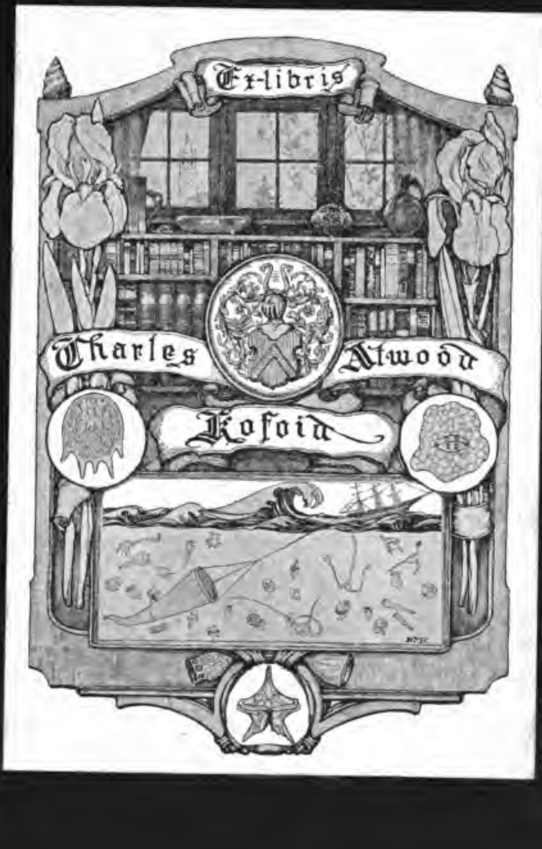
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CHIPS AND CHAPTERS

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"I weigh my words well when I assert, that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of nature."—*Professor Huxley's Lecture 'On a Bit of Chalk,' British Association*, 1868.

CHIPS AND CHAPTERS

A BOOK

FOR

AMATEUR AND YOUNG GEOLOGISTS

BY

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PREFACE.

THE worker in any department of science, if he keeps abreast with its progress, has usually some discovery to announce, some paper to read, or some address to deliver. Of such miscellaneous matter—selected chiefly with a view to instruction in the Principles of Geology—the present volume is in a great measure composed. What has been of interest to the few, may often, with slight modification, be made attractive to the many; and in particular to those who, having no need, and indeed no time, for systematic training in science, are yet desirous to become acquainted with its more prominent facts and bearings. This is all the Author aims at by the publication of these "Chips and Chapters," and he will be specially gratified should they fulfil the end intended, or aid in any way the young geologist to a clearer comprehension of his subject. The field of Geology is a wide and varied one, and whatever may help to a sounder appreciation of its importance, or induce another labourer to enter, however trivial it may appear to the practised worker, should at least have the opportunity of doing so by being put in the requisite form and addressed to the proper quarter.

D. P.

EDINBURGH, GILMORE PLACE,
April 1869.

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BRITISH STRATIFIED SYSTEMS,

TO WHICH THE FOLLOWING SKETCHES MORE ESPECIALLY REFER.

The subjoined tabulation exhibits the arrangement of the British stratified rocks, as accepted by our leading geologists—minor and local devia-tions of superposition being subordinated for the sake of distinct comprehension and ready reference :—

Systems.	*Groups.*	*Periods.*	
QUATERNARY.	In progress. Recent.	CAINOZOIC.	NEOZOIC CYCLE.
TERTIARY.	Pleistocene. Pliocene. Miocene. Eocene.		
CRETACEOUS.	Chalk. Greensand.	MESOZOIC.	
OOLITIC.	Wealden. Oolite. Lias.		
TRIASSIC.	Saliferous Marls. Muschelkalk (?). Upper New Red Sandstone.		
PERMIAN.	Magnesian Limestone. Lower New Red Sandstone.	PALÆOZOIC.	PALÆOZOIC CYCLE.
CARBONIFEROUS.	Coal-Measures. Millstone Grit. Mountain Limestone. Lower Coal-Measures.		
OLD RED SANDSTONE.	Yellow Sandstones. Devonian Limestones and Slaty Shales. Red Sandstones, Conglomerates, and Cornstones. Grey fissile Sandstones and Conglomerates.		
SILURIAN.	Limestones and Shales. Limestones, Slates, Grits.		
CAMBRIAN.	Slates, Schists, and Grits.		
LAURENTIAN.	Gneissic Schists, Quartzites, Serpentines, &c.	EOZOIC.	

OF VOLCANIC. (Quaternary to Cretaceous)

RANGE OF TRAPPEAN ROCKS. (Tertiary to Laurentian)

RANGE OF GRANITIC ROCKS. (Cretaceous to Laurentian)

ORDER AND SUCCESSION OF LIFE,

ESPECIALLY AS REFERRED TO IN THE FOLLOWING SKETCHES.

The subjoined tabulation exhibits proximately the stages at which the great ascending sections of Plants and Animals make their first appearance in the stratified systems :—

CAINOZOIC.	QUATERNARY.	Man. Plants and animals of existing species and distribution; a few genera recently extinct.
	TERTIARY.	Placental mammals. Plants and animals of existing orders; a large proportion, however, of extinct genera and species.
MESOZOIC.	CRETACEOUS.	Marsupial mammals, birds, reptiles, fishes, shell-fish, crustacea, zoophytes; palms, coniferæ, ferns, lycopods, sea-weeds.
	OOLITIC. TRIASSIC.	Marsupial mammals, birds, reptiles, fishes, shell-fish, crustacea, zoophytes; palms, cycads, coniferæ, ferns, lycopods, sea-weeds.
PALÆOZOIC.	PERMIAN. CARBONIFEROUS.	Reptiles, fishes, shell-fish, crustacea, zoophytes; coniferæ, ferns, lycopods, sea-weeds.
	AND- STONE.	Fishes, shell-fish, crustacea, zoophytes; ferns, lycopods, sea-weeds.
	SILURIAN.	Shell-fish, crustacea, worm-tracks, zoophytes; sea-weeds.
EOZOIC.	CAMBRIAN.	Crustacea, worm-burrows, and zoophytes.
	LAURENTIAN.	Traces of lowly or foraminiferal organisms.

RANGE OF INVERTEBRATA. (Laurentian upward)
RANGE OF AMPHIGENS. (Laurentian upward)
RANGE OF VERTEBRATA. (Fishes, shell-fish … stage upward)
RANGE OF ACROGENS. (Fishes, shell-fish … stage upward)
RANGE OF GYMNOGENS. (Permian–Carboniferous upward)
RANGE OF ENDOGENS. (Oolitic–Triassic upward)
RANGE OF EXOGENS. (Tertiary upward)

that it is but the waste and debris of some other rock-formation that preceded it. And further, as the forces that now act leave record of their operations in the rocks they produce, so the older rocks contain the history of the manner in which they were formed and of the conditions under which they were aggregated. To study the rocks of the earth's crust and the history they contain, from the most recent and superficial to the oldest and deepest we can reach, is the prime aim of geology; and the more thorough our knowledge of existing conditions and operations, the more perfect will be the interpretation. In other words, the more we know of the physical geography of the present day, of the forces that act and the results they produce, of the plants and animals that live, and the mode in which they are entombed in the rocks, the better will we be enabled to infer from our examination of the old rocks the mode in which they were formed, the distribution of sea and land at the time of their formation, and the conditions under which their imbedded plants and animals existed.

The aim of geology is therefore to read, through its rocks and fossils, the history of the earth's crust and the changes it has undergone. We see at the present day how sedimentary or stratified rocks are formed in lakes, in seas, and in estuaries, through and by the agency of water, and we therefore infer that all stratified rocks in the crust have been produced in a similar way. We see sands and gravels laid down along shore, and muds and marls in deeper water, and therefore conclude that all rocks of similar composition and structure have been formed in similar positions. We know that the plants and animals of the land and the lake differ from those of the sea, and that those of the estuary, again, differ from both; and so, when examining the fossil plants and animals (the flora and fauna) of any set of strata, we can determine whether these strata are of lacustrine, of estuarine, or of marine formation. Again, we see how unstratified rock-masses are produced by volcanic eruption, and how the earth's crust is rent and fissured by earthquake convulsions, and we rightly infer that all unstratified rocks are of igneous origin, and that the fractures and faults among the older strata have been brought about by subterranean disturbance. In this way we get glimpses of the past conditions of the globe—the distribution of its lands and waters, the kind of plants and animals by which it was successively peopled, and in the main of its geographical conditions and appointments. And by arranging the whole in chronological order (from the deposits of yesterday to the deepest rocks we can reach) we get something like a connected history of the earth through its ancient, medieval, and recent aspects, just as we get of human history through its ancient, medieval, and modern developments.

But while engaged in this task it will be found that ancient changes and ancient rock-formations are far less evident and of much more difficult interpretation than those of recent date, and that this difficulty goes on increasing as we descend in the earth's crust until we reach a stage when everything becomes obscure, and all the rocks are converted into homogeneous, or all but homogeneous, crystalline masses. The clays, muds, marls, sands, and gravels, which form the superficial accumulations, bear obvious evidence of the manner in which they have been aggregated, and of the conditions under which their imbedded plants and animals lived—and the sandstones, shales, ironstones, coals, and limestones of the older strata, with their enclosed fossils, reveal in a similar way the general facts of their formation; but in these deepest rocks, where stratification is in a great measure effaced, and not a trace of plant-life or animal-life can be discovered, the geological record ceases, and all beyond becomes mere matter of guess-work and conjecture. It is important, then, for the young geologist to know that the field of his labours is restricted, or all but restricted, to the stratified fossiliferous rocks. In these, with their imbedded fossils, he sees the sediments of former lakes, seas, and estuaries, and can infer with some degree of certainty as to the former distributions of sea and land, and the life by which they were peopled. In these, with their accompanying volcanic products—their fractures, upheavals, and depressions, he can trace the physical agencies of bygone periods, and compare them with the present. But in the old crystalline rocks, where the record of life and geographical aspect is obliterated, he can decipher with certainty no further, and must close his labours as an inductive geologist.

The scope of geology as a science of observation and deduction is restricted, therefore, to the stratified and accessible crust. In this, built up, modified and re-modified a thousand times by the forces now operating around us, we can trace a long and wonderful history of physical and vital mutation; and it is to the perfection of this history in all that has reference to geographical aspect, operative cause, and vital progress, that the modern geologist directs his attention. All that relates to the primordial condition of the earth, and to its origin and evolution as a member of the solar system, belongs to cosmogony and astronomy, and not to geology; and however attractive it may be as a speculation, it cannot be admitted among the observed facts and legitimate deductions of our science. It is of paramount importance, then, that in geology, as in other departments of science, the student should thoroughly understand the aim and scope of his subject, concentrating his energies on what seems fairly attainable, rather than dissipating his thought on what belongs to another theme, if indeed it be not altogether unapproachable.

The aim of geology being to read the history of the Earth through its rocks and fossils, and its scope being restricted to that portion of the crust which gives evidence of the causes by which it was produced and the conditions accompanying its formation, the student has before him a task which, however arduous, is at least intelligible, and hopefully within his reach. In his surveys, maps, and sections he can separate the younger from the older strata—can say whether they have been deposited in lakes, in seas, or in estuaries—can tell the nature of the plants and animals imbedded within them—can indicate the climatic conditions under which these had lived and flourished—show the changes which these strata have undergone by contemporaneous or subsequent volcanic activity—and in the main depict the geographical features which the region of his study has successively undergone. The successive features he may call *stages*, or *formations*, or *systems;* and by arranging them in chronological sequence he gains a view of the long line of world-history similar to that which the historian arrives at by the study of modern, medieval, and ancient populations. In reading this long history he perceives that the earth's crust is in a state of incessant change—that the forces which act are ever the same in kind though differing in degree—that in the plants and animals there has been a progress in the main from lower to higher forms—and that all the changes, whether of a physical or of a vital nature, have ever been in accordance with certain modes and processes, or, in other words, under the unerring direction of fixed and enduring Law. Were it not so, observation might be deceiving us at every turn, and we could never hope to arrive at anything like certainty in our deductions.

Such being the aim and scope of geology, a very cursory inquiry will suffice to show that its bearings, scientific and practical, are of commensurate importance. As a theme requiring minute observation, discriminating reflection, and the power of logically tracing results to their producing causes, its intellectual bearings are of the highest order; while the influence of its deductions on botany and zoology, on the science of life in general, and on our conceptions of time and the operation of natural law, have been such as to mark within the last half-century an era altogether new in our scientific convictions. What ennobling views of creation, of time, change, continuity, and undeviating order, has the study of geology imparted, compared with the restricted notions of our forefathers! what exalted conceptions of divine prescience and method compared with the fitful, temporary, makeshift plans that were formerly ascribed to the Creator! Nor are its practical or economic bearings less varied and valuable. Arranging as it does the rocky crust into stages and formations, it can point with precision to the sites of the various rocks, minerals, and metals, to their scarcity or abundance, and thus confer on the miner, the engineer, builder, and farmer, information of direct practical utility. And when we reflect how much mankind are dependent on the minerals and metals for all that relates to comfort, civilisation, and progress, it will be readily granted that the economic bearings of geology are fully commensurate with those that are scientific or intellectual.

Such is a brief indication of the aim, scope, and bearing of geological inquiry. Under the operation of certain forces we see this world of ours undergoing incessant change, and each change marked by its own peculiar rocks and their relations, and believing in the fixed and enduring nature of these forces, we seek to discover the changes it has undergone in time past by examining the rock-formations of the crust; or, by reversing the order, we try from the earliest traces of change in the rocky crust to read the history of the earth onwards and upwards to the changes now going on, and the rocks that are now forming around us. In either case we believe in the fixity and uniformity of nature's operations, and further believe that every period and change leaves its own record of waste and reconstruction in the crust, together with some memorials of the plant-life and animal-life that peopled the surface during its continuance. Geology is thus the history of our planet read through its rocks and fossils; and where the former contain no fossils, nor exhibit by their structure and texture any evidence of the conditions under which they were formed, then the task of inductive geology ceases, and the primordial state of our globe is handed over to the physicist and astronomer. The aim and scope of geology being clear—and what an ambitious aim, and how vast the field of inquiry!—the bearings of the science, theoretical and practical, are readily understood and easily appreciated. No knowledge can bear more directly on the industry of a country so long as the minerals and metals are indispensable to mechanical achievement and progress; no science of recent times has spread so rapidly or influenced so broadly our ideas of time, change, continuity, and creational progression.

PRACTICAL BEARINGS OF GEOLOGY.

"UTILITY," says one of the master-minds of Europe, "is the bane of science." "Philosophy," says another thinker, "is never more exalted than when she stoops to administer to humanity." Perhaps neither extreme is absolutely correct, and, as in most matters of human concern, truth may be found between. Science, it is true, may be cultivated solely for its own sake, and to a certain class of minds the acquisition of abstract truths—the pure pleasure of knowing—may be sufficient reward. But to another class differently trained, or, it may be, differently constituted, knowledge is of itself nothing unless it can be brought to bear on the pursuits, the toils, and enjoyments of everyday existence. Man is a compound being—compound alike from the individuality he has to sustain and the part he has to perform. Living in a world of incessant activities, his life is not only a continual struggle with external conditions, but a continued investigation of the forces against which he has to contend. He has thus, in virtue of his position, physical wants which cannot possibly be disregarded, and intellectual desires as imperative in their cravings as are those of his bodily requirements. It is apparently the oversight of this fact which makes the philosopher too often disregard the practical, and the man of practice too commonly undervalue the purely philosophical. Science and its applications cannot be disjoined; industry would be fruitless without knowledge to direct it. Where science seeks merely to know, and industry tries to apply the results of this knowledge, utility can be no bane; and where practice is ready to accept, philosophy may contribute her aid without stooping from the position that becomes her.

Like other branches of knowledge, geology has its scientific as well as its practical aspects. It may be studied from the purely intellectual side; and what a wide field for investigation, what a rich fund of truth and matter for speculation, it unfolds! It may be viewed from the practical; and what valuable assistance, what trustworthy aid, its deductions afford! What knowledge of deeper interest than that of the nature and history of the globe we inhabit? What study more attractive than to trace this world of ours through all its phases of change and progression, from the earliest fact registered in the rocky crust to the phenomena that are now taking place around us? What more wonderful than to learn that, under the operation of existing forces, sea and land are ever changing places, and that not a particle of matter we now examine but has been wasted and reconstructed times without number—now solved and sundered by water, now melted and reconstructed by fire? What more marvellous than to know that the organic forms which now exist are but the merest fraction of a life-scheme that stretches away immeasurably into the past, and which, stage after stage, has advanced from simpler to more complex forms, and, as a necessity, from the performance of lower to higher and more exalted functions? What more ennobling than the conviction, that amidst all this mutation and progress—these ever-varying aspects and functions—there is a plan and design to which the whole has ever been conformed, and immutable laws by which the means and processes are ever held in operation and in harmonious adjustment? What more godlike than, from a knowledge of all that this world has been, and from the conviction of all that it will continue to be, to extend our being into the past and into the future, and to live, as it were, far beyond the period of our sentient existence? All knowledge of nature is good, and there is no science, physical or natural, which is not invested with its own special value; but there is none, perhaps, which brings the mind in more immediate contact with God's workings in nature, none that unfolds so broadly the method of the creative mind, as geology; and this knowledge were of itself sufficient to excite our keenest research, and to sustain our most enthusiastic interest.

But beyond this purely scientific interest, the study of geological phenomena stands unexcelled as a means of mental training and exercitation. At every step the most minute and discriminating observation is necessary. Every external feature, every particle of rock, every fragment of fossil plant or animal, carries with it its own history; hence everything in the interpretation of that history depends upon the aptitude to observe and this power to discriminate. How marked the power of the trained observer to perceive minute differences in form and structure compared with that of the unpractised worker; and what endless variety and contrast this power discovers in nature, where to the casual observer there appears nothing save sameness and monotony! Besides this discipline of observation, there is also necessary the tact to describe, for without this the facts and phenomena would in a great measure be lost to others, if, indeed, the faulty description did not often mislead them. Dealing with such vast and complicated phenomena, the exercise of the reflective faculties is not less necessary than that of the perceptive. Knowledge of causation, sifting of evidence, balancing of probabilities, and power of generalisation, are never more needed than in dealing with geological phenomena; and he who goes earnestly and truthfully to work can scarcely have a wider and more varied field for their exercise and development.

But, over and above this intellectual exercitation of a general nature, geology has bearings of special importance to the other sciences: to astronomy, as indicating the structure and composition of the planetary brotherhood; to chemistry, as supplying at once new substances for research, and new problems for solution; and, above all, to botany and zoology, as having extended immeasurably their domains, and interwoven more closely their cosmical connections. A century ago the botanist and zoologist dealt only with the existing forms of plants and animals; now their review must embrace the extinct as well as the living, and thus give greater consistency and intelligibility to the scheme of vitality. As the simpler forms of life throw light on the structure of the more complex, so a knowledge of the earlier forms throws light on the relationships of the existing; and henceforth there can be no satisfactory consideration of plant-life or of animal-life that does not combine in one category the extinct with the existing. Attractive as may be the relations of the living economy, they become doubly so when studied in connection with the fossil,—the whole marking a progress in time from the simple to the complex, from the general to the special, and from the merely sentient to the higher attributes of conscious intellect and will. Had geology made no other contribution to science than the revelation of the extinct forms of life, vegetable and animal, that lie entombed in the crust of the globe, it would have been sufficient to invest the study with undying interest, and enough to place it in the foremost rank of those themes which the enlightened mind delights to investigate.

But, however attractive the scientific or intellectual aspects of geology may be, it has practical interests to attract and substantial benefits to bestow. This globe is our earthly home, and all that confers on it beauty, diversity, and grandeur, is the result of geologic operations. Its soil is the nursing-mother of vegetable life, its surface the theatre of animal activity. Its crust is the vast storehouse of the minerals and metals, those substances so indispensable to civilised power, and without which industrial progress would be impossible. But inasmuch as these rocks and gems and metallic ores are not scattered broadcast through the crust, but hold determinate positions, it is of prime importance to know their place and abundance; and this kind of knowledge can only be ascertained through and by the labours of the geologist. Be it miner in search of coals and metals; builder in quest of durable and beautiful materials; engineer tunnelling and cutting his roads, excavating his canals and harbours, or sinking for water; farmer ameliorating his soils; landscape-gardener beautifying the aspects of his locality; or settler pushing his fortunes in a new country,—all must alike draw on geology for aid, or grope in the dark by the old, unsafe, and expensive system, or rather non-system, of trial and error. Let us try on the present occasion if we can make good these assertions, and meet the objection which is sometimes urged against the study of geology as being a science speculative, hypothetical, and uncertain. And all the more are we called upon to make this effort, from being not unfrequently told that the means for promoting the science would meet with greater support from *practical men*—that is, from engineers, architects, builders, farmers, and the like, had it any feature of practical importance to recommend it.

Without weakening the claims of geology on the miner and mining engineer, it may be readily conceded that the art of mining may often be largely and profitably carried on without any scientific acquaintance with the deductions of the geologist. But while this is conceded, it is equally clear, on the other hand, that a skilful engineer, well acquainted with geology, will ever be the safer guide, and better able to surmount the difficulties that lie in the way of his admittedly arduous calling. Whether he be searching for metals among alluvial drifts, following veins and lodes for ores, or sinking shafts for coal, ironstone, fire-clay, and other stratified rocks, there are numerous facts connected with the occurrence of these minerals, their dislocations, continuity, extension, and accessibility, which can be arrived at only through the generalisations of geology. For want of such knowledge much useless labour has been spent among river-drifts in search of gold and tin, where a slight acquaintance with the science could have told at once that search was hopeless; while from the same cause immense toil has been spent on scattered sands and gravels, which a little skill could have traced up to the parent veins from which, in the course of ages, they had been disintegrated and borne away. It is also clear that in metalliferous districts, where there are several sets of veins of different ages, different contents, and different directions, there can be no satisfactory procedure without competent geological investigation. Mere empiricism may sometimes succeed, but millions have been squandered by this empiricism where a little elementary science would have forbidden the adventure. In like manner we have had ruinous searches for coal where geology could have shown its non-existence, unprofitable workings from ignorance of the geological structure of the coal-fields, and empirical dogmatisms respecting he non-existence of coal-seams where men of science had clearly indicated their extension and continuity. To the competent geologist a fossil twig or stem, a shell, coral, or fish-scale, is sufficient to indicate the presence and extent of a formation; to the mere empiric such unfailing indications have no significance. The successful sinking for coal through the New Red Sandstone of England is as much a triumph of scientific deduction as the obstinate boring for it at the base of the Old Red Sandstone in Strathearn was a defeat of empirical ignorance.*

And here we cannot help remarking how anomalous it is, in a country raising 100,000,000 tons of coal, manufacturing upwards of 8,000,000 tons of pig-iron, with lead, copper, zinc, tin, and other metals in proportion, employing hundreds of thousands of men, and expending millions of money, that there should be no qualification demanded from the mining engineer, the colliery-viewer, and others who undertake the direction and management of our mining concerns. Considering the hazardous nature of mining operations, the number of lives depending on their skilful management, and the amount of capital at risk, there never was a graver error or more culpable remissness. We demand qualifications from the captains and mates of our mercantile navy, and withdraw their certificates for error and negligence; and yet in a branch of industry requiring as much skill, and involving as much risk, any one having sufficient confidence in himself, or with a few friends to support him, may set up as mining engineer, and undertake the gravest responsibilities, without any one to question his qualifications! Surely this is not as it ought to be; and if it be true, as is sometimes said, that capital can look after itself, there ought

* The latest misdirected attempt in search of coal that has come to our knowledge took place during the summer of the current year, a mineral borer of great ingenuity and mechanical skill having been negotiated with by two noble proprietors to make trials on their estates in the county of Banff and the northern district of Aberdeenshire!!

at least to be something done in this direction by Government, in the interests of humanity, and in behalf of a class of men who, even under the closest care and the highest skill, are ever exposed to more than the ordinary perils of industrial occupation. Considering that the law now forbids the employment of children, restricts the hours of labour for the young, and prevents the engagement of females in mines, the time is surely not far distant when provision must be made for their more skilful management, and a higher standard of qualification demanded from their viewers and engineers.

To the builder and architect in quest of beautiful, strong, and durable materials for their structures, a knowledge of Geology cannot fail to be of advantage. It is not merely the knowing where such materials occur, and how they can be most advantageously raised from the quarry, but the question of their durability, how they are affected by the weather, their absorption of moisture, the effect of exposure on their colour, hardness, and other architectural qualities. In a neighbourhood where long experience has tested the properties of a building-stone, geological information may be of little moment; but where large cities and public edifices have to draw their supplies from new and often distant localities, such knowledge is indispensable. Not only does the geologist know the abundance and position of those materials, but he sees during his field-work how they are affected by the weather, the change of colour they undergo, their tendency to absorb and retain moisture, and, generally speaking, all those properties which render them suitable or unsuitable for the purposes of the builder. It is true that chemical and mechanical tests may often be applied for the same purpose with effect, but there are cases—need we point to many of the public buildings of our own country?—where such tests have signally failed, and where only the wide observation of the geologist could have been appealed to for certain information.

Again, to the civil engineer, making road and railway cuttings, tunnelling through hills, excavating canals, docks, and harbours, boring for water, or arranging for water-supplies, no science can be of more direct importance than geology. It is true he may, in each special case, appeal to the skilled geologist, but even the appreciation of that advice will depend in a great measure on his acquaintance with the principles of geological science. No doubt, with the aid of good geological maps, and the proper skill to interpret them, the civil engineer may often see his course in a general way; but there is ever an amount of detail—quality of rock, dip, jointing, dykes, dislocations, and the like—which ordinary maps do not embrace, and which can only be safely ascertained by personal inspection. Looking at the vast amount of work and capital that has been intrusted to civil engineers during the last twenty years, and to the extent to which much of the work has been blundered and bungled, one cannot avoid the conclusion, that millions might have been saved had these men possessed a competent knowledge of the nature and structure of the rock-materials through which they were passing, and in and with which they had to operate. Every height to be cut through or tunnelled has a composition and structure of its own; and though the work may be accomplished by the sheer force of capital and modern mechanical appliances, the proper question is, Will the thing pay? and could not the difficulty have been otherwise overcome, or altogether avoided, and another road chosen? Stores of water are locked up in the strata of the earth's crust, but these stores depend upon the nature of the strata—their alternations, their unbroken extent, their superficial covering, the absence or presence of dykes and faults, and other kindred phenomena—

and without a knowledge of these, no man is in a position to say where or where not the well has to be sunk or the boring carried down. We have recently seen, in one of the largest manufacturing towns in Scotland, an eighteen-inch bore of more than 600 feet in depth, carried down at great expense, and in a situation where the merest tyro in geology could have told the attempt was utterly hopeless. And thus it will happen again and again till men begin to understand that the earth's crust has specialties of structure which can be studied and determined by the science of geology.

As with tunnelling, excavating, and boring, so with other operations that come under the direction of the civil engineer; and yet not one in ten of those so designated has anything like a competent knowledge of geology. It would be invidious to point to individual instances, but there is scarcely a contested railway bill, water bill, or dock bill that comes before a Parliamentary committee, which does not exhibit the most disgraceful exhibition of counter and incompetent evidence on matters involving a knowledge of geology. Good and excellent many of these men undoubtedly are—capable of running levels, calculating earthworks, and applying mechanisms, but sadly ignorant of the structure of the country over which and through which their works have to be carried. And thus it is that we have alteration following alteration, and expense heaped upon expense, till at last the undertaking ceases to yield a return, and the capital of the unfortunate shareholders is virtually sacrificed to the ignorant blundering of so-called "Engineering."

Though dealing with the soil, or mere superficial covering of the earth, yet seeing that the soils are either derived from, or have fixed relations to, the rocks beneath them, the farmer may, in like manner, derive important hints from a study of geology. It may be quite true that high-farming and most remunerative farming have been conducted without any acquaintance with geological deductions; but surely the man who knows the rock-structure of his district, and how this may affect the composition, the retentive or absorbent nature, of the soils and subsoils with which he has to deal, has a power at his command which cannot be employed by his less-informed neighbour. The choice of an eligible farm, drainage, mixing and ameliorating soils, the facility of obtaining lime, marl, and other mineral manures, must ever be peculiarly aided by some knowledge of geology; and he in possession of this will ever have—other things being equal—the better chance of success. And what to the mere farmer will ever prove an advantage, becomes indispensable to the land agent and valuator. No estate can now be fairly valued, either for sale or for farming, without taking into account its mineral resources; and though the agriculturist may obtain this information through the mineral surveyor or geologist, yet some acquaintance with the science must enable him the better to appreciate these reports, and to shape his own estimates for the behoof of his employer. We have known an estate in Fifeshire sold for thirty years' purchase of the rental of its poor, sterile, clayey surface, and which, for the outlay of some twenty or thirty guineas in a mineral survey, would have readily brought three times the price to its stupid and ill-advised proprietor.

And if to the farmer and land agent at home a knowledge of geology be of advantage, much more must it be to the emigrant and settler in a new country. He has to make his choice not only of soil and situation, but of mineral wealth below; and what may be uninviting in the landscape and soil, may be more than compensated by the treasures that lie beneath. Indeed, to no one can a scantling of geology be of greater service than to the settler in a new country;

and scarcely one of those who have made land purchases in America, in Australia, or New Zealand, but continue to regret that they had not been in some measure acquainted with the science. Even the officers of our army, the traveller for pleasure, and the sportsman in search of adventure, each and all admit the want they have felt, and the chances they have missed, from their ignorance of mineralogy and geology. The discovery of a new plant or of a new animal may be an acquisition to science, without being of any economical importance, but it rarely happens that the discovery of new mineral fields is not a gain alike to science and to industry.

To the landscape gardener and artist a knowledge of geology and its relations to scenery cannot fail to be of value. On the rocks and soils of a district depend its capabilities for improvement; and without a knowledge of this connection there can be no judicious laying out of estates, planting of woods, and otherwise adding to the beauty and amenity of a situation. The rocks of a country form the framework and basis of its scenery; its hills, its crags and precipices, its glens and ravines, its sea-cliffs, bays, and promontories, all taking their aspects and hues from their structure, the manner in which they yield to the weather, and other physical characteristics. A knowledge of anatomy is not more necessary to the animal-painter, than a knowledge of geology is to the painter of the landscape; and though landscapes of undying grandeur and beauty have been painted without any special acquaintance with geology, yet will such knowledge be of service to the ordinary artist, and serve to heighten still more the productions of genius.

Such is a hasty glance at some of the more obvious bearings of Geology—bearings which, whether scientific or practical, would require a volume for their full and satisfactory explication. To such professions as we have alluded—mining engineer, builder, civil engineer, farmer, settler, landscape gardener and painter—it requires little effort to see how closely the science bears on these pursuits, and how greatly they would be assisted by some acquaintance with its leading deductions. But, independently of this more immediate and economic value, the science of geology has many claims to its study, even by those who may never be called upon to apply it. As the history of our world, through all its phases of time, change, and progress, it must ever have charms for the educated intellect; a healthful and exhilarating pursuit, whose objects are scattered everywhere beneath and around us; a study whose objects are open at all seasons; and a science whose problems are graven on every feature of the landscape—hill and valley, lake and river, crag and gorge, beetling sea-cliff, and sandy shore.

Nor do its intellectual attractions as a main branch of natural science constitute its sole attractions. Its bearings on other departments of knowledge, its startling speculations and bold generalisations, can never fail to secure the interest of the cultivated intellect; nor least the bearings of these generalisations on modern thought in all that appertains to new notions of time, immutability of law, continuity and progress, and other themes that are gradually widening the restricted boundaries of olden belief, and giving a more catholic impulse to human aims and to human aspirations. And if all this, or even less than this, can be ascribed to geology during its brief cultivation of little more than half a century, what, we may presume to ask, will be the influence of its teachings during the remaining portion of the century that lies before us?

THE NATURE OF GEOLOGICAL EVIDENCE.

THE increasing number of intelligent minds now devoting themselves to geological pursuits is evidence sufficient that the objects of the science, and the methods by which its cultivators seek to obtain them, are more and more meeting with appreciation and approval. Notwithstanding all this success, we not unfrequently hear from the outside misrepresentations of geology, and undervaluing of its results, as if its aim was to unsettle old beliefs without establishing more rational in their stead, and its deductions were illogical and uncertain. That views which run counter to long-cherished and popular opinions should be received with caution and hesitancy is only what geologists, in the prosecution of their inquiries, may expect; but it is no honest reason why their science should be misrepresented or its advocacy traduced.

What we propose, therefore, on the present occasion is, to direct attention to the nature of geological evidence; to show that, when the observations of our science are competently made, they furnish the most reliable of all testimony; to prove that its leading deductions must be accepted as demonstrations; and to insist that any refusal of these must arise either from incapacity to comprehend, or from an untruthful and wilful resistance to conviction. At the outset, it must be admitted that the assertions of geology, often startling and at variance with popular beliefs, demand the most critical scrutiny. When a science tells, in opposition to what has been taught for ages, that this earth is of unknown antiquity; that its existing seas and lands were not the seas and lands of former epochs, any more than they will be the continents and oceans of the future; that existing plants and animals are not the same as those that lived in bygone periods; that there has been a gradual ascent in time from lower to higher forms; that all life is bound together by a common plan of evolution; that man himself partakes of this plan, and has been an inhabitant of the globe for untold centuries;—when a science makes these and similar averments, we admit that it is but reasonable its doctrines should be received with hesitancy, and submitted to the most searching investigation. If, however, these averments are made in good faith, and have been logically deduced from correct observation, there is no getting over them, however much they may differ from our preconceptions, and we are bound to admit them into the category of our rational convictions.

Of course, in all our reasonings respecting the past, we must be guided by our knowledge of the present, and by faith in the even uniformity and continuity of the operations of nature. We must believe, for instance, that frosts disintegrated, winds blew, rains fell, rivers eroded, waves wasted, and currents transported, in time past precisely as they do now; and that heat, light, moisture, and other climatic conditions, exerted their influence on plants and animals in the remotest ages of the world in the same manner, and with the same results, as they do at the present moment. This belief lies at the foundation of all our reasonings. The whole argument of our science proceeds upon the conviction that this world of ours is governed, as it was designed, with a perfection of design and an even uniformity of action that leaves no room for interruption, interpolation, or novelty. "It is true," says Professor Ansted,* "that this view of the government of the universe does not accord with the feelings of those who desire to have their attention directed in a definite manner to the repeated systematic personal intervention of a Divine Power, and who cannot recognise this power without being able to trace what is called the finger or the hand of the Creator in all His works. In a certain sense, no doubt, every contrivance, or, in other words, every arrangement, in the universe may be made to yield evidence of this. But we would venture to suggest that the noblest view of creation, and a knowledge of the real greatness of the Creator, can only be learned by those who seek to discover the much higher and nobler intelligence that designed the whole system. That there should be an interfering hand is a mark of weakness in the original plan. If the structure be perfect, interference is not necessary." And again: "All true science has for its object not only the observation of facts, but the investigation of methods and the discovery of laws. These laws can only be binding and unalterable because they cannot be changed with advantage—in other words, because they are perfect, as being instituted by One who is Himself perfect." This doctrine of uniformity of action and continuity of method, acting in conformity with a higher law of universal progress, is fundamental to geological reasoning; for once anything irregular or cataclysmal were admitted into our reasonings, there would be an end to all satisfactory argument and certainty of result.

Admitting this uniformity—and not a step in advance

* 'Physical Geography,' p. 442, 443.

can be taken without it—geological evidence presents itself sometimes as direct, most frequently as circumstantial, and in many instances as negative merely. Where we cannot get direct or primary testimony, we must, as in matters of law, fall back upon secondary or circumstantial; and where both of these are wanting, we must, as in the affairs of everyday life, content ourselves with the inference that certain things were not, because we have no indication of their being. Of course, in geology, direct or primary evidence can have reference only to the existing. No one doubts or can doubt the formation of a new island by volcanic agency when the event, as in the case of Santorino, is witnessed and described by trustworthy authorities. No one gainsays the effects of running water in eroding glens and ravines, or the power of waves to wear and waste away considerable tracts along our sea-coasts, when the facts are so abundantly obvious. No one denies the distinctly recorded discharges of the Skaptar Jokul in 1783, the upheaval of the Chilian coast in 1822, or the submergence of Port Royal in Jamaica in 1692. Where we have good living witnesses, or authentic historical evidence, the facts of geology are just as certain and entitled to belief as the facts connected with the everyday affairs of life, and far more reliable than most of the testimony taken under oath, which is either falsified by the bias of the witness, or obscured, if not indeed perverted, by the cross-examination to which he may be subjected. But as direct and historical testimony refers only to the most recent phenomena in the field of geology, and as the phenomena of the remote are infinite in comparison with those of the recent, the great bulk of our evidence must be secondary or circumstantial. We have no eyewitness of the phenomena of the past, but we have the results registered in the crust of the earth with undeviating certainty and sequence, and yielding, when properly interpreted, the most convincing evidence of the causes that produced them.

Let us see how far a science having such materials to found upon can be said to be uncertain. We are draining, for example, through some basin-shaped, level-surfaced meadow-land. The general form and flatness of the spot may have suggested the idea that it was the site of an ancient or silted-up lake; but the moment we dig, the geological evidence converts the inference into a matter of certainty. We pass first through the superficial soil, next through a bed of peaty earth, then through a layer of shelly marl, and, lastly, through a stratum of clayey silt. In the peat we detect antlers of deers and bones of oxen; in the marl, innumerable shells of fresh-water mollusca; and in the silt, rude canoes hollowed out of a single log. Here we have the whole history of the lake recorded with an exactness and sequence to which human chronicling can seldom aspire, and we can trace its successive stages as clearly as if we had lived by its shores from the time it was a rippling sheet of lowland water to the hour of its final obliteration. First, the open lake, over which the simple native paddled his rude canoe; second, the shallower sheet, where fresh-water shell-fish luxuriated in myriads, and succeeded each other generation after generation; third, the peaty marsh, over which deer and oxen occasionally ventured and were mired; and, lastly, the level meadow, when the site had become too dry for the peat-forming vegetation of the morass. It is true we have no chronology for those events; nothing save sequence or a certain order of occurrences. We cannot say whether the canoes were sunk in the silt two thousand or three thousand years ago; or whether six centuries or sixteen centuries have elapsed since the deer were mired in the morass. Did Roman remains occur in the peat-bed, as they sometimes do, we would then have an approximation to the date of the deer, as we know historically the time when the Romans invaded this country; but of the canoes, all we can say is, that they were pre-historic and of unknown antiquity. We may form some idea from the known date of lake-silting; for when we have sufficient observation in geology, time-averages may be struck with considerable accuracy, and they are quite as much entitled to belief as averages in life-statistics, or in other economical matters upon which men so implicitly rely. When, therefore, certain objects are found at certain depths in lake-silts and in deltas, we are entitled—judging from the average rate of accumulation of such deposits—to say whether it could be less than four thousand or six thousand years since they were entombed.

In general, geology contents herself with a relative chronology, and does not condescend upon dates in years and centuries; but though this is her practice, and wisely so, there is nothing to prevent an approximation through averages, where observation has been carefully and sufficiently long continued. There would be an end to all inference by reasoning if we did not allow our knowledge of the present to guide us in our conceptions of the past, as well as to aid us in our expectations of the future. Though the conclusions of our science be thus inferential, they are founded upon unerring testimony, and their value will ever be in proportion to our knowledge of existing nature and our power to observe with accuracy. Had we no record of the entombment of Herculaneum and Pompeii, we could, from the remains now excavated, and our knowledge of Roman history and Roman art, have approximated the date of the catastrophe. But had these remains borne no resemblance to anything Italian, Roman, Greek, Etruscan, Phœnician, or Egyptian—had they had nothing in common with any of the civilisations that have been evolved along the Mediterranean—then we would have been compelled to regard them as pre-historic, and to have dated them prior to the oldest of these nationalities. Than this there is no other course left for the geological reasoner; and where the argument has been carefully conducted, the inference may be relied on as implicitly as any other inference upon which we found our convictions. And yet, either from want of scientific training, from bias of old beliefs, or from a wish to pander to popular prejudices, it is by no means uncommon to hear geological inferences denounced as uncertain and fallacious. "Here is a cavern," say these opponents, "containing traces of animals still existing, human implements of flint and bone, and remains of extinct animals,—and what does it prove? Simply this and nothing more, that it was a cave when the extinct animals lived in it, a cave when man took shelter in it, and a cavern still when the wild beasts of the country frequent it." Could any argument be more irrational or disingenuous? Is there no element of time, no sequence of events, no chronology, in fact, in the order of these occurrences? Let us see.

In certain caverns the geologist finds the bones of various animals imbedded in the calcareous earth that has accumulated on their floors. This stalagmitic crust is in general a thing of slow formation. It may increase through the winter more than through the summer, or more during a wet year than a dry one; yet, on an average of years and centuries, its increment is pretty regular, and may be calculated with considerable certainty. On breaking up this stalagmite we discover that many of the bones have been gnawed, and that some, and especially the hollow ones, have been split up into longitudinal splinters. We ascribe the gnawing to den-frequenting carnivorous animals like the hyæna, and the splitting to human instrumentality, as we know of no other creature save man capable of so manipulating. These inferences are of themselves sound and reliable, but they amount to absolute certainty when, on further examination, we discover the hardened and peculiar excrement of the hyæna, and the stone hatchet of the rude, marrow-sucking savage. Supposing no implements had been detected, and that doubts existed as to the splitting of the bones, we find, on more minute research, ashes and fragments of wood-charcoal scattered through the stalagmite, and then the presence of man in these caverns becomes at once an established certainty. No creature save man lights a fire—no creature save man ever lighted one; and the testimony of these wood-ashes as to the existence of a cave-dwelling race is as conclusive as if we had witnessed their grimy countenances lighted up by the fires of which these fragments were the latest embers. And now the sequence is clear; the deeper in the stalagmite, the older the remains. The bones of the existing fauna are found in the mere superficial crust—the bones of the extinct animals and the flint implements deep in the cave-earth, and bespeaking an antiquity, not of centuries merely, but of hundreds of centuries. Such is the nature of our evidence—such the line of our argument; and the mind that fails to comprehend, or refuses to accept, may be fairly set aside as incapable either of comprehension or conviction.

As already mentioned, the true appreciation of geological evidence depends upon our knowledge of the existing forces, methods, and operations of nature. Similar causes acting under similar conditions must produce similar results; and from well-observed results we can surely reason back with certainty to their producing causes. Within the last half-century, for example, philosophers have studied with minuteness the action of ice on land as well as its results on water. They have seen how the glacier pushes its way down the Alpine valley, grinding, rounding, smoothing, and striating the rocks over which it passes, and leaving, as it melts away, its burden of rock-debris in terminal, medial, or lateral moraines. They have also witnessed how the glacier of the polar regions pushes its way seawards, till, in deeper water, it floats and breaks away, carrying with it its burden of rocky fragments, and dropping them on the sea-bed as it melts in more genial latitudes.

In countries now far removed from glacial action, the mountain glens are frequently fringed with spits of shingle, or barred at their lower extremities with transverse mounds of sand and gravel; while the subjacent rocks are all rounded and polished, and grooved precisely like those of existing glacier regions. No known agency save land-ice produces such smoothings and groovings; none but the glacier leaves such mounds of miscellaneous rock-debris. Are geologists wrong in ascribing similar results to similar causes, or illogical in inferring that these mountain-heights were once covered with perennial snows, and their glens filled with glaciers? Widespread over the lowlands of the same countries are huge boulders, often many tons in weight, having their surfaces smoothed and striated, miles removed from their parent rocks, and which no force of moving water could transport. Witnessing the transporting power of ice, are geologists wrong, or are their inferences uncertain, when they refer the dispersion of these boulders, in some instances, to the movement of an ice-sheet on land; and, in others, to the floatage of icebergs on water? Nor are these evidences and inferences applicable alone to physical phenomena, but tell with equal force when applied to life and its relative chronology. We find, for instance, in many of our British clay-beds, abundance of shells now living in polar seas; and as we have no reason to suppose that the relations of life to external conditions were ever otherwise than at present, we are entitled to infer that when these clays were deposited and shells lived, a climate similar to that of Greenland prevailed over British latitudes. If facts be of any value, such are the facts; if knowledge of existing nature be of any importance to reason, such are the conclusions at which honest and unbiassed reasoning must arrive.

Again, remains of reindeer and musk-ox occur in the superficial accumulations of France and Belgium, and remains of mammoth and tichorrhine rhinoceros in those of France and Britain. The presence of the reindeer and musk-ox bespeaks an arctic climate; and that of the mammoth, from all we have learned of its character in the frozen sands of Siberia, implies conditions still more rigorous and boreal. Now, as changes in climate are brought about by the slow oscillations of sea and land, such extensive changes as those we have referred to in the latitudes of France and Britain could only have been brought about after the lapse of ages; and we are constrained to refer these remains to a high but indefinite antiquity. And, by a similar process, when traces of man and of his works occur in the same formations with those of the extinct mammoth and rhinoceros, we are necessitated, it may be against all our preconceptions, to assign to man a contemporaneous antiquity in Western Europe. What this antiquity may be in years and centuries, geology has yet no means of determining; but, judging from all the combined circumstances of climatic change and extinction of species, it must lie far, very far, beyond the range of our popularly-received chronology. And here one cannot help remarking, that to all these oscillations of sea and land, to all these changes of climate, and to all these extinctions of species, certain minds will give the readiest assent; and yet the moment that man's antiquity becomes involved in the argument, the same minds bristle up with antagonism, and seek to explain away the plainest facts by reasoning that might be laughed at for its absurdity, were it not for the uncharitable spirit by which it is almost invariably accompanied. And it does seem strange and unaccountable that men who are perpetually straining after a high antiquity for their individual families, should have such a mighty dislike for a venerable antiquity for the race!—strange that individuals who pride themselves on their descent, and are never satisfied till they have struck the roots of their family tree to a depth that defies contradiction, should entertain such antipathy to a few thousand years being added to the chronology of the whole human family!

Such are a few examples of the nature of geological evidence and geological methods, as applied to the more recent formations, and which we have given first, as being more intelligible to the non-scientific mind. But the testimony is equally convincing, and the methods the same, when applied to the remotest phenomena in the crust of the earth. Wherever we find stratified rocks, there we know that water has been, either as sea, lake, or estuary; for it is only through and by the agency of water that stratified rocks can be formed, and in water that they can be deposited. As the greater portion of the earth's crust is composed of stratified rocks, hence the unavoidable inference that what is now dry land has been under water, and, *vice versa*, that which is now under water was the dry land of preceding epochs. Nor are we at a loss to determine what was formerly lake, or sea, or estuary; for the fossils imbedded in the strata—fresh-water for the lake, marine for the sea, and intermediate for the estuary—deliver a testimony as convincing as if we had lived by the water-side and had witnessed their growth, decay, and entombment. Any series of limestones, sandstones, and shells, for example, containing star-fish, sea-urchins, or corals, are set down as having been deposited in the sea, because all experience teaches that such organisms are never found living in any other than sea-water, just as certain shells (*lymnea*, *paludina*, &c.) are evidence of fresh-water, or an admixture of river and marine organisms indicative of estuarine conditions. So long as we know of no change in the governing conditions of life, the testimony of the rocks on this point must be received as conclusive; and we have the same ground for saying that this stratum is of marine origin and that of lacustrine, as we have for pronouncing a whale to be aquatic and a horse terrestrial. Nor is it otherwise with the unstratified rocks: we find them piled up in mountain masses, breaking through the stratified rocks, and tilting, bending, and throwing them out of their original horizontal positions, filling up the rents and fissures as dykes, or interstratified among them as overflowing sheets. There is not a relation in which they stand to the stratified rocks but is amply paralleled by the phenomena of existing volcanoes; and no competent observer can have greater difficulty in accepting the evidence which the unstratified rocks give of former igneous activity and convulsion than in admitting the eruptions and earthshocks of Etna and Vesuvius. The whole crust is replete with evidence of its own history—evidence that leaves no room for doubt, nor needs anything extraneous by way of supplement or corroboration.

Nor, in dealing with its extinct forms of life, has the palæontologist anything more of doubt to contend with, though he has perhaps a much more difficult task. Fossils, such as they are, are real and genuine—the absolute relics of bygone life—not sports of nature, delusive and deceptive. They may be sorely mutilated and defaced, strangely altered by mineral and chemical action, scattered in fragments, and difficult to be deciphered; but there they are, awaiting the touch of competent skill to restore their forms and determine their relations. Acquainted with the intimate structure of plants, knowing their living orders, and understanding how they are affected by external conditions, the fossil botanist, though dealing with a very obscure and difficult subject, can arrive at many important determinations. The evidence he has to deal with may be deficient, but it is never deceptive, if right methods are taken, and nothing assumed beyond what is apparent. And so, also, but in a more satisfactory manner, with fossil zoology. To the skilful anatomist, every bone, and tooth, and scale, and fin-spine is perfect evidence of class, or order, or family; and as we have no ground for supposing that the relations of life to external conditions were ever different from what they are at the present day, he can indicate the conditions—terrestrial, aquatic, or aërial—tropical, temperate, or boreal—under which the creatures existed with certainty, always in proportion to the perfection in which the animal has been preserved. And more: knowing the great law of co-relation, which adapts every portion of the animal framework to every other portion for the performance of certain functions and the accomplishment of certain ends, he can restore the forms and indicate the habits of the individual creatures that formerly peopled our globe, and thus present a picture of its successive epochs such as the geographer attempts at the present day. He may err in his interpretations, or may allow his imagination to overrule his judgment; but the evidence remains reliable and certain as ever to those who are more competent to use it.

Besides the direct evidence of modern events, and the circumstantial evidence that refers to bygone ages, the geologist has occasionally to draw his inferences negatively—or, in other words, to conclude that certain things did not exist, or certain events did not happen, because all evidence to the contrary is wanting. Such a course may not be altogether satisfactory—and the opponents of Geology have generally made the most of this so-called "negative evidence;" but in many instances, in the affairs of everyday life as well as in matters of science, we have no other ground upon which to found our convictions. No discoverer has yet demonstrated the existence of great sea-serpents, mermen, or mermaids; and hence, though all parts of the ocean have not been explored, men in general disbelieve in mermaids, mermen, and sea-serpents, and this entirely on the faith of negative evidence. No hippopotamus has been seen in the rivers of America, and on the strength of this negative testimony we exclude the hippopotamus from the fauna of the New World. In the same manner, because research has hitherto failed to detect, geologists do not believe that fishes existed prior to the upper Silurian period, reptiles before the Carboniferous era, birds antecedent to the New Red Sandstone, or true mammalia earlier than the Tertiary epoch. It is true that this is negative testimony, and nothing more; but mankind must believe provisionally according to their knowledge; and surely what is universally acted upon in other matters cannot be consistently refused to geology.

Such, then, in brief and general terms, is the nature of geological evidence, and the methods in which it is employed in geological reasoning. So far as honest observation goes, there can be nothing uncertain in the evidence; so far as competent knowledge can interpret, there need be nothing unreliable in the deductions. It is upon evidence such as this—partly direct, partly circumstantial, and partly negative—that geology bases her conclusions—her conclusions of the inconceivable antiquity of the earth, the frequent changes its surface distributions have undergone, the repeated extinctions of old, and introduction of new, species of plants and animals, the gradual ascent from lower to higher forms of life, the evolution of the whole vital scheme according to some plan of progressive development, and other similar deductions, which mark a new era in human thought, as well as in human philosophy.

Concerning subjects so vast and novel, it was not to be expected that the deductions were to pass unchallenged, or the testimony to remain unquestioned; but it is expected, and it is demanded, that both should be treated with fairness, and not subjected to misrepresentation. If geologists should occasionally decline to be decisive, it is not because their evidence is uncertain, but simply because they wish it to be more complete. If they should sometimes seem to hesitate, it is not that they feel their argument is weak, but simply because, in dealing with phenomena so complex and wonderful, they shrink from being dogmatic. It is true they may occasionally doubt; but, as Humboldt observes, "physical philosophy doubts because it seeks to investigate, distinguishes between that which is certain and that which is merely probable, and strives continually to perfect theory by extending the circle of observation." Let us continue, then, to observe; let us weigh well between the certain and the probable; and let us doubt rather than arrive at conclusions where the data are scanty or in any way liable to misinterpretation. And if the great German philosopher has pronounced emphatically that true "geognosy is a science as capable of certainty as any of the physical descriptive sciences can be," we may surely accept the dictum of his gigantic and sagacious understanding, and continue to work under its encouragement, rather than be deterred by the clamour of a wilderness of unreason and prejudice. And even where the facts are too complicated or too obscure for our keenest discernment, and the truth lies far beyond the grasp of our strained and wavering comprehensions, let us console ourselves with the remark of Dugald Stewart, that, "when we cannot trace the process by which an event *has been* produced, it is often of importance to be able to show how it *may have been* produced by natural causes; for by this means the mind is not only to a certain degree satisfied, but a check is given to that indolent philosophy which refers to a miracle whatever appearances in the natural or moral worlds it is unable to explain."

In this world of ours we see nothing save a ceaseless round of causes and effects, of means and ends, of processes and products; and we may depend upon it that these activities and results will never be understood unless we work under the inspiring belief that they were all intended to be known. The way to their comprehension may be toilsome, the timid may halt, and the stoutest may fail, but mankind may rely that satisfactory and permanent convictions of God's workings in nature will never be arrived at except through the exercise of the observing mind and the reasoning intellect. In the case of our own special science, let this be the hope that impels and the belief that determines. Its facts and evidences are scattered everywhere around and beneath us; they are graven in indelible characters on the rock-formations of the crust: let us rest not till we have read; and when we have read, let us rest not till the newer knowledge they impart has become the common property of man.

UNIFORMITY AND PROGRESSION.

In the earlier days of geology every unusual appearance on the surface or in the crust of the earth was ascribed to cataclysms and convulsions of nature—if not to cataclysms, at least to something unwonted and abnormal. Was it a clay containing huge water-worn blocks and boulders, then it was the result of some extraordinary current or over-sweeping wave of translation; a deep ravine or precipitous mountain-gorge, then it arose from some internal convulsion; or were it the coal-formation, with its thick and wide-spread masses of transformed vegetation, then abnormal conditions of climate and atmosphere were evoked to account for the phenomena. These notions arose, no doubt, partly from a limited and imperfect knowledge of nature, but chiefly from traditionary beliefs respecting the age of the earth, which required all the appearance in the rocky crust and all its external features to have been produced within the brief space of a few thousand years. Where the phenomena were so vast, and the time so limited, the producing causes must have been correspondingly gigantic, and thus it was that the idea of cataclysms and convulsions took possession of the scientific mind. As observation was extended, and men's knowledge of nature became more intimate, these notions of spasmodic energy gradually gave way to ideas of undeviating and enduring order in nature; and hence the newer doctrine of *uniformity*, in opposition to that of *cataclysm* and *convulsion*—the school of "uniformitarians" or "quietists," as opposed to that of "revolutionists" and "convulsionists." Let us see for a while how much more rational and philosophical the newer doctrine is, and how much more satisfactorily it accounts for the phenomena of the earth's crust, than the older idea of convulsion and disorder.

As far as individual experience or the range of human history extends, everything in nature appears to be brought about by established methods, and in fixed and undeviating order. Even where the results are sudden and gigantic, the methods are the same: *quantitatively* they may differ, but *qualitatively* they belong to the same order, and arise merely from the same forces exerting themselves under conditions more favourable to their fuller development. All the motions of the heavenly bodies, all the influences we derive from the sun, so far as experience goes, have ever been of the same kind, and where perturbations occur, these are restricted to certain limits, so that in the main we have regularity and order, which may be relied on and determined. And in the same way with all the secondary phenomena of our planet, whether meteoric, aqueous, igneous, chemical, or organic. They may exert themselves with greater or less intensity, according to the conditions under which they act, or the relationships under which they are placed; but their modes of action are the same, and their results over wide averages of time and space are marked by a marvellous amount of regularity and uniformity. Heavy rainfalls, sudden meltings of snow, flooded rivers, storms of the sea, hurricanes of wind, volcanic eruptions, and earthquake convulsions, are at the most mere local and temporary phenomena; and though to that extent they may be regarded as cataclysmal, yet, as affecting the whole globe, they are merely parts and parcels of regular law-directed and law-restricted forces. Were it not so, we would be living in a world surrounded by agencies so fitful, that it would be as futile to prepare for the future as it would be hopeless to determine the course of the past.

Believing in this uniformity of natural operation, geologists turn to the crust of the earth and make their knowledge of the existing the key whereby to unlock the history of the past—their acquaintance with the present the interpreter of the facts and phenomena of former ages. They see at present that the waste of the dry land by frosts, rain, rivers, winds, and waves, is borne down by running water, and deposited as sediment in lakes, estuaries, and seas, in layers or strata more or less horizontal, and in thickness according to the amount of matter carried down, and the time during which it has been forming; and so they regard all stratified rocks as of sedimentary origin, and as having been derived by meteoric and aqueous action from pre-existing lands. They perceive that muds, sands, gravels, calcareous marls, and vegetable debris, are deposited under certain conditions and by certain agents; and in like manner they ascribe the formation of the shales, sandstones, conglomerates, limestones, and coals of the solid crust to the existence of similar conditions, and the operation of similar agents. Nothing can be more logical or satisfactory than this procedure; and when a shale or limestone of uncommon thickness, or a conglomerate of unusually large pebbles, presents itself, the uniformitarian, instead of calling to his aid abnormal conditions and cataclysms, appeals more philosophically to longer time or to more favourable phases of local operation. Our knowledge of existing nature is not sufficiently intimate to collate all the conditions under which any local rock-mass may be aggregated; and it is certainly more philosophical to believe in order and method—in the midst of so much that is orderly and methodical—than attempt to justify our ignorance by appeals to revolutions and convulsions.

As with the stratified rocks in all their varied aspects and relations, so with the unstratified. The geologist perceives at the present day the operations of the earthquake and volcano from their gentlest manifestations, which may pass by unobserved, to their fiercest intensity, which upheaves new hills and submerges former islands. In this operation rocks of various character and consistency are ejected by the volcano, fissures and inequalities of surface produced by the earthquake. By a study of these volcanic rocks, their composition, the manner in which they break through, displace, and alter the stratified formations, the geologist sees at once the exact counterparts of much that occurs in the solid crust; and believing that like results are produced by similar causes, he ascribes the basalts, greenstones, porphyries, tufas, their effects on the stratified rocks, the displacement of strata, and the filling of rents and fissures with igneous products, to the operation of earthquakes and volcanoes during former ages of the world's history. Than this he has no other course to follow, and he would be utterly impotent to read the history of the earth's past unless he drew his interpretation from his knowledge of her existing operations. As he looks upon the volcano and earthquake as necessary to the conservation of a terraqueous surface, he cannot regard them as cataclysmal unless in the most limited and local sense, and in the same light he is led to consider all the volcanic phenomena of former ages. As the manifestations of vulcanism are restricted to certain areas in the present day, so the geologist finds it restricted in former ages, there being no period in the world's history (that is, its history as revealable by geology), when vulcanism was universal, or when its manifestations were on a scale of greater magnitude than at the present moment. Here, then, as in the case of the stratified rocks, the doctrine of uniformity supplies a method of interpretation at once trustworthy and easy of application, making no impossible demands on our belief, but uniting the past with the present in one continuous and intelligible current of world-history.

Again, in studying the relics of vegetable and animal life which occur imbedded in the stratified rocks, the geologist judges of the mode in which they have been entombed by his knowledge of the manner in which he sees similar remains borne down at the present day by rivers, silted up in lakes and estuaries, or buried in the sediments of the ocean. He perceives the causes that bring death to individuals as well as to numbers—decay from maturity, the overturning of forests by hurricanes, death from disease, the sweeping away of flocks and herds by floods and inundations, the destruction of shoals of marine animals by storms, poisonous exhalations, and other similar causes; and as he regards these in the ordinary course of nature, so he is prepared to regard the relics of former life, whether occurring singly or in masses by thousands. As the uniformitarian sees nothing like general destruction of plants and animals in the present day, so he cannot believe that in time past there were any great revolutionary "breaks in life,"—those cataclysmal removals of organic beings, and repeoplings of the earth with other and newer species, upon which the earlier geologists delighted to descant with so much eloquence and marvel. So far as we can see, the great current of life is ever onwards, birth and death, reproduction and decay, ever accompanying each other; and we may safely believe that such was the order of life in all former ages. The fiercest hurricane, the widest inundation, the most fatal epidemic, has never more than a mere local and temporary position. Can geology discover anything in the past that should invest them with a wider or more permanent character?

Such is the doctrine of uniformity, and such is the belief that has given consistency to the whole teachings of modern geology. Not only is it more consistent and philosophical in itself, but it better accords with the facts observed in the rocky crust. There is not a mechanically-formed rock—clay, shale, sandstone, or conglomerate—but implies long-continued wear and waste from other and pre-existing rocks, and gradual deposition in water, such as we observe going on at the present day. Convulsion and cataclysm bespeak rupture, fracture, and pell-mell disorder—a thing never witnessed in the stratified formations, unless in the most local and limited degree. Even among the igneous rocks we have here a shower of ashes, there an overflow of lava; here the strata bent and fractured, and there a rent filled up with molten matter from below; but never mountains of instantaneous formation, nor continents submerged or upheaved in an instant. Again, as regards the organically-formed strata—the limestone and coals—there is not a bed of any extent that does not bear evidence of its slow, gradual, and uniform increase; the growth, decay, and aggregation of coral, shell, or shield—the growth, decay, and deposition of stem, branch, and leaf—such as we witness in the coral-reefs, the shell-beds, peat-mosses, and swamp-growths of the present era. The whole crust, as Dr Hutton long ago taught, is a thing of slow and gradual transformation; here worn and wasted away by frosts, rains, rivers, winds, waves and tides—there reconstructed by the deposition of the debris in lakes, seas, and estuaries; here submerged by vulcanic commotion within, and there upheaved into new lands, again to undergo the same process of waste from without, and of reconstruction from within.

Indeed, without this belief in the uniformity of nature's operations there could be no geological history. If nature were not uniform in her methods, this rock might have been formed by precipitation, that by sediment; this by water, and that by fire; this in a day, and that in a thousand years. The belief that similar results are produced by similar means lies at the foundation of geological science, and the moment departure from this belief is introduced, geology becomes a mass of uncertainties, and the phenomena of the rocky crust a series of isolated results, having no reliable cause, and unconnected by any continuity of method or design. The causes now productive of geological change must have been productive of similar changes in former ages. They may have acted at certain periods over wider or over narrower areas, and they may have acted with greater or less intensity according to the conditions by which they were accompanied, just as we see them operate in different areas in the current epoch, but we have no real evidence in the rocky crust that they ever acted by fits and turns, either with spasmodic violence or by general convulsion.

But while interpreting the earth's crust by this principle of uniformity, it must ever be remembered that we are living in a world of progress, and that ideas of uniformity and continuity must be held in connection with, if not in subordination to, this higher notion of universal progression. Geographically, the world is ever passing from one phase to another; vitally (so far as geology has interpreted), it has been peopled at each successive stage by higher and higher forms of existence. Though rain will ever act in the same way, the rainfall of any region may be less or greater now than it was in former ages; and though the earthquake and volcano will ever be followed by similar results, the district that was formerly convulsed may be now quiescent. Physically and vitally, the same phenomena may never be, and indeed are never likely to be, enacted again in the same region, and thus it is that the doctrine of uniformity must be held in connection with that of progression and advancement. More than this: while to the mere geologist this world of ours "shows no traces of a beginning nor symptoms of an end," it may yet be established by the physicist and astronomer that there are causes beyond this earth, and to which this earth must be subject, which have ever been slowly affecting its individual condition as well as its planetary relationships; and that what we now consider uniform is only apparently so—nothing in nature repeating itself, but everything steadily though slowly passing on to other and other phases. But though these higher views were established to-morrow, and would necessarily affect our speculations as to the past and future of our planet, for all practical purposes in geology the doctrine of uniformity might still be retained, as giving consistency to our reasonings and leading to intelligible results.

Astronomical speculations, for example, relating to the gradual cooling of our globe from a state of igneous fusion—to its consequent contraction and greater rapidity of rotation—to the secular diminution of the sun's heat, and its ultimate effect on the relations of the whole solar system—these and kindred speculations, which, under the advancement of physical science, are beginning to assume something like the consistency of theory, do not materially affect this idea of "uniformity with progression" as held by geologists. Indeed, the physicist may prove, contrary to the dictum of Hutton, that we can perceive "traces of a beginning and symptoms of an end" to this world of ours; but in doing so the means he calls into play are so slow and gradual that no perceptible deviation in their mode of action can be perceived since the deposition of the oldest rock-systems, or the period to which the labours of the geologist are legitimately restricted. Within this range—and the time is inconceivably vast—the doctrine of "uniformity with progression" is the only one that gives consistency and stability to geological research, a safer guide to observation, and a surer key to the interpretation of the phenomena observed. Since its adoption, geology has taken, perhaps, the highest place among the natural sciences; before its reception, geology, as reliable world-history, can scarcely be said to have existed.

PRESENT ASPECTS OF GEOLOGICAL INQUIRY.

To the cultivator of any department of science it is of special importance that he should now and then take a review of its progress, noting the strength and weakness of its several points, and, in particular, of such innovations as have a tendency to affect the general conclusions already arrived at. This "stock-taking," if we may so speak, which is necessary to all knowledge, is more especially needful in geology—a science whose progress during the current century has been more rapid than that of any other branch of natural history, and whose conclusions are not unfrequently received as fanciful and uncertain. On the present occasion we attempt such a review, noting some of the leading moot points, and the grounds upon which they may be opposed or defended.

And here at the outset, and notwithstanding these differences, it may be safely remarked that the study of geology was never in a more equable and well-balanced condition. No one branch seems to be in the ascendant, or cultivated exclusively to the detriment of others. Mineralogy and the discrimination of rock-species are not now, as at the beginning of the century, regarded as constituting the science of geology; nor is it the fashion to allow palæontology to absorb the whole of our interest and attention. Mineralogy and chemical geology, palæontology and physical geology, have each their students and cultivators; and though occasionally some novelty like the 'Origin of Species,' the 'Antiquity of Man,' or the 'Potency of Ice-Action,' may temporarily arrest the attention, yet, on the whole, the students of our many-sided science seem convinced that its general progress can be best promoted by every one labouring in that department to which he has been led by his natural predilections, and for the cultivation of which he has the greatest facilities. It is thus that the chemistry of our science is promoted by such researches as those of Bischoff, Delesse, Deville, Hunt, and Forbes; its physics by those of De Beaumont, Hopkins, Thomson, Mallet, and Sorby; its palæontology by Agassiz, Owen, Hall, Huxley, Pictet, De Köninck, Milne Edwards, Heer, Davidson, and others too numerous for detail; its stratigraphical successions by Murchison, Logan, Ramsay, Jukes, Rogers, Barrande, Hochstetter, Oldham, Hector, Selwyn, and others intrusted with government and colonial surveys; its systemal connections and higher generalisations advanced by such writings as those of Lyell, Phillips, Darwin, Dana, and Sedgwick; while in every county and provincial district a host of local observers are each contributing his mite of observation and discovery to the general fund of geological progress. No other branch of natural science, indeed, has of recent years made such rapid and substantial progress as geology; and though many problems yet remain to be solved and old errors to be exploded, still, on the whole, we may well congratulate ourselves on the nearer and hopeful attainment of something like an intelligible world-history. The increase of local observers, the augmented facilities for travel, the institution of government surveys by the different nations of Europe, the

States of America, and our wide colonial possessions, are every year adding immensely to our geological stores; while every new addition enables us to arrive at sounder conclusions than could be derived from the limited data supplied by our own little islands. But while all this is satisfactory for the present, and encouraging for the future, there are still many points requiring immediate and careful consideration, and to some of these we would now direct the attention of the geological inquirer.

Fundamental Strata.—Premising that all demonstrable geology commences with the oldest stratified rocks, the question naturally occurs, Where and what are these oldest strata? We have traced life down to the Cambrian grits and slates, but beyond these lie the more crystallised gneiss, quartz-rocks, and granitoid schists of the Northern Hebrides. Shall we, with Sir Roderick Murchison, designate these the "fundamental gneiss," and, seeking their equivalent in the Laurentian schists of Sir William Logan, regard them as the earliest and oldest of our stratified system? Even in these Laurentian strata, metamorphosed and crystalline as they are, Sir William Logan and his assistants, and more recently Principal Dawson, have detected traces of lowly organisation;* and in some portions more metamorphosed than others, more traces may yet be discovered. Time was, and that within the memory of most of us, when the lower Cambrians were considered as *azoic;* but now that life has been carried downward into an older and deeper system, true philosophy requires that we discard in the mean time all ideas of "fundamental rocks" and "prim-

* A foraminiferal organism, *Eozoön Canadense,* occurring among the serpentinous limestones in large sessile patches, after the manner of *Carpenteria* and *Polytrema.* The same organism has been more recently detected in the Connemara marbles of Ireland, and in the serpentines of Bohemia.

ordial zones," and leave the beginning of our stratified systems, like the origin of life, an undetermined, though not a hopelessly determinable problem. We may admit into our tabulations the Cambrian and Laurentian as well-defined and fossiliferous systems; but dealing with rocks so metamorphosed and obscure in their stratification, we must regard them not as the oldest or deepest, but merely the oldest and deepest with which we are at the present time acquainted. Finding that the traces of life are year after year carried deeper and deeper in the stratified rocks, and that in the older Silurians and upper Cambrians (the Lingula flags) the number of discovered organisms are also greatly augmented,* we are clearly not in a position to dogmatise on fundamental strata or primordial zones, and far less to regard any series of strata, however altered and crystalline, as *azoic* and *hypozoic*. Even where traces of life may be too obscure for the eye and microscope of the palæontologist, the tests of the chemist may detect the presence of organic matter, *or mineral products that could only result from the presence of organic matter*; and thus we are clearly debarred from doing more than merely placing *provisionally* the Cambrian and the Laurentian rocks as our oldest stratified and fossiliferous systems. We say *stratified* and *fossiliferous*, for our own belief is that life was coeval with the first-formed sediments; and that the meteoric and aqueous conditions that promoted the formation of sediments were such as would permit, at the same time, the development of vegetable and animal existences. Let us, then, accept provisionally the 'Cambrian' of Professor Sedgwick and the 'Laurentian' of Sir William Logan as separate and fossiliferous systems; but let us discard

* See the discoveries of Mr Hicks, in the so-called "primordial zone" or Lingula flags, as noticed in the 'Journal of the London Geological Society' for August 1864, and in subsequent numbers.

all ideas of "fundamental strata" and "primordial zones," and at the same time let us abandon such terms as *azoic* and *hypozoic*, which are founded alone on the uncertain and unsatisfactory basis of negative evidence. If a term must be had for these old schists and crystalline strata, perhaps that of "unresolved schists" would be as suitable as any other, involving no opinion as to their fossiliferous or unfossiliferous character, but simply implying that as yet they remain apart and unresolved into any chronological system or series.

Metamorphism.—The consideration of these older sediments brings us necessarily in contact with the subject of *metamorphism*, and on this point it seems that modern geology, under the sanction of high authority, is insensibly drifting into error. And, in the *first* place, it may be observed, that where any series of metamorphic strata have a clearly-defined position—that is, are sequentially connected with other fossiliferous strata, or contain, in some of their less metamorphosed beds, remains whose age can be determined—there can be no error and much advantage in calling them by the name of the system to which they belong, and discarding the term metamorphic. But where all sequential connection is lost, or at all events obscure and uncertain, and where not a trace of organism has been detected, as in the schists of our Scottish Highlands, it seems to be safer and more philosophical to regard them as simply "metamorphic," rather than designate them by the name of any system—Silurian or Cambrian—to either of which, to both of which, or to none of which they may yet be discovered to belong. The geological map of Europe is made more intelligible by marking the metamorphic strata of the Alps, for example, by the colour of the system to which they belong; but it is more than questionable how far the geology of Scotland is explicated, or the science itself promoted, by delineating, as has been recently attempted, the crystalline schists and quartzites of the Highlands as lower Silurian. As a fact, the term *metamorphic* conveyed no error; as a hypothesis, the designation *Silurian*, in absence of all fossil evidence, imparts no new knowledge, and tends to retard investigation.

In the *second* place, some geologists are evidently carrying the idea of metamorphism beyond its legitimate limits, and would ascribe to its intenser manifestations the production of the granites and granitic compounds. Now no one who has studied the porphyritic gneisses of our own Highlands will deny that some granites may be the result of intense metamorphism; but to assume that all granites have had this origin, and that none of them are truly eruptive rocks, is, in our opinion, an obvious and retarding error. Carry, if you will, with Sir William Logan, metamorphic action to such intensity as to render the masses plastic or semifluid, and what then? Simply this, that you have a highly-heated or vulcanic product capable of being forced into rents and fissures, and to all intents *intrusive*. But does it never occur to those who would deny the eruptive character of some granites, that these granites, like the schists with which they are associated, have undergone a metamorphism of their own, and that they were originally truly igneous like the basalts and greenstones? Place, for example, the Carboniferous and and Old Red strata of Edinburgh, with their associated porphyries, basalts, and greenstones, at great depths in the crust, and subject them to metamorphic action, and what would be the likely result? Evidently, that while the sandstones and shales and limestones and ironstones were being converted into quartzites, crystalline schists, and marbles and hæmatites, the porphyries and greenstones would also undergo metamorphism, and be changed into granites and syenites. So in all probability it has been with the old crystalline schists and their associated granites—both have undergone a metamorphism, but the former is not less sedimentary, nor the latter less eruptive or igneous, because of this internal mineral rearrangement.

Let us, then, clearly understand what we mean by the term *metamorphic*, and take care how it is applied. It is a convenient term for altered strata whose age we cannot determine by the aid of fossil organisms. It is a sound designation when applied to altered rocks, whether sedimentary or igneous; but its action, however intense, does not affect the fact that such rocks were primarily of aqueous and igneous origin. Some granitic masses may be merely highly-metamorphosed schists, but that does not affect the circumstance that others are truly igneous, though altered in their mineral texture by a similar metamorphism. The truth is, every substance in the earth's crust is continuously and incessantly undergoing metamorphism—the latest eruption of lava as well as the latest deposition of sea-silt, or the vegetable layer which last summer's growth contributed to the gradually-increasing peat-bog. Heat by contact—heat by transmission, conduction, or absorption—heat by permeation of hot water—electric and magnetic currents, chemical action and reaction, molecular rearrangement under pressure, and the like—are all conducing to this mineral change; but though we fail to detect in every instance the producing causes, we need not on that account, and for the sake of some cherished hypothesis, confound the obvious results.

Passage-Beds.—Another point of our science which requires careful and cautious consideration is the systematic disposal of what have been termed "passage-beds," or strata that lie between and partake of the characters of two contiguous systems. There are, for instance, passage-beds between the Silurian and the Old Red, between the Old Red and the Carboniferous, between the Trias and Lias, and in all likelihood between most of the other great stratified "systems." The final disposal of such strata involves the question, What constitutes a system? Shall we regard a system as a great series of strata characterised by the same *facies* of organic remains? or shall we consider a system as bounded on both sides by great physical breaks or unconformities in stratification? If we adopt the former view, the line between systems must often be vague and uncertain; and if we adhere to the latter, we find that physical breaks are not always followed by an immediate and total change, either in the flora or fauna. The truth is, that in this as in other geological questions, we must adopt a somewhat provisional course, avoiding sharp lines of demarcation, and using the term "passage-beds" where neither mineral nor fossil characters are decided enough to lead us to a conclusion.

Were we to adopt the views of some, the lowermost Old Red flagstones of Scotland would rank as uppermost Silurian; while the uppermost yellow beds would go to form the base of the Carboniferous formation. In this way the Old Red Sandstone of Scotland would be reduced to mere subordinate formation, and this without rendering more intelligible the boundary between Murchison's Siluria and Devonia on the one hand, or giving to the officers of the Irish Geological Survey a surer basis for their Carboniferous system on the other. In the same way with the Rhaetic and Penarth beds that lie between the Trias and Lias. In some districts the fossil assemblage seems to point to the Lias, and in others to the Trias, and where there is no physical break it matters little to which system we assign them. But where a physical break or unconformability occurs, that break should be held as the boundary between the Triassic and Jurassic systems. And more than this: where such questions cannot be solved by the examination of British strata, we should appeal to the wider field of foreign geology; ever remembering that what is limited and irregular in one district may be continuous and regular in another, and that we are bound always to take the fullest development we can discover as the typical standard of our groups and systems. Let us, then, abide by this idea of *passage-beds* as a provisional convenience, avoiding all sharp demarcations between contiguous systems, believing that nature's operations are incessant and continuous, and that all breaks, whether physical or vital, are at the most but local and limited phenomena.

Systemal Arrangements.—A fourth point to which we would direct attention is the discovery of numerous secondary coal-fields, and the effects of such discoveries, *first*, on many cherished theories respecting the conditions of the Carboniferous era; and, *second*, on the chronological arrangement of our secondary formation. The fact that we have important coal-fields of triassic, oolitic, and cretaceous life, like those of Virginia, Brazil, Vancouver's Island, Austria, India, the Indian Archipelago, and Australia, must for ever set aside as untenable all hypotheses of abnormal climates, carbonic acid atmospheres, and universal conditions for Carboniferous epoch. The truth is, that coal is a product of every age, and that the coal-forming conditions, like other conditions, will vary in intensity according to the geographical arrangement of sea and land, and the consequent climatic influences which such arrangements may induce. Besides, we are far from having proved the strict contemporaneity of the so-called palæozoic coal-fields;

on the contrary, every new foreign survey raises the gravest doubts on this point,* and leads to the belief that these old coal-deposits range throughout the whole cycle embraced by the Devonian, the Carboniferous, and Permian systems of the British Islands. Again, the difficulty which foreign surveyors find in co-ordinating their discoveries with our trias, lias, oolite, and chalk, suggests the idea that the time is not far distant when we must modify the range and nomenclature of these arrangements. Be it from America, India, Australia, or New Zealand, complaints are continually reaching us of the difficulty, or even impossibility, of co-ordinating their strata with those of the British systems. To abide by these systems were to set up our petty archipelago as the type of the wider world, and to retard the progress of geology; and we may rely on it that the time is fast drawing near when we must both modify and intercalate—modify what we now consider systems, and intercalate others to which there is no equivalent in these islands. It is true that, under the present "systemal arrangements," geology has made most excellent progress—and these on that account should not be lightly abandoned; but to be ever forcing unnatural co-ordinations is obstructive alike to truth and the labours of the distant observer. As the old arrangements of Lehman and Werner gave way to the wider knowledge of the earlier British geologists, and those again to the still more advanced information of the present day, so we may naturally expect the arrangement of the present to be superseded by the more exact information of future observers.

Contemporaneity.—And this difficulty of co-ordination

* See the able Report by Professor Oldham on the Geology of India, and, in particular, on that of the Indian Coal-fields, as given in the Proceedings of the British Association for 1867.

brings us, in the fifth place, to remark on the very difficult but most important question of *contemporaneity*, or contemporaneous formations. Hitherto the general idea has been that identity of genera and species in any set of strata, however widely separated, was proof of contemporaneity of deposit. Founding on this notion, a thousand facts in geology became inexplicable; but believing that species and genera in time past had their centres and areas of distribution just as they have at the present day, and that under the oscillations of sea and land they may have taken ages to travel from one hemisphere to another, the difficulties vanish, and we require to call in no abnormal conditions of universal sameness of life, sameness of climate, changes in the earth's axis of rotation, or suchlike causes, at total variance with all that we know of the present ordainings of the universe. Identity of species, therefore, unless in limited areas, instead of proving contemporaneity of deposit, would go to prove the reverse, and would merely show that the areas in which they are now found fossil had at one time or other the means of transference placed between them. From this view, then, it by no means follows that the palæozoic coal-fields of America were contemporaneous in formation with those of Europe, or that those either of Europe or America were synchronous with those of Australia. On the contrary, thousands of ages may have intervened between their depositions; and all that we can attempt, or philosophically are permitted to attempt, is co-ordination in fossil forms and similarity of conditions, but not co-ordination in time or synchrony of formation.

Take, for illustration, the post-glacial beds of the Clyde, that contain certain species of shells now extinct in the latitudes of Britain, but which still flourish in the seas of Greenland. The post-glacial era is separated from the present by an immense lapse of time; and yet, were the muds of the Greenland seas and the clays of the Clyde presented to future palæontologists, they might, according to the practice of co-ordinating by species, be regarded as contemporaneous. Nothing, however, could be further from the truth; and so nothing is more likely to be erroneous than many of the contemporaneities that have been attempted by geologists. In the very nature of things, few species can have a world-wide distribution; the spread of plants and animals from their specific centres is slow and gradual; and the oscillations of sea and land that produce these external conditions, favourable or unfavourable to the geographical transference of life, are also extremely gradual. As in dealing with the problems of physical geology we reason from the present to the past, so in dealing with organic questions we must reason, in like manner, from the existing to the extinct. At present no two regions present the same specific *facies*, and we are not to presume that any other order prevailed in bygone ages. If we argue for uniformity in the *forces* of nature, we can scarcely refuse to admit a similar uniformity in her *methods*. According to this doctrine, each area in time must have been peopled by its own specific forms; and, as at the present day, different species may be entombed in widely-separated deposits, which are strictly synchronous, so in former epochs, as has been well remarked by Professor Huxley, "absolute diversity of species is no proof of difference of date, just as absolute identity can be no evidence of contemporaneous deposition." We may, and must, as far as we can, establish a similarity of order—*homotaxis*, as it has been termed—between the strata of different regions, but similarity of order is not to be confounded with synchrony of deposit; and we must therefore, if we would place the solutions of our science on a philosophical basis, abandon, as all sound geologists are rapidly abandoning, the idea that specific identity of fossil forms is proof of stratigraphical contemporaneity.

Surface Configuration.—Another subject at present exciting the keen contention of geologists, is that of scenery or surface configuration; whether it has been brought about by external agencies—such as frosts, rains, rivers, and other forces acting from without—or whether it is not mainly and primarily attributable to the volcano and earthquake, which are productive of irregularities by acting from within? To the unbiassed observer the subject at first sight presents little difficulty, as both forces are ever more or less concerned in affecting the reliefs of the land—the one producing original inequalities of surface by upheaval and fracture, and the other ever modifying these inequalities by waste and degradation. But in geology, as in other matters of human interest, people will allow their feelings to get involved, and thus they most unphilosophically "take a side," as the saying goes, and then their own special views get magnified into a matter of immense importance, while those of their opponents, however honestly held and ably defended, diminish in a corresponding ratio. There is no truth in geology more obvious than this, that the scenery of a country must depend mainly upon the age and nature of the rocks of which its surface is composed; and it is the losing sight of this truth which has given rise to much of the existing contention. If a country consist mainly of recent and stratified formations, such as deltas and great alluvial plains (*e.g.*, the great plains of America and Siberia), its scenery will be comparatively tame and uninteresting, and all that can possibly affect it is the waste produced by rains, rivers, and other meteoric agents; and, on the other, if it consist mainly of igneous rocks, such as the Sandwich Islands, then its reliefs may be very rugged and irregular, and wholly depending on the eruptions of the volcano and the convulsions of the earthquake. Again, if it consist chiefly of secondary rocks unbroken by igneous eruptions, like the greater portion of southern and eastern England, its scenery will depend mainly on external causes of waste, and on the comparative hardness of the strata; while in a country like that of the Jura and the Alps, where the same secondary strata are altered, upheaved, and dislocated by igneous forces, the reliefs become wild and irregular, and arise partly from external and partly from internal causes. Further, if a country consist of very old rocks, igneous and metamorphosed, like our own Wales, the lake district of England, or the Scottish Highlands, which have been repeatedly under the water and repeatedly above it, and consequently repeatedly subjected to convulsion from within and waste and denundation from without, then it is clear that the causes of their scenery are of a very varied and complex character, and that no view can approach to the truth unless it embraces at once igneous forces from within, meteoric and aqueous from without, and, above all, the nature of the rocks themselves, whether they be of a nature that can be readily wasted and worn away, or of a kind that will stand up unchanged and resisting. And more than this: the geographical condition of every country must be considered on its own merit, whether it be volcanic or quiescent—rainless, or subjected to heavy rainfalls—temperate, or subjected to ice-action; for it is evident that what will happen under the rainfall of India will not occur in the rainless region of Peru; what will appear under the volcanic influences of Sicily cannot occur in the quiescent region of Britain; and what will result from the glacier action of the Alps will be looked for in vain among the heights of the Andes. The truth is, the scenery of every country is the resultant of many and varied causes—forces acting from within and forces acting from without, the hardness or softness of the exposed rocks, and the time to which they have been subjected to the operating agents; for it must never be forgotten that, however great the irregularities originally produced by vulcanic forces, it is to the slow, silent, and long-continued action of external agents—frosts, winds, rains, rivers, waves, and tides—that all the old land-surfaces owe in major part their present contours and reliefs, their outlines and configurations.

Quaternary Accumulations.—Another point materially affecting the present position of our science, and one which calls for immediate remedy, is the very unsatisfactory arrangement of the post-tertiary, quaternary, or superficial accumulations. It is true we may generally classify them according to the agents by which they have been formed, or, in other words, according to their composition and the causes by which they have been produced. In this way we have fluviatile, lacustrine, marine, chemical, organic, and igneous accumulations, but these convey no idea of succession or history in time. What our science requires is, that we endeavour to arrange them in chronological order, as we have done with the earlier systems. The arrangement proposed by the late Dr Fleming into taragmite, akumite, and phanerite, is so purely hypothetical, and so obviously at variance with observed facts, that it has not been and cannot indeed be accepted. The broader arrangement into *prehuman* and *human* periods is obviously too general to be of much advantage to working geologists, at the same time that it can give us no clue to determine when the prehuman ends and the human begins. Again, such terms as the "Leda clay" of the St Lawrence, and the "Saxicava sand" of Montreal, though good and distinctive enough for local purposes, are inappropriate for other regions; and others, as "Pampean formation," "Erie clay," and the like, merely announce a geographical fact, without conveying any idea either of fossil remains or chronological sequence. Had the post-tertiaries, like most of the tertiaries, been strictly sedimentary, some percentage system of fossil forms like that by which Sir Charles Lyell threw so much light and order over the latter might have been adopted. But these post-tertiaries being here terrestrial and there lacustrine, here fluviatile and there turbary, here marine and there fresh-water, prevent any such arrangement, and we must seek some other method more general and provisional.

Perhaps the oldest of our post-tertiary deposits are those raised beaches and marine silts that immediately followed the glacial epoch, and in which the remains of seals, whales, and boreal shells are most abundant; next in order are the lacustrine, fluviatile, and estuarine silts and drifts, marked by the remains of mammoth and other elephantine forms; then follow the lake and bog silts and peat-mosses, containing bones of deer and oxen; and, lastly, we approach accumulations containing works of human art and civilisation, and this brings us to the dawn of history. In this way we arrive at a *cetacean*, an *elephantine*, a *bovine*, and a *historical* period, or more generally perhaps, a *mammothian*, *reindeer*, *bovine*, and *historic* period; and this, so far as Europe is concerned, might be adopted provisionally and without involving much error. But when we seek to apply it to South America, to Australia, or to any other distant region, it fails as a distinctive arrangement, and we are driven to seek some other that is strictly local, and which can only be co-ordinated in a general way with our European accumulations. Altogether the arrangement, or rather non-arrangement, of our quaternary accumulations is a reproach to our science, and no finer field presents itself to the young geologist who would benefit his study or advance his own reputation. Sequential arrangements we must have; and whether these be founded on lithological or on fossil evidence, he will be no mean benefactor to his science who first indicates the way to a solution of the difficulty.

Antiquity of Man.—And here it may be remarked, that it is this want of sequential arrangements among quaternary deposits that has surrounded the question of the antiquity of man with so much doubt and difficulty. We are every day hearing of the discovery of bones and flint implements in "the drift." But what drift? Is it the glacial drift, or later river-drift? Is it drift formed in times immediately post-glacial, or in ages immediately pre-Celtic? At the present moment there is the widest and vaguest notions as to the relative ages of these implement-yielding deposits, and until more light shall have been thrown on the age and sequence of all post-tertiary accumulations, the antiquity of man must continue to remain an unsettled and perplexing problem. Indeed the problem is at the present moment in a more unsettled state than it was some years ago; and all that has been really gained by the discussion is, that it has been made an open question—a subject which any geologist may discuss from a purely natural-history point of view, without having his motives suspected or his orthodoxy called in question. I say "natural-history point of view," for there is no reason why he may not discuss the antiquity of man with as much freedom and philosophy as we discuss the antiquity of the mammoth or mastodon. It is true, and it is much to be regretted, that some inquirers have unguardedly mingled up the question of man's origin with that of his antiquity. The two questions, however, stand on widely different platforms. The one involves considerations purely stratigraphical; the other, considerations at once physiological and geological—involves, in fact, the whole theory of Life and Life-development. Let us not, then, be led away from a problem that is hopefully soluble into one which, if not beyond our solution, is placed at all events so much beyond our present reach that generations may pass away before we arrive even at the methods by which the solution is to be attained. Adhering to the whole question of the antiquity of man, whose own remains and the remains of his rude implements have been found along with those of the mammoth and tichorine rhinoceros in the quaternary deposits of Europe, let us first determine the chronological sequence of these deposits; and then, before giving expression to our beliefs in years and centuries, let us carry our researches into Asia and Africa, where there is every reason to believe that mankind existed for ages before his ruder offshoots found their way to the shores of Western Europe. Our own opinion is, that this question of man's antiquity has also suffered by the injudicious haste of some observers to give numerical expression to their beliefs. That mankind existed for ages beyond the commonly-received chronology, few geologists who have studied the question can for a moment have any doubt. But whether this were sixteen thousand or sixty thousand years we have no means of determining, and all numerical expressions merely excite the hostility of the prejudiced, and provoke unnecessary and retarding discussion.

Life—Progressive Development.—Lastly, this question of man's antiquity naturally suggests the comportment of geology towards the whole subject of *vital development* as deducible from the facts of palæontology. Admitting the order of ascent from lower to higher forms (and numerous as the missing links may be, no one has yet denied this order of ascent on the great scale), the question still remains to be solved—and geology, as the originator and establisher of the doctrine of vital progression, is bound to consider it—How, and by what means, has this progress from lower to higher forms been effected? There are two methods, as we have elsewhere observed,* by which the problem seems capable of solution, though both require much more minute and extensive observation than science has yet at her command: *first*, the changes in the organisms themselves may be such as to indicate the manner in which they have been affected, and, by inference, the causes that produced them; and, *second*, if there is a law of perpetual progression, it must be still operative on living plants and animals, and we might arrive at its nature by a careful study of the variations which existing species undergo, and the proximate causes on which these variations depend. Than these, scientifically speaking, there is no other way of approaching the question. To appeal to the doctrine of creative acts and the will of the Creator, is to put the question beyond the limits of science—to treat it as a matter of faith, and not as a subject of logical investigation. As geologists, it is evident we must deal with the problem as one of natural history—reasoning from result to cause, and from the order of causation to the higher bearings of a general and enduring law. There need be no uneasy tenderness in dealing with the question of Life, any more than in dealing with the questions of metamorphism and crystallisation. In all its phases and surroundings—in its growth, reproduction, and decay—it is under the immediate operation of physical laws. A little more heat or a little more cold, an excess of drought or an excess of moisture, the exclusion of the air or the withdrawal of the sun, are sufficient to influence, or even to destroy, its existence; and though we may never be able to comprehend the origin of life, we clearly perceive that all its subsequent manifestations are

* 'Philosophy of Geology:' Blackwood & Sons, 1863.

closely bound up in definite order with the operating forces of the universe. As such, the question of vital development becomes, philosophically, not only a fitting subject for our research, but one whose every bearing is hopefully within our determination. Impossible or not, the loftier we direct our aims, the higher at all events will be our scientific efforts to attain them; and to shirk the question through fear of arousing unworthy prejudices would be to belie at once our position as students of nature, and subordinate that spirit of inquiry with which God has endowed us to seek to comprehend His workings in the wonderful world we inhabit.

Such are some of the points in geological inquiry that appear to be worthy of the consideration of the working and philosophical geologist. Had time permitted, we might have adverted to the present unsatisfactory state of *palæontology* as regards nomenclature, unnecessary multiplication of species, and, in particular, as regards the neglect of fossil botany; to the doctrine of *uniformity* in natural law as sufficient to account for the phenomena of the past; to the law which seems to regulate the recurrence of *colder* and *warmer climates* over the same latitudes, and to several other questions that still continue as moot points among geologists;—but enough, we presume, has been said to show that our science, notwithstanding all its progress, has yet many problems to solve and difficulties to remove. That many of these difficulties will speedily be removed, the progress of geology during the last quarter-century gives us every reason to be hopeful. The number of observers has increased immensely, and is yearly on the increase. Geology is now taught in our schools as a branch of elementary education. An acquaintance with its leading doctrines is required in most of our professional examinations, and it ranks as an item in all the competitive trials for civil and military service. The surveys instituted by the different governments of Europe and the States of America, along with those more recently set on foot in our Colonial Possessions, must also add amazingly to our stock of sound and accurate knowledge, and thus it is the future progress of geology is rendered so hopeful and encouraging. It may never be the lot of our race to attain to a perfect history of our planet—the records of past life being so fragmentary, the various formations being so denuded, disturbed, and altered, and so great a portion of the earth's crust being permanently hid from investigation by the waters of the ocean—but enough, we presume, remains to enable us to trace the great outline of such a history; and earnest geologists best fulfil their functions when labouring diligently within their own districts to observe and record—each well-established fact becoming a permanent addition to the chapters of this marvellous history. There are few districts that do not possess sufficient phenomena to attract, and there is no observer so restricted in his range that he may not contribute his mite of observation, and even should he fail in this, he can give at all events the hand of fellowship and encouragement to others. And after all, when the substantial rewards of science are so few, it is this encouragement, this pleasurable fellowship, that forms half the recompense, and he who bestows it cordially and with no niggard hand, is fairly entitled to take rank with the worker, and share in the honours of his discoveries. In this spirit, then, let us continue to contribute to the progress of geology—working in the field where we can, and where we cannot, encouraging those who do, by those graceful acts of fellowship which so well become the cultivators of a science devoted, as ours is, to the study of God's works in the beautiful and orderly world that surrounds us.

GEOLOGY AS A BRANCH OF GENERAL EDUCATION.

"The study of the structure of the Earth must tend to enlarge the mind of man, in seeing what is past, and in foreseeing what must come to pass in the economy of nature; and here is a subject in which we find an extensive field for investigation, and for pleasant satisfaction."—HUTTON'S *Theory of the Earth*, 1795.

IN the present Chapter I mean to direct attention to "Geology as a Branch of General Education;" to the necessity of its being taught in our schools, academies, and colleges; to its importance both as a means of intellectual training and as a special preparation for engaging in some of the most essential departments of human industry. In this task I have to appeal at once to the geologist who understands the nature and bearings of his science, and to the public, who have only a general notion that geology has something to do with the rocky structure of our planet, and with the curious fossils, minerals, and metals that may be occasionally discovered therein. For this purpose I must speak plainly, and, at the outset, endeavour to explain the true purport of geological investigation. Much of what I have to say may, in all likelihood, be known and felt by many of my geological readers, but I address myself less perhaps to them than through them to the public, and am anxious to obtain the sanction of their approval, that it may give further weight to the views I am endeavouring to inculcate.

What, then, are the aim and object of geology? What does it profess to teach? What are its certainties, and how far can these claim the acceptance of the educated or well-informed mind? In general terms, as most people are now aware, the object of geology is to discover the constitution and unfold the history of our planet. What are the materials of which this earth is composed; what are the causes which have led to their formation and present arrangement; what the nature of the vegetable and animal remains they entomb, as compared with those now peopling the land and waters; what evidence do these afford of past change and progress; and, combining the sum of such evidence, what is the history of our globe from the current hour to the earliest moment of which we have record in the rock-formations we investigate? This is Geology: it grasps the whole earth in its plan; it is the Physical Geography of former ages, and endeavours to depict the successive phases of the world's past, just as the geographer depicts the phases of the present. And while intellectually reading this world-history in the hills and plains, in the ravines and river-estuaries, in the beetling sea-cliffs and sandy shores—while reinvesting the earth with its former aspects of vegetation, and peopling it with the animal forms long since extinct—geology, like a willing workman, is not ashamed to stoop in the quarry and toil in the mine for those minerals and metals which administer so much to our necessities, and confer the luxuries of wealth and power on every nation that has learned to apply them. Our science has thus a purely scientific aspect and a practical aspect —one which appeals to the intellect and the pleasure of knowing, another that is applicable to the industrial purposes of life, and indispensable to their advancement; one that appeals to the student, another to the miner, engineer, architect, agriculturist, and others, who have to deal with the earth's crust and the substances that compose it.

Such are the leading objects of geology, and though one of the youngest of the natural sciences, it is already in possession of much interesting world-knowledge, and has many important teachings to impart. It teaches, for instance, that the dry land of this terraqueous surface is subject to incessant change of aspect through the agencies of air and water—that organic and chemical forces are also perpetually sorting and reassorting the earth's materials, and that the vulcanic forces from within are as ceaselessly upheaving and reconstructing what the air and water, and other agents from without, are wasting and wearing down. It teaches that this terrestrial crust is ever held in habitable equilibrium between these contending forces—that sea and land are slowly but unceasingly changing places—that the continents of the present day are but the sea-formed sediments of former ages, and that the ocean now rolls over the submerged surfaces of former lands. It finds, moreover, remains of plants and animals in these ancient sediments as evidence of the kind of life that then prevailed, and in these ancient volcanic upheavals traces of the extent and power of the forces that operated. In this way the rocks of the earth's crust became, as it were, the leaves of a great record impressed with evidence both physical and vital of the past conditions of our planet; and to arrange this record in chronological order, to interpret the facts aright, and to arrive at something like a connected history of the whole, is the sum and substance of all sound geology. True geology has nothing to do with the origin of matter or the formation of the universe, but restricts itself to the appearances in the earth's crust—tracing back from the recent to the remote, and from the remote to the remoter still, till all traces of change become obliterated, and the further history of our planet is lost in obscurity.

Proceeding upon this inductive method, geology has arrived at most important results in world-history, and its certainties, now rapidly on the increase, are such as must commend themselves to every inquiring mind. It teaches what no other science could have taught, and what, for instance, had formerly never been dreamed of: *First*, That the earth's crust is in a state of ceaseless change, and that the causes—meteoric, aqueous, igneous, chemical, and organic—that now operate have been productive of similar changes in all time past. *Second*, That these changes are governed by imperative laws, and that the mineral structure of the globe arising therefrom has consequently a definite and determinable arrangement. *Third*, That this arrangement, as displayed in the numerous rock-formations, implies an enormous lapse of time, and therefore establishes an antiquity for our globe far beyond all previous conception. *Fourth*, That during the long periods which these successive formations imply, the earth has been peopled by different races of plants and animals—all evidently belonging to the same great scheme of life, but varying widely in their characteristics during each succeeding epoch. *Fifth*, That during these periods there has been an ascent, in the main, from lower to higher forms; and that the plants and animals now inhabiting the globe are, on the whole, higher and more specially organised than the plants and animals of any former period. *Sixth*, That these successive appearances and distributions of plants and animals are connected together by some great law of development which, though not yet satisfactorily discovered, is evidently bound up with the operating forces of the universe. And, *lastly*, The earth being still subjected to the same causes of change that operated in time past, the future aspects of our planet must differ from the present physically and vitally, and its present living races give place to others of a still higher and more specialised organisation.

Modern geology, however, has not only attained to high scientific truths, but its deductions are also capable of important practical application. The minerals and metals upon which so much of the progress and amenities of civilisation depend, are all derived from the crust of the earth; and as they are not scattered at random in that crust, but are found in certain formations, or in veins that hold determinate positions, it is of vast importance to know where they exist, and with what facilities they can be obtained. Geology is the great index-finger to this kind of information; and just as its deductions become more widely known—just as its maps and sections are more studied and better understood—so will mining adventures be conducted with greater certainty and safety. But it is not to the miner alone that the science is of practical importance. The engineer, in tunnelling through hills, cutting railways, excavating canals and harbours, and sinking for water, derives valuable aid from its deductions; the architect is also assisted in his search for abundant and durable materials; while the agriculturist, gardener, and others who have to deal with lands and soils, may profit greatly by a knowledge of its truths. To the landscape gardener and painter it likewise affords important hints, some acquaintance with the rocks that give shape and character to the landscape being as necessary to them as a knowledge of anatomy to the delineator of the human figure. In this way geology becomes not only of high intellectual or scientific interest, but of direct and practical value; and claims, as strongly as any of the natural sciences can claim, an important place in the curriculum of modern education.

What I mean by a place in the curriculum of modern education is, that the elements of the science should be taught by text-books, diagrams, and exhibition of specimens to the advanced pupils of our ordinary schools; and that, with the addition of field-excursions, it should also form part of the systematic training in our higher academies; while in all our colleges there ought to be separate chairs for the fuller exposition, not only of its details, but of its principles and scientific methods. We teach our children botany, zoology, and geography; why not geology, which is the complement of the whole? If they cannot comprehend all its reasonings—and no judicious teacher will ever make such an attempt with juvenile minds—they can at least acquire some of its leading facts; and this, we presume, is the most that is done with the other branches of knowledge professed to be taught them. We carry our advanced pupils to mathematics and algebra, and even attempt astronomy; why not geology, which requires as much exactitude of reasoning, and possesses more immediate interest to attract? It is true that within the last ten or fifteen years the attempt has been made in several of our better schools, that text-books adapted to the youthful comprehension have been prepared, and that geology holds a place in the competitive examinations for professional honours and Government appointments; but the attempt is yet by no means on a scale commensurate with the importance of the science, and we claim for it a wider and much more cordial acceptance. It is true we have chairs of geology in several of the English and Irish colleges, and that the science is taught as a subordinate branch of natural history in the universities of Scotland; but the importance of the subject demands a broader recognition than this—demands, in fact, the establishment of independent professorships, devoted exclusively to the exposition of world-history, as revealed by Geology, Mineralogy, and Palæontology. As a theme for mental exercitation, geology is certainly superior to the classics, and is not surpassed either by logic or metaphysics; while in point of direct utility, it stands on a higher platform than either. We have one School of Mines in London, but none in Edinburgh or Dublin, and none in the great seats of mining industry—a circumstance not creditable to us as a nation, and evincing worse than apathy on the part of those who would be most immediately benefited by the establishment of such institutions.

That this state of matters cannot long continue, the recent progress of geological science gives us every reason to believe. The establishment of Readerships of Geology in Oxford and Cambridge is comparatively a recent event; the London University and King's College are modern institutions, and so also are the Queen's Colleges in Ireland. The founding of chairs in each of these great seats marks but the commencement of a better era, of which also the London School of Mines, in connection with the Government Geological Survey, is a hopeful and gratifying sign. The opening of geological classes in several of our higher schools and academies is symptomatic of the improvement we advocate; while numerous local societies—each busy in observing, noting, and discussing—determine the fact that geological information is sought after, and that people will endeavour to supply by mutual instruction what they cannot obtain through a general educational system. It is to strengthen this indication of improvement that we would now direct public attention to geology—scientifically and industrially—as a branch of general education; as an excellent means of *intellectual* training on the one hand, and as a necessary preparation for engaging in some of the most important departments of our *national industry* on the other.

First, then, if geology be world-history, that history can only be interpreted by a study of the rocks of which the globe is composed, by a knowledge of the fossils they contain, and by an acquaintance with the alterations to which these rocks have been subsequently subjected. A knowledge of the rocks themselves implies mineralogy and chemistry; of their fossils, botany and zoology; of their subsequent alterations, chemistry and mechanics; while a consideration of the whole demands habits of correct observation, strict logical inference, and powers of orderly arrangement. We cannot take a grasp of the aspects of the past without a geographical knowledge of the present, and thus reflection and imagination are called into play to complete the picture. Now, to attempt all this, or even a tithe of this, in ordinary schools with children of fourteen or fifteen years, were downright absurdity; but they might be familiarised with the characters of the principal rocks, with the forms of the leading fossils, with the order of the formations, and with the mechanical effects of winds, rivers, waves, volcanoes, and other forces that are productive of change in the crust of our planet. Once acquainted with the nature of the changes now going forward, they would have little difficulty in understanding how former changes were effected; and as change implies history, they would readily perceive that the world had a history, and they would soon acquire an intelligent glimpse of its palæozoic, mesozoic, and cainozoic periods, just as they now do of human history in its ancient, medieval, and modern divisions. With the pupils of the higher schools and academies the task would be still easier, inasmuch as they are generally older, have better elementary training, and, at the same time, greater facilities for travel and observation. Applying their knowledge of physical geography, botany, and zoology, they—I mean youths from fifteen to eighteen years of age—may be led into the reasonings of geology, and farther into its practical observation by occasional excursions in the field, and days of examination in our public museums. In this way a large amount of substantial geological information may be imparted; and if any one be inclined to doubt, let him try the experiment as I have done, and am weekly doing, and I feel convinced of his speedy and certain conviction.

There is no greater mistake in modern school tuition, and none so general, as the neglect of the natural sciences; and yet there are few departments of knowledge to which boys are more readily and earnestly attracted. The majority are naturally observers and collectors — as witness their little cabinets of birds' eggs, butterflies, and minerals; and it only requires encouragement and direction to make them reasoners and reflectors. If it be an important point in education to foster habits of observation and discrimination, then assuredly there is no theme so admirably adapted as the field of nature, and no section so accessible at all seasons as that of geology. It is true that the ordinary branches of tuition must ever occupy the main share of the schoolboy's attention; but there are intervals when natural history would be a recreation, and in that recreation the otherwise dormant mind might be first awakened to interest and energy. Get the mind by all means aroused to self-exertion; let it once taste the pleasurable excitement of knowing in one department, and the battle is won. The desire for further knowledge increases with the growth of that knowledge and strengthens with its strength. And even where such subjects as geology form no part of the regular curriculum, a day in the field or an afternoon in the museum might be given as a reward for diligence and proficiency in other departments, and in this way a certain amount of available information might be imparted without any attempt at formal instruction. Our present business, however, is not to indicate methods, but to suggest the necessity; and there are hundreds of ways by which the intelligent teacher can secure his purpose, when once he becomes convinced of its value and importance.

To students—not the mere boys who are admitted without test to our universities, and who would be infinitely better under the care of the schoolmaster, but those of properly matured thought—the study of geology becomes at once a source of high mental exercise and intellectual enjoyment. The examination of its rocks and rock-formations involves the consideration of numerous physical problems—its fossils, those of botany, zoology, and life in general—while the extent and distribution of those formations and fossils require for their elucidation acquaintance with climate and all those external conditions which confer on the globe its geographical beauty and diversity. It by no means follows that they should be deeply learned in all the allied sciences here referred to, for no one mind can adequately cope with the whole, but a general acquaintance is necessary for the comprehension of geological history, the minuter workings-out being left to that departmental study into which every science, sooner or later, is sure to be arranged. Thus equipped, the student of geology finds in its multifarious problems the finest field of mental exercitation, and in their solution, whether in the field or in the closet, the highest and purest intellectual enjoyment. Here, for example, is an ordinary sandstone: From what former rock have its particles been derived? These water-worn particles are laid down in a certain way: From what direction came the current that transported them, and in what depth of water were they deposited? Were they laid down layer by layer, in quiet, still waters, or in areas subjected to currents and commotions? The surface of the sandstone is ripple-marked, or pitted with burrows, or, it may be, marked by the tracks and trails of aquatic creatures: Are these wave-ripples, current-ripples, or wind-ripples? and are these the burrows and trails of annelids, mollusca, or minute crustaceans? Again, the sandstone imbeds the remains of plants and animals: Have these lived and died *in situ* when the sandstone was the soft silt of some estuary or sea-shore? or have they been drifted from afar from the dry land? are they aquatic or terrestrial, fresh-water or marine, and do they seem to have lived and flourished in a genial or ungenial climate? to what orders and genera and species of life do they belong? and what their approximations to, or divergences from, the same orders that are still existing? Again, the sandstone may be covered over by igneous rocks: Have these overflowed it as molten lava? or have they been accumulated as showers of volcanic dust and ashes? Further, the sandstone stratum is rent and fissured throughout: Are these rents regular or irregular? do they trend in one main direction? are they the result of desiccation and shrinkage? or have they resulted from vulcanic and earthquake disturbance from below? These and a thousand similar questions present themselves at every step of geological investigation—requiring correct observation and the nicest discrimination, and exercising at once the keenest logical acumen and the highest powers of generalisation.

Nor is the intellectual enjoyment of geological investigation less than the intellectual exercitation. There are few of the natural sciences that afford the same amount of healthful exercise and exhilarating pursuit. Botany, zoology, and geography have their living realities of variety and scenery to excite; so also, to the same degree, has geology, while over and beyond, it has all the interest of the past to inspire and its mysteries to hallow. To the uninitiated a bed of sandstone or a cliff of basalt is but a bed of sandstone or a cliff of basalt—

> A block of sandstone 'tis to him,
> And it is nothing more;

but to the geologist every particle of the one is instinct with a history of waste, and transport, and sediment; and every column of the other with a history of internal force, eruption, and consolidation. To the uninitiated the rock-formations of the earth have merely a *present* interest; to the geologist they have not only the interest of the present, but that of a marvellous *past*, to gratify his curiosity and reward his research. To the botanist, zoologist, and geographer, the earth's surface has myriads of phenomena to delight; to the geologist the earth's crust contains a thousand such surfaces, each replete with beauty and variety as the present, and each as pregnant with proofs of creative wisdom, goodness, and design!

We have been speaking here chiefly to the educated or university student, but there are thousands of others who cannot participate in the curriculum of a college, but who may become students of geology, like most of the members of our "Field-clubs" and "Scientific Societies," through self-tuition and mutual instruction. To all such—and they form at present by far the larger proportion of geological inquirers—the science holds out the same benefits of mental exercise, and the same attractions of intellectual recreation and enjoyment. In naturally well-endowed minds there is always a desire for some mental pursuit or recreation over and above that devoted to the business or calling which forms the everyday duty of life. One takes to botany, another to zoology, a third to geology, and a fourth to astronomy; one takes to birds, another to shells, a third to insects, and a fourth to eggs; one takes to coin-collecting, another to minerals, a third to fossils, and a fourth to objects of antiquity. In all this there is at once intellectual training and enjoyment. The pursuit may not in every case assume a very exalted form; still, if it be there, it is worthy of commendation, and deserves encouragement to something of a higher nature. Now, without unduly exalting geology, I know of no other natural study that offers either to the man of leisure, the professional man, the merchant, or mechanic, so many facilities for research or inducements to inquire. The objects of research are scattered everywhere beneath and around him; in every walk by the sea-shore, along the hill-side, or up the river-glen, they are there beside him; and, unlike the objects of botany or zoology, they are there, the same at all times and all seasons. The botanist must wait the flowering of his plants, and the entomologist till the hybernation of the insect-world is over; but no seasonal change ever interrupts the studies of the geologist. Every heap of coal and ironstone beside the mine, every mass of gravel by the gravel-pit, every pile of clay in the brick-field, nay, every mound by the old deserted quarry, which to other men is merely "rubbish," becomes to him a treasure. In all this he has not only the intellectual pleasure and pursuit, but he enjoys the varied landscape and exhilarating breeze; confers health on his body, and finds his mind soothed and abstracted for a while from the cares and crosses that may daily perplex it. To such inquirers—and they have hitherto formed the main staff of geological observers—the science becomes at once a source of mental training, and of luxury and enjoyment. It is true that their knowledge is self-acquired, as nine-tenths of all our knowledge is, and must ever be, acquired in this way; but it would have immensely facilitated their efforts had they enjoyed at school the benefits of an elementary training in the natural sciences. How different would it have been with many members of our provincial societies had they received, in their schoolboy days, along with their modicum of Latin and Greek, the merest rudiments—the A B C, as it were—of Botany, Zoology, and Geology! Let us take care, then—and this is the main object of the present Chapter—that the deficiencies we now feel may be speedily supplied in the education of the succeeding generation.

Nor let it be supposed that, while we contend for this reform in the education of our sons, we are at all unmindful of the training of our daughters. It may not be possible in miscellaneous seminaries to do much in this way, for the average length of attendance at school by girls is far beneath what it ought to be; but in all our so-called ladies' institutions, training colleges, and boarding-schools, a great deal might be done in imparting an elementary knowledge of the natural sciences. At this age young ladies are quite as apt as young gentlemen in acquiring this kind of information; and it is often pitiable to observe the apathy and languor that are engendered, to say nothing of the positive suffering produced, by ignorant attempts to enforce the acquisition of accomplishments which require special gifts for their acquirement, while a knowledge of the natural world would be received with delight, and might lead to broader intellectual development. In several instances the attempt has been made with the best results, and no difficulty has been experienced save the want of qualified teachers, or the prejudices of lady-superintendents, and foolish mammas unable to extricate themselves from the fripperies of fashion and conventionality. And, after all, how little of these dear-bought "accomplishments" is retained after leaving school; and how much precious time is thrown away on that refined trifling, or rather, I would say, busy idleness, called "ladies' work"! A love for natural knowledge once acquired, it would stand by them in all time coming—a relaxation from duties at home, and a source of unfailing enjoyment when in the open country; and as the infant mind is always much impressed by maternal example, their children might also be led to cultivate similar tastes and enjoy such elevated pastimes.

Nor let this advocacy of geology as a branch of female education be thought in the least chimerical. We have already on the list of British observers and collectors a fair array of female names; and many more might be added were only ordinary care taken to turn their early education in the direction of the natural sciences. They are not expected to enter deeply into physical, chemical, or palæontological problems, which require a special knowledge of mathematics, chemistry, and anatomy; but a general acquaintance with the truths of geology could be readily acquired, and their minds prepared to appreciate the marvellous world-history revealed by its discoveries. We have never yet found them deficient in curiosity, or devoid of enthusiasm when once that curiosity was awakened; and assuredly there are few topics better calculated to enkindle both than the revelations of geology,—and this without interfering, more than any other relaxation, with the discharge of those domestic and social duties which, after all, form woman's noblest and most natural function. Taking it simply as a refined amusement, they would soon perceive that few were so many-sided in their inducements, and none, perhaps, so cheaply procured. "They would soon discover," as we have elsewhere observed,* "in the forms and colours of mineral gems and metallic ores, a source of attraction other than that of mere personal ornament; they would find the remains of plants and animals embalmed and preserved in a state that the most delicate

* 'Advanced Text-Book of Geology.' 4th Edition. 1867.

need not shrink from investigating; they would find that a knowledge of the distinctive features stamped on each landscape by geological phenomena, enabled them to add the truths of nature to the graces of their sketch-books; while during every walk by the sea-shore, and ramble on the hill-side, they would find in every pebble, which the feet of the ignorant would spurn from their path, something to amuse and interest, even where instruction is not sought after, nor intellectual attainments prized for the advantages they confer on their possessors. Thus, take geology in no higher light than a mere recreation for an idle moment, it will be found at least an innocent and exhilarating one—one that need never interfere with the comfort of a neighbour, nor bring to the observer one pang of mortification or regret."

Take it as a whole, there cannot be for either sex a more attractive or ennobling study than that of geology. Ranked second to astronomy in the magnitude and sublimity of its objects, and intimately related to all the physical sciences, its scope is at once vast and varied, and its interest illimitable. The immense antiquity of our globe, the numerous changes its terraqueous surface has undergone, and the infinite variety of organic forms by which it has been successively peopled, all conspire to increase our interest in its history, and excite our research. Many-sided in its aspects, geology affords ample scope for every observer—subjects which may be taken up for the recreation of a leisure hour, or studied with all the zeal and laborious research of scientific enthusiasm. At every turn can be traced the hand of beneficent design and the operation of enduring law; and thus more than most other themes the science is calculated to exalt our conceptions of Creative Wisdom, and inspire with new feelings of reverence and devotion. No doubt the same may be argued for the existing aspects of nature; but how much more forcible the appeal when made through the facts and phenomena of untold epochs! Beautiful as may be the living garniture of the surface we survey, how hallowed the reflection that beneath us lie a thousand such surfaces, each replete with the remains of organised forms which were the objects of the same Creative Care that governs and sustains the existing!

Enough, we think, has been said to show that geology, in its purely scientific aspects, is a theme well fitted alike for mental training and intellectual enjoyment, and that on these grounds it is worthy, like other branches of natural science, to hold a place in the scheme of education. In its simplest or elementary form in our ordinary schools, in its more advanced aspects in our higher academies, and as a theme of extended study in all our colleges and universities, it might be introduced as a profitable and pleasurable branch of instruction. To the adult mind also—to the man of leisure, the merchant, and mechanic—geology, in one or other of its departments, offers one of the finest fields for mental recreation,—a subject that may be dealt with cursorily, or studied as deeply as the human mind is capable of carrying its investigations. Multifarious in its objects, and many-sided in its aspects, there are few topics that so much induce to correct observation, nice discrimination, and logical inference; while none, perhaps, affords the same amount of healthful and exhilarating recreation. But while geology has thus, like other departments of natural science, many intellectual inducements to excite, it has also, like many others, and much more than most, important economical advantages to attract. The rocky crust upon which we dwell, is not only the great record upon whose tablets are impressed all the former phases of our planet—thus binding, as it were, by material attributes, the living intellect that interprets with the divinity of Creative Thought in the remotest past; but it is, at the same time, the foundation of all geographical diversity, the varied habitat of plants and animals, the scene of man's life-labours, the field he cultivates, and the sole storehouse of those minerals and metals upon which the progress of civilisation is so intimately dependent. Geology, then, becomes a study of importance to the miner, the engineer, architect, farmer, landscape-gardener, painter, geographical explorer, and all those whose callings lead them more immediately to deal with the internal structure and superficial aspects of our planet. It is by no means expected that these men are to make themselves conversant with all the niceties of geological theory, but merely that they should learn enough to appreciate the leading deductions of the science, and be able to apply them each to his own special requirements. As science can and must often indeed be studied without reference to its ultimate applications, so may the practical man lay hold of the truths of science, and apply them in an empirical way, without being able to work out the problems upon which these truths have been founded.

Deriving all our mineral and metallic treasures—our coal and iron, our gems and precious metals—from the crust of the earth, it is of vast utility to be able to discriminate between mineral substances, to determine in what formations they occur, and to say where they are or are not to be found. The miner cannot proceed a step in safety without the guidance of mineralogy and geology; and though mining existed long before the truths of science assumed a technical aspect, yet do its operations proceed with certainty and precision only in proportion to the advancement of scientific generalisation. Certain of our minerals—like coal and iron, for instance—occur in several of the stratified formations. To what formation does any special field belong? what its extent and thickness? Are its beds of easy access, or are they disturbed by dykes and dislocations? Again, certain other minerals, as copper and tin, occur in lodes and veins; and as lodes and veins hold certain determinate directions in reference to the hills or eruptive axes of a district, what are the directions of these veins and cross-veins? Are they more prolific in one set of rocks than another? Are the new cross-veins richer than the primary lodes? And what the character of the ore-stone which indicates this richness? Still further, some metals, like gold and tin, frequently occur in drifts of sand and gravel: whence have these gravels been derived? Can the veins be discovered from which they were originally worn out? Can the geologist in this way determine the gravels that are productive from those that are altogether barren? These and scores of similar questions occur in every mining adventure; and though they may sometimes be satisfactorily answered by the old-fashioned system of trial and error, yet every intelligent man knows that the strata and structure of a district can only be determined with certainty by the competent geologist. Under the old system of trial and error, and the superstition of the divining-rod, thousands have been expended in searches for minerals, where a glance from the merest tyro in geology could have told that no such minerals existed. Under the old method, mining was often little better than groping in darkness; under the guidance of geology, every fossil scale and tooth and stem is instinct with the certainties of sound information. To mining engineers and mineral-viewers such knowledge is indispensable; and considering the amount of capital, the number of lives, and general interests involved in the decisions of these men, certificates of qualification are as much needed from them as from the captains and mates of our commercial marine. Even as concerns the working miner, some scantling of geological information were desirable. A miner may be an excellent workman and yet know nothing of geology; but he may still be as good a workman and be acquainted with the general principles of the science, while some knowledge of the wonderful history of the rocks and minerals and fossils among which he is toiling might gratify his thoughts and tend to lighten his labours. To some it may seem that in this matter I am somewhat over-sanguine; but my own belief is, that the time is drawing near when the geological map and geological section will be as closely studied by the mining engineer and miner as the sailing chart is now by the navigator.

To the civil engineer—the constructor of roads, railways, and canals, the excavator of tunnels, the sinker of wells, and the drainer of cities—the importance of geological knowledge is so obvious that the fact requires little explanation. Possessed of a carefully-constructed lithological map, on which are delineated the various kinds of strata, their dip, strike, and other particulars, the engineer who can read these facts aright has the surest guide to the correct execution of his undertaking. He sees at once the nature of the rocks through which his work has to pass, whether road, railway, or canal—can make deviations according to his own knowledge—can estimate with certainty the expense of construction, and avail himself of minerals which he knows must lie in the vicinity, while one ignorant of geological truths would blindly pass by such advantages. In fact, not a railway or canal can be constructed, not a tunnel excavated or well sunk, without deriving important benefits from a knowledge of the geological structure of the district; and it is just from a want of this information that so many blunders are perpetrated, and important works rendered unremunerative to the proprietors.

The builder and the architect may also derive important assistance from the geologist, both as regards the position and abundance of certain rocks, the facilities with which they can be obtained, and their relative durabilities. The understanding of a geological map and geological section is quite as essential to the quarryman and the builder as it is to the civil engineer; and though experience is, after all, the best test of durability, yet, by observing the effects of natural weathering, the peculiarities of structure and composition, and similar characters, the geologist is often in a position to pronounce with certainty on the architectural fitness of any particular stratum. In Britain we have many varieties of building-stone, each of which has its peculiar quality of weight, hardness, strength, colour, facility of being dressed, cheapness, and so forth; and while these are admittedly matters for the builder and the engineer to test and decide, yet there are many points on which the advice of the geologist, and the geologist alone, may be taken with obvious advantage.

As with the builder so with the farmer and the land-valuator. The value of a soil depends at once upon its composition and the nature of the subsoil and rocks underlying. A soil may possess all the mineral ingredients necessary to fertility, and yet the underlying rocks may afford no facilities for natural drainage, and thus render the soil wet, cold, and unproductive. A geological map of a district, exhibiting the position and extent of its trap-rocks, limestones, clays, and gravels, is of prime importance to the agriculturist, not only as indicating the nature of the superincumbent soils, but as pointing out the facilities with which lime, marl, clay, and other admixtures may be obtained for permanent improvement of that which may be naturally deficient. In fact, without a knowledge of the mineral structure of an estate it is impossible to ascertain its true value; and he who can read aright the delineations of the geologist, even though not a professed geologist himself, is always the safest man to be consulted, whether by the proprietor, the purchaser, or lessee. It may be true that the functions of the land-valuator are altogether distinct from those of the mineral-surveyor, and that the report of the one should be accompanied by the report of the other: but even in the valuing of land for mere agricultural purposes, the man who is ignorant of the mineral facilities of a district—its natural drainage, available rocks, limestones, clays, marls, shell-sands, phosphates, and so forth—can give but a very uncertain and unsatisfactory opinion.

Again, to the painter who has to delineate the aspects of the landscape, and to the landscape-gardener, who has to fence, plant, and lay out estates, a knowledge of the leading principles of geology is also of special importance. As the painter of the human figure is benefited in his art by a knowledge of anatomy, so the painter of the landscape must derive advantages from an understanding of the nature of the rocks which give character to, and form, as it were, the skeleton of his scenery. Every formation has its own peculiar scenery—bold, rugged, rounded, or level, as the case may be; and surely he who is acquainted with the causes of these peculiarities is more likely to excel in his art, than one who is altogether unacquainted with the subject. So it is with the gardener who would add new features to, or bring out more prominently, the existing beauties of the landscape. Acquainted with surface peculiarities and the causes that have produced them, he may occasionally succeed; but, ignorant of these, he only mars where he seeks to mend, and renders his efforts incongruous and ridiculous. "The laws of the organisation of the earth," says Mr Ruskin, "are distinct and fixed as those of the animal frame—simpler and broader, but equally authoritative and inviolable. Their results may be arrived at without knowledge of the interior mechanism; but for that very reason ignorance of them is the more disgraceful, and violation of them more unpardonable. They are in landscape the foundation of all other truths—the most necessary, therefore, even if they were not in themselves attractive. But they are as beautiful as they are essential; and every abandonment of them by the artist must end in deformity, as it begins in falsehood."

Nor is it only the miner, the engineer, builder, farmer, landscape-gardener, painter, and the like, who can turn to profitable account the deductions of geology. The capitalist who speculates in land and mines, the emigrant, the traveller and voyager, the statistician and statesman, may all derive assistance from the same source, and bring a knowledge of its facts to bear on the progress of their respective countries. So also the holiday tourist, the military officer stationed in a distant country, and others similarly situated, if possessed of the requisite knowledge, might do good service, not only to the cause of science, but to the furtherance of our material prosperity. Indeed, we do not affirm too much when we assert, that had one tithe of those who, during the last fifty years, have travelled or settled in America, Australia, New Zealand, India, and other countries, been possessed even of a smattering of geology, these countries, as to their substantial wealth and social progress, would have been in a very different position at the present day. Our Government is now making something like amends, by the institution of geological surveys not only at home but in our colonial possessions—Canada, the West Indies, Australia, New Zealand, and India; but what, we are fairly entitled to ask, will be the use of all these elaborate surveys, and maps, and sections, and reports, if we have not a population sufficiently educated to avail themselves of the information? In the mean time, their significance is only known to the professional few; under the system we advocate, the majority of educated men would be able to consult them, and reap the benefits they are intended to convey.

To the general student of nature also—the man who cultivates science for her own sake, and not for the material advantages which such knowledge may confer—the study of geology offers many inducements and attractions. The assistance which it has conferred, and the new light its deductions have thrown on the other branches of natural science, must ever rank among its highest claims to general attention. The comparatively recent study of Physical Geography, in all that relates to the surface-configuration of the globe—its climate and temperature, the distribution of plants and animals, and even touching the development of man himself, as influenced by geographical position—can only lay claim to the character of a science when treated in connection with the fundamental doctrines of geology. So also, in a great degree, of Botany and Zoology: the reconstructing, as it were, of so many extinct genera and species, has given a new significance to the science of Life; and henceforth no view of the vegetable and animal kingdoms can lay claim to a truly scientific character that does not embody the discoveries of the Palæontologist. In fact, so inseparably woven into ONE GREAT SYSTEM OF LIFE are fossil forms with those now existing, that we cannot treat of the one without considering the other; and can never hope to arrive at a knowledge of Creative Law by any method which, however minute as regards the one, is not equally careful as concerns the other. Combining, therefore, its theoretical interest with its high practical value—the complexity and nicety of its problems, as an intellectual exercise, with the substantial wealth of its discoveries—the new light it throws on the duration of our planet and the wonderful variety of its past life, with the certainty it confers on our industrial researches and operations,—geology becomes, as we have already observed, one of the most important of modern sciences, deserving the study of every cultivated mind, and the encouragement of every enlightened government.

Such, in conclusion, are some of the leading views I have long entertained on the subject of "Geology as a Branch of General Education." Be it observed, I am advancing no mere theory; I am advocating only what I have long practised, and what, if I do not deceive myself, I have succeeded to some extent in accomplishing. It is now thirty years since I began to lecture on the subject to miscellaneous audiences; and though I do not attach the same value to popular lectures that some do, yet I know of many who are now fair geologists, and find, in the pursuit of the science, a source of the purest and never-failing enjoyments, who were first attracted to the science by these addresses. It is now more than twenty years since I first attempted elementary treatises in one form or other, and thousands of these have been introduced into schools, or employed in self-tuition, where the name of geology was formerly unknown. What has been done in this way, I am willing to believe, is only the merest fraction of what has been accomplished by the writings of Lyell, Phillips, Jukes, Ansted, Dana, Hugh Miller, and others; and surely, since the possibility of so far disseminating geological knowledge has been proved, there need be no obstacle to its general and systematic extension. No man can be more averse to that practice of tuition which would make learned philosophers of boys, and cram them with everything, to the risk of making them perfect in nothing, if not of utterly disgusting them with education. What I have advocated in this address is, the most modest amount of elementary geology for schools, and the importance of its being made a theme of systematic study in all our colleges and universities. And when school tuition has ceased, and the sterner business of life has been begun, I only claim for it a place along with other subjects, as one well calculated to become a source of the purest intellectual recreation and enjoyment.

As the history of the planet we inhabit, geology abounds in strange and startling revelations, is replete with problems of the highest interest to educated minds, and, at the same time, rich in the substantialities that minister to our material necessities. Do we ask too much when we claim for it a place along with other departments of natural science in the educational arrangements of our country? Other sciences, being more obvious and apparent, may have been earlier studied; but none can take a higher position in intellectual interest, or claim a broader platform of practical utility. Knowledge of itself is always desirable, but it is doubly so when capable of industrial application. However proud a thing it may be to philosophise on nature and nature's phenomena, philosophy is never more exalted than when she stoops to administer to the necessities of everyday existence. The tree of knowledge is ever fair and beautiful, but the perfection of its beauty is the fruit that it bears. It is on this twofold ground of scientific and economic importance that geology presses its claims as a branch of general education, and on this ground, also, that we now prefer the claim to the attention of the intelligent public. All that has been advanced, and much more that will readily suggest itself, may have been long known and felt by every one interested in the study of geology; I only crave that these will join me in giving audible utterance to their feelings, and a practical tendency to their utterance. "It may not," as was aptly remarked by Hutton now more than seventy years ago, "import anything to human policy to know what alterations time has made upon the form and quantity of this earth, divided into kingdoms, states, and empires, or what may become of these continents long after every kingdom now subsisting is forgotten; but it much concerns the present happiness of man to know himself, to see the wisdom of that system which we ascribe to nature, and to understand the beauty and utility of those objects which he sees."

GEOLOGY AND MODERN THOUGHT.

We hear a great deal in the present day about the tendencies of "modern thought;" let us inquire for a moment how far this newer thought has been influenced by the teachings of Geology. At first sight such a subject may seem to have little connection with the plain facts and practical observations which form the main business of working geologists; but as the highest aim of all science is the furtherance of human progress, so it is good for us now and then to pause and inquire how far the special department we cultivate has been concerned in this development. It is on this ground I now turn to the present topic, believing that geological discovery has had direct and beneficial influence on the development of modern thought and feeling, because this influence in certain quarters has been misapprehended and opposed, that it is the duty of every geologist to do what he can to remove the misapprehension. Had the leading geologists of this country always given full and free expression to their opinions, the opposers of geological generalisations, who are in general as ignorant of the facts of the science as they are of what is going on on the surface of Saturn, would have long since been silenced; and it is just because of this timidity and reticence that we have still to encounter their outcry against the "dangers and disturbing tendencies" of the conclusions to which we are compelled to arrive at by a study of the facts and phenomena that surround us.

By "modern thought" is meant, I presume, those ideas now entertained respecting the nature of man, and his relations to the universe, in contradistinction to the opinions that were held by our more immediate predecessors. One notable feature of this thought is the view now entertained of the age of our planet, and the processes by which its crust has been moulded into its present form. The six or seven thousand years believed in by our forefathers is now a thing of the past; and if it remains at all, it is only with those unfortunately debarred by their position from this newer knowledge; or, still more unfortunately, with those who are obstinately unwilling to acquire it. The numerous formations—aqueous and igneous—composing the earth's crust, the gradual processes by which they have been accumulated, the successive races of plants and animals entombed within them, and the repeated oscillations of sea and land which these formations imply, all point to an inconceivable lapse of ages during which our planet has existed under its present ordainings. To question this high antiquity—whatever may have been the views of our forefathers—would be to shut our eyes to the most obvious facts, and oppose the clearest inferences that reason ever deduced from the phenomena of nature. Olden thought, restricted to a narrow circle of time, saw in creation a mere series of spasmodic efforts and revolutionary events; modern thought, on the other hand, limited to no circle, perceives in nature an undeviating regularity and solemn order, involving a lapse of time commensurate with boundless space and endless energy. In the olden view the manifestations of creative power were but things of yesterday; in the modern, they stretch backwards through periods vast beyond the grasp of our finite comprehensions. And with this knowledge of a higher antiquity have also arisen other opinions as to the secondary processes by which the earth has assumed its existing form and appointments. Less than a century ago, the instantaneous creation of the solid framework of the earth was a matter of universal belief; now, every man of ordinary education knows that the rocky crust has been gradually formed by aqueous and igneous agencies—that it has undergone a thousand modifications, and is still, under the operation of these forces, passing on to other and newer aspects. At the same period, the existing seas and continents were regarded as the lands and waters originally separated at the creation; now, every one acquainted with the rudiments of geology is aware that sea and land have repeatedly changed places, and are even now gradually passing on to other distributions, with necessarily other climates and other vegetable and animal appointments. So far, then, as concerns the antiquity of our globe, and the simultaneous creation of its rocky exterior, modern knowledge and ancient belief are wide as the poles asunder. By the latter, the formation of the world was regarded as an *act* recent, instantaneous, and accomplished; by the former, it is received as a *work* of unknown beginning, gradual in development, and still in progress.

With this belief in the recentness of the world, our forefathers had no true conception of the creational order and succession of vegetable and animal existences. A vague notion, to be sure, prevailed as to the appearance of higher and higher forms within the space of one or two creative days; but at that time geology had not revealed the long and orderly ascent from lower to higher races; nor had it shown that during the vast ages of this ascent thousands of species and genera had become extinct, and that the plants and animals now living were but a mere fraction in comparison with those that had utterly perished. According to the belief of our forefathers, the flora and fauna now inhabiting the world were identical with those by which it was originally peopled. It was admitted there had been growth, and reproduction, and decay; but no idea was entertained that whole families and orders had become extinct; nor was it ever dreamt that the existing races of plants and animals were so widely different in form and character from those that had gone before. Geology has thrown an entirely new light on the science of life; and modern philosophy has now to deal not merely with existing plants and animals, but with those found fossil in the earth's crust, and which bear, in many instances, but slender resemblance to those that surround us. How wide the field that botany and zoology have now to traverse! How different our notions of the great scheme of life compared with those that were entertained by the most accomplished biologists even at the commencement of the current century! Former notions were exclusively restricted to living forms; modern thought takes a wider range, embraces past and present, traces newer affinities, and arrives at other views of geographical distribution and functional performance. Former thought regarded the existing flora and fauna as things in themselves complete and accomplished; modern thought, on the other hand, views them merely as portions of a great vital scheme connected with the extinct by the nicest adjustments, and gradually passing on to other and higher developments. And who dare gainsay that, with this broader and more accurate knowledge of nature, will arise higher and sounder conceptions of the God of nature?

Again, believing in the six or seven thousand years of the world's existence, the antiquity of man was necessarily limited by our forefathers to the same duration. Neither plants nor animals could, of course, be older than the globe on which they were placed; and thus all the remains of life, all the dispersions of races, all the rises and declines of nationalities, and all the concrete progress of civilisation, were restricted to these six or seven thousand years. By-and-by, however, as geology began to unfold the numerous successions of plants and animals, and the cycles required for their development, and as explorers began to discover the remains of man and his works in certain formations which, in the ordinary course of nature, could not have been deposited within the received chronology, a new light broke in upon modern thought, and most people are now prepared to admit that man, in one or other of his varieties, may have been an inhabitant of this earth for hundreds of centuries. We say in one or other of his varieties, for in the present state of knowledge it is undetermined which was the earliest variety; though it is matter of scientific belief that our own or the Indo-European is the latest, and that the others (the Ethiopian, Mongolian, Malay, and American) are not and could not have been descended from it, as acquiesced in by our immediate predecessors. By this newer notion freer scope has been given to the reasonings of the ethnologist, the philologist, and the historian, and many anomalies in the variation and dispersion of the human race are likely the sooner to receive a more philosophical and satisfactory solution. It has been said (as it has been said of many other subjects that engage the human mind) that it matters little to the business of life whether man has existed on this earth for six thousand or for sixty thousand years. Let us beware, however, how we entertain such an argument. If knowledge were sought after only for its material results, man would indeed know little, and desire to know still less. Indifference is too often, in science as in morals, the first and facile step to error and declension.

Still further, as palæontology has shown an orderly progression in time from lower to higher forms, and this in a way that closely accords with the ordinal rank prevailing among living plants and animals, the question has naturally arisen—Has this progression been the result of successive creations, or has it been brought about by some secondary law of gradual development? Much, it must be admitted, has been written on both sides, but the acrimony with which the subject was discussed some twelve or fifteen years ago has died away,—it has become an "open question," which may be treated from a philosophical stand-point; and now perhaps the majority of qualified naturalists are beginning to lean to the opinion that the entire vital scheme—animal as well as vegetable—is genetically connected by some process of developmental descent. They perceive that life is intimately associated with the physical conditions of the universe, and throughout these physical conditions they trace only the operation of secondary causation; hence the fair inference seems to be that life, like the conditions on which it is dependent, is under a similar mode of causation and the operation of natural law. Such a process of development being admitted—no matter how difficult it may be to trace it in all its ramifications—man must be genetically connected with the antecedent forms of life, and the man of the present day must excel the man of the past, just as the man of the future will excel, physically and intellectually, the man of the present. If there be a law of progressive development, such must be its inevitable result; and this new idea of progression, originating with geology, has already done much to influence the tone of modern thought and modern philosophy. The science of Anthropology, or the study of man as a branch of natural history, has been one of its immediate results; and much will yet flow from that study, both of a philosophical and practical nature. Observe that, however man may have originated, it does not alter his position in the scale of being. It is no degradation to have been descended from some antecedent form of life, any more than it is an exaltation to have been formed directly from the dust of the earth. He lives, and breathes, and is dependent on physical conditions as much as the lowest creature with which he is associated in the scheme of vitality. His position depends, not upon the physical life which he shares in common with other animals, but upon his intellectual nature; and this in either way can only be resolved into a newer and higher creational endowment.

Observe, legitimate geology does not aver that this process of development has yet been satisfactorily explained, nor does it fail to admit that there are many difficulties, palæontological and physiological, in the way of its final explanation; but it regards the fact of progression as undeniable, and ascribes it, as it ascribes all other phenomena, to the will of the Creator operating through the medium of natural law. And it is this idea of Law, in contradistinction to a belief in creational interferences and interventions, that has impressed its mark most perceptibly on the reasonings of modern philosophy. To the thought of our forefathers, creative interference was direct, and as occasion might require; to modern thought, creative energy operates through law, and this law fixed, enduring, and ascertainable. According to the olden belief, the Deity was invested, as it were, with human attributes, changeable in method, provisional in action, and open to external influence; according to the newer philosophy, the work of creation is carried on by fixed and ascertainable methods, perfect in their appointments, and because perfect, enduring and unchangeable. Both views might be alike reverential, but the latter carries along with it more spiritual and more exalted conceptions. To believe that the whole operations of nature are held in concert by great pre-ordained laws—the incidents of to-day with those of the remotest eras—is surely a nobler view of creation and its Divine Architect than that which provides only for present purposes and special requirements. And the more this idea of natural law can be made to pervade modern thought, the more will its influence be felt and appreciated in morals as well as in philosophy. So long as the human mind believes in the efficacy of confession and humiliation in procuring immunity from the consequences of its evil-doings, so long will it feebly resist the temptations to error; but let it once be convinced that certain results must inevitably follow from certain acts, and that there is, indeed, in the order of creation "no variableness, neither shadow of turning," and you provide it with one of the strongest incentives to reason and resistance. So far as confession and repentance concern the individual mind, the effect may be wholesome as leading to resolution and resistance; but so far as they relate to general law, it would be reversing all philosophical views of the enduring order of nature to suppose that they could be instrumental either in producing change or in procuring exemption.

I am aware it has been attempted to fix on geology, as the main promoter of this idea of natural law, the ban and odium of materialism. That some geologists may entertain materialistic views, just as other men who know nothing of geology believe in similar doctrines, is by no means improbable; but if there be any such, let it be clearly understood our study disclaims their reasonings and ignores their principles. Instead of being conducive to such opinions, geology, more perhaps than any other of the natural sciences, is calculated to impress with convictions of Divine intelligence and design. Our forefathers drew their evidences chiefly from the living world around them; the modern theologian obtains through geology a wider field and more abundant material. The inanimate rock now tells its tale as eloquently as the living organism, and the rocky crust carries back the argument through cycles compared with which the appointments of the present are but as the moments of yesterday. Our forefathers passed over the earth's crust as a mass merely of rocks and minerals; the modern inquirer, on the other hand, has his observation turned aside at every step by the organisms which it entombs, and his thoughts hallowed by the reflection that beneath him lie myriads of life-forms which were the objects of God's care thousands of ages before his own race was called into existence.

Another and most important feature with which modern thought has been impressed by our science, is the idea of incessant progression. Ignorant of the physical and vital progress revealed by geology, our forefathers regarded the world, with all its garniture of plants and animals, as a thing accomplished. To them it presented a mere stereotyped round of decay and reproduction—the same now as it had been, and as it would continue to be in future ages. Instead of looking forward to its onward and upward progress, they dreaded its termination, and were ever predicting its end. Modern philosophy, on the other hand, which has traced a progress in the past and perceives no decline in the forces of nature, looks confidently forward to newer and higher developments—physical, vital, and intellectual. As the life of the present excels the life of the past, so the fair and logical inference is, that the life of the future will excel that of the present. As the march in the past has been ever onward and upward, so that in the future will be onward and upward still, and man himself partake of the same progression. As higher and higher forms have appeared in the past, so science believes in the appearance of higher and higher forms in the future. Nor can this idea of irresistible progression fail to affect the general tone and character of modern belief, or cease to impress with the conviction that everything physical, vital, intellectual, and moral is passing, and must pass on, to other and higher aspects. Nothing stands still,—truth alone is eternal; and in the search for this truth, and under the conviction of incessant progression, how futile the attempt to bind by creeds and dogmas the ever-ascending and ever-expanding attributes of the human intellect!

Another essential difference between modern philosophy and olden belief is the greater impulse the former gives to intellectual activity and progress. Formerly, whatever the human reason could sufficiently unravel for belief was ascribed to Divine interposition, and there the matter ended. Now, however, since modern thought has been trained to seek for the operation of Law and sufficient causation in nature, the mind is ever on the alert, observing, inquiring, and striving to interpret. By this exercise its faculties are awakened to new activity and strength; and hence in a great measure the rapid progress of the current as compared with that of preceding centuries. A belief in secondary causation may be equally devout with faith in direct interposition, but the effect on the reason is altogether different. By the former the mind is impelled to activity, by the latter it is lulled to a passive satisfaction. As the field of nature in all its variety and complexity is ever spread out before us, so it is evidently intended for our research, and surely no nobler duty can engage the creature than the discovery of the means and methods of the Creator. As Mind is to us the highest result of creation, so no higher homage can be rendered to the God of mind than its ever-active exercise and rational convictions.

Such is a hasty glance at some of the topics on which modern thought has been more especially influenced by the teachings of geology. Nor is it the mere correction of this or that belief, but the removal of all the opinions that have been founded upon or flow from these beliefs. In this way the influence of our science extends beyond the limits I have indicated, and its effects may yet be traced in quarters where at present it is least suspected. And if it be the truth it teaches, the sooner its influence can be accelerated and extended the better. To timid minds who dread the effects of these newer views, the history of the Galilean astronomy may become a source of encouragement; to the ignorant who misapprehend them, the rapid dissemination of our science will soon suffice to explain; and to the intolerant who condemn, the progress of recent years may surely carry the conviction, how lightly falls their reproach, and how unavailing their opposition. As geology seeks only for truth, so it dreads no blame. Its field of observation is our planet; its functions the reading of that planet's history. It may err in its interpretations, but the facts remain intact; and the higher knowledge of another day may make clear what the information of the present is unable to explain. As we have no creeds to restrict, so we have no dogmas to defend; and as we have all learned how liable we are to err in our interpretations, so we have ceased to be intolerant. In this way, and over and above the influence of its teachings on modern thought, the history of geology, like that of astronomy, is pregnant with useful lessons to other departments of human inquiry.

In offering these brief remarks, I have been desirous, first, to show the higher connections of our science as an incentive to further research; and, secondly, to remove misapprehension as to the real bearings and tendencies of its teachings. We cannot be always in the field, and our discoveries, without their higher bearings, would lose half their significance. We cannot sit quietly by and hear our reasonings misrepresented, without feeling we are untrue to ourselves and condoning the ignorance and error of the offenders. I am thoroughly aware that the views I have expressed, like the truths they are meant to elucidate, are liable to misinterpretation. On this, as on other occasions, however, I by no means wish to implicate other geologists, but merely exercise my own thoughts, and give my own convictions. As surely as every man has his own distinctive form and features, so surely has he been endowed with his own individuality of mind, and it is only by the exercise and utterance of this individuality that progress can ever be effected. As in external nature all growth and movement depend upon the action and reaction of dissimilars, so there can be no intellectual or moral advancement without the interactions of individual opinion. Whatever, therefore, tends to impede this individuality or repress its utterance is a sin against the order of nature, and demands our sternest resistance.

ROCKS—THEIR FORMATION AND METAMORPHOSES.

THE origin of matter may be admitted within the domain of speculation, but it lies altogether beyond the province of inductive geology. Given the chemical elements, and we can see how, by their unions and combinations, rock-matter may be produced; but as to the origin of these elements science is mute, and cannot offer even the shadow of an explanation. The elements once combined, however, so as to form the solid framework of our globe, and we can readily trace the formation of rocks, such as we now see them, partly to chemical, partly to organic, and partly to mechanical processes. There may be combinations and intermixtures of these processes occasionally somewhat difficult to determine, but for all ordinary purposes of investigation the rocks of the crust may be ascribed to one or other of these methods, and the student who fully comprehends them has at his command the key to the solution of most of the problems in physical geology. As to the internal changes or metamorphism which rocks may undergo subsequent to their formation, this is a much more difficult matter of research, and until the department of Chemical Geology is more intimately studied, the most that can be offered in many cases is little better than indication and suggestion. In the mean time, let us trace in a general way the formation of the more abundant rock-masses, and the internal as well as external changes to which they have been most frequently subjected.

The *chemical* formation of rocks belongs more perhaps to Mineralogy and Crystallography than to Geology proper, for chemically-formed products are usually of a simple and homogeneous nature, whereas the prevailing substances with which the geologist has to deal are of a mixed and unequal composition. Still, as rocks of chemical origin arise both from aqueous solution and igneous fusion, a considerable portion of the earth's crust—the so-called minerals, metallic ores, homogeneous masses, and igneous rocks—belongs to this category. From aqueous solution and the permeation of water we have most of the mineral crystals, metallic ores, and vein-stuffs; while from the same source are precipitated such masses as siliceous-sinter and siliceous-tufa, chalcedony and opal, calcareous-sinter and calcareous-tufa, rock-salt, gypsum, salts of soda, potash, borax, and other similar compounds. And as water holding mineral matter in solution is ever permeating the earth's crust, rocks originally of mechanical origin, such as sandstones and breccias, may, by infiltration, assume a quasi-chemical character, just as, by farther solution and permeation, coral-reefs and shell-beds may be chemically converted into sparkling and variegated marbles. Where water holding mineral matter in solution passes through the crust, sometime or other this matter must be precipitated either *within*, in the interstices and cavities of rocks, and in veins and fissures, as independent crystals, crystalline rocks, metallic ores, and sparry matrices, or *without* on the sea-bed or on the earth's surface, as rock-salt, gypsum, sinter, tufa, travertine, and other homogeneous masses. A considerable portion of the earth's crust is thus composed of substances either directly obtained from chemical solutions, or indirectly altered by the permeation of water holding in solution the matter which has converted them into quasi-chemical strata.

A large portion, however, of the chemically-formed rocks has arisen from igneous fusion, the ingredients of which they are composed assuming a crystallised or crystalline form on their cooling and consolidation. To this category belong the various granites, porphyries, felstones, basalts, greenstones, trachytes, and lavas, whose texture (glassy, granular, or crystallised) and structure (spherical, tabular, or columnar) have arisen chiefly from the rapidity with which, and conditions under which, they have been cooled. As to the moot point whether certain granites and porphyries be of truly *igneous* or merely of *hydro-igneous* origin, it matters little to our present consideration—either process depending upon the actions and reactions of the ingredients of which the masses are chemically composed. It is true, the history of a rock of direct chemical origin—such as gypsum, quartz, obsidian, or basalt—is very different from that of one originally of mechanical or organic origin, and subsequently altered both in composition and texture by chemical changes, such as quartzite, marble, or coal; and it is this metamorphism, as we shall subsequently see, that renders the history of many of the stratified rocks so perplexing and uncertain. And even among the unstratified or igneous, similar difficulties occur; what was originally mere mechanical aggregations of volcanic dust, cinders, and lapilli, being frequently converted by subsequent changes into homogeneous tufas and amygdaloids. In all such cases no great error can be committed by regarding them of chemical formation, though, if precision of history be aimed at, such terms as hydro-thermal and hydro-igneous, chemico-mechanical, and mechanico-chemical, may be advantageously employed to designate the double origin.

Under the designation of *organically* formed rocks are embraced all those that have been produced through and by the instrumentality of vegetable and animal life. Among those arising from vegetable growth and decay at the present day we have peat-mosses, swamp-growths, jungle-growths, tree-drifts, and submerged forests; and to similar accumulations we may ascribe the lignites, coals, anthracites, and graphites of the older formations. As the vegetable masses of the current epoch vary in extent, thickness, purity of composition, and the like, so we find the lignites and coals of former ages varying in the same manner, some being limited and thin, others extensive and thick—some almost absolutely pure, and others so mingled with earthy impurities as to be unfit for combustion, and to pass into the no doubt as to the formation of these rocks through and by character of shales more or less bituminous. There can be the long-continued accumulation of vegetable matter, either by growth and decay *in situ*, or by mere mechanical drift and aggregation; and all the ultimate appearances they assume as compact bituminous coals or glistening anthracites, have arisen from chemical changes within the buried vegetable masses. By pressure and the slightest chemical change a spongy peat is converted into a solid lignite; a lignite, by further pressure and bituminisation, into a hard glistening coal; and a bituminous coal, by chemical discharge of its gases, into a dry flameless anthracite or stone-like mass of carbon. To the same category belong the fossil gums, resins, and asphalts, jet, amber, and the diamond—all being primarily of vegetable origin, though every trace of that origin has long since been obliterated by the chemical transformations to which they have been subjected. Nor must we forget to notice those stratiform masses, such as tripoli, polishing slate, and the like, which have arisen from the growth and decay of diatomaceous organisms—the "microphytal earths" of some authors—and which frequently assume dimensions, both in the late and earlier formations, of considerable magnitude.

Of the organically-formed rocks, those produced through and by the agency of animal life are much more varied than those of vegetable origin. Some of those, like coral-reefs, arise from secretion *in situ;* others, like shell-beds, shell-marls, and foraminiferal deposits, from growth and decay *in situ;* and some again, like certain shell-masses and bone-breccias, from drift and mechanical accumulation. However they may arise, the great bulk of them are calcareous—resulting in marls, chalks, and limestones; and only a comparatively small proportion are of a siliceous or a siliceo-ferruginous nature, such as flints, from the decay of sponge-growths and flinty earths from some infusorial deposits. Many of them, too, owing to the ready solubility and crystallisation of lime, soon undergo internal changes, and become compact limestones, crystalline marbles, and cherts, which have little resemblance to the original masses, and give little or no indication of the sources from which they were derived. Indeed, the study of the organically-formed rocks, whether of vegetable or of animal origin, is fraught with unusual interest: the accumulation of masses so gigantic by means apparently so insignificant—the collecting again of rock-matter that had been dissolved and dissipated through air, earth, and water—being amongst the most marvellous phenomena that come under the cognisance of the geologist.

The great bulk, however, of the stratified rocks, and indeed of the earth's crust, is composed of *mechanically* formed compounds. As frosts, winds, rains, rivers, waves, tides, and currents are ever wearing and wasting away some portion or other of the solid crust, so the waste matter or debris must find a place in some other position, and this position is generally determined by the transport of water to lakes, to estuaries, or to the ocean. As the water comes to rest, this debris will be deposited in beds of varying thickness, regularity, and composition, according to its amount, and the degree of attrition to which it has been subjected. Rock-matter broken off by frosts and storms, and subjected to little attrition, will form rubble and shingle; the same matter subjected to longer tear and wear will become rounded, and form gravel; the gravel, by further attrition, will be reduced to sand; and sand, by still further comminution and sifting, will be converted into mud and impalpable sediment. As all these processes are ever going on at the same time, and new matter ever being transported, washed, sifted, and deposited, there will frequently be comminglements and admixtures of these ingredients, though in the main their respective gravities will determine their deposition as shingle, gravel, sand, or miscellaneous mud-silts. As alternations of these are deposited, pressure, infiltration of cementing matter, chemical change, and the like, lead to consolidation; and thus shingle becomes *breccia*, gravel *conglomerate*, sand *sandstone*, and mud *shales* of varying character and consistency. With the exception of some limestones, coals, rock-salts, and the like, of chemical or organic origin, all the stratified systems are mere mechanical aggregations—the spoils of pre-existing rocks transported and deposited through and by the agency of water.

And as with the mechanical rocks, so with those of chemical and organic origin; all are derived by disintegration and dissolution from pre-existing masses. There is nothing new created, but merely the same matter ever circulating from place to place, and from form to form. Unless it be, perhaps, from the fall of meteoric masses (and these, be it observed, are still of doubtful origin), this world of ours, as far as we know, has received no accession of matter from its beginning, but merely presents the same elements, ever shifting their forms and positions in obedience to the operation of certain forces acting either from without or from within. So long as these forces exist—and we see no symptoms of decline—the matter of the rocky crust must ever continue to undergo transmutation, not merely from form to form, but from place to place, so that not only the rocks themselves, but the continents which they compose, must partake of the like mutations.

But granted the formation of rocks through chemical, vital, and mechanical agency, no sooner has any rock been so formed than it begins to change either its internal or external character, and this more or less intensely according to the conditions to which it is subjected. This *metamorphism*, as it has been termed, may be brought about by pressure, by heat, by chemical actions and reactions, by electro-magnetic currents, by new molecular arrangements, or, it may be, by all these forces acting more or less in combination. Metamorphism of rock-masses is indeed one of the most difficult and complicated problems in geology, involving questions of chemical change under long-continued pressure and heat which cannot possibly be simulated in the laboratory; hence the reason of so much difference of opinion as to the causes of crystallisation, the evolution of new minerals, cleavage, foliation, and other appearances in rocks which were originally of mechanical and sedimentary origin. We can see in some degree how a stratum of ordinary limestone may be converted by heat, pressure, and the presence of water into a saccharoid marble—or how, by the infiltration of silica, it may assume the character of a chert; and in like manner we may trace the production of quartzites from sandstones, and sparry amygdaloids from vesicular volcanic tufas. But it is not so easy to perceive how such mountain-masses as gneiss, mica-schist, serpentine, and clay-slate, with all their phenomena of crumpling, foliation, and cleavage, and with all their garnets, tourmalines, and other accidental minerals, could have been metamorphosed from ordinary sedimentary rocks (sandstones, shales, and limestones), even though we call in ages of pressure, heat, chemical action, and the other metamorphosing agencies which are usually appealed to. The subject of rock-metamorphism is, in truth, a most difficult problem, requiring for its solution more extended chemical research and profounder reasonings in physics than it has yet received; and in the present state of our knowledge, the ordinary geologist may rest satisfied that the slow and long-continued action of pressure, heat, chemical action, magnetism, crystallographic segregation, and similar subtle forces, are, and have been, the main agencies concerned in its production. And this much also he must ever remember, that no sooner has any rock-mass been formed, whether by chemical, vital, or mechanical means—a travertine, shell-bed, peat-moss, or stratum of sand—than it begins to undergo internal change, and this in proportion to the depth at which it may be placed, and the mineral conditions by which it may be surrounded.

Along with this internal metamorphism or change of *texture*, there is usually produced some external alteration or change of *structure*, such as "jointing," or the separation of many strata into regular blocks of shrinkage; "crumpling" and "folding" by pressure; and "cleavage," or that fissility across the bedding which characterises roofing-slate, and seems to be due partly to pressure and partly to molecular segregation. Nor must we forget to mention the tabular, spherical, and columnar structure which characterise so many of the igneous rocks (granites, greenstones, and basalts), and which arises partly from the degree of fusion to which the mass has been subjected, but chiefly to the rapidity and conditions of its cooling. Indeed, there is no rock-mass that suffers internal change but undergoes at the same time a corresponding change in its external aspects, whether it be of chemical, vital, or mechanical origin—sedimentary or eruptive. And when once brought to the surface of the crust, it suffers still greater change of aspect through those meteoric and aqueous causes to which we have already alluded, being "weathered" by the atmosphere so as to present an aspect altogether different from its internal texture; smoothed and abraded by moving water; or polished, rounded, grooved, and furrowed by glaciers in their downward passage from the mountain-heights on which they are engendered. These external changes are generally, however, of much easier comprehension and solution than the internal; but though simpler of explanation, they are not the less important to that never-ceasing circulation of matter which it is the main duty of the geologist to trace through all its varied forms and countless modifications.

Such is a hasty glance at the formation of the rock-masses that constitute the crust of the earth, and the metamorphoses to which, for the most part, they are subsequently subjected. Amid all the changes which the rocky crust has undergone, and is still ceaselessly undergoing, there is no evidence that anything material (or that through which force manifests and exerts itself) has ever been added or abstracted from the globe. It is the same matter ever changing, in obedience to operating forces, its form and place—now solved and separated by air and water, now reconstructed by fire, now chemically severed by antagonisms, now united by affinities, now built up into myriad forms of beauty and wonder by life, and now scattered again by dissolution and decay. Comprehending this incessant circulation, and the means by which it is brought about, the student of geology has the key to the solution, not only of the mere formation and metamorphism of rock-masses, but to the whole history of cosmical change which it is the province of his science to interpret. And where, from deficiency of knowledge or want of mental power, he is unable to reveal the whole of that marvellous history, it is something at least to be able to trace in dim perspective what is altogether shrouded in darkness to the uneducated and non-scientific mind.

BY THE SEA-SHORE.

For the thoughtful and inquiring the sea-shore has endless attractions; to the student of nature a thousand inducements to frequent its scenes. The stilly loneness of the long level sands on a summer gloaming, the pulse-like ebb and flow of the tide, the hazy outline of the far-distant horizon, or the shimmer of the moonlight on the midnight waters, offer an ever-present theme for thought and a boundless field for imagination. On the other hand, the myriad forms, half vegetable, half animal, that clothe the rocks, the strange and varied life that throngs the pools and reaches, the sea-fowl that soar round the cliffs or dose dreamily on the islets, and the creeks and caves and crags, with their ever-shifting lights and rugged outlines, all afford inexhaustible themes of study to the lover of nature. But it is to the geologist, more perhaps than to any other, that the sea-shore displays its irresistible allurements, and affords its most valuable lessons. In the quarry and the railway cutting, or in the ravine, he may trace the sacred letters of that great stone book which he seeks to decipher, but on a narrow and restricted scale compared with the sea-shore, where miles of unbroken section are fully exposed to his view. Not only in the cliffs above can he study the succession of deposits, and the mode in which they have been rent and bent and broken by vulcanic forces, but at tide-ebb, on the shore beneath, he can see, as on a ground-plan, the manner in which these rock-masses are disposed. And not only does the sea-shore afford this clearer and fuller insight into the doings of the past, but in its waste and degradation in one district, and in its accumulations and deposits in another, we get intelligible evidence of the means and processes by which geological change is effected, and new distributions of land and water secured. Let us glance for a while at the shores of our own island in corroboration of these views, and as an inducement to the young geologist to betake himself betimes to the sea-side.

And while geology is his prime object, he will find along the shore and the seaboard—that narrow belt of amphibious bordering land—a thousand things at once to gratify and to instruct. The maritime and marine flora and fauna, the picturesque creeks and coves and cliffs, the old grey ruins of keep and castle, the quaint and curious features of the little fishing village, and the busy bustle of the thriving seaport, meet him at every turn, giving new themes for thought, and a zest to his more immediate labours. "Round the shores of Great Britain" was an early ambition of ours, and full fifteen hundred miles during summer holidays we had accomplished, when the day of paralysed limbs came, putting an end to this as to many other long-cherished intentions. But though closed to one it is open to others; and where we cannot again be, we may at least be able to induce others to go for the same purpose, and with equal gratification. Naturalist, archæologist, ethnologist, poet, and painter, will alike find it a fertile field for their research: to the geologist who would gain a clear conception of the structure of the rocky crust its study is indispensable. Along this little island of ours there are illustrations of every system and formation; sections which no artist could trace, and whose manifold teachings no transfer to paper could convey. To be appreciated they must be seen; to be fully understood they must be studied, hammer and note-book in hand. When once so traced the impression they leave can never be effaced, the lessons they have taught can never be forgotten.

Should the geologist wish to study the *Granites*, for instance, and their relations to the other old rocks through which they have burst, displacing, enveloping, and contorting, let him go to the heads and gullies of Cove, or to the Bullers of Buchan, and there the massive structure, the block-like partings, the intersecting dykes and veins, and all that gives character to the formation, are presented with a grandeur and impressiveness that strike home at once to the mind and the memory. The inland crag and open quarry may teach much and well, but the long line of cliff, the bold headland, and the in-cutting gorge, present the phenomena with a distinctness which carries its own interpretation, and leaves no room for question. Dr Hutton is said to have gone into ecstasies on witnessing the relation of the granites to the schists of Glen Tilt; how much greater his delight had he studied them along the shores of Banff, Aberdeen, or Kincardineshire? Or be it the *Metamorphic Rocks* — those unresolved masses of the Highland hills which cannot yet be ascribed to any system—and where can he study their foldings, contortions, and reversions more readily than in the gneisses, the mica-schists, and chlorite-schists that stretch so boldly between Stonehaven and Aberdeen, or in the gneisses, quartzites, limestones, and serpentines of Portsoy? The river-glen and wayside quarry may exhibit a few facts; the sea-shore, on the other hand, exhibits the whole system in all its alternations and varied metamorphoses. Again, should he wish to acquaint himself with the aspects of the *Laurentian* — the oldest of the fossiliferous systems—with its gnarled and contorted gneiss, its flinty quartzites, and granite-like ribbings; and where will he find a display so grand and instructive as along the wild shores of Lewis, or those of the opposite mainland? Or be it the *Cambrian* system, with its splintery slates and schists and gritstones, its straight-cleft precipices and jagged peaks; and where can he study it with more distinctness and effect than along the north-western shores of Wales—the Cambria of our forefathers—which has given to the formation its name?

Would he study the *Old Red Sandstone*, with its flag-stones, sandstones, cornstones, and conglomerates; and where can he find a wider field than the cliffs and coves of Ross and Cromarty, made classic by the pen of Hugh Miller, the frowning headlands of conglomerate that stand between Stonehaven and Bervie,* or the still bolder cliffs and deeper caves that lie between Red-Head and Arbroath in Forfarshire? Every member and alternation of the system is there displayed with a clearness and fulness that leave no room for doubt, and with features so wild and varied that each fact assumes its own individuality, and becomes ever memorable. Or would he read the *Devonian*, that marine equivalent of part of the Old Red, let him go to the coral-limestones of Plymouth or Torquay, with their clefts and caves, or to the still more varied rocks and picturesque cliffs of Ilfracombe on the Bristol Channel. There mildness of climate, beauty of scene, and the purest waters, offer new

* An equally instructive study may be made of the conglomerates of the upper Old Red along the shores of Bute from Rothesay to Ascog. There the exposed and wave-washed surfaces exhibit the nature of the pebbles, and the whole composition and aggregation of the strata, in a way unequalled in any other district we have examined; while the intersecting dykes of basaltic greenstone and the old beach-levels, with their cliffs and caverns, give additional interest to the study, and suggest other problems of equal importance to the geologist.

inducements to research, and confer fresh charms on the objects of his labours. Or, rising still higher in the scale of time, would he unfold the history of the *Carboniferous System*, with its manifold alternations of limestones, sandstones, shales, coals, and ironstones, their upheavals and depressions, their faults and fissures, and all the activities to which that epoch of luxuriant growth by estuary, lake, and river was subjected; and where can he turn to a finer and more instructive field than to that long stretch of cliff and shelving shore that rounds by Fife Ness from St Andrews to Anstruther? There every stratum is so clearly traceable, every bend and flexure so obvious, and every fault and dyke so sharply defined, that the whole physical history of the formation can be read with certainty, and as much learned in the course of a few days as could be done during weeks in other districts. Nor is the *Permian*, which crowns the long list of the palæozoic systems, less instructively displayed in those readily accessible rocks which stretch between Cullercoats and the Wear, rise up in cliff and cave, stack and arch and needle, in the beautiful bay of Marsden, and exhibit in perfect sequence the marl-slates, sandstones, and magnesian limestones of that curious, and as yet imperfectly interpreted, system.

Leaving the palæozoic and rising to the neozoic cycle, the conglomerates and marlstones of the *Trias* have their composition and structure most fully displayed in the wasting "stacks" and cliffs of Dawlish in Devonshire; while the *Lias* and *Oolite* present their whole sequence, composition, and history in unparalleled clearness along the shores of Yorkshire, or (if a milder region is desired), with equal effect, perhaps, along the soft and genial shores of Dorset. Not a limestone, or shale, or clay of these truly marine formations but these wasting cliffs exhibit, alike in their stratigraphical relations and fossil contents—every slip and fall disclosing some new fact, and inciting to further discovery. And then what magnificent displays of the *Chalk* by Brighton, Hythe, Folkestone, and Dover; how instructive the *Tertiary* sections by Hampshire and the Isle of Wight!—every point and headland unfolding itself as a diagram for the study of the young geologist and inviting him to research. The inland chalk-quarry, the gravel and clay pits, have no doubt yielded many treasures; but, lithologically, their revelations are as nothing compared with those obtained from these long lines of sea-shore, with their sections ever fresh and ever advancing. Or be it the *Glacial drifts* and *Post-glacial accumulations*, with their boulder-clays, gravels, silts, and sands; and where can we trace them so clearly as along the wasting shores of Norfolk and Holderness, where every winter produces a new cliff-face, and every stormy spring-tide presents some new discovery? Indeed, to whatever part of the sea-shore we go—the resisting headland of granite, or the wasting bluff of post-tertiary clays and gravel—we find the structure of the crust exhibited with a breadth and fulness which can nowhere else be witnessed; and it is not, perhaps, saying too much when we affirm that without our many magnificent coast-sections, British geology could never have attained, nor attained so rapidly, its present position of exactitude and certainty.

Nor is it the mere stratigraphical relations of the geological systems that can be studied so effectively by the seashore; but their fossil contents have been equally developed by research in the same localities. Not only is the position of certain fossils in the strata more clearly seen, and their mode of entombment made more manifest, but every fall of the wasting cliff lays bare in an instant what years of quarrying would not suffice to reveal! What magnificent displays of the carboniferous flora have been made by the falls of the Fifeshire coast; what wonderful forms have been revealed in the lias and oolite by the degradation of the Yorkshire and Dorsetshire cliffs; what insight into the marine life of the chalk seas have we obtained from the shore-slips of Kent; how much have we learned of the tertiary flora and fauna by the waste of the Isle of Wight; and what curious information regarding post-tertiary conditions has been supplied by the wearing away of the bluffs of Norfolk and Holderness! To the expert in fossils every cliff-fall is a treasure, and many of the finest specimens in our public museums have been obtained by this process from the strata of the sea-shore. By the cliffs and reefs at ebb-tide the young palæontologist, hammer in hand, has ample scope for research—a field where there is room for all, and a storehouse that is never exhausted.

It is not, however, the rocks and fossils alone that can be studied so well by the sea-shore, but the processes of waste and reconstruction, of upheaval and depression, which govern in the main the distribution of sea and land, are there also displayed in a breadth and fulness unknown in any inland situation. Wherever strata of unequal hardness present themselves to the beat of the waves or the scour of the tides, there underminings are sure to take place; and where the softer beds are worn from beneath, there the overhanging cliffs give way, to be pounded to fragments by the restless waves, and to be swept by the tides as sand and mud to some sheltered recess. Wherever, too, the strata are intersected by dykes and faults and fissures, there the sea will cut into the land by gorge and cave and gully, and there the land will stand out in ness and headland, or rise up in "scaur," or "stack," and "needle"—the resisting remnant of the harder dykes and strata. Watch the waste of the pleistocene cliffs of Bridlington, Hornsea, and Withernsea at the rate of two or three yards a-year, and mark how sharply the debris is scoured away by the tide and laid down in the long, flat, silty reaches of the Humber and the coast of Lincolnshire. Or take the alternating shales and sandstones of the St Andrews cliffs, and note the encroachment of the sea as it slowly but surely undermines them; and yet not a particle of debris is left at their base—the whole being borne away by the tide as fast as formed to the sands and sand-dunes (Pilmoor and Tentsmoor) that stretch away in miles between the mouths of the Eden and Tay.

As sure as degradation takes place in one locality, so certainly does accumulation occur in another, and this by processes whose every mode we can watch, and whose rate of progress we can determine. It is by this reciprocal process of waste and reconstruction that hundreds of acres of headland and promontory in these islands have been wasted away, and thousands of acres of low-lying sea-fen and sand-dune accumulated. And when we consider the millions of miles of sea-coast that are exposed to the waves and tides and currents, we can readily imagine how much, in the course of centuries, the distribution of sea and land must be changed, and all that is dependent thereon affected. The inland waste that takes place through frosts and rains and rivers is no doubt great, but having reference chiefly to altitude it makes comparatively little impression; whereas the waste by the sea-shore being horizontal, creates new relations between land and water, and is everywhere followed alike by new physical and new vital results. The headlands and promontories of our forefathers are now far-out "stacks" and "needles" washed by the waves; the Saxon churches and graveyards "by the sea" have long since been swept away; and the "seaport" of six or seven centuries ago is now, in many instances, the site of the inland grange, with its green fields and ditches.

"There rolls the deep where grew the tree;
Oh Earth! what changes hast thou seen?
There where the long street roars has been
The stillness of the central sea.

The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mists, the solid lands,
Like clouds they shape themselves and go."

Nor is it merely waste and reconstruction that are so perceptible by the sea-shore, but that slow uprise or depression of the land which occurs in so many tracts can be studied and proved only by observation along the coast-line. The inland dweller might remain for ever ignorant that his country was either rising or sinking, but a few rambles by the sea-side will convince him whether elevation or subsidence is going on—the former by the level lines of raised beaches now high above the waters, the latter by the submergence of lands and forests and buildings that must at one time have been high and dry above the tides. There is no study within the whole range of geology more attractive than these oscillations of the land; the terraces of raised beach, the line of caverns, and the submarine forest, all proving that, independent of exterior waste and reconstruction, there is a process of upheaval and depression going forward by which the distribution of sea and land is changed, and all that is dependent on the position, contour, and relief of the land-masses must be effected. By the sea-shore alone can these phenomena be studied, and the geologist who neglects this field foregoes the power of proving some of the most important problems in his science.*

It is thus by the sea-shore that the young geologist can learn so much of his favourite study, and this much so readily and so well. The magnificent sections stretching for miles, with every line and layer unobscured, with every

* See Chapter on "Raised Beaches and Submarine Forests."

bend and fold apparent, and every dyke and fault and fissure standing out as if in a diagram, present physical illustrations rarely or ever to be witnessed in inland situations. In no other place can the relations of rock to rock be better displayed, and nowhere is the structure of the earth's crust more fully revealed. The rapid disintegration of the coast in certain localities, and the extensive rock-falls that take place every winter, afford, too, the finest opportunities for the collecting of fossils; the amount exposed by a single fall often exceeding what could be mined or quarried during a twelvemonth. And then the perfection in which they can be obtained compared with the gropings of the miner, or the chance chips of the quarryman. Again, in the waste and reconstruction that are ever taking place by the sea-shore, he can study to perfection those processes by which the rocky crust is weathered and worn away in one tract, and in another re-formed by the accumulation and assortment of the drifted debris,—an example—it may be within his morning's walk—of that ceaseless circulation of matter which is ever passing from one condition to another, from the formed to the unformed and back again, and this without diminution or loss. And, lastly, by the sea-shore alone can he study those gradual elevations and depressions by which the position, the contour, and the altitude of the land are affected, and through these the climate they enjoy, and the flora and fauna with which they are peopled. In fine, in the Sea-Shore the student has a great geological preceptor, and a lesson at every turn; while in its varied scenery, its life, and busy industry, he will find endless themes for thought, and inexhaustible sources of intellectual recreation.

LOCHLANDS, AND THE TALE THEY TELL.

A TRAVELLER over the Lowlands of Scotland will often hear the name of "Lochlands" where no loch or lake, mire, marsh, nor swamp meets his view. He sees around him a tract of uniform flatness intersected by drains and ditches, with here and there a rising mound, and, encircling the whole, a bank-like margin of varying slope and altitude. Should he visit the spot before the morning mists of summer have been dispelled, or after sunset, when the night fogs are creeping along the valleys, he will find himself enshrouded in a lake of vapour, with the bank-like margin dry and visible all around. Or should he look down from the margin on the foggy flat below, the slightest touch of imagination is only required to convert the whole into a misty sheet of water—the loch as it spread out in former ages. These "lochlands" are but the sites of ancient lakes, which have been drained partly by the hand of man, but chiefly by that slow process of silting which is ever going on wherever there is an entering stream and the presence of vegetable and animal life in the waters. Cut through by ditch and drain, they tell a curious and far-back tale—curious, as of most varied interest, and far-back, as carrying us ages beyond the oldest standing-stone or earliest burial-cairn. Let us glance at some of the facts they have chronicled and the history they unfold.

And first, let us trace the process by which the old lake has been obliterated, and by which every existing lake is steadily tending to obliteration. Wherever there is an entering stream or runnel, there sand, mud, and miscellaneous debris are sure to be accumulated. Clear as the running stream may appear in summer, there are times—after sudden and heavy rainfalls, the melting of the upland snows in spring, and the like—when the current is discoloured and laden with earthy impurities. When the stream comes to rest in the lake, these impurities fall to the bottom—gravel, sand, and mud, according to their respective gravities; and thus year after year, and century after century, the lake becomes shallower, or even indeed converted into alluvial meadow-land. And as the waters become shallower this silting process is greatly facilitated by the growth of reeds, bulrushes, equisetums, and other aquatic plants which spring up on the little deltas, and act as so many sieves and screens to intercept and entangle the stream-borne debris. But not only do these plants intercept the floating impurities, their own annual growth and decay are incessantly adding to the accumulation, and in a few generations the reedy mire is converted into the rushy meadow. In this way the little deltas are continually encroaching on the lake, while its central parts are also receiving more or less of impalpable sediment, or are the nursing-grounds of myriads of aquatic molluscs—*lymnea*, *paludina*, *planorbis*, &c.—whose shells, generation after generation, accumulate in limy layers of marl, which further tend to the shoaling of the waters. And while stream and vegetable and animal growth are thus gradually filling up the lake, its waters are further diminished by the auxiliary process of the out-flowing stream, which is as persistently and incessantly deepening its channel, and more and more draining its present supply.

By this double process of silting and draining, the lake becomes gradually shallower and shallower, till at length what was formerly a sheet of rippling water assumes the character of a stagnant mire, with here and there a pool of dark and deeper water, caused by some hidden spring beneath, or by the operations of the marl-dredger. In process of time the reedy mire is converted by plant-growth into the grassy marsh or meadow, and at last man steps in and completes the process of extinction by his drains and ditches. The lake is gone; the haunt of coot and mallard is extinguished; no more will the peasant ply his line for perch or pike, nor sportsman float his punt in quest of wild-fowl. But though extinguished, it has left the record of its own history; and in these layers of silt and sand, of marl and peat-earth, through which the drainer cuts his way, we find the whole tale of its length and breadth and depth, the life it nourished, and in many instances indications of the animals that frequented its shores, and of the people who successively dwelt on or crossed over its waters. Let us follow the drainer from east to west and from north to south, through his shallowest to his deepest excavations.

And here at first he passes through bog-earths and peat-moss, which bespeak the old swamp and morass—the last days of the lake, when its winter waters scarcely sufficed to cover the luxuriant growth of reed and rush which had gradually encroached on its domain. A few feet beneath, and where the treacherous swamp and "well-eye" had been,* his spade passes through the mingled bones of ox,

* "Well-eye" (eye or origin of the well) is the term usually given to that portion of a mire (quagmire) from which some deep-seated spring arises and keeps the immediate area always soft and spongy. Covered

horse, deer, pig, dog, and man—the bemired remains of modern times, where carelessness or accident had led to their loss and entombment. Still deeper, and the bronze sword or eagle bespeak the time—the two thousand years ago—when the Roman legions sought a passage through its waters or encamped by its shores. Two thousand years ago! and yet the gauge of this long lapse is but three or four feet at most of silt and bog-earth—a mere fraction of the deposits that have still to be passed through. As the drainer descends, antlers of red-deer, larger by far than any now existing, skulls of the wild ox, bear, wolf, and beaver, are occasionally met with—all pointing to a fauna different from the present, and to a time when the beasts of the forests were supreme, and men few and widely scattered through the country. Still deeper, and in the dark-blue silt a log of oak intercepts his progress; and not a log merely, for on removal it is found to have been hollowed out and fashioned—a veritable canoe, in which the skin-clad savage of other days had paddled over the waters. What a wonderful history these old lake-silts reveal! and yet, as the work advances to that grassy knoll—"the inch" —that rose above the general surface of the flat, still stranger sights and revelations await us. Here not a mound of sand or gravel or rock, but a mass of piles

by floating weeds or tufts of marsh-plants, a well-eye is exceedingly treacherous ground, and any unlucky animal approaching too near to drink, or to crop the green herbage in early spring, is sure to be mired, and to sink beyond sight in course of a few hours. In this way many well-eyes become perfect storehouses of skeletons—deer, oxen, horses, sheep, pigs, dogs, and even man himself being often discovered in these dangerous receptacles. One of the most instructive we have heard of in recent years was that on the farm of Bent of Haulkerston, near Laurencekirk, which was cut through in draining a marsh or lochland in 1861, and yielded bones of nearly a dozen genera—red-deer, roe-deer, ox (*primigenius*, *longifrons*, and a hornless variety), sheep, horse, pig, dog, fox, man, &c.—a large portion of which have been, with intelligent care, preserved in the neighbouring museum of Montrose.

and planks and rubbish—the crannoge or lake-dwelling of former days—reared by primitive men for their protection and defence, and made up of piles, planks, branches, stones, and other material, to give it consistency and stability for the erection of their rude dwellings thereon.* And as spade and mattock make their way through this mass, here a stone hammer and axe, there a flint spear-head—here a split bone, and there a fragment of rude pottery—unfold the kind of life the inmates led, and the degree of civilisation to which they had attained.

The mound is passed, and deeper in the silt the drainer cuts through a layer of the whitest marl, which, on being thrown to the surface, reveals the disintegrated and disintegrating shells of numerous genera, which must have lived and multiplied for untold centuries before a layer of such thickness could have been accumulated. But far beyond mound and marl he stumbles upon bones and antlers of the reindeer and gigantic Irish deer, or even occasionally upon the tusks of the great mammoth, all of which point to other conditions of climate than we now enjoy, and to times prehistoric, if indeed not to times before these islands were

* These lake-dwellings or crannoges (Pfahlbauten of the Swiss archæologists) seem to have been common in early times all over the middle and west of Europe. They have recently received minute and discriminating attention from the savans of France and Switzerland (Troyon, Keller, Morlot, &c.), and have yielded an immense number of objects both of antiquarian and ethnological interest. They are by no means uncommon in Ireland and Scotland, but hitherto very little has been done in the way of systematic research. So far as they have been examined, they seem to be similar to those of Switzerland—the older of which yield implements of *stone* associated with the castaway bones of deer, boar, and wild ox; those of intermediate age, implements of *bronze* associated with bones of the domestic ox, pig, and goat; and the more recent, *iron* swords and spears accompanied by bones of ox, pig, sheep, by carbonised grains of barley, and by fragments of rude textures woven of flax and straw. Our Scotch lochs and lochlands are worthy of special search, many of their mounds and inches being evidently artificial, and prepared by an early people as dwelling-places of safety and shelter.

inhabited by man. And thus our drainer descends through bed after bed—from moss to marl, from marl to silt, and from silt to clay—till at length he reaches the solid rock, or, more frequently, the stiff blue boulder-clay with its rounded ice-borne blocks—the original bed of the lake when its waters were first gathered together at the close of the glacial period, hundreds of centuries ago, alike pre-historic and (so far as we know) pre-human. The drainer has closed his operations; the flat is now waving with grain or verdant with green crops; can we realise aright the long and marvellous history which its silts and sediments have disclosed?

First, we have the clear sheet of water rippling in the European landscape—*European*, for Britain has not yet been detached from the Continent—and surrounded by forests of pine and brushwood of birch and willow; for the climate is yet severe, and the woolly-haired mammoth crushes his way through the glade and down to the loch-margin, to enjoy himself with his fellows. Centuries pass by, and reindeer and Irish deer betake themselves to the water during summer, or cross its frozen surface during the snows of winter, to be mired during their love-fights, or to sink through the treacherous surface. Ages roll away, the northern hemisphere now enjoys a milder climate, and Britain is severed from the Continent. Our lake is gradually shoaling; reeds and bulrushes encroach on its western marge; oak-clumps adorn its heights; wolf and bear prowl through their shades; the beaver builds his dam across the entering streams; and the red-deer and wild ox stand lolling in the summer waters. A race of short, broad, round-headed men settle by the shore, or pile and wattle the rude crannoge, scoop out the oak-trunk with fire and their stone adzes, spear the ox and the deer in the woods, and begin to enjoy the amenities of a dawning civilisation. Time rolls away; our lake grows shallower and shallower, its reedy and rushy margin broader and broader, and all that has sunk or been dropped in its waters are now sealed up in silt as memorials of the events it has witnessed. A new race of men, taller, lither, and higher-headed, have taken possession of the scene: they have settled on the slopes, erect their rude altars in the oak-clumps, domesticate the ox, horse, and dog, and attempt a scanty cultivation. The Romans invade and scatter the natives, encamp by the lake, erect their votive altars, make their plank-roads through the marsh, and drop their implements and utensils in close proximity with those of the ancient Briton—a strange admixture of refinement and semi-barbarism. The pre-historic ages have passed, and we now see, though dimly and somewhat confusedly, the onward history of the gradually shallowing and lessening waters. The Romans disappear, Celt and Saxon contend for the soil, and in the uppermost silts and bog-earths we trace their presence in the bemired remains of existing breeds of ox, sheep, horse, dog, pig, and other domestic animals—in their dropped tools and implements of iron, as well as in other objects of art which carry us on to the time of our immediate predecessors, when the spirit of improvement and the demands of an ever-increasing population compel the conversion of the loch-marsh into arable farm-land.

Such is the long and wonderful course of events which these lake-silts have registered, and such, when rightly interpreted, is the history which their record reveals. Broad in outline, though wanting in details, there can be no question as to its accuracy; and could we unearth the whole area as the drainer does his long narrow lines of ditch and drain, a thousand corroborative facts would be added to the testimony. And as with these admitted "lochlands," so with a large portion of all the straths and dales and vales of our island. Most of the low and level areas are but the sites of extinct lakes; and could we expose their clays and silts and marls, layer after layer, we would find abundant evidence of the process by which the waters were extinguished, and of the events which accompanied that extinction. The reader can have no want of examples; and in these days, when, hand in hand, archæology and geology are giving us clearer and deeper insight into the earlier history of mankind, it were worse than indifference to allow any draining or other excavations to pass unobserved. We have seen instances in almost every part of these islands, and especially in Fife and Forfar, which lay more immediately in the way of our observation. One of the finest examples we know is that of Lochore, in Fife, drained towards the end of last century, and which has yielded almost every kind of remains to which we have alluded. Lying at the southern foot of Benartie, it stretches away, level as a bowling-green and intersected by deep open drains, a wide expanse of cultivated farm-land. Years ago on its eastern borders, at "Temple," were early Christian remains; on its northern slopes were the unobliterated trenches of a Roman encampment at "Campfield;" on a peninsular projection on the north stands the farm of "Chapel," where bronzes, altar-stones, and baths of the Roman period have been found; on its eastern margin are several standing stones and cairns ("Pitcairn") of Celtic origin; and near its eastern edge stands the "Castle," an old rent and ruined keep built upon an artificial island—the "crannoge" of the still earlier and pre-Celtic period. Skulls of oxen, antlers of gigantic red-deer, Roman coins and bronzes, stone hatchets and tree-canoes, have all been taken from this single area, marking a succession of occupancy and progress as clear and sequential as if one had lived by the lake from the time of its earliest gathering up to its final obliteration in the year seventeen hundred and ninety-two.

As with lochlands, so to a great extent with marshes and peat-mosses. All are alike accumulations of slow and gradual growth, and entomb, as they grow, remains of plants and animals, as well as the remains of man and his works; and when cut through and drained for agricultural purposes, reveal in a similar way the secrets they have kept so long and so well. Within the present century thousands of acres of such peat and bog growths have been converted into arable fields, and most of the objects that were discovered have been lost to science through ignorance and neglect. But thousands of acres have still to be reclaimed; and, through the more intelligent interest and finer spirit that is now abroad, it is fondly to be hoped that every object exhumed will find its way to the proper quarter, and that geologists in particular will keep watchful care over every local excavation, not only for the sake of their own study, but for the advancement of the kindred sciences of Archæology and Ethnology. Where history is silent—and silent because but a thing of yesterday—these lakelands and marshes and peat-mosses may throw some glimmer of light on the pre-historic men of these islands, indicating in some degree who they were, whence they were, and what they were, in the doings and dealings of their everyday existence.

SPRINGS IN THEIR GEOLOGICAL ASPECTS.

No wonder that the ancients, and especially those of hot and arid countries, celebrated their springs in song, and believed the more remarkable, each to be under the special care of some presiding divinity. There are few things so gladdening, nothing more refreshing, than "wells of water in a thirsty land;" few things so lifelike and mysterious as a cool and copious spring, whether gushing from the cleft of a rock or noiselessly boiling up from its sandy fountain. Men and animals crowd to its source, trees overshadow its banks, and the greenest of verdure marks its track through the desert. Death and the stillness of death may reign for leagues, but around the bubbling spring and its sparkling runnel life instinctively appears, and flourishes under its genial influence. Even in temperate countries man builds his house by the spring and the water-brook—health, cleanliness, cultivation, and all the necessities of existence depending so intimately and directly on the beneficent element they supply. But springs are not all of the same character, some being pure, others impregnated with mineral and gaseous matters; some cold, others hot; some permanent, others temporary and intermittent; some simple, and others invested with therapeutic qualities which have rendered them famous for ages. No wonder, then, that they should have become the themes of song and adoration, that shrines have been reared over their sources, offerings paid to their virtues, and festive processions and well-deckings practised alike in all countries where their waters arose in copious supplies to meet alike the personal necessities and the industrial requirements of man. But while thus indispensable to the animal and vegetable worlds, they are not less important to the mineral —permeating and percolating the rocky crust; dissolving, diffusing, transporting, and reconstructing its ingredients; and, on the whole, discharging geological functions which no other agent could perform. It is to these functions that we would now direct the attention of the reader, bespeaking his interest in what at first sight seems so insignificant, and yet which, when fully understood, are amongst the most widespread and effective of geological agencies.

And first let us trace the element water in its incessant circulation from the ocean to the atmosphere, from the air to the land, and from the land once more back to the ocean. Nothing seems so marvellous, and yet nothing is so certain, that the water which now issues forth as the gladdening spring has passed times without number from sea to air and from air to land—has been in the atmosphere, now invisible and now visible—has fallen as rain, or lain on the mountain-top in snow and glacier for centuries—has coursed in vivifying currents through the tissues of plants and animals, or been locked up in the mineral crystal for ages. Rising, under the influence of the sun, from the ocean, it mingles invisibly with the air or floats in mists and clouds, till, condensed by cold, it falls in rain or snow on the terrestrial surface. A great portion of this rain- and snow-fall is carried off at once by runnel and stream and river to the ocean; but a large and unknown amount sinks slowly into the soil, permeates and percolates the rocky crust to unknown depths, and then, when every pore and chink is saturated, is returned again by springs to the surface, once more to be borne back by runnel and stream and river to its parent sea. Distilled from the ocean, water is absolutely pure; floating in the atmosphere, it may absorb nitrogen, carbonic acid, and other gases; sinking into the crust, it begins its geological functions, loses its purity, and carries along with it and out with it a very miscellaneous burden of mineral impurities. Individually, and in the case of any known spring, the amount of geological work performed may be very insignificant; but as springs occur in myriads, and their supply passes through every variety of soil, subsoil, and rock, the amount of waste, change, and reconstruction they occasion is enormous, and, to be appreciated, requires but the slenderest indication.

Water is the great universal solvent in nature. Powerful when cold and pure, more powerful when hot, and most of all when charged with certain gases and gaseous compounds. As the rainfall descends, it generally entangles a certain amount of common air, nitrogen, and carbonic acid; as it percolates the soil, it may part with these gases, or receive an additional supply; but whether or not, its own solvent power, as it descends into the crust, is ever carrying something from stratum to stratum, till it becomes more or less impregnated with mineral matter; and then when it ascends again and issues forth in the form of *springs*, it bears to the surface some portion of that which it has dissolved from the solid rocks. In this way the effect of spring-water may be said to be fourfold—*first*, in dissolving something from the rocks through which it passes; *second*, in producing changes among the strata, by carrying from one set what may be absorbed by another; *third*, by laying down the matter which it dissolves from the interior, partly on the surface in the form of new rocks; and *fourthly*, by carrying a large proportion of its mineral burden to the sea, there to maintain the composition of the oceanic waters, to supply the requirements of marine plants and animals, or to be precipitated as solid compounds. To comprehend more clearly these operations and effects, let us glance at them separately and in order.

And first of all, nothing can be clearer than that, if water has any solvent power whatever, it must, as it descends into the earth, transfer some mineral matter from the strata above to those that lie beneath. In this case, lime, silica, iron, or other ingredient, may be carried down to rocks already possessing them, and thus surcharging them as it were with these materials; or they may be conveyed to rocks void of these ingredients, and then mineral changes and metamorphism (hardening, crystallisation, and so forth) will take place through this process. That some rocks are impervious to water is well known, and thus many strata, when mined through, are all but absolutely dry; but the great majority are more or less permeable by water, and it may be safely concluded that the downward passage of water into the crust is one of the main causes of mineral change and metamorphism. Indeed we see this change daily taking place among the superficial strata—the percolation of rain-water through siliceous limestones carrying off the lime, and leaving the silica as a light porous "rotten-stone;" the permeation of rain-water through dune-sands dissolving the lime from the upper beds, and converting the lower into hardened masses of "littoral concrete;" and a similar permeation through bog-earths and morasses, producing beneath them a "pan" or layer of "bog-iron ore." What occurs so obviously among the superficial masses must take place in a greater or less degree among the rocks that lie beneath; and thus it may be safely concluded that the descent of water into the solid crust is a means of mineral change or metamorphism, and especially among the strata of the sedimentary formations. A bed of sandstone, for example, may, by the reception of lime or iron from some stratum above, be converted into a calcareous or ferruginous sandstone ; or a bed of soft earthy limestone, by the permeation of silica, be transformed into a jaspery chertstone. To what extent this may take place we have no direct means of estimating ; but, considering the universality and amount of rainfall, and the loose porous character of most of the superficial accumulations, a vast quantity of water must ever be seeking downwards in discharge of this function. And if we have any doubt of its solvent power, we need only turn after heavy rainfalls to every superficial spring, drain-mouth, and runnel, to be convinced that not only is matter dissolved, but that it is carried away by the process of permeation. There is not a limestone cavern to which we can turn whose stalactites and stalagmites do not convey the most obvious evidence, even to the unscientific observer, of this dissolving and transforming power of percolating water.

In the next place, it is equally clear that, though some springs, as they issue into day, are all but absolutely pure, the majority are more or less impregnated with mineral matter. Considering the depth to which the original rain-water has descended, and the depth from which it has re-ascended, its passage could scarcely fail to be marked by the solution of one kind or other of mineral or metal. And the more when it is remembered that much of this ascending water has increased in temperature, and some of it even to and beyond the boiling-point, thereby increasing its solvent power and its capacity for absorption. These "mineral springs," as they are termed, whether calcareous, siliceous, chalybeate, or saline, occur in every country, marking their course by the deposition of new rock-matter, and this, as in the case of the hot springs of Iceland, the Azores, New Zealand, and California, with siliceous masses of considerable amount, or in the case of the cold springs of Italy, France, and our own country, with calcareous tufa of equal dimensions. But the amount of flint, limestone, iron, or salt deposited by such springs on the land is but the merest fraction of that which is borne onwards to the ocean, and we can form only a very vague idea of the whole by chemically testing their waters and calculating their numbers and magnitude. But it is not their flow for one season or century, but for thousands of centuries, that must be taken into account, and then we may faintly imagine the amount of change that has been worked both within the crust and on the surface of our globe by this slow, silent, and apparently feeble agency. The numerous caverns in limestone districts—such as the "Mammoth Cave" of Kentucky—are proofs of the dissolving power of spring-water on the one hand, just as the masses of travertine near Rome are evidences of its power of accumulation on the other.

But what is witnessed on the land, as has been already mentioned, is altogether insignificant compared with what is borne to and accumulated in the ocean. All the lime taken up by the foraminifera, coral-animalcules, shell-fish, and crustacea, and deposited over the ocean in leagues of calcareous mud, and beds and reefs of solid limestone, is but the spoils of the rocky crust dissolved out by springs and borne down by streams and rivers. And in the same manner with all the silica, magnesia, potash, soda, and other salts and earths which enter into the composition of sea-water, and which are indispensable to the myriad and far-spreading growths of plants and animals that people its waters. And what is taken up by plants and animals may, after all, be but a small portion compared with what is precipitated and deposited in the depths of the ocean, or held in solution in its waters. Whatever may have been the composition of the primeval ocean, we know that its equilibrium is now sustained by the influx of mineral salts from the land, and that these salts are dissolved mainly through and by the agency of spring-water. And in this way, considering the magnitude of the ocean, and that its solid ingredients amount to between three and four per cent of its mass, we readily perceive how vast the power of those agencies by which the permanence of this composition is sustained.

Such, then, are the aspects which springs assume when viewed from the stand-point of the geologist. To the ordinary observer they are ever-welcome objects of beauty and utility, clothing the land with verdure and fertility, and supplying some of the most urgent necessities of animal existence. To the geographer they are associated with some of the leading features of his science—the sources of rivers and lakes, the determiners of the presence of plants and animals, and not unfrequently, also, the causes which have led to the permanent settlement of men and the localisation of their special industries. To the geologist, on the other hand, who can likewise view them in all these relations, they assume a new and deeper interest, as being indispensably associated with many of those processes by which the appointments of the globe are conserved and their permanence and continuity secured. If springs were praised and deified by the ancients, if votive shrines and festive offerings were their meed, because they quenched the thirst of man, watered his flocks, or fertilised his fields, how much more would they have been prized had these simple and earnest men been acquainted with all their properties, and the cosmical functions they have to perform!

But laying aside these broader views, and restricting his survey to the more immediate operations of springs, the young geologist cannot fail to perceive how intimately their solvent, permeating, and transporting powers are connected with many of the problems of his science, and that unless these powers are understood, he is deprived at least of one important means of solution. Mere mechanical processes may lay down the masses of the stratified formations, or break them up by repeated convulsions, but that slow interchange of mineral matter from bed to bed and from mass to mass can only be secured by the solvent and permeating properties of water. That the metamorphism of rock-matter results in no small degree from these properties will be readily conceded, and all the more when it is remembered that water is everywhere and ceaselessly percolating the crust of the globe. But it is not alone in the interchange of mineral matter and metamorphism that the operation of springs become of importance to the geologist; they are bearers of numerous ingredients from the interior, and formers of rock by deposition on the surface, while their surplus is borne down to the ocean, there to supply a thousand organic wants, and administer to innumerable physical requirements. It is thus that often the most silent and least observable of nature's agencies become, under the operation of incalculable numbers and unlimited time, productive of the most gigantic results—a truth that cannot be too strongly impressed on the mind of the geological inquirer.

SPLIT OR FRACTURED BOULDERS.

EVERY geologist is more or less familiar with *boulders*—those rounded, smoothed, and often striated blocks so characteristic of the "Glacial Drift" or "Boulder-Clay" formation. These blocks, whether occurring in clays or in pebbly drifts, are of all sizes, from one to one hundred tons; of all shapes, from angular to rounded and polished masses; and of all the older rocks—granites, porphyries, greenstones, limestones, and sandstones—sufficiently hard to have withstood the long-continued tear and wear of ice-action. But though boulders in their ordinary aspects are familiar objects, *split or fractured boulders* are by no means common, and occasionally present appearances extremely difficult of explanation. We say *fractured* boulders, for the term *split* may convey the idea of some readily fissile or laminated block, whereas the phenomenon to which we refer is a fracture right across the hardest and most homogeneous boulders of granite, greenstone, and siliceous sandstone.

If we remember rightly, it was Mr Smith of Jordanhill and Mr Charles M'Laren who first drew attention to these "split boulders," assigning as the cause their falling from cliffs on which they had been perched when these cliffs had been subsequently wasted and undermined by meteoric and aqueous action. Such an explanation may do for a boulder like that noticed by Mr Smith on the Little Cumbrae, or for that long pointed to by Mr M'Laren at the foot of Salisbury Crags, but now removed and broken up for road-metal; but it will not account for those that we find imbedded in clay or in sand, or, it may be, lying on the surface, and in all cases far removed from cliffs and rocky inequalities. We have seen several of very large size near Ballingry, in Fifeshire, lying on the surface and broken right through, the separated portions being quite adjacent, and in some instances not a couple of inches apart. Some years ago we witnessed one in a railway-cutting through the boulder-clay near Granton, on the Firth of Forth, merely cracked, and resting on another of much larger dimensions beneath it. And during the present year our attention was attracted to one at Viewforth, in the suburbs of Edinburgh, more remarkable than any other we have hitherto seen, inasmuch as it lay among the finest stratified sand, and was fractured right across—the smaller portion detached only a few inches from its original place, and the interstice filled with the sand by which the whole was surrounded.

Falling from cliffs will not account for the fractures in any of the above instances, for they all lay in flat tracts far removed from cliffs; and if it should be argued that the fractures took place before the blocks were drifted from their native precipices, the argument is equally untenable, for the rounding and smoothing must have taken place subsequent to their rupture from their original sites, and even if fractured after being rounded, the chances are a thousand to one against the two portions being taken up, carried for long distances, and then dropped in such close proximity by any form of ice with which we are acquainted. In the case of the Ballingry boulders, which are of compact greenstone, and in many cases subangular and only partially rounded, the fracture is likely to have been occasioned by pressure, the blocks being held in the glacier or iceberg, and cracking against the subjacent rock by the unequal pressure of the stupendous mass in which they were entangled. In the case of the Granton boulder, which was of compact sandstone and of an oblong form, the fracture, which was clean and sharp, may have been produced either by pressure or by impact against the greenstone block on which it rested. But in the case of the Viewforth boulder there was no hard object either for pressure or for impact, and we can only account for its fracture by previous impact in the iceberg by which it was floated and dropped among the sandy debris. Being of an oblong shape—8 feet by 6 feet, and only between 2 and 3 feet in thickness—its fracture by the impinging of the ice-mass against some subaqueous ledge would be no difficult matter, and in this fractured state it might be held and floated about till its ultimate stranding on the spot where the two portions lay in the closest proximity. The boulder was of the syenitic greenstone of the Corstorphine Hills, beautifully smoothed and striated, and must have been fractured subsequent to this external dressing; and the only way in which its fracture and the close proximity of its parts can be accounted for is, by supposing that it was broken while held in the floating ice-mass, either by pressure or by impact against some hard and resisting object, and then left undisturbed among the sandy debris as the stranded iceberg melted away.

The huge size and weight of many boulders, their polished and striated surfaces, their far removal from their parent rocks, and the curious positions in which many of them are perched, have long been matter of wonder and speculation; but the fracturing of masses several feet thick, and of the hardest and toughest material, as many of these boulders are, is a subject equally deserving the attention of geologists. The explanation of Messrs Smith and M'Laren may do for the recent fracture of a few boulders that may have fallen from high and wasting cliffs, but it is wholly inapplicable in cases where no precipices are near, and, above all, for those boulders imbedded in the clays and sands of the glacial period. The mere *splitting* of a boulder may be accounted for by disintegration of the laminated rock, or by the expansion by freezing of the water between its laminæ; but cross-fracture of a hard homogeneous mass of granite or of greenstone can only be explained by impact or by pressure of the ice-mass in which it was imbedded. The pressure of a glacier or iceberg many thousand tons in weight must be enormous; and the impact of a similar mass drifting at the rate of only three or four miles an hour must be still more tremendous. Any boulder, therefore, adhering to the outside of such a mass, and coming in contact with any submarine ledge, would be readily fractured, and all the more that it was of a flattened or oblong shape, and composed of such crystalline rocks as greenstone or porphyry.

That mere pressure against a resisting mass might be sufficient for the fracture no one knowing the enormous weight of a moving *glacier* will gainsay, but the fact of the portions lying so closely together and undisturbed is rather against this supposition. On the other hand, the fracture by a drifting *iceberg* is, perhaps, more easily accounted for, while its stranding and melting away in shallow water would scarcely if at all disturb the position of the fractured portions. On the whole, therefore, we regard these fractured boulders, and especially those lying apart from others, as evidence of floatage by icebergs—the block having been fractured by impact while held in the ice, and then left with its parts in juxtaposition when the stranded berg had slowly and quietly melted away. To the glacier or land-ice in its long and gradual march from the mountain-glen to the sea-shore we can readily ascribe their rounding and smoothing and striation, but for their subsequent fracture and contiguity of parts we must appeal to the drifting and stranding of the iceberg.

CONGLOMERATES AND BRECCIAS.

It is easy to assert—and the assertion seems true—that conglomerates are compacted and cemented gravels, and that breccias have arisen from a similar consolidation of rubbly or angular fragments; but it is not so easy to comprehend by what agencies such heterogeneous masses as the conglomerates of the Old Red Sandstone and Permian formations have been aggregated, or by what processes the fragments of brecciated rocks were first broken up and subsequently brought together without undergoing a much greater amount of attrition. Indeed, the formation of conglomeratic masses several hundred feet in thickness, and composed of blocks and boulders of all sizes, is a very intricate problem, and demands more consideration than it has yet received from working geologists. Let us glance for a while at some of these difficulties, and try to indicate, if we can, the way to their removal.

And first let us see how far the physical operations of the present day throw any light on the question; for unless we appeal to this source, any explanation that may be offered can at best be little better than guess-work and conjecture. Along the exposed shores of all free-flowing seas—that is, seas subjected to wave and tidal action—

gravel occurs in greater or less abundance, and in pebbles from the size of a pea to that of a bomb-shell;* and it is not difficult to understand how, by the infiltration of lime or of iron, or of calcareous and ferruginous muds, such gravel might be converted into *conglomerate.* Indeed, in the so-called "littoral concretes"—that is, masses of cemented beach-gravels—we see the conversion actually in process, and there is no difficulty in accounting for the formation of many of the older conglomerates by a similar method. Again, in ice-locked seas, or seas that are for the greater portion of the year covered by ice, and where the fragments torn from the cliffs by frost are not subjected to attrition and rounding by the waves, we can as readily understand that the consolidation of these shingly fragments would result in a *breccia;* and how, also, such rubble and shingle carried away by shore-ice might be piled up on some distant coast and converted into a *brecciated conglomerate.* Miles of shingly talus were noticed by Dr Kane during his arctic voyage, not only at the existing sea-level, but in raised beaches of various altitudes; and Dease and Simpson, in passing Point Barrow, were witnesses of the manner in which beach-ice, laden with shingle, could during heavy storms pile up the material high above ordinary tides, and for leagues along-shore. And farther, we can likewise understand how—on a coast like that of Greenland, where glaciers bring down blocks and boulders to the shore, and where storms and ice-floes lift and impact such miscellaneous debris above water-mark—how, in course of time, it might be converted into a rough *rubbly conglomerate* alto-

* One of the finest examples of a gravel beach, if indeed not the finest in Europe, is that of the Chesil Bank, stretching for miles along-shore, and out from the mainland to Portland Island, and composed of pebbles so gradually assorted that fishermen and smugglers, it is said, can determine their place on the bank even during night by the size of the pebbles.

gether different from that produced by the ordinary action of waves and tides.

By no other process than one or other, or all, of the preceding, are pebbly, gravelly, and bouldery masses aggregated at the present day, whether in tropical, temperate, or polar regions; and we may rely that by no other means were conglomeratic rocks produced in former ages. In trying, therefore, to account for the conglomerates and breccias of the stratified formations, we must first examine the nature of the constituent fragments, the amount of attrition they have undergone, and, above all, the manner in which they are piled together, and then see how far the facts can be explained by appealing to existing operations. By so doing there is little difficulty in accounting for the formation of Post-Tertiary river-drifts, raised-beach gravels, or littoral gravels and shingles, whether loosely aggregated or compacted into concretes and conglomerates; and there is usually as little difficulty in explaining the origin and accumulation of Tertiary conglomerates and pudding-stones. The only masses connected with these periods which present real difficulties are the *kaimes*, *eskars*, *osars*, and similar so-called "drifts" that are spread so widely over the higher latitudes of either hemisphere. These, so long as the ordinary operations of water are appealed to, seem inexplicable. Their great magnitude, their peculiar positions, the heterogeneous nature of their composition — angular blocks, boulders, gravel, and nests of sand, and the irregular manner in which these ingredients are arranged—point obviously to moving forces of gigantic power; and no forces in nature with which we are acquainted seem equal to the result save moving ice, whether dropping its burden as bergs and floes, or leaving its moraines as the glacier and ice-foot. At this conclusion all, or nearly all, geologists have arrived; and though the subsequent action of rain and rivers has so greatly altered the original features of these masses that we cannot always perceive the precise nature of the producing ice-force, still everything within them—the huge angular blocks, the smoothed and striated boulders, and the pell-mell aggregation of coarser and finer material—points to conditions essentially and unmistakably glacial.

Again, when the conglomeratic or rather pebbly beds of the Greensand, Trias, or Coal formation are examined, they present so little that is at variance with ordinary shore-action, that we ascribe them at once to this source, whether consisting of thick-bedded masses, or merely of pebbles scattered here and there through the sandstone strata. The thicker beds are but the long-accumulated gravels of the exposed sea-shores of these periods, while the solitary or sparsely-scattered pebbles may have been raised by storms, floated by sea-weeds, or borne by other means of occasional transport. We see nothing in their composition at variance with this explanation—nothing that may not have taken place along the shores of any free-flowing sea of the present day; and as to the presence of solitary pebbles in sandstone, or even occasional boulders in chalk, we perceive every winter how pebbles may be floated by the attachment of sea-weeds and cast on soft sandy shores, and how boulders may be dropped by melting icebergs on the chalky ooze of the Atlantic thousands of miles away from their parent habitats. But when we come to the *bouldery conglomerates* of the Old Red Sandstone—such as those exposed in the bold sea-cliffs between Stonehaven and Bervie, in the Forfarshire hills of Turin and Finhaven, or along the shores of Rothesay—and to the *breccias* of the Permian or New Red Sandstone as exposed in the Abberley and Malvern hills, or along the wasting sea-cliffs of South Devon, then we meet with a composition so heterogeneous (angular blocks, boulders, rounded pebbles, and interlaminated sandstones), and with an arrangement so heterogeneous, that the ordinary operations of waves, tides, and currents are altogether unequal to the explanation.

With regard to the conglomerates of the Old Red Sandstone, while its constituent fragments are evidently derived from all the older rocks—quartzes, granites, porphyries, gneisses, grits, slates, and mica-schists—these fragments occur so unequally water-worn, so unequally assorted as to size, and so unequally arranged as to form, that no power of moving water, whether in waves, tides, or currents, can be appealed to for their accumulation. Here we have lying side by side rounded boulders and pebbles of quartz with sharply-angular blocks of grit, porphyry, and gneiss—there we have blocks more than a ton in weight imbedded in pebbles less than a walnut; here we have blocks and boulders lying on their flattened sides, and, jammed among them, slabs on their thinnest edges—there we have the hardest quartz worn into the smoothest pebbles alongside fragments of mica-schist that have scarcely lost their fractured corners; here a patch of the finest-grained sandstone imbedded among the roughest blocks and boulders; and generally throughout, large and small, rounded and angular, soft and hard, thrown pell-mell together without the slightest reference to form or to gravity. Clearly such an arrangement could never have been produced by the waves of a free-flowing sea, however fierce its storms or gigantic its breakers. We may have gravel of all sizes, shingle of all shapes, and boulders bulkier than those of the "boulder beach" of Appledore, in North Devon; but we have never rounded and sharply-angular fragments together, never fine sand interlaminated with shingly fragments, never flattened slabs indiscriminately standing on edge or lying on their sides, and never hard rock fragments commingled with soft ones which a few days of wave-action would reduce to impalpable sediment. The whole action of free-flowing tidal seas is that of an assorting one; and notably, even to the eye of the common observer, there is nothing like assortment among the materials of these Old Red Sandstone conglomerates.

The only competent agency with which we are acquainted is that of shore-ice acting for ages in conjunction with glacier transport from the adjacent lands. We can account for the piling up of such heterogeneous masses of shore-ice; but the power that kept up the supply must have been a terrestrial one, fracturing, wearing, and grinding down the old hills, and bearing the eroded material in its various stages of attrition to the sea-margin. Had it been a sudden and violent power, the angular blocks would have preponderated; had it been of short duration, schistose and slaty fragments would have exceeded the quartzes and porphyries. As it is, angular blocks are the exception, and quartz-pebbles constitute the greater portion of the mass. And how well these smooth and rounded quartz-pebbles tell the tale of ages of waste and attrition! In the hills of the Scottish Highlands from which these conglomerates were largely derived, quartz holds but a subordinate position in veins and pocket-like masses, the great bulk being gneisses, mica-schists, chlorite schists, and other schistose rocks. How many hundreds of feet must have been worn down—what glens and corries must have been scooped out to supply such an enormous amount of quartz-pebbles as these Old Red Sandstone conglomerates contain! And here, while the schists from which they were originally derived have been for the most part pounded to impalpable sediments, these quartz-pebbles remain as evidence of long-continued and enormous denudation—a testimony as convincing to the geologist as the steps of a demonstration in Euclid is to the mind of the mathematician.

Everything, therefore, in the composition and arrangement of the great conglomerates of the Old Red Sandstone points to the action of ice—tear and wear, and transport from inland by glacier, and piling and accumulation by ice-floe on shore. Nor does it seem otherwise with the breccias and brecciated conglomerates of the Permian formation. Such masses of angular fragments as those of South Devon could never have been severed from their parent rocks save through the agency of ice, and no known power save floating ice could have carried them and piled them together without rounding and smoothing the chips and blocks of which they are composed. We have chiselled from these breccias chips of slate and fragments of Devonian limestone as fresh in their fractures and sharp in their angles as if they had been newly broken from their parent rocks, and which a few days' attrition in moving water would have sufficed to convert into pebbles or shingle. And when we turn to the Abberley and Malvern hills described by Professor Ramsay, and find blocks and boulders of all sizes indiscriminately huddled together—some rounded, some sharp and angular, and some boulders even grooved and striated like those of the "boulder clay"—the evidence amounts to a demonstration that such brecciated masses are largely due to the fracturing, transporting, and aggregating agency of ice.*

* Professor Ramsay, who was the first to advocate, in a decided manner, the glacial origin of these breccias, founds his belief on the following evidences: 1. The great size of many of the fragments—the largest observed weighing (by a rough estimate) from a half to three-quarters of a ton. 2. Their forms. Rounded pebbles are exceedingly rare. They are angular or subangular, and have those flattened sides so peculiarly characteristic of many glacier-fragments in existing moraines, and also of many of the stones of the pleistocene drifts, and the moraine matter of the Welsh, Highland, Irish, and Vosges glaciers. 3. Many of them are highly polished, and others are grooved and finely striated, like the stones of existing Alpine glaciers, and like those of the ancient glaciers of the Vosges, Wales, Ireland, and the Highlands of Scotland; or like many stones in the pleistocene drifts. 4. A hardened cementing mass of red marl, in which the stones are very thickly scattered, and which in some

Nor is there anything in geological history—that is, in the slow shiftings of sea and land, the uprise and depression of continents, the change of ocean-currents, and the consequent alterations of climate—at variance with this conclusion. We witness at the present day large circumpolar areas subjected to ice and ice-action; and we know also that at the close of the Tertiary period a much larger area of the northern hemisphere was similarly subjected to boreal influences—forming "boulder clays," collecting "kaimes and osars," and grinding, smoothing, and striating all exposed rock-surfaces. What is taking place now, and was enacted during a former period, may have occurred during many former periods; and nothing in the physical history of the globe forbids the conclusion that the aggregation of these Permian breccias and Old Red conglomerates was mainly due to the long continuance of glacial agencies over the regions in which they respectively occur. Dr Hooker, in his 'Himalayan Journal,' makes the significant remark: "The further we travel, and the longer we study, the more positive becomes the conviction that the part played by these great agents (the glacier and iceberg) in sculpturing the surface of our planet is as yet but half recognised"—a remark not less applicable to the phenomena of the older formations than to those of the Upper Himalaya by which it was originally suggested. How or by what means these alternating epochs of glacial intensity are brought about—whether by astronomical causes at fixed periods, or by mere variation in the distribution of land and water at irregular times—science in the mean time is unable to determine. The question, however, is under investigation, and many years may not pass by when the astronomer will

respects may be compared to a red boulder clay, in so far that both contain angular, flat-sided, and striated stones, such as form the breccias wherever they occur.—'Journal of Geological Society,' vol. xi.

be enabled to fix something like absolute dates to the recurrence of these great cosmical phenomena.

As we seek to explain the breccias and conglomerates of the stratified formation, so we endeavour to account for those of igneous origin — namely, by appealing to what is now taking place in centres and areas of volcanic activity. By so doing there is no great difficulty in understanding how, in some instances, volcanic ejections—such as sand and lapilli, and other triturated fragments—might form a conglomerate or "agglomerate," while in others irregular fragments and bombs would be converted by the cementing of dust and ashes into a veritable breccia. Such variable and fragmentary compounds occur among the igneous rocks of all ages, from the Silurian up to those of the present day, and much that is puzzling in their composition depends upon whether they have been aggregated on dry land near and around the centres of eruption, or whether they have been showered abroad and been deposited in water along with pebbly fragments of true aqueous origin. It is this circumstance that renders the history of many trap conglomerates, breccias, and ash-beds so obscure; and geologists can never hope to arrive at any satisfactory solution of their origin unless through a consideration of the means by which similar compounds are aggregated and consolidated at the present day. As we see scoriæ, lapilli, and bombs cemented by ashes and by overflows of volcanic mud on land, or consolidated by aqueous debris when deposited in adjacent waters, so we may rely they were aggregated, cemented, and consolidated in former ages—each case bearing, when minutely examined, some evidence of its own special origin and history.

Such is a slight endeavour to indicate the history of the breccias and conglomerates that occur in every formation, and which constitute no inconsiderable portion of the masonry of the rocky crust. As existing operations vary with the latitude—tropical, temperate, or polar—and act with greater or less intensity according to local conditions, so we may rely they varied in former ages; and it is only by taking a wide survey of nature, and believing in the uniformity of her agencies, that we can ever hope to arrive at a satisfactory explanation of the rocks and rock-formations of our planet. To appeal, in the case of breccias and conglomerates, however vast in mass or heterogeneous in composition, to cataclysmal and revolutionary forces, when existing forces are sufficient to the explanation, were to shrink from that labour of investigation and patient deduction upon which have ever been founded all that is true and lasting in philosophy, and to substitute instead a mere mass of conjecture as variable and incoherent as the fancies of their suggestors. The masses of the olden time may in some localities be more gigantic and heterogeneous than anything we witness in the same localities at the present day, but they are the same in kind, and are merely the result of similar forces acting through longer periods and under more favourable conditions of local accumulation. We know that sea and land are ever shifting places, and that with every change in the position, contour, and relief of the land, new climatic conditions are engendered; and there is no difficulty in conceiving how, by such terraqueous shiftings, the glacier and iceberg may have once played their part over the latitudes of Britain, as they now operate over the latitudes of Greenland and the islands of the Arctic Ocean.

MAPPING OF SUPERFICIAL ACCUMULATIONS.

EVERY one is aware of the value of a good reliable geological map, exhibiting by distinctive colours the position and extent of the various rock-formations, and by appropriate marks and signs the outcrops, inclinations, and dislocations of their respective strata. With such a map, and a few well-chosen sections, the geological reader is in possession of a fund of information which volumes might fail to convey; and where the contour-lines are marked, or a graduated system of hill-shading is adopted, he has at command all, or nearly all, that is necessary to complete a conception of the physical framework of a country. But this framework of rocks, of heights and hollows, however accurately delineated, can afford him but little idea of the superficial aspects of the land—its soils and subsoils, its mosses, moorlands, sand-dunes, and carse-clays, upon which its amenity and agricultural value are so intimately dependent. What is needed for this purpose is the laying down of these surface-formations on a separate sheet in distinctive colours, and with the same precision as the older rock-systems. We have long advocated the necessity for two sets of geological maps—one exhibiting the underlying rock-formations as is ordinarily done, and another the superficial accumulations which mask these formations, and frequently have no lithological connection with nor characteristic dependence upon them. In the present paper we renew this advocacy, and give some of the reasons upon which it is founded.

Were soils and subsoils always derived by disintegration from the subjacent rocks, there might be no great necessity for a set of superficial maps; but in nine cases out of ten these soils and subsoils have no connection with the rocks on which they rest, but have been brought from a distance, and in many instances of an altogether opposite character. The sands and gravels, for example, which occupy so much of Strathmore, Strathearn, and Stratheden, in Scotland, have little or no connection with the underlying Old Red Sandstone; and the geological map that indicates these places merely as Old Red Sandstone, conveys no idea whatever of the immense masses of glacial drift which constitute their surface. Again, a vast extent of estuary silts constitutes the Carse of Gowrie and the Carses of Falkirk and Stirling; but no one looking at an ordinary geological map could learn anything of this fact; or if these carse-clays were indicated by distinctive colours, these would obscure the Middle Old Red that lies beneath the former, and the Coal-formation on which the latter reposes. Further, no one could know from our ordinary geological maps that the sand-dunes which extend so largely between the Tay and the Eden reposed on boulder-clay, and this again on the Old Red Sandstone; or that the recent marine silts of the Lincolnshire fens were underlaid by drifts and clays, and these again by the Chalk and Greensand. Or, still further, who could know from a map of the old rock-formation where peat-mosses, lake-silts, or boulder-clays occurred; could understand where the old rocks came hard and bare to the surface, or where masked by superficial accumulations many fathoms in thickness?

It is true that on the maps of the Geological Survey an attempt is made to indicate "alluvium, peat-moss, &c.," by a distinctive colour, but this attempt more frequently misleads than instructs. Lithologically speaking, peat-moss has no connection with alluvium; they are formed by totally different agencies; and the former may be thousands of years old, while the latter is still in course of formation. Not only so, but the same pale tint that indicates "alluvium" includes not only recent river and lake silts, but old lake-silts, glacial sands, and gravels and clays, thus confounding things not only of totally different composition and character, but of totally different chronology. What is wanted is a separate map, indicating by different colours the position and extent of recent river alluvia, of lake-silts, marls, peat-mosses, ancient estuary deposits or carse-clays, boulder-clays, glacial sands, and gravels—of all those accumulations, in fine, which overlie the old rock formations, and which has each its own geological history in time as well as in mode of formation. Such a mapping could not fail to be of use to the farmer, to the land-agent, landscape-gardener, civil engineer, road-maker, and all those whose business leads them to deal with the soils, subsoils, and general superficies of a country.

Many years ago we constructed such a map of Fifeshire, and the late Professor Johnston, while chemist to the Highland Society, invariably exhibited it along with the ordinary geological map when illustrating to the farmers of that county the intimate connection between geology and agriculture. Had he exhibited the mere rock-formations, the connection would have been apparent only in the case of the trap-soils, which constitute but a small fraction of the county, the greater portion being composed of old glacial clays and gravels, of lake-silts, peat-mosses, and sand-drifts, which have no lithological relationship whatever with the underlying Old Red Sandstone and Carboniferous formations. Let any one consult a geological map of the district or county with which he is most familiar, and he will find how little information it conveys respecting the superficial accumulations; and then let him reflect on the connection between these accumulations and the aspect and fertility of the country, and he will perceive at a glance the importance of such delineations as we are now contending for. As well, indeed, might the artist attempt to present the aspect and outlines of the human form by its skeleton, as the geologist the physical geography or geology of a country without its superficial formations.

But altogether independent of their practical or industrial value, such mappings are absolutely necessary in a purely scientific point of view. The geology of a country by no means closes with even the latest of the so-called "Stratified systems." The old boulder-clays and glacial drifts, the carse-clays, the lake-silts, and peat-mosses, have all their tales to tell of change and time—of changes as important in the history of the globe as those that accompanied the older rock-systems, and of time so vast that we vainly endeavour to reckon it by any standard of years and centuries. What changes have taken place in the physical aspects of these islands of ours since the glacier filled their mountain-glens and the iceberg floated on their estuaries; what mutations in their vital aspects since the whale and the seal frequented their sea-lochs—the mammoth, the reindeer, and Irish elk their plains and valleys—and the beaver, bear, and wild boar their rivers and forests; and what revolutions in human history since the pre-Celtic savage paddled his log-canoe across their lakes, made his feast of shells by their sea-shores, or sheltered himself in their caverns! And yet of all these changes we have no other record save that preserved in these old carse-clays, lake-silts, peat-mosses, and cave-earths—those Superficial Accumulations, in fine, which, though often described in words, are seldom or ever attempted to be delineated on our geological maps, or traced in our geological sections.

IN THE FIELD!

We have searched for plants, dredged for shell-fish, and, as the sneer goes, "hunted for butterflies;" but of all natural-history pursuits, that of geology is, to our mind, the most exhilarating and thought-inspiring. Botany and zoology have no doubt their charms and attractions, require much research and discrimination, and bring us in contact with some of the subtlest problems that can engage the human intellect; but they deal with the recent, and with a phase of the world which at best is but temporary and external. Geology, on the other hand, deals with the internal as well as with the external, with the past as well as with the present; lifts the veil from the extinct, and marshals in chronological order the long line of events, physical and vital, which constitutes the history of our globe from the current hour back to the remotest ages. All physical change, all vital relationship, all continuity of law and of order, come within the range of its cognisance, requiring the minutest observation and the most exact and sequential reasoning. Even as a mere field exercise, geology has higher and more permanent allurements. Botany and zoology, however attractive their objects, are restricted in a great measure to certain seasons of the year, whereas the objects of geology are ever patent—in the precipice, ravine, and sea-cliff; in the quarry, mine, and road-cutting —wherever there is a rock-surface exposed, or a section presented to investigation. Be it the excitement of searching for fossils, the bracing exertion of climbing over ledge and scaur, the deeper thought inspired by a survey of wild ravines and hoary mountain-heights, or the freer breathing and wider scope of the breezy upland, there is something ennobling in a geological field-day that we seek for in vain in any other pursuit. Even the ordinary objects of the public highway become invested with interest to the geologist unknown to other travellers, presenting fresh subjects for examination at every turn, and suggesting new problems for solution. Let us glance at some of these objects, and the new importance they assume when viewed from the stand-point of the working geologist.

Breakfasted, and off at eight on a fine summer morning with staff in hand, bag a-shoulder, and hammer and chisels in waist-belt, the young geologist is presented with a thousand objects beneath and around him that would pass unobserved by the ordinary excursionist. Out of, but scarcely beyond, the suburbs of the town, there is the stone-breaker busy at his heap of blocks and boulders gathered from the adjacent fields, or carted from the neighbouring sea-shore. A mere heap of road-metal! True, but what a wonderful assemblage of rocks—quartzites, granites, porphyries, greenstones, felstones, and jaspers—enough to teach the whole science of lithology, or fill a cabinet with specimens of the primitive rock-systems! And then, what wonderful incidents in world-history these despised blocks and boulders suggest! Wear and waste from far-off hills; grinding and rounding by ages of attrition; transport by ice-sheet or iceberg in distant epochs, when this island of ours lay mantled in snow and ice, or, sunk beneath the ocean, received the drift of berg and floe as they melted away in the upper sunshine. Let no one who values the teachings of his science pass indifferently by the heap of road-metal, whether consisting of miscellaneous boulders from the fields, shingle from the sea-shore, greenstone from the hills, chert from the limestone scaur, or flint from the chalk-pit. Each has its own lesson fraught with information, or its problem to suggest. Nor let him despise the knowledge of the homely stone-breaker, or refuse to listen to his quaint questions and often quainter theories. There may be curious ideas simmering in that bonneted grey head; strange intelligence peering through the wire-gauze that shades those twinkling eyes of his. We have been led to a knowledge of some of the finest intersecting dykes of basalt, and some of the strangest varieties of chalk-flints we ever witnessed, by a friendly chat with an honest labourer as he took his simple meal by the dusty wayside. And what has been the luck of one may readily be the luck of all, if they will only exercise a little frankness and affability to secure it.

Onwards our young friend goes, and the road which would seem dull and monotonous to the uninitiated, presents to him objects of interest and instruction even in its very fences. These, for the most part, are built of the nearest and readiest material—here of sandstone, there of greenstone; here of blocks trenched from the neighbouring fields, and there of limestone too impure to be reduced to quicklime. These road-fences form in general the best and readiest indices to the geology of a district, and he who notes them attentively is not only premonished of the rock-formations that lie around him, but sees also the manner in which they are affected by exposure to the weather. Often has the examination of a roadside wall led to the knowledge of some peculiar mineral stratum; and not unfrequently the weathering of their unhewn blocks has led to the discovery of some fossil structure which no other process could have so delicately displayed. What magnificent polyzoa, bleached and apparent as the network of the laundress, have we witnessed on an Ayrshire roadside; what superb encrinites, relieved to the minutest ossicle, have been gathered from a Yorkshire stone-wall! Let the roadside fence along which the young geologist may travel, or on which he may seat himself to indulge in his meerschaum, never be passed without examination. It is sure to lead to a knowledge of the rocks and quarries of a district the while that the observation of its materials will help to beguile the tedium and monotony of the way.

Even where metal-heap and stone-wall may be insufficient to attract, or are altogether absent, there is always some superficial excavation by the way—field-drains, sand and gravel pits, clay-pits, and suchlike openings, which should never be passed without examination. We have seen outcrops of strata and junctions of formation laid bare by field-draining which could never have been otherwise exposed; and was it not in the gravel-pits of the Somme that Boucher de Perthes first found evidence of the contemporaneity of man and the extinct mammalia? But here comes the clay-pit—a miry affair at the best, and a capital test of the enthusiasm of amateur geologists; and down our young friend goes in search of boreal shells and star-fishes, remains of arctic birds, seals, and whales. And what a treasure often awaits him! A perfect cabinet of shells, barnacles, and star-fish within the space of a few yards, or it may be the skeleton of a seal or the first exhuming of the gigantic remains of a Northern whale. There is scarcely a clay-pit we have visited on the east coast, from the Humber to the Moray Firth; or on the west, from the Clyde to the Solway, but has yielded such remains, proving as clearly as if we had been witnesses of the event that these islands of ours were at a period comparatively recent in geology surrounded by boreal conditions such as now prevail along the coasts of Greenland, Spitzbergen, and northern Scandinavia. And thus the clay-pit, forbidding to the ordinary tourist, and far from attractive even to the labourer to whom it becomes a source of daily bread, presents allurements to the geologist which draw him for days and weeks to its interior, and make him quite at home where others see only dirt and discomfort. The delight in discovering a new shell, the pleasure of cutting out the skeleton of a seal, or the sensation experienced in watching the day-by-day uncovering of the gigantic bones of a whale *in situ*, are things that may be described to others but can be known and felt only by the working geologist. We speak from experience; and, disabled though we be, we would willingly go once more to Cupar-Muir to secure another seal, or to Stirling to watch the exhuming of another whale.*

Attractive, however, as may be the treasures of the clay-pit, our young friend has other objects before him, and he must not linger. On he goes, certainly not improved in appearance by his pokings among the clay, but all the more

* How a discovery of this kind sometimes strikes the non-geological mind may be told of Thackeray. When lecturing in Scotland, he happened to be at Cupar station on the afternoon I had exhumed my first seal from the brick-clay of Stratheden. As the men came on the platform carrying the mass of clay in which the skeleton was imbedded, one of them addressed me: "Ye'll be gaun to tak' your banes in beside you?" a question which tickled the humour of the novelist, and he became quite facetious, firing joke after joke to the great amusement of some friends who had accompanied him to the station. As I explained to him how and where the skeleton was found, his manner changed in an instant,—"So this beautiful valley," he inquired, "has been once an arm of the sea; not Noah nor Deucalion? Quite clear! but how many ages ago?" And thus the seal, the sea, and the earth's changes became the sole subjects of his conversation as the train bore us away, and for the rest of our journey.

workman-like, and all the readier for the mishaps of the field, which are only unmitigated miseries to patent leather, frock-coats, and kid-gloves. As he rounds the neighbouring hill, there the new railway-cutting, like a huge plough-track, stretches before him for miles, exposing boulder-clays, polished and striated rock-surface, dykes, faults, anticlines and synclines—a perfect epitome of geology which it would take weeks to observe and volumes for the description. How clearly that dark tenacious "till" and its enclosed blocks tell their tale of ice-waste and ice-drift; waste from old land-surfaces and drift from far-off crags whose place is unmistakably indicated by the composition of these worn and rounded boulders! And how fully these underlying rocks with their polished and striated surfaces bespeak the long presence of the glacier and ice-mantle, rounding, smoothing, and furrowing these exposed British hill-sides as they do now the higher glens of the Alps or the sterile uplands of Greenland! And then what magnificent sections of the stratified rocks, their bendings and foldings, their fissures and faultings, their intersecting dykes of basalt and interbedded greenstones! In fine, the whole internal structure and history of that hill-range is laid bare as in a diagram, and but for this railway undertaking might have been for ever unknown, and even unsuspected. Let no young geologist, as he values his own information and the progress of his science, neglect the railway in progress. We say *in progress*, for in a few weeks the sides of these cuttings are dressed, built up, or otherwise interfered with—destroying the details of the section, if not altogether obliterating its legibility and value. During the last thirty years these railway-cuttings and tunnellings have revealed the structure of our island in a way that centuries of mining and quarrying would have failed to accomplish, and every additional undertaking is certain either to reveal new facts or to corroborate former information. But our young friend has yet miles of country before him, his ultimate object being the fossils of the lime quarry that lies in the opposite hill-range. And as he crosses the intervening plain, dreary with swamp and peat-bog, he finds even there something to attract and interest where all to ordinary eyes is but a scene of sterile monotony. There, on the bleakest and blackest of the moor, the peat-diggers are busy at their thrifty trade, and as they cut through the vegetable mass that has been accumulating for untold centuries, here they stumble upon some relic of bemired red-deer, there upon some gigantic oak that could not possibly find a footing under our present climate; and not unfrequently in some situations upon the Roman plank-ways that had crossed the swamp seventeen hundred years ago, or even the traces of axe and fire by which these invaders had destroyed the forest and converted its undrained area into a quaking swamp or peat-bog. How these geologically recent but historically ancient incidents strike the young inquirer need not be told, for there, among the peat-piles, in splitting and examining, in noting remains of trees (oak, fir, alder, hazel, willow, and the like), and in gathering nuts, seed, and fragments of insects, two long summer hours are spent before he attempts the hill-brow with its fossiliferous shales and limestones, the objects for which he had originally started.

And now, in the long line of limestone quarries that encircle the hill, what treasures for his cabinet! Polyzoa, corals, encrinites, spines of cidaris, trilobites, bivalves, and univalves in hundreds are scattered over the old rubbish-heaps, relieved from their matrix by *weathering* with a clearness which art seeks in vain to imitate, and with a delicacy of detail which no other process could excel. Not only in the old waste-heap, but in the recent workings he sees the whole tale of these marine deposits—their coral, encrinite, and shell growths—with a fulness that written history never attempts, and with a certainty to which it never attains. Even from the crumbling mud-rubbish beneath his feet he can, by careful washing and manipulation, extract abundant evidence of old sea-life in the microscopic foraminifera and entomostraca that occur in myriads, though unseen by the naked eye, and undreamed of by the uninformed. Let the young geologist lay it to heart and treasure it in his memory, that in the old quarry-mounds and shale-heaps of the deserted coal-mine, which other men regard as mere dirt and rubbish, there are often fossil gems to be found which he would seek for in vain in recent workings, and that these waste-piles should never be passed without a careful scrutiny, though it should subject him to the laugh and jest of the ignorant and uninitiated.

But now the level rays of a late afternoon, and the dropping of the quarry tools, amid the click and clank of which he has spent a few pleasant hours, remind our young friend that his field-day is drawing to a close. We say a few *pleasant* hours, for, independently of the pleasure of his pursuit, no geologist who loves his science will ever avoid a friendly word or two with the quarryman, miner, or stoneworker. The exchange of his snuff-box, a light to his pipe, a seat beside him as he takes his mid-day meal, obtains from him not only what information he can afford, but a friendly reception to those who may come after. The rudest we have ever met, if treated as a fellow-worker (and are we not all of us brother-workmen?), had always some new information to give; and the friendly interchange of a few words not only excited his interest for the time being, but what was of greater importance, secured his attention to the preservation of any fossil relic that might be laid open by his hammer, or turned up by his pick-axe. The courtesies of life, the young geologist may depend on it, are not less efficacious in the field than they are in daily intercourse of business and society.

Homeward, and laden with his fossil treasures, the student has still new phenomena to observe and new lessons to learn. The clear relief in which the lowering sun has thrown every knoll and crag, every glen and gorge of the distant hillside, explains to him more clearly than words the agencies of waste and denudation—of frost and ice, of rill and runnel—to which it has been successively subjected. The rounded knoll (*roche montonnée*) bespeaks the grinding of the ice-mass, the crag with its shingly talus, the action of frost and rain, the gorge the power of running water, and the broader glen, with its occasional cross-mounds, the score and grind of the retreating glacier. The long ages of waste and denudation to which that hill-range has been subjected as it has alternately sunk beneath the sea and emerged again into the atmosphere, are unveiled by that sunlight in a way that leaves no room for doubt, and renders every feature of the easiest recognition. And thus, where others would "homeward plod their weary way," the field-geologist has his thoughts carried away from the present into the far-distant past—gleaning a new fact in world-history at every turn, and calling up vanished aspects of sea and land by the magic wand of scientific deduction. The scenery of nature which, to most observers, is a mere passive circumstance and nothing more, is to him a thing instinct with a thousand activities and producing causes; and what in them is a mere transient gleam of admiration, becomes in him an enduring glow of the clearest understanding.

Oh the delight of the young geologist as, seated on some craggy peak, he looks down on the hills and glens and valleys that surround him! It is not alone the presence of their beauty or wildness or grandeur that strikes him as it must strike other observers, but the conscious knowledge of the agencies by which their aspects were produced, and the looking backwards in time through the long ages of change to which they have been subjected. That hillside smoothed and rounded by the ice-sheet, that glen, with its lateral and terminal moraines gouged out by the glacier, and that winding valley eroded by aqueous and meteoric action, is each graven with a history which speaks to the eye of science, and makes these mountain solitudes rife with the presence of nature's powers and activities. To others it may be given to admire, to the geologist it is given to comprehend, and in that comprehension to enjoy the purest pleasure which a survey of the phenomena of nature can convey. "To sit on rocks, to muse o'er flood and fell," may be a joy to the poet and painter; but to know how that rock was formed, to trace that flood through its previous workings, and to connect that fell with all its former associations, is a nobler and more soul-inspiring delight, and one which none save the earnest student of nature can ever hope to achieve.

It is thus *in the field* that the student of geology obtains his fullest and newest information, collects additional stores, and corrects former misconceptions. A day well spent in the field is worth a dozen of reading at the fireside, the while that its bracing exercise paints the cheek with a ruddier glow, and confers fresh strength on the worker. As geology is primarily a science of observation and description, the field is its proper arena, and no one will ever arrive at true conceptions of world-history unless through the immediate study of the leaves on which that history is recorded. Travel and observation are the prime essentials of the science, and he who forgoes these, to the extent of his opportunity, omits the main chance of understanding aright its numerous and complicated problems. "To the field on every fitting occasion," should be the guiding maxim of the young geologist; and though new discoveries may not always reward his toil, though he should even fail to obtain what others have obtained before him, he is at least in the way of doing both, and in the excellent practice of training his powers of observation. And when his day's work is done, however little it may have added to his scientific stores, he has secured one luxury at least by his twenty miles' ramble in the pure country air—a blessing which comes to the poor unasked, and which the rich but too seldom enjoy—the luxury of feeling tired.

SCOTTISH GEOLOGY—ITS PROOFS AND PROBLEMS.

By the *proofs* of Scottish geology we mean what is known, or at least generally admitted, by competent observers; and by its *problems*, what is still doubtful, and requires further investigation. Our object in the present paper is not to sketch the history of Scottish geology, which about the beginning of this century was an inextricable labyrinth of theories and disputations between "Neptunists and Plutonists," and which at a later period was little else than a bald nomenclature of rocks and minerals;* but simply to try to distinguish between the established and the doubtful, that the student may better know what to accept, and where to direct his investigations. And yet, while alluding to the history of Scottish geology, one cannot avoid mentioning the names of such men as Hutton, Playfair, Ure, Hall, M'Culloch, and Jameson, as contributing largely, even

* This was the grand epoch of rock and mineral collections, the age of magnificent cabinets filled with rocks, minerals, and cut gems—the arranging of these into groups, and genera, and species (after the systems of botany and zoology), being the minute but futile labours of the collectors. A knowledge of Lithology and Mineralogy is no doubt indispensable to the study of Geology; but the idea of dealing with mixed rocks as with mineral, vegetable, and animal *species*, was a fancy that retarded rather than accelerated the progress of the science.

amidst these unproductive discussions, to the substantial progress of the science. Geology, such as we now understand it, can date back little more than forty years; and during this period its advancement in Scotland has been indebted in no small degree to the labours of M'Culloch, Jameson, Fleming, M'Laren, Cunningham, and Hugh Miller, and especially to those of Lyell, Murchison, Nicol, and others, who are still steadily endeavouring to unravel its many complicated physical as well as palæontological problems. Our present purpose, however, is not the history but the facts of the science; a brief indication, for the guidance of the young geologist, of what is already established, and of what remains doubtful, and to the elucidation of which he could with advantage direct his observation. In a field so vast, and where the labourers are so few, it is ever of importance that the new-comers, instead of treading in the old beaten tracks, should have their attention directed to the determination of the doubtful and the discovery of the unknown.

If the student will turn to any of the geological maps of Scotland—M'Culloch's, Nicol's, or Knipe's—he will find that the various rock-formations have all a south-west and north-east *strike*, with their *dip* to the south-east—thus placing the older rocks to the north-west, and the younger, in regular succession, to the south-east. The same holds good in England, so that a line drawn from London to North Wales would pass in succession through all the formations from the Tertiary to the Cambrian, just as a line drawn from the Firth of Forth to Cape Wrath would pass through the upper coals on through all the underlying formations to the Lower Laurentian. This fact is of use as affording a sort of index to the stratified systems—the traveller passing from younger to older if he begins at the south-east, and the reverse, or from older to younger, should he begin at the north-west. In this extreme north-west (the Island of Lewis and Cape Wrath), the schists and quartzites are supposed to be of *Laurentian* age, and the fossiliferous limestones and sandstones of Durness and Loch Maree of *Cambrian*. We say "supposed," for there are still doubts as to the true relations of the latter rocks—whether indeed they pass under the gneiss and mica-schists of Sutherland, or are not merely faulted and disrupted portions of the same series. If they be faulted portions of the same series, then we have as yet no ground for separating the great metamorphic masses of the Highlands into systems and formations; but if, on the other hand, these limestones and quartzites do pass continuously under the gneiss and mica-schist, then (as their fossils seem to indicate) they must be regarded as of Cambrian age, and all the gneiss rocks that lie beneath them (the "fundamental gneiss" of Murchison) be held as the equivalents of the Norwegian and Canadian Laurentians. In the mean time, the majority of those who have surveyed the district (Murchison, Harkness, Geikie, &c.) lean to the latter opinion; though Professor James Nicol, a cautious observer, and well acquainted with our Highland rocks, still entertains the belief that the rocks of Lewis, of Durness, and of Sutherland, generally belong to one and the same series of metamorphic schists, whatever be their age—Laurentian, Cambrian, or Silurian. The matter, it must be confessed, requires still further elaboration—more extended examination of the rocks themselves, and more minute discrimination of the fossils which may yet be found in more convincing states of preservation. During the last eight or ten years nothing has been done towards the solution of this problem, and we are tempted, in the interests of geology, to inquire—Is the question to remain in abeyance till the officers of the Geological Survey in the next generation reach these distant lochs and headlands, or is there no geologist of sufficient enthusiasm and leisure to put it at rest to the satisfaction of existing inquirers? Between 1856 and 1859 a strong current of interest was directed to these "fundamental gneiss rocks" and Cambrian fossils, but since then nothing has been done either to corroborate the opinions of Sir Roderick Murchison, or to refute those of Professor Nicol—the geological world remaining somewhat divided in opinion, and the non-geological, so far as it takes any interest in the matter, inclined to accept the conclusions of Sir Roderick.

Turning next to the *Silurian system*, we find, in that broad belt of upland which stretches from St Abb's Head to Port Patrick, that all the members of the formation—Lower, Middle, and Upper—have been detected; but, strange to say, no one has yet attempted the delineation of these subdivisions on our maps, or done more than merely admit the fact of their existence. In fact, beyond the admission that the whole belt is Silurian, and the finding of certain fossils at Grieston, the Pentlands, Moffat, Nitberry Hills, and Girvan, nothing has been done in a comprehensive way to co-ordinate the Silurian of southern Scotland with those of England, or to say how far the most southerly and most highly metamorphosed belt of them (the old Greywacké proper) must be assigned to the Cambrian system. In the north of Scotland, on the other hand, the gneisses, mica-schists, and clay-slates—the "metamorphic rocks," in fine, of the Highland mountains—have recently been coloured on some of our maps (that of Sir R. Murchison and Mr A. Geikie) as *Silurian*, though not a vestige of fossil organism has yet been detected in any portion of that vast mass and area. This colouring (mainly, we believe, at the suggestion of Sir Roderick) we consider premature and apt to mislead, though we know, from personal observation, that there is an orderly succession among these strata, and one which, if carefully followed up, might lead to the unravelling of the series. Nay more, we do not despair of yet finding fossils among the less metamorphosed slates and limestones of the Scottish Highlands (in the North Esk, the Lethnot, the Cruick, and in some of the gorges of the Abruchil Hills, for instance); and in this case the true epoch of the series would be determined, and we would then be in a position to colour them as Silurian, or as Silurian and Cambrian, according to the nature of the evidence. In the mean time, whether we look at the less metamorphosed Silurians of the southern Highlands or the more metamorphosed slates and schists of the north, it must be admitted there is still much to be determined, and the young geologist could not do better service to his science than devote a summer or two *first* to the stratigraphical sequence of these masses, and *second*, to the discovery of fuller fossil evidence upon which to found their true age and relationships. That the northern masses are not devoid of sequence is at once seen by their alternating limestones, schists, and clay-slates; and that the southern are by no means wanting in fossil evidence is equally certain from the number of species that have been recently discovered in the Pentlands, at Moffat, the Nitberry Hills (Lesmahagow), and at Girvan. Are the quartzites and limestones of Portsoy, the limestones and gneiss of Frazerburgh, the limestones and mica-schists of the Dee, and the limestones of Lochearn, one and the same series, brought up at distant localities by plication and upheaval; or are they not in reality, as they appear to be on altogether different horizons? And if the Silurians of the Pentlands and Nitberry be of admitted Ludlow age, may not those of Girvan be the representatives of the Wenlock, and those of Moffat and Peebles the equivalents of the Llandeillo, or lowermost beds of the system? And further, may not the more highly metamorphosed rocks (the "Greywackés") of Roxburgh, Selkirk, and Wigton shires be the equivalents of the older schists of Wales, the true *Cambrian* strata of Professor Sedgwick?

Ascending in the scale of time, we come next to the *Old Red Sandstone*, whose subdivisions—Lower, Middle, and Upper—are more largely developed in Scotland than in any other part of the British Islands. Though the system has been long and assiduously studied for its fossils, its stratigraphical relations have received less attention, and there are still doubts how far the three great subdivisions are conformable or unconformable to each other. In Forfar, Perth, and Lanark there seems to be an unconformity between the lower and middle groups, but how far this is general (in Caithness and Cromarty, for instance) has not been determined. Again, though the middle and upper divisions appear to be conformable wherever they occur in connection, the upper in some districts (as in Berwick and Roxburgh) is superimposed directly on the upturned edges of the older Silurian. On the whole, therefore, as far as our present information goes, the Scottish Old Red, though consisting of three well-marked groups (lithologically as well as palæontologically)—the *grey* flaggy beds of Perth and Forfar, the *red* thick-bedded sandstones of Perth, Fife, and Forfar, and the *yellow* and *whitish* beds of Elgin, Dura Den, and Roxburgh—requires more minute working out, and especially as regards its sequence and conformability.

Palæontologically, the subdivisions of the system are marked by very different suites of fossils—the lower by obscure plant-remains, gigantic crustacea (*Eurypterites*), and cephalaspid and acanthodean fishes; the middle solely by fish-remains, as coccosteus, pterichthys, asterolepis, dipterus, diplopterus, &c.; and the upper by lepidendroid stems and fern-fronds (*adiantites*), and by fishes, such as holeptychius, glyptolæmus, phaneropleuron, and species of pterichthys. In none of the groups has a single fragment of shell, coral, or other undoubtedly marine organism been detected, hence the question has very naturally arisen—Are the Scottish Old Red groups, and especially the lower, of marine or of fresh-water and estuary origin? So far as fossils are concerned, though the general opinion leans to a marine origin, the question is fairly open to discussion, and cannot be settled by reference to the "Devonians" of England. These Devonians are clearly a deep-sea deposit, but they do not represent the Scottish Old Red in its entirety, and no greater misnomer has ever occurred in geological classification than the substitution of *Devonian* for that of *Old Red Sandstone.* The slates and limestones of Devonshire may be the equivalents in time of the middle and upper Old Red groups of Scotland, but they cannot possibly be co-ordinated with the lower, and leave the marine or fresh-water origin of the Angusian flagstones to be solved by other evidence. Additional light has very recently (1868) been thrown on this question by the discovery of pteraspis along with shells and other marine remains in Cornwall, which tends to favour the idea of an oceanic origin for the Lower Old Red of Scotland; but the greater question of succession from Cornwall through Devonshire has still to be worked out before any satisfactory co-ordination between the whole of the Scottish Old Red and the so-called "Devonian" can be ultimately established.

Again, so far as can be seen in Fife, Roxburgh, and Berwick, the Upper Old Red passes conformably into the Lower Coal-Measures; but though thus conformable, the nature of the strata themselves, as well as their fossils (those of Dura Den and the Jed), give no countenance whatever to the attempt of the Irish surveyors to place these upper "yellow beds" as the base of the Coal-formation. The characteristic colouring of the sandstones and marls, the paucity of vegetable remains, and the total absence of those dark carbonaceous and bituminous shales so peculiar to the carboniferous system, as well as the fact of no genuine pterichthys, holoptychius, or glyptolæmus having ever been detected in the lower carboniferous strata, go all to establish the connection of these so-called "yellow-beds" with the other members of the Old Red Sandstone. And while thus contending for the retention of these yellow beds as the upper group of the Old Red Sandstone, we may also direct the attention of the student to the contemporaneity of igneous action with the deposition of the system. The absence of interbedded greenstone and trap-ash in some localities has led to the belief of comparative quiescence during the period; but the student has only to study the structure of the Forfarshire hills, and, above all, those in the neighbourhood of Dundee, to arrive at a very different opinion. Indeed, the contemporaneity of igneous action during the deposition of the Lower Old Red has recently been proved by well-boring in Dundee, in a way that was little anticipated—an 18-inch bore of 600 feet or thereby passing through several thick alternations of grey sandstones, trap-tuffs, and trap-conglomerates, and proving, if anything can prove, the co-existence of volcanic eruption with the deposition of the grey sandstone and flagstone.

Passing next to the *Carboniferous system*, which from its great economical value has been more intimately investigated than any other formation, we find that while its leading aspects are well known, there are still several specialties that require examination and solution. Thus, while the great subdivisions of Lower Carboniferous, Carboniferous Limestone, and Upper Coal-Measures are universally admitted, there are still doubts how far Scotland presents in any district the true equivalent of the English Millstone Grit, and also whether certain red sandstones that cap the system should be regarded as upper coal, or as the base and equivalents of the Lower Permian. It is true that in Midlothian, Fife, and Lanarkshire there is a great thickness of unproductive sandstones occurring in the position of the Millstone Grit; but the boundaries between these sandstones and the rest of the system are so obscure, and their lithology so like the other portions of the formation, that the value of such a subdivision is little appreciable, and, unless from a desire to conform to the English arrangement, would never have, perhaps, been sought after. The upper red sandstones, however, still require examination, and while leaning to the opinion that they are as much "Permian" as some of the red sandstones in Durham, we would retain them as portions of the Carboniferous, rather than complicate our maps with patches of uncertain colouring which, in the mean time, can lead to no practical result or satisfactory generalisation.

But laying aside these questions as to the great subdivisions of the carboniferous system, there are still many problems of climate, of fossil botany and zoology, and of local vulcanicity, that remain for solution. What, for example, were the geographical conditions under which the lower carboniferous strata were deposited, compared with those of the upper coal-measures? for clearly, both in their lithology and fossil remains, there are wide and important differences between these subdivisions. Again, the varieties of coal that occur in the same coal-field have not as yet been well accounted for. Are these differences to be attributed partly to different kinds of vegetation, partly to drift, partly to growth *in situ*, partly to the fact that some beds may have been converted into lignites before their ultimate submersion, and partly to the chemical changes they may have suffered in their conversion from vegetable matter to bituminous coal? And further, the differences that present themselves between the Mountain Limestone series of England and Scotland, though long noticed, have not yet been sufficiently explained. Why the massive and continuous limestones of the one, and the thin and interrupted strata of the other? Was vulcanicity more active and intense in the Scottish area than in the English—breaking up the depths of the sea, and interrupting the coral and encrinite growths by which these limestones are mainly attributable? Again, the fossil flora which is so abundant, and in general so well preserved, in the Scottish coal-fields, has not received the attention it deserves; and while dozens of collectors are busy among the organisms of the limestone and limestone shales, few have hitherto directed attention to the reptile life that has evidently prevailed during the carboniferous period, and still fewer to the insect life, though evidences of such slender relics are by no means uncommon. And lastly, though much has been done of recent years to reveal the successions of the carboniferous strata, the boundaries of the coal-fields have not yet been sufficiently determined, nor has care been taken to mark the distinctions between eruptive traps, which disturb or destroy the coal-beds, and *interstratified* traps, beneath which some of our best coal-seams lie unbroken and unaltered. Our maps and sections also require revision; for while the outcrops of coals and ironstones and limestones are noted, those of the oil-shales, now become of paramount importance, are passed over unmarked, as if they were unknown, or of no economical value.

After passing the carboniferous system, the superior formations, so largely developed in the south-east of England, occur in Scotland in limited areas, and often in widely detached and sporadic patches. We have new red sandstones in Ayrshire and in Dumfriesshire, but how much of these may belong to the *Permian*, and how many are truly *Triassic*, is by no means well determined. If those of Ayrshire are of Permian age, as they seem to be, then the most of those in Annandale and along the Solway are likely, as has been long believed, to be the equivalents of the lower trias of England. Beyond the "footprints" of the Dumfriesshire sandstones, few or no fossils have been detected in these red beds; and yet, from indications we have seen, there can be little doubt that local and diligent research would be rewarded by the discovery of legible and typical plant-remains. The recent reports of the Geological Survey on the Permians of Ayrshire are worthy of attention, partly from the determinations of contemporaneous vulcanism, and partly from the close (shall we say inseparable?) connection that subsists between them and the subjacent coal-measures. How far they may be ranked with the "upper red sandstones" of the Fife and Midlothian coal-fields is a problem that requires solution by a rigorous *lithological* comparison, for as yet no fossils have been detected to assist in the inquiry; and under the same category, to a certain extent, comes the reptiliferous sandstones of Lossiemouth and Cummingstone in Morayshire. Are these beds, as their fossils would seem to indicate, the true equivalents of the English trias, or may it not be from their closer proximity to the upper old red sandstone that they stand in nearer relation to some of the series of the carboniferous era? Beyond reptile remains and doubtful footprints, no other legible organism has yet been detected in these long debatable sandstones;* and yet we feel assured, from indications

* Originally regarded as part of the contiguous Old Red Sandstone, these Lossiemouth beds have recently, on the strength of their reptilian remains, been transferred to the trias; and yet among certain geologists

we have seen, that a diligent summer along the Moray shores would discover other evidence (shells and plants) that would finally settle the question.

When we ascend to the *lias* and *oolite*, we find these formations occurring in Scotland in still more widely-separated and limited patches, as in Skye, at Brora and Eathie in Sutherlandshire, at Linkfield near Elgin, and in a cutting of the Banff branch railway. That these isolated patches are all less or more Jurassic there can be no doubt, but in how far each can be co-related to some portion of the wider formations of England, is a task that remains still unaccomplished. Again, looking at these sporadic patches, were they originally deposited in local and limited areas, or are they the mere fragments of a wider formation that has been all but removed by subsequent waste and denudation? If the former (which can scarcely be), it opens up some new and curious questions in Jurassic geography; and if the latter, how enormous the amount of time involved in their removal!

Of the *Cretaceous system* there is no decided representative in Scotland, unless those calcareous clays, with fragments of chalk and chalk-flints, which occur on the uplands of Buchan in Aberdeenshire, be regarded as the remains of a denuded formation. That the chalk formation once spread over Buchan is the commonly received opinion, but fuller evidence than the clays and flints of Blackhill is still wanting to confirm the conviction. Chalk and chalk-flints are found abundantly in some of the post-glacial brick-clays; and as these are clearly the result of drift, so those on the plateau of Buchan may have been brought by a similar agency. The question is one of curious interest, and

there are still doubts as to their real relations—that is, whether truly triassic, or merely a portion of the Old Red more recent than the sandstones of Elgin, Dura Den, and Denholm in Roxburghshire?

though fair evidence has been adduced in support of the denudation theory, the other hypothesis has by no means received the consideration it deserves.

With regard to the *Tertiary system*, which, in one or other of its members, bulks so largely in Europe, we have not a trace in Scotland beyond the miocene leaf-beds of Mull, and, it may be, some pre-glacial gravels or old land-surfaces of pliocene age which underlie in some parts of Ayrshire, Fife, and Kincardineshire the true boulder-clay or "till." The leaves from the Mull beds have been competently examined, and declared to be of miocene age; but little or no attention has been given to pre-glacial land-surfaces, though these, if carefully sought after, might yield important information respecting the flora and fauna immediately preceding the advent of the glacial epoch.

And then as regards the *Glacial Drifts* themselves, while we have three well-marked stages in Scotland—1st, the lower "till" or true boulder-clay; 2d, the middle bouldery and gravelly drifts; and, 3d, the fossiliferous brick-clays, the kames, and moraines—there is much to be worked out as concerns the formation of these by glacier or by ice-berg, and during the stages of an uprising or of a descending land. And even when the different stages of the glacial epoch have been determined, and the formation of the respective drifts satisfactorily accounted, there is still much to be learned concerning the origin of many superficial clays and gravels which cannot be ascribed to the ice-epoch. These meet us in almost every district, and at every turn, and yet just because they are numerous and superficial we have failed to determine whether they are to be ranked with the older drifts, or with the accumulations of the current epoch. And under the same category may be placed the *Raised Beaches* and *Submarine Forests* of our sea-board; the former giving evidence of successive up-lifts of the land, and the latter of depressions and oscillations. The altitude and character of many of the old sea-margins have been determined with considerable accuracy; but little has yet been done to ascertain the character of the flora and fauna of our islands when these now submerged forest-growths were flourishing high and dry, the sheltering abodes of an equally luxuriant fauna. Considering the numerous places at which they are exposed (see Chapter on Raised Beaches and Submarine Forests), and the freshness of their remains, vegetable and animal, it is scarcely creditable to British geologists that so little should have been done towards their elucidation.

And now also, since lake-silts, peat-mosses, and river-drifts, cave-earths, shell-mounds, and crannoges are receiving so much attention in other quarters on account of their pre-historic revelations, those of Scotland, equally rich in these remains, should meet with closer scrutiny from local geologists and antiquarians. There is scarcely a marsh or peat-moss that has been drained during the current century but has thrown light on the early flora and fauna of the country, as well as on the pursuits and civilisation of the pre-historic inhabitants; and much more might be gained not only by watching the operations of the land-reclaimer, but by systematic explòrations of these olden deposits. Caverns are not very numerous in Scotland, but where they occur let them be systematically explored. Shell-mounds are by no means uncommon, and are easily laid open; and crannoges or lake-dwellings are much more frequent in swamps and lake-silts than is at present suspected by archæologists. Some good work has recently been done in this direction, but the field is a wide one, and invites co-operation, and a more systematic record than scattered notices in the proceedings of learned societies. Had our country a more genial climate some five or six thousand years ago? what was the character of its flora and fauna? who the peoples that preceded the Celts and early Britons? and what the amount of physical change on these islands since they were invaded by the legions of Rome some eighteen hundred years ago?—these and similar questions are ever recurring to the worker among these latest formations, and they can only receive solution by a more zealous and systematic investigation than has hitherto been attempted.

Nor when we turn from the stratified systems to the *Igneous Rocks*, boldly as these are exhibited in Scotland, and long as they have been studied, do we find among numerous facts fewer important problems still waiting solution. What, for example, is the origin of the granites? Are they all truly igneous, or are some of them merely metamorphic? and if metamorphic, are they metamorphs of aqueous or of igneous compounds? Eruptive rocks undergo metamorphism as well as sedimentary; and from the way in which many, if not indeed most, of the granites are associated with the stratified formations, may it not be that they are merely igneous rocks rendered more highly crystalline by this long-continued metamorphism? Again, the traps of Scotland constitute a very heterogeneous and puzzling group, and require revision, both as concerns nomenclature and theories of origin. What, for example, are the relative ages of the true porphyries, the "felstones," and greenstones? Are the porphyries the older products; the felstones chiefly of old red sandstone age; and the greenstones of subsequent manifestation? Are any of the basalts, such as those of Mull, of Stirling, and Arthur Seat, contemporaneous (as has been suggested) with those of the Giant's Causeway, or are they not merely special products of the great trap series that occurs so broadly over the lowlands of Scotland? Geologists speak of *intrusive* and *contemporaneous* trap-rocks occurring among the stratified formations. Are such interbedded masses not for the most part contemporaneous overflows? and are intrusive masses, strictly so called, of rare occurrence, and of the most limited dimensions? Another point of interest in connection with rocks so multifarious and widespread as the traps of Scotland is the distinguishing of those which have resulted from the consolidation of fragmentary ejections, and those that are the result of cooling from true igneous fusion. All are usually grouped together as mere *trap-rocks*, and yet in their mode of formation, and in particular in their effects upon the adjacent strata, nothing could be more diversified and dissimilar. Again, all the formations in the British Islands are faulted and dislocated more or less by vulcanic action: is there any evidence of faulting or dislocation subsequent to the formation of the boulder-clay? These and similar problems still demand solution, and those who take an interest in the more physical aspects of the science cannot have a finer field for their ingenuity than the igneous rocks of Britain, and especially as they are manifested in the area of Scotland.

Another subject—and the last to which our space will permit us to allude—is the *Scenery of Scotland*, and its producing cause or causes. On this matter a good deal has recently been written, but much of it from a local and restricted point of view. Dividing the country broadly into Highland and Lowland, it is obvious that the scenery of both is the result of many and complex causes—the former, from the Cambro-Silurian period, having been subjected to repeated submergence and upheaval, to marine denudation and meteoric waste, to ice on land and ice on water, and to the general waste of frost, rain, and rivers; and the latter to the same agencies, but only from periods subsequent to the depositions of the old red sandstone and carboniferous. On looking at the glens and gorges of the Highland hills, who can tell how much of these may have been scooped out long anterior to the deposition of the old red or carboniferous; and who can say how much of this scooping out is to be attributed to marine denudation, and how much to meteoric waste and the erosion of stream and river? The same remark is equally applicable to the lesser hills and valleys of the Lowlands. Where land has been repeatedly submerged and upheaved, subjected to vulcanic disturbance at successive periods, and during each period has been long the prey of aërial waste and aqueous erosion, it is impossible to ascribe its existing scenery to one or even to several causes. The scenery of every country consisting of old formations must necessarily be the resultant of many and diverse forces, and when it is considered through how many phases it must have passed from ancient to recent times, it will readily be perceived how little of it is strictly owing to existing forces and existing operations.

Such is a brief indiction of the *proofs* and *problems* of Scottish geology—that is, of the points that have been established, and of those that require still further investigation. Brief as the indication has been, the student will perceive that, along with much that is certain, there is also much that is doubtful, and a great deal that is altogether unknown. As labour is always most effective when it knows precisely what is required, so the student of Scottish geology may be enabled to direct his energies most successfully by an indication of the problems that still remain for solution. Limited as the area of Scotland is, and that area made up of a few of the older formations, the geology of the country embraces most important questions in mineralogy, metamorphism, physics, and physical geography; and few countries of the same dimensions present these problems in a light so striking and decided. Though not abounding in fossiliferous formations, there is still a fair field for the palæontologist in the old red sandstone and carboniferous; and even in districts where fossils are altogether wanting, that want is more than compensated for by the magnitude and complexity of the physical problems. And after all, the mere collecting and hoarding of fossils, without a knowledge of their bearings on world-history, is at best but an inferior and mechanical pursuit. Beautiful and wonderful as fossil forms may be—and all of them are wonderfully attractive—without a knowledge of their relations to the general scheme of Life, to Time, and to Space, one might as well become a collector and hoarder of his grandfather's snuff-boxes, walking-canes, and shoe-buckles. It is not an empirical knowledge of a thing by itself, but the understanding of its relations to other things, and to the cosmos in general, that constitutes science and the philosophy of the sciences.

THE NATURAL SCIENCES—THEIR PLACE IN EDUCATION.

Outside at present (1868) there is a great deal of noisy stir and pother about the importance of Scientific Education. Busy-bodies, who imagine that their buzzing turns the wheel of progress; social quacks, who are ever discovering some new elixir for the ills of the body politic; and alarmists, who see in the near horizon the sunset of Britain's supremacy,—seem all to be agreed that the one thing needful is Scientific and Technical Education. One would almost believe, from the outcry that has been made during the last six months, that science was altogether unknown in these islands, and that nothing, either individually or corporately, had ever been done for its encouragement and promotion. Judging from this clamour alone, a stranger would be apt to conclude that in this country of ours—the birthplace of Bacon and Newton and Watt, and the busiest centre of human industry, commerce, and mechanical achievement—there were no chairs of science in our universities, no scientific societies, no mechanics' institutes, no lecture associations, no field clubs, no British Association, no science classes in our schools, and no text-books for their assistance. The whole efforts of the last thirty years seem to be ignored, and the matter continues to be declaimed on as if Britain had fallen asleep, and the rest of Europe had shot full half a century before her. How much of this clamour is mere platform exaggeration and Kensington make-shift, we need not stop to inquire; that it has some foundation in fact we are compelled to admit; and on the present occasion mean merely to advert to that phase of the question which comes more immediately within the scope of our Science—viz., "The Natural Sciences, and the place they ought to hold in the curriculum of a liberal education." We do not take up the question of the natural sciences as against the exact or mathematical sciences, nor do we enter upon the old contention as to the relative educational value of the sciences and the classics. Our object is simply to urge the importance of such subjects as Physical Geography, Geology, Botany, Zoology, and Physiology, in general education, as at once proper themes for training the intellect and for storing the mind with available knowledge.

And first of all, if by education is meant the information and development of the whole mental faculties, so as to fit the individual for the right understanding of his relationships, and the duties he has to perform, then every enlightened government is bound to provide a national system, and to see that system universally enforced. However much we may differ as to working details, there is no getting over this preliminary condition of a national and compulsory system; and we might as well think of making the law of the land a matter of voluntary compliance, as to attempt to establish a system of education without making its acceptance imperative. Every man, whatever may be his condition in life, stands in certain relationships to the world that surrounds him, and these relations can never be fulfilled till he has been educated to know what they are, and the obligations they imply. We have all, for instance, our relations to external nature, our relations to our fellow-men, and our relations to the great Author of nature; and these no power can avoid nor ingenuity evade. In a knowledge of these relationships, and the duties they involve, consists the whole sum and substance of education; and as we have no intuitive knowledge of these, and they are imperative on all, so it is necessary that every man and woman should be brought to know them to the utmost of their opportunity and to the best of their power. Where there is ignorance of these relations, there must necessarily be error in their fulfilment; and though mere school-training may not be always able to restrain the idle and vicious, yet it would be running counter to all the instincts and experiences of humanity to aver that a broad and liberal scheme of education was not the surest guarantee for raising up an industrious, provident, and virtuous population. How anomalous, in a country of so much boasted superiority, that millions should be spent in the detection and punishment of crime, and so little done by a national and rational system of education in the way of prevention! During the last forty years, such a system has been often essayed, but as often prevented by the battling and opposition of creeds, each sect, in the professed service of God, apparently willing to sacrifice to some dogma the minds, the morals, and the souls of thousands. The poet makes the devil gloat with glee on witnessing Cain's jealousy of Abel's sacrifice; how much more exultant must his jubilation be at the continued jealousy of sect to sect, which permits their fellow-men to live and die in the ignorance of brutes, and in all the misery and degradation which such ignorance involves? Let us hope, and let each of us do our best to fulfil the hope, that in the forthcoming attempt at legislature there will be an end to this miserable and obstructive contention, and that the general voice of an intelligent land will carry the establishment of a broad and unsectarian system of education—a system making secular provision for all, and enforcing those provisions with a stringent and uncompromising uniformity.

Admitting, then, the necessity of a general and enforced system of education, the question occurs at the outset, of what that training shall consist? Fortunately, most people are at one as to the elementary branches, — Reading, Writing, and Arithmetic; and they differ only when the elementary boundary is passed, and the faculties of the child are capable of grasping a higher and wider range of subjects. Now, however important other branches of knowledge may be—and we do not undervalue the least of them—we would claim for the Natural Sciences a prominent, and indeed indispensable, place in every course of tuition. Whether we deal with the objects that more immediately surround us — plants, animals, minerals, and places; or with their less obvious and more abstruse qualities—their intimate nature, composition, and activities—we are treating of things which have at once an intellectual interest and economic importance. Be it geology or geography, botany, zoology, or physiology, we are training at once the observing and reflecting faculties—the tact that leads to practical applications, and the deeper insight that rises to the discovery of natural law. In all the natural sciences we proceed from the observation and description of phenomena to the causes that produce them; from the producing causes to the purpose which these phenomena subserve in the economy of nature; and from a consideration of the whole we ascend stage by stage to the expression of the law by which they are governed and sustained in perfect harmony and interdependence. Whether we deal with the simplest facts or with the most recondite problems, the methods of investigation are the same; hence the value of the natural sciences as a means at once of intellectual training and of useful information; of storing the mind, and of bearing on the requirements of every-day existence.

Let us illustrate our position more fully. Every object in botany, zoology, geology, or physical geography, requires observation; and before it can be described it must be observed with care and discrimination; hence the exercise of the observing faculties so eminently secured by the study of the natural sciences. Again, certain phenomena are observed, and we want to know how these are caused, or by what processes they are brought about; hence the exercise of judgment and reflection—the balancing of facts and probabilities—the logical sequence, one false step in which would be as fatal to a theory as a slip in reasoning would be to a demonstration in Euclid. Still further, we perceive a certain sequence of events, an unfailing round of means and processes; and we trace in this unerring recurrence what we term a method or law of Nature: and thus, in tracing the method, we perceive how far we can turn it to the utilities of life; or where we cannot subdue, we learn to adapt ourselves to the law which is inflexible. Even higher still in these laws and methods, these endless harmonies and nicest adjustments, creative wisdom and power are so apparent at every turn, that from the contemplation of the design the mind instinctively rises to the admiration of the Designer, and is drawn by a thousand inducements to a compliance with the order that prevails. Be it the life of a plant or animal, the formation of a rock, the phenomenon of the tides or trade-winds, the act of respiration, or any other fact in natural science, with which we have to deal—and in all we must acknowledge how much observation, description, reasoning, and tact are necessary before any satisfactory conclusion can be arrived at, either as regards their nature, their producing causes, or the functions they are destined to fulfil. As themes, then, of intellectual exercitation, and altogether apart from their practical utilities, the natural sciences are pre-eminently fitted for a place in education, whether in our elementary schools or in our advanced academies and colleges.

Nor is it mere intellectual fence and industrial utility which may be secured by a knowledge of nature, but long after youth has passed, and the stern realities of life have to be encountered, the tastes sown at school may yield good and pleasant fruit to their possessors. Whether engaged in manual toil, or in the discharge of professional duties, or leading a life of utter leisure, acquaintance with and a taste for some department of nature will afford a never-failing source of recreation and enjoyment. Even should the knowledge advance little beyond the mere collecting and admiring of natural objects—plants, shells, insects, minerals, or fossils—it is a pursuit that may be freely indulged in by both sexes, and may gladden many a solitary moment, and hallow many an hour which might otherwise be spent in idleness and dissipation. The objects of nature are scattered everywhere—above, beneath, and around us; but it is only to the educated mind that they appear in their most varied and most wonderful aspects—aspects which, like those of the kaleidoscope, assume newer beauties at every turn, and leave more enduring remembrances; a thing of beauty being a joy for ever. Nor, to secure this desirable end, is it necessary to go deeply into many, or even into one branch of science. A very modest modicum of knowledge, with the formation of the tastes and habits, is the most that can be aimed at, and in many instances all that can possibly be attained. Whether, then, we look upon the natural sciences as means of intellectual training, as sources of new and useful information, or simply as themes of recreative enjoyment in our riper years, they are deserving alike of our individual culture, and of a prominent place in every system of juvenile education.

Of course, to carry these sciences into the general education of the country, regard must be had to the age of the learner, to the condition of the learner, and to the ultimate requirements of the learner. As well continue to teach the incomprehensible dogmas of the Shorter Catechism, as to attempt geology or physiology with children of tender years. Not only would it be to attempt information beyond their mental grasp, but it would be trenching on the time that could be more profitably devoted to suitable subjects, besides running the risk of disgusting them with education altogether. There is nothing that dulls the perception and stupefies the whole intellect more than the enforcement of information which it cannot comprehend; and though the objects of natural science come very early within the scope of the young, yet it would be injudicious to commence their systematic treatment in any one branch under ten or twelve years of age. Again, with children whose school-time amounts at most to five or six broken years, it becomes an important question, What are the subjects that can be reasonably overtaken, and how much of these can be taught effectively and well? It is a well-grounded knowledge of some things, and not a smattering of many things, that the judicious teacher will ever aim at; and the amount of this knowledge must in every instance be governed by the time which the pupil can bestow. Of course, if there were a compulsory system, the time of the pupil would be regulated, and the teacher could shape his plans accordingly; but, even under any system of education, the school-days of the majority must be limited, so long as the exigencies of life press so heavily and immediately on the parents. But beyond the age and condition of the learner, his after requirements in life should also be kept in mind, and especially towards the close of his curriculum. No doubt it has been cleverly said, that school training should consist in "knowing something of everything," and professional training in "knowing everything of something;" but where there are a multiplicity of subjects, those only should be chosen (and especially towards the close of a school career) which are most likely to bear on the after life of the learner. That school education should be as general as possible, no one acquainted with the development of the human mind will for a moment gainsay; but surely the rudiments of geology or chemistry are more likely to be useful to an intending farmer than conic sections or astronomy; physical geography of greater advantage to a merchant-trader than botany or geology; and some scantling of physiology of higher importance to all than either botany, geology, or astronomy.

In contending for an indispensable place in education to the natural sciences, we by no means undervalue the study of the classics; but we contend that hitherto, and without regard to the ultimate requirements of the learner, too much time has been spent in mastering the dead languages, and too little devoted to a knowledge of nature. We admit most frankly that the nomenclature of the sciences is chiefly derived from the Greek and Latin; that the graces of expression may be fostered by a knowledge of classical models; and that insight into the policy and principles of society may be gained from these sources. But if one of the chief aims of education be to train the observing and reflecting faculties—to teach aptitude of observation and exactitude in reasoning—then must the natural sciences, which depend so intimately upon the exercise of these powers, be a more important element in education than any amount of intimacy with the literature, the manners, or the mythologies of the ancients. The acquisition of languages is, for the most, little more than a matter of memory; and as the memory for words manifests itself most strongly in the young, youth is no doubt the proper season for this acquisition. But though this be true, it is no good reason why every child should be dragged through the same course, and the major portion of the school-time of all given up to this one theme, and this at the sacrifice of other subjects much more appropriate and needful. If school-years be limited to all, and very brief to the majority, let us endeavour to make the most of the period. If the main object of school training be preparation for the life that lies before us, let the subjects to be learned have reference, more or less directly, to the realities of that event. In this world of ours we have ever to deal with realities and activities; and the sooner we become acquainted with the nature and scope of these forces, the better will we be equipped for the contest. If there be time for science and the classics, so far good; but if the time be limited, as it must ever be in our elementary schools, let a scantling of science be given by all means in preference to a snatch at the classics. The former furnishes not only superior mental training, but provides at the same time some modicum of available knowledge.

Our relations to external nature, we have already said, are unavoidable, and their requirements inexorable. Nature is most liberal in her gifts, but stern and unbending in her demands; and it is science alone, and a knowledge of nature's laws, that teach us to avoid where we cannot avert, and to adapt ourselves to the situation where we cannot subdue. No knowledge of ancient song or fable, no intimacy with olden history or heathen mythology, can ever teach us to ameliorate our soils or modify our climates, to combat with winds and tides, to accelerate our speed over land and water, or to increase our mechanical power, and meet the demands of a teeming and ever-increasing population. Even laying aside the practical aspects of the question, the mental training imparted by a study of the sciences is altogether of a different quality. By mere classical learning the energies of the mind are enfeebled, and its superstitious tendencies increased. By scientific training, on the other hand, the genius of thought is set free, and every myth and dogma put to the test of reason and reality. Had the natural sciences ruled in our schools and colleges one-fourth of the time that classical learning has been dominant, there cannot be a breath of doubt that most of the myths and dogmas which now hang like millstones round the necks of mankind would have long since been scattered to the winds. Every generation widens the distance between the present and the past, and though in the nature of things the present must be related to that which has gone before, still, to hang up the thoughts and beliefs of the far past as models to the present, is as absurd as to ask the full-grown man to double himself up to the dimensions of the cradle of his infancy.

Even those who advocate most strenuously the continuance of classical education must admit, that all have not alike the gift for languages, any more than all can be poets, painters, or musicians. By the introduction into school treatises of such subjects as physical geography, geology, botany, zoology, and physiology, the range of the pupil's choice is widened, and he must be a very dull and unusual scholar who does not take kindly to one or other of these subjects. We have seen boys (and we speak from experience) who were ever dunces in Latin and Greek, and yet who made admirable progress in physical geography and geology. And what was the ultimate result? Minds formerly depressed by continued dunning and drudgery, where there was no natural aptitude, began by degrees to be conscious of their own powers, and with this conscious pride awoke the new desire to master other themes; and in more instances than one, the previous "dunce" has turned back and made respectable progress even in the classics. The more we know, the more we desire to know. By thinking the mind is taught to think; and one of the most important steps in education is to awaken the mind to a consciousness of its own powers, and an honest pride in its own capabilities. By the introduction of the natural sciences into all our schools—and the objects of these sciences are realities everywhere patent to observation—we give the pupil a greater chance of cultivating his special powers; and thousands who have passed into the business of life with little knowledge of the classics beyond a sense of the dreary drudgery they entailed, and with something akin to disgust at all schooling, might have gone forth with a fair rudimentary acquaintance with the sciences, and pleasant recollections, had the opportunity been presented them to learn what they had naturally the gift for.

Admitting the importance of the natural sciences in education, and not disparaging the classics where time and opportunity occur for their study, the question arises, how the former can be more generally and most acceptably introduced? In a country full of established usages, no sudden and revolutionary measures can be safely adopted. Discussion, opposition, and delay are the certain consequences of any proposal to overturn; and introduction of improvements is always best secured by proper regard to existing systems. We need no new educational creed promulgated from Kensington, no "Great Eastern" scheme of twenty thousand teaching-power, to bring about the desired result.* The diplomatic circle of Kensington has hitherto had no great charm for the country, and our experience of Great Easterns has been by no means of a kind to induce either confidence or adoption. What is needed, in the mean time, is simply the addition and subdivision of a chair or two in our universities—physical geography and geology, engineering and technology; the establishment in our academies and burgh schools of a mastership of natural science, as there is in most instances one of mathematics and natural philosophy; and the introduction into our parochial and ordinary schools of the sciences, just as we have at present the teaching of the languages. Let a modest beginning be made in our colleges and academies, and the result will soon be felt in the elementary schools, as the teachers themselves have become acquainted with the sciences. Let science qualifications be made indispensable to graduation for honours to our learned professions and to the leading Government appointments, and the supply will soon meet the demand. Let our heritors and school directors advertise for teachers qualified in science, as they now advertise for those skilled in the languages, and in a few college sessions there would be candidates in abundance.

But beyond the formal education of our schools and colleges, there must ever be, in a populous country like ours, a large body of adults earnestly seeking after further and higher information; and to these important aid might be given, either by the extension of the mechanics' institute system, or of the establishment of science classes, aided by local rates, and encouraged by grants from Government. The present science-classes scheme of Kensington will not, and should not, be allowed to meet this want. It has too

* See speeches of Messrs Buckmaster and J. Scott Russell at Conference of Scottish Society of Arts in Edinburgh, 1868.

little of the real metal, and, like most that comes from that quarter, too much lacquer and japan. Its "organising system," as it is called, where the organising master is the author and vendor of the books to be taught, and examiner at the same time, is thoroughly vicious. The "payment according to results," unless, to be sure, the teacher had the command of the population and the making of the brains, is an insult to the educational profession. Ask our friends the lawyers and doctors to square their fees to results; apply the system to the clergy, and there would be such a collapse that even the most extreme Dissenters in the Scotch metropolis would cease to consider the Annuity-Tax a burden! What is really wanted in the scientific and technical training of our adults is, not that they be held in the leading-strings of Kensington, but that in every sufficiently populous community there should be a rate of maintenance supplementary to a scale of small fees; the system to be by Act of Parliament; and the power to adopt it at the volition of the ratepayers. A country once appreciating the results of a national system of education would not be long in finding ways and means to meet the wants of its adult population; and were its natural sciences generally taught, special art-education would be a matter of easy attainment. What is wanted in art is not a uniform style promulgated from Kensington, and mechanically followed by our workmen like so many bees and beavers, but the free and fresh results of their own genius, fostered as that genius ought to be by an elementary training in science, under a system of national education. There was never greater nonsense talked than there is at present about this matter of art-education. "Teach it," say the alarmists, who see in Berlin statuettes, Bohemian glass-ware, and Sevres pottery, some beauties not to be found in our own—"teach it to our workmen, or very shortly Britain will be beaten out of the markets of France and Germany!" Teach it by all means, say we; but remember what a poor thing this empirical copyism will be, compared with that genuine art which would spontaneously flow from a general system of education, and from that knowledge of natural objects which must ever lie at the foundation of all artistic eminence. A knowledge of objects as they occur in nature—the eye to observe the beauty and individuality of their forms, and the mind to trace their relations—are the great desiderata, and these can only be secured through and by the scientific training we contend for.

Such is a brief indication of the value we attach to the natural sciences, and the place we would assign them in the general education of the country. We claim for them a place, because, dealing with things accessible on all hands, they are calculated to train the powers of minute and discriminating observation. We claim for them a place, because, treating of phenomena dependent on means and processes, their study leads to the exercise of sustained thought and reflection. We claim for them a prominent place, because, in striving to ascertain the relations that subsist between the various phenomena of nature, exact and logical reasoning is indispensable at every step, and accurate habits of thought are thereby established. We claim for them a leading place in the education of the young, because, dealing with objects and not with abstractions, they are better fitted for their capacities; and we claim for them the attention of adults, as at once calculated to elevate the mind, and afford an ever-accessible and permanent source of recreation and enjoyment. And we claim for them a place in the education of all, as leading alike to a knowledge of the powers and processes with which we have to contend in the battle of life, and to purer and more rational views of those higher relations which subsist between man and the Creator of all things.

Nor in claiming for the natural sciences this prominent place in education, do we seek anything extravagant or Utopian. A fair beginning has been made within the last dozen years in many of our leading schools and academies, and we merely wish to extend the system to all the educational establishments in the country. We disclaim all interference with the elementary tuition of the younger pupils, and merely ask the introduction of such subjects as physical geography, geology, zoology, and physiology; into the advanced classes. Considering the few years that most children are at school, and the number of subjects usually attempted, it would be absurd to aim at too much. Whatever may be attempted should be done well; and we presume there would be no difficulty in teaching the general principles of one or more of these sciences by the aid of a text-book, the exhibition of objects and diagrams, and an occasional excursion into the country. We merely ask for the most modest beginnings, and would be satisfied were little gained beyond the formation of the tastes for the study and cultivation of one or other of the natural sciences.

And as concerns our adult population, and especially those who are only entering on the business of life, were once the taste formed at school, there would be little difficulty, through the instrumentality of mechanics' institutes, field clubs, and popular lectures, in sustaining the habit. The numerous lecture associations and scientific societies now scattered through the country, are evidences sufficient of the tastes that are abroad, and which only need encouragement and extension, by *first* educating in science a larger number of the young, and, *secondly*, by giving to the societies a more systematic and more permanent character. For want of some general system of maintenance, many of these institutes and associations are restricted and intermittent in their efforts; some mode of local rating, supplemented by additional grants, would give to them all the impetus and permanence they require.

If, then, the scientific and technical education now so loudly talked of shall ever be secured and rendered effective, it must be—*first*, by the establishment of a national and enforced system of juvenile education; *secondly*, by the introduction into that system of a larger amount of science, and especially of the natural sciences, than has hitherto been taught in our schools; and, *thirdly*, by fostering among our adult population, and especially among our young artisans, a taste for scientific and artistic pursuits, either by a system of direct rewards or by certificates of merit, which will become their passports to higher and more lucrative situations. But whether or not the present outcry be productive of practical results, we think it sufficiently obvious that, in the education of the present day, when men are dealing more and more with realities, and more and more extending their domain over to the realms of nature, that the natural sciences should hold an important, and indeed an indispensable, place.

DURA DEN—ITS PLACE IN GEOLOGY.

It was in the early spring of eighteen hundred and thirty or thirty-one, that, in company with a few fellow-students from St Andrews, we first visited the wooded cliffs and winding recesses of Dura Den. Our ramble had no very definite object: partly to spend a holiday, partly to enjoy the free fresh breeze, and partly to witness the scenery which now and again called up the poetic raptures of our Professor of Humanity—the late Dr Thomas Gillespie. Geology had nothing to do with our excursion; and if a passing thought of science flitted at all across our minds, it never manifested itself in more than picking up a wild violet by the wayside, or a primrose from the grassy slopes of the sheltered ravine. At that time Dura Den was little known and seldom visited—its romantic beauties meeting only the eye of an occasional Sunday stroller from Cupar, a stray trout-fisher from Dundee, or a small picnic party of young ladies and elderly gentlemen from St Andrews. Now, how altered the case! The locality has a world-wide celebrity; and wherever geology is cultivated, there the name of Dura Den is a favourite and familiar word. Why this change? whence this celebrity? The answer is given in three words—*Its Fossil Fishes.* These fishes, wonderful in their structural characteristics—wonderful from the vast numbers entombed in so limited a space—and wonderful from their fine state of preservation—have conferred on Dura Den not a scenic but a scientific renown; and we are not maligning our fellow "folks of Fife" when we express the conviction that the name is better known to the geologists of Europe and America, than to many of the inhabitants of the county.

To point out the geological relations of the locality—to glance at its fossil fishes, and the conditions under which they lived, died, and were preserved—and to pass in review the long ages that have elapsed since their entombment, is the object of the present chapter; and, whatever the treatment, the subject is, of itself, sufficient to command the interest of the geological inquirer. There are few fossil localities so inviting in point of scenery, or exhibiting finer rock-sections, and none more accessible than Dura Den. It is true that the quiet glen of forty years ago, with its rustic meal and flax mills, is now in part busy with water-wheels, and resonant with spinning-machinery; but enough is left to maintain its beauty. The trees are somewhat higher and hoarier, and the stream, when in flood, dashes down through its rocky course as headlong and wildly as of yore. But, though all its accessories were changed, there still rise the cliffs of yellow sandstone and variegated shales, and there sinks the watercourse, with its out-cropping strata replete with those fossil treasures which form the pursuit of the palæontologist; and for these, and these alone, though all else were gone, Dura Den would still maintain its celebrity. Exhumed during the last thirty years, they are now to be found in almost every public museum and private collection — their dark enamelled forms, finely relieved by the light-yellow matrix, rendering them at once objects of beauty and of scientific interest; and Dudley is not better known for its trilobites, Whitby for its ammonites, or Kent tyro in physical geology can have no difficulty in drawing a distinction. But though the rocks of the two systems were even more alike, their fossil contents are altogether dissimilar—showing that the two series have been formed under different conditions, and, therefore, entitled to be ranked as different formations. *Pterichthys*, *Holoptychius*, *Glyptolæmus*, and *Phaneropleuron* do not occur in the carboniferous system; and though fishes allied to *Holoptychius* and *Phaneropleuron* have been found in the lower coal-measures of Fife and Mid-Lothian, they have been discovered, on critical inspection, to belong to very different species; while there is in the yellow sandstones of Dura Den, Elgin, and Roxburgh, an all but total absence of those vegetable organisms which characterise so abundantly the very lowermost beds of the carboniferous. And now for the fishes themselves, and their mode of entombment and preservation.

Following the critical discriminations of Professor Huxley, as contained in his Essay on the Systematic Arrangement of the Devonian Fishes, published in 1861, the fishes of Dura Den, as far as at present known, belong to the two great orders, *Ganoidei* (enamelled scales) and *Teleostei* (perfect bones). The former embraces all the members of his sub-order, *crossopterygidæ* (fringed fins—that is, lobate fins with a fringe of rays); while the latter, in his opinion, are represented by the remarkable genera coccosteus and pterichthys. The subjoined list contains all the genera and species which have yet been obtained and critically determined, from the yellow sandstones of Dura :—

ORDER—GANOIDEI.

Sub-order—Crossopterygidæ.

Family, *Glyptodipterini.*
Sub-Family, A. with rhomboidal scales.
Glyptolæmus Kinnairdi.

Glyptolæmus sp. (?)
Glyptopomus minor.
Sub-Family, B. with cycloidal scales.
Glyptolepis Andersoni.
———— Flemingii.
———— nobilissimus.
———— formosus.
Another Genus—undescribed.
Family, *Phaneropleurini.*
Phaneropleuron Andersoni.

ORDER TELEOSTEI.

Family, *Placodermi.*
Pterichthys hydrophilus.
———— major.
———— sp. (?)

Although minute technical descriptions of the preceding genera would be out of place in a sketch like the present, yet as several forms, not included in our list, have been named by others, it may be of use to the student not only to mention what these are, but our reasons for excluding them; and in this we submit not our own opinion only, but that of our friend Mr Powrie, who has long and critically examined the fishes of the old red sandstone.

Of *Glyptolæmus*, so named by Professor Huxley from the sculptured plates covering the throat, only one species has yet been determined (*G. Kinnairdi*); but a smaller fish of similar form and with rhomboidal scales is not unfrequent on the same slabs, and this (though imperfect preservation prevents determination) we have placed provisionally as a species of the same genus.

Of *Glyptopomus*, so named by Agassiz from its sculptured cheek-plates, only one species (*G. minor*) has yet been discovered. At first supposed by the Swiss palæontologist to have been a species of his genus Platygnathus, it was named *P. minor* in the plates accompanying his Monograph of Old Red Sandstone Fishes, but was subsequently removed. It is rare in Dura Den, and generally in poor preservation;

but the same fish (and once at least in a beautifully perfect condition) has been found in the yellow sandstones of Elgin.

Respecting *Glyptolepis* (sculptured scale), it may be remarked that, previous to Professor Huxley's Essay of 1861, this genus was supposed to be peculiar to the lower divisions of the old red (Gamrie, Lethen Bar, Orkney, &c.), the nearly allied fishes of the upper red and yellow beds being named *Holoptychius* (all-wrinkle). In the Essay of 1861 the great probability of the necessity of merging these two genera is clearly pointed out; and following out this suggestion, Mr R. Walker of St Andrews (having the finest and most extensive collection of Dura Den fishes under his inspection) shows in the 'Annals of Natural History' for 1863, that, with the exception of *H. Andersoni*, all the other Holoptychii from Dura undoubtedly belong to the same genus as the *Glyptolepis* of Gamrie and the north, while the close alliance of *H. Andersoni* to those other forms demonstrates the necessity of abandoning one of these generic names. We retain that of *Glyptolepis* as more in keeping with the general nomenclature of old red sandstone fishes (osteolepis, &c.), and restrict that of *Holoptychius* to the carboniferous species. The most abundant species in Dura Den are *G. Andersoni* and *G. Flemingii.* Scattered in the same slabs with these species are frequent detached scales of a much larger size; and in 1858 a magnificent specimen bearing these larger scales was disinterred, and is now in the collection at Rossie Priory. Its close resemblance to the old *H. nobilissimus* leaves little doubt of its identity, and we have placed it accordingly. Mr Walker in the paper referred to describes, but does not name, another distinct species of Glyptolepis. "The fishes in question," he says, "have the head rather shorter in proportion to the whole length; the first dorsal and ventral fins are placed an inch (in some cases more) nearer the head; the dorsal and anal fins are longer than the same fins in any specimen of *Holoptychius* (*Glyptolepis*) *Flemingii* that I have seen; and the scales have their external sculpturing much finer." We have examined the same specimens, and would suggest for them, in reference to the finer sculpturing of the scales and their general proportions, the specific term *formosus*, or that which appears in the foregoing list.

Of *Phaneropleuron*, so named by Huxley from the obvious appearance of its ribs, only one species, *P. Andersoni*, has yet been detected in Dura Den; though other species of the same genus are not uncommon in the lower carboniferous series. These have been found at Cornceres and Burdiehouse, but have not, so far as we know, been critically examined and described.

Pterichthys hydrophilus—the Pamphractus hydrophilus of Agassiz—is by no means uncommon in Dura Den, many of the slabs being quite covered with their detached plates and pectorals. Plates of *P. major* occur more sparingly, though in the Jedburgh beds of the same age they are scattered so abundantly as sometimes (as at Langlee) to form a perfect breccia. In the collection of the late Mrs Dalgleish of Dura there is a specimen of Pterichthys of larger size than hydrophilus, and with such characters as seem to mark a distinct species, and this we have noted accordingly.

What may be called one of the gems, if not the gem, of the St Andrews collection, and as yet neither described nor named, is a large specimen belonging to a genus widely differing from any of those we have mentioned. The specimen is yet unique; and to Mr Walker, under whose charge it is, we look for a detailed discrimination and description.

In addition to the genera we have noticed, Agassiz, in his

Monograph of Old Red Fishes, describes under the name of *Platygnathus Jamesoni* a fragment showing the posterior portion of the body, together with the caudal and part of the dorsal and anal fins. From a careful examination of the specimen, which was long in our possession, and by comparing it with many similar fragments, it seems to be unmistakably a portion of *G. nobilissimus*, and as such we have classed it in our list. And here it may be observed that the sculpturing of the scales, varying in different parts of the same fish, and the fuller development of the fins in stronger or it may be male individuals, has frequently, and not unnaturally, led to the erection of new and unwarranted genera and species. In Dr Anderson's Monograph of Dura Den, a head of *Glyptolæmus Kinnairdi* is figured and named as *Diplopterus Dalglisiensis*, and Agassiz is given as the authority for the generic name. A tooth of *Dendrodus* and some scales of *Phyllolepis concentricus*, both of large size, are also mentioned as having been found in these sandstones; but as no indication of such genera has ever appeared in any of the hundreds of slabs we have examined, we decline to include them in the list of Dura Den fishes.

We have witnessed the results of every important excavation since 1838, whether accidental, as those by the mill-owner—or intentional, as those by the proprietor of the estate, by Lady Kinnaird, with the proprietors' consent, by the Committee of the British Association on two successive summers, or by the Literary and Philosophical Society of St Andrews; and in all, those in the preceding list were the only genera and species discovered, if we except a few doubtful and illegible fragments. That other genera and species may exist in the fossiliferous strata no one can gainsay; but, judging from the material already excavated, and bearing in mind that the scales of these fishes differ in size and ornamentation not only on different parts of the body, but also according to age, sex, and individual growth, we have yet seen no good grounds for extending the list of Dura Den fishes beyond that which we have indicated. There is no graver error in palæontology, and none that retards the science more, than the founding of new genera and species on data which the luckier discoveries of another day may overturn. Such a practice has already been the bane of our science, and should on every fitting occasion be resolutely resisted.

But whatever the species, the state of preservation is for the most part quite astonishing. Not only is the general form of the fish well preserved, but the bones of the head, the teeth, scales, fins, and fin-rays are all in place, as if the creatures had been suddenly enveloped in the sandy matrix, and this before the slighest maceration, decay, or displacement had taken place. There they lie in hundreds within the space of a few square yards, and often overlapping and overlying each other, as if overtaken and destroyed by some sudden catastrophe. Genera differing so widely as Glyptolepis and Glyptolæmus, and above all, Pterichthys, were not likely to live in the same shoal, and their indiscriminate admixture in a fossil state would seem to imply that they had been drifted together after death. And yet drift and entombment must have taken place immediately after life was extinct, for otherwise it is impossible to account for the extreme perfection of their preservation. Marine fishes may be destroyed in shoals by a sudden influx of fresh water; and *vice versa*, fresh-water species may be killed by an influx of salt water. Fishes passing suddenly from cold water to a hotter medium, or *vice versa*, are paralysed and destroyed. They may also be killed in myriads by the emanation of deleterious gases from submarine volcanoes; or poisoned in a similar way by the sudden influx of noxious waters. They may be shoaled, till death ensues, during earthquake convulsions; or they may be cut off in lagoons from the main water, and there be covered up by drifting sands in the course of a few tides. In whatever way the different genera of Dura Den may have been brought together, it is evident that their death has been sudden, and that they have been as quickly sanded up and protected from drifting and decay. There is seldom any separation of parts—no mutilation by garbage-feeders—no wasting or obliteration by natural decay. Every part is in place and in form, every sculpture and ornamentation as perfect and distinct as if they had been newly taken from the waters. And now, after the lapse of ages, there they lie —pursuer and pursued—in their yellow cerement of stone, an instructive story to the naturalist, and a theme of wonder to the uninformed. Can mind grasp the measure of their antiquity, or indicate the succession of events since they disported in the waters of the old red sandstone sea? How many changes has this limited area of earth-crust—the Dura Den of to-day—witnessed since these yellow slabs formed the soft yielding sands of a primeval sea-shore? Let geology attempt a reply.

And first, the *Coal-formation*, with its thousands of feet of sandstones, limestones, ironstones, shales, and coals, was deposited in a later sea that swarmed still more abundantly with life; whilst along its shores and estuaries there flourished that exuberant vegetation whose consolidated relics furnish that fuel so indispensable to the requirements of modern civilisation. What ages of growth and decay to form these successive seams of coal! What æons of waste and transport to pile up these thousand alternations of sandstones and fire-clays and shales! But these too passed away: and while the old red sandstone and coal-formation were here and there raised into dry land, a still younger sea received the sands and marls of the *New Red Sandstone* epoch—an epoch marked by other forms of life and other conditions of existence. Again this passed, and while the new red, coal, and old red sandstone were still farther upraised, and constituted the continents and islands, another and newer sea received the muddy silts and limestones of the *Lias* and *Oolite*, and swarmed with other forms of fish-life, with myriads of cuttle-fishes (ammonites) and gigantic reptiles. These reptiles, with a few birds and lowly mammals, were then the lords of creation; and it may be that ages before Dura Den was hewn out of the rock, or Kemback Hill had been moulded into form, there and on the same spot the iguanodon, megalosaur, and hylæosaur sunned themselves on the slopes or cropped the foliage of the oolitic flora. But sea and land are continually though slowly changing place. The oolitic seas are upraised into dry land, and newer sea-areas receive the limy muds and zoophytic debris of the *Chalk-formation.* Land in the northern hemisphere has now a broader area, the seas are shallower and more circumscribed, and in these seas and lagoons are deposited the sands, gravels, and gypsums of the *Tertiary era*, with occasional skeletons of the birds and mammals that now begin to people the earth. At length the conditions of the tertiary period begin to change, in obedience to that incessant law of cosmical mutability; and the land over large areas in the northern hemisphere begins to sink beneath the waters. The currents of the ocean are changed, and now a cold and rigorous climate ensues. The land still subsides, and down its slopes and hill-sides the glacier grinds its way, and on the submerged surfaces the melting iceberg drops its burden of clay and boulders. This is the *Glacial* or *Boulder-Clay epoch* of geologists. Ages roll by; the land begins to rise again; newer currents are established; the climate grows less severe; and ultimately, within the limits of appreciable change, the sea and land, with all their varied tenantry (vegetable and animal), begin to assume their existing aspects. The Howe of Fife is still a long narrow arm of the sea, replete with seals and aquatic birds;* the valley of Ceres is a large shallow lake; and its drainage finds its way over the sandstones and greenstones that lie between it and the estuary of the Eden. The land still ascends; Stratheden is a plain of lakes and marshes; the stream from Ceres Loch still deepens its channel through the soft yellow sandstones, drains the lake, and, cutting still deeper and deeper, forms at length the romantic Den of Dura.

Skin-clad savages—we know not of what race—now seek shelter in the caves of Dura, or erect their wigwams on the slopes of Blebo, fish in the streams, or hunt with stone-spear and arrow the reindeer and wild ox in the plains of the Eden. Another and stronger race succeed, drive the old savage from the field, erect their hill-forts on Clatto, fight their battles at Kemback, raise their cairns on Cairngreen, and burn their sacrifices within the Druidic circle of Dairsie. The Romans come, push the Pict and Celt to the unhospitable hills, take possession of the more fertile valleys, and raise on the sacred circle of stones at Chapelwell † a chapel and altar to their god of victory. Sore pressed by the Goths, the Romans must attend to their own matters at home, and Britain is abandoned. A few, however, remain, and get amalgamated with the old Horestii of Fife; and by-and-by Culdee and Catholic missionary take possession of the Roman altar, and erect

* The remains of whales, seals, and arctic birds have been found in the post-glacial "brick-clays" of Stratheden.

† All the names in the neighbourhood—Dairsie, Kemback, Kinnaird, Blebo, Clatto, Dura, Cairngreen, Chapelwell and the like—bear ample evidence not only of the successive races who peopled the district, but even of the aspects of the country, and the events that took place.

thereon the first Christian church at Dairsie. They Christianise the rude inhabitants, teach them to cultivate the soil, and to erect corn and meal mills on the waterfalls of Dura Den. For the first time that old geologic stream, which has hitherto done nature's work, is diverted from its course, and associated with the wants and wishes of humanity. But Culdee and Catholic are alike amenable to the law of change and progress. Protestantism usurps their place. The old church and prelatical palace of Dairsie fall into other hands, and Dura Den becomes the witness of newer events. The cave in the yellow sandstone for which Pict and wild beast contended, shelters in turn the Catholic recluse and the Covenanting martyr. Protestantism, however, is but the religious phase of a freer and higher intellectual activity; and with that activity come new wants to supply, and newer desires to gratify. And so at length it comes about that the stream of Dura must do harder and heavier work. The meal and lint mills are removed, and the headlong current is now directed against the ponderous wheel of the spinning-factory, with its thousand shafts and spindles. As the workmen divert the watercourse for this purpose, the glittering fossil treasures of the yellow sandstone are revealed, and in 1836 Dura Den becomes geologically famous.

Strange that the requirements of the most mechanical of everyday arts should have been the means of unfolding the hidden treasures of nature to the eye of science! And, stranger still, that this revelation should take place only at the time when the minds of men were prepared to receive and appreciate! The old Pict would have valued a sling stone from the stream a thousand times more than the rarest of fossil fishes. To the Culdee and Catholic these relics of past life would have merely become the objects of superstitious reverence and error. Our forefathers, even up to the beginning of the present century, ignorant of the marvellous history that geology unfolds, would have ascribed the whole to that most convenient solution of all terraqueous difficulties — the Deluge; and so the matter would have lain misinterpreted and unimproved. The discovery of these fossil fishes in 1835 and 1836, when the credibility of geology was ardently discussed, and when the master-minds of the science were strongly directed to the old red sandstone, is surely something more than a mere coincidence. We are no audacious intruders into the designs of Providence, but to us the course of nature would be shorn of half its significance, did we cease to believe in the coadaptation of events, and the prearrangement of occurrences. Under this belief, the history of the past becomes hopeful, and its interpretation intelligible; without this conviction, the study of creation would be but an unencouraging task—a very dreary uncertainty.

Such, once more, is Dura Den. All honour to those—Dr George Buist, Dr Anderson, Mr Dalgleish, the lord of the manor, the British Association, and others—who have aided in the discovery of these fossil treasures! all encouragement to those who may yet assist in the interpretation of much that remains unexplained! To the student who has followed this brief and imperfect explanation, we trust that facts formerly known have been rendered somewhat clearer, and that things unknown before have been made intelligible. Should he visit the interesting locality—and it is not the less interesting because there the powers of nature have been made to minister to the wants of humanity, or the works of men have taken origin and position from the pre-existing works of God—these explanations may throw some new attraction round the objects of his visit, and may add to the enjoyment of his ramble. Should it be in winter, when the swollen stream rushes on in its impetuous course—in spring, when the yellow primrose stars the banks—in summer, when the overhanging foliage affords a grateful shade—in autumn, when the wooded cliffs assume a thousand fading tints—during day, when the hum of busy wheels mingles with the murmur of the waterfall—during the stilly gloaming, when the rustling of the leaf and the tinkling of the imprisoned stream are the only sounds that greet the ear,—it may be that a knowledge of these fossil forms shall awaken other thoughts than those suggested by the surrounding scenery, and these thoughts be hallowed by the reflection that under the spot on which he treads are entombed myriads of beings that were the objects of God's care thousands of ages before "man became a living soul," and that in these fossil forms we trace the essentials of the same vital plan on which our own life is founded, and by which its economy is governed.

SOILS AND SUBSOILS—THEIR NATURE AND ORIGIN.

GENERALLY speaking, the soils and subsoils of a country receive but scanty consideration from geologists, yet few things are more curious in their formation, none so indispensable in the cosmical purposes they subserve. It is true they are recent, and insignificant in mass, compared with the rocky crust which forms the great theme of geology; but considering how intimately they are associated with the manifestations of vegetable and animal life, as well as with the food-supplies of man, they are deserving of a closer inquiry, whether as regards their origin, their qualities, or their artificial amelioration. They meet us at every turn on the terrestrial surface, and, like the outer covering of plants and animals, give beauty and unity of outline to the stony skeleton that lies below—here levelling inequalities, there smoothing over asperities, and everywhere conferring on the harder elements softer and more attractive features. According to depth and quality they are wet or dry, cold or warm; here teeming with a luxuriant plant-growth, there scantily covered with the lowest forms of vegetable existence; here capable of amelioration by human ingenuity and industry, there defying all change, and doomed to everlasting sterility. There are few things, indeed, more varied in character, and none that tells so directly on the aspects, the fertility, the industry, or the general well-being of a country. Let us note a few facts relating to their origin and more conspicuous characteristics; and, first, of the origin of *soils*, and their slow and gradual formation.

Take the surface of the hardest and most refractory rock —say granite or porphyry; strip it of every loose and incohering particle, sweep it bare by the conjoint agencies of wind and water, and then let it remain exposed to the influences that naturally surround it. In a few years the gases of the atmosphere will have *weathered* and wasted the surface, the frosts disintegrated, and the winds and rains blown and washed the disintegrated fragments into the sheltered hollows and depressions. Insects, the droppings of passing animals, the drift of wind-borne debris, and the like, will mingle with the rocky fragments—and thus imperceptibly the naked surface receives the first beginnings of a soil. In a few years more, the air-borne spores and seeds of plants will germinate and take root, and, however feeble the growth of the lichen and moss, or other lowly plant, its annual decay is ever adding to and altering the character of the scanty mould; and thus, in the course of generations, the naked rock is covered with soil, partly through mechanical, partly through chemical, and partly through vital agencies. And as this soil is ever thickening and increasing, higher plants and higher animals will gradually find a new home—each in turn preparing the way for another—till at length, in the course of ages, the flinty rock is clothed with a fertile and life-sustaining envelope.

Take, again, the surface of the recent lava-stream, bare, blistered, and vitrified, and which looks as if it would resist for ever the powers of disintegration and decay; and yet see how it yields to the combined influences of chemical and vital action, and breaks down at last into soil and fertility.

The vine, olive, and myrtle clad slopes of Vesuvius, a few hundred years ago, may have been as rough and slaggy as the overflows of 1868; and these, in time and under the same agencies, will be covered with a similar mantle of softness and greenery. "The decomposition of lava," says Professor Phillips, in his recent work on Vesuvius, "is effected by the action of air and water, aided by the growth and decay of vegetation. According to the nature of the particular current, its order of silication, the state of its aggregation, and the presence of iron, alumina, soda, potash, magnesia, or lime, changes in the mineral substance are more or less easy. The carbonic acid of the atmosphere, with that derived from the decay of plants, operates slowly but effectually in breaking the chemical bond of union among the elements, and making new arrangements. The iron oxide becomes a hydrate or a carbonate, the alkalies are separated, and the rock is reduced to soil, on which plants operate farther changes. Even on the solid lava, the almost unobserved lichen—itself a sort of living fibre of stone—fixes its unfriendly hold, breaks up the firmest union of grains, and admits the farther action of other vegetable growth. Nor must we omit the supply of gaseous agents: sulphuretted hydrogen, productive of sulphurous acids, and carbonic acid, which is the long-enduring follower of eruptions, and ascends through innumerable fissures, to perform its almost universal work of disintegrating the not everlasting rocks."

Or take the sand of the sea-shore blown by the winds beyond tide-mark, and left high and dry in its barren purity. Spotless and glittering in the sunshine as it may remain for years, the time will come when some drifted seed of maritime plant will take root and bind the shifting surface into clumps. Other plants will gradually follow, and their annual decay, together with fragments of seaweed, the droppings of sea-fowl, the wasting of the shells incorporated in the sand, and the like, will prepare the way for the stronger sand-reed with its conservative roots, and then the first beginnings of turf or surface-soil is established. We have watched the process by the sandy shores of the Tay and Eden, where acres of barren shifting sands are now clothed with a luxuriant growth of sand-reed, mosses, sedums, grasses, rest-harrow, trefoils, and other plants, whose annual growth and decay, incorporated with the remains of insects, the droppings of rabbits and sheep, and other animal exuviæ, are gradually accumulating a layer of dark and composite soil. And in this way, and none other, have millions of acres of sea-formed sands been converted into dry, rolling, pleasant, and profitable pasture-lands.

Or still farther, let us take the oft-repeated instance of the coral islet, and note, as it emerges from the sea, how its own fragments pounded into sand by the surf, together with broken shells, sea-urchins, dead fishes, and other marine exuviæ, are gradually forming a receptacle for the nuts and seeds that may be drifted from some older land. These seeds come at last; the cocoa-palm strikes its roots, and waves its feathery fronds along the shores of the solitary atoll—the first harbinger of other vegetable forms, whose growth and decay will in a few generations clothe the sunny islet with a soil of the richest fertility. This conversion of the coral-reef into a fertile island is well illustrated by Pratas Island, about 170 miles from the mainland of China, and 250 from Formosa. "This islet," says Dr Collingwood, "is about a mile and a half long, and half a mile wide, and is only visible at a distance of eight or nine miles in clear weather—not rising in its highest part more than twenty or thirty feet above the level of the sea, though the bushes that cover some parts give it an additional elevation of ten feet or so. It is formed entirely of coarse coral sand or debris, generally shelving gradually, but in some parts having a steep bank about three feet high. The interior is rough and irregular from accumulations of similar white sand blown up from the shore; and so overgrown is it with shrubs as to be in some parts almost impenetrable, though the soil might be supposed to be anything but favourable to vegetable growth, nothing but sand being everywhere visible, and that of the coarsest and loosest description."

Even the stagnant pool, the quaking morass, and the long reach of sea-mud, gradually acquire by accumulation and drainage a surface consistency; and on that surface, where the green scum formerly mantled, now spring up terrestrial plants, whose growth and decay, associated with animal exuviæ and the castings of the earth-worm, are season after season converting the whole into rich and exuberant soil. This effect of the earth-worm was long since noticed by White in his 'Natural History of Selborne,' who remarks, that "by perforating and loosening the soil they render it pervious to the rain and to the fibres of plants; and by drawing straws and stalks of leaves into it, and especially by throwing it up into coils called *worm-casts*, they fertilise it—for that matter, being their excrement, is a fine manure for grain and grasses." More recently, Mr Darwin has shown that worm-casts, which so annoy the gardener by defacing his smooth-shaven lawns, are of no small importance to the agriculturist; and that this despised creature is not only of great service in loosening the earth, but is also a most active and powerful agent in adding to the depth of the soil, and in covering comparatively barren tracts with a superficial layer of fertile mould. His attention had been directed to several fields at Maer Hall in Staffordshire, some of which had, a few years before, been covered with lime, and others with burned marl and cinders, which substances had in every case been buried to the depth of several inches below the turf, just as if (as the farmers believe) the particles had worked themselves down. After showing the impossibility of the supposed operation, Mr Darwin affirms that the whole is due to the digestive process by which the common earth-worm is supported; since, on carefully examining between the blades of grass in the fields above mentioned, he found there was scarcely a space of two inches square without a little heap of cylindrical castings of worms—it being well known that worms swallow the earthy matter, and that having separated the nutritive portion, they eject at the mouths of their burrows the remainder in little intestine-shaped heaps. The same observer notices a still more remarkable instance of this kind, in which, in the course of eighty years, the earthworm had covered a field, then manured with marl, with a bed of fine rich mould, averaging thirteen inches in depth! Indeed there is no portion of the earth's crust that has not a tendency to be transformed into soil—whether by mechanical, chemical, or vital agency—save where the restless winds are ever shifting the loose material, the rains ever washing away, or the volcano ever scattering abroad its scorching showers of cindery and clinkery material.

And when the minute agencies by which these soils are formed, and their consequent slow rate of augmentation, are taken into consideration, it must be evident, thin and insignificant as they may appear in comparison with the underlying strata, that many of them must be of venerable age, and long antecedent to the historic era. The turf with which the Romans, two thousand years ago, faced the circumvallations of their encampments, had depastured the herds of the natives ages before the invaders set foot on these islands; and long before savage man erected his wigwams on British soil, that soil had been gradually accumulating under the conjoint influences of mechanical disintegration, chemical change, and vital aggregation. When digging through some fertile loam, with here a land-shell and there a tooth, here a bronze spear and there a flint arrow-head, here the wood-ashes of some savage fire and there a circle of calcined cooking-stones, how little do we reflect on the long lapse of time of which these relics give evidence, or of the high antiquity of the earthy envelope that contains them! To the antiquarian and geologist this mere epiderm or scarf-skin of the earth's crust is a thing of deep and enduring interest, connecting the past with the present, and man and his works with the manifold forms that preceded him.

Such are the *soils* composed of inorganic and organic materials. Let us now turn to the *subsoils*, or purely mineral accumulations that lie beneath them. The former, being partly composed of organic material, and being exposed to the direct influences of air and rain, consist of many varieties—loams, sandy loams, clayey loams, unctuous clays, bog-earths, vegetable moulds, and the like; while the latter, unaffected by surface influences, consist mainly of clays, sands, gravels, and other rocky debris. Between the two, or immediately underlying the fertile soil, there frequently occurs what is termed by farmers a "sole" or "pan"—a thin hard layer of ferruginous or calcareous earth inimical to vegetation, and formed by matter dissolved from the soil and carried down by the percolation of rain-water. Beneath this "pan," where it occurs, lies the true subsoil, and may consist either of the disintegrated underlying rock-formation, of boulder-clay, drift-sand, or gravel, or it may be the miscellaneous silts of some dried-up lake, or the clay-silts of some carse or upraised estuary. These subsoils all vary, less or more, with the locality; here decomposed trap-rock, dry and friable—there the decomposed outcrops of sandstones and shales, tough and less pervious to water; here carse-clays and lake-silts soft and wet, but highly capable of amelioration—there boulder-clays, tenacious, retentive, and defying all culture; here drift-sands and gravels, dry and irregular in composition—there marine sand-silts, compact, variously retentive, and homogeneous in aggregation. In fact, the subsoils, properly so called, are merely those portions of the "superficial accumulations" of the geologist which are placed beyond admixture with organic matters, and consequently remain unconverted into dark, pulverulent, and fertile soils. But though not themselves converted into soils, many of them are capable of profitable admixture with the soils we cultivate, and a knowledge of their presence and nature is ever of advantage to the agriculturist. Here a tenacious and too retentive clay may be rendered friable and pervious by an admixture of sand, there a light sandy soil may be improved by an admixture of clay; here a soft vegetable mould may be consolidated by an admixture of loamy earth, and, *vice versâ*, a poor silicious soil may be rendered sufficiently fertile by a corresponding admixture of vegetable mould. Soil and subsoil are intimately connected in formation and history; and with a sufficient knowledge of geology, the former could in many instances be rendered deeper, richer, and more fertile, and this by the mere admixture and treatment of the mineral matter that lies beneath it.

And if the soils in many instances give evidence of their high antiquity, and carry us back through thousands of years of slow and gradual accumulation, how much more must these subsoils, whether lake-silts, estuary-silts, river-drifts, or glacial accumulations! Though, geologically speaking, they are the most recent and superficial of all formations, yet, chronologically, they carry us far beyond human times, and to the days of the glacier and ice-sheet that enveloped all the higher latitudes of the northern hemisphere. From then till now, all that has been borne and laid down by the glacier and iceberg over the rocky formations—all that has been formed and accumulated by frost, rain, and wind, by river, lake, and wave—belong to these Post-Tertiary formations, which are thus invested with a geological interest not inferior to that of any of the older systems. Though seldom noted on our maps and little studied in detail, these soils and subsoils are really of high geological interest, whether as regards their mode of formation, their composition, the fossil relics they contain, or their indispensable presence for the manifestations of vegetable life and agricultural fertility. In their composition and mode of aggregation we detect the agencies that have been at work from the glacial period down to the present day; in the relics they contain we can trace the local extinction of life-forms, and often the successive stages of the human inhabitants, thus giving them an antiquarian as well as geological interest; and in their relative natures, science can detect the means of their admixture and amelioration, and thus confer upon them, and especially upon the soils we cultivate, new and increased fertility and amenity. But it is less from an economical than from a scientific point of view that we now regard them—directing the attention of the young geologist to a subject of interesting study in every field through which he takes his walks, and in every superficial opening that has been made by the spade and pick-axe of the delver and ditcher.

RAINPRINTS, SUN-CRACKS, FOOTPRINTS, AND BURROWS.

In rainprints, sun-cracks, ripple-marks, footprints, miscellaneous tracks, and burrows, we are furnished with a set of fossil evidences of rare and curious interest. What more marvellous than that the shower which fell millions of ages ago should have registered in the earth's crust not only its intensity, but the direction of the wind by which it was driven; what more wonderful than that the wandering water-bird of bygone epochs should have left its footprints in the same crust when every other evidence of its existence has been destroyed! These "physical and physiological impressions," as they have been termed, are indeed surpassingly strange, and often startle the young geologist more than the discovery of the veritable substance of a fossil organism. He is prepared, in some measure, for shells, bones, and other organic remains, but traces like these are beyond his expectation, and when discovered, he views them not only with wonder, but with a certain amount of doubt and incredulity. Let us take a passing glance at their nature, their modes of occurrence, and the leading facts which they so instructively reveal.

And first, of the *rainprint*, which can be traced on rocks of all formations, from the sandy slabs of the Silurian up to the desiccated muds of the summer just gone by. As on these muds the heavy thunder-shower left its deeper indent and elevated margin, the drifting blast its slanting impress, and the gentle rain its less distinct and close-set patter, so all of these in their varying intensities have been registered in the rocky crust—proving, if aught can prove, that in every epoch of the world's history winds have blown and rains have beaten even as they still blow and beat around us. On the Old Red Sandstones of Forfarshire (Ferryden) we have seen rainprints of the deepest intensity; on the Millstone Grit of Derbyshire (Buxton and Whaley Road) we have traced the slanting spatter of the wind-driven shower; and on the Carboniferous flags of Linlithgowshire (Kirkton of Bathgate) have discovered the closer patter of the gentler rainfall, and this crossed and recrossed by the winding track of an annelid or of a mollusc, just as the rainprints on muds of the present day are frequently crossed by the trail of the earth-worm. In all of these instances there could be no doubt as to the producing agent; and to render the evidence still more certain, we constructed in 1858 a mud-tray, in which every form of rainfall was temporarily registered, and in each case the resemblance was perfect. Indeed, if we had dried these rainprints of 1858, and covered them over with a coating of mud-silt or sand-silt, and allowed both to harden, the mould and its cast, on splitting, would have been in almost every example undistinguishable from those of the palæozoic flagstones.

And in the same way the *sun-crack* or *desiccation-crack* has registered in the rocky crust its evidence of drying winds and evaporating sunshine. These sun-cracks occur, too, in all formations, and for the most part on the surfaces of fine-grained argillaceous flagstones. Some of the finest examples we have witnessed were taken from the yellow sandstones of Dura Den (now or lately in Cupar Museum), and from a quarry of Lower Carboniferous age at Grange, near Edinburgh; but equally startling specimens are of frequent occurrence in the New Red Sandstones of Cheshire and Dumfriesshire. Let the observer note some shallow pool or clay-pit when the drought of summer has evaporated the water, and he will find that the clayey mud begins to shrink and crack in a most fantastic fashion, and occasionally with something approaching to geometrical regularity. Let him suppose this fissured mud to be thoroughly dried and hardened, and then overlaid by a new deposit of sandy silt or other sediment; and further, that both are consolidated into rock, he would find, on splitting them asunder, the mould and cast preserved in every line to the minutest reticulation. And this is precisely what the geologist discovers in these old-world sun-cracks—some reticulated like the venation of a gigantic leaf, others tessellated like a work of art, and some again so curiously arranged that they have been mistaken by the quarrymen for the tracery of Gothic windows, and noted in local newspapers as antiquarian marvels. These desiccation-cracks are often, indeed, of very curious interest, and, as might be anticipated, the overlying bed, or that retaining the *cast*, is that which presents the most entire and satisfactory evidence—the cast being always less or more raised or in relief, whereas the mould usually appears as a hackly and imperfect depression.

Belonging to the same category as the rainprint and sun-crack are those *water-marks* or *ripple-marks*, whose tiny undulations diversify the surface of many sandstones in all the stratified formations. As the existing shore-sands are frequently rippled by the receding tide, or as the lighter sands of terrestrial tracts are thrown into similar wavelets by the passing winds, so have these old sandstones been rippled and hardened and preserved in the integrity of their undulated surfaces for millions of ages. Nor is it merely the ripple-mark that has been preserved, but frequently over this ripple the trail of the annelid or of the mollusc may be traced as clearly as it can be followed over the sands that have been deserted by the latest tide. The finest of this description we have ever witnessed occurred on the Old Red flagstones of Ardoch Mill, in Perthshire, and there the ripple extended over every foot of exposed surface, and was marked throughout by the winding trails of some annelid, or of some gasteropod mollusc. In examining these ripple-marks, the question may sometimes be raised, Are they water-ripples or wind-ripples, or how can the one be distinguished from the other? It is true there is a close similarity between all kinds of ripple, whether produced by tides, by gentle movements of shallow water, or by gentle currents of wind; but seeing that these ripples are so frequently traversed by winding trails, and knowing, moreover, that they must have had sufficient consistency to retain the form of these tracks, the likelihood is that the greater portion we witness on sandstone surfaces have been formed on the shores of open seas and tidal estuaries.

But wonderful as these mere physical impressions are, they fall short of the interest which attaches to the physiological—the *footprints*, the *tracks*, and *burrows* of creatures that flourished during these far-distant epochs. As the sea-bird and reptile leave their footprints on the silty shores of existing seas and estuaries, so the old wader and amphibious reptile left their foot-tracks on the shores of palæozoic and mesozoic waters—here traversed thickly and indistinctly in crowds, and there singly and distinctly, footfall after footfall, in continuous directions; here in a single bipedal row, and there in a double quadrupedal series.

There can be nothing more beautiful and convincing than these *ichnites* or fossil footprints (Gr. *ichnon*, a footstep), whether they be those of birds, of reptiles, or of lowlier creatures. Though no bone, nor tooth, nor scute of the creatures may have been detected, yet there the impress of the foot is conclusive of its presence, and often indicative of its kind and proportions. Though *ichnites* have been discovered in all formations—from the Silurian upwards—it is chiefly those in the New Red Sandstone (Hildburghausen in Saxony, Stourton and Taporley in Cheshire, Corncockle in Dumfriesshire, Cummingstone in Moray, and Connecticut in North America) that have received the attention of palæontologists. On some of these New Red flagstones the footprints are evidently those of birds (*ornithichnites*) with the impress of every toe, and the corrugations of the skin entire; while on others (or intermingled with those of birds) the implants are those of reptiles (*sauroidichnites*)—sometimes light and slender as those of a lizard, and sometimes heavier and more decided than those of the largest crocodile. And here, in the New Red Sandstone, where no bird-bone has yet been discovered, these footprints become the only and sufficient testimony to the palæontologist that, on the shores of these old tidal waters, birds of various orders wandered in quest of food—now searching slowly with tortuous step, and now coursing rapidly with lengthened stride and heavier footfall. To the student who may not have the opportunity of examining these curious impressions in the field, we could not recommend a source of a few hours' more pleasant study than the 'Ichnology of New England,' by Professor Hitchcock; the 'Ichnology of Annandale,' by Sir William Jardine; or the 'Fossil Foot-marks in the Red Sandstones of Pottsville, Pennsylvania,' by Professor Lea of Philadelphia.

Besides these undoubted footprints of birds and reptiles, there occur on many flagstones various *tracks*, as if made by the more numerous feet of crustacea, or by the pectoral fins and fin-spines of fishes. In these instances the tracks are usually arranged on either side of a medial trail, as if the creatures had dragged their caudal extremities with more or less effort over the still unsolidified surface. Such tracks are occasionally found on the finer surfaces of the Old Red flagstones (Ferryden, Balruddery, and Ardoch), and have likely been formed by some of the crustacea (*eurypterites*) that abound in that formation; while others in the Carboniferous system (Fifeshire and Mid-Lothian) may have been produced by the pectoral spines of fishes, such as those of the gyracanth, which, from their worn extremities, seem to have been used in moving along the sea-bed, if not even for shorter periods along the open shores.* These tracks, whether made by the patter of many-footed crustacea, or by the slower oaring of pectoral-spined fishes, have received as yet but slight attention from palæontologists; but they form a curious subject of research, and as they are by no means uncommon, they are well deserving the study of the young and ardent inquirer. Along with a knowledge of the fauna of a formation, they may indicate habits and functions which the organisms themselves may fail to furnish, and thus contribute to a more thorough understanding of the life-relationships of the period to which they belong. It is no ordinary gratification to study the structure of a palæozoic crustacean, but it is something more to trace the character of the track which that structure left on the sandy sediments of its native waters.

The next set of impressions which demand our attention

* Several existing fishes are known to have this habit of using their pectorals, and of temporarily leaving the water—such as the mottled angler, the climbing-perch of India, an allied genus in the Amazon, noticed by Professor Agassiz, and that still rarer fish of the Nile and its Abyssinian tributaries alluded to by Sir Samuel Baker.

are those designated *trails*, resembling the winding course of the earth-worm on a muddy surface after a summer shower, or that of the natica and periwinkle on the slimy silt of the sea-shore. Such trails appear in great profusion on the smooth surfaces of flaggy sandstones, and in all formations; sometimes with slight lateral ridges, as if formed by smooth-ringed annelids—sometimes broader and jagged, as if by fimbriated annelids—sometimes shallower and corrugated, as if by gasteropod molluscs—and at other times more tortuous and cylindrical, as if produced by some minute and burrowing crustacean. They are, indeed, very varied in form; and when it is borne in mind that such trails are now produced by many kinds of annelids, by gasteropod molluscs, and by minute crustaceans, it will be seen how difficult it is to pronounce with certainty as to the nature of this kind of fossil impression. As yet they have been but imperfectly examined, palæontologists contenting themselves with giving them a name (*helminthites*, &c.), rather than investigating their differences and minuter specialties. We have watched the tracks of annelids, molluscs, and minute crustaceans, and noted their differences; but once on a surface of mud we traced a trail more suddenly tortuous and differing from either of these, and after a distance of three or four feet arrived at the producing cause, and found it to be a poor bemired bee that had struggled onward and forward till it stuck fast and died of exhaustion! So different may be the producing agents, and so much the more need, therefore, of careful and cautious discrimination.

The last kind, but not the least curious, of these impressions to which we will here advert, are those designated *burrows*—tubular perforations, as it were (but, of course, now filled up), in sandstones of all formations, from the Cambrian to those of the Tertiary period. In many instances these so-called burrows (*arenicolites*) are not larger than those of the lob-worm, and are often surmounted by a mass of *worm-cast* or internal ejection; but in other instances, such as in the Old Red Sandstones of Forfarshire, we have seen them from twelve to twenty inches in depth, and in irregular diameter from one to three inches. Whether all are really the burrows of annelids is yet an unsolved problem; but, considering their frequency in some cases, and their occurring in pairs like those of the lob-worm, together with the presence of *castings*, little doubt can be entertained that many are truly the result of burrowing worms, whose habits were much akin to those of species that still frequent our sandy shores and muddy sea-beaches. Much greater difficulty occurs in determining the nature of the tortuous burrows (*scolites*) which run along the surfaces, or immediately under the surfaces, of many flaggy sandstones, and especially of those in the Carboniferous, Limestone, and Millstone Grit series. Whether they have been produced by annelids, by fossorial crustaceans, or by some other burrowing creature, it is extremely difficult to determine; and though the general opinion seems to lean to annelid agency, yet it must be confessed that this seems founded more on mere resemblance than on true scientific discrimination.

Such are these "physical and physiological impressions"—rainprints, sun-cracks, ripple-marks, footprints, tracks, and burrows—which cannot fail to arrest the attention of every practical worker in the field of Geology. They occur in every formation, and especially on those argillo-arenaceous beds which mark the tidal and inundation limits of shallow shores and river-estuaries. They are valuable as evidences of former natural operations, and as evidences of the presence of life-forms of whose existence we have no other traces; and they are curious as showing us how wonderfully minute the register which nature keeps of her commonest and most transient transactions. We know of nothing more startling than many of these impressions, and certainly of nothing that more directly encourages the hope of Geology yet attaining to something like a history of this world of ours through all her former phases and transformations. If such physical facts as rainfall, drought, wind-ripple, and water-ripple, and such vital operations as the walking of a bird, or the crawling and burrowing of a worm, have been registered with unerring care, can we doubt for a moment that thousands of those "missing links" in the continuity of life which science now desiderates, will one day, and in good time, reward the research of the earnest and diligent geologist?

RAISED BEACHES AND SUBMARINE FORESTS.

THAT the relative level of sea and land is frequently disturbed by earthquake convulsions is matter of common observation in every region of volcanic activity. Here the land may be suddenly and permanently submerged to the extent of several feet, there the sea-bed may be as suddenly and permanently elevated into dry land. Such oscillations are by no means uncommon in countries subjected to earthquake disturbance — Chili, New Zealand, West Indies; and the observer perceives at once the cause of their production. But in many regions far removed from volcanic activity there is a slow and gradual process of upheaval and depression going forward—so slow, that its effects become perceptible only after the lapse, it may be, of several centuries. To these slow oscillations the name of "crust-movements" has been given, and whatever their origin, they are not to be confounded with the upthrows and downthrows of the earthquake. The motions of the earthquake are sudden and decided, and for the most part restricted to limited areas; crust-movements, on the other hand, are almost imperceptible, and extend continuously over many degrees of latitude and longitude. Earthquakes we at once associate with the internal fire-forces of the globe; crust-movements we cannot help connecting with the same source, although unable in the mean time to determine the precise mode in which the expansions and contractions are effected. It is to these crust-movements that we ascribe those long level lines or terraces of raised beach which occur along our own islands, as well as along the seaboard of many other countries; for, however slow the process—were it even to a small fraction of an inch per year—it must, in the long-run, leave its traces on the configuration of the land, and this whether in cases of depression or upheaval. The most obvious results of these crust-movements are *Raised Beaches*, or old sea-margins, and *Submarine Forests*, or submerged forest-growths—the former giving evidence of upheaval, and the latter of depression, or, it may be, of oscillations both of submergence and emergence. To these, therefore, we devote the present sketch, noting the proofs they afford of former geographical conditions, and at the same time the influence which all such oscillations must exercise on the climate and flora and fauna of the regions in which they occur.

Every one is acquainted with the existing sea-beach or narrow belt over which the tide alternately ebbs and flows; here consisting of miscellaneous silt, there of sand; here of gravel and shingle, and there of a mere shelf or caverned line along the rocky precipice. Whatever its nature, it preserves a uniform level; and in any general movement of upheaval, whether to the extent of five or of fifty feet, this level would be preserved, and the new "raised beach" or "old sea-margin" would run like a shelf or terrace all along the seaboard of the country. It would vary, of course, in breadth—forming a broad level expanse at the mouths of certain rivers, a narrow terrace along the softer rocks, and a mere water-mark along high and refractory cliffs. Such terraces or old sea-levels are common along our own shores and those of the opposite continent, along the coasts of Northern Europe and Asia, along the shores of North Greenland and the arctic islands, as well as along the southern seaboards (Pacific and Atlantic) of South America. Some of these raised beaches are of high antiquity, and date back as far as the glacial epoch; others approach nearer our own time; and in some tracts, the process, though perceptible only at distant intervals, is still going forward. And as some tracts are thus slowly emerging from the waters, so others, like the southern extremity of Greenland, the southern shores of Scandinavia, and the seaboard of the Carolinas in North America, are as obviously sinking beneath them. Depressions, however, are less obvious than upheavals—the latter leave their traces on the dry land to be examined and compared, the former carry most of their evidences beneath water, and beyond the reach of investigation. But in either case there is always sufficient evidence to determine upheaval or depression; and of this evidence, the most remarkable features, perhaps, are the raised beach and the submerged forest.

If it be true that during the glacial epoch our islands were submerged to the extent of 2000 feet or thereby, the land, as it re-emerged from the waters, must have been marked by numerous sea-margins at great elevations; but these having been so long subjected to the obliterating influences of frosts, rains, and runnels, are not now to be traced with anything like certainty; and he would be a bold observer who should venture to pronounce on any well-defined sea-margin beyond the altitude of two or three hundred feet. From this limit downwards the evidences become more certain—the line of level is more continuous; and in the sea-worn sand and gravel, as well as in traces of marine exuviæ, we have frequently completion of the proof. Of course, the longer the land stood at any one level, the deeper and more decided the incuttings of the sea; and, on the contrary, the more rapid the uprises of the land, the less marked the beaches or old sea-levels. From 120 feet down to the present sea-level, we have a series of well-marked shore-lines—120, 63, 40, 25, and 12 feet—marking a succession of uprises, and these clearly all prehistoric, if we except the last, which indicates, on the whole, no very high antiquity. When our islands stood at 120 feet lower than at present, a vast area of the present seaboard, the most of our estuary plains and larger river-valleys, must have been under water; and any evidences of sea-margins at higher levels must have still reduced the dimensions of the dry land. Every successive uplift has therefore increased the dimensions of the British Islands; but every uplift has at the same time decreased the general temperature of the country in the proportion of one degree of Fahrenheit for every 250 feet of uprise or thereby.

These raised beaches are not all alike well marked and decided, owing partly to the nature of the rocks into which they have been respectively cut, and partly, as has been already observed, to the length of time at which the sea stood at these respective levels. The lowest or 12-feet beach is generally marked by terraces of recent shells and gravel, and in some parts by caverns in the existing sea-cliffs, but of course to that extent above the reach of the waters. Though the latest and perhaps least defined of British raised beaches, this uprise must have taken place long antecedent to history; and there is not, so far as we are aware, any certain evidence either of upheaval or depression since the time of the Romans, although certain misinterpreted appearances have led some observers to an opposite conclusion. Any remains found in the caves of the 12-feet beach are savage and pre-Celtic—showing that the uprise had taken place before (and it may have been very long before) the occupation of these primitive inhabitants. The 25-feet beach is perhaps the most striking—stretching for miles in unbroken continuity, composed also in many districts of recent shells and gravel, frequently backed by old caverned cliffs, and forming the level site for most of our modern seaports and fashionable watering-places. At this level the sea must have stood for ages, eating into the cliffs which now form a picturesque background to our maritime villages, and laying down in the estuaries much of that clay-silt which now constitutes the bulk of our fens and carses. The 63-feet beach is also well defined on many tracks of the seaboard, but its once overhanging cliffs have been obliterated by the tear and wear of the elements, its shells and exuviæ dissolved and destroyed, and its gravel-beds now covered for the most part by soil and greensward. Of the higher beaches little is known with precision or accuracy, and the most that can be said is, that certain elevated flats and terraces seem to be old water-levels, and these levels the result of marine degradation. In discriminating the shells, starfishes, and other organisms that occur in the upraised silts and clays of former sea-beds, we must ever bear in mind that different zones of depth are characterised by different forms, and that those forms are often of themselves sufficient to prove the extent of the uprise—whether it has been 10, 20, or 40 fathoms.

As along our own shores so along those of Northern Scandinavia, as described by Sir Charles Lyell in his 'Principles of Geology;' the shores of Spitzbergen, as noticed by Mr Lamont in his 'Seasons with the Sea-Horses;' the seaboard of Siberia, as commented on by Von Wrangell; the coast of North Greenland, as depicted by Dr Kane in his 'Arctic Explorations;' the shores of most of the arctic islands, as often noticed by voyagers such as Ross, Belcher, and Armstrong; and along the coasts of Chili and Patagonia, as long ago described by Mr Darwin in his 'Journal of a Naturalist.' In these cases the beaches are at various elevations—10, 20, and 40 feet; Mr Lamont mentions 20, 60, and 120 feet; and Dr Kane noticed a series of terraces rising in some instances to the height of 480 feet.* Such uprises in these boreal latitudes must be attended by a marked diminution of temperature; and as the highest of these terraces are of no great antiquity, geologically speaking, great changes must have taken place in the flora and fauna of these regions. And hence it is that the flora has been gradually dwindling away, and the fauna (musk-ox, reindeer, Esquimaux, and Omiaks) as gradually

* "The opportunity which I had to-day (23d March 1855) of comparing the terrace and boulder lines of Mary River and Charlotte Wood Fiord, enables me to assert positively the interesting fact of a secular elevation of the crust, commencing as yet at some undetermined point north of 76°, and continuing to the Great Glacier and the high northern latitudes of Grinnell Land. This elevation, as connected with the equally well sustained depression of the Greenland coast south of Kingatook, is in interesting keeping with the same undulating alternation on the Scandinavian side. Certainly there seems to be in the localities of these elevated and depressed areas a systematic compensation. I counted to-day forty-one distinct ledges or shelves of terrace embraced between our water-line and the syenitic ridges through which Mary River forces itself. These shelves, though sometimes merged into each other, presented distinct and recognisable embankments or escarps of elevation. Their surfaces were at a nearly uniform inclination of descent of 5°, and their breadth either 12, 24, 36, or some other multiple of twelve paces. This imposing series of ledges carried you in forty-one gigantic steps to an elevation of 480 feet; and as the first rudiments of these ancient beaches left the granites which had once formed the barrier sea-coast, you could trace the passing from drift-strewn rocky barricades to clearly-defined and gracefully-curved shelves of shingle and pebbles. I have studies of these terraced beaches at various points on the northern coast of Greenland. They are more imposing and on a larger scale than those of Wellington Channel, which are now regarded by geologists as indicative of secular uplift of coast. As these strange structures wound in long spirals along the headlands of the fiords, they reminded me of the parallel roads of Glen Roy—a comparison which I make rather from general resemblance than ascertained analogies of causes.—Kane's Arctic Explorations, ii. 81, 82.

declining in numbers and area of diffusion.* Such great cosmical changes may pass unnoticed for generations, but in the long-run they leave their impress too strongly on external conditions not to be both seen and felt; and as such changes now go forward, so we may rest assured they have in former ages been the means of similar geological, climatal, and vital results.

When we turn, on the other hand, to the slow downward movements of the crust, we find them much less perceptible than those of uprise, and it is chiefly through works of art —harbours, houses, and the like—and through the more sluggish flow and drainage at the mouths of rivers, that we become convinced of their existence. The downward set of South Greenland, for example, is proved by the submergence of early Danish erections, and that of the Southern States of North America by the increase of sea-swamps, and the further inset of the tidal waters; but in other instances, the gradual submergence is only suspected from the absence of shore-deposits, and the gradual encroachment of the sea upon the dry land. In the case of *submerged forests*, however, the evidence is conclusive, not only of depression, but,

* Alluding to the gradually decreasing population of Siberia, Von Wrangle mentions a saying of the natives, "that there were once more hearths of the Omoki on the shores of the Kolyma, than there are stars in the clear sky." He also mentions the occurrence of forts formed of the trunks of trees, and of tumuli (the latter especially near the Indigirka) which he supposes to have been erected by the Omoki, who have now disappeared.

Referring to the same subject, Dr Kane says of Greenland :—"There is no doubt on my mind, that at a time within historical and even recent limits, the climate of this region was milder than it is now. I might base this opinion on the facts, abundantly developed by our expedition, of a secular elevation of the coast-line. But independently of the ancient beaches and terraces and other geological marks which show that the coast has risen, the stone huts of the natives are found scattered along the line of the bay in spots now so fenced in by ice as to preclude all possibility of the hunt, and, of course, of habitation by men who rely on it for subsistence."—Arctic Explorations, i. 308.

in most instances, of re-elevation, or, in other words, of oscillations of the sea-level even in regions like our own, where the crust-movements have had a general upward tendency since the close of the glacial epoch. These submerged forests constitute, indeed, a curious, and as yet imperfectly explained, episode in the geological history of the British Islands, and demand more exact investigation, both as regards their levels, the nature of their vegetation, and the character of their imbedded fauna. They occur at many localities around our islands: the shores of Moray; the Firths of Tay, Eden, and Forth; near the Tyne, Tees, and Humber; along the coasts of Lincoln and Norfolk; near Exmouth and Plymouth; the Mersey and Morecambe Bay; and generally where the coast is flat, and dipping gradually away beneath the waters. We have examined them, as occasionally exposed near the Tay, Eden, Largo Bay, Hartlepool, and the Humber, and find in these, as well as in those described by others, a wonderful amount of resemblance—pointing all to the same period, and the same conditions of submergence.

In all there is the same peat-like accumulation enclosing the prostrate trunks of oak, fir, birch, alder, hazel, and willow, and not unfrequently the stools of these trees imbedded firmly, and as they had grown, in the dark clay bed beneath. The upper portion is generally the more peaty, and consists of mosses, grasses, equisetums, and other aquatic plants; the under portion is the true forest-growth of trunks, branches, and leaves, together with layers of sphagnum, and usually enclosing seeds, hazel-nuts, acorns, and the wing-cases of beetles, and occasionally the antlers of elk and gigantic deer. The whole forms a consistent bed, from two to five feet thick, of peat, or peaty lignite, which had evidently been formed before submergence, and which is again overlaid by a marine silt or clay, containing recent shells, and varying, according to locality, from twelve to twenty feet. The inferences to be drawn from the occurrence of these submerged forest-growths all round the British Islands are—*first*, that these forests grew high and dry, and at considerable elevation above the sea-level; *second*, that a downward movement of the land destroyed the drainage of the flats on which they flourished, and that they were consequently overthrown and converted into peat-mosses; *third*, that the movement of the land being still downwards, these forest-beds were submerged and covered by a great thickness of sea-silt; and *fourth*, that after a long submergence an upward movement again took place, thus converting these sea-silts into alluvial tracts, and exposing, at very low tides, the subjacent forest-growths. Here, then, we have convincing evidence both of downward and upward movements of our island areas at (geologically speaking) a comparatively recent period, and evidence, moreover, of change in geographical and climatal conditions.

We have evidence of geographical change inasmuch as all the forest-beds extend seawards to unknown limits, and consequently prove that the area of the British Islands was much more extensive during the period of their growth—so extensive, indeed, that in all likelihood the low south-eastern coasts of England were in contact with the corresponding low tracts of Holland and Denmark. Again, they indicate considerable alteration in climate, for oaks and firs of such dimensions (oaks from three to four feet in diameter) could not now be grown in promixity to the German Ocean; while the character of the insects, which seem to have thronged the forests in myriads, presents a more southern facies, or such as is now to be found in the latitudes of the Spanish peninsula. On the whole, the submerged forest-growths, whether as regards their extent, or the character of their flora and fauna, tend to prove that, since the glacial epoch, there has been not only upward and downward movements of these islands, but a period of considerable duration when they enjoyed a more genial and equable climate than they do at the present day.

That the higher latitudes of the northern hemisphere enjoyed a more genial climate during a period between the glacial epoch and the present day is corroborated, not only by these submerged forest-growths of Great Britain, but by the masses of decayed and semi-fossilised wood which occur in many localities within the arctic circle. Such masses, sometimes as *drift*, and other times *in situ*, have been noticed by many voyagers—by Dr Armstrong in Baring Island (74° 27′ N.), by the exploring party of the Resolute in Prince Patrick Island, by Lieutenants Hedenström and Anjou in New Siberia, by Sannikov in Kotelnoi Island (75° 30′ N.), by Von Wrangell in the tundras or moss-steppes of Siberia proper, and, indeed, by almost every explorer in these distant regions.* From the nature and size of the trees, from their comparatively recent appearance, and from the character of the soil and loose deposits in which they are imbedded, it would seem they are of no great antiquity, geologically speaking, and in all likelihood were contemporaneous with our own submerged forests. Should this be the case, we have a new and curious chapter in geological history opened up—namely, that of a warmer climate all over the northern hemisphere, somewhere between the glacial epoch and the current era. It is a subject of most curious interest, and is worthy of further research, as bearing most intimately on the now much-discussed question of secular variations in climate, as depending on fixed and astronomical causes. Coming nearer our own time than the glacial epoch, this warmer period may be more readily

* See the arctic explorations of Ross, Richardson, Belcher, Armstrong, Von Wrangell, and others.

accounted for; and the occurrence of similar masses of fossilised wood in the islands of the antarctic seas, where the scantiest vegetation is now barely possible, might be a further aid to the solution of the problem. It is thus that all things hang together, and, from a plant to a planet, are mutually dependent—the apparently trivial occurrence of a submerged forest-growth leading to the most important of cosmical demonstrations.

The general conclusions to be derived from the occurrence of these old sea-margins and submarine forests are: that the crust of the earth is subject to slow movements of uprise and depression, not to be confounded with those of the earthquake, which are abrupt, and for the most part restricted to limited areas; that these movements, though differing in character from the convulsions of the earthquake, arise from great secular expansions and contractions of the crust, which are likely dependent on the earth's internal conditions; that they are main instruments in altering the distribution of sea and land, and thereby affecting the distribution of their flora and fauna; and that in the same latitudes they diminish the general temperature by upheaval, and, on the contrary, increase it by depression. As instruments of change in the terraqueous arrangements of the globe, these crust-movements are deserving of a closer investigation than they have yet received from geologists. The records of their operations are instructively and attractively preserved in the "raised beaches" and "submarine forests" that occur along the coasts of many regions, and especially in those that present themselves so clearly along the seaboard and shores of the British Islands. What is more especially needed is, the tracing of the old sea-margins along considerable distances, obtaining their average altitudes, determining the nature of their organic remains where such are present, and investigating the deposits in any caverns that may occur in their respective rock-cliffs. And as with the raised beaches so with the submarine forests—their position and extent, and, above all, the character of their imbedded flora and fauna, and the evidences which these afford of the climate and conditions under which they had apparently flourished. Towards these ends very little has been done in a truly scientific manner (Dr R. Chambers's 'Ancient Sea-Margins' being the only systematic but unfinished attempt), though the subject presents many inducements to research, and is replete with important bearings on geographical as well as on geological speculations.

SPECIES-MAKING AND NOMENCLATURE.

THAT every object should have a name by which it may be distinguished from every other object, is a maxim applicable alike to the most familiar concerns of everyday life and the most abstract matters of scientific investigation. That the name should be appropriate—that is, should have reference to some leading feature, quality, or condition—is of the first importance; and though an object may in time become generally known by any sort of name, still that which points to some distinguishing feature or quality must always be the most significant, and consequently most readily remembered. If this holds good in the ordinary matters of life, much more must it be applicable to the objects of science, and especially to those of Geology, which embraces so wide a field in time as well as in space, and in all the kingdoms of nature—mineral, vegetable, and animal. And yet in no modern science is the nomenclature so heterogeneous and often unmeaning; in none is the practice of species-making carried to such a ridiculous and retarding excess.

An observer, for instance, falls in with an unknown rock, and he gives it a name from some external feature or resemblance; another observer meets with the same rock, or with a mere variety of it, but founding on some quality rather than appearance, he gives it a name instead of considering it merely as a variety; and a third observer, stumbling upon another variety, disregards what has been done by his predecessors, and gives a third name, which refers to locality, and has nothing to do either with appearance or with inherent quality. In this way, Lithology and Mineralogy (two important departments of Geology) became a confusing mass of synonyms, some relating to external aspect, others to inherent qualities—some to locality where found, and others, again, to the name of the finder—and yet each and all referring to the self-same object, or at most to a mere accidental variety of it. Nothing can be more perplexing than this to the student—nothing more retarding to the genuine progress of the science; and yet, considering the generally distinctive features of rocks and minerals, nothing could be more easily avoided.

In dealing with simple rocks and minerals, there is always some external character or inherent quality whereby one mineral can be distinguished from another, and such character or quality should be seized on and embodied in the name as referring to a distinctive fact in nature. To found upon locality—or, worse still, to found upon the names of discoverers—is to convey not a single jot of information as to the nature of the mineral, but simply to give a sound instead of sense, and to administer to personal vanity rather than to disseminate information. Again, as to mixed rocks—sandstones, shales, coals, limestones, granites, and the like—which present every degree of variety, any attempt to arrange them under distinctive generic or specific names is not only impossible, but futile and perplexing. A student may soon learn to recognise a crystal of beryl, and will understand at once what is meant by an impure variety of beryl; but he can attach no idea whatever to the term *Davidsonite.* Most people understood what is meant by a cannel coal, and what an earthy variety of cannel signifies; but few, if any, could associate any intelligible idea with the designation *Torbaneite.* And yet, when we come to inquire, *Davidsonite* is but a local and impure variety of beryl, and *Torbaneite* an equally local and tough earthy variety of cannel!

And when we turn to the palæontological side of the science, matters are even still worse—new, specific, and even generic designations being founded on distinctions often the most trivial and temporary. In Fossil Botany, for instance, we find Dr Hooker * complaining that "the botanical evidences which geologists too often accept as proofs of specific identity are such as no botanist would attach any importance to in the investigation of existing plants. The faintest traces, assumed to be of vegetable origin, are habitually made into genera and species by naturalists ignorant of the structure, affinities, and distribution of living plants, and of such materials the bulk of so-called systems of fossil plants is composed." This is a grave charge, indeed, and yet it must be confessed it is too true, both as regards the temerity to give names to unintelligible fragments, and the principles of the nomenclature itself. Carbonised and coaly fragments, it may be either of stem, of branch, or of leaf, are yearly erected into genera and species; roots, stems, and leaves of the same plant often receive different generic titles; and legible fragments of well-known genera have as regularly conferred upon them new specific designations because of some accidental or temporary variation. And thus it is that the science of Fossil Botany is cumbered with unnecessary genera, while the specific names convey no information whatever, either as to appearance, structure, or affinity. The term *Whit-*

* Himalayan Journal.

biensis, for instance, conveys no botanical information, and even misleads, when the same fragments are known to be found in Dorsetshire; while the designations *Brownii*, *Jonesi*, and *Robinsoni* (after men totally unknown to science) are simply worse than ridiculous.

In dealing with imperfect and partially legible fragments no detriment could arise to the science by the discoverer retaining them unnamed till the detection of more perfect specimens, while there would be a positive gain to the student in not having to learn to-day what he may be called upon to unlearn before the lapse of another season. The vanity of being first in the field, of claiming priority of discovery, overrules, however, in many minds this wise caution; and not till scientific societies, as a body, set themselves in opposition to such a practice, can any improvement be looked for. But the technicalising of imperfect fragments is a minor evil compared with that of founding new species upon the slightest variation in form which age, conditions of soil, and climate can readily account for. Mere temporary and gradational phases of a plant are thus erected into specific distinctions; the labour of acquisition is increased; and many are deterred from the study simply by the array of names they have to encounter.

Nor is the matter one whit better when we come to examine the practice in Palæontology Proper, or Fossil Zoology. The slightest variation in form is sufficient for a *Smithii* or *Brownii* being added to the list of species; while a greater variation is almost certain to lead to the establishment of another genus. Three forms of palatal teeth, for instance, are discovered in the Carboniferous system, and each receives a generic name; a few years of research pass by, and all three forms are found to belong to the same mouth! Two forms of fin-spines are detected in the Old Red Sandstone, and each receives generic distinction, even from an Agassiz;

several years pass by, and a single fish is discovered possessing the two spines—one form for the pectorals and another for the dorsals! Scales with slightly different ornamentation are dignified with specific titles, and yet, when a perfect fish is secured, these scales are found to be merely variations on different parts of the same body! Such are the evils that arise from giving names to imperfect fragments; such is the worthlessness of hundreds of provisional designations, arising from the vain desire of being foremost in the race of priority. Taken by themselves, a few specimens of certain shells may appear to warrant a specific designation; but when a large assemblage of these shells has been brought together, the graduation of one form into another is so imperceptible, and the whole so similar to some established species, that the propriety of regarding them merely as varieties of that species can no longer be questioned. And it is simply for want of this careful and sufficiently extensive comparison that species are manufactured out of the most trifling differences, and that our fossil lists are encumbered with factitious and questionable distinctions. Age, sex, individual condition, and the like, make wonderful differences in living species, and yet such circumstances are seldom taken into account in the discrimination of those that are fossil.

Commenting on this indiscriminate manufacture of "species" in Zoology, Professor Carpenter condemns it in the following emphatic terms, which are equally applicable to the field of Palæontology: "There are still too many who are far too ready to establish new species, upon variations of the most trivial character, without taking the pains to establish the value of these differences, by ascertaining their constancy through an extensive series of individuals—thus, as was well said by the late Prince of Canino, 'describing specimens instead of species,' and burdening science not only with a useless nomenclature, but with a mass of false assertions. It should be borne in mind that every one who thus makes a bad species is really doing a serious detriment to science; whilst every one who proves the identity of species previously accounted distinct, is contributing towards its simplification, and is therefore one of its truest benefactors." And even when the species is good, the name has often no reference whatever to the distinction, being altogether meaningless and absurd. Such terms as *striatus*, *reticulatus*, *falcatus*, and the like, have a meaning, and convey the distinction to which they refer; but *Cornubicus* or *Jamesii* has no significance at all, or if it has, it is a misleading one, as the organism may be found in other districts than Cornwall, and James may have had no hand whatever in the discovery of the species to which he stands godfather.

In deprecating this system, or rather non-system, of indiscriminate species-making and meaningless nomenclature, we are by no means arguing against the value of scientific names and technical distinctions. New objects must have new names, and new facts new phrases, to express their relations. We are not even undervaluing the advantage of provisional terms and temporary distinctions. What we object to is the absurdity of conferring specific names on minute, and, it may be, mere accidental variations; of giving generic and specific names to obscure fragments till further discovery has revealed fuller and clearer information; of applying meaningless instead of descriptive and significant terms;* and of thus cumbering the science with names

* This fashion of fanciful and meaningless terms is invading not only the realms of science, but those of ordinary topography, and this to such a degree that the modern names of country-seats, suburban villas, and town streets convey no notion whatever either of their character or origin —thus ignoring all external features and confounding all historical associations. The old Celtic and Saxon names of our hills and valleys,

instead of realities. No student who values the purity and progress of his special science can possibly defend the practice at present followed; and the best way in which he can assist in counteracting its tendency is by carefully and resolutely adopting for his own discoveries a strictly descriptive nomenclature, and by as cautiously refraining from conferring generic appellations on obscure fragments, which the discoveries of another day may show to belong to something already determined. It is long ago since Cuvier, in speaking of the living world, avowed his belief "that the difference between two *species* is sometimes entirely inappreciable from the skeleton, and that even *genera* cannot always be distinguished by osteological characters;" what temerity, therefore, on the part of ordinary observers, to attempt the erection, not only of species, but of genera, on the scattered and mutilated fragments of bygone epochs, and on their creation of these genera to found the boldest and most revolutionary of cosmical speculations!

our castles and country-seats, our towns and streets, had something to recommend them, and render them descriptive and memorable; modern nomenclature, on the other hand, is often as absurd and meaningless as the priggish inanity that invents it.

SCENERY—ITS CHARACTERISTICS AND CAUSES.

As the surface-configuration of the earth is infinitely varied, so the causes of that diversity, whether internal or external, must vary in a corresponding degree. Variety of aspect and contrast involve, in fact, dissimilarity of producing agency—complexity in the one being but the natural result of diversity in the other. Here we have plains that are spoken of as tame and monotonous, there fens and moors described as waste and dreary; here hills and dales regarded as gentle and pleasing, there crags and glens as picturesque and romantic; here splintery cliffs and precipitous gorges viewed as wild and awful, and there mountain-peaks and shaggy ravines invested with the attributes of grandeur and sublimity. This surface-diversity or scenery, so long the theme of the poet and painter, is not less the subject of the geographer and geologist. The former take it as they find it, and describe it in words, or transfer it to their canvas; the latter, equally appreciating its variety, attempt to arrive at its intimate nature and producing causes. In this, as in other efforts to interpret phenomena, diversity of opinion is naturally expected; and hence, at the present time, scenery is one of the moot points of Geology—some attributing it mainly to external agencies of waste and reconstruction, some to internal agencies of upheaval and depression, and others, taking a broader and more catholic view, partly to internal and partly to external causes. Let us try, within the compass of a few pages, to explain that all scenery or surface-diversity is owing partly to the agents of waste and reconstruction that are ever transferring and remodelling the crust of the earth; partly to geological structure, or the nature of the rocks on which these forces operate; partly to geographical position, or the conditions under which they act; and partly to the time that any portion of the terrestrial surface has been subjected to their operations.

In the first place, it requires little effort to perceive that whatever the original surface-configuration of any part of the earth's crust—island or continent—that configuration must be incessantly undergoing change and modification. Attacked from without by frosts, rains, and rivers, by waves, tides, and currents, its rocky asperities will be gradually worn and rounded, its depressions more deeply excavated, and its shores rendered more rugged and irregular. Frosts must split and crumble, glacier grind and smooth, rains soften and wash away, rivers erode, waves degrade, and tidal currents scour and transport. And just as these forces from *without* are incessantly remodelling the surface-configuration, so the forces from *within*—the volcano, earthquake, and crust-movement—are as ceaselessly operating towards the same end: the volcano by the accumulation of new hills; the earthquake by the production of elevations, depressions, and fractures; and the crust-movement by slow and gradual uprise of some regions, and by equally slow and gradual submergence of others. Depending on the earth's primal and cosmical relations, these agencies are ceaseless and enduring; and to them, therefore, and the nature of the rocks on which they operate, the geographical conditions under which they appear, and the time they have acted, must the surface-diversity of the earth be largely ascribed. Of course, as each agent has its own peculiar mode of action, the results will generally give evidence of the producing cause; but in many instances where several agencies have acted simultaneously, or where one agent has been succeeded by another, the results will be greatly complicated, and it becomes impossible to do more than indicate in a very general way the forces that have been instrumental in their production.

In the second place, it must be equally evident, even to the most casual inquirer, that geological structure is one of the fundamental causes of surface-diversity. The alluvial plain, from the soft and recent nature of its deposits, must always be more or less flat and uniform in surface. Link-lands and sandy deserts, from the shifting character of their material, must be abruptly uneven and irregular, and though on the large scale as monotonous as the alluvial plain, yet within limited areas may present not unpleasing diversity. Chalk hills, from the soft and homogeneous texture of their rocks, weather into rounded and easy undulations; hence the softened outlines of the downs and coombs of southern England. Limestone strata, being of a harder texture, but of fissured and jointed structure, break up into wall-like scaurs and precipices and table-topped heights; hence a main cause for the peculiar scenery of the Dolomite mountains, and for many of the features in the dales of Derbyshire and western Yorkshire. Volcanic hills, being chiefly products of eruption, assume a conical form—regularly conical or "sugar-loaf," like the Peak of Teneriffe—when made up of loose cindery material; irregularly conical, like Etna, when consisting partly of scoriæ and partly of lava; and more flatly conical, like Hecla, when mainly composed of lava, which, from its molten nature, must always rest at a lower angle. Trap hills, on the other hand, built up of old volcanic ejections, now converted into tuffs and greenstones and basalts, present (like those of the Scottish Lowlands) more or less a terraced outline—the softer tufa having weathered into slopes, and the interbedded basalts and greenstones standing out as steps and terraces. Granites and porphyries weather slowly into bald, round-shouldered mountains, like the Grampians—sterile, heath-clad, and dreary, because of the hard, uniform, and resisting character of the rocks. Slaty and schistose formations, usually standing at high angles, and consisting of harder and softer strata, present jagged peaks and pinnacles, the weirdest of heights and the wildest of gorges.

The stream that erodes for itself a valley through a soft formation, can only cut for its waters a narrow ravine through harder strata. The river that flows smoothly in its channel through beds of uniform consistency, becomes a noisy cataract through rocks of unequal resistance, or plunges in noisy tumult over some harder ledge or intersecting dyke into the softer strata below. Over widespread formations, consisting of strata of unequal hardness, the courses of the streams are generally determined by the strike of the softer beds; and thus arise those undulations of hill and vale—the former representing the sandstones and limestones, and the latter the clays and shales. The sea-cliff of uniform formation may stand like an even wall for ages; that of irregular resistance will be gouged into gorge and gully of the wildest description. And for the same reason this promontory may stand bald and bare and unbroken through all time, while that may be hewn into arch and stack and needle by the restless surge of the waters. In fine, no geologist can glance at the diversity of the terrestrial surface without being instantly convinced that the varying nature of rocks and rock-formations is one of the fundamental causes of that diversity and configuration. And just as the rock-structure is uniform or varied, just as it lies unbroken or disturbed by volcanic agency from below, so will the surfaces it presents be uniform or irregular, abruptly thrown into heights or sunk into hollows. In geological structure, therefore, we find a main cause of surface-configuration; and he who best understands the geology of a country will be best qualified to appreciate the diversity of its scenery.

In the third place, it must also be obvious that whatever the geological structure, that structure will be variously affected according to the geographical position of the country in which it occurs. What will take place under the glacial influence of the polar regions cannot occur under the temperate zones; and what may happen under the alternate frosts and thaws of temperate latitudes will not be produced under the uniform climate of the tropics. Rocks that may be weathered and worn into the tamest outlines in a variable climate like Britain, may stand out bold and precipitous for ages in one like that of Egypt. The cliffs and precipices that may rise unbroken for centuries in lower latitudes would be split and fractured into a thousand fragments by the frosts of boreal latitudes and glacial heights. The same rocks that are gouged and furrowed by the rains and runnels on the eastern slopes of the Andes, remain intact on the rainless counter-slopes of Peru. The volcanic mountains of the East Indian Archipelago, that are seamed and channeled by the monsoon-rains to the height of eight or ten thousand feet, rear their cindery cones smooth and unbroken beyond that elevation. Far above the snow-line the clefts and precipices of moistureless mountains, like the central Andes, may remain rugged and untouched, as formed by the volcano or fractured by the earthquake; while in moister regions at the same altitudes the glens and precipices would be rounded and smoothed by the grind of the glacier. Wild and rugged and desolate as may be the shores of ice-locked seas, like those of northern Greenland, they never can compare in variety and picturesqueness with those of tidal and free-flowing waters.

In reasoning, therefore, on the general characteristics and causes of scenery, geographical conditions must ever be taken concomitantly with those of geological structure. And if the influence of geographical position be admitted on physical features, much more must they be allowed on the vital aspects, or that which gives the ultimate colouring and charm to all terrestrial diversity. Striking as may be the impress produced by mere physical features—whether beautiful, picturesque, grand, or awful—that impress is ever heightened by the adjunct of vegetation, be it the tangling luxuriance and greenery of the tropics, or the less exuberant growth and ever-changing tints of more temperate regions. Wildness and grandeur may be associated with rugged mountain-cliffs, snow-clad peaks, and desolate ice-shores; but picturesque beauty and charm of landscape can only be realised by the presence and disposition of the vegetation that adorns it. And as this is the direct offspring of geographical and climatal conditions, it must be obvious that, important and fundamental as geological structure may be, it cannot of itself produce all the accessories that are essential to variety and contrast in scenery.

In the fourth place, it must be equally obvious that the effects of waste and reconstruction will be more intensified in countries consisting of the older formations, inasmuch as they have been longer subjected to these forces, and occasionally to a succession of these forces in their alternate submergence and elevation above the ocean. A recent volcanic range, for instance, may consist of hills more or less conical and regular in outline; whereas an old volcanic range, long subjected to the tear and wear of frosts, rains, and runnels, will be furrowed with glens and gorges—the regularity of its cones broken up, and its more resisting lavas standing out as cliffs and precipices. And further, had this old range been submerged beneath the ocean, and again upheaved, it must have undergone marine denudation both during its descent and ascent, thus still more defacing its original aspect, and conferring upon it new and often very puzzling configuration. Who can tell, for example, how often the old rocks of Britain have been beneath and above the waters; how long subjected to waste and erosion during their upheavals; or how much disturbed and dislocated by successive manifestations of vulcanism, of which the granites, porphyries, and trap-rocks are the products? As with the British Isles so with all other countries consisting of the older rock-formations. It is not alone the changes they are now undergoing, but the changes they have suffered in former periods, and which to a great degree have determined the course of the present, that must be taken into account in speculating on the characteristics and causes of scenery; for without these considerations existing causes would often appear unequal to the results, and the observer be lost in a maze of uncertainty and error.

Applying these principles of waste and reconstruction, of geological structure, geographical position, and time, to the scenery of the British Islands, the geologist may arrive at something like a solution of a very complex and difficult problem. In these islands, which have been repeatedly under the waters, and as repeatedly above them, it is not to existing forces alone that we can appeal for the production of their surface-diversity. From the upheaval of the Silurian rocks until now, the surface has received new mouldings and remodellings during each successive elevation and depression, partly through marine denudation, partly from meteoric waste, and partly from river erosion. Some of our existing valleys may have been scooped out before the deposition of the Old Red Sandstone; and the conglomerates of the Old Red, as well as the breccias of the Permian, point in some instances to the very hills from which they were eroded. Following this train of reasoning from the Old Red Sandstone down through the subsequent eras of the Coal, New Red Sandstone, Oolite, Chalk, Tertiary, and Glacial epochs, we cannot fail to perceive the complexity of the forces as well as the immensity of time concerned in the formation of British scenery. The forces of the glacial epoch, so often appealed to for the moulding of our hills and the scooping out of our valleys, only followed the lines of relief produced during preceding epochs, and merely intensified their forms by its severer and more forcible agency. Nor was it mere waste from without; but during these long ages our islands were repeatedly subjected to vulcanic disturbance from within, and thus variously fractured and rendered still more irregular in surface-configuration. By these means old watersheds were destroyed and new slopes produced, the erosion of rivers diverted into other channels, and the whole agents of change variously modified and rearranged.

In studying some mountain-glen, for example, we perceive that the eroding power of the existing stream is wholly inadequate to account for its dimensions; we discover traces of old moraines and glacialised rock-surfaces, and find that the glacier has been there grinding, deepening, widening, and smoothing; but our investigation cannot end here. What gave direction to the glacier? Not the softer nature of the rocks, for they are the same as those on either side; not any old rent or earthquake fissure, for the strata are unbroken in that direction; nothing, in fact, we can suggest, save that it was a glen ages before the advent of the glacier, which merely for a while took possession, and by its rasping and grinding left it deeper and broader than it was before. Frost and ice are no doubt powerful agents, but to ascribe all that has been recently attributed to their action is altogether an exaggeration of their power and a misinterpretation of the phenomena. Most of our river-glens and all our broader valleys had existence and configuration ages before the advent of the glacial era. All that ice-action did or could accomplish was merely to round off asperities, widen and deepen pre-existing depressions, and leave the eroded material as gravel-mounds and ridges. All that existing rivers and meteoric action have done since the glacial period consists in the deepening of channels, the cutting through of moraines, and scarcely the obliteration of the smoothed and striated rock-surfaces. The broader outlines of British scenery were graven ages before, and this by repetitions and continuance of the great agents of waste and reconstruction to which the earth's crust has ever been subjected.

On the other hand, if some have attributed too much to external waste and denudation, others, taking a still more circumscribed view, would ascribe all surface-diversity mainly to inequalities originally produced by fracture and convulsion from within. It is true that volcanic eruptions give rise to new hills and elevations, and that earthquake convulsions produce faults and fissures, upheavals and depressions; and it is further true that these inequalities may determine watersheds, slopes, and courses of rivers; but in all countries subjected to external waste these vulcanic inequalities are speedily operated on—soft matters washed away, heights degraded, fissures filled up and smoothed over, and generally after the internal forces have ceased the further diversification of the surface is left entirely to external agency. According to these convulsionists, hills and glens, precipices and gorges, were all produced by volcanic eruption and fracture, whereas this holds true only in certain instances, and even in these instances only to a limited extent. Many hills are the remnants of denudation rather than the products of upheaval; and ninety out of a hundred glens are the result of aqueous erosion, and altogether independent of fissure or fracture. Seal up the fires of Etna, and let it for the future stand cold and silent in the surrounding atmosphere, and what would be the result? The existing inequalities would give direction to the runnels and streams, the softer tufas would be eroded into glens, and the harder basalts remain as cliffs and precipices. In one sense the internal forces of Etna might be said to have determined this new diversity, but in reality they were only very remotely concerned, all the prominent features of that diversity being substantially the results of disintegration and erosion. And the farther we carry this reasoning back in time, the more obvious it becomes that the existing surface-diversity of the globe must be mainly, though not entirely, ascribed to the operation of external forces.

It is thus that scenery—its origin and characteristics—becomes a very complex and difficult problem, involving considerations not only of waste and reconstruction, of lithological structure and of geographical conditions, but considerations of anterior geological changes which may have left their impress on the terrestrial surface, and given direction and intensity to existing causes. And as these anterior changes are yet but very slenderly known, geologists will exhibit their wisdom in the mean time by offering provisional hypotheses rather than indulging in confident and dogmatic assertions. It is not to external waste alone, whether as manifested now or exerted during the glacial epoch, that we can ascribe the characteristic features of British scenery—nor is it to internal convulsions alone, however violent, or however repeatedly displayed; but it is to both of these, each acting in its own way, and during successive ages, that we must appeal, if we would ever arrive at anything approaching to a satisfactory solution of the problem.

A FORGOTTEN CHAPTER.

MANY years ago, when more antiquarian than geological, we stumbled upon a curious chapter in Verstegan's 'Restitution of Decayed Intelligence in Antiquities concerning the most noble and renowned English Nation.' Being more than two hundred and sixty years (1605) since Verstegan wrote his 'Restitution,' and the chroniclers of that day being but slenderly geological, the chapter is indeed a curious one, relating, as it does, to a question which in recent times has received the attention of several of the most eminent geologists in France and England. The question, Whether Great Britain was ever joined to the Continent?—or, as our author puts it, "the Ile of Britaine sometime continent with Gallia?"—had been often discussed even before Verstegan's time, and in the early part of the present century was made the subject of a prize competition by the Academy of France. The successful competitor on this occasion was the well-known geologist Desmarest, and in reading his essay one cannot avoid being struck with the similarity (we had almost said identity) of his arguments with those of the old English chronicler. On first reading the chapter in 1838, we made it the subject of a paper to the Literary and Philosophical Society of St

Andrews, and subsequently communicated the facts to Sir Charles Lyell, who embodied them in the seventh edition of his 'Principles of Geology' with acknowledgment and comment. Beyond our locally published paper and Sir Charles's brief reference, nothing seems to be known to English geologists of Verstegan's reasoning and arguments; and it may gratify many to have this "Forgotten Chapter" reprinted in its quaint old-fashioned style and original integrity.

The title of the chapter (the fourth in the work) is set forth in these words: "Of the Ile of Albion, afterward called Britaine, and now *England*, *Scotland*, and *Wales*. And how it is shewed to haue beene continent or firme land with Gallia, now named *France*, since the floud of Noah;" and the arguments are as follow:—

"In what manner and forme it pleased Almightie God in the beginning of the world, to diuide the sea from the drie land, is vnto vs wholly vnknowne; but altogether vnlikely it is that there were any Iles before the deluge; and so much may be gathered by the words of the Scripture. *Dixit vero Deus: congregentur aquæ quæ sub cœlo sunt, in locum vnum, & appareat arrida: Et factū est ita. Et vacauit Deus aridam terram, congregationesque aquarum appellauit maria,* Whereby appeareth, that the waters were gathered together in their owne place by themselues, and therefore had no such inter course between land & land, as now they haue, and so consequently there were no Iles before the flood of *Noah:* howbeit by that great and vniuersall deluge, many Iles were doubtlesse caused. Moreouer it is manifest by the Scripture, that since the time of the aforesaid deluge, some alterations both of sea and land haue also beene made, as may appeare where it is said of the meeting together of certaine Kings. *Omnes hi conuene-*

runt in vallem syluestrem, que nunc est mare salis. All these met together in the wood-valley, which is now the salt sea; so as this valley hauing in the time of *Abraham* beene full of trees, was now in the time of *Moses* the salt sea. *Plinie* saith that it sometimes hath hapned that Iles haue been drowned and deuoured by the sea, and that at other times they haue appeared out of the sea, where before they neuer were seene, and haue so continued. Moreouer that it hath bin seene that Iles being situated neere vnto the continent, haue become ioyned and annexed vnto it; and contrariwise parts or Peninsulaes that were annexed vnto the continent, haue bin separated & made Iles. Of all which he giueth in his naturall Historie both the examples and the reasons. *Ouid* also saith, that he hath seene land where sometime was sea, and sea where sometime was land. Sundrie the like examples might in like manner here be set downe, of the alterations that haue bin wrought by the inundations and course of the sea, as where it hath in many places gained of the land, and contrariwise where the land hath recouered it selfe againe from the sea, all which were onely to shew how vsuall a thing it hath bin for the limits and bounds of many maritime places, to haue bin most subiect to such alterations & changes.

"That our Ile of *Albion* hath bin continent with *Gallia*, hath beene the opinion of diuers, as of *Antonius Volscus*, *Dominicus Marius Niger*, *Seruius Honoratus*, the French Poet *Bartas*, our countriemen M. *Iohn Twine*, and M. Doctor *Richard White*, with sundrie others; but these Authors following the opinion the one of the other, are rather content to thinke it somtime so to haue bin, then to labour to find out by sundry pregnant reasons that so it was in deed.

"The first appearance to moue likelihood of this thing, is the neernes of land betweene *England* and *France* (to vse the moderne names of both countries) that is, from the clifs of *Douer*, vnto the like clifs lying betweene *Calis* and *Bullin*, for from *Douer* to *Calis* is not the neerest land, nor yet are the soyles a like: the shore of *Douer* appearing vnto the saylers high and chalkie, and the shore of *Calis*, low and altogether sandie, as in like manner the English shore towards *Sandwich* (which is more directly ouer against *Calis* then *Douer* is) also doth.

"These clifs on either side the sea, lying iust opposite the one vnto the other; both of one substance; that is, of chalke and flint; the sides of both towards the sea, plainely appearing to bee broken off from some more of the same stuffe or matter, that it hath sometime by nature been fastned vnto; the length of the said clifs along the sea shore being on the one side answerable in effect, to the length of the verie like on the other side, and the distance between both, as some skilfull saylers report, not exceeding 24 English miles; are all great arguments to prooue a coniunction in time long past, to haue beene betweene these two Countries; whereby men did passe on drie land from the one vnto the other, as it were ouer a bridge or *Isthmus* of land, being altogether of chalke and flint, and containing in length about the number of miles before specified, and in bredth some sixe English miles or there abouts, whereby our countrie was then no Iland but *Peninsula*, being thus fixed vnto the maine continent of the world.

"To make this more plainly to appeare, this *maxime* or *principle* must be granted, that there is nothing broken, but it hath beene whole, for albeit Nature doth now and then (against her owne intent) commit some errors, and that sometimes the things shee formeth haue too much, and sometimes too little, yet deliuereth she nothing broken or disseuered, but such as it is, how euer in deformitie it be, yet is it alwayes whole and neuer broken, vnlesse afterward by accident. So ought it also to be beleeued that Almightie God the cause and conductor of Nature, in creating the world did leaue no part of his worke imperfect or broken. But manifest it is, that these clifs (not being by God and nature at the first so framed) are seene to be broken, yea euen as it were cut off steepe or straight downe, from the top to the bottome, and not coming by degrees sloping down, as inland-hills ordinarily do vnto their valleys; but euidently appeare to haue beene by force broken off, and that not inward towards the land, but outward towards the sea, either side in such maner still remaining correspondent to other, and either shewing the lacke of the matter or substance which it hath lost: and that being one selfe thing, to wit, chalke and flint, it plainely thereby doth declare vnto vs that sometime it was conioyned together in on same substance, and consequently was first by nature made one soyle.

"Some may here obiect, that other hilly parts or clifs of the sea shore are in many other places seene to be broken away, as steepe and as straight downe as these here spoken of, which I confesse to bee true, and thereunto doe answere, that it is a plaine signe that the violence of the sea hath so worne and eaten out the sides of them beneath at the bottome; that the vpper part for want of vnderpropping, hath falne downe. And moreouer where it also is found that inland rocks or hills are seene to haue had some parts of them broken away, as I haue obserued in passing the *Alpes* and other mountaines, this may well bee thought to haue proceeded in old time by occasion of earth-quakes, but the breaches found in rockes are neuer seene to passe all along in any sort of euennesse, but here and there without any kind of course or order. Besides, they may often seeme broken when they are not, because they are formed craggie by *Nature*, or the winde and the raine hauing long since beaten away the earth from them, may thus haue left them to appeare the very true anatomies of themselues.

"It is further to be noted, that in our ancient language the cut off or broken mountaines on the sea sides, are more rightly and properly called clifs, then by the name of rocks or hills; that appellation being more fitting vnto the inland mountaines; but the name of cleft coming from our verbe to cleaue, is vnto these more aptly giuen, for that they seeme vnto our view as cleft or clouen, from the part that sometime belonged vnto them, and albeit (as I said before) many clifs are in many places of the sea shore to be seene, as well as at *Douer;* yet are they not seene so to bee answeréd and corresponded vnto by others right ouer against them, nor to be of such neerenesse and such selfe matter or substance, as these haue here beene shewed to bee. This coniuncture to haue remained for some space after the great and generall deluge, and the breach and separation of *Albion* from *Gallia* by the said deluge not to haue beene caused, is by sundrie reasons to be prooued.

"The first that I will bring is from the *Netherlands,* which so farre as they are euen and plaine without any hilles or hilly grounds, haue vndoubtedly heretofore in time long past beene sea: yea, and that before and since the flood of *Noe.* The proofes that they haue bin sea; are, first the lownesse of their Situation, some of the more maritime parts of them as *Zealand* and *Holland,* with some parts of *Flanders,* &c. being so low, that by breach or cutting of the sand banckes or downes, which the reiection of the sea by little and little hath raised and cast vp, and the labour of man here and there supplied, might easily be drowned and conuerted from land into sea againe: and of the great harmes that these parts haue heretofore by eruption of the sea sustained, I could here set downe sundrie examples, but one among others shall suffice, because our owne Chronicles giue testimonie thereof, and that is of the mightie inundation in the raigne of King *Henrie* the first, whereby a great part of the countrie was irrecouerably lost, and many of the poore distressed people being bereft of their habitation came into England; where the King vpon compassion (as also for that hee saw they might bee profitable to the Realme by instructing his subiects in the art of clothing) first placed them about *Carlel* in the North of *England*; and after remoued them into *South-Wales*, where their posteritie hath euer since remained. Moreouer, long before this hapned, to wit, in the yeare of our Lord, seauen hundred fiftie and eight, when the Danes and the Gothes did fortifie the Iles of *Zealand* by driuing in of piles and making bankes at ebbing water, they were so prouident as first to make certaine mounts in sundrie places, whereunto they might retire at high water, as also flie to saue themselues, if the sea should at any time happen to breake in vpon them, the which artificiall hilles are yet vnto this day in the Ile of *Walkers* to be seene. But now besides these low places that adioyne vpon the sea, being properly *Holland* and *Zealand*, the greater part of *Flanders* and *Brabant*, doe lie of such great euennesse of ground as do both the said countries of *Holland* and *Zealand*, though not so low as they, but of such height as no inundation of the sea can any whit annoy them, yea although the sand bankes or downes now on the sea side were neuer so much broken or cut through, & that both *Holland*, *Zealand*, and some of the next confining parts of *Brabant* and *Flanders*, were altogether drowned.

"*Hubert Thomas* a man of verie good parts, sometime chiefe Secretarie vnto *Fredericke* Count Palatine of *Rhenè*, and Prince elector, in his description of the countrie of *Leige*, saith, that the sea hath come vp euen vnto the walles of *Tongres*, (now well nigh an hundreth English miles from the sea) which seemeth vnto *Lewis Guicciardin*, verie strange, in so much as he thinketh *Hubert Thomas* to haue farre ouer-shot himselfe, and to haue beene of slender consideration in weening that the sea hath euer come vp as farre as vnto *Tongres*, notwithstanding the good reasons which the other alleageth to proue it (and among other that the great Iron rings are there yet remaining, vnto which the shippes that there sometime arriued were fastned) because saith *Guicciardin*, *Tongres*, lieth now so farre from the sea, and that the sea could neuer haue had course so farre as thither, without the ruine of such countries as lie betweene it and the sea. With the said *Guicciardin* while he liued I was acquainted, and haue found him to confesse some errors that by mistaking or mis-information he had in his writings committed, and were he yet liuing hee might easily bee brought to confesse this also, and so to become of the opinion of *Hubert Thomas*, for whereas he would ouerthrow the reasons of the said *Thomas*, because *Tongres* is now so farre from the sea, and that the countries lying betweene that and the sea, must then of the sea needs haue beene ouer-flowne, what refutall is this, when it can be prooued that they so were, I meane, all such as lie in an equall euennesse without any hills, for the great euennesse of all ground that naturally is so, hath doubtlesse beene so first made and caused by water; as the plaine and euen medowes haue without all doubt in time past so beene made by the water wherewith they haue beene couered, and the water either seeking some course by chanell, or otherwise drained or holpen to haue issue, the Sun in time drying vp the mud hath made them to become firme and fruitfull grounds. An especiall reason then that these parts of the Low Countries haue beene sea, is their maruelous great euennesse, which nothing can haue caused but water.

"Another reason is, that with this great plainnesse or euennesse of ground, the soyle generally, both of *Flanders* and *Brabant*, is sandie, which doth naturally demonstrate those parts (in times past) to haue beene the flats, sands or shores of the sea.

"A third reason is, that in digging about two fadome deepe in the earth, though in some places more and in some lesse, innumerable shells of sea-fish are found, and that commonly in all places of these plaine and euen grounds, both in field and towne, and hereof to bee thoroughly informed I haue talked with such labouring men as vsually haue digged wells, and the deepe foundations of buildings, and they all agree, that they doe commonly in all places find an innumerable quantitie of these shells, some whole and some broken, and in many places the great bones of fishes whereof I haue seene many, and haue had some euen as they haue beene digged out of the earth:

"For a more plaine description of the manner and forme of these bones and shells of fishes, and to giue the curious Reader herein the more satisfaction, I haue thought good in the next ensuing page to set downe some of them in picture:—

[*The engraving contains two vertebræ and a rib of whale, two valves of cyprina, and a fish-tooth—the "fish-toungs" of our Author.*]

"The chine bones are commonly found in this manner, of about a foot in length, some much more, and some lesse, the peeces of broken ribbes are sometimes found as thicke as a beame of timber, and sometimes farre lesse, the shelles are not like vnto our cockle shelles, but on the outside plaine and euen and about a quarter of an inch thicke, especially the bigger sort which are of ten or twelue inches in compasse about by the edges. Moreouer potters in working their clay which is gotten in some especial places, doe find in it certaine things which are as hard as stone, and of the very forme and shape of the toungs of some sortes of fishes, each with the root vnto it, to make it the very markable and right proportion of such a kind of toung in all respects, some beeing more then two inches long, and some lesse then one inche, and they that thus find them do not otherwise call them, but the toungs of fishes, which beeing so, and turned into very hard stone, is a strange thing in nature, but the lesse strange because nature in her conuersions of other substances into stone, is often seene to worke the like. True it is, that in some places Fir trees haue also bin found in digging in the earth in these low countries, and commonly with the roots lying to the Southwest, and the toppes to the Northeast, but these are not to bee thought euer to haue grown in the *Netherlands*, because none are knowne to grow there, the soyle not beeing by nature apt to produce them, but are most commonly found in cold hilly places, or vpon high mountaines, as in *Germanie* & other partes, & these in the time of the deluge might from thence by the rage of waters, be driuen thither. There is moreouer some sorte of shelles sometimes found in the veneyards of *Champagne in France*, which is not low or euen, but rather a hilly or vneuen country; of these it cannot otherwise bee imagined but that they haue in like manner by the great rage and tossing of the waters in the vniuersall deluge bin cast thither, if they haue bin of any sea shell fish; and such as horse-muscles which are found in fresh water; for that may also bee a question, seeing no man can thinke that the sayd country hath euer bin sea, no reason or likely-hood in the world there vnto concurring: nor of these shelles are there any great store: neither lie they deepe in the earth but are now & then found by a chance; whereas the shells found in the *Netherlands* are in such innumerable quantitie, that they lye all along within the earth as do the vaines or differences of the earth or soile it selfe, in other places: and here and there the great bones of fishes (as before haue bin shewed) are also found lying among them. Yea it hath hapned that anckors haue bin found in digging on the heath in the sandy *Kempinia of Brabant.* Moreouer, at such time as the Famous water-passage was digged from *Bruxels*, vnto the riuer of *Rupel* at *VVillebrook*, which was by the labour of men cut or digged, through corne-land, wood-land, and medowes, about the space of fifteen English miles: begun in the yeare of our Lord, 1550, and ended in Anno 1561, (a marueilous attempt to bee vndertaken by one Citie) there was found among other things the bones or anatomie of a sea Elephant, the head whereof, which is yet reserued, my selfe haue seen. It is also to bee noted that albeit in digging deep in the Earth in *Brabant* and *Flanders* great aboundance of the shelles of fishes are found, yet in digging in the Earth in *Holland* and *Zealand*, none at all are perceiued, howbeit on the sands on the sea shore there are very many, and of these the Emperor *Caligula* caused his Souldiers to gather great store, to carrie with them to *Rome*, and there in the *Capitoll* to present them in token of Triumph, as hauing taken the spoyle of the *German Ocean.* The reason then why such shelles are not found in the earth in *Holland* and *Zealand* as they are in *Brabant* and *Flanders*, is, because those parts haue bin in time long past, part of the depth of the sea: and the partes aforesaid of *Brabant* and *Flanders* the flats or shore; and on the flats & not in the depths such kind of shel-fish is naturally nourished.

"The *Netherlands* thus beeing shewed to haue bin sea; it is now to bee demonstrated that they were sea both before and since the floud, and not by the floud only so caused; and this may appeare by the little time that the floud lasted, because there could not in so shorte a space such an innumerable multitude of shel-fishes breed and increase to such bignesse, the shelles beeing so big and so thicke as before is shewed; but they must needes haue had a farre longer time, and therefore the sea heere to haue remayned many yeeres after the floud. Neither could such inumerable multitude from elswhere by the said floud which was very vehement and raging be brought hither, as such few might paraduenture be, as now and then by chance are found in some vineyeards of *Campaign*, whereof I haue spoken before, but these being heere in such an exceeding quantitie, lying in such an equall course & order, which the confused course of that floud could not so dispose, plainly sheweth them to haue bin there first bred and nourished by nature, and in that sort and loose kind of redish sand, somewhat of the colour of clay, suncke downe and setled together, by litle and litle, before it grew to the nature of hard and dry land, the which hauing bin sea before the floud (in which time this store of shel-fish may haue bin bred, it must needs also haue continued sea after the floud), for the floud could not be the cause to make any part land that before had bin sea, but rather many parts sea, that before had bin land.

"And apparent reason must then bee sought, how it hath come to passe that these *Netherlands* hauing bin sea, haue become to be land; and if so be that this question were moued of such partes onely of these countries as *Holland*, *Zealand*, and their confines, which may by the seas inundation (as before hath bin said) easily be drowned, & made sea againe, it might by the ordinary answer that the sea doth often gaine in one place and loose in another, soone be resolued: but speaking of these partes of *Flanders* and *Brabant*, which hauing bin sea and beeing become land, can no more by any inundation bee made sea againe, this I say requireth an imminent reason to be sought for; the which cannot bee found, but in the breaking of the *German Ocean*, through that *Isthmos*, or narrow passage of land, which once conioyned *Albion* to *Gallia*, that is to say, *England* to *France*, by which only meanes the sea finding out a new course, all the euen parts of the *Netherlands* hauing (as is aforesaid) before bin sea, became eftsoones dry land: euen as by common experience wee see that watry or moorish grownds are drayned dry, when an issue may bee found to lead away the water to some lower chanel, poole, or riuer. And euen so in like manner this breach in our *Isthmos* beeing once made, and the sea hauing bin before the said breach somwhat lower on the west side thereof then on the east side; the course of the water, by a naturall readines, taking scope down through this new Chanell (which before was onely a kinde of gulfe as is *Mare Rubrum*) towards the most huge Westerne Ocean, the greater deuider of *Europe*, and *Africa*, from the late found *America*, it did without all doubt worke this great effect, and no way is there else to bee found or imagined, whereby these Seas might be drayned or drawne away, to make these former shallow places to appeare and become drie Land, but onely by this way and course.

"That the Sea on the West side of the said *Isthmos* was lower then the Sea on the East side thereof, is besides this great worke thereby wrought, to bee iudged by the sundry flats and shallowes on the East side, as well on the coast of *England* as of *Flanders*, yea one in a manner lying between *Douer* and *Calis*, of about three English miles in length, of some called our Ladies sand. And contrary-wise on the West side no such flats at all to bee found, whereby may well be gathered that as the Land vnder the Sea remaineth on the one side lower then on the other, so accordingly did the Sea also. It is moreouer to bee iudged by the very present course of the Sea; for it is obserued that the currant of the water is more swift downe the Chanell towards the West, then from the West vnto the East: old shippers of the *Netherlands* affirming, that they haue often noted the Voyage from *Holland* to *Spaine* to be shorter by a day and a halfe sayling, then the Voyage from *Spaine* to *Holland.* That the Seas are different in height one from the other, euen in places where they haue but narrow seperations of Land betweene them, is very manifest, for heretofore at such time as some of the Kings of *Egipt* went about by cutting the separation of land which is beetweene the *Red-sea* before recited, and *Mare Mediterraneum* or the *Midland-sea,* to bring them both into one, it was found by the *perpendiculum* or instrument of water-leuel, that the *Red-sea* was much higher then the *Mediterranium* sea, and beeing but shallow in diuers places it was feared it would in those places haue become so dry that it would not haue bin nauigable, but rather that people might haue passed through it on foot, though not as *Moyses* with the children of *Israel* miraculously did, but euen vpon dry ground, and for this and other inconueniences which might haue ensued it was left vndone. Moreouer it hath also bin found that the sea on the west side of *America,* vulgarly called *Mar del zur,* is much higher then the *Atlanticke* sea, which lieth on the east side, so as if it had so bin that the *Isthmos* of land betweene *Panama* & *Nonbre de Dios* might haue bin cut through, that passage there might haue bin made into the *Pacifike sea,* otherwise called *Mar del zur,* without sailing so farre about as by the straights of *Magellan,* yet would some other great inconueniences haue growne through the inequalitie of the heigths of these two seas.

"Another reason there is that this separation hath bin made since the floud, which is also very considerable, & that is, that the Patriarch *Noe* hauing had with him in the *Arke* all sortes of beasts (all else besides throughout the whole world beeing destroyed) these then after the floud beeing put foorth of the *Arke*, to encrease and multiply, did afterward in time disperse themselues ouer all partes of the continent or maine land, but long after it could not bee before the rauenous wolfe had made his kind nature knowne vnto man, and therefore no man vnlesse hee were mad, would euer transporte of that race for the goodnes of the breed, out of the continent into any Iles: no more then men will euer carry foxes (though they bee lesse damageable) out of our continent into the Ile of *Wight*. But our Ile as is aforesayd, continuing since the floud fastned by Nature vnto the great continent, these wicked beasts did of themselues passe ouer, and if any should obiect that *England*, hath no wolfes in it, they may be answered that *Scotland*, beeing therewith conioyned hath very many, & so *England* it selfe somtime also had, vntill such time as King *Edgar*, tooke order for the Destroying of them throughout the whole Realme, which generall Destruction they well deserued by a Kings commaund, hauing before that Kings time bin the Destruction of two Kings of the Britaines, which were, *Madan* and *Mempricius*.

"But now whether the breach of this our *Isthmos*, were caused by some great Earth-quake, whereby the sea first breaking through, might afterward by little & little enlarge her passage, or whether it were cut by the labour of man in regard of comoditie by that passage, or whether the inhabitants of the one side or the other by occasion of war did cut it; thereby to be sequestred and freed from their Enemies, must needs remain altogether vncertain; but, that our Ile hath bin continent with *France* and that since the deluge, hath here bin shewed: and although not out of the writings of old authors, yet by euident reasons and markeable demonstrations, such as well in this case are to be allowed for sufficient authors; yea, and that before such as might perhaps deliuer vs some such report, vppon some others heare-say, and want such due proofes as here haue bin alleadged to confirme it. And no maruaile is it, that in olde Authors no relation of this is found, considering that they must in deede be very old, that hereof must make mention, yea, they must haue bin such as in those times, must haue liued about these parts, or had good meanes from these parts to haue vnderstood it, both which, considering those so very ancient ages, and the want of knowledge of letters, generally of all people in these parts of *Europe*, cannot possibly be expected. Many ages were ouer-past betweene the time of the deluge, and the time wherein the first Author liued, that euer made mention of our Ile, and let *Berosus* the *Chaldean* Priest (if hee were before *Aristotle*) haue the credit to bee the first, who liued (as it is sayd) about 340 yeares before the time of Christ, and so farre from our Ile, that neither he nor others for sundry ages after him, could come to haue true knowledge thereof, seeing they neuer came to conuerse with any of the inhabitants, that so they might haue learned it by tradition, if by tradition among such barbarous people, it had vntill then bin conserued; for by writing could they not vnderstand it from them, that in many ages after, knew not what writing meant: and when afterward in length of time their posterity came to the knowledge of letters, then had both this and other things belonging to their antiquities, long before beene worne out of remembrance: And thus will I here end this Chapter, and so returne againe to prosecute my former course."

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THE END.

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