only, and the depth from the fire-mark, the wrinkle on the lava, to the bottom of the water-mark, two feet, gives a rate of one foot of lava in five hundred years. The rate, in all probability, is far too rapid, but it gives a great age for these Icelandic rocks, and for those on which they rest.

At other spots streams have cut wide and deep channels in lavas of the same kind. The river at Godafoss, in the

north, has cut a deep channel, and has worked its way backwards for some hundreds of yards. The smoothed water-worn surface is plainly seen on cliffs far below the fall. The river is large, so it must work faster than the Oxerá ; but if one has cut 900 feet, while the other has only cut two, they cannot have begun to work at the same time. Giving one river credit for only one-third of the work done, the rate makes the age of the lava at Godafoss 150,000 years.*

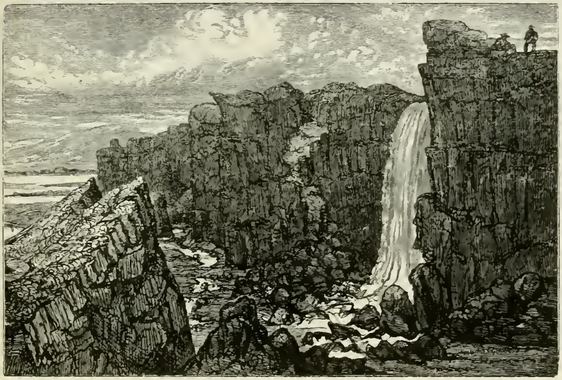

FIG. 19. ICELAND, July 30, 1862.—FALL OF THE OXERA.

But where streams do not flow on the lava about Godafoss, the wrinkles have not been worn off, so weathering has not denuded a quarter of an inch of igneous rock in that time at least.

Other Icelandic rivers have done a great deal of work. The Bruerá has drilled large pits, and it has scooped out smooth channels of considerable depth.

* 300 feet, at one foot in 500 years.

At Merkiarfoss, near Hecla, a small stream has dug out a large trench, and it has drilled the most fantastic peep-holes through a black conglomerate of ashes and stones, and this river began to work after the volcanic mountain had grown.

At Skogarfoss, a river falls over a cliff on a sea-beach, and it has dug backwards into the hill for some fifty or sixty yards. It began to dig after the sea had done its undermining, and had retired towards the horizon away from the base of the old sea-cliff. At the wearing rate the sea made the cliff 75,000 years ago.*

All these times may be wrongly calculated; they may be too short or too long; but when the last formed igneous rocks have endured so long, it is plain that the wearing of rocks to form known sedimentary beds must have gone on during ages, which it is vain to calculate. However rapid the rate may have been when the grinding-engine first began to work, it has been carving and packing chips for a very long time. The world is an old world; and sculptures on it are old inscriptions, though made with engines which are working now.

A river is a grinding-wheel in the denuding engine; a soft tool which makes a mark. Tools of the same kind are cutting and have been cutting patterns on rocks ever since water rose from the sea, fell on shore, and flowed towards the earth's centre; but each river had a beginning, and the time which has elapsed, since land rose above the sea, is too short for the work attributed to many rivers.

* 150 feet at 1 in 500 years.

CHAPTER X.

DENUDATION—RIVERS.

Before a craftsman can recognise a tool-mark, he must be familiar with the tool; before a geologist knows river-marks, he must study the ways of rivers.

Falling water proverbially wears a stone; stones wear in many ways, and at different rates; but that which the Oxerà and other Icelandic rivers have done to lava, streams must have done to rocks, from the time when the first shower fell, and the first stream began to flow. So ancient river-marks ought to be found on the oldest rocks, and these ought to resemble modern river-marks.

Clouds rise up from earth and sea. A river takes its rise in the clouds, from which drops fall. Fallen drops collect and roll from hills into hollows, and so a river grows. On the stony top of a granite mountain puddles may be seen forming during a shower. They fill from above, overflow, and so help to fill lower hollows in every rock and stone. These, in their turn, overflow and send off larger rills, which take the shortest way towards the earth's centre, and roll down the steepest slope.

Streams which flow straight down steep hill-sides must cut straight furrows, if they cut at all. Such trenches may be seen on the flanks of Icelandic volcanos, which have grown up in modern times; and on the sides of steep hills everywhere, and this river-mark always has the same general form.

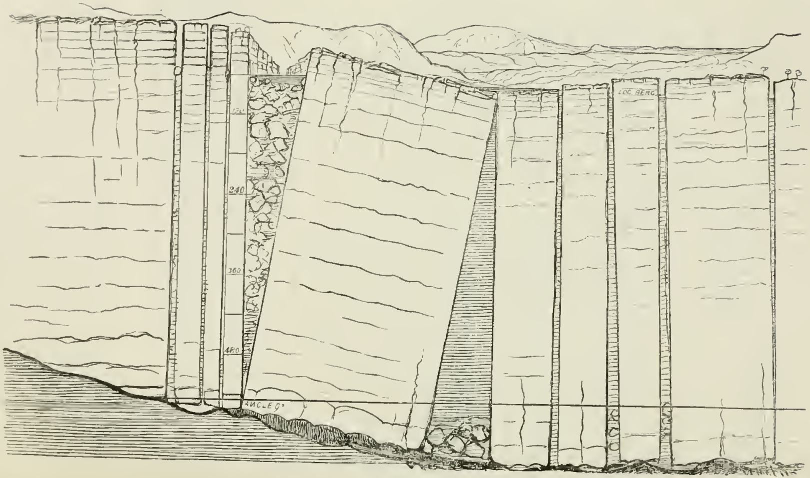

Fig. 21.

The steeper the mountain, the straighter are its gorges ; the deeper the trench dug by rain, the more rain-water tends to gather in it ; the water makes a path, and follows it, and it works faster as the work grows deeper. The mark is like V.

For this cause an ancient mountain, which has borne the brunt of the battle for a long time without the shelter of the sea, generally is so deeply furrowed, that little of the old shape remains. A cone, for instance, is grooved and fluted into steep peaks and ridges which meet at the highest point where water falls. The mountain is weathered, and becomes a rain-mark, unless it dives under water for protection. The shape is like Λ.

The mark which a river engraves on a country-side, is like a flat branch. Rain-pools are leaves and buds, rills are twigs, and rivulets branches which spring from a stem whose roots are in the delta at the sea.

The plan, at first, is a repetition of the forms of the letters V and Y, in which straight lines meet at various angles. But as the slope gets less, straight lines curve, and the stream winds in the plain like the letter S.

Any wide landscape seen from a high mountain, any well executed map or model, shews these characters which fluid engraves upon solid. They recur in every quarter of the globe, in every continent, field, or gutter, and could be read anywhere.

The section of a gorge dug by a torrent is angular, like V ; or the sides are perpendicular, like U ; on a gentle slope the section of a river bed is curved ‿ ; and the curve gets flatter as the river spreads and winds in a shallower bed, on a smaller slope. The section of the Λ is a convex curve ⁀, fluted by numerous river-beds. It is a mark of deposition, not denudation.

The whole of these familiar forms result from the movements of flowing water, and these result from the force which drags water towards the earth's centre ; and from the resistance of the crust which impedes the movement, changes its direction, and stops it at last in some rock basin.

The seed from which a river grows is a rain-drop. A drop of rain falls perpendicularly in a calm on a flat stone, and spreads every way. It strikes, rebounds, splashes, and scatters. If water is poured upon level glass, it spreads every way. The form is a star *

The force which moved fluid towards the horizontal plane is turned aside by resistance, and the water is pushed sideways, at right angles to its original direction of movement ⊥.

Ink, dropped on box-wood, obeys the law, and draws its own shape for the engraver.

Fig. 22.

As drops diverge, so showers spread from a mountain-top, and rivers part from a watershed.

Water flowing in any open channel rebounds from side to side, and from the bottom ; so a river wears its rocky bed

irregularly, but on system. Resistance on the right bank reflects the stream towards the left, and there it digs a hollow, and swings back. Resistance at the bottom throws the stream upwards ; but only to fall again after drawing a convex curve. Where the water falls, it digs a concave hole, from which it rebounds again ; and so the river wears its bed according to force and resistance, and in curves. On a steep slope, zigzag movements are small in proportion to the fall ; the water hits the side of the trench at a small angle, and rebounds at one still smaller. So the mountain torrent works most at the bottom, where it hews out rock pools ; leaping from step to step, through deep ravines, in foaming cascades.

The Ruikan Foss in Southern Norway is a good specimen of river work.

The rock, over which a considerable stream now falls, is a coarse sandstone or conglomerate. The upper valley is a rounded hollow, at the bottom of which the river has dug a shallow trench. The upper hollow ends in a steep slope ; and the lower valley, like the upper, is a rounded curved rock-groove, through which the river meanders ; but the bottom of the groove is covered with beds of gravel. Both these glens, the slope, and the surrounding hills, bear marks of ice ; so the river did not hew out the glens ; but it has dug a narrow trench in the slope, and it is sorting the debris in the lower glen. The notch in the slope is 700 feet deep ; and rounded water-marks are clearly seen on the steep walls of the gorge, from top to bottom. The fall is working rapidly up stream ; digging at the bottom of the pool, at the foot of the rock ; undermining, sawing, and working back into the slope. It leaps out of the pool with a wild roar ; the bed of the stream is cumbered with enormous stones. Where undermined cliffs have fallen, long banks of talus slope down

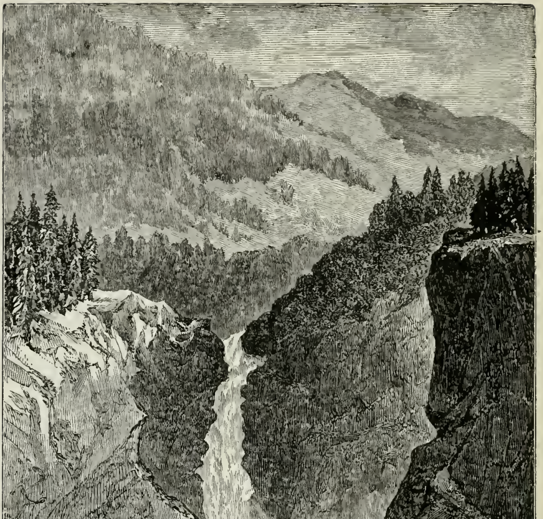

Fig. 22.

to the water's edge, ready to be swept away, and sorted lower down. The tool, the mark, and the chips, are together; and the power of the engine is displayed in the work.

On one point it is possible to lie on a long flat stone, look over, and drop pebbles from the outspread hands, 700 feet down into the gorge.

If a fall of undermined rock chokes the stream in this big ditch, there will be a deep lake in the slope between the glens. The water will fall harmlessly into it, and the rate of wearing and scene of action will change. The water will work most below the dam, till it is removed, and then the lake will disappear, and the river will begin at the bottom of the old fall again. But the sides of the trench will be angular where fractured, or smoothed where water-worn; the torrent-mark will continue like the letter U ploughed out of the bottom of the curved glen ‿. It will always be an angle L dug out of a slope.

The Vöring Foss in the Hardanger Fjord is another notable specimen of river-work of this class.

A large stream flows from snowy mountains, amongst which a few glaciers still nestle. It flows over an ice-ground plateau, in which it has worn a shallow bed; but when it reaches the sloping side of the lower valley, the stream plunges suddenly sheer down about a thousand feet, into a black chasm, so deep and narrow that the fall can only be seen by looking straight down at the pool.* Great clouds of spray dash out, and whirl up, rebounding, and driven by a strong wind caused by the fall. The spray collects on the hill-side, and streams down the rocks in miniature falls, which are blown up again. So the air in the gorge is filled with clouds of spray, and the pool is generally invisible. About

* By dropping stones, and timing their fall, the height was made 1100 feet.

Fig. 23. The Polished Glen, Eight Miles below the Voring Pass.

a Torrent cutting through and obliterating the ice-mark. *b* Ice-polished hill. *c* Birches, small pines, berries, fine turfs upon ice-polished rocks, with boulders and perched blocks.
d River which has not obliterated the old marks upon rock points in it. [illegible]

noon, when the sun is clear, a traveller craning over the edge sees three parts of a rainbow about a black shadow with luminous edges ; a ghost of himself, wading through white clouds, which whirl and drift down the gorge like boiling mist.

It is impossible to sketch a hole of this sort ; but the mark which the river is hewing out in the hill-side is one which could not well be mistaken for any other tool-mark. It is the same as the mark at the Ruikan Fall, L.

The valley into which the river leaps bears other marks, which are as easy to read when the tool which makes them has been seen at work. The glen was scooped out ; but rivers are only cutting through and wearing out traces of ice. The river-mark is more than a thousand feet deep, but it is a mere scratch on the side of the glen in which the river flows.

Another famous Scandinavian fall is Tann Foss in Jemptlan.

It is near the watershed of the country, and the frontier between Norway and Sweden, on the road between Trondhjem and Sundsvall, between 63° and 64° N. lat. It is not a fall in a river ; there is no rapid above it. The water of placid narrows at the end of a quiet lake suddenly tumbles over a slate cliff, and becomes a quiet lake again, when it escapes from a boiling pool. The fall is 120 feet high without a break. The cliff over which it leaps is sharp, and its structure is clearly shewn where the broken horizontal beds project into the foam. In the very middle of the fall, level with the upper lake, is a square block of dark slate, which has resisted wear and tear at the edge. It is called the Chest. It is told that a bear, in trying to cross the narrows above the fall, got carried down and landed on the Chest. There was no escape ; so, in the extremity of his dismay, the bear screeched fearfully. A man heard him, and taking a most unfair advantage, pelted the

brute till he sprang over the fall, and drowned himself in despair.

Peasant proprietors still pay a nominal tax for a right to gather drowned elks and other game at this fall; for the smooth narrows tempt creatures to swim over, and many used to be drowned like the bear, when game was abundant.

From the top of Areskutan, a neighbouring mountain, which is some 3000 feet higher than the lakes, and 4000 above the sea, the work of this northern Niagara is seen to be a mere notch chipped out of the edge of a long terraced step, which runs along the hill sides, north and south, for many miles. It seems to be one of the many contour lines which coincide in general direction with the coast of the Gulf of Bothnia. The rock basin, which is a lake on the upper step, overflows; and the waste, which is about equal in volume to the Thames at Windsor, must have slid down the terraced rock into the lower basin at first. It has dug an angle now; but it has dug less than a hundred yards into the slate, for the original slope is entire elsewhere. It cannot dig much deeper than the water-level of the lower basin, for the water guards rock.

From this northern Rhigi, a vast expanse of country is seen on a clear day; and it has the characteristic shape of ice-ground rocks. The district is one great undulating slope of gray rock, green forest, meadow, and corn land; with conical peaks, rising here and there, and with silver lakes shining in their rough stone setting everywhere. One white snow-flake, a speck ten miles off, shews where water is foam, and a river is grinding rock at Tann Foss.

On a calm, clear evening, in September 1850, the wide landscape was very beautiful, and figures in it, and sounds in the still air harmonized well with the scene. A wild call

blown from a birch-bark tube rose up from a village at the foot of the hill, and then far below, as it seemed, almost under foot, tiny cows, and sheep, and goats, came slowly dropping, one by one, out of the forest into the road. Their bells tinkled as they went streaming after a bevy of girls, poking their noses into their hands for salt, lowing, bleating, and capering homeward to be milked and housed.

Close at hand a family of Röjoxa (*garulus infausta*) with their bright burnt-sienna wings, chattered and fluttered amongst green and yellow birches; and high overhead rose the peak, white with the first snow of winter, but rosy with the glow of sunset.

The denudation of rocks in this district is conspicuous, and the amount is enormous. It is plain that rivers and weathering will not account for the shape of Sweden. It is equally plain that other engines have worked here.

On the watershed, not far from Tann Foss, at the road-side—at a height which Robert Chambers estimates at 2000 feet—the clearest marks of glacial action are still perfectly fresh on rocks, in spite of weather and rivers. These marks prove that ice travelled over the hills from N.E. to S.W., at 2000 feet above the present sea level, at the place where streams now part and run to the Baltic and to the Atlantic.

It is an established geological fact that Scandinavia is rising from the sea. It is proved by marks made on stones in the Baltic, and watched since 1731, and by other marks.

It is evident that the hill-tops must have risen first, so the highest fall must be the oldest. Tann Foss, working at 1000 feet above the sea, has worked longer than Trollhattan, at about 307 feet; and the ice-mark at 2000 feet is older than the river-mark at Tann Foss, if it was made floating ice.

At the famous fall of Trollhattan on the Götha Elf, a

green river as large as the Thames at London, the waste of a great inland sea, and the drainage of a large tract of mountain and forest, escapes from a rock-basin, over a shoulder of rock, and slides down a rock-groove for about three miles. It rolls over the edge unbroken, like a great sea-wave, and slides down for twenty or thirty yards before it is streaked with foam. Below the rapids, the river meanders through a plain of boulders and drift, which partly fills the rock-groove. The plain fades into the sea, and rounded islands of rock, of the same pattern as the hills on shore, gradually decrease in height and size, till they become sunken rocks, and disappear at last under the Kattegat.

A good Tornea rapid is almost as grand as Trollhattan.

The striking feature of the place is the absence of river-marks. Denudation, worked by water, is insignificant. There is no section, no cliff, no step L worn in the slope. Trollhattan is a slide, not a fall. It is but a baby in geological time.

The country is well known to the writer; it is well described by Robert Chambers in the Edinburgh Journal, N. S., 1849.

From Stockholm to Göteborg, from Malmö to Christiania, glens, mounds, and hills, are ice-ground rocks of one pattern. Speaking generally, ridges and hollows, rock-grooves and river courses, rock basins, and lakes large and small, stretch N.E. and S.W.; and in many places striæ are fresh on the rocks, and point the same way.

At Christiania serpulæ adhere to rocks which are now 186 feet above the sea-level. When these shells lived where their mortal remains are found, the sea was over the rock.

At Udevalla, further south, a bed of sea-shells is found in a bank of gravel about 200 feet above the sea.

At Sarpsborg sea-plants have been found twenty miles inland, and at a level of 450 feet.*

But a sea 500 feet deeper would join the gulf of Bothnia, the Wettern and Wenern, the Kattegat, Skagerrack, and the German Ocean; sink Denmark, drown most of southern Scandinavia, abolish Trollhattan, and stop the war.

So Trollhattan only became a water slide, and began to grind rocks about the time when sea-shells and plants died for want of sea-water at Sarpsborg, Udevalla, and Christiania.

The river-mark is a measure of time, for the fact is established that this river began to slide when the lip of the rock-basin rose above the sea-level.

In Glen Fyne, in Scotland, are similar gorges dug by mountain-torrents in the sides of rounded hills.

The Eagle's Fall, above Ardkinglas, is not less than 300 feet high, and it has dug a wild, precipitous gash like the bed of the Vöring Foss; but the gash is scarcely seen from the valley below, which was scooped out by some other engine.

There is scarce a glen or rounded hill in Scotland which has not some modern river-work upon its steep sides, to contrast with wider, deeper, and older marks of denudation. There are numerous marks which prove beyond dispute that Scotland has risen from the sea, and that many of her waterfalls were born after the death of shells which are buried on hill-sides.

Farther north, about lat. 66° in Lulea Lappmark, is a fall which is famous all over the district, but which no Englishman has yet described. The Lapps call it Njoammel Saskas, or the hare's leap, because a hare can spring over a large river where it has dug a trench in solid rock.

* For details, see Chambers. The papers are very true and amusing pictures of Scandinavian travel, and geologically valuable.

Still further north, about lat. 70°, a large river which drains the great Enare Träsk, leaps down a fall in a narrow gorge which it has sawn through rocks. The country retains marks of glaciation over five degrees of latitude, between the Polar Basin and the Gulf of Bothnia.

All the large Swedish rivers, without exception, have one character ; they have done very little denudation since they began to saw through ice-ground rocks ; and what they have done is work of one pattern, more or less advanced, and most advanced at the highest level.

If the value of the unit could be found, the amount of river-work done might be measured from the ice-ground surface, and dimensions converted into geological time.

In Iceland, where streams work on igneous rock, the torrent carves the same pattern. At Melar, in the north, a small river leaps down a steep hill-side. It has made a succession of falls, with deep rock pools and rock pits. The rock is bedded trap, traversed by whin dykes, but the pattern of the river-bed is the same as in Welsh slate.

At the Devil's Bridge near Aberystwith a stream has sawed a groove in blue slate. It is ninety feet deep, and about six wide. The smooth water-worn surface is fresh from top to bottom on both sides of the groove, and at the bottom, in the bed of the stream, there is no joint or fracture to be seen. The whole is a river-mark, a trench sawn by running water straight down into the slope of compact slate which some other denuding agent wore out before the river began. The rivulet has but ploughed a groove at the bottom of a curve ; it has turned **V** into **Y**. River-marks are the same everywhere, and this is the mark of a mountain torrent **L**.

But drift and sea-shells have been found on Welsh hills at a height which would sink the hills at the Devil's Bridge

far under the sea, and all Wales is ice-ground. So this torrent, like the rest, had a beginning, and from that the begining of the groove must date.

The highest fall in Europe is that of Gaverni, in the Pyrenees. In descending the pass which leads from Spain into France, it is seen about four miles up a valley to the right. It is amongst the wildest of rocks and mountains, and there does not seem to be a tree within miles of it. In September 1842 new fallen snow reached down to the verge of the cliff, and early frosts kept the stream low. The fall seemed little more than a white thread on the dark rock face, but the water fell unbroken to the bottom except at one spot where it touched. In this it is unlike the Staubach in Switzerland, which, though lower, reaches the bottom as a shower of spray. The river at Gaverni is of considerable size, but the river-work is as nothing to the glen which some graving tool had sculptured before the river began to fall over the cliff.

High up in the Pyrenees are tiny glaciers, and the glens bear the marks of old ice.

Rivers have done similar work in Spain.

At Ronda, a small stream, which was almost dry in June 1842, runs through a trench hewn in sandstone. It is a strange water-worn Barranco cumbered with big stones, amongst which Spanish washerwomen do their best to rinse clothes. The sides are so steep that the river bed can only be reached at a few places. It is so narrow that a small bridge, with a single Moorish arch, joins the two sides. Emerging from this narrow groove, the water leaps down several steps cut in the sandstone rift, and through the cliff; it passes under the famous Ronda Bridge, turns several mills, and finally winds off through a lower plain, marking its course with verdure. The town is entered from the upper plain, and

this great cliff and chasm are so little seen that three seedy travellers spent a hot day in a venta a hundred yards from the great bridge, voting Washington Irving's description of the place to be a sheer invention. It is, in fact, one of the strangest places in Europe—a town built on a kind of rocky island on a cliff which a mountain stream has sawed off from a raised plain, with a broken edge.

Some other tool must have carved the Spanish hills, and at Grenada snow and ice still glitter above the hot plain, on the peaks of the Sierra Nevada. In the plains are beds of clay, which look very like ice-work.

In the Morea it is the same. The beds of torrents are grooves with steep sides ; the glens through which the rivers flow are wide rounded hollows, and on high mountains near Cape Matapan and above Sparta, snow-wreaths still out-last summer heats.

In the Alps, where glaciers abound, rivers often run long courses, beneath ice roofs. They do the work of rivers loaded with ice-floats, and the glaciers work beside the rivers, which flow with them in rock-grooves.

Old marks of larger glaciers are found in large rounded glens, on the banks of brawling streams, which are sawing narrow trenches at the bottom of every glen. A good collection of photographs will best shew these forms, and they are common now-a-days.

In Iceland, where glaciers are far larger than Alpine glaciers, many rivers and their marks are peculiar.

Enormous tracts are covered with vast snow-heaps and glaciers, and though the surface of this upper system of beds is tolerably even, the next series below it—the shattered igneous rocks upon which the glaciers rest—must have a surface of

hill and dale like neighbouring districts where the upper series is absent.

The water series deposited from air is fusible at ordinary temperatures, and it is constantly melting, if it is constantly growing from above. In summer, the surface melts, because a hot sun shines down upon it. The undermost layers are always melting slowly, because the ground is warm. When the earth-light shines out; when a volcanic eruption bursts forth under the snow; when the earth's internal heat radiates upwards more than usual, the snow turns to water and steam. The water flies back to the clouds, or sinks as far as it can, through snow, névé ice, and shattered lava. It flows down hill like other water, gathers in glens and valleys, bursts through passes under ice and lava roofs, and comes to light at last a full-grown river.

Large rivers are hidden throughout long courses, and burst out of ice-caves to fall into the sea after a daylight course of a few miles.

The rivers which drain the country which lies under Myrdals Jökull, and the Vatna Jökull, are of this kind.

The glaciers approach the sea, and their drainage is in proportion to their great size and nature. A mass of frozen water as wide as Yorkshire, and many thousands of feet thick when exposed to a hot sun; or when a flood of lava spouts up into it, sends down streams of muddy water, larger than rivers which flow from tracts of equal area elsewhere.

Many Icelandic rivers are in fact as broad as they are long, and run their whole daylight course over a delta.

These are always difficult to ford. Travellers pass them guided by men who know the district, mounted upon ponies used to wading, which are called "water-horses." A string of ponies, loose or loaded with baggage and riders, are tied head

and tail; and the train, led by the water-horse, crosses over the delta, up one side, and down the other; wading, sinking, scrambling, sometimes even swimming; sometimes on dry sand-banks, fording for a distance of several miles. Sometimes the river-bed has ice upon it under water. When the horses tread on one side, the stream gets under the upper edge of the broken ice, and great plates rise up and turn over and slap down, as if to crush the rider. Sometimes the leading horse sinks up to his girths in a quicksand, and it takes a cool head and a skilled guide to know what to do in riding over such an unusual ridge of country. The plan of the trail is Λ, the section ⌒.

In spring these broad fords are impassable. The water is too deep and strong even for Icelandic ponies to stem; and it is cumbered by great blocks of ice, which fall from the glacier, and float out to sea—no creature could live in such a torrent.

The bed of these subglacial rivers must be like the beds of other rivers, but their banks must be very different. In the hollow glens through which they now flow, will be traces of denudation of two kinds, if the ice melts. Marks will shew the wearing of rocks, by a river loaded with ice-floats, mud, and stones, and also the work of heavy land ice, which a change of climate may cause to vanish altogether from this region.

When an eruption takes place water-floods do marvellous work in a very short time, for the rate of denudation changes. Farms are obliterated; houses, cattle, land-marks, men, and their works, are swept away like a heap of rubbish, and the sea-bed is filled near the shore with large banks and heaps of debris, sorted by water, in water.

If ice were gone, volcanos extinct, eruptions forgotten, and the sea-bottom raised higher, it would be hard to account for

hills of debris which skirt some parts of the Icelandic coast, and which seem to have been formed in this way.

They are monuments of fire and frost, denudation and deposition, and they must contain records of sea and land, confusedly mingled, though packed in layers.

In Greenland and in Spitzbergen, according to the descriptions of travellers who have visited these regions, subglacial rivers find their way into the sea without shewing their dirty faces in daylight anywhere. A sea discoloured for miles is the only symptom of the stream which must be sawing rocks under ice as it does in the open air.

The beds of such streams can only be got at by inference, but the inference is plain.

From Greenland to Iceland, from Iceland to Scandinavia, thence to the British Isles, and to Cape Matapan, there is one connected series of cause and effect. The engine is working at one place, the marks are at another, but engines and marks are side by side at many places, and the marks of rivers are plain everywhere.

North and south, east and west, European river-marks are alike, and bear witness to the fact that rivers have done very little geological grinding since they began to flow down European rocks.

In many places in Iceland rivers are subterranean. The drainage waters of large tracts of country sink bodily into the riven porous earth, and not a drop is to be seen on the surface. On Hecla and the lava plains to the north there is no water in summer, but clear cold streams burst out at a place called the springs, near the foot of Hecla. Hot springs burst out at many places, and the plains which lie between the sea and cliffs of igneous rock, all round the island, are bogs which rival the worst in Connemara. There is hardly

any water to be found about Skjaldbreið. There is no river of any size to feed the lake at Thingvalla, but a very large river runs out of the lake.

What the beds of these underground streams may be like is not easy to guess, but probably they resemble underground rivers elsewhere, and some of these may be got at.

In Park mine, near Wrexham, the course of a subterranean river was cut in looking for lead. It can be got at by scrambling, and it is a curious place. A large cavern is water-marked from top to bottom, and old sand-beaches in passages mark a water-level fifty or sixty feet above the stream. The stone is drilled into the most fantastic shapes—oval windows, peep holes through which candles glimmer and water shines ; handles to grip, peaks and pillars are common, but there is no straight line or flat plane or acute angle, except where stones have fallen ; and fallen stones remain where they fell. The rock is mountain limestone, cupped by millstone-grit ; and rain-water, which contains carbonic acid, melts limestone, slowly, as water melts salt. In the bed of the stream are pebbles washed from a distance. A clear murmuring brook can be followed for a great way up stream ; down stream it plunges into a hole, and disappears with a roar. It breaks into Minera mine lower down, and where all the water goes at last no one seems to know or care, so that it is got rid of. In some of these underground worlds beds of silicious fossil shells are washed out of the lime, and look like shells piled on a beach. No human hands could dig them from their tombs as water does.

In limestone all over the world caves with subterranean rivers are common.

In Yorkshire are many. In the Alps, streams leap from holes in steep cliffs. Near Trieste a large stream flows into a

cave in a hill-side, and ten miles off a stream of the same size runs out of another cave. One pool is seen in the famous Addlesberg cavern, which has now been explored for many miles. It was known for three miles in 1841. It is an old river-mark filling with lime; a wonderful grotto, hung with glittering white festoons and pendants, and paved with white marble, which rain-water extracts from the hill through which it strains, and leaves in the cave when it gets to air and evaporates.

But the pool, with its strange creatures, the bed where water flows, is like a pool in the free air, and it is worn like the river bed in Park Mine. River-marks under the earth are like river-marks on the surface, when they can be got at; so, probably, river-marks under lava are like those of other Icelandic rivers.

On small slopes sidelong movements are greater in proportion to fall. The resistance is greatest at the bottom, and the downward movement is more easily reflected as the fall decreases. A hill-stream works most at the sides, where there is least resistance. The undermined rock slides, falls, and breaks; the bed of the stream is choked with fallen debris; there are many rapids and pools, but few falls; and the river-bed curves like the curving stream which makes it. But the shape of the trench depends on the fracture of the rock through which the river has made a way.

On a gentle slope the fall is less, and resistance the same. The stream is pushed on rather than dragged down, and it swings from side to side. It works as it moves, wearing the banks more than the bed.

There are many windings in a plain, few deep pools, and a smooth bed; there is smooth water and bad fishing; and

the work done by the river is chiefly the sorting of chips brought down from rock-grooves in the hills.

Every Etonian knows how streams work in their beds; for rowing and swimming teach the lesson.

Fig. 24. THE THAMES.
Sketched from the top of the Round Tower, Windsor, 1862.

a Surly. *b* Lower Hope. *c* Bargeman's. *d* Bovney. *e* Rushes. *f* Athens. *g* Upper Hope. *h* Cuckoo wear. *i* Brocas clump, *j* Brocas.

The Thames flows eastward on a gentle slope, and does not trace a straight line, but winds like a snake through the green fields.

From "the Rushes" to "Upper Hope" the river curves very slightly southwards, and the depth is tolerably even on both sides. But it is greatest on the northern side, which is the outside of the curve, where the water moves fastest. There

the bank is steep, the bottom clear, and the stream rapid. On the south side there is a shelving bank, a muddy bottom, and dead water. So boats rowing up stream keep the southern bank, and brush the northern on their way down.

The water is swinging eastwards round a point somewhere to the south; the river is working northwards along the circumference of the curve, and writing part of the letter **S**.

At Upper Hope the main stream has dug into the northern bank so far as to make the curve shorter. It strikes harder upon a higher bank, undermines it more, and rebounds faster to the other side, which it reaches at Lower Hope.

Boats ascending cross the stream at Lower Hope, brush the willow bushes with their oars, and scrape the gravel to keep in the dead water near the southern bank. But on the way back they cross the bay at Upper Hope, hug the northern bank, and shoot down with a rapid stream.

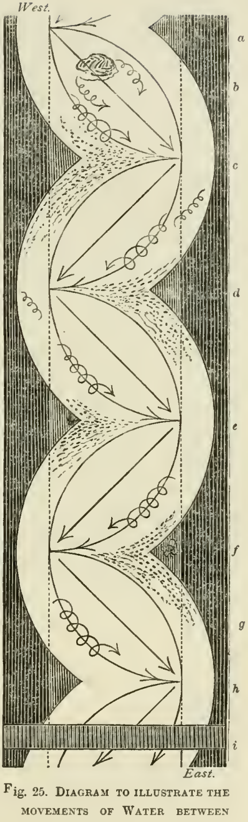

Fig. 25. Diagram to illustrate the movements of Water between the Rushes and Windsor.

a Rushes. *b* Athens. *c* Upper Hope. *d* Lower Hope. *e* Bargeman's Bush. *f* Brocas clump. *g* Brocas. *h* Eton. *i* Windsor Bridge.

The river flows south and works east between the Hopes, and it swings round a point on the west.

At Lower Hope, the main stream shoots over to the southern bank, which it undermines ; and thence it rebounds, swinging on the outside of a gentle curve, about some point to the north, and circling in miniature whirlpools as it slides along the steep clay bank ; till it swings away, and across to the "Brocas" at Bargeman's Bush.*

Ascending boats cross at Bargeman's, and hug the northern bank as far as Lower Hope, keeping the inside of the curve, where there is dead water, and a muddy bottom ; and when they return they keep in the stream.

Between Lower Hope and Bargeman's Bush the river is working southwards, away from the northern point about which it circles ; it is writing the other half of the letter **S** ; and from the round tower at Windsor, the whole silver letter is seen upon its emerald ground.

From Bargeman's Bush to Brocas clump the stream digs into the northern bank, and curves about a southern point. And so the Thames swings from side to side throughout its whole course. It is always gnawing into its banks northwards and southwards as it flows east ; but there is scarce a rock to be seen in the river. The valley of the Thames is half-full of chips, for some other engine had hollowed the valley, and filled it with drift and gravel before the river began to dig.

The Thames is a type of streams flowing on a gentle slope ; and ocean-currents swing between their banks on the same plan. The rain which streams along the roadway on Windsor bridge after a shower ; the Thames, the Oxerá on its lava bed, the smallest and the biggest, the oldest and the newest

* Now demolished.

streams, all dig on one principle, and do similar work. River steamers, canoes, boats, and boatmen ; Indians, Lapps, and fish, all work up stream on the same plan as an Eton Funny.

The sculler or swimmer who knows the stream has the best chance in a race, and gets on best in strange lands and waters. The geologist who tries to understand the work of large currents may learn a lesson from small streams.

Salmon-fishers must study the nature of rivers, or they will have sorry sport. Fish haunt particular parts of their domains, for good reasons ; and he who knows the reasons knows where to look for fish. They cannot rest in strong currents, so they avoid them ; unless there be nice stones or rocks at the bottom, to give shelter from the water gale. They do not like to rest in shallows, for they cannot there be hid from their foes in the air. In dead water there is mud, and no supply of fresh eatables drifting about ; and a salmon is an aristocrat who hates ploughing in dirt, and likes to have his dinner brought to him in a clean place. So fish hang about pools where the water is rough and deep enough to hide them ; and they choose particular spots, where there is stream to bring game, but not too much for the gentleman's comfort.

A salmon likes to have a cool breeze of clear, fresh, well-aired water blowing in his face ; and he rests in his nook poised on his fins, like a gull, or a hawk, or an osprey, floating head to wind behind a cliff, high in the air. And there he puffs, and champs his white jaws, and rolls his unwinking eyes, and wags his broad tail, till something worth having appears. Then the doser awakes ; and, with a sudden rush, the glittering silver sportsman dashes out, open-mouthed, with every fin spread like a fan, and every muscle tight and

quivering; and when he has snapped his hooked jaws upon some nice morsel, he glides back into his place, and waits for more. If he has taken a sham fly, with a sharp hook in its tail, strike home when he turns. If he has missed, give him a rest, and try again.

An old fly-fisher knows the look of places where fish abide, even in strange rivers, for surface-forms indicate submerged obstructions. In his own ground, he knows every corner of every pool, every shallow and hole, stone and eddy in it. So river-marks are familiar to fishermen, who are always watching the flow of water, and the work which it does; and the sportsman who knows most gets most sport. A still-net-fisher plants his snares in the way of travelling fish, and chooses his station by the run of the stream. Nets and spearing stages set in the Tana and Tornea are planted by Lapps and Quains in the way of ascending boats. Fish and boatmen strive to avoid the strongest stream, and cross at the same places. Fishermen know the stream, and the shape of its bed, by waves on the surface. The work of the river depends on its movements, so the nets mark out the run of the stream.

Floating bodies follow the stream, and shew its movements. If floats carve marks, they shew the course of the stream which moved the floats.

It used to be a time-honoured Eton custom for the long boats to muster once or twice in the spring, row up to the Rushes, and drift down, while the crews sang.

The captain in the "Tenoar," five or six "Eights," some "Sixes" and "Fours," and all the Funnies and double and single scullers that could get up in time, joined the fleet, and lay on their oars in a thick cluster; while some musical

"wet bob" chanted verses, and the whole of the crews roared the chorus. A favourite performance was—

Rule Britannia,
Britannia rules the waves,
Britons, never, never, never, never, never, will be slaves.

It was a grand song; but Old Father Thames would not be ruled. He never would carry Britannia's sons directly home, or keep their boats in their stations, or even follow his own curved bed. At first, boats to the north forged ahead, and swung their sterns to the bank; those to the south hung back, the long boats whirled slowly round, and bumped and jostled as they floated. The concert was varied by cries of "Paddle on easy"—"Pull round, bow"—"Back-water, stroke"—or "Bow, side oars in the water."

But when the musical squadron had passed the bathing-place at Athens, and had reached Upper Hope, where the stream runs full tilt at the bank, the crews had to row to avoid shipwreck.

The first part of the concert ended with a thundering rattle of oars in the rollocks by way of applause; nearly a hundred oars dipped into the water, and the captain's word was "Paddle on easy to Lower Hope." There it was, "Bow side, paddle hard," and "pull round."

Then the concert began again. The brown swarm gathered into a cluster, and covered the whole breadth of the stream; while "George Barnwell," Black-eyed Susan," "God save the Queen," and similar lays, were performed with the usual applause, and under the same difficulties.

But on this reach the movements were reversed.

The northern boats hung back, the southern drifted ahead, and the long boats slewed round against the sun.

It was "Pull round, stroke side—backwater, bow," for the

sterns were always trying to pass the bows, by scraping against the southern bank, while shoving the bows across the river into dead water.

The water whirled as it flowed, and it whirled the floating boats. It turned them with the sun, from left to right—east, south, west, north ; with the hands of a watch, where the river curved, sunwise, eastwards, and about a southern point ; from the Rushes to Lower Hope. But small whirlpools on that reach turned the other way, on the outside of the curve, because the bank holds the water back. The boats turned against the hands of a watch and widershins where the river curved eastward, and about a northern point, between Lower Hope and Bargemans ; and there small whirlpools and floats of froth revolve, sunwise, under the high bank.

By watching these, similar movements on a larger scale may be understood. Corrie Bhreacan and the Maelstrom are but larger whirlpools in a larger stream, and circular storms revolve on the same principle as a whirlpool in a mill race.

What boats tell about movements in a stream is tested by swimming in it. Many a hot summer hour pleasantly spent in the cool Thames ; many a long swim from the Rushes to the Brocas, and from bank to bank at every bathing station ; long dives in the pools—have made this bit of river-bed familiar to all bathing Etonians.

Elsewhere they find that which is true of one stream to be true of all.

That which is true of boats and swimmers is true of other floating bodies ; of trees and ships, ice-floes, icebergs, and clouds.

In Scandinavia are vast forests, in which a harvest of so-called " Norway deals" is reaped.

The reapers live in the open air for months at a time, and

brave great hardship, and some danger; for pines often grow in chinks, in the face of high rocks, where it is impossible to get at them without a rope.

Hardy Norsemen and Swedes fell the pines, hew off the branches, and roll and drag the trunks to the nearest water. Once launched, the logs find their own way to saw-mills; and sometimes they drift about in lakes and roll in streams for several years before they arrive.

Many get water-logged and sink; and these may be seen strewed in hundreds upon the bottom, far down in clear green lakes.

Many get stranded in the mountain gorges, and span the torrent like bridges; others get planted like masts amongst the boulders; others sail into quiet bays, and rest side by side upon soft mud.

But in spring, when the floods are up, another class of woodmen follow the logs, and drive on the lingerers.

They launch the bridges and masts and stranded rafts, help them through the lakes, and push them into the stream; and so from every twig on the branching river, floats gather as the river gathers on its way to the sea.

Sometimes great piles of timber get stranded, jammed, and entangled upon a shallow, near the head of a narrow rapid; and then it is no easy or safe employment to start them.

Men armed with axes, levers, and long slender boat-hooks, shoot down in crazy boats, and clamber over slippery stones and rocks to the float; where they wade and crawl about amongst the trees, to the danger of life and limb. They work with might and main at the base of the stack; hacking, dragging, and pushing, till the whole mound gives way, and rolls and slides, rumbling and crashing, into the torrent, where it scatters and rushes onwards.

It is a sight worth seeing; the power of a float, moved by water, begins to tell, and denudation is seen in progress.

The brown shoal of trees rush like living things into the white water, and charge full tilt, end on, straight at the first curve in the bank. There is a hard bump and a vehement jostle; for there are no crews to paddle and steer these floats. The dashing sound of raging water is varied by the deep musical notes of the battle between wood and stone. Water pushes wood, tree urges tree, till logs turn over, and whirl round, and rise up out of the water, and sometimes even snap and splinter like dry reeds.

The rock is broken and crushed and dinted at the water-line by a whole fleet of battering-rams, and the square ends of logs are rounded; so both combatants retain marks of the strife.

The movements of ice are the same.

At one mill at Christiansand, 70,000 trees thus floated down are sawn up every year; and there are many other mills in the town; so the work done upon rock by floating timber is on a considerable scale.

The work done by river-ice is greater, but similar. The rocks are worn at the water-line, and undermined, and when they fall, there remains a perpendicular or jagged broken bank.

About ten miles from the town, at Vigelund, at another large saw-mill, there is a fall in the Torisdals river, where the lateral and vertical whirling of flowing water, and its action upon floats and rocks, is well seen.

Above the fall it has been found necessary to protect the rock from floating bodies, so as to preserve the run of the stream. It threatened to alter its course, and leave the mill dry, for the rock was wearing rapidly.

It is a good salmon station, and a tempting spot for a sketcher to watch in summer.

At every moment some new arrival comes sailing down the rapid, pitches over the fall, and dives into a foaming green pool, where hundreds of other logs are revolving, and whirling about each other in creamy froth. The new comer first takes a header, and dives to some unknown depth ; but presently he shoots up in the midst of the pool, rolls over and over, and shakes himself till he finds his level ; and then he joins the dance.

There is first a slow sober glissade eastwards, across the stream, to a rock which bears the mark of many a hard blow ; there is a shuffle, a concussion, and a retreat, followed by a pirouette sunwise, and a sidelong sweep northwards, up stream towards the fall. Then comes a vehement whirling over and over ; or if the tree gets his head under the fall, there is a somersault, like a performance in the Halling dance. That is followed by a rush sideways and westward, where there is a long fit of setting to partners under the lee of a big rock. Then comes a simultaneous rush southwards, towards the rapid which leads to sea, and some logs escape and depart; but the rest appear to be seized by some freak, and away they all slide eastwards again across the stream to have another bout with the old battered pudding-stone rock below the saw-mill. And so for hours and days logs whirl one way—in this case against the sun—below the fall, and they dash against the rounded walls of the pool, leaving their mark.

Lower down, near the sea, is a long flat reach between high rounded cliffs ; and there these mountaineers, floating on to be sawn up, form themselves into a solemn funeral procession which extends for miles.

But the curve of this stream of floats is always greater

than the curve of the river's bed; for the water is slowly swinging from side to side as it flows, and the floats shew the course of the stream, and its whirling eddies. Many marks which remain in rocks in this great valley are clearly not marks of this wearing agency. They were neither made by trees nor by river ice.

A practised swimmer who knows what he is about, and leaps head foremost down a small cascade, is carried downwards with great rapidity, and is then shot upwards to the surface, a long way down stream, where he can swim safely to land.

It is pleasant thus to dash through water like a fish ; to feel the eddies and the tickling air bubbles, and to hear the many sounds of the gurgling river. It is pleasant on a summer's day to dive through a cascade, and sit behind the water screen, and watch the flickering light amongst swarms of summer flies which there abide ; but the swimmer who gets out of the run of the water may fare ill, for he drifts round like a log, and if he struggles with the power which is stronger than he ; he may whirl till he sinks, or knocks his head against a stone and drowns.

But the diver learns to know the movements of water beneath the surface, and the surface forms which indicate them ; and he can apply his knowledge elsewhere.

A geologist who wants to know how rivers work upon their beds may profit by the experience of boatmen, fishermen, lumberers, and swimmers ; for he must learn the movements of fluids, before he can safely pronounce upon work done by them.

As fluids move in curves, marks which they make are curved also ; and as water works very slowly, and follows every inequality, water-marks are fine and smooth, though irregular.

The finished work is like the polish which a carpenter gives to a surface with his hand, after he has formed it and smoothed it with rougher tools.

Projecting angles in the bed of a stream are polished and rounded, but they are not rubbed off.

Rock-pools, and all water-worn hollows retain irregularities. Sometimes deep round holes are drilled in hard rocks, below falls, and on the sea-shore ; but these are not simply water-marks. They are marks which water makes by moving solids, and the tools used are often left in holes made with them. Rock-pits often contain round stones, sand, and water.

A river, then, is always working slowly downwards and up stream, changing a **V** into **Y**, by digging trenches, drilling holes, and undermining rocks over which it flows ; and an ocean-stream works on the same principle.

But marks which flowing water engraves upon rock during a man's whole life are as nothing.

The Oxerá has not deepened its bed two feet since the history of Iceland began. The Thames has not changed its course since Magna Charta was signed, though the Thames works on gravel. What rivers and seas have done is not matter of observation but of inference for short-lived men.

Still water may be set to sculpture soft materials, and the touch and the work done may then be compared with similar work on any scale or material done anywhere during any period of time. Having found a power, it may be set to work.

The tank figured above shews how streams move vertically.

Let a sheet of glass be sloped in clear water, and drop ink, milk, or water charged with pipeclay upon the upper edge of the glass. The heavy fluid sinks, and rolls slowly down the

slope, through the clear still fluid. The upper edge of the stream curls and rolls back, and every movement is clearly seen. When a breeze passes a fixed chimney, or when a steamer moves through a calm, the same forms and eddies are seen in smoke. Wherever a moving fluid passes through fluid at rest, there are similar vertical eddies ; and though they are invisible they often leave their marks.

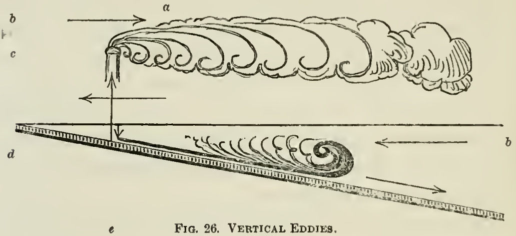

FIG. 26. VERTICAL EDDIES.

a Weight. *b* Resistance. *c* Air. *d* Water. *e* Heat.

Horizontal eddies are seen behind every stick in a stream.

The woodcut is from a sketch made in London. The square stands for a post, the lines and arrows shew the paths described by bubbles floating on the Thames. But the laws

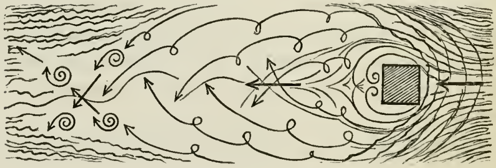

FIG. 27. HORIZONTAL EDDIES IN WATER.

which controlled the movements of these tiny floats and streams would hold good though the post were an island, the

stream an ocean-current, and the floats ice-floes. Where such floats leave marks they are drawn on a similar plan.

There are vertical and horizontal eddies, whirlpools, and whirlwinds, in the atmosphere and in the ocean ; and all streams and moving floats flow and move on the same principles.

Similar curves appear in a tea-cup when stirred with a spoon, in a mill-stream, and in the Thames ; they are seen in a strait, from a hill-top, where a rapid tide is flowing amongst an archipelago of rocky islands ; they are described by a stream of molten iron ; their tracks are on ancient hills.

There are eddies in streams moving through fluid at rest, or past pebble, post, rock, island, point, or sunken continent ; in air moving past a chimney, a volcano, an ice-peak ; or rolling north and south from pole to pole.

But the movements of all streams may be learned by studying the run of water in rivers ; and stream-marks may be learned from working models.

The following simple experiments will imitate river-marks :—

1. Mix fine pipeclay in water, and place a sheet of glass at the bottom of the vessel which contains the mixture. After a few minutes raise the glass slowly out of the water, and there remains a film of wet clay upon plane glass. Slope the glass to let water drain slowly off, and in half an hour the clay on the glass will be marked by flowing water as clay is marked by streams in the great valley which stretches seawards between Hecla and Eyafjalla, or similar alluvial plains elsewhere. Water clears channels on glass, and leaves clay islands ; and the resulting forms are those which are seen from the high ground whence Gunnar looked upon his favourite glen, and where he sleeps in his cairn : they are the same.

Everywhere the plane glass is a plan of a plain through which a stream meanders.

2. Vary the experiment by pouring thicker mud into clear water, to represent a quiet lake or sea into which a river falls. The descending current is seen whirling clay-clouds into beautiful curves, as it pushes through the clear still water; but when the movement has ceased, the glass at the bottom is covered with a thin even layer of clay. Raise and slope the glass at various angles, and river-forms of various curvatures re-appear.

3. Slope a square foot of glass, and pour fine mud over it, till the glass is covered with a pretty thick stratum of even consistency. Stick a lump of clay at one corner, and let clear water, and water coloured with brown ochre, drip slowly upon it.

Flowing water digs out channels and colours them; and the resulting forms are those which mark the great boggy plains which surround the igneous rocks of Iceland; and similar plains elsewhere.

The model is like a map. The work of centuries of slow action on one scale, is done in miniature in half an hour; time and quantity differ, but mechanical forces, materials, movements, and resulting forms are the same.

4. Build a heap of clay on a garden walk, and pour water upon it; or throw clay upon the roof of a house where rain may fall upon it—and the work of denudation will soon begin naturally upon miniature plains of mud, deposited in hollows on the ground, but washed from the roof. The larger the experiment the longer is the time; but the tool-marks of all streams are alike.

5. Change the course of a rivulet—turn it loose in a clay field, or on a sea-beach—and watch its proceedings day by day;