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THE ORIGIN OF THE OLDEST FOSSILS AND THE DISCOVERY OF THE BOTTOM OF THE OCEAN.

In the *Origin of Species* Darwin says that the sudden appearance of species belonging to several of the main divisions of the animal kingdom in the lowest known fossiliferous rocks, is at present inexplicable and may be truly urged as a valid objection to his views.

If his theory be true, he says that "it is indisputable that before the lowest Cambrian stratum was deposited long periods elapsed, as long as, or probably far longer than the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures. "Here," he says, "we encounter a formidable objection; for it seems doubtful whether the earth, in a fit state for the habitation of living creatures, has lasted long enough." "To the question why we do not find such fossiliferous deposits belonging to these assumed earliest periods prior to the Cambrian system I can give no satisfactory answer."

On its geological side this difficulty is even greater than it was in Darwin's day, for we now know that the fauna of the lower Cambrian was rich and varied; that most of the modern types of animal life were represented in the oldest fauna which has been discovered, and that all its types have modern representatives. The palæontological side of the subject has been ably summed up by Walcott in an interesting memoir on the oldest fauna which is known to us from fossils, and his collection of 141 American species from the lower Cambrian is distributed over most of the marine groups of the animal kingdom, and except for the absence of the remains of vertebrated animals, the whole province of animal life is almost as completely covered by these 141 species as it could be by a collection from the bottom of the modern ocean. Four of the American species are sponges, two are hydrozoa, nine are actinozoa, twenty-nine are brachiopods, three are lamellibranchs, thirteen are gasteropods, fifteen are pteropods, eight are crustacea, fifty-one are trilobites, and trails and burrows show the existence of at least six species of bottom forms, probably worms or crustacea. The most notable characteristic of this fauna is the completeness with which these few species outline the whole fauna of the modern sea-floor. Far from showing us the simple unspecialized ancestors of modern animals, they are most intensely modern themselves in the zoölogical sense, and they belong to the same order of nature as that which prevails at the present day.

The fossiliferous beds of the lower Cambrian rest upon beds which are miles in vertical thickness, and are identical in all their physical features with those which contain this fauna. They prove beyond question that the waters in which they were laid down were as fit for supporting life at the beginning as at the end of the enormous lapse of time which they represent, and that all the conditions have since been equally favorable for the preservation and the discovery of fossils. Modern discovery has brought the difficulty which Darwin points out into clearer view, but geologists are no more prepared than he was to give a satisfactory solution, although I shall now try to show that the study of living animals in their relations to the world around them does help us, and that comparative anatomy and comparative embryology and the study of the habits and affinities of organisms tell us of times more ancient than the oldest fossils, and give a more perfect record of the early history of life than palæontology.

While the history of life, as told by fossils, has been slow and gradual it has not been uniform, for we have evidence of the occurrence of several periods when modification was comparatively rapid.

We are living in a period of intellectual progress, and, among terrestrial animals, cunning now counts for more than size or strength, and fossils show that while the average size of mammals has diminished since the middle Tertiary, the size of their brains has increased more than one hundred per cent.; that the brain of a modern mammal is more than twice as large, compared with its body, as the brain of its ancestors in the middle Tertiary. Measured in years the middle Tertiary is very remote, but it is very modern compared with the whole history of the fossiliferous rocks, although more of brain development has been effected in this short time than in all preceding time from the beginning.

The later palæozoic and early secondary fossils mark another period of rapid change, when the fitness of the land for animal life, and the presence of land plants, brought about the evolution of terrestrial animals.

I shall give reasons for seeing, in the lower Cambrian, another period of rapid change, when a new factor, the discovery of the bottom of the ocean, began to act in the modification of species, and I shall try to show that, while animal life was abundant long before, the evolution of animals likely to be preserved as fossils took place with comparative rapidity, and that the zoölogical features of the lower Cambrian are of such a character as to indicate that it is a decided and unmistakable approximation to the primitive fauna of the bottom, beyond which life was represented only by minute and simple surface animals not likely to be preserved as fossils.

Nothing brings home more vividly to the zoölogist a picture of the diversity of the lower Cambrian fauna, and of its intimate relation to the fauna on the bottom of the modern ocean, than the thought that he would have found on the old Cambrian shore the same opportunity to study the embryology and anatomy of pteropods and gasteropods and lamellibranchs, of crustacea and medusæ, echinoderms and brachiopods that he now has at a marine laboratory; that his studies would have followed the same lines then that they do now, and that most of the record of the past which they make known to him would have been ancient history then. Most of the great types of ancient life show by their embryology that they run back to simple and minute ancestors which lived at the surface of the ocean, and that the common meeting point must be projected back to a still more remote time, before these ancestors had become differential from each other.

After we have traced each great line of modern animals as far backwards as we can through the study of fossils, we still find these lines distinctly laid down. The lower Cambrian crustacea, for example, are as distinct from the lower Cambrian echinoderms or pteropods or lamellibranchs or brachiopods as they are from these of the present day, but zoölogy gives us evidence that the early steps in the establishment of these great lines were taken under conditions which were essentially different from those which have prevailed, without any essential change from the time of the oldest fossils to the present day, and that most of the great lines of descent were represented in the remote past by ancestors which, living a different sort of life, differed essentially, in structure as well as in habits, from the representatives of the same types which are known to us as fossils.

In the echinoderms we have a well defined type represented by abundant fossils, very rich in living forms, very diversified in its modification and therefore well fitted for use as an illustration. This great stem contains many classes and orders, all constructed on the same plan, which is sharply isolated and quite unlike the plan of structure in any other group of animals. All through the series of fossiliferous rocks echinoderms are found, and their plan of structure is always the same. Palæontology gives us most valuable evidence regarding the course of evolution within the limits of a class, as in the crinoids or the echinoids; but we appeal to it in vain for light upon the organization of the primitive echinoderm, or for connecting links between the classes. To our questions on these subjects, and on the relation of the echinoderms to other animals, palæontology is silent, and throws them back upon us as unsolved riddles.

The zoölogist unhesitatingly projects his imagination, held in check only by the laws of scientific thought, into the dark period before the times of the oldest fossils, and he feels absolutely certain of the past existence of a stem, from which the classes of echinoderms have inherited the fundamental plan of their structure. He affirms with equal confidence that the structural changes which have separated this ancient type from the classes which we know from fossils, are very much more profound and extensive than all the changes which each class has undergone from the earliest palæozoic times to the present day.

He is also disposed to assume, but, as I shall show, with much less reason, that the amount of change which structure has undergone is an index to the length of time which the change has required, and that the period which is covered by the fossiliferous rocks is only an inconsiderable part of that which has been consumed in the evolution of the echinoderms.

The zoölogist does not check the flight of his scientific imagination here, however, for he trusts implicitly to the embryological evidence which teaches him that, still farther back in the past, all echinoderms were represented by a minute floating animal which was not an echinoderm at all in any sense except the ancestral one, although it was distinguished by features which natural selection has converted, under the influence of modern conditions, into the structure of echinoderms. He finds in the embryology of modern echinoderms phenomena which can bear no interpretation but this, and he unhesitatingly assumes that they are an inheritance which has been handed down from generation to generation through all the ages from the prehistoric times of zoölogy.

Other groups tell the same story with equal clearness. A lingula is still living in the sand bars and mud flats of the Chesapeake Bay, under conditions which have not effected any essential change in its structure since the time of the lower Cambrian. Who can look at a living lingula without being overwhelmed by the effort to grasp its immeasurable antiquity; by the thought that while it has passed through all the chances and changes of geological history, the structure which fitted it for life on the earliest palæozoic bottom is still adapted for a life on the sands of the modern sea floor?

The everlasting hills are the type of venerable antiquity; but lingula has seen the continents grow up, and has maintained its integrity unmoved by the convulsions which have given the crust of the earth its present form.

As measured by the time-standards of the zoölogist lingula itself is modern, for its life-history still holds locked up in its embryology the record, repeated in the development of each individual, of a structure and a habit of life which were lost in the unknown past at the time of the lower Cambrian, and it tells us vaguely but unmistakably of life at the surface of the primitive ocean, at a time when it was represented by minute and simple floating ancestors.

Broadly stated, the history of each great line has been like that of the echinoderms and brachiopods. The oldest pteropod or lamellibranch or echinoderm or crustacean or vertebrate which we know from fossils exhibits its own type of structure with perfect distinctness, and later influences have done no more than to expand and diversify the type, while anatomy fails to guide us back to the point where these various lines met each other in a common source, although it forces us to believe that the common source once had an individual existence. Embryology teaches that each line once had its own representative at the surface of the ocean, and that the early stages in its evolution have passed away and left no record in the rocks.

If we try to call before the mind a picture of the land surface of the earth we see a vast expanse of verdure, stretching from high up in the mountains over hills, valleys, and plains, and through forests and meadows down to the sea, with only an occasional lake or broad river to break its uniformity.

Our picture of the ocean is an empty waste, stretching on and on with no break in the monotony except now and then a flying fish or a wandering sea bird or a floating tuft of sargassum, and we never think of the ocean as the home of vegetable life. It contains plant-like animals in abundance, but these are true animals and not plants, although they are so like them in form and color. At Nassau, in the Bahama Islands, the visitor is taken in a small boat, with windows of plate-glass set in the bottom, to visit the "sea-gardens" at the inner end of a channel through which the pure water from the open sea flows between two coral islands into the lagoon. Here the true reef-corals grow in quiet water, where they may be visited and examined.

When illuminated by the vertical sun of the tropics and by the light which is reflected back from the white bottom, the pure transparent water is as clear as air, and the smallest object forty or fifty feet down is distinctly visible through the glass bottom of the boat.

As this glides over the great mushroom-shaped coral domes which arch up from the depths, the dark grottoes between them and the caves under their overhanging tops are lighted up by the sun, far down among the anthozoa or flower animals and the zoöphytes or animal plants, which are seen through the waving thicket of brown and purple sea fans and sea feathers as they toss before the swell from the open ocean.

There are miles of these "sea gardens" in the lagoons of the Bahamas, and it has been my good fortune to spend many months studying their wonders, but no description can convey any conception of their beauty and luxuriance.

The general effect is very garden-like, and the beautiful fishes of black and golden yellow and iridescent cobalt blue hover like birds among the thickets of yellow and lilac gorgonias.

The parrot fishes seem to be cropping the plants like rabbits, but more careful examination shows that they are biting off the tips of the gorgonias and branching madrepores or hunting for the small crustacea which hide in the thicket and that all the apparent plants are really animals.

The delicate star-like flowers are the vermillion heads of boring annelids or the scarlet tentacles of actinias, and the thicket is made up of pale lavender bushes of branching madrepores, and green and brown and yellow and olive masses of brain coral, of alcyonarians of all shades of yellow and purple, lilac and red, and of black and brown and red sponges. Even the lichens which incrust the rocks are hydroid corals, and the whole sea garden is a dense jungle of animals, where plant-life is represented only by a few calcareous algæ so strange in shape and texture that they are much less plant-like than the true animals.

The scarcity of plant-life becomes still more notable when we study the ocean as a whole. On land herbivorous animals are always much more abundant and prolific than the carnivora, as they must be to keep up the supply of food, but the animal life of the ocean shows a most remarkable difference, for marine animals are almost exclusively carnivorous.

The birds of the ocean, the terns, gulls, petrels, divers, cormorants, tropic birds and albatrosses, are very numerous indeed, and the only parallel to the pigeon roosts and rookeries of the land is found in the dense clouds of sea birds around their breeding grounds, but all these sea birds are carnivorous, and even the birds of the seashore subsist almost exclusively upon animals such as mollusca, crustacea and annelids.

The seals pursue and destroy fishes; the sea-elephants and walruses live upon molluscs; the whales, dolphins and porpoises and the marine reptiles all feed upon animals and most of them are fierce beasts of prey.

There are a few fishes which pasture in the fringe of seaweed which grows on the shore of the ocean, and there are some which browse among the floating tufts of algæ upon its surface, but most of them frequent these places in search of the small animals which hide among the plants.

In the Chesapeake Bay the sheepshead browses among the algæ upon the submerged rocks and piles like a marine sheep, but its food is exclusively animal, and I have lain upon the edge of a wharf watching it crunch the barnacles and young oysters until the juices of their bodies streamed out of the angles of its mouth and gathered a host of small fishes to snatch the fragments as they drifted away with the tide.

Many important fishes, like the cod, pasture on the bottom, but their pasturage consists of molluscs and annelids and crustacea instead of plants, and the vast majority of sea fishes are fierce hunters, pursuing and destroying smaller fishes, and often exhibiting an insatiable love of slaughter, like our own blue fish and tropical albacore and barracuda. Others, such as the herring, feed upon smaller fishes and the pelagic pteropods and copepods; and others, like the shad, upon the minute organisms of the ocean, but all, with few exceptions, are carnivorous. In the other great groups of marine animals we find some scavengers, some which feed upon micro-organisms, and others which hunt and destroy each other, but there is no group of marine animals which corresponds to the herbivora and rodents and the plant-eating birds and insects of the land.

There is so much room in the vast spaces of the ocean, and so much of it is hidden, that it is only when surface animals are gathered together that the abundance of marine life becomes visible and impressive; but some faint conception of the boundless wealth of the ocean may be gained by observing the quickness with which marine animals become crowded together at the surface in favorable weather. On a cruise of more than two weeks along the edge of the gulf stream, I was surrounded continually night and day by a vast army of dark brown jelly-fish, (Linerges mercutia) whose dark color made them very conspicuous in the clear water. We could see them at a distance from the vessel, and at noon when the sun was over head we could look down to a great depth through the centre-board well, and everywhere, to a depth of fifty or sixty feet, we could see them drifting by in a steady procession, like motes in a sunbeam. We cruised through them for more than five hundred miles and we tacked back and forth over a breadth of almost a hundred miles, and found them everywhere in such abundance that there were some in every bucketful of water which we dipped up, nor is this abundance of life restricted to tropical waters, for Haeckel tells us that he met with such enormous masses of Limacina to the northwest of Scotland, that each bucket of water contained thousands.

The tendency to gather in crowds is not restricted to the smaller animals, and many species of raptorial fishes are found in densely packed banks.

The fishes in a school of mackerel are as numerous as the birds in a flight of wild pigeons, and we are told of one school which was a windrow of fish half a mile wide and at least twenty miles long. But while pigeons are plant eaters, the mackerel are rapacious hunters, pursuing and devouring the herrings as well as other animals.

Herring swarm like locusts, and a herring bank is almost a solid wall. In 1879 three hundred thousand river herring were landed in a single haul of the seine in Albemarle Sound; but the herring are also carnivorous, each one consuming myriads of copepods every day.

In spite of this destruction and the ravages of armies of medusae and siphonophores and pteropods the fertility of the copepods is so great that they are abundant in all parts of the ocean, and they are met with in numbers which exceed our power of comprehension. On one occasion the "Challenger" steamed for two days through a dense cloud formed of a single species, and they are found in all latitudes from the arctic regions to the equator in masses which discolor the water for miles. We know, too, that they are not restricted to the surface, and that the banks of copepods are sometimes more than a mile thick. When we reflect that thousands would find ample room and food in a pint of water, one can form some faint conception of their universal abundance.

The organisms which are visible in the water of the ocean and on the sea bottom are almost universally engaged in devouring each other, and many of them, like the blue-fish, are never satisfied with slaughter, but kill for mere sport.

Insatiable rapacity must end in extermination unless there is some unfailing supply, and as we find no visible supply in the water of the ocean we must seek it with a microscope, which shows us a wonderful fauna made up of innumerable larvæ and embryos and small animals, but these things cannot be the food-supply of the ocean, for no carnivorous animal could subsist very long by devouring its own children. The total amount of these animals is inconsiderable, however, when compared with the abundance of a few forms of protozoa and protophytes, and both observation and deduction teach that the most important element in marine life consists of some half-dozen types of protozoa and unicellular plants: of globigerina and radiolarians, and of trichodesmium, pyrocystis, protococcus and the coccospheres rhabdospheres and diatoms.

Modern microscopic research has shown that these simple plants, and the globigerinæ and radiolarians which feed upon them, are so abundant and prolific that they meet all demands and supply the food for all the animals of the ocean.

This is the fundamental conception of marine biology. The basis of all the life in the modern ocean is found in the micro-organisms of the surface.

This is not all. The simplicity and abundance of the microscopic forms and their importance in the economy of nature show that the organic world has gradually taken shape around them as its centre or starting-point, and has been controlled by them.

They are not only the fundamental food-supply but the primeval supply, which has determined the whole course of the evolution of marine life.

The pelagic plant-life of the ocean has retained its primitive simplicity on account of the very favorable character of its environment, and the higher rank of the littoral vegetation and that of the land is the result of hardship.

On land the mineral elements of plant-food are slowly supplied, as the rains dissolve them; limited space brings crowding and competition for this scanty supply; growth is arrested for a great part of each year by drought or cold; the diversity of the earth's surface demands diversity of structure and habit, and the great size and complicated structure of terrestrial plants are adaptations to these conditions of hardship.

At the surface of the ocean the abundance and uniform distribution of mineral food in solution; the area which is available for plants; the volume of sunlight and the uniformity of the temperature are all favorable to the growth of plants, and as each plant is bathed on all sides by a nutritive fluid, it is advantageous for the new plant-cells which are formed by cell-multiplication, to separate from each other as soon as possible, in order to expose the whole of their surface to the water. Cell-aggregation, the first step towards higher organization, is therefore disadvantageous to the pelagic plants, and as the environment at the surface of the ocean is so monotonous, there is little opportunity for an aggregation of cells to gain any compensating advantage by seizing upon a more favorable habitat. The pelagic plants have retained their primitive simplicity, and the most distinctive peculiarity of the microscopic food-supply of the ocean is the very small number of forms which make up the enormous mass of individuals.

All the animals of the ocean are dependent upon this supply of microscopic food, and many of them are adapted for preying upon it directly, but a review of the animal kingdom will show that no highly organized animal has ever been evolved at the surface of the ocean although all depend upon the food-supply of the surface.

The animals which now find their home in the open waters of the ocean are, almost without exception, descendants of forms which lived upon or near the bottom, or along the sea-shore, or upon the land, and all the exceptions are simple animals of minute size. A review of the whole animal kingdom would take more space than we can spare, but it would show that the evidence from embryology, from comparative anatomy and from palæontology, all bears in the same direction and proves that every large and highly organized animal in the open ocean is descended from ancestors whose home was not open water but solid ground, either on the bottom or on the shore.

Embryology also gives us good ground for believing that all these animals are still more remotely descended from minute and simple pelagic ancestors, and that the history of all the highly organized inhabitants of the water has followed a roundabout path from the surface to the bottom and then back into the water.

When this fact is seen in all its bearings and its full significance is grasped, it is certainly one of the most notable and instructive features of evolution.

The food-supply of marine animals consists of a few species of microscopic organisms which are inexhaustible and the only source of food for all the inhabitants of the ocean. The supply is primeval as well as inexhaustible, and all the life of the ocean has gradually taken shape in direct dependence upon it.

In view of these facts we cannot but be profoundly impressed by the thought that all the highly organized marine animals are products of the bottom or the shore or the land, and that while the largest animals on earth are pelagic the few which are primitively pelagic are small and simple.

The reason is obvious. The conditions of life at the surface are so easy that there is little fierce competition, and the inorganic environment is so simple that there is little chance for diversity of habits.

The growth of terrestrial plants is limited by the scarcity of food, but there is no such limit to the growth of pelagic plants or the animals which feed on them, and while the balance of life is no doubt adjusted by competition for food this is never very fierce, even at the present day, when the ocean swarms with highly organized wanderers from the bottom and the shore. Even now the destruction or escape of a microscopic pelagic organism depends upon the accidental proximity or remoteness of an enemy rather than upon defense or protection, and survival is determined by space relations rather than a struggle for existence.

The abundance of food is shown by the ease with which wanderers from the land, like sea birds, find places for themselves in the ocean, and the rapidity with which they spread over its whole extent.

As a marine animal the insect, Halobates, must be very modern as compared with most pelagic forms, yet it has spread over all tropical and sub-tropical seas, and it may always be found skimming over the surface of mid-ocean as much at home as a Gerris in a pond. I never found it absent in the Gulf Stream when conditions were favorable for collecting.

The easy character of pelagic life is shown by the fact that the larvæ of innumerable animals from the bottom and the shore have retained their pelagic habit, and I shall soon give reasons for believing that the larva of a shore animal is safer at sea than near the shore.

There was little opportunity in the primitive pelagic fauna and flora for an organism to gain superiority by seizing upon an advantageous site or by acquiring peculiar habits, for one place was like another, and peculiar habits could count for little in comparison with accidental space relations. After the fauna of the surface had been enriched by all the marine animals which have become secondarily adapted to pelagic life, competition with those improved forms brought about improvements in those which were strictly pelagic in origin, like the siphonophores, and those wanderers from the bottom introduced another factor into the evolution of pelagic life, for their bodies have been utilized for protection or concealment and in other ways, and we now have fishes which hide in the poison curtain of Physalia, crustacea which live in the pharynx of Salpa or in the mouth of the manhaden, barnacles and sucking fish fastened to whales and turtles, besides a host of external and internal parasites. The primitive ocean furnished no such opportunity, and the conditions of pelagic life must at first have been very simple, and while competition was not entirely absent the possibilities of evolution must have been extremely limited and the progress of divergent modification very slow so long as all life was restricted to the waters of the ocean.

There can be no doubt that floating life was abundant for a long period when the bottom was uninhabited. The slow geological changes by which the earth gradually assumed its present character present a boundless field for speculation, but there can be no doubt that the surface of the primeval ocean became fit for living things long before the deeper waters or the sea floor, and during this period the proper conditions for the production of large and complicated organisms did not exist, and even after the total amount of life had become very great it must have consisted of organisms of small size and simple structure.

Marine life is older than terrestrial life, and as all marine life has shaped itself in relation to the pelagic food supply, this itself is the only form of life which is independent, and it must therefore be the oldest. There must have been a long period in primeval times when there was a pelagic fauna and flora rich beyond limit in individuals, but made up of only a few simple types. During this time the pelagic ancestors of all the great groups of animals were slowly evolved, as well as other forms which have left no descendants. So long as life was restricted to the surface no great or rapid advancement, through the influences which now modify species, was possible, and we know of no other influences which might have replaced them. We are, therefore, forced to believe that the differentiation and improvement of the primitive flora and fauna was slow, and that, for a vast period of time, life consisted of an innumerable multitude of minute and simple pelagic organisms. During the time which it took to form the thick beds of older sedimentary rocks, the physical conditions of the ocean gradually took their present form, and during a part at least of this period the total amount of life in the ocean may have been very nearly as great as it is now without leaving any permanent record of its existence, for no rapid advance took place until the advantages of life on the bottom were discovered.

We must not think of the populating of the bottom as a physical problem, but as discovery and colonization, very much like the colonization of islands. Physical conditions for a long time made it impossible, but its initiation was the result of biological influences, and there is no reason why its starting point should necessarily be the point where the physical obstacles first disappeared. It is useless to speculate upon the nature of the physical obstacles; there is reason to think one of them, probably an important one, was the deficiency of oxygen in deep water.

Whatever their character may have been they were all, no doubt, of such a nature that they first disappeared in the shallow water around the coast, but it is not probable that bottom life was first established in shallow water, or before the physical conditions had become favorable at considerable depths.

The sediment near the shore is destructive to most surface animals, and recent explorations have shown that a stratum of water of very great thickness is necessary for the complete development of the floating microscopic fauna and flora, and it is a mistake to picture them as confined to a thin surface stratum. Pelagic plants probably flourished as far down as light penetrates, and pelagic animals are abundant at very great depths. As the earliest bottom animals must have depended directly upon the floating organisms for food, it is not probable that they first established themselves in shallow water, where the food supply is both scanty and mixed with sediment; nor is it probable that their establishment was delayed until the great depths had become favorable to life.

The belts around elevated areas far enough from shore to be free from sediment, and deep enough to permit the pelagic fauna to reach its full development above them, are the most favorable spots, and palæontological evidence shows that they were seized upon very early in the history of life on the bottom.

It is probable that colony after colony was established on the bottom and afterwards swept away by geological change like a cloud before the wind, and that the bottom fauna, which we know was not the first. Colonies which started in shallow water, were exposed to accidents from which those in great depths were free; and in view of our knowledge of the permanency of the sea-floor and of the broad outlines of the continents, it is not impossible that the first fauna which became established in the deep zone around the continents may have persisted and given rise to modern animals. However this may be, we must regard this deep zone as the birthplace of the fauna which has survived; as the ancestral home of all the improved metazoa.

The effect of life upon the bottom is more interesting than the place where it began, and we are now to consider its influence upon animals, all whose ancestors and competitors and enemies had previously been pelagic. The cold, dark, silent, quiet depths of the sea are monotonous compared with the land, but they introduced many new factors into the course of organic evolution.

It is doubtful whether the animals which first settled on the bottom secured any more food than floating ones, but they undoubtedly obtained it with less effort, and were able to devote their superfluous energy to growth and to multiplication, and thus to become larger and to increase in numbers faster than pelagic animals. Their sedentary life must have been favorable to both sexual and asexual multiplication, and the tendency to increase by budding must have been quickly rendered more active, and one of the first results of life on the bottom must have been to promote the tendency to form connected cormi, and to retain the connection between the parent and the bud until the latter was able to obtain its own food and to care for itself. The animals which first acquired the habit of resting on the bottom soon began to multiply faster than their swimming allies, and their asexually produced progeny, remaining for a longer time attached to and nourished by the parent stock, were much more favorably placed for rapid growth. As the animals of the bottom live on a surface, or at least a thin stratum, while swimming animals are distributed through solid space, the rapid multiplication of bottom animals must soon have led to crowding and to competition, and it quickly became harder and harder for new forms from the open water to force themselves in among the old ones, and colonization soon came to an end.

The great antiquity of all the types of structure which are represented among modern animals is therefore what we should expect, for after the foundation of the fauna of the bottom was laid it became, and has ever since remained, difficult for new forms to establish themselves.

Most of our knowledge of the sea bottom is from three sources: from dredgings and other explorations; from rocks which were formed beyond the immediate influence of continents, and from the patches of the bottom fauna which have gradually been brought near its surface by the growth of coral reefs, and from all these sources we have testimony to the density of the crowd of animals on favorable spots. Deep sea explorations give only the most scanty basis for a picture of the sea bottom, but they show that animal life may thrive with the dense luxuriance of tropical vegetation, and Sir Wyville Thomson says he once brought up at one time on a tangle which was fastened to a dredge over twenty thousand specimens of a single species of sea urchin. The number of remains of palæozoic crinoids and brachiopods and trilobites which are crowded into a single slab of fine grained limestone is most astounding, and it testifies most vividly and forcibly to the wealth of life on the old sea-floor.

No description can convey any adequate conception of the boundless luxuriance of a coral island, but nothing else gives such a vivid picture of the capacity of the sea-floor for supporting life. Marine plants are not abundant on coral islands and the animals depend either directly or indirectly upon the pelagic food-supply, so that their life is the same in this respect as that of animals in the deep sea far from land.

The abundant life is not restricted to the growing edge of the reef, and the inner lagoons are often like crowded aquaria. At Nassau my party of eight persons found so much to study on a little reef in a lagoon close to our laboratory that we discovered novelties every day for four months and our explorations seldom carried us beyond this little tract of bottom. Every inch of the bottom was carpeted with living animals, while others were darting about among the corals and gorgonias in all directions; but this was not all, for the solid rock was honeycombed everywhere by tubes and burrows, and when broken to pieces with a hammer each mass of coral gave us specimens of nearly every great group in the animal kingdom. Fishes, crustacea, annelids, mollusca, echinoderms, hydroids and sponges could be picked out of the fragments and the abundance of life inside the solid rock was most wonderful.

The absence of pelagic life in the landlocked water of coral islands is as impressive and noteworthy as the luxuriance of life upon and near the bottom.

On my first visit to the Bahama Islands I was sadly disappointed by the absence of pelagic animals where all the conditions seemed to be peculiarly favorable.

The deep ocean is so near that, as one cruises through the inner sounds past the openings between the islets which form the outer barrier, the deep blue water of mid-ocean is seen to meet the white sand of the beach, and soundings show that the outer edge is a precipice as high as the side of Chimborazo and much steeper.

Nowhere else in the world is the pure water of the deep sea found nearer land or more free from sediment, and on the days when the weather was favorable for outside collecting we found siphonophores and pteropods, pelagic molluscs and crustacea and tunicates and all sorts of pelagic larvæ in great abundance in the open water just outside the inlets.

Inside the barrier the water was always calm, and day after day it was as smooth as the surface of an inland lake. When I first entered one of these beautiful sounds, where the calm transparent water stretches as far as the eye can reach, while new beauties of islets and winding channels open before one as those which are passed fade away on the horizon, I felt sure that I had at last found a place where the pelagic fauna of mid-ocean could be gathered at our door and studied on shore. The water proved to be not only as pure as air but almost as empty. At high water we sometimes captured a few pelagic animals near the inlets, but we dragged our surface nets through the sounds day after day only to find them as clean as if they had been hung in the wind to dry. The water in which we washed them usually remained as pure and empty as if it had been filtered, and we often returned from our touring expeditions without even a copepod or a zoea or a pluteus.

The absence of the floating larvæ is most remarkable, for the sounds swarm with bottom animals which give birth every day to millions of swimming larvæ. The mangrove swamps and the rocky shores are fairly alive with crabs carrying eggs at all stages of development, and the boat passes over great black patches of sea-urchins crowded together by thousands. The number of animals engaged in laying their eggs or hatching their young is infinite, yet we rarely captured any larvæ in the tow net, and most of these we did find were well advanced and nearly through their larval life.

It is often said that the water of coral sounds is too full of lime to be inhabited by the animals of the open ocean, but this is a mistake, for the water is perfectly fit for supporting the most delicate and sensitive animals, and those which we caught outside lived in the house in water from the sounds better than in any other place where I ever tried to keep them, and instead of being injurious, the pure water of coral sounds is peculiarly favorable for use in aquaria for surface animals.

The scarcity of floating organisms can have only one explanation. They are eaten up, and competition for food is so fierce that nearly every organism which is swept in by the tide and nearly every larva which is born in the sounds is snatched by the tentacles around some hungry mouth.

Nothing could illustrate the fierceness of the struggle for food among the animals on a crowded sea-bottom more vividly than the emptiness of the water in coral sounds where the bottom is practically one enormous mouth. The only larvæ which have much chance to establish themselves for life are those which are so fortunate as to be swept out into the open ocean where they can complete their larval life under the milder competition of the pelagic fauna, and while it is usually stated that the larvæ of bottom animals have retained the pelagic habit for the purpose of distributing the species, it is more probable that it has been retained on account of its comparative safety.

These facts show that competition must have come quickly after the establishment of the first fauna on the bottom, and that it soon became very rigorous and led to severe selection and rapid modification; and we must also remember that life on the bottom brought with it many new opportunities for divergent specialization and improvement. The increase in size which came with economy of energy increased the possibilities of variation and led to the natural selection of peculiarities which improved the efficacy of the various parts of the body in their functions of relation to each other, and this has been an important factor in the evolution of complicated organisms.

The new mode of life also permitted the acquisition of protective shells, hard-supporting skeletons and other imperishable parts, and it is therefore probable that the history of evolution in later times gives no index as to the period which was required to evolve from small, simple pelagic ancestors the oldest animals which were likely to be preserved as fossils.

Life on the bottom also introduced another important evolutionary influence: competition between blood-relations. In those animals, which we know most intimately, divergent modification, with the extinction of connecting forms, results from the fact that the fiercest competitors of each animal are its closest allies, which, having the same habits, living upon the same food, and avoiding enemies in the same way, are constantly striving to hold exclusive possession of all that is essential to their welfare.

When a stock gives rise to two divergent branches, each escapes competition with the other so far as they differ in structure or habits, while the parent stock competing with both at a disadvantage is exterminated.

Among the animals which we know best, evolution leads to a branching tree-like genealogy with the topmost twigs represented by living animals while the rest of the tree is buried in the dead past. The connecting form between two species must therefore be sought in the records of the past or reconstructed by comparison.

Even at the present day things are somewhat different in the open ocean, and they must have been very different in the primitive ocean, for a pelagic animal has no fixed home, one locality is like another, and the competitors and enemies of each individual are determined in great part by accidents.

We accordingly find, even now, that the evolution of pelagic animals is often linear instead of divergent, and ancient forms, such as the sharks, often live on side by side with the later and more evolved forms. The radiolarians and medusæ and siphonophores furnish many well-known illustrations of this feature of pelagic life.

No naturalist is surprised to find in the South Pacific or in the Indian Ocean a salpa or a pelagic crustacean or a surface fish or a whale which was previously known only from the North Atlantic, and the list of species of marine animals which are found in all seas is a very long one. The fact that pelagic animals are so independent of those laws of geographical distribution which limit land animals is additional evidence of the easy character of the conditions of pelagic life.

One of the first results of life on the bottom was to increase asexual multiplication and to lengthen the time during which buds remain united to and nourished by their parents, and to crowd individuals of the same species together and to cause competition between relations. We have in this and other obvious peculiarities of life on the bottom a sufficient explanation of the fact that since the first establishment of the bottom fauna, evolution has resulted in the elaboration and divergent specialization of the types of structure which were already established rather than the production of new types.

Another result of the struggle for existence on the bottom was the escape of varieties from competition with their allies by flight from the crowded spots and a return to the open water above; just as in later times the whales and sea birds have gone back from the land to the ocean.

These emigrants, like the civilized men who invade the homes of peaceful islanders, brought with them the improvements which had come from fierce competition, and they have carried everything before them and produced a great change in the pelagic fauna.

The rapid intellectual development which has taken place among the mammals since the middle Tertiary, and the rapid structural changes which took place in animals and plants when the land fauna and flora were established, are well known, but the fact that the discovery of the bottom initiated a much earlier and probably more important era of rapid development in the forms of animal life has never been pointed out.

If this view is correct the primitive fauna of the bottom must have had the following characteristics: 1. It was entirely animal, without plants, and it at first depended directly upon the pelagic food supply.

2. It was established around elevated areas in water deep enough to be beyond the influence of the shore.

3. The great groups of animals were rapidly established from pelagic ancestors.

4. The animals of the bottom rapidly increased in size and hard parts were quickly acquired.

5. The bottom fauna soon produced progressive development among pelagic animals.

6. After the establishment of the fauna of the bottom elaboration and differentiation among the representatives of each primitive type soon set in and led to the extinction of connecting forms.

Many of the oldest fossils like the pteropods are the modified descendants of ancestors with hard parts, and there is no reason to suppose that the first animals which were capable of preservation as fossils have been discovered, but it is interesting to note that the oldest known fauna is an unmistakable approximation to the primitive fauna of the bottom.

The lower Cambrian fossils are distributed through strata more than two miles thick, some, at least, of them showing by their fine grain and by the perfect preservation of tracks and burrows which were made in soft mud, and of soft animals like jelly fish, that they were deposited in water of considerable depth. The sediment was laid down slowly and gently in water so deep as to be free from disturbance aud under conditions so favorable that it contains the remains of delicate animals not often found as fossils.

While the fauna of the lower Cambrian undoubtedly lived in water of very considerable depth it was not oceanic but continental, for we are told by Walcott that "one of the most important conclusions is that the fauna of the lower Cambrian lived on the eastern and western shores of a continent that in its general configuration outlines the American continent of to-day." "Strictly speaking the fauna did not live upon the outer shore facing the ocean, but on the shores of interior seas, straits or lagoons that occupied the intervals between the several ridges that ran from the central platform east and west of the main continental land surface of the time."

This fauna was rich and varied, but it was not self-supporting, for no fossil plants are found, and the primary food supply was pelagic. Animals adapted for a rapacious life, such as the pteropods, were abundant, and prove the existence of a rich supply of pelagic animals. All the forms known from the fossils are either carnivorous, like the medusae, corals, crustacea, and trilobites, or they are adapted, like the sponges, brachiopods, and lamellibranchs, for straining minute organisms out of the water or for gathering those which rained down from above, and the conditions under which they lived were very similar to those on the bottom at the present day.

Walcott's studies show that the earliest known fauna had the following characteristics: It consisted, so far as the record shows, of animals alone, and these were dependent upon the pelagic food supply for support. While small in comparison with many modern animals, they were gigantic compared with primitive pelagic animals. The species were few, but they represent a very wide range of types. All these types have modern representatives, and most of the modern types are represented in the lower Cambrian. Their home was not the bottom of the deep ocean, but the shores of a continent under water of considerable depth.

The Cambrian fauna is usually regarded as a half-way station in a series of animal forms which stretches backwards into the past for an immeasurable period, and it is even stated that the history of life before the Cambrian is larger by many fold than its history since.

So far as this opinion rests on the diversity of types in Cambrian times, it has no good basis; for if the views here advocated are correct the evolution of the ancestral stems took place at the surface, and all the conditions necessary for the rapid production of types were present when the bottom fauna first became established.

As we pass backwards towards the lower Cambrian we find closer and closer agreement with the zoölogical conception of the character of primitive life on the bottom. While we cannot regard the oldest fauna which has been discovered as the first which existed on the bottom, we may feel confident that the first fauna of the bottom resembled that of the lower Cambrian in its physical conditions and in its most distinctive peculiarities; the abundance of types, and the slight amount of differentiation among the representatives of these types; and we must regard it as a decided and unmistakable approximation to the beginning of the modern fauna of the earth, as distinguished from the more ancient and simple fauna of the open ocean.

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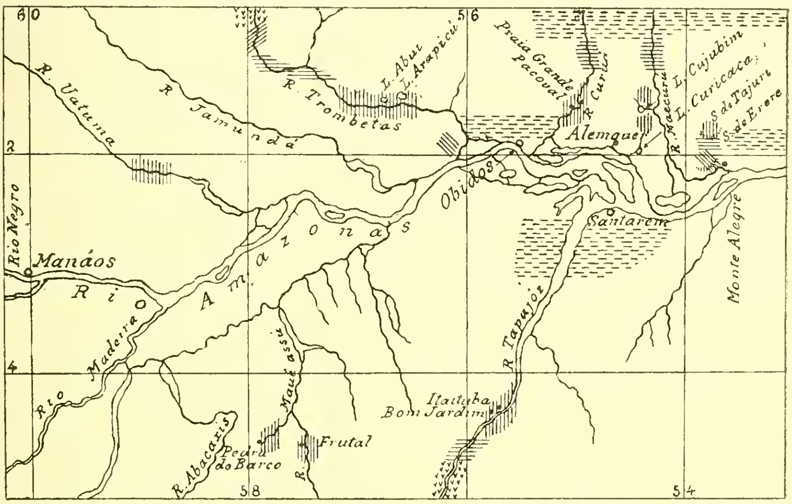
THE AMAZONIAN UPPER CARBONIFEROUS FAUNA.

As, from recent discussions of correlation and geographical distribution, the Upper Carboniferous fauna of the lower Amazonian region seems to be considered a somewhat important element, it appears desirable to make it known more completely than it is at present. A description of the brachiopods was published in 1874 (Bulletin of the Cornell University, Science, No. 2), and a revision of that group with some new material and a complete study of all the material known from Amazonian localities was made shortly afterward, but withheld from publication from lack of means for preparing the necessary plates. This study is now out of date as regards nomenclature, and many of the species then regarded as new have very likely been since described from other regions. As, however, from various circumstances the probability of being able to revise it in view of the recent literature, and to publish it with proper illustrations, is now extremely remote, it is thought best to give the following resumé. Palæontologists will find much to criticise in the identifications, notes, and comparisons made a dozen years ago and only very incompletely revised since, but it is hoped that they will be able to recognize the most characteristic types and that they will find enough of interest in a more complete presentation of this interesting fauna to overlook the shortcomings of the present note.

The region in which this fauna is definitely known is represented in the annexed sketch map, taken in great part from Steiler's Atlas, but with some modifications introduced from the map given by Mr. H. H. Smith in his work, *Brazil, the Amazons and the Coast*, New York, 1879. This map represents the upper part of what is locally known as the lower Amazonas, that is to say the section below the mouths of the Rio Negro and the Madeira, where the valley is narrowed by the approach of the highlands from either side to, or near, the banks of the great river. The supposed Archean, which appears in the rapid section of the Tapajos on the south and of the Trombetas on the north, consists on the former river of metamorphosed quartzites and porphyritic eruptives, and on the latter of syenite and similar porphyritic eruptives. The latter prove on microscopic examination to be much altered plagioclase rocks, presumably



Archean (?) Upper Silurian Devonian Carboniferous
Cretaceous Tertiary

augite-porphyrites. Resting on these are, on the Trombetas, slightly disturbed sandstone beds with Upper Silurian fossils. Below them comes a zone of sandstone and shales with *Spirophyton*, which has been better explored on the Curuá and Maecurú and at the foot of the small Serra de Ereré near Monte Alegre, where an abundant Devonian fauna has been found. Beds with *Spirophyton* have also been observed on the Tapajos below the falls, and these, originally supposed to be Carboniferous, are now referred to the Devonian. The best explored Carboniferous locality is on the Tapajos at the village of Itaituba and the neighboring limestone cavern of Bom Jardim, where five fossil-bearing members have been recognized, the faunas of which are discriminated in the annexed table. The characteristic feature is a blue amorphous limestone containing beautifully preserved silicified fossils which, by the decay of the limestone where washed by the river, become dissolved out of the rock and accumulated on the beach. Similar limestone cavern and beach specimens are reported by Mr. Chandless and the late Major Joâo Martins da Silva Coutinho, the companion of Agassiz and first discoverer of fossils on the Amazonas, at Pedra do Barco and Frutal on the Mauéassu, a small river between the Tapajos and Madeira.

The localities on the northern side have been examined by the writer at the Serra de Tajaurí near Monte Alegre, and on two small lakes, Araptoú and Abui, in the flood plain of the Trombetas at the margin of the highlands; by Mr. H. H. Smith on the Curuá and in the district about Alemquer between that river and the Maecurú, while the occurrence of beach-worn fossils similar to those of the Tapajos has been reported by the Brazilian botanist Barbosa Rodregues on the Uatumá, a small river between the Trombetas and the Rio Negro. At the Serra de Tajaurí, at Lake Cujubim (bed No. 3 of Mr. Smith's section) in the Alemquer district and Lake Abui on the Trombetas, limestone with silicified fossils occurs; at Praia Grande on the Curuá, beach specimens similar to those at Itaituba; at Lake Curucaca and Cujubim (Nos. 5, 8, and 9) in the Alemquer district, Pacoval on the Curuá and Lakes Arapicú and Abui on the Trombetas, shales with fossils. Those from the Trombetas are apparently decomposed limestones and are associated with flints like those of Itaituba, which are also represented with chance specimens from one or two other Trombetas localities.

To the Cretaceous is referred the disturbed sandstone mass with fossil leaves of the Serra de Ereré, and a similar mass, in which, however, no fossils have been found, near Obydos, and to the Tertiary, the low plateau (100 meters more or less) of horizontal sands and clays back of Santarem on the Tapajos, the denuded ridges of Monte Alegre and Obydos and the high plateaus (300 meters more or less) on the Curuá and Maecurú, which are evidently the prolongation of the table-topped hills of Parauaquara and Almeirim to the eastward of the limits of the map. Presumably the Tertiary beds cover, or have covered, a large part of the areas left blank on the map.

A full list of the fauna, so far as known, is given in the following table with the distribution of the species in the different localities. Out of the total number of 122 species 62 have been found in the limestone of Bom Jardim near Itaituba, which, being the formation from which the most complete collections have been made, and apparently also the richest in species, may be taken as the standard with which the others may be compared. The silicified specimens found free on the beach at Itaituba are evidently washed out of a decayed limestone, and the character of the specimens as well as the numerical comparison indicates its complete identity with that of Bom Jardim, since of the 33 species recognized on the beach, only five rare forms of Bryozoa, Echinoderms, and Eusulina have not as yet been found in the limestone.

The peculiar siliceous boulders have every appearance of being weathered out of a limestone bed and their position on the beach at Itaituba indicates that this bed was intimately associated with that furnishing the loose beach specimens, if not identical with it. Of the 32 species recognized in the boulders, 13 have not been found in the limestone, and of these 10 (six being gasteropods) have not been found in the other Itaituba rocks though two of these occur in the shale of Pacoval on the Curuá The fauna of the boulders is characterized by the abundance of lamellibranchs and gasteropods, making up two-thirds of the species, and the differences between its fauna and that of the limestone are presumably of habitat rather than of horizon. Large coarse forms predominate and are for the most part so rare that no certain conclusion regarding them can be drawn. The exceptions are *Streptorhynchus correianus* and *Productus cora*, which are abundant and characteristic. The former has not been found in the other rocks at Itaituba, though it occurs elsewhere, and the absence from the limestone of the latter, one of the most abundant and widespread of the Amazonian species, is remarkable.

Of the 38 species of the white decomposed cherts, also found loose on the beach of Itaituba in small fragments, 17 have not been found elsewhere at that place though four of them occur at one or another of the other localities. The leading characteristic of the chert fauna is the abundance of small lamellibranchs, 14 species, of which six have not been found in the other rocks of Itaituba though three of them occur elsewhere, and of gasteropods, 13 species, of which seven occur also in the limestone and one in the siliceous boulders. It is to be noted, however, that the greater part of the fossils of these two groups found in the limestone are from cherty nodules in the upper part, which leads to the hypothesis that the white decomposed cherts may have weathered out of the limestone or of some layer in immediate connection with it. The two brachiopods, *Spiriferina spinosa* and *Chonetes amazonica*, peculiar to the cherts, are exceedingly rare forms.

Stronger indications of a possibly independent fauna are found in the few loose fragments of an impure argillaceous limestone, from which five species are known, none of which have been found in the purer limestone of Bom Jardim, though two occur in the boulders and one, probably two, in the cherts. These fragments possibly represent the rock from which the boulders and cherts have weathered out, and presumably come from above the limestone with a continuation of its fauna with differences due to habitat. In short, all of the Itaituba material indicates essentially the same horizon.

The Mauéassu limestone at Pedra do Barco and Frutal is identical in aspect and character of the fossils with that of the Tapajos at Itaituba. Of the 18 species known from Pedra do Barco, two species of *Productus*, a *Pleurotomaria*, and an *Euomphalus* have not been found at Itaituba. The limestone No. 3 at Lake Cujubim has only one species, *Productus cora*, out of 11 not found in that of Itaituba, although it occurs in the boulders and cherts. This same *Productus* and another of the *P. nebrascensis* type (occurring also at Pedra do Barco) are the only distinct forms among the 10 in the limestone at the Serra de Tajaurí. The beach specimens from Praia Grande on the Curuá are exactly similar to those from Itaituba, and of the 12 species known from that place only an undetermined *Athyris* has not appeared at Itaituba. The yellow shale, probably a decomposed limestone from Lake Arapicú with 11 species and the limestone and shale of Lake Abui with five, show the same close relationship and indicate that the limestone extends westward to the Trombetas. None of the fossils from the Rio Uatumá, still farther to the westward, have been seen by me, but according to the note of Sr. Barbosa Rodregues they agree in character and mode of occurrence with those of Itaituba.

The fauna from the shale at Pacoval on the Curuá is thought by Mr. Smith to come near the top of about 600 feet of shale above the limestone furnishing the beach specimens of Praia Grande. The rock is decomposed and of a marly aspect, indicating a high original proportion of calcareous matter. Of its 37 species, 10, all lamellibranchs, have not been found at Itaituba, the others occurring at that place mainly in the cherts and boulders in which also occur the three (*Productus cora*, *P. nebrascensis* and *Streptorhynchus correianus*) out of its 13 brachiopod species that have not been found in the Bom Jardim limestone. The shaly beds at Lake Cujubim and Lake Curucaca in the Alemquer district, also placed above the limestone by Mr. Smith, agree, so far as their fossils can be made out, with the Pacoval fauna.

Thus, although there is on the Lower Amazonas a considerable thickness, probably from 1,000 to 2,000 feet, of supposed Upper Carboniferous rocks, all the known fossils are marine and from a single, or two closely related horizons. As stated in my paper on the brachiopods and afterwards confirmed by an examination of a collection brought from Lake Titicaca by Prof. Alex. Agassiz (Bull. Mus. Comp. Zool., No. 12) the Andean Carboniferous fauna is of about the same horizon. In southern Brazil, where there is an extensive Carboniferous area, fresh-water conditions seem to have prevailed and marine fossils have thus far proved to be rare and unsatisfactory. So far as their characters have been made out they agree with the prevailing vegetable and reptilian types in presenting a decided Permian, or perhaps early Secondary, facies. Both in its physical and palæontological characteristics this formation of southern Brazil offers considerable analogies with those of South Africa, India, and Australia, containing the Glossopteris flora (see Waagen, Neues Jahrbuch, 1888, II., pp. 172–177). If on further study this analogy is found to hold good, we shall have at, or near, the close of the Palæozoic two strongly contrasted chains of similar formations extending from east to west across the whole present land area of the globe. The one with an abundant and characteristic marine fauna reaches from China to Bolivia with the Salt Range and the Lower Amazonas (also the Pichis river locality in Peru) as intermediate links; the other, with predominant freshwater and terrestrial conditions, reaches from Australia through India and Africa to southern central South America.

Terebratula itaitubense.—Dr. Waagen who distinguishes the group of Terebratulas, to which this species belongs by King's name Dielasma identifies this species on the limit between the middle and lower division of the Productus limestone in the Salt Range, India.

Terebratula sp.—The forms represented by fig. 24, pl. III. of my paper and referred with doubt to the young of the preceding species, prove to belong to a distinct type of short louped Terebratuloids without or with only rudimentary septal plates in the dorsal valve. This character, combined with dental plates in the ventral valve, would perhaps place it in Waagen's genus *Zugmeyeria*, which thus far is only known in the Rhaetic.

Athyris subtilita.—Dr. Waagen, who makes a new genus *Spirigerella*, for types similar to this, considers the Indian and Brazilian forms as identical and distinct from the North American *A. subtilita*, proposing to distinguish them by the name *S. derbyi.* His doubt as to whether I may not in my description have somewhat exaggerated the importance of the foramen may be well founded,

	Itaituba.					Rio Maueassu.		Alemquer District.					Rio Curua.		Rio Trombetas.		
	White Cherts.	Siliceous Boulders.	Beach.	Argillaceous Limestone.	Limestone Bom Jardim.	Pedra do Barco.	Frutal.	Cujubim No. 3.	Cujubim No. 5.	Cujubim No. 8 & 9.	Curucaca.	Tajauri.	Pacoval.	Praia Grande.	L. Arapicu.	L. Abui.	
Terebratula itaitubense, Derby	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
T—— sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Waldheimia coutinhoana, Derby	x	x	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Eumetria mormoni, Marcou	x	..	x	..	x	..	..	..	..	..	..	..	..	x	..	..	..
Athyris subtilita, Hall	..	x	x	..	x	x	x	..	..	..	..	..	..	x	x	..	..
A—— sublamellosa, Hall	..	..	x	..	x	x	x	x	..	..	..	..	x	x	..	..	..
A—— (?) sp	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..
Spirifer camarata, Morton	..	?	x	..	x	x	x	x	..	..	..	..	x	..	?	..	..
S—— rockymontana, Marcou	..	x	x	..	x	x	x	..	..	..	..	x	..	x	..	..	..
S—— (Martinia) perplexa, McChesney	..	..	x	..	x	x	x	x	..	..	..	x	x	..	..	..	..
S—— (Martinia) planoconvexa, Shumard	..	..	x	..	x	..	..	x	..	..	..	..	x	x	x	x	..
Spiriferina transversa, McChesney	..	..	x	..	x	x	..	..	..	..	..	..	x	x	..	..	..
S—— spinosa, Norwood and Pratten	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rhynchonella pipira, Derby	x	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Camaraphoria sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	x	..	..
Orthis penniana, Derby	..	..	x	..	x	x	x	x	..	..	..	..	..	x	..	..	..
O—— morganiana, Derby	..	..	x	..	x	x	x	..	..	..	..	..	..	..	x	..	..
Streptorhynchus correanus, Derby	..	x	..	..	..	..	..	..	?	..	..	..	x	..	..	x	..
S—— hallianus, Derby	..	..	x	..	x	..	x	..	..	..	..	?	..	..	..	..	..
S—— tapajotensis, Derby	..	..	x	..	x	x	x	..	..	..	..	x	..	..	x	..	..
Chonetes amazonica, Derby	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
C—— glatra, Geinitz	..	..	x	..	x	x	..	x	..	..	..	..	x	..	..	..	..
Strophalosia cornelliana, Derby	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Productus semireticulatus, Martin	..	..	x	..	x	..	..	x	..	..	..	..	x	x	..	..	..
P—— cora, d'Orbigny	x	x	..	..	..	..	..	x	..	..	..	x	x	..	..	x	x
P—— chandlessi, Derby	..	x	x	..	x	x	x	x	..	..	..	x	..	..	x	..	..
P—— batesianus, Derby	..	..	x	..	x	x	..	?	..	..	..	..	?	..	?	..	..
P—— rhomeanus, Derby	..	..	x	..	x	..	..	..	..	..	..	..	..	x	..	..	..
P—— wallacianus, Derby	..	..	x	..	x	x	x	..	..	..	..	x	?	..	..	..	..
P—— clarkianus, Derby	x	..	..	..	x	x	..	..	..	..	..	..	..	..	..	..	..
P—— nebrascensis, Owen	?	..	..	..	..	?	..	..	..	..	..	x	?	..	..	..	..
P—— punctatus, Martin (?)	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
Crania sp	..	..	..	..	x	..	..	..	..	..	..	x	..	..	..	..	..
Discina sp	x	..	..	x	..	..	..	..	..	..	..	..	x	..	x	..	..

	Itaituba.					Rio Maueassu.		Alemquer District.					Rio Curua.		Rio Trombetas.		
	White Cherts.	Siliceous Boulders.	Beach.	Argillaceous Limestone.	Limestone Bom Jardim.	Pedra do Barco.	Frutal.	Cujubim No. 3.	Cujubim No. 5.	Cujubim No. 8 & 9.	Curucaca.	Tajauri.	Pacoval.	Praia Grande.	L. Arapicu.	L. Abui.	
Entolium aviculatum, Swallow (?)	x	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Lima retifera, Shumard	x	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Aviculopecten occidentalis, Shumard	x	x	..	..	x	..	..	..	..	x	..	..	..	..	..	x	..
A—— carboniferous, Stevens	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
A—— neglectus, Geinitz	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
A—— coxanus, Meek and Worthen	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
A—— sp.	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A—— (Streblopteria ?) hertzeri, Meek	x	x	..	..	..	..	..	..	..	..	..	..	x	..	x	..	..
Avicula, cf. A. longa, Geinitz	..	x	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
A—— sp.	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
A——, cf. Bakewelliabicarinata, King	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A——, cf. B—— parva, Meek and W	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A——, cf. B—— sedgwickiana, King	..	..	..	..	..	..	..	..	..	x	?	..	x	..	..	..	..
Pseudomonotis sp.	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Posodonomya (?) sp.	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	x
Pinna peracuta, Shumard	x	..	..	..	x	..	..	..	..	..	..	..	x	..	..	x	..
Myalina kansasensis, Shumard	x	x	..	..	x	..	..	..	..	x	..	..	x	..	..	..	..
M—— sp.	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..
Modiola (?) sp	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
M—— (?) sp.	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x
Yoldia (?) sp.	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Nuculala sp.	..	..	..	..	..	..	..	..	..	x	?	..	..	..	..	..	..
Macrodon tenuilineatus, M. and W. (?)	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..
M—— sp.	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..
Solenomya sp.	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Solenopsis (?) sp.	..	x	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..
Schizodus wheeleri, Swallow (?)	?	..	..	x	..	..	..	..	?	x	..	..	?	..	..	..	..
S—— rossicus, de Verneuil (?)	x	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
S—— sp	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
S—— sp	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Conocardium sp	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Astartella (?) sp	x	x	..	..	x	..	..	..	..	..	..	..	x	..	..	..	..

	Itaituba.					Rio Maueassu.		Alemquer District.					Rio Curua.		Rio Trombetas.		
	White Cherts.	Siliceous Boulders.	Beach.	Argillaceous Limestone.	Limestone Bom Jardim.	Pedra do Barco.	Frutal.	Cujubim No. 3.	Cujubim No. 5.	Cujubim No. 8 & 9.	Curucaca.	Tajauri.	Pacoval.	Praia Grande.	L. Arapicu.	L. Abui.	
Pleurophorus tropidophorus, Meek (?)	..	x	..	..	..	..	..	..	..	..	?	..	x	..	..	..	..
P—— sp	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Allorisma subcuneata, M. and W.	..	..	..	..	x	..	..	..	..	?	?	..	x	..	..	..	..
A—— sp	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A—— (?) sp	..	x	..	..	..	..	..	..	..	?	..	..	..	..	..	..	..
A—— (Sedgwickia) sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Chaenomya (?) sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Pleurotomaria speciosa, M. and W.	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
P—— marcouana, Geinitz (?)	x	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
P—— conoides, M. and W. (?)	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
P——, cf. P—— subdecussata, Geinitz	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
P——, cf. P—— depressa, Cox	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
P—— (?) sp	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Murchisonia sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
M—— sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
M—— sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Loxonema sp	x	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Aclis sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Naticopsis nana, Meek and Worthen	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
N—— (?) sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Polyphemopsis sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
P—— sp	x	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
P—— (?) sp	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Euomphalus sp	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
E—— (?) sp	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Platyceras nebrascensis, Meek	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Dentalium sp	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Bellerophon carbonarius, Cox	x	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
B—— crassus, Meek and Worthen (?)	..	x	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..
B—— sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

	Itaituba.					Rio Maueassu.		Alemquer District.					Rio Curua.		Rio Trombetas.		
	White Cherts.	Siliceous Boulders.	Beach.	Argillaceous Limestone.	Limestone Bom Jardim.	Pedra do Barco.	Frutal.	Cujubim No. 3.	Cujubim No. 5,	Cujubim No. 8 & 9.	Curucaca.	Tajauri.	Pacoval.	Praia Grande.	L. Arapicu.	L. Abui.	
Synocladia biserialis, Swallow (?)	..	..	..	..	x	..	..	?	..	..	..	..	?	..	..	..	..
Fenestrella shumardi, Prout (?)	..	..	x	..	x	..	..	..	..	..	..	..	x	..	..	..	..
F—— imtermedia, Prout (?)	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
F—— sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Glauconome trilineata, Meek (?)	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Polypora submarginata, Meek (?)	..	x	..	..	x	..	..	..	..	..	..	..	x	..	..	..	..
P—— sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Ptilodicta carbonaria, Meek (?)	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
P—— sp	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gen. et sp. indet	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Campophyllum sp	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Lophophyllum sp	..	..	..	..	x	..	..	..	..	..	..	..	..	x	..	..	..
Stenopora sp	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Michelinia sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Fistulipora nodulipora, Meek (?)	..	..	x	..	x	..	..	..	..	..	..	..	..	..	x	x	..
Rhombipora lepidodendroides, Meek	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Aulopora sp	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Monticulipora sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Polycœlia sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Eocidaris hallianus, Geinitz (?)	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Archæocidaris sp	..	..	x	..	x	..	..	..	..	..	..	..	..	x	..	..	..
Erisocrinus (?) sp	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
Gen. et sp. indet	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Phillipsia sp	x	x	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..
P—— (Griffithides) sp	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fusulina sp	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
TOTAL. 122 species	[illegible]	32	33	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a point that can only be cleared up by a reëxamination of the material. At all events it seems to me more probable than his suggestion that the two forms may occur in Brazil. As stated in my paper, the Brazilian specimens differ somewhat from the generality of those seen from North America, while their correspondence, especially in internal characters, with those from the Salt Range, fully justifies Dr. Waagen's opinion of their identity.

Athyris sublamellosa.—Some years ago I saw in the National Museum, at Washington, shells from various western localities variously referred to *A. royssil*, Eveille, *A. hirsuta*, Hall, and *A. orbicularis*, McChesney, that I could not, from the external characters seen, distinguish from the Brazilian and that occurred in the same association, which is not the case with the original *A. sublamellosa.*

Athyris? sp.—A thick shell from Praia Grande, Rio Curuá, with acute umbonal ridges, giving it something of a Centronella aspect, is here referred, on account of its resemblance to a form from Spergen Hill, which is clearly an *Athyris* (*Spirigerella* of Waagen).

Spirifer camaratus.—An examination of specimens from Lake Titicaca (Bull. Mus. Comp. Zoöl. No. 12, p. 279) establishes the identity of the Bolivian form (*S. condor*, d'Orbigny) with the Brazilian. Dr. Waagen separates *S. condor* and *S. musakheylensis* from the Salt Range, India from the North American form principally on account of the prominence of the concentric lamellæ. On well preserved Brazilian specimens these are as strong as on the Bolivian shells, and if they prove to be absent from equally well preserved specimens of the North American form, the Brazilian shells may have to be referred to the Bolivian or Indian type.

Spirifer rockymontanus.—*S. opimus* in my paper. Dr. White has shown that Marcou's name has precedence over that of Hall.

Spirifer (*Martinia*) *perplexa.*—Dr. Waagen, who adopts McCoy's name *Reticularia* for shells of this type, is also of the opinion that the North American and Brazilian form is distinct from the European *S. lineatus*, Martin.

Rhynchonella pipira.—The distinct truncation of the beak of this species would appear to place it in Waagen's genus *Terebratuloidea.* The internal characters are unknown.

Camaraphoria sp.—A small smooth species of this genus is quite abundant in white decomposed chert from Lake Arapicú, Rio Trombetas, and rare in the Itaituba limestone, being at both places too imperfect for determination.

Orthis morganiana.—Specimens from New Mexico referred with doubt to *O. resupinoides*, Cox, by Dr. White, are possibly identical, in which case that name will take precedence. They are smaller and casts do not show the prominent dental lamellæ and septum of the Brazilian form, but the material is too poor for a satisfactory comparison. Specimens from Old Baldy near Virginia City, Montana, in the National Museum at Washington, labeled *O. resupinata*, Martin, by Mr. Meek, are almost certainly identical. Dr. Waagen describes a closely allied form from the Salt Range under the name of *O. derbyi.*

Streptorhynchus.—According to Dr. Waagen's arrangement, based on well defined internal characters of this perplexing group, *S. correianus* takes the name of *derbya*, *S. hallianus* remains with that of *Streptorhynchus*, while *S. tapajotensis* becomes *orthothetes.* The specimens from the shale of Pacoval, Rio Curuá, referred to *S.* (*derbya*) *correianus*, are more depressed and less irregular than those from Itaituba, but for the most part attain as large a size and present the strong ventral septum of that species, though possibly some of the smaller specimens not showing internal characters may belong to *Orthothetes.*

Chonetes glabra.—Some of the specimens from Pacoval, Rio Curuá, referred here are larger than those from Itaituba and have the mesial sinus very indistinct, or lacking, thus approaching the characters of *C. amazonica*, which possibly may prove to be identical.

Productus semireticulatus.—Specimens from Lake Titicaca that undoubtedly represent *P. inca*, d'Orbigny, prove that the Bolivian form does not belong to *P. semireticulatus*, as usually referred, but rather to the *P. costatus* group, though probably distinct from the European form.

Productus cora.—In the argillaceous strata of the Curuá and Trombetas the forms here referred become very large and take on extravagant shapes from irregular marginal expansions, but no good characters could be found for separating them from the more symmetrical forms from Itaituba. The material brought from Lake Titicaca by Prof. Alex. Agassiz, though rather unsatisfactory for this type, appears to prove the complete identity of the Brazilian shells with the original Bolivian type of *P. cora.*

Productus chandlessi.—A single specimen from Lake Titicaca shows that this form occurs also in Bolivia and thus renders it probable, notwithstanding the differences in the figures, that d'Orbigny's *P. peruvianus* is identical, in which case that name will of course take precedence.

Productus batesianus.—The specimens from the localities on the north side of the Amazonas, referred with doubt to this species, may possibly be distinct. If identical, those from Pacoval and Cujubim represent a dwarf and less distinctly sinuated variety; those from Lake Arapicú agree more nearly with the typical form from Itaituba but are larger.

Productus rhomeanus. — North American forms apparently identical with this are referred to *P. longispinus*, Sow., by Meek & White, from which, however, it seems to me to differ by important internal characters.

Productus wallacianus.—A small Productus extremely abundant in the shale of Pacoval, Rio Curuá, is either distinct or a dwarf variety of this species. This type, which appears to be rare or lacking in the North American beds, is represented in the Salt Range by *P. opuntia*, Waagen.

Productus clarkeanus.—This is probably identical with *P. pertenuis*, Meek.

Productus nebrascensis.—A specimen from the limestone at the base of the Serra de Tajaurí, is almost certainly identical with the North American shell; those from other localities are too imperfect for positive identification.

Productus punctatus (?).—A specimen from Pedra do Barco, is identical with the North American shells usually referred to *P. punctatus* but which have been separated by Dr. White under the name of *P. nevadensis.*

Discina.—Two or more species probably occur. One of these is very similar to *D. missouriensis*, Shumard.

Entolium aviculatum (?).—The doubt in regard to this species is due to imperfection of the material. So far as the characters can be made out the agreement with the North American type is complete.

Lima retifera.—In a direct comparison with Nebraska City specimens no difference of importance could be detected, as these show a grouping of the ribs in pairs very characteristic of the Brazilian shells but not represented on most figures of this species.

Aviculopecten occidentalis.—The material here referred shows considerable variability, but no constant characters could be found for distinguishing more than one species, or for separating this from the North American form which appears to be equally variable. The more typical forms with subequal ribs and furrows are from Itaituba, while those from the Curuá have furrows wider than the ribs, giving these an alternating appearance.

Aviculopecten carboniferous.—So far as can be made out from a comparison of left valves alone the Brazilian specimens agree perfectly with those from Nebraska City.

Aviculopecten neglectus.—The hinge line shows obscurely a row of cartilage pits such as are represented by Meek & Worthen on specimens from Illinois.

Aviculopecten coxanus.—Compared with figures of this species the Brazilian shells appeared to differ in the greater length of the posterior sinus and by the shortness of the hinge line but they agree in these respects with authentic specimens from Nebraska City.

Aviculopecten sp.—A large coarsely ribbed left valve and a smooth right valve, ribbed on the posterior ear, are presumed to belong together. A Kentucky shell described by Cox under the name of *A. providencesis* agrees in size and some other characters but no close comparison can be made.

Aviculopecten (*Streblopteria*) *hertzeri*.—The Brazilian specimens agree very well with the figures and description of the Ohio shells.

Avicula, five sp.—The general character of the aviculoid forms of the fauna is indicated by the comparisons of the above table. All were regarded as new, though on direct comparison of authentic specimens the first, and possibly the second, may prove identical with *A. longa*, from which, however, it appears to differ in its larger size, less attenuated form, shallower sinus and smaller ear. The three last species have the general appearance of Bakewellia but the hinge characters are those of Avicula.

Pseudomonotis sp.—Apparently identical with specimens from Nebraska City, referred with doubt by Meek to *P. radialis*, Phillips, but thought to be really distinct.

Posidonomya (?).—A peculiar type with the surface ornamentation of Posidonomya and the form of Avicula. *Avicula acosta*, Cox, from Kentucky, is perhaps congeneric, but differs in the character of the ears.

Pinna peracuta.—Fragments from the Curuá indicate a length of about 20 centimeters. The material is too fragmentary for satisfactory comparisons, but appears to be identical with fragments from Kansas, referred to Shumard's species.

Myalina kansasensis.—Compared with Kansas specimens the Brazilian form seems never to have attained so great a thickness in the cardinal region, but otherwise they present no differences of consequence. Small specimens with a well developed lobe have the aspect of *M. swallowi*, McChesney, but are connected by insensible gradations with the larger more typical forms.

Myalina sp.—Similar to *M. subquadrata*, Shumard, but probably distinct.

Modiola, two sp.—The two forms differ materially in aspect, but the differences are due to the character of the material in which they are preserved. That from the shale of Pacoval is similar in many respects to *M.(?) subelliptica*, Meek, from Nebraska, but the latter is narrower with a less inclined hinge line. The Itaituba specimens are more gibbous than any known to me from elsewhere.

Yoldia sp.—Too badly preserved for identification, but very similar to *Y. subscitula*, Meek & Hayden.

Nuculana sp.—Similar to *N. obesa*, White, but too imperfect for a satisfactory comparison.

Macrodon, two sp.—The smaller is identical with specimens from Leavenworth, Kansas, labeled *M. carbonarius* by Mr. Meek, but considered by Dr. White to be *M. tenuilineatus*. The larger one resembles somewhat *M. carbonarius*, Cox, but has coarser ribs and is apparently distinct from any described North American species.

Solenomva sp.—A single specimen occurs in chert from Barreirinha on the Tapajos above Itaituba, where it is associated with *Productus cora*. It resembles somewhat some figures of *S. biarmica*, de Verneuil, but differs from the generality of figures of that species and is probably distinct.

Solenopsis sp.—Referred to this genus from a general resemblance to *S. solenoides*, Geinitz, from which it is distinguished by being wider posteriorly than anteriorly.

Schizodus, four sp.—No. 1 is referred with doubt, due principally to imperfection of the material, to *S. wheeleri;* No. 2 is apparently identical with the Nebraska shell referred by Mr. Meek with doubt to *S. roseus* but thought by him to be really distinct; No. 3 is of the type of *S. wheeleri*, but is different from any North American shell with which it has been compared; and No. 4 is possibly a dwarf variety of No. 3, but is regarded as more probably distinct.

Conocardium sp. — Too imperfect for positive identification but apparently new. The ornamentation is similar to that of *C. obliquum*, Meek & Worthen.

Astartella (?) *sp.*—A shell agreeing in hinge characters with Hall's type, *A. vera*, from Iowa is quite abundant at Itaituba and Pacoval. A Nebraska shell described by Geinitz as *Astarte nebrascensis*, but thought by Meek to be an *Edmondia* or *Cardiomorpha*, is similar in form and ornamentation but probably generically distinct. In the National Museum at Washington there is a shell from Lake Titicaca showing the hinge, which is identical with the Brazilian forms. This is very likely the *Trigonia antiqua* of d'Orbigny.

Pleurophorus.—Two species occur, one of which is apparently identical with *P. tropidophorus*, Meek, though no direct comparison of specimens could be made. The other and larger form is apparently new, though resembling somewhat an undetermined species figured on plate XXVI., fig. 6b, of vol. V. of the Illinois report.

Allorisma subcuneata.—Compared with authentic specimens from the western United States, the Brazilian form appears identical.

Allorisma sp.—Possibly a variety of the preceding but probably distinct.

Allorisma (?) *sp.*—Similar in form to *Edmondia? glabra*, Meek, but appearing to have a sinuated pallial line which, if not a deceptive appearance, would place it in Allorisma.

Sedgwickia (?) *sp.*—A large pyriform shell with a double umbonal ridge is here referred. Nothing like it has been seen from North America.

Chaenomya (?) *sp.*—A large shell of the general type of *C. cooperi*, Meek & Hayden, but probably distinct from that species.

Pleurotomaria.—The general character of the Pleurotomarias of this fauna is indicated by the doubtful identifications and comparisons of the above table. As the comparisons have only been made from figures it is quite possible that the first five forms may prove to be representatives of North American types. The sixth by the circular form of its whorls and central position of the smooth spiral band differs from any species known to me.

Murchisonia.—Two of the species belong to the section of the genus characterized by a strong angular carina represented in North America by *M. copel,* White, and *M. nebrascensis,* Geinitz, with the former of which one of the Brazilian forms may prove to be identical. The third resembles in form and ornamentation *Turetella* (?) *stevensoni,* Meek & Worthen, but has the spiral band of Murchisonia.

Loxonema sp.—Similar to but probably not identical with *L. scitula*, Meek.

Aclis sp.—Similar to but probably not identical with *A. stevensana*, Meek & Worthen.

Naticopsis nana, Meek & Worthen. The Brazilian specimens are larger than those figured in the Geology of Illinois but show no essential differences from specimens from other North American localities.

Naticopsis (?) *sp.*—A peculiar little shell with a form like Ampullaria and indistinct indications of a spiral band which, if not deceptive, would place it in *Pleurotomaria.*

Polyphemopsis sp. A medium sized shell with a deep suture and elongated volutions, giving it the aspect of certain Silurian forms for which Conrad proposed the name of *Subulites.*

Polyphemopsis sp.—An elongated form somewhat similar to *P. peracuta*, Meek & Worthen, but too imperfect for identification.

Polyphemopsis (?) *sp.*—A subglobose form resembling *P. inornata*, Meek & Worthen, and which may prove to be *Machrocheilus.* A small specimen in chert shows traces of color.

Euomphalus.—Two species occur. One with angular whorls is of the type of *E. pentangulatus,* Sow.; the other with elevated spire and rounded whorls perhaps does not belong to this genus.

Platyceras nebrascensis.—A single small specimen agrees with Dr. White's figure of this species in Wheeler's report.

Dentalium sp.—Too imperfect for positive identification. Ornamentation like that of *D. meekianum*, Geinitz, but larger and more rapidly expanded.

Bellerophon.—Of the three species of this genus, one, from a direct comparison of specimens from Danville, Ill., can be positively identified with *B. carbonarius*, Cox ; another is probably identical with *B. crassus*, Meek & Worthen, while the third, a beautifully cancellated, non-carinate little species, is apparently new.

Polyzoa.—All the identifications in the above table are given with doubt, because no opportunity has been had for a comparison with specimens nor, in some cases, with figures. The specimens referred to *Synocladia biserialis*, *Fenestrella shumardi*, and *Glauconeme trilineata* agree well with the figures seen ; those referred to *Polypora submarginata* are probably distinct if that species is correctly figured ; *Fenestrella intermedia* and *Ptilodictya carbonaria* are identified from descriptions alone, while a species of Polypora and of Fenestrella cannot be referred satisfactorily to any described form known to me. The former bears considerable resemblance to *Synocladia virgulacea* as illustrated, but appears to differ generically, while the latter is somewhat like a species from the Ohio Corniferous (*P. gilberti*, Meek). A species of *Fenestrella* agrees well with some from Nebraska referred to, but probably not identical with, *F. plebeja*, McCoy. A peculiar ramose form closely resembling, in general appearance, *Rhombipora lepidodendroides*, but with Escarella-like cells which show it to be a Polyzoa, cannot be satisfactorily referred.

Campophyllum sp.—The Brazilian specimens appear to be identical with a small undetermined coral from Kansas City, Mo., and also with a Subcarboniferous form from Marion Co., Iowa, that has been referred to *Zaphrentis spinulosa*, Hall.

Lophophyllum sp.—Small specimens are somewhat similar to *L. proliferum*, McChesney, but the species cannot be satisfactorily referred to any described North American form.

Stenopora sp.—This form is apparently new.

Michelinia sp.—With smaller cells than any described form known to me except *M. concinna*, Longsdale, from Russia.

Fistulipora nodulifera (?).—Not identical if well preserved North American specimens are without spines as described. This may prove to be a *Monticulipora*.

Rhombipora lepidodendroides.—Well determined by a direct comparison with authentic specimens of the North American type.

Aulopora sp.—The long straight cells give a greater resemblance to *Syringopora* than to the usual small creeping forms of *Aulopora*, but the tabulæ and connecting tubes of the former genus are lacking.

Monticulipora sp.—Dr. White informs me that an identical form occurs in North America, where it has been referred to an European species.

Polycoelia sp.—No American form of this genus has been described, though Shumard mentions one from Texas.

Eocidaris hallianus (?), Geinitz.—Water worn spines agree with this species so far as their character can be determined.

Archæocidaris.—Three, or perhaps four, species are represented by material too imperfect for positive determination. *A. biangulatus* and *A. triserratus* are perhaps represented together with another type of spine that cannot be satisfactorily referred. A single interambulacral plate from Praia Grande, Rio Curuá, may belong with one of these three types of spines.

Erisocrinus (?) *sp.*—A single calyx appears to belong to this genus. It is distinguished by great concavity of the base and by ridges along the joints rising into spines at the angles. An undetermined genus of crinoid is represented by a hexagonal, spinose radial plate with two facets for arms, and columns of at least two generic types occur.

Trilobites.—Two, or perhaps three, occur representing the genera *Phillipsia* and *Griffithides*, which appear to be distinct from any of the described species.

Fusulina.—A few water-worn specimens have been found on the beach at Itaituba.

A few fish teeth and two species of cephalopods also occur, but the notes regarding them have been lost. One of the cephalopods is mentioned by Prof. Hartt in his description of the Tapajos section, which from its position is now thought to be probably of Devonian age.

ORVILLE A. DERBY.

Sãn Paulo, May 23, 1894.

GEOLOGICAL SURVEYS OF OHIO.

But little was known of the geology of Ohio so long as its surface was covered with the primeval forest. Bedded rock, suitable for use as building stone, was found, if at all, by the early settlers in the valleys of the principal streams. In many districts such stone was hauled a dozen miles or more where now as good or better can be found in every mile of the interval. The clearing away of the forest, the drainage of the swamps and the straightening of the channels of the streams have increased the efficiency of the floods to such an extent that scores or hundreds of exposures of rock are now found where a hundred years ago there was but one. The presence of coal in the southeastern quarter of the State was not unknown at an early date; but it is surprising to find at how few points it was noted by the early occupants of the country, and how completely the most important seams, as we now know them, were concealed from view.

The earliest scientific observations extant on the geology of the State, which I have been able to discover, are to be found in *Silliman's Journal*. In Volume I., 1818, two communications appear from the pen of Caleb Atwater, Esq., of Circleville, one on the Origin of the Prairies and Barrens of the West, including northern Ohio, and the second on the Scenery, Geology, Mineralogy, etc., of Belmont County.

Between 1820 and 1835 numerous notes and papers appeared in the same journal on the geology of Ohio, some of which were of extreme interest and value. Three articles in particular, written by Dr. S. P. Hildreth, of Marietta, and published respectively in 1826, 1828 and 1832, deserve special mention as by far the best statements that had appeared up to this date on the geological order of the Coal Measures of the State. Many important facts concerning their stratigraphy and structure were clearly recognized and stated, and very interesting information was furnished as the facts and conditions of the occurrence of salt water, petroleum and natural gas in the Muskingum Valley and in southern Ohio, generally.

The discovery of cannel coal for the first time in the United States was announced in a letter written by Hon. Benjamin Tappan, afterwards United States Senator from Ohio, to the *American Journal of Science* (previously Silliman's), published in Volume 18, 1830. The coal was found near Cambridge, Guernsey county, and came from a seam that has been found to be altogether worthless, while valuable cannel has since been discovered in many other localities in this State, as well as elsewhere in the country, but the discovery named above awakened great interest at the time.

The subject of state geological surveys was being considered about this time, and some of the articles already referred to were written in the apparent interest of such a survey of Ohio.

The first official suggestion of a geological survey of Ohio is to be found in the annual message of Gov. Robert Lucas, to the Legislature of the State, dated December 8, 1835. Hon. A. G. Thurman was private secretary of the Governor, and was credited by those conversant with the facts with the probable authorship of this portion of the message. The Governor's recommendations, which were very earnest and cordial, were referred to a select committee of the State Senate, who subsequently reported a joint resolution appointing Dr. S. P. Hildreth, John Locke, J. S. Riddell and Mr. I. A. Lapham a committee to report to the next Legislature the best method of obtaining "a complete geological survey of the State" and an estimate of the probable cost of the same. The committee made an elaborate report in due time, and, in accordance with its recommendations, an act was passed by the next Legislature, viz., in March, 1837, providing for "a complete and detailed geological survey of the State," which should also include the chemical analysis of soils, ores, marls, saline and other mineral waters, the construction of a geological map of the State, and the collection of the organic remains of the various formations and the supplying of sets of the same to the leading institutions of learning of Ohio. In their estimate of expenses, the committee recommended an annual appropriation of twelve thousand dollars ($12,000) for four years as adequate to cover the work above outlined. The report further recommended that for the prosecution of the survey there should be appointed "a skilled geologist" with not more than four assistants, one of whom was expected to be a naturalist. It was also recommended that a topographical engineer should be added to the corps.

In pursuance of this action the Governor appointed Prof. W.W. Mather principal geologist and Drs. S. P. Hildreth and John Locke and Professors J. P. Kirtland and C. Briggs, Jr., as assistants, and Col. Charles Whittlesey as topographical engineer. Professor Mather was a graduate of West Point and was, at this time, engaged in the geological survey of New York, having charge of the work in the southeastern portion of that State, an experience which brought him great prestige in Ohio. Dr. Hildreth was unable to continue in the active work of the survey by reason of the infirmities of age, and retired, after a service of a few months, during the summer of 1837. Col. J. W. Foster, of Zanesville, was added to the corps during the first summer. Prof. J. P. Kirtland was the naturalist of the survey, and it is safe to say no man in the State was so well fitted for this place as he. Dr. John Locke, an Englishman by birth, and at the time professor of chemistry in one of the medical colleges of Cincinnati, brought to the service of the State good powers of observation and sound scientific training, though it does not appear that before this time he had devoted special attention to geology proper. Col. Whittlesey was, like Mather, a graduate of West Point, and had been connected for a long time with the army. While in this service he had had opportunity to make important geological explorations around the south shores of Lake Superior. He was, in fact, one of the first to report upon the mineral wealth of the now famous districts of Marquette and Keweenaw Point. Professor Charles Briggs, Jr., was a resident of Massachusetts, but had been specially trained in the geology that was known at this time. He was a modest, unpretending man, but very clear and decided in his opinions and judgments on the geological facts with which he had to deal.

The first survey had thus brought together some of the best scientific talent and training of the State. Its work was begun in 1837, but so late in the season as to preclude extensive investigations. Still, a report of much value and interest was furnished to the Governor in December of that year, and issued by the State early in 1838 under the designation, "First Annual Report of the Geological Survey of the State of Ohio, by W. W. Mather, Principal Geologist, and the several Assistants." It consisted of 134 pages, and contained reports from Professor Mather, Drs. Hildreth and Kirtland, Professor Briggs and Col. Whittlesey. Professor Mather gave special attention to the coal of the State, endeavoring to convince his readers of its practical value and comparing it with charcoal in iron manufacture. He also discussed our native ores with reference to the iron supply of the State, and called attention to the soils of Ohio. The services of a geological survey to agriculture had been strongly insisted on, in the discussions leading to the organization. Dr. Hildreth also discussed the Coal Measures of Ohio, and pointed out particularly some of the leading stratigraphical elements in the series. He also discussed at some length the sources of salt that were known in the State. Professor Kirtland pointed out the advantages to be derived from botanical and zoölogical knowledge, calling special attention to the possible medicinal properties of our native plants. Professor Briggs gave the results of a reconnoissance of the country between the Hocking and Scioto rivers, in which, among other things, he pointed out the geological order of what we now know as the Subcarboniferous System. Col. Whittlesey's report was confined to questions pertaining to the mapping of Ohio.

The next summer, viz., that of 1838, found all the members of the geological corps promptly in the field, and busy, each with the task that had been assigned to him. A chemical laboratory had been equipped by Dr. Mather, and analysis of minerals and soils was begun by him. This year proved to be the last of the organization, and if this fact had been foreseen a somewhat different direction would undoubtedly have been given to the work of the corps. But as it was, the time was turned to good account. The second annual report, made to the Governor in December, 1838, consisted of 286 pages, and comprises papers from Prof. W. W. Mather, Col. C. Whittlesey, Col. J. W. Foster, Prof. C. Briggs, Jr., Drs. J. P. Kirtland and John Locke.

Dr. Mather's report gives the results of a reconnoissance, extended to all the principal divisions of the State, and that gave apparently for the first time a clear view of the entire geological column of Ohio. He also continued the discussion of the soils of the State, to which he had referred in his previous report, and published the system of analysis which was to be applied to the coals and ores of the State. Colonel Whittlesey confined himself mainly to the topography of the State, but discussing at some length the variation of the magnetic needle and giving a general section from Cleveland across the Western Reserve. The most important part of his report was the determination of the dip of the strata in central and southern Ohio. Colonel Foster described the geology of Muskingum and Licking counties and the adjacent regions. Professor Briggs' report covered a brief examination of very distinct districts of the State, viz., Wood and Crawford counties in the north, Athens and Hocking in the south, and Tuscarawas in the central portion of the State. The most valuable part of his report pertains to the Coal Measures, the order of which was coming to be quite clearly seen. Professor Kirtland published a report of great value on the zoölogy of Ohio, which is still regarded with interest by all students in this field. Dr. John Locke's geological report on the formations of southwestern Ohio and particularly of Adams county, Ohio, is a paper of great interest and permanent value.

The financial stress that began to overspread the entire country in 1837 was the principal cause of the abrupt discontinuance of the geological survey at the close of 1838. The demand for economy in the State administration was urgent, and the expenditure in scientific work, small though it was, was naturally the first to be cut off.

Probably there was some reaction from the extravagant claims that had been made as to the immediate practical results of the survey, and there was also a measure of criticism directed against certain members of the corps. These facts may have had some influence upon the action of the Legislature.

Up to the close of 1838 there had been expended $16,000 in field work, and eleven counties had been reported upon. The State had also made a small outlay in the publication of the reports. Professor Mather's estimate of the amount required to complete the survey was, at this time, $50,000.

As to the valuable results of this work there can be no question. The State never received larger returns from any other equal expenditure than from the $16,000 used in the first geological survey. The increase of wealth in a single county, through the development of mining industries, largely based on the work of the survey, was asserted to be many times more than the entire expenditure which the State had made in its support.

The most important points established in its brief duration were the following, viz.:

1. The oldest rocks of the State are the so-called blue limestone formation of southwestern Ohio.

2. The newest bedded rocks of our column are the Coal Measures of southeastern Ohio.

3. A very gentle southeasterly or southerly dip prevails throughout Ohio, a proper understanding of which renders all its stratigraphy intelligible.

4. Some interesting notes on Pleistocene and Paleozoic paleontology were introduced into the several reports. Colonel Foster, for example, gives the original description in his report of 1837 of *Castoroides ohioensis* (2d Rept., p. 30). Professor Briggs furnishes interesting data as to the *Mastodon* remains

found at Bucyrus (2d Rept., p. 127). Doctor Locke gave a restoration of *Asaphus megistos* (2d Rept., p. 247), and many valuable references to fossiliferous strata and good localities for collecting fossils are to be found in the several reports.

5. Ohio archæology received more or less attention in many of the reports. A decided impulse was given to the study by the work of the survey. Doctor Locke gives a good account, accompanied by a map, of Fort Hill, Highland county.

The two reports of the first survey were limited to a few thousand copies each. The volumes are eagerly sought for at the present time, and command a good price whenever found in the market.

The discontinuance of the survey was a source of regret and mortification to the more intelligent citizens of the State, and efforts presently began to be made looking to its revival and to a completion of its work. It became quite the fashion with successive governors to call attention to the great desirability of prosecuting the survey, and bills were introduced into successive legislatures having this end in view. One such bill was introduced by Gen. J. A. Garfield, while a member of the State Senate in 1860. Nothing came of these efforts, however, until the legislative session of 1869. At that time, inspired by the cordial recommendation and aided by the hearty coöperation of Gov. R. B. Hayes, a bill was passed ordering a geological survey of the State on the lines that the present state of the science demanded. The law authorizing the survey was, before passage, approved, in most of its details at least, by several of the leading geologists of the State, and particularly by Dr. J. S. Newberry, who was subsequently put in charge of the work thus inaugurated.

The support of the agricultural interest of the State was again invoked in behalf of the geological survey, and the unwarranted expectations of 1837 were again encouraged, of large and immediately valuable results to be derived from the analyses of soils and mineral fertilizers. This interest found expression in the requirement of the survey, that one of the three assistants should be a "skillful analytical and agricultural chemist."

By the organic law the survey was to be completed in three years from the time of its organization, but, it may be added, that a longer tenure was anticipated by the friends of the survey, both in and out of the Legislature. Governor Hayes appointed Prof. J. S. Newberry Chief Geologist, Professors E. B. Andrews and Edward Orton, assistants in geology, and Hon. J. H. Klippart, assistant in agriculture. Mr. Klippart had been for a number of years secretary of the State Board of Agriculture, and was one of the most conspicuous exponents of scientific agriculture in the State at this time. His connection with the survey lasted but a year or two, and his only report is one that appears in the Report of Progress for 1870. Prof. T. G. Wormley, a distinguished chemist, was made analyist of the survey, and a number of local assistants were brought into the field, some of whom began their field work here. In the list of local assistants may be found the names of geologists that have since become distinguished, such as R. D. Irving, Henry Newton, G. K. Gilbert, Andrew Sherwood, W. B. Potter, J. J. Stevenson, and N. H. Winchell.

Professor Newberry was, at the time of his appointment, professor of geology in the School of Mines of Columbia College, New York. This position was an important and permanent one, and he did not feel that it was wise to resign it for an office the tenure of which was not only uncertain, but which must be short at the best. He therefore undertook to carry on the duties of both offices, making compensation to the State for such time as was used in the New York professorship by the employment of assistants at his own charges.

The arrangement proved, in some respects, unfortunate. If Professor Newberry had been able to devote all his time and energy, even for three or four years, to the survey he would have found plain sailing and could have had everything from the legislature which he could reasonably ask, for the feeling of the State was thoroughly favorable to the survey at the outset. But the non-resident feature of the Chief Geologist's appointment exposed him to constant criticism and attack. His absence from the State during at least half the year, while the Legislature was in session and while laws in regard to the survey were in process of enactment, was the cause of numerous mistakes, particularly in the publication and distribution of the reports. It was undoubtedly this feature of the survey that led to its premature suspension.

Of Dr. Newberry's ability as an all-round geologist nothing now needs to be said. Active and thoroughly trained in field work, a brilliant and sagacious paleontologist, alive to all the demands of the economic interests involved, of the widest opportunities for observation and study, capable at once of minute observation and broad generalization, and master at the same time of a style that was a model in respect to simplicity, lucidity and elegance, he was easily the foremost geologist that Ohio has produced. Admirable as is his best work in the survey reports, many of his friends feel that he has left nothing that adequately and fully represents his great ability as a geologist.

It is unnecessary to describe in detail the contents of the various reports of the survey. A list of all its publications will be found at the end of the present paper.

Professor Newberry's original plan was a comprehensive one. He aimed to cover the entire stratigraphy and paleontology of the State in a series of parallel reports, and at the same time he proposed to meet the demands of the people for practical guidance in dealing with their great mineral staples by the preparation of a volume on economic geology proper. In this last work he was from the first deeply interested. His plan also contemplated a fourth volume, to be entitled "Agriculture, Botany, and Zoölogy."

The fortunes of the second survey must be briefly traced. At the end of the three years assigned for its completion, not more than half the counties of the State had been reported upon; but no strenuous objections were made to its continuance, even with increased appropriations, for several succeeding years. In

1873, the first of the so-called final volumes of the survey was published. As already noted, the volume was planned to appear in two parts, one on geology proper, and embracing as many of the county reports as practicable, and the second part to be devoted to paleontology. For the preparation of this last named volume, the service of the distinguished paleontologist, F. B. Meek, had been secured. The so-called parts of Volume I. differ in size and quality of paper, through an unfortunate oversight and miscalculation of the Chief Geologist. An edition of five thousand copies was recommended by the Chief Geologist. The Governor expressed himself in favor of twice this number and the State Legislature authorized an edition of twenty thousand copies, the cost of the publication of which exceeded $80,000. The plates alone of the paleontological part cost $34,000.

Volume II., also published in two parts, followed in the next year, viz., 1874. The inequality in the size of the two parts that was introduced, as before explained, by an oversight in Volume I., was continued in Volume II., as the result of a choice between evils. When these two volumes had been published, it was found that the local reports of the counties would demand another volume, and consequently the Legislature extended the life of the survey through 1874 and made provisions for the preparation of Volume III., also in two parts, viz.: Geology and Paleontology. The first part, Geology, was published in 1878, and in it the remainder of the county reports found place. It was announced at that time that the corresponding part on Paleontology would be in readiness for presentation to the Legislature in the succeeding winter.

But the State was beginning to experience a financial pressure from which it has never since emerged, and the legislatures of the next succeeding years found it impracticable to undertake the large outlays ($50,000 or more) required for the paleontological part of Volume III., although a considerable outlay had already been made in its preparation. A principal section of the paleontology prepared for this volume was held in manuscript for several years by its author, Professor R. P. Whitfield, and was then published with the consent of Professor Newberry, in the annals of the New York Academy of Science.

There now remained to be prepared and published two of the volumes embraced in the original plan of the Chief Geologist, viz., the volume on Agriculture, Botany, and Zoölogy, designated Volume III., and that on Economic Geology, designated Volume IV. The first of these, which it was now necessary to call Volume IV., was published in 1882 with a title abbreviated from the original plan, and which the facts of the case required to be still further shortened. No special report had been prepared upon the subject of Agriculture, though more or less material bearing upon this subject is to be found in the separate county reports, and, by what has proved to have been a fortunate accident, the manuscript of the botanical list which had been prepared was mislaid and could not be found in time for the printer. The volume, therefore, is entirely confined to the subject of Zoölogy, and, even in this, only the leading divisions of the animal life of the State are included. The volume that was to be devoted to "Agriculture, Botany, and Zoölogy," and which appears under the title Zoölogy and Botany, thus turned out to be a report on the Vertebrates of the State. Dr. Wheaton's list of the birds of Ohio may, however, be noticed as especially complete and authoritative. Professor Newberry had by this time virtually withdrawn from actual connection with the survey, being hopeless of securing the appropriations necessary for the execution of his plans. In 1882, however, the Legislature, which looked with special interest to the volume on Economic Geology, made provision for its publication, but put the work into my charge, Professor Newberry turning over such matter to me as he had accumulated for this purpose. In 1884, the long-delayed volume, now entitled "Volume V., Economic Geology," was issued.

Just at this time the remarkable discoveries of gas and oil in the Trenton limestone of northwestern Ohio were in progress, and were awakening a greater interest in geological questions throughout the State than there had ever been before. The Legislature was, therefore, easily persuaded to extend the investigations on the economie geology of the State so as to include these recent discoveries. As a result, a "Preliminary Report on Petroleum and Inflammable Gas" was published in 1886, and in 1888 the completed volume, entitled Volume VI., Economic Geology, was issued.

The work of the second survey was thus being gradually merged in the work of a new organization ; and, in 1889, formal provision was made for carrying on geological work henceforth on a new basis, which may be called the Third Geological Survey of Ohio. Continuous work on a small scale was provided for, or rather, it was made possible for the State Geologist to keep the track of such development as was going forward and to present the facts in annual reports. The first report under this plan was published in 1890, and is entitled "First Annual Report, Third Organization." Before the second report was due, I was disabled by illness to such an extent that I could no longer carry on the active duties of State Geologist. Considerable material had, however, accumulated in my hands during the preceding year, and there were also several unfulfilled promises and obligations of the Second Geological Survey which it was now found possible to execute. Accordingly there has been printed, and is now in the binder's hands, a volume entitled Volume VII., the first part of which is devoted to Economic Geology, and which may be considered the equivalent of the second and third annual reports, and the second part of which is mainly occupied with the fulfillment of pledges to the State made by the Second Geological Survey. This part contains a chapter on the Archæology of Ohio, which was repeatedly promised by Dr. Newberry, and also the "Botany" mentioned above, viz., a list of the plants of the State, immensely superior to the list that was lost ten years ago ; and also two chapters on Paleontology which were prepared for Volume III., but which, as will be remembered, the Legislature had refused or failed to publish. Several other chapters in the same general line have been added to the volume. A small edition of the first part of this volume (economic) was issued separately in December, 1893, but it is also included in the volume that is now in the binder's hands.

Among the principal results thus far obtained in the investigation of the geology of the State at the public expense the following may be named:

1. The order, mineral composition and thickness of the leading elements of our scale have been determined, and their outcrops have been mapped with all needful accuracy.

2. The salient features of the geological structure of the State have been brought clearly to light.

3. The paleontology of the State, while it has not been treated systematically or symmetrically, has still received a considerable measure of attention and expenditure. Hall, Meek, Whitfield, Newberry, and Cope have made contributions of great value to our knowledge of the fossils of our series.

4. A great deal has been done in the interests of our economic geology. Chemical analysis has been applied to our limestones, cement rocks, clays and building stones, by no means exhaustively, but still fully enough to furnish safe, practical guidance to our people in every section of the State. But it is to the coal fields of Ohio that the largest measure of service has been rendered. The several seams have been carefully mapped so that the areas of each above drainage are known (Vol. VII.), the order of the seams has been definitely settled with a few unimportant exceptions, and correlations have been established with the Coal Measures of Pennsylvania, Kentucky, and West Virginia. The analyses of our coals have been made on a system that renders the figures fairly representative, and they accordingly command universal confidence in the markets of the country. The mode of occurrence of oil, gas, and salt water in the State has been carefully studied, and the search for these elements of mineral wealth has been aided and rationalized thereby, to some extent.

As to what remains to be done, it is not necessary to speak.

Every road in science leads to the end of the world, and the further we advance, the deeper the problems that arise.

As to the expenditures, by which all this work has been accomplished, exact figures cannot be furnished for the reason that the publication of the various reports has been made by the State printer, and in many instances the several items of expense—paper, printing, binding—have been included in general appropriations, from which they could be separated only with difficulty. The amounts belonging here are not large. For the later reports, full provision for publication has been made in the survey appropriations.

First Survey, 1837–8, - - -	$16,000.00
Expenses attending the same, cost of publication not included, - - - -	700.00
Second Survey, 1869–1890, - -	280,000.00
Cost of publication mainly included.	
Third Survey, 1890–1894, - - -	11,000.00
Cost of publication mainly included.	
	$307,700.00

PUBLICATIONS OF THE GEOLOGICAL SURVEYS OF OHIO.

FIRST SURVEY.	DATE.	NO. PAGES.	NO. COPIES.	GEOLOGIST IN CHARGE.
First Annual Report.	1838	134	6,000	Mather.
Second Annual Report.	1838	286	6,000	"
SECOND SURVEY.				
Report of Progress.	1869	176	14,500	Newberry.
Report of Progress.	1870	568	14,500	"
Report of Progress.	1871	3	300	"
Geology of Ohio, Vol. I.				
Part I.	1873	680	20,000	"
Part II.	1873	401, 49 plates	20,000	"
Geology of Ohio, Vol. II.				
Part I.	1874	701	20,000	"
Part II.	1875	431, 59 plates	20,000	"
Geology of Ohio, Vol. III.				
Part I.	1878	958	20,000	"
Geological Atlas.				
Scale 4ms=1inch.	1879		5,000	"
Geology of Ohio, Vol. IV.				
Zoölogy and Botany.	1882	1,070	20,000	"

Geology of Ohio, Vol. V. Economic.	1884	1,124	10,000	Orton.
Preliminary Report on Petroleum and Gas.	1886	76	2,500	"
Geology of Ohio, Vol. VI.	1888	831	15,000	"
THIRD SURVEY.				
First Annual Report.	1890	323	10,000	"
Geology of Ohio, Vol. VII. Part I.	1893	290	2,500	"
Geology of Ohio, Vol. VII. Parts I. and II.	1894	990 / 55 plates	7,500	"

Maps, plates of sections, etc., accompany many of the volumes.

The disposition of the reports has been made almost exclusively by the State Legislature, the members of each General Assembly dividing among themselves for gratuitous distribution the full edition of the volume or volumes of which they had authorized the publication. Not the slightest reference was had to the maintenance of complete sets of the reports. It is scarcely credible that after such large outlays in publication, the volumes should have been scattered in this reckless way. By attention at the times of issue of the several volumes, those specially interested were generally able to complete their sets. Of the later volumes copies have been left on sale, at cost of publication, in the hands of the Secretary of State. He is the only State officer who is able to supply any of the volumes. The reports find their way, however, to bookstores and, owing to the increasing interest of the last few years, hundreds of sets have been thus completed.

EDWARD ORTON.

Studies for Students.

PROPOSED GENETIC CLASSIFICATION OF PLEISTOCENE GLACIAL FORMATIONS.

Pleistocene formations that are not either directly or indirectly of glacial origin are not embraced in the classification herewith proposed.

There are at least three appropriate modes of classification of the Pleistocene glacial formations:

(1). A classification based upon the structural characteristics of the deposits.

(2). A classification based upon the origin of the formations.

(3). A classification based upon the time relations of the deposits.

Only the second will be here considered. A purely structural classification has an indispensable value, and is a fit subject for more and more critical consideration as our knowledge of the glacial formations increases. The classifications of the past will doubtless continue to need extension and more precise definition as glaciology advances. Nevertheless, our structural classifications do not seem to be so lacking in exhaustiveness, nor so defective in discrimination as our genetic classifications, and as time will not permit an adequate treatment of the three forms of classification, it has seemed best to pass the first by with a mere mention.

A chronological classification of the Pleistocene formations possesses the highest interest and constitutes one of the two great goals sought by glaciology. One of these is to ascertain how the formations were produced, the other, the times and sequences of their production. But it is too early yet to fix upon a satisfactory chronological classification. The data are not yet sufficiently gathered nor have they been tested with sufficient severity, to admit of satisfactory correlation of the successive glacial stages even within the limits of a single province. How much less, then, those of different continents. While recognizing, therefore, the supreme interest that attaches to a chronological classification, I am impressed with the feeling that it is best to postpone a formal attempt to establish such a classification until the data shall be more adequately developed. It is believed that the development of a more satisfactory genetic classification will be a step toward a more satisfactory chronological classification.

The following outline is submitted for discussion:

Six general classes are proposed.

A. GENERAL CLASSES.

I. *Formations produced by the direct action of Pleistocene glaciers.*—As very much of that which is commonly embraced, for convenience, under the general phrase *glacial formations* is not the direct and simple product of glaciers, but springs in part or in whole from accessory agencies, it is thought serviceable to discriminate the simple from the complex formations. In this classification glaciers are assumed to be the primary and chief agency in the production of the formations classified, but the secondary and associated agencies are very important, and often the final expression of the deposits is due chiefly, and sometimes wholly, to these auxiliary agencies.

II. *Formations produced by the combined action of Pleistocene glaciers and accompanying glacial drainage.*—All of the ice of the glaciers except that portion which was transformed into vapor passed away in the form of glacial waters, and to this there was added the rain precipitated upon the glacial expanse. The combination of the work of this large volume of water with that of the ice gave rise to results which neither the ice alone nor the water alone could accomplish. These constitute a distinct class of deposits.

III. *Formations produced by glacial waters after their issuance from Pleistocene glaciers.*—While the glacial waters were acting on the glacier, or more especially in tunnels within or under the glacier, they were constrained by the presence of the ice walls and forced into modes of action that they would not have assumed of themselves on free and open surfaces of the land. The formations of free glacial waters after their issuance from the ice are thus distinguishable from the confined glacial streams of the ice-body itself. The products of glacial waters after their issuance differ from the products of ordinary surface waters in the fact that they were overloaded with detritus in an extraordinary and peculiar way, and in the fact that this detritus differs from ordinary land waste. This difference furnishes one of the most valuable criteria in the discrimination of Pleistocene formations.

IV. *Formations produced by floating ice derived from Pleistocene glaciers.*—Assuming that the greater mass of the glacial deposits of Pleistocene age were formed by the primary agency of glaciers, it nevertheless remains important to distinguish the secondary products that were formed through the agency of floating ice derived from these glaciers. Just as the waters from the melting glaciers bore away and deposited a certain constituent of the material that had been wrought at first hand by the glaciers, so icebergs bore off and deposited in a fashion of their own another portion. The two classes are secondary and dependent upon the original glacial action, and some of the characteristics of the material must be sought in the original glacial action, but in their final stages the deposits take on character of their own.

V. *Formations produced by shore ice and ice-floes due to low Pleistocene temperature but independent of glacial action.*—The presence of the great ice sheets and the glacial conditions that produced them appear to have given rise to a class of independent ice deposits that may fittingly be put in this classification. These are believed by some writers to attain great importance. Whatever their extent, they need to be scrupulously discriminated from the products of both glaciers and glacier-derived icebergs.

VI. *Formations produced by winds acting on Pleistocene glacial and glacio-fluvial deposits under the peculiar conditions of glaciation.* —It is not unreasonable to suppose that the tracts bordering the great glaciers, especially those recently abandoned by them, were exposed to very effective wind action. The differences of temperature between the ice-clad fields and the adjacent ice-free lands may be supposed to have induced strong wind currents. Between their strength and the facilities offered for their action by bare surfaces of recently-formed incoherent material, there is ground for the belief that æolian deposits of more than usual magnitude and of peculiar characteristics were formed. So also, it is highly probable, if not certain, that some of the rivers of glacial times were accompanied by broad flats which they had themselves built up, and which they alternately flooded and left exposed, and that here the winds found a special field of effective action. Such æolian formations as resulted from these agencies are probably not so important in themselves as in the erroneous inferences to which they are likely to lead, if unrecognized. Such wind-blown sands and silts might easily be borne up to high levels and lodge there. If these are attributed to water action (which seems the natural alternative) they lead to hypotheses of flood-heights or of submersion of much magnitude; and these lead on to other conclusions of much consequence. The recognition of the class, especially in framing working hypotheses and interpretations, is thought to have some importance.

With the foregoing general statements, we may turn to the more special consideration of the several classes indicated.

B. SUB-CLASSIFICATIONS.

I. *Formations produced by the direct action of Pleistocene glaciers.* —Under this head may be recognized three sub-classes:

1. Formations that gathered at the bottom of the glaciers.

2. Formations derived from material borne on the glaciers and within them (but not at their basal contact) and deposited at their margins, or let directly down by their melting, when stagnant.

3. Formations produced by the mechanical action of the edge of the ice.

I. It is believed that the base of the glaciers was the great seat of action; that here took place the disrupting of the material and the larger part of the rubbing, grinding and crushing to which it was subjected in transportation. All of this material, however, did not come to final rest beneath the ice. A portion of it was borne away by the glacial drainage, a portion was thrust up into the ice and borne along to its edge and there deposited as superglacial material, and a portion may have once been uncovered by the retreat of ice and have been subsequently plowed up by a re-advance and so have taken on a new form of aggregation. There is, therefore, a discrimination to be observed between material that was *produced* at the base of the glaciers and that which was finally *deposited* at their base. It is only the latter class that is included here. Of deposits originating under the ice the following sub-classes are distinguished.

(1). *Subglacial sheets of till.*—These constitute one form of ground moraines; the form which is perhaps most commonly recognized. There are to be embraced here those broad sheets of till which were spread out under the ice and left, on its retreat, as a blanket mantling the surface of the land. These sheets are not uniform in thickness nor universal in their presence. In this classification it has been thought best to separate all distinct and special forms of aggregation from the more nearly uniform sheets of till, and to place them in the following sub-class. This is done in the belief that the causes of these special aggregations were somewhat special and peculiar, and that these forms are worthy of distinction for working purposes until their final significance and classificatory value shall be determined.

(2). *Subglacial aggregations of till.*—These admit of subdivision into two varieties, between which there is no sharp dividing line and which are perhaps separated from each other genetically only by the degree of their development. These are

a. *Drumlins.*

b. *Aggregations not strictly drumloid in form.*

a. Of the drumlins, four sub-varieties may be recognized, and it may prove serviceable to distinguish these and treat them as distinct varieties until the mystery of the drumlin formation shall be solved and the importance, or otherwise, of these distinctions be determined.

(*a*) *Lenticular or elliptical hills.*—These are the typical variety of drumlins and consist of very remarkable aggregations of till in hills of dolphin-back form whose longer axes are two or three, or at most a few, times longer than their transverse diameters. The longer axis lies in the direction of glacial movement. This is the most familiar form.

(*b*) *Elongated ridges.*—These have the same constitution as the preceding and have similar terminal contours. The body of the hill is, however, elongated to the extent of two or three or occasionally several miles. These elongated ridges commonly lie parallel to each other, giving a markedly fluted character to the surface. They are thought worthy of being distinguished for the present, because the elongation of their forms may prove a significant feature, and lead to the recognition of some of the essential conditions of drumlin formation.

(*c*) *Mammillary hills.*—These have the same constitution as the previous types. but differ from them in the extreme shortness of the axis. This, in some instances, is scarcely longer than the transverse diameter. These are thought worthy of being distinguished, because they emphasize more than either of the preceding varieties the vertical element of the constructive process. I know of nothing more extraordinary in glacial formations than the building up of these domes to the height of 50 to 60 or more feet with such steep sides and on so circumscribed and so nearly circular a base. There are no cases, so far as I am aware, in which the base is strictly circular. There seems always to be an element of elongation in the direction of glacial movement.

(*d*) *Till tumuli.*—These are low mounds of more than usually stony material (so far as I have observed). They have not generally assumed the drumloidal curves of contour and profile, but their nature is such as to have suggested that they are the immature nuclei of drumlins. Further investigation is proposed, and they are here introduced tentatively.

b. There are several classes of aggregations of till that are not strictly drumloidal in form but which are thought to deserve recognition, for the present, as varieties, for their possible suggestiveness respecting the physical processes of subglacial accumulation.

(*a*) *Crag and tail.*—These embrace the well known accumulations of till in the lee of rocky crags or embossments.

(*b*) *Pre-crag.*—These embrace the less well recognized accumulations of till in front of crags or embossments of rocks. These two forms may co-exist in connection with the same protuberance of rock and may coalesce. From this has arisen the suggestion that their coalescence might initiate a drumlin. In support of this, it is cited that many drumlins have a core or pedestal of rock. Against this is cited the fact that many drumlins have no such nucleus of rock so far as observation can discover.

(*c*) *Veneered hills.*—These are hills of rock, coated somewhat uniformly with till, the surface conforming approximately to that of the underlying rock. These differ from the crag-and-tail and pre-crag accumulations in the genetically significant fact of a much more uniform distribution of the till over the rock embossment and in the subordination of veneering to the pre-existent contour rather than the formation of a new contour.

(*d*) *Till billows.*—There is a class of drift accumulations which take on a billowy surface. They differ from the drumlins in their want of conformity to axes lying in the direction of the drift movement. The drumlins are also usually separated from each other by low flat ground. The till billows, on the other hand, are arranged more closely together, are disposed more irregularly, and are connected with each other by saddles or cols. Between these billows are frequent undrained basins. The type, it will be observed, graduates into, if it does not strictly belong to, the class designated below as submarginal moraines. Tracts of these till billows are usually distributed parallel to the margin of the ice, and to that extent conform to the habit of terminal accumulations. I have thought that they might be an intermediate form between submarginal moraines and drumlins, but, while they unquestionably graduate into the former, I have never observed their graduation into the latter. It seems, therefore, probable that they should be removed from this division and placed below.

(*e*) *Irregular till hills.*—Besides the above forms which show a tendency to some definite law of development, there is a considerable class of aggregations of till that seem to pay no respect to laws of symmetry or to systematic principles of growth. At present no classification seems tenable except one based upon their very irregularity.

(3). *Submarginal ridges of till parallel with the ice border.*—Both the till sheets (1) and the subglacial aggregates (2) that have been described above occupy territory extending for considerable distances back from the border of the ice, indeed, ideally the first class may be regarded as covering the entire territory occupied by the ancient glacier. On the contrary, the ridges of till here considered lie along what was the immediate border of the ice at certain of its stages. They are thought to have been formed under the edge of the ice, but it remains to be determined to what an extent they were accumulated under the immediate border of the ice and to what an extent they were deposited at the distance of one, two, or three miles from the precise edge of the glacier. It does not seem at present possible to determine, or at least it does not seem to have been determined, whether the whole of the accumulation was built up simultaneously throughout its entire breadth, or whether the outer portion was accumulated under the immediate edge of the ice and the inner portions built up a little later in like manner under the edge of the ice when it had withdrawn somewhat. These ridges are from one to a few miles wide, are composed essentially of till (though assorted material may form a greater or less constituent), possess in the main a gently flowing contour which distinguishes them from the rougher ridgings and sharper contours of frontal moraines formed by the mechanical thrust of the ice, or by the dropping of superglacial material at its edge.

(*a*) *Submarginal or lodge moraines* (*a variety of terminal moraines*).—The most important form falling under the above head may be designated submarginal or lodge moraines. They are designated submarginal, not so much because they are believed to be formed near the edge of the ice and not absolutely at its edge, as because they are believed to be formed *under* the margin of the ice. Three varieties of moraines, all of which may be called terminal, are recognized, being produced in three distinct ways. The first are formed from material borne on or in the ice (the latter being brought to the surface by ablation before reaching the edge) which is dropped at the terminus of the ice and which, when the ice remains stationary for a sufficient period, grows into a bordering ridge. These may be given the rather homely but expressive name *dump moraines.* The second is formed by the mechanical thrust of the ice when it advances against any incoherent material that lies in its path. These may be designated *push moraines.* The third variety consists of that under consideration, and which may be designated *lodge moraines*, from the conviction that the material, instead of being carried or pushed or dragged forward to the extreme edge of the ice, is permitted to lodge under its thin border, and constitute a submarginal accumulation. The lodge moraine is not in its nature or material radically different from the ground moraine which lodged farther back from the edge of the ice, and constitutes the subglacial till sheet. It differs from it, perhaps, only in the fact that the thinned and weakened edge of the ice presented conditions specially favorable to deposition, and that, as a result, a thickened belt of drift formed under the border of the ice when it remained approximately stationary for a sufficient period and took on the special billowy contours above described. The submarginal moraines were doubtless subjected to more or less mechanical action of the ice as it oscillated forward and backward. This action is thought to have been of the nature of an over-riding or an over-sliding of the ice rather than of a pushing or plowing up by the edge of the ice. It is my growing conviction that this form of the terminal moraine is the predominant one in the great American glacial field. I incline to the opinion that the broad complex tracts of thickened drift that mark the border of the ice sheet at several of its stages were chiefly formed in this submarginal way, and that, while there is usually present a constituent dropped from the surface of the ice and a constituent formed by the mechanical thrust of the ice, the great mass of these moraines, in general, accumulated by lodgment under the border of the ice but near its edge.

(*b*) As only those ridges which have some measure of persistency and which mark notable stages of the ice action should be formally designated terminal moraines, it seems advisable to recognize under a different head local ridges of till arranged transversely to glacial movement. These are to be contrasted with the drumlins which are elongated ridges of till whose axes lie in the line of glacial movement. These transverse local ridges are in some cases perhaps of the same nature as the submarginal moraines except that the action was limited. But for the greater part they may be presumed to have sprung either from exceptional conditions of accumulation, which led to exceptional deposition when the force of the ice was weakened, or to exceptional conditions favorable to deposition, the conditions in both cases determined by local agencies. They are thus distinguished from the products of those general agencies that produced the persistent submarginal moraines.

2. *Formations derived from material borne on the glaciers and within them (but not at their basal contact) and deposited at their margins or let directly down by their melting when stagnant.*

(1) *Dump moraines (a variety of terminal moraines)*.—In various well known ways a certain amount of material finds lodgment on the surface of a glacier, and a certain additional amount becomes incorporated within its body. Leaving out of consideration such part of this as finds its way to the bottom, both the englacial and superglacial material is carried

forward and by ablation is at length brought to the surface of the ice and is carried on to its edge and dropped there. If the material is considerable and the border of the ice remains stationary for some time, notable accumulations may result in the form of border ridges constituting the variety of terminal moraines designated as dump moraines. When the englacial and superglacial material is inconsiderable in quantity the deposit may not amount to a ridge but may yet constitute a very definite and distinctive belt of material. The bowlder belts of several of the interior states are classed here. They cannot be said to be moraines in so far as that term implies ridging, but they are terminal border deposits that have much the same significance as terminal moraines and belong to the same general genetic class.

(2) *Englacial or superglacial till* ("*upper till*").—When this englacial and superglacial material is let down over the whole territory of the ice, either during its successive stages of retreat or by being let down directly through the melting of the glacier when it becomes stagnant, it forms a superficial sheet quite analogous to the subglacial sheet already considered. This was some years ago designated "upper till" by Torrell, Hitchcock, Upham, and others, but because the term upper till was also used to designate a re-duplication of the subglacial till sheet by many other geologists, it was thought best to propose the term englacial or superglacial till. There still exist differences of opinion as to how much of existing deposits is to be referred to englacial and how much to subglacial till, and the criteria for discriminating between these are still under discussion, but the importance of the classification and the significance of its bearing upon the interpretation of glacial action and of glacial history seems beyond question.

(3) *Medial moraines.*—These familiar forms of glacial deposits do not call for remark, further than to note that they merge into dump moraines at the frontal edge of the ice and into superglacial till in cases in which they are let directly down by melting without being carried on to the terminus of the

glacier, and to observe further that they are very subordinate elements in the great Pleistocene glacial deposits.

3. *Products of the mechanical action of the edge of the ice.*

(1) *Push moraines* (*a variety of terminal moraines*).—The distinctness of this familiar variety will doubtless be sufficiently recognized without further remark. It is perhaps, however, worthy of note that two sub-varieties may be recognized based upon the glacial or non-glacial character of the material involved, since the latter variety is sometimes overlooked.

a. The first and common variety is formed of glacial material which may belong either to the subglacial, englacial, or superglacial variety, or it may be formed of glacio-fluvial or glacionatant material. It must, however, be presumed to have been previously brought forward to the edge of the ice or beyond it, and to be thus subject to be plowed up or pushed up into ridgings by the thrust of the advancing ice, which is the essential factor in the formation.

b. The second variety embraces local material of any kind that lay in the path of the advancing edge of the ice and was pushed into ridges by it. It is non-glacial material except in the simple fact that it was ridged by ice action. It is entitled to be regarded as a moraine so far as its origin as a topographic form and a re-arranged formation are concerned. In other senses it is not.

(2) *Lateral moraines.*—These familiar forms need no discussion.

N. B. Interlobate moraines form a variety of terminal moraines and not, as is quite often stated erroneously, a variety of lateral moraines. They are produced along the line of contact of adjacent glacial lobes, but the direction of ice movement is perpendicular or approximately perpendicular to the moraines, and not parallel with them. The mode of ice action involved in their production, and the nature of the morainic aggregation resulting, is that of the terminal and not that of the lateral moraine. These interlobate moraines may belong to either of the three classes above designated—the dump, the push, or the lodge moraine, or they may be formed of the three combined.

II. *Formations produced by the combined action of Pleistocene glaciers and glacial drainage* (*assorted drift*).—The large amount of water derived from the melting of the ice, and the added amount contributed by rains, constituted a very important auxiliary agency and gave rise to much assortment and re-arrangement of the drift.[1]

Three classes of deposits may be discriminated, those that are the products 1) of subglacial streams, 2) of superglacial streams, and 3) of marginal waters.

1. *Deposits of subglacial streams.*

Subglacial waters may be classified in two groups, the first embracing those which flowed in well established tracts or tunnels formed in the base of the ice, the second embracing those which flowed in a more diffuse and irregular way under the ice. These appear to have given rise to corresponding deposits.

(1) *Osars* (*asar*) *or eskers* (*kames of many authors*).—It is thought to be now beyond question that trains of gravel accumulated in tunnels formed by subglacial streams and that these, on the disappearance of the ice, formed ridges. The course of these seems to have been conditioned partly by the slope of the land and partly by the direction of glacial movement. They are best developed where these approximately coincide. It can scarcely be said, however, that osars are limited to such coincidence. The more extensive, branching and typical forms were probably also conditioned by stagnant or approximately stagnant states of the ice in its vanishing stages. The Scandinavian term *asar* seems entitled to precedence both because these remarkable forms are typically developed there, and because they first received notable attention there. The term *eskers* is coming to be used somewhat freely by many American writers as a synonym and is preferred by some for phonic reasons, while the term *kames* is being used for a cognate variety of gravel accumulations, to

[1] It is to be noted that only that assortment of the drift which was *contemporaneous* with the ice epoch and connected with the ice action is here taken into consideration. Modifications of the drift that took place subsequent to the disappearance of the ice, or independent of it, belong to a class quite distinct from that under discussion here.

be mentioned below. Whatever the terminology, it seems important to distinguish the long branching gravel ridges that represent the longitudinal drainage of the ancient glaciers from those gravel accumulations that are associated with terminal moraines, and that appear to be the debouchure deposits of glacial waters. A variety of osars or eskers may have been produced by superglacial streams, as will be recognized below.

(2) *Simple tracts or patches of drift formed by subglacial drainage.*—Thin sheets and lenses of sand and gravel in the midst of subglacial till are common phenomena and, while they may in many cases be produced by streams running in tunnels which afterward shifted their position and left no other mark than these patchy deposits, it seems probable that many of these detached sheets and lenses were produced by a diffuse and local drainage developed by any one of several combinations of conditions while the ice was still present and continuing its deposition of till. Similar patches on the surface were perhaps produced in a similar way.

2. *Deposits of superglacial streams.*

For the most part superglacial streams, after short courses, descend through crevasses or moulins and become englacial or subglacial. This was doubtless true of the Pleistocene glacial streams, and the material which they bore along found its final deposition either in connection with subglacial streams or with the glacial waters after they had emerged from the ice. Nevertheless, there are two forms of deposition by superglacial streams that probably find some representatives among Pleistocene formations. The first embrace those which were carried along by superglacial streams that succeed in reaching the edge of the ice or a channel which they cut back into the margin of the ice. In the one case it probably took the form of delta cones, in the other of narrow ridges formed through the restraining aid of the channel walls. The other variety is presumed to have been formed from deposits which gathered along the course of superglacial streams and were let down by the melting of the ice after the glacier became stagnant, retaining essentially the form of their original accumulation in the superglacial channel, except so far as they were disturbed in the process of descent. Of these there are perhaps two varieties.

(1) *Superglacial osars* (*asar*) *or eskers* (*kames of some authors*).—Under this head are to be classed such channel-deposits as retained their elongated form and became ridges, and hence fall under the Scandinavian type. In the earlier studies of the subject a considerable number of specialists would have inclined to classify most osars under this head, but opinion appears to be inclining toward the reference of the greater part of the osar ridges to subglacial agencies.

(2) *Superglacial kames.*—Sheets or pockets of assorted material gathered on the surface of the ice were doubtless subjected to much disturbance and re-arrangement in the process of descent. The resulting deposits would constitute undulatory tracts of drift or groups of hillocks for which there is perhaps no specific name, but which may be thrown under the general class kames for the present.

3. *Marginal deposits.*

Under this class are embraced all those deposits of glacial streams that were made at the margin of the mer de glace, and whose forms were dependent upon the conditions that obtained at the margin. The following classes are recognized:

(1) *Kames.*—To this class I refer irregular heapings of assorted drift generally arranged in lines or tracts transverse to glacial movement. They are often closely associated with and merge into terminal moraines of till. Sometimes they largely constitute the terminal moraines, the action of glacial waters being so great as to assort nearly all of the material brought forward to the edge of the ice. In such cases the morainic factor (in the genetic sense) is found in the mechanical action of the ice in restraining the action of the waters, in controlling the nature of the heapings and in pushing of the accumulations, distorting and modifying them. Irregular heapings of assorted drift of this variety are not, however, wholly confined to border tracts, but occur irregularly distributed over the area abandoned by the ice.

They differ from the osar type in their marginal relation to the ice and their transverse arrangement. There is, however, a gradation between the two, and no sharp line of demarkation has yet been found; probably none exists. But there appears to be this important genetic difference: the typical kames appear to be the products of relatively active vigorous glaciers, while the typical osars appear to be the products of extremely inactive, if not stagnant, glaciers. This important difference of significance is thought to amply justify the recognition of the two classes whatever may be the difficulties in sharply separating them.

The difficulties of sharply discriminating between the osar type and the kame type are increased by the fact that there is a class of gravel ridges having forms precisely like the typical osars, that lie more or less transverse to the glacial movement. These yet await thoroughgoing investigation, but I incline to the belief that they are to be regarded as true osars, and that they were formed during the stagnant conditions of the ice just before its disappearance, their transverse course being due to the control of the underlying topography. It has been stated that the course of the osars was conditioned partly upon the direction of the ice movement and partly upon the topography of the land surface. In this instance, it appears that the land topography dominated the osar formation, and that the movement of the ice became uninfluential. In support of this view it may be added that some osars on reaching the border of the ice turn to a course nearly parallel with it.[1]

(2). *Osar* (*esker*) *deltas or fans.*—It appears that when the glacial streams reached the border of the ice sheet and were free from bounding ice walls, they spread themselves out widely and dropped a large portion of their burden in the form of deltas or fans. These are not uncommon in the interior as well as in Maine, where the osar phenomenon has its most remarkable development in America. These deltas are very significant both

[1] Dr. Lundbohm has directed my attention recently to the fact that this is a not uncommon phenomenon in Sweden, as shown by the geological maps of the Swedish Survey.

in respect to the method of formation of the osars and in respect to the position and restraining functions of the ice sheet at the time of their formation.

(3). *Overwash aprons.*—When terminal moraines grew to constitute notable barriers along the border of the mer de glace, and when the ice pressed against these moraines so as to obstruct the transverse flow of the glacial drainage along their inner border, the waters derived from the ice crept over the moraines in numerous small streams, which deposited gravel, sand, and silt on the outer flank of the moraine. These deposits are often distributed along the moraines for great distances and constitute a fringe of assorted material to which Shaler has given the apt name "apron." These constitute one of the most satisfactory demonstrations of the marginal character of the moraines and of the relations of the ice to them. The material varies widely in coarseness according to the conditions of formation, and a structural sub-classification may be based upon it embracing (*a*) gravel—(*b*) sand—(*c*) silt-aprons. Immediately next to the moraine the material is sometimes exceedingly coarse, constituting little less than a boulder belt. At the other extreme of the series the silt sometimes forms a clay deposit and sometimes it takes on that peculiar assortment which constitutes loess.

The class of aprons here described are dependencies of definite terminal moraines. There were, however, tracts of assorted material formed by waters outflowing from the ice where no definite terminal ridging took place. Such forms may be designated *outwash* aprons in distinction from *overwash* aprons. This class is usually made up of sand or silt. In the latter case there are gradations into the great flanking tracts of loess which appear to have arisen in the manner indicated on very low slopes with prevailing slack drainage.

(4). *Pitted plains* (*in part*).—Both the osar deltas and the overwash aprons are characterized in certain regions by a surface marked with numerous depressions, sometimes symmetrical (kettles), sometimes irregular, with undulatory bottoms and embracing knobs and sub-basins, giving the surface an expression resembling the kames. A part of these pitted plains seem to be intimately connected in origin with the ice edge and to be due to marginal conditions, among which it has been thought that the incorporation of ice fragments, the grounding of ice blocks, the movement of the ice edge, and the development of underground ice sheets were among the special agencies, but the full explanation of the pitted plains can scarcely be claimed to have been reached.

III. *Formations produced by glacial waters after their issuance from the Pleistocene glaciers.*

1. *By glacial rivers.*

One of the most familiar facts of glaciology is the detritus-laden condition of the icy streams as they issue from the body of an active glacier. A portion of this material is thrown down immediately at the margin under the special conditions there presented and constitutes the formations classified above, but the larger portion is borne onward to varying distances and deposited quite independently of the agency of the ice. Two varieties of this class of deposits are worthy of being specially recognized.

(1). "*Valley drift.*"—In those cases in which the previous surface agencies had developed a definite drainage topography, and in which the gradient was favorable, the detritus was borne down the valleys leading away from the ice border in trains of gravel and sand. As the glacial streams were usually greatly overloaded with detritus at the outset, they built up their valley bottoms by depositing material from bluff to bluff constituting a valley plain, out of which subsequently beautiful systems of terraces were often cut. The most notable class of this type consists of those gravel valley-plains which head in a terminal moraine or, more strictly speaking, in the overwash apron of a terminal moraine. Sometimes the apron gathers in for many miles on either side giving a very broad expanded head to the valley tract. As these valley tracts may head on successive moraines and may be traceable far down their valleys, they afford most admirable means of working out glacial history by determining the intervals between the successive moraines and the topographic conditions under which they were formed. As the gradient of the streams that formed these valley tracts may be estimated, they afford valuable criteria for determining the altitude and the attitude of the land at the time of their formation.

(2). *Loess sheets.*—The above valley tracts grade from the coarsest gravel through sand to the finest silt. So long as they are confined definitely to the valleys, a sub-classification of them on the basis of coarseness or fineness of material would be rather structural than genetic though carrying a genetic significance. But when the waters spread widely beyond the immediate vicinity of the valley and the material took on a peculiar and distinctive assortment, there seems to be sufficient ground for recognizing a second genetic class. The great tracts of fluvial loess (not all varieties of loess) are placed here. These are valley phenomena, in part. They have for their axes the great valleys of the region and their thickest deposits are along the valleys. They, however, spread widely over the adjacent country so that conjointly they mantle the whole region. They also coalesce with the great fringing sheets of loess that are classed above as outwash deposits. The class graduates into typical valley deposits on one side, into typical fringing deposits on another, and, apparently, into wind deposits of loess on a third side.

2. *By fringing lakes.*

This class obviously embraces deposits of suspended material brought out from the ice into bordering lakes by glacial streams and spread over their bottoms, being generally of the clayey type, sometimes bearing lacustrine fossils, sometimes not; sometimes commingled with stony material dropped by floating ice derived from the edge of the glacier, sometimes not, at least not in notable quantities, and always more or less commingled with wash from the adjacent land not covered by ice. Theoretically, the type is characterized by the peculiar border of the deposit next the impounding ice. Practically, this characteristic is not always readily demonstrable.

3. *By bordering seas.*

This class differs from the preceding in the fact that the waters were not impounded by the ice (as they usually, but not always, were in the preceding case), and in the fact that the deposits are commingled with oceanic sediments, marine fossils, and impregnated with saline waters, which may or may not have been wholly removed subsequently.

IV. *Formations produced by floating ice derived from Pleistocene glaciers.*

The type of this class is glacio-natant till, in which the constituents are identical with those of glacial till except when formed under the action of currents which induced secondary modifications. Two sub-classes are to be recognized :

1. *Local.*—In general these are lacustrine but may be oceanic. Commonly the deposits took place in glacier-fringing (usually glacier-formed) lakes and constitute only a secondary phase of glacier formation. In cases in which the ice entered an arm or bay, or even the border of the ocean, and the deposit took place in the immediate vicinity, the deposit remained essentially a local one. If marine fossils or marine sediments were commingled, or if the marine factor is for any reason regarded as important, a sub-classification distinguishing between lacustrine and marine glacio-natant local deposits is justified.

2. *Foreign.*—These are essentially marine glacio-natant deposits and are due to icebergs derived from distant glaciers bearing to the point of deposit material wholly of foreign origin. Among the genetic conditions involved in this case are the submergence of the land beneath the ocean at the time of the deposit and its subsequent elevation. Local lacustrine glacio-natant deposits may be formed at various heights above the ocean level and subsequently exposed by the drainage of the lake without involving oscillations of the crust or the sea level. In the case of the great lakes, iceberg material borne from one

side and deposited on the opposite and distant side might constitute a recognizable sub-class under this head. Such deposits have been described.

V. *Formations produced by shore-ice and ice-floes due to low Pleistocene temperature but independent of glacier action.*

1. *Shore ridges due to ice push.*—In northern latitudes the shore action of ice (not including icebergs) is very notably, producing shore ridges of unusual strength, configuration, and importance. It is held by some writers that much of the phenomena placed on the above classes is referable to this. Without conceding this, it seems beyond question that this class of deposits need special recognition in the study of the Pleistocene formations.

2. *Littoral deposits.*—If we confine the above class to those ridges which were pushed up on the shore above the reach of the waters, we need also to recognize a class which was deposited beneath the border of the body of the water. These differ from ordinary littoral deposits in the special contribution resulting from the ice action.

3. *Off-shore deposits.*—These embrace the material of the ice action of the shore borne back in suspension or by ice floes into still waters and there deposited. They must, in the nature of the case, very closely similate the formations produced by floating ice derived from glaciers.

VI. *Formations produced by winds acting on Pleistocene glacial and glacio-fluvial deposits under the peculiar conditions of glaciation.*

Recalling what was said under this head near the opening of this discussion, it may suffice here to simply indicate two classes that may be recognized under this head.

1. *Dunes.*—These differ in no important respect from ordinary dunes, except that the material is made up in part of grains formed by glacial grinding instead of disintegration and wave wear, and in their correlation with the ice border and the glacial waters that issued from it, rather than with the sandy shores of lakes and seas.

2. *Æolian loess.*—While the larger part of the loess found in

the glaciated region of North America is believed to be the product of glacial waters, it still remains, in my view, probable that certain parts of it were deposited by winds. This part is believed, in general, to have been derived from the water-deposited portion, but perhaps this is not universally true. Along the leeward side of the Mississippi river, for instance, we find dunes of sand and dune-like accumulations of loess that seem in both instances to have been derived by winds from the flooded flats of the river below. In like manner, there seems ground for the belief that in Pleistocene times, the glacial floods alternately extended and withdrew themselves, leaving great silt-covered flats exposed to wind action, and that from these silt was swept up and deposited over adjacent and perhaps somewhat distant highlands. It seems also not improbable that the conditions of the surface may have been such as to permit the lodgment of this more uniformly over the surface than is the habit with dunes. There seems ground for this in the distinction between the formation of dunes and the supposed deposits. Dunes are formed from sand driven along the surface by winds, but not in any notable degree carried by the winds in full suspension. The supposed silt deposits, on the other hand, are presumed to have been formed by silt borne in free suspension until, by contact with the earth, it was lodged. Such contact might obviously be widespread and the lodgment product might have a wide and measureably uniform distribution. While, therefore, coinciding with what seems to be the majority opinion among American geologists that the loess deposits of the glaciated region are chiefly water-lain, it appears to me prudent, if not important, to recognize the æolian class, and to search diligently for criteria of discrimination between the two classes.

The foregoing classification is consciously incomplete. In some instances the bases of distinction border closely upon the structural rather than the genetic, but it is believed that there is involved in every case an important genetic factor, though it may sometimes be most conveniently expressed in structural terms.

T. C. Chamberlin.

Editorials.

WITH profound sorrow we announce the death of our colleague, Dr. George Huntington Williams, Professor of Inorganic Geology in the Johns Hopkins University of Baltimore. Tidings of his death came to most of us like a sudden flash of lightning from a cloudless sky. In the midst of ceaseless activity, and at the height of ever-increasing effectiveness, he has been cut off. To those who for three weeks watched the rising fever, and endeavored by every means known to medical science to avert a fatal crisis, his death was almost as unexpected. Subsequent examination showed the presence of an organic disorder which had rendered his system incapable of withstanding the attack of typhoid. Truly "in the midst of life we are in death." To those of us who have been intimately associated with Professor Williams, his death comes as a personal bereavement, for his amiable disposition, his generous sympathy, and his unselfish interest in his friends bound them to him with ties of lasting affection. To those who were fortunate enough to study under his guidance, his death must come with peculiar force, for he possessed in a high degree those qualities which render a teacher powerful. His learning was broad and deep, and his reading extensive. He was gifted with a memory that was not only strongly retentive, but had the rare trait of storing up the kernel of a matter, and letting go the chaff. His speech was clear, graceful and vigorous. The enthusiasm with which he attacked every subject in the varied range of his work communicated itself through his words to his hearers. His successful labors in the field of original research not only added to the sum of knowledge in general, but served as an example and powerful incentive to those who were following his teachings. His pupils will indeed be fortunate if they have caught anything of the spirit of his inspiration, or have learned to follow in his footsteps. The science of geology has lost a strong and able advocate and promoter, and geologists of all countries have lost an illustrious associate. *The Journal of Geology* in particular sustains a heavy loss, for Professor Williams has taken an active part in its establishment, contributing materially to its support in various directions. It will be our privilege to publish at some future time a fitting sketch of his life work.

J. P. I.

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THE Peary Relief Party left Brooklyn, N. Y., on the 20th of June, taking passage on a regular steamer plying between New York and St. Johns, Newfoundland. The party stopped at St. Johns until the 7th of July, when they sailed for Peary's headquarters. The vessel which carried the party from St. Johns, the Falcon, is a German-built steam sealer, made with especial reference to voyages in polar seas. She is under the charge of Captain Bartlett, who took the Peary party to its destination last year, and who, during that trip, made the quickest passage of Melville Bay on record. The party consists of seven members: Henry G. Bryant, leader; Professor T. C. Chamberlin, University of Chicago, Geologist; Professor W. Libbey, Jr., of Princeton, Geographer; Mr. H. C. Bridgeman, of Brooklyn, Historian; Dr. Olef Ohlin, of Sweden, Zoölogist; Mr. Amiel Debitsch (Mrs. Peary's brother), Civil Engineer, and Dr. H. E. Wetherell, Surgeon.

It was the plan of the party to make several stops before reaching Peary's headquarters. The first of these was to be at Disco Island, the second in Waigat straits, the third at Cape York, and the fourth at the Carey Islands. It is possible that it will be found necessary to omit some of these. The stop in Waigat straits, if made, will be for the purpose of studying the Tertiary formations there exposed. From Cape York, if time and circumstances favor, a short excursion will be made inland. The stop at the Carey Islands is planned for the purpose of securing, if possible, information concerning the two Swedish naturalists who were wrecked there two years since. From the Carey Islands the party will proceed direct to Peary's headquarters on Bowdoin Bay, a dependency of Inglefield Gulf, latitude about $77°30'$.

If the conditions are favorable, six of the party will occupy the interval between the arrival at Peary's headquarters and the date of the return, about September 1st, in the exploration of Ellesmere Land and Jones Sound. Instead of accompanying this party, Professor Chamberlin will remain in the vicinity of Inglefield Gulf. While incidental attention will be given to other geological questions, the work of the ice will constitute his principal study. This locality has been chosen for the special study of glaciation, since it is the testimony of those who have seen it, that glacier ice in all stages of activity is here accessible, and that it occurs in a great variety of topographical situations and relations. Attention will be especially directed to the basal contact plane of the ice. A serious effort will be made to find out as exactly as possible what is taking place at this horizon. The margin of the ice, and the territory recently abandoned by it, will furnish the chief field for this study. By indirect means it is hoped that the studies along the margin of the ice will throw light upon the questions of ice activity back from the margin. All possible phases of glacial deposition, as well as all drainage phenomena of the ice will be studied in as much detail as time and conditions permit. It is hoped that data may be secured bearing upon the question of the rise of material from the basal to the superficial portions of the ice, and so upon the general question of superglacial drift, about which there is so much difference of opinion. It is hoped also that the phenomena to which stagnant ice gives rise may be found in process of development. Fiord glaciers, which have received attention from many glacialists heretofore, will have but a secondary place in Professor Chamberlin's studies. The same may be said of the upper surface of the mer de glace. It is planned, however, to make one or more excursions back from the edge of the ice. It is most fortunate for the science of geology that one so well equipped for this work as Professor Chamberlin was able to undertake it.

Lieutenant Peary's plan was to carry his outfit and provisions to the summit of the ice during the winter, and cache it at advanced points, so as to save time and labor when the spring opened. He expected to start early in the spring, and to follow very nearly his previous route northeasterly across the ice to the East Greenland sea, latitude about 81°30′, longitude about 34° west. Here his party was to divide. One division was to trace the east coast southward to the point previously reached by explorers from the south, and then strike westward across the inland ice to headquarters. This route will carry the explorers across the broadest part of the great mer de glace, and, if successful, should give important data concerning the maximum height of ice and snow accumulation, and concerning the conditions of accumulation under these extreme conditions. Lieutenant Peary himself, with one or two aids, expected to trace out the insular land lying beyond the point previously reached by him. His route was to be controlled more or less by what he found, as well as by local conditions favoring or preventing progress. Should both these parties be as successful as hoped, they will bring back an essentially completed outline of Greenland, and its northern insular dependencies. The Peary parties expect to reach headquarters on Inglefield Gulf by the 1st of September. The ship's party will have returned by that time, and Professor Chamberlin's work at Inglefield Gulf will cease when the party is ready to start homeward.

*

The polar expedition of which Captain Cook has charge, was obliged, on the point of starting, to change vessels. Among those accustomed to northern seas, there was unfavorable comment concerning the vessel—the Miranda—in which this party sailed. They seem to have reached St. Johns, Newfoundland, in safety. From this point they started northward. It is reported that when 57 miles west of Belle Isle, the Miranda collided with an iceberg, and was compelled to return to St. Johns for repairs.

The accident occurred on the 17th. According to the reports which are at hand, no one of the party was injured, and the vessel was not so seriously damaged but that she could be repaired without great delay. The exact course of this expedition is not known to the writer.

*

At about the same time that the Peary expedition left St. Johns, an English polar expedition started, under the direction of Mr. F. G. Jackson. Mr. Jackson expected to leave London on the 11th of July, in a vessel of four-hundred-tons yacht measurement. The party was to call at Archangel, where a Russian hut, built in sections, and thirty dogs of West Siberian breed, were to be taken on board. Thence Mr. Jackson intends to proceed to Franz Josef Land. Here the party will disembark, establish their principal depot, and send their vessel, the Windward, home. This is expected to be accomplished by the end of August or the beginning of September. The winter will be spent at the depot, and about the end of March next Mr. Jackson hopes to be able to push northward up Austria Sound to Cape Flagely, latitude 82° 30′, the most northern point yet reached by Europeans. At intervals of thirty or forty miles depots for the storage of provisions will be formed, so that there will be no lack of food on the return. Mr. Jackson will endeavor to reach Petermann's Land, and to go as much further as may be possible. Sufficient food was to be taken to last four years, on the estimate of six pounds three ounces to each man per diem.

The main considerations which induced Mr. Jackson to select Franz Josef Land as the first objective point of his expedition were: 1. The accessibility of Franz Josef Land late in the summer, when approached along the meridian of 45° east, or some meridian between that of 45° and 50° east. 2. The northward extension of Franz Josef Land to a latitude as high as 82° 30′ at Cape Flagely, the long stretch of land forming a safe route for advance and retreat, and providing all that is needed in the way of sites for depots and cairns. 3. Standing on Cape Flagely, Payer saw, 60 or 70 miles to the northward, the highest outlines of an ice-covered land of apparently large extent. This he called Petermann's Land, and that land lay undoubtedly in a latitude as far north as any yet reached. It is this land which Mr. Jackson and his party will try to reach next spring, after having marched over the ice of Austria Sound. 4. The great abundance of animal life on the southern shores of Franz Josef Land during the winter, and all over the known country in the summer, make this a desirable starting point.

A specially constructed aluminium boat, each section of which will float by itself, a copper boat, and three Norwegian boats were taken by Mr. Jackson; eighteen sledges, each of which is capable of carrying one thousand pounds, are among the articles of equipment. These will be drawn by the Siberian dogs. The party will take with it a complete set of meteorological and other instruments for scientific work, and Mr. Jackson hopes to be able to add much to geographical knowledge, as well as to our imperfect information concerning the natural history of the Arctic regions. The expense of the expedition headed by Mr. Jackson is borne by Mr. Alfred C. Harmsworth, and is known as the Jackson-Harmsworth Polar Expedition.

R. D. S.

REVIEWS.

The Iron-Bearing Rocks of the Mesabi Range in Minnesota. By J. EDWARD SPURR. Bull. No. X. of the Geol. and Nat. Hist. Surv. of Minn. Minneapolis, 1894, pp. 259, 10 plates and figures in the text.

While this volume presents nothing new in general results, it is an interesting expansion of the summary given in the *American Geologist* for May, 1894, and forms a valuable supplement to Bull. No. VI. on the Iron Ores of Minnesota, and *the Mesabi Iron Range* by H. V. Winchell in the 20th An. Rep. of the Geol. and Nat. Hist. Surv. of Minn.

Part of the bulletin is devoted to a detailed description of the stratigraphy and the megascopic and microscopic study ot the different classes of rocks which serve as a basis for several chapters of more general scientific interest in which such questions as the Process of Metasomatosis; Metamorphic Agents; Prismatic Jointing; Slaty Cleavage; Banding and Bedding; the Origin of the Iron-Bearing Rock; and the Formation and Structure of Ore Deposits are discussed.

Mr. Spurr makes the following classification of the iron-bearing rocks:

1. The normal class including (*a*) the primary spotted-granular rocks, (*b*) the ferruginous spotted-granular rocks, (*c*) the siliceous spotted-granular rocks.

2. The oxidation and concentration class, including (*a*) the leached rocks and (*b*) the ferrated rocks.

3. The shearing class including (*a*) the magnetite-hematite slates, (*b*) the chlorite actinolite slates, (*c*) the silica slates.

4. The impregnation class.

5. The shearing impregnation class.

As the underlying and overlying rocks show very little metamorphism, the writer concludes that the metamorphic agents could not have been heat or mechanical disturbance, but were oxygen, alkalies. and acids carried in by the surface waters.

After discussing the eruptive origin and theory of chemical deposit which have been advanced to explain the occurrence of these ores, the writer argues that they are formed from beds of glauconite, and gives a rather lengthy discussion of the occurrence, structural features, and decomposition products of glauconite. He sums up his conclusions as follows:

1. At the beginning the rock was probably of sedimentary nature, consisting mainly of glauconitic grains with probably some associated calcareous and siliceous matter.

2. The elevation of the beds exposed them to atmospheric agencies which decomposed the glauconite into silica and iron oxide.

3. The various stages of decomposition and certain reconstructive processes have produced the present phases of the iron-bearing rock.

4. The iron is concentrated in the regions of greatest oxidation; the silica in the regions of least oxidation. T. C. HOPKINS.

The Mineral Industry, its Statistics, Technology, and Trade in the United States and Other Countries, from the Earliest Times to the end of 1893. Annual. Vol. II., pp. 894 + XL., and six plates. Price $5. R. P. Rothwell, Editor, Scientific Publishing Co., N. Y.

Volume II. of the Mineral Industry, while following the general plan of the first volume, covers several new topics and discusses some of them at greater length, so that there is increase in size of more than a third over the first volume. The fact that but little of the first volume is repeated in the second, makes both necessary to those interested in the mineral industry from either a commercial or scientific standpoint. To the economic geologist they are indispensable.

"Its statistics, technology, and trade" describes the aim of the work, but these terms hardly stand in the order of their relative importance as treated in the volume. As it takes the place of the annual statistical number of the *Engineering and Mining Journal*, it is probable that statistics was the primary object in the mind of the editor. But in the two volumes published the statistical feature is overshadowed by the others; this, however, is not to be regretted, as, instead of being merely reference tables of production, they form convenient handbooks to which the scientist as well as the tradesman turns for information on any of our mineral products. A good index and table of contents add to its value as a work of reference.

The following subjects are treated by able specialists, many of them in the form of condensed up-to-date monographs: Carborundum. Aluminum, Arsenic, Asbestos, Asphaltum, Bauxite, Cadmium, Cements, The Chemical Industry, Clay, Coal, Copper, Feldspar, Fluorspar, Iron and Steel, Lead, Limestone, Marble, Lime, Lithographic Limestone, Manganese, Marls, Mica, Onyx, Ozokerite, Phosphate Rock, Pyrites, The Rare Elements, Sulphur, Talc and Soaptone, and Zinc. Some of these topics are each treated by several specialists, thus on copper, for example, there are articles by five different writers besides the editor.

Besides the above there are articles by the editor on Abrasive Materials, Alum, Antimony, Barytes, Bismuth, Borax, Bromine, Chrome Iron Ore, Copperas, Cryolite, Gold and Silver, Graphite, Gypsum, Iodine, Magnesite, Magnesium, Nickel, Peat, Petroleum, Phosphorus, Precious Stones, Quicksilver, Salt, Slate, Sodium, Tin, Tungsten, Whetstones. Scythestones, and Grindstones.

There are also valuable summaries of the condition of the mineral industry in the following foreign countries: Australasia, Austria-Hungary, Belgium, Canada and other British Colonies, Chile, France, Germany, Greece, Italy, Japan, Norway, Portugal, Russia, Spain, and Sweden.

A chapter on Miscellaneous Statistics gives the imports and exports of Denmark, 1884–93; Holland, 1880–92; Roumania, 1882–93; Switzerland, 1885–93; and the imports of Egypt, 1881–93, and Shanghai, 1889–93. The mineral production of the United States, 1880–93, and of the United Kingdom of Great Britain and Ireland, 1860–92, is tabulated in a convenient form. In the United States five products show a yearly value exceeding $40,000,000, as follows:

	1892.	1893.
Coal, bituminous	$124,230,532	$118,595,834
Coal, anthracite	89,727,982	93,091,670
Pig iron	134,668,035	93,888,309
Silver, coining value	84,038,500	78,220,450
Building stone	44,589,500	40,000,000
Total value of all mineral products	724,821,009	645,084,730

Nearly all the products show a decrease in value in 1893 from the production in 1892, the total decrease being $79,736,279.

In tabular form are given the assessments levied by mining companies 1887–93. The conditions and fluctuations of the stock market at New York, Boston, and London are given in condensed form.

A new addition to the present volume is a chapter on the Mining Schools of the United States and Canada, in which twenty-four mining schools in the United States and two in Canada are described. State Geological Surveys are given a half page of generalization, which might well be extended to some length, giving specific information of interest and value, or else omitted entirely.

Chapters on the Progress in Ore Dressing in 1893, The Development of Views on the Origin of Ores, and Advance in Methods of Stone Quarrying, all by prominent specialists, complete the contents of the volume.

The portraits and the biographical sketches of some of the leading contributors in the introduction is not the least interesting part of the work. We see nere the familiar features of many prominent workers in economic geology.

The one hundred and eleven pages of advertisements are not an attractive feature, and detract from the convenience, appearance, and dignity of the work. The defect might be overlooked if it is only by this means the publishers are enabled to give us so valuable a work of reference, but we surely find no excuse for the nineteen pages of complimentary notices bound up in the volume.

While the second volume did not appear so promptly as the first, yet when one considers the size and varied contents of this volume and the vast quantity of statistical matter collected from all quarters of the globe, he cannot help but marvel at the promptness and dispatch with which Mr. Rothwell, the editor, and Mrs. Braeunlich, the business manager, have put this work on the market. It is practically an up-to-date handbook on the subject, and as such is without a rival in the field.

T. C. Hopkins.

THE

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THE CENOZOIC DEPOSITS OF TEXAS.

The purpose of this paper is to give a brief account of the Cenozoic deposits of Texas as they are now understood, and to make such correlation of the various horizons as may appear to be warranted by the stratigraphical position and fossil contents.

The statements are based, partly on my own field work, partly on that of other members of the survey, and the paleontological studies of Cope, Harris, and Cragin, the details of which have been given in previous publications or will appear in the Fifth Annual Report of the Geological Survey.

Eocene.

So far as known, all of the deposits referable to the Eocene Tertiary in Texas are confined to the Coastal Slope. They have been divided as follows:

3*d* Frio clays.
3*c* Fayette sands.
3*b* Yegua clays.
3*a* Marine beds.
2 Lignitic beds.
1 Will's Point or Basal clays.

Basal Clays.—The basal beds of the Eocene consist of stiff laminated clay, yellow, red, blue or bluish green in color, with some laminæ and beds of sand, boulders and indurated strata of calcareous material, containing in places many fragments of shells. The boulders are irregularly distributed through the clay, and sometimes form continuous bands for considerable distances, as in the vicinity of Tehuacana. Another phase assumed by the lime is the small cauliflower-like concretions which abound in certain beds. Gypsum crystals are also plentiful.

In areal distribution the Basal clays are principally found north of the Colorado river, and, although a few localities are known south of that stream, the beds are, for the most part, obscured by overlap.

Typical exposures of the beds can be found in the vicinity of Elmo, Will's Point, Tehuacana, and on the Rio Grande near the Maverick-Webb county line.

The fossils, which occur in pockets, have been determined by Harris, who assigns the beds to the horizon of the Midway stage of Alabama. Characteristic fossils are:

Ostrea pulaskensis Har., *Cucullæa macrodonta* Whitf., *Yoldia eborea* Con., *Crassatella kennedyi* Har., *Pleurotoma ostrarupis* Har., *Volutilithes rugatus* Con., *V. limopsis* Con., *Pseudoliva unicarinata* Ald., *Aporrhais gracilis?* Ald., *Enclimatoceras ulrichi* White.

Lignitic Beds.—These beds are composed, for the most part, of siliceous sand of various colors, usually much cross-bedded, micaceous and often containing specks or grains of glauconite. Clays of various colors occur, laminated, as interbedded and interlaminated sands and clays, and in massive beds. Lime is present in the form of nodules, concretions and beds of siliceous limestones. Gypsum is also found in places. Brown coal and lignite beds, varying from a few inches to ten and twelve feet in thickness, are of frequent occurrence, and traces of oil and gas are found. Silicified wood is common. Iron occurs in the form of pyrites, and also in nodules, strings and small seams of clay ironstone.

The upper portion of the beds is composed of a series of red and white sands and white clays—the Carrizo sands of Owen and Queen City beds of Kennedy.

The lignitic beds are well marked from the eastern limit of the state to the Rio Grande, forming, as a usual thing, gently rounded hills covered with forests of oak. Typical exposures may be found at Athens, Calvert Bluff, Rockdale, Lytle, Carrizo Springs, etc

The fossils, which, according to Mr. Harris' determinations, are those characteristic of the Lignitic of Alabama, include the following:

Dentalium micro-stria? Heilp., *Pleurotoma moorei* Gabb, and numerous others which are common to these beds and those underlying or overlying them.

In addition to the invertebrate forms these beds also contain a varied and well preserved flora which has not yet been studied.

Marine Beds.—The Marine beds are composed of sand, with considerable amounts of glauconite, clays and iron ores, and are the principal fossil-bearing beds of the series. The lower beds contain extensive deposits of ferruginous sandstones and laminated iron ores, while the upper comprise brown fossiliferous sand, green sand marls, stratified black and gray sandy clays and green clays, and are the principal fossil-bearing beds of the substage. Thin beds or laminæ of carbonate of iron occur throughout the entire section, but the heavier beds or ore deposits are found toward the top of the lower beds. The lower ores are laminated, while those above are nodular.

The surface exposure of the Marine beds forms a broad ridge or range of hills crossing the state from the east, where it forms the greatest elevation of that portion of the Eocene belt, to the southwest. Its topography is the consequence of the resistance of the iron ore caps of the eastern plateaux or hills to erosive agencies, and the similar service of the brown sandstones of the west. In areal extent this is the most widely distributed of the sub-divisions of the Eocene.

In elevation it varies from 375 to 700 feet above sea level.

The fossils are very abundant and well preserved, and among those characteristic of it may be noted:

Ostrea alabamiensis Lea, *O. sellaeformis* Con. var, *divaricata*, Lea, *Anomia ephippioides* Gabb, *Modiola houstonia* Harris, *Yoldia claibornensis* Con., *Venericardia planicosta* Lam., *Semele linosa* Con., *Terebra houstonia* Har., *Cancellaria gemmata* Con., *Marginella semen* Lea, *Terebrifusus amœnis* Con., *T. costatus* Lea, *Levifusus trabeatoides* Har., *Nassa texana* Gabb, *Murex vanuxemi* Con., *Dis-*

tortrix septemdentata Gabb, *Mesalia claibornensis* Con., *Turritella nasuta* Gb., *Natica limula* Con., *Sigaretus declivis* Con., *S. inconstans* Ald., *Belosepia ungula* Gb.

Yegua Clays.—This sub-division was proposed to include the gypseous and saliferous clays, lignites and sands lying between the Marine beds and the sandstones of the Fayette with which they were united in the first use of that name. The area occupied by them is, for the most part, only gently rolling, except toward the southwest, where it sometimes happens that considerable hills occur, the summits being capped by the harder sandstone or quartzite of the Fayette beds.

The clays are dark blue, weathering to a dirty yellow, with a profusion of crystals of gypsum. In places the clays are massive, at others laminated. The sands are gray and white, often laminated or cross-bedded, but sometimes massive. The fossil wood contained in them is simply silicified and not opalized, as in the succeeding beds. The brown coal and lignite deposits of this sub-division are as extensive as those of the Lignitic stage, beds with a measured thickness of sixteen feet having been observed on the Colorado.

While the lithological characters of the Yegua clays are clearly marked and plainly traceable entirely across the state, its fauna connects it directly with the Marine beds. Typical exposures of the beds may be seen near Alto and Lufkin, on the Yeguas in Lee county, and between Pleasanton and Campbellton.

In addition to the many forms common to this and the Marine beds, the following seem to belong exclusively to the Yegua:

Tellina mooreana Gabb var., *Turritella nasuta* var. *houstonia* Har., *Natica recurva* Ald.

Fayette sands.—This name was originally applied by Penrose to the entire series of deposits between the top of the Marine beds and the base of the Coast clays. It is used here, with a greatly restricted significance, for that sub-division of the Tertiary to which the name is most applicable. This is a series of sands and sandstones with some clays, which contain a large amount of opaline and chalcedonic materials. The sands are usually coarse, angular to rounded in shape, forming sandstones of variable degrees of hardness, highly quartzitic in places, and cemented by an opaline matrix at others. Large quantities of opalized wood occur, and chalcedony is abundant, especially in the southwest, where it forms the centers of geodes, the septa of septaria, and even fills crevices in the sandstone. Beds of volcanic dust and siliceous sinter also occur interbedded with the clays and lignites. In the Nueces valley cone-in-cone structure is widely developed, and considerable aragonite occurs in the basal portion of the bed. Many of the clays are white, and of sufficient purity to be valuable for the manufacture of the finer grades of earthenware. The beds of lignite are, for the most part, small and unimportant.

There is no sharp line of demarkation between these beds and the Yegua clays below, but the change in the character of the sediments has caused a corresponding change in the topography. The gently rolling area of the Yegua clays is bordered on the south by a disconnected range of hills, whose northward-facing scarps and bluffs (often 150 feet in height) can be traced from Rockland, on the Neches, westward, by Riverside, Muldoon, and Tilden, to the Rio Grande. Southward from this scarp the descent is more gradual. The influence of these beds of sandstone on the course of the rivers which cross them is very marked, producing a sharp east or northeast deflection, such as that of the Trinity on the northern boundary of Walker county.

While the Fayette beds of the eastern part of the State are almost without invertebrate fossils, so far as determined, the fauna increases toward the Rio Grande, and on that river includes large beds of immense oysters. The forms specially characteristic of it are:

Ostrea alabamiensis var. *contracta* Con., *Siliqua simondsi* Har., *Ceronia singleyi* Har., *Cornulina armigera* var. *heilpriniana* Har., *Cerithium pliciferum* Heilp.

It is connected with the underlying beds by such forms as *Nucula magnifica* Con., *Venericardia planicosta* Lam., *Corbula ala-*

bamiensis Lea., *Levifusus trabeatoides* Har., *Pseudoliva vetusta* Con., *Calyptrophorous velatus* Con.

The flora of this sub-stage is quite varied, and some of the forms very well preserved, but up to the present no study of it has been made.

Frio clays.—The Fayette subdivision passes upward into a series of gypseous clays with sand and sandrock, differing greatly lithologically from the underlying beds. This subdivision is therefore proposed for them. According to Kennedy, they are not present (in this form at least) on the Neches river, but I found them well developed on the Frio and Nueces.

The clays are dark colored, greenish gray, red or blue, usually massive, with quantities of gypsum and with calcareous concretions arranged in lines, giving them a stratified appearance. The sandy clays are laminated and bedded, green, red or blue in color, and interbedded with brown and green sandstone, which is concretionary and, in places, highly indurated. Brown sands overlie these, and are followed by laminated chocolate clays containing concretions of crystalline limestone with manganese dendritions. These clays weather white, as at the mouth of the Frio.

Typical exposures: Between Weedy creek and Oakville on Atascosa and Frio rivers, and on the Nueces south of Tilden.

While the fossils are not very abundant, enough were found to determine its close relationship with the underlying beds. The *Ostrea*, *Corbula*, etc., are distintly lower Claiborne forms.

So far as our observations go, this is the highest bed referable to the Eocene and from the evidence now before us it appears that there are no deposits in the State belonging either to the Upper Claiborne, Vicksburg, or Jackson, since no fossils characteristic of either of these stages have yet been found.

The Texas Eocene, as a whole, is therefore composed of a series of comparatively shallow water deposits, laid down during a period of slow and gentle oscillations. Numerous local unconformities exist between the several subdivisions, and even among the beds of the same subdivision. The Carrizo sands show a more or less wavy structure throughout their extent, and this is continued upward into the Marine beds. Some portions of the Marine beds seem to have been subjected to erosion before the deposition of the Yegua clays, and faults of slight throw are quite common. As a whole the beds thicken from the Colorado-Brazos divide to the eastward and toward the Rio Grande and are also more indurated in the latter region. The general dip is south to southeast 10 to 50 feet per mile, although reverse dips are common in places.

The fossils which these beds hold in common with deposits of similar age of the Pacific slope, some of which are not found in the Tertiary of the Atlantic coast, bear evidence to the fact that the Gulf of Mexico was at that time connected with the waters of the Pacific. The fossils common to these deposits and the Tejon beds are, according to Harris:[1]

Whitneya (*Strepsidura*) *ficus* Gabb, *Natica ætites* Con. equiv. to *Nevireta secta* Gabb, *Solarium alveatum* Con. equiv. to *Architectonica cognata* Gabb, *Solarium amœnum* Con. equiv. to *Architectonica hornii* Gabb, *Cardita hornii* Gabb equiv. to *Venericardia planicosta* Lam.

The influx of large amounts of hydrous silica, beds of siliceous sinter and volcanic ash, and the development of cone-in-cone structure in the upper portion of these deposits is worthy of note as indicating the manner in which these Tertiary deposits became a land area.

NEOCENE.

Beds of Neocene age are found both in the Coastal slope and on the Llano Estacado. They probably exist in the trans-Pecos district also, but have not as yet been positively identified. The deposits include beds both of Miocene and Pliocene age, and the following division is proposed:

[1] Science, August 16th, 1893.

	Coastal slope.	Llano Estacado.
	2 b Reynosa	
Pliocene	2 a Lagarto	
	2 Lapara	Blanco
Miocene	1 a	Goodnight
	1 Oakville	Loup Fork

MIOCENE.

The Loup Fork beds of the Llano Estacado are composed of alternating beds of bluish and almost pure white sand, capped by a conglomerate of siliceous pebbles in white sand matrix. In areal extent they are found overlying the Triassic of the Plains throughout its northern portion, but extending to the south only as far as Mulberry canyon. The fauna, as described by Cope,[1] in addition to a number of species hitherto found only in beds of the Loup Fork terrane, and thus fixing the age of the Texas bed, contained two new forms: *Protohippus pachyops*, Cope, and *Procamelus leptognathus*, Cope.[2]

On the Coastal slope the Frio beds of the Eocene are succeeded by a series of deposits, which in a general way resemble the underlying Fayette sands, and have hitherto been regarded as a part of those beds. While it is possible to distinguish between them, the differentiation is complicated in many instances by the overlap of still later beds largely derived from both these and the Fayette, and therefore bearing a very close resemblance to them lithologically.

The deposits are those of rapid currents of shallow water. Grits and coarse sand, cross-bedded,[3] with some beds of clay but oftener with balls, nodules or lenses of clay imbedded in the grit. Some of the sand forms a sandrock which is apparently firm and hard, but much of it is so feebly coherent as to fall apart on a

[1] Fourth Annual Report, Geological Survey of Texas, Part II., pp. 18–40.

[2] Professor W. B. Scott regards these beds as equivalent to the Archer beds of Florida, which Dall, for stratigraphic reasons, places in the Pliocene. Bull. Geol. Soc. Am., vol. ii. p. 595.

[3] Cf. Loughridge, Tenth Census of the U. S., Cotton Production of the State of Texas, p. 21.

slight blow of the hammer. Local beds of conglomerate occur, and, on the Nueces, a heavy bed of black flint gravel was traced from its outcrop until the dip carried it below the water line.

As I now understand this division, the base is found at La Grange bluff, described by Penrose,[1] and it embraces the beds from which the fossils came which were reported by Shumard (Trans. St. Louis Academy, 1863, p. 140) and determined by Leidy (Proc. Phil. Ac. Nat. Sc., 1865, p. 176, and 1868, p. 231, etc.).

Mill creek, between Brenham and Burton, marks a lithological change, the rocks west of that stream, which are the lower, being more compact than those east, which at Brenham have the character of cross-bedded grits with pebbles of clay, containing water-worn cretaceous fossils, as well as numerous fragments of the bones of vertebrates. A similar division was noticed east of La Grange.

On the Nueces the beds, which are here highly saliferous, are well exposed from Oakville to Fort Merril, at which place they are overlaid by the Pliocene. Here begin the silicifications of portions of the materials, which becomes a more and more prominent feature of the deposits further west.

Among these silicifications may be mentioned the rocks, known as Las Tiendas, on the road between San Diego and Tilden. On the outside these rocks resemble masses of light-colored flint, the surface of which is highly polished by blown sands. Closer examination shows that they are simply portions of the interbedded clays and sands of the Oakville beds, which have become silicified without destroying the original structure of the beds. Thus the bedding and lamination is apparent in portions of the mass, and the siliceous pebbles, so common in the unaltered beds, are found in these masses also.

To the same age as the Oakville beds I have also referred the range of hills in the valley of the Nueces, known as the Picachos.

These hills, running northwest and southeast, are nowhere

[1] First Annual Report, Geological Survey of Texas, p. 54.

over 100 feet higher than the valley in which they stand, but their serrated tops give them the appearance of a range of eruptive hills. The beds here, unlike those at any other place in the Texas Tertiaries, stand at high angles, and have a dip of 75 to 80 degrees to the southeast.

The materials of which they are composed are claystones interbedded with porcelaneous and siliceous rocks, partly flinty, partly opaline, with bands and network of chalcedony and with seams of ferruginous material. A few seams of calcite, in the form of dog-tooth spar, and a bed of aragonite, 20 feet in thickness, banded in brown and white and much knotted and twisted, are found. The true opaline character of the rock was shown by an analysis by Dr. Mellville, and the present condition may be regarded as the result of infiltration of hydrous silica in hot solution into the Tertiary marls, and their consequent alteration. A number of specimens collected show that the marl was cracked in every direction, and that these fissures are now filled with chalcedony, while the marl is changed to a porcelaneous substance.

The sands and clays of this division form the scarp known as the Bordas, which forms the southern border of the Nueces valley from Dinero to Los Angeles. It also caps many of the outlying hills in the valley.

Only a few fossils have been found, but such as are determinable—*Protohippus medius* Cope, *P. perditus* Leidy, and *P placidus* Leidy, *Aphelops meridianus* Leidy, etc.—are sufficient to determine its age as Loup Fork.

The exact relation of these beds and those found in boring the Galveston deep well has not been determined, since no deposits containing similar marine Miocene fossils have been found at the surface on the Coastal slope. The relationship of the Deep Well Miocene and deposits of Florida and the West Indies is shown by Harris[1] in his report on the organic remains from that boring.

On the Llano Estacado there is no great break between the

[1] Fourth Annual Report Geological Survey of Texas, p. 118.

Loup Fork beds and the Blanco or Pliocene, but they are directly connected by a deposit which has been called the Goodnight beds. The fauna, according to Professor Cope, contains forms which are found in the underlying Loup Fork, and others which extend upward into the overlying Blanco, as well as three which are peculiar to itself—*Protohippus lenticularis* Cope, *Hippidium interpolatum* Cope, and *Equus eurystylus* Cope. It is possible that more detailed investigations of the upper portion of the Oakville beds above Lapara creek, and between Brenham and Long Point, may furnish evidence of a similar condition.

PLIOCENE.

The Blanco beds—Pliocene of the Llano Estacado are composed of clays and sands interbedded with diatomaceous earth and capped with calcareous sandstone and limestone. They constitute the eastern scarp of the Plains from the Double Mountain Fork of the Brazos river on the south, to Palo Duro Canyon on the north, resting directly on the red clays of the Triassic.

The vertebrate fauna of these beds is described in the Fourth Annual Report of the Texas Survey, Pt. ii, pp. 47–74.

The species are: *Testudo turgida* Cope, *T. pertenuis* Cope, *Crecoides osbornii* Schuf., *Megalonyx leptostomus* Cope, *Canimartes cumminsii* Cope, *Borophagus diversidens* Cope, *Felis hillanus* Cope, *Tetrabelodon shepardii* Leidy, *Dibelodon humboldtii* Cuv., *D. tropicus* Cope, *D. præcursor* Cope, *Equus simplicidens* Cope, *E. cumminsii* Cope, *E. minutus* Cope, *Platygonus bicalcaratus* Cope, *Pliauchenia spatula* Cope.

On the Coastal Slope the beds are grits and clays overlaid by light colored clays, gravel, and tufaceous limestone. In this area I have suggested the following divisions: Lapara, Lagarto, and Reynosa-Orange sand.[1]

The Lapara division, as shown on Lapara creek and on Hog

[1] McGee, in the Twelfth Annual Report of the U. S. Geological Survey, has correlated the Reynosa and Orange sand with his Lafayette formation; but I retain the names originally given to these beds for purposes of description, and their precise relations to the Lafayette formation can be determined later.

Hollow, on the opposite side of the Nueces, consists of sands and clays interbedded and somewhat cross-bedded. The sands are coarse and sharp, often forming grits, and including pebbles of clay and calcareous concretions. The clays are jointed and parti-colored—light red, green, etc.—and in some localities appear as a conglomerate of clay pebbles. Fragments of bone are common in them, but they are often so worn as to prevent recognition. The fossils were submitted to Professor Cope, who pronounced the horizon to be the Blanco, and states that nothing from either locality indicates a horizon as low as the Loup Fork. Similar deposits were observed on the Southern Pacific railroad between La Grange and Columbus, and in the vicinity of Brenham.

The Lagarto division includes a series of sands and clays of a different character from the Lapara, and overlying them. It comprises light colored clays—lilac, lavender, sea-green, greenish brown and mottlings of these colors—jointed and showing many slips. In places the upper portion contains a considerable amount of sand, gravel, or lime, and the change in a single stratum from one kind of rock to another takes places within a very few feet. In localities where the lime predominates it closely simulates the Reynosa. Where the limestone or calcareous sandstone caps the clays, strings of limestones extend downwards into them for a distance of six or eight feet. The clays contain quantities of semi-crystalline limestone pebbles with manganese dendritions, and, indeed, manganese appears to be one of the characteristics of the clay wherever found. The upper portion of the beds is usually a sandstone. No fossils have been found in them.

Reynosa division.—Lithologically this is the most characteristic of all of the Neocene deposits. While I use the name given it by Penrose in 1889, it had been observed previously by Schott and Shumard, both of whom referred it to the Cretaceous. This reference, made on lithological grounds alone, has in its favor the fact that there are many localities where the Reynosa deposits so closely resemble those of the Austin limestone that, were they found within the Cretaceous area, they would be passed without question, even by those better acquainted with the Cretaceous than were these observers. Loughridge, in his Report on Cotton Production, (Tenth Census Report), comes nearer the truth when he refers it to the Port Hudson.

The very variable series of beds intended to be included in this division, has, usually, at the base a conglomerate of pebbles of various sizes, imbedded in a lime matrix, often indurated, sometimes tufaceous, sandy or even clayey. Above this is often, but not always, a series of interbedded clays, limy clays, limy sands and sandstones with some pebbles. This closely resembles the Lagarto clays. The whole is capped by the Reynosa limestone. This is a tufaceous lime rock, but often so mixed with clay or sand as to lose that character. There are few exposures which show the entire series of beds. In places along the middle Rio Grande, the basal bed of conglomerate is all that is present, while on the divides the basal and uppermost beds are usually found, but without the intermediate Lagarto.

The Reynosa, in its typical form, is only found west of the Colorado, so far as I have observed. East of the Guadalupe the lime is gradually replaced by iron, the Orange sand phase appears in the Colorado drainage and east of that stream becomes the prevailing form, although some lime is present at many localities. This change is obviously due to the fact that in the western part of the State the erosion of the Cretaceous limestones furnished the materials for the Reynosa, while in the east the ferruginous beds of the Tertiary supplied the materials for the Orange sand.

No fossils have been found in this deposit which can certainly be said to be indigenous to it. A number of shells of Bulimus were found imbedded in an upper crumbly layer of it, but they are simply on the surface and are probably later.

No other bed of the Tertiary has anything like so wide a distribution as this. I found it at the top of the escarpment of the Llano Estacado in Garza county, at the point marked "11" on the map of the Llano Estacado accompanying the Third Annual Report of this Survey, and also just south of Big Springs, resting on the northern slope of the Cretaceous hills. Cummins has traced it over a large portion of the Plains, and while we have no record of it on the top of the Cretaceous plateau between Big Springs and the Nueces canyon, it may be there, and have been overlooked owing to its close resemblance to Cretaceous materials. In the canyons, however, on the southern edge of the plateau, its presence has been reported by Hill and Taff, and I have traced its continuation southward from the line of the Southern Pacific railway to San Diego. While no direct connection of these beds with those of the Llano Estacado has been observed, their lithological identity and stratigraphical relations to the Blanco beds below and the Equus beds above seem to warrant the conclusion that a connection did exist either across or around the Plateau.

While erosion has removed the Reynosa from a large part of the Guadalupe and Nueces valleys, it still caps the divides and higher elevations and forms the surface of that plateau between the Nueces and the Rio Grande which is in many respects the homologue of the Llano Estacado, and may well be called the Reynosa plateau. On this plateau it attains an elevation of over eight hundred feet above sea level in an area which appears on all topographic maps as lying below the 200 foot contour.

In the Orange sand area the conditions are somewhat different. The beds do not appear to have covered the entire area, as did the Reynosa, but to have been laid down in drainage channels, lakes or bays among the islands or promontories of Eocene materials.

The Neocene deposits, taken as a whole, represent a period of lacustrine, fluviatile and estuarine deposits. With the exception of the fossils obtained from the Galveston deep well there is nothing to indicate marine conditions anywhere in the region during Neocene times.

At the close of the Pliocene the beds were elevated and subjected to considerable erosion prior to the deposition of the Pleistocene. The Sun mound, west of Waller, is an outlier of the Orange sand, and Damon's mound, in Brazoria county, seems to belong to the Reynosa, although many miles to the seaward of any other exposure referable to that horizon. Every contact which I have observed also bears evidence to the fact.

PLEISTOCENE.

The Pleistocene deposits include the Equus beds and connected deposits found along various rivers and creeks; the Coast clays and their extensions along rivers and creeks and contemporaneous deposits of the Seymour plateau; and the later river, creek and surface deposits either of aqueous or subaerial deposition.

Equus beds.—In the valleys and depressions hollowed out by the erosion of the Pliocene materials were laid down the ash-colored limy sands and gravel which constitute the typical Equus beds of San Diego and southwest Texas and the more ferruginous beds of the same age east of the Colorado. So far as I have observed them they rest with great unconformity upon the Reynosa, indeed, there is no equal unconformity visible between any other two series of beds in the Texas Cenozoic.

The deposits consist, in their typical exposures, of limy conglomeritic ashy material, containing pebbles derived from the underlying Reynosa. The beds are without trace of stratification, except that here and there through them the calcareous matter appears as a line of nodules, or bed of pebbles will follow a straight line for several feet. The beds are usually ashy yellow in color, but lighter in places, and grade upward into a grayer and more sandy body, and then into a black soil. Their ashy appearance is one of their distinguishing characteristics. When damp they are easily dug into, but when dry are very hard. The vertebrate fossils, to which they owe their name, are found in the lower portion of the beds, while they are rare in the upper or grayer portion, which carries instead a number of forms of land and fresh water shells. However, no line of division can be drawn between the two portions as the change is very gradual.

The thickness of the beds, so far as observed, is in no place over 20 feet, and they appear to occur in detached and irregular basins, usually connected directly with some drainage channel, present or past. The Equus beds of the Llano Estacado are similarly related to the underlying Blanco beds, and in one instance, on Wild Horse creek, rest directly on the Trias. In addition to the typical locality at San Diego, these beds are found at many other localities on the Coastal slope, some of which have been noted in the publications of Cope and Leidy and others by this Survey. They also extend up the river valleys for considerable distances, as is proved by the presence of characteristic fossils from the second bottom deposits as far inland as Austin. The species described from the Plains are as follows:

Testudo hexagonata Cope; *T. laticaudata* Cope; *Mylodon? sodalis* Cope; *Elephas primigenius* Blum; *Equus excelsus* Leidy; *E. semiplicatus* Cope; *E. tau* Owen; *E. major* Dekay; *Holemeniscus sulcatus* Cope; *H. macrocephalus* Cope.

From the San Diego beds the following have been reported:

Cistudo marnockii Cope; *Elephas primigenius* Blum; *Canis sp. Glyptodon petaliferus* Cope; *Equus tau* Cope; *E. semiplicatus* Cope; *E. excelsus* Leidy; *E. occidentalis* Leidy; *E. crenidens* Cope.

In addition to these many others have been reported from localities to the eastward, proving the existence of the beds over a large portion of the Coastal slope.

The shells collected from the upper part of the San Diego beds and determined by J. A. Singley are as follows:

Bulimulus dealbatus Say; *Physa gyrina* Say; *P. heterostropha* Say; *Patula alternata* Say; *Planorbis lentus* Say; *P. bicarinatus* Say; *P. parvus* Say; *Amnicola peracuta* P. & W.; *Unio texasensis* Lea; *U. sp.?*, *Sphærium elevatum* Hold.?; *Helicina orbiculata* Say; *Helix texasiana* Mor.

Coast clays.—The Coast clays which are regarded as the western extension of the Port Hudson group of Hilgard, and as belonging to the Champlain Period of Dana, underlie the greater part of the area of the coast prairies. They form a wide belt lying between the Reynosa and the sandy coastal strip, and in many places stretch to the very shores of the bays which border the gulf.

The Coast clays are for the most part heavy limy clays of various colors, yellow, red and blue in places, in others olive green and brown. They are interbedded with sand, contain nodules and concretions of lime, are often high in iron, and the sand, which for the most part is uncompacted, at times forms concretionary masses of considerable size. These clays vary from east to west in accordance with the varying character of the beds from which they were derived, being more silty eastward and denser toward the west.

In the only contact of any extent which I have seen, that on the Brazos river east of Sealy, the Coast clays rest unconformably upon the Equus beds, as they do upon the Reynosa further west, in such places as the Equus are lacking. In them have been found several varieties of land shells, and fossil vertebrates occur at many localities. They too, stretch inward for many miles along the river channels forming the second bottoms, and even the highlands, as proved by the fossils secured from such deposits. These are usually characterized by *Elephas* and *Equus* remains. Similar remains as well as those of smaller animals, are also found in the body of the deposit itself.

These clays have been studied very little. The exposures are so very few and usually so widely separated, the fossils so scattered, and the economic questions outside artesian water and agriculture, so few, that they have not received the attention they deserve. It seems probable, however, that when more thoroughly studied, they will be separable into two portions, the lower being much darker and more evenly bedded than the upper or massive beds.

The evidence before us now, however, is to the effect that the second bottoms of the rivers are by no means referable to any one division either of the Pliocene or Pleistocene, but that they comprise deposits ranging in time from Blanco to Recent.

Either to this or to the upper Equus horizon must also be referred the brown silty clay which is found on some of the divides in the Coastal slope. In places this carries land shells and exhibits a loess-like structure. It is well developed on the divide between the Nueces and the Leona, and has been observed in many other localities.

The Seymour Plateau, which is referred to this horizon because of its mid-Pleistocene, or at least post-Equus fauna as determined by Cope, stretches northeast from the Texas and Pacific railway west of Sweetwater, with a width varying from 16 to 50 miles, to Red river, north of Vernon, a total length of 160 miles. The western border of this ancient lake is sharply defined by a range of gypsum hills, as may be seen on the Fort Worth and Denver railroad east of Quanah. In elevation it varies between 1200 and 1600 feet above sea level, and although at present cut through by many streams, whose beds are sometimes 150 feet below the plain, the general flatness of its surface is still well preserved.

Of the latest of the divisions of the Pleistocene little can be said, because it has been studied least of all. It comprises the sands of the immediate coast area, which stretch inland in places for 50 miles and more; the later stream gravels, and other deposits of gravels and sands which are found on the surface at many localities. The sand dunes of the west and southwest also belong here.

CONCLUSIONS.

None of the beds of the Eocene having yielded fossils characteristic of horizons higher than the lower Claiborne, the deposits referable to that series are confined to its basal portion.

Certain forms indicate a connection of the Eocene waters of the Texan region with those of the Pacific.

In the Texan region dry land probably existed from mid-Eocene times far into the Miocene.

Although there is a possibility that the lower portion of the deposits referred to the Miocene may prove a little earlier, the fossils so far discovered belong to the upper portion of that stage—the Loup Fork.

The exact relation of the Loup Fork and the marine Miocene of the Deep well is undetermined,

There exists, both on the Llano Estacado and on the Coastal slope a series of beds, overlying the Loup Fork and underlying the Equus beds which contain a "fauna more nearly and strictly Pliocene than any of the lacustrine terranes hitherto found in the interior of this continent."[1] This stage culminated similarly both on the Stockaded plain and on the Coastal slope.

The strong unconformity existing between the Equus beds and the Pliocene deposits, together with their relations to the overlying Coast clays, seem sufficient warrant for making them the base of the Pleistocene.

E. T. Dumble.

[1] Cope. Fourth Annual Report Geological Survey of Texas. Pt. II, p. 47.

OUTLINE OF CENOZOIC HISTORY OF A PORTION OF THE MIDDLE ATLANTIC SLOPE.[1]

In the spring of 1891, I published a preliminary account of the Mesozoic and Cenozoic formations of eastern Virginia and Maryland, in which there was given a brief resumé of the history.[2] Studies have been continued in the region, and much new information has been acquired, especially regarding the relations and history of the younger formations. Notice of the results of these studies was given at the meetings of the Geological Society of America, in December, 1892, and August, 1893. In this paper, there is presented a brief summary of the principal features, but further details and a more extended discussion, will appear later in a memoir now in course of preparation.

The middle Atlantic slope extends with fairly regular declivity from the Appalachian range to the ocean. It comprises two provinces, the Piedmont and the Coastal plain. The former, which lies to the westward, is a high undulating plateau carved in greater part in crystalline rocks; the latter slopes to the ocean, and is underlain by unconsolidated deposits ranging from Cretaceous to Pleistocene in age. The Piedmont belt is traversed by rivers which flow in gorges, and the minor water ways run in deep rocky valleys. The slope to the eastward is gentle and the province merges into the Coastal plain in a zone of moderate width, in which, to the northward, there is increased declivity. The surface of the Coastal plain comprises wide areas of plateau to the southward and rolling hills to the northward, which attain maximum elevations from two hundred to three hundred feet. It is bordered on the eastward by low terrace plains, and traversed by wide depressions, which contain terraces of various heights. The gorges of the rivers of the Piedmont

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Geol. Soc. Am., Bull., Vol. II., pp. 431–451; Plate 10.

belt open into these depressions and the larger rivers become tide water estuaries in the Coastal plain.

The formations underlying the Coastal plain province are a series of widely extended sheets of gravels, sands, clays, and marls lying on an east-sloping floor of crystalline rocks. They are separated by unconformities and, in greater part, dip gently and thicken gradually, to the eastward. They emerge at the surface in succession to the westward, but there is more or less overlap of the younger formations beyond the edges of the older formations. The Cretaceous and Tertiary representatives are the Potomac and Raritan formations, consisting of clays and sands of early Cretaceous age; Magothy[1] sands and brown sandstones of Maryland; the great greensand series of New Jersey represented by the carbonaceous sands of the Severn formation in Maryland; Pamunkey formation consisting of glauconitic sands and marls of Eocene age; Chesapeake formation consisting of clays, fine sands, and diatomaceous clays of Miocene age, and the Lafayette formation consisting of gravels, sands, and loams of later Neocene or Pliocene (?) age.

On the terraces in the depressions, and on the low lands to the eastward, there are deposits of gravels, loams, and sands of Pleistocene age which have, in greater part, hitherto been comprised in the "Columbia formation." I have found, however, that these depositions consist of two series of deposits, an earlier, which lies on the higher terraces westward and is the basal member eastward, and a later deposit, which lies on the lower terraces, and overlies the earlier deposits eastward and southward of the Potomac valley. This difference in altitude is due to emergence and strong tilting from the northwestward between the time of deposition of the earlier and later deposits. The area of this emergence is shown by the heavier ruling in figure 4. The earlier deposit has not been differentiated before, but it is an important and distinct member of the Coastal plain series. The general relations of the various formations near the latitude of Washington are shown in the fifth section on figure 3.

[1] Recently defined by DARTON, Am. Jour. Sci., 3d Ser., Vol. XLV., 1893, 45 pp.

TERTIARY BASE-LEVELS.

It is now very clearly recognized that the Piedmont plateau is a peneplain of Tertiary age. This plain extends eastward over the Coastal plain region, and with gradually decreasing altitude finally passes beneath tide water level not far from the present coast line. In the Piedmont region, the plain has been deeply trenched by drainage ways, but wide areas are preserved in the divides. On the Coastal plain, it is overlain by the Lafayette formation by which it is largely preserved to the southward, but in northern Maryland, Delaware, and New Jersey, this formation has been removed and the peneplain gives place to rounded hills or to later terrace levels. The Tertiary peneplain extends over the Piedmont plateau to the foot of the mountains and through their gorges into the great Appalachian valley. Its altitude near the Blue Ridge west of Washington is about 600 feet, but it rises gradually along the foot of this range to 900 feet on James river. A short distance west of Washington, its altitude is 400 feet, and a few miles to the eastward, where it is widely overlain by the Lafayette formation, it is 270 feet. At the shore of Chesapeake Bay, east of Washington, it is 110 feet, and near the mouth of the Potomac river, 90 feet. At Richmond, it is 200 feet, and it passes beneath tide level near Norfolk. These altitudes indicate a gradual slope to the east, and to the south along the Blue Ridge near James river. There is, also, a general increase of altitude to the northward along the Coastal plain, which has resulted in the wide removal of the Lafayette formation and degrading of the underlying peneplain in that direction. In figure 5, an attempt has been made to represent the contour of the peneplain by one hundred foot contours, restoring the portions which have been degraded. The steep slopes in the Washington-Baltimore region are due mainly to the inter-Columbia tilting. A portion of the general tilt to the east, especially to the southward, was probably pre-Lafayette, and the peneplain had originally, of course, a moderate seaward slope. The surface contour of the peneplain is quite smooth. On the

Coastal plain, the Lafayette formation lies on a very smooth surface, but there are low depressions along the lines of the present valleys of the larger streams south of, but not including, the Potomac. In the Piedmont region, there is a system of very low flat divides coincident with those of the present drainage systems. There are a number of "monadnocks" or unreduced areas of hard rocks, which rise more or less abruptly to various heights above the plain. These are shown on figure 5. Parrs Ridge, the large, unreduced area west of Baltimore, rises gradually to only a moderate elevation, but its slopes are nearly everywhere clearly demarked from the peneplain. The monadnocks are portions of the old Cretaceous peneplain which was the slope on which the Tertiary peneplain was excavated. Probably the tops of some of the higher monadnocks stood above the Cretaceous plain.

During the development of the Tertiary peneplain, there were deposited the Chesapeake, Pamunkey, and possibly portions of earlier deposits, and the long time intervals by which these formations are separated represent intervals of uplift and increased planation. It has not been possible, as yet, to differentiate the topographic products of these epochs in the Piedmont region, and probably the local features to which the earlier conditions gave rise were effaced in succeeding epochs. A certain amount of base-levelling progressed in the Piedmont region during the deposition of Lafayette formation, but the relative amount is not known. Probably it was not great for the formation represents but a small time compared with preceding depositions and uplifts.

TERTIARY DEPOSITS.

There are three formations of Tertiary age in the Coastal plain region, Pamunkey (Eocene), Chesapeake (Miocene), and Lafayette (Pliocene?). The Pamunkey formation consists of glauconitic sands and marls, which attain a thickness of about 180 feet east of Washington. It represents but a small proportion of Eocene time, and according to a recent comparison by G. D.

Harris,[1] is equivalent to a small member near the lower portion of the Eocene series of the Gulf region.

The Chesapeake formation consists of clays and fine sands with large amounts of diatom remains in the lower members. Its thickness is about 800 feet in eastern Maryland and Virginia, but it is only from fifteen to thirty feet thick about Washington, and is thin all along its western edge. In New Jersey, it is over 1,400 feet thick in artesian wells at Atlantic City, but here it includes a lower series, the Shiloh marls, which do not reach the surface in Maryland and Virginia. In the Gulf region, there are still older Miocene members. The youngest members so far studied are found in the Yorkton-Suffolk region, in Virginia, and these are at about the horizon of the youngest Miocene known.

The Lafayette formation consists of bowlders, gravels, and sands westward, but the materials become finer to the eastward and southward. It is a thin sheet varying from fifteen to twenty feet in thickness in greater part. It overlaps the edges of preceding formations, and its western edge extends for some distance on the crystalline rocks in the Piedmont plateau. A shore formation of talus and bowlders along the eastern foot of the Catoctin Range is of this age, and according to Mr. Keith there are outliers on a high summit a short distance eastward.

As before mentioned these formations are the products of the base-levelling of the Piedmont region. They are separated by erosion intervals, during which base-levelling extended over the Coastal plain region.

The western thinning of the Pamunkey and Chesapeake formations may be due entirely to increased uplift and planing in that direction, but there is some meagre stratigraphic evidence that the original deposits thickened eastward, and that there are older members in that direction which are overlapped westward by the later deposits of the formations. Throughout its course, the Pamunkey formation is overlapped westward by the Chesapeake formation, although at a few localities, the overlying Chesapeake beds have been removed locally. The original

[1] Am. Jour. Sci., 3d Ser., Vol. XLVII., April, 1894, pp. 301-304.

extent westward of the Chesapeake and Pamunkey formations is not known, for no shores or shore deposits remain, and the superimposed drainage may be of later age. As they were deposited in moderately deep waters and the shores were probably low, at least in Chesapeake times, it is possible that the deposits may have originally extended far west of their present terminations. In Virginia, both formations abut against steep shores of crystalline rocks or Potomac sands, but in their original thickness they may have overlapped these local steep shores. About Washington, and west of Baltimore, outliers of probable Chesapeake cap the highest summits under a protecting cap of Lafayette gravels, and as one stands on these outliers and looks westward, there is strong suggestion that the formations may have originally extended far in that direction.

PLEISTOCENE TERRACES.

The earlier Pleistocene terrace, or that on which the earlier Columbia deposits lie, is tilted to a high altitude to the northwestward, but it dips to the east and south, and finally passes beneath the terrace level of the later Columbia deposits. The latter is also slightly tilted to the eastward. As the southeastward tilt of the Tertiary peneplain is greater than that of the Baltimore terrace, the Lafayette formation passes beneath the deposits of that terrace along a line near the zero line in figure 5. The relative slopes of these terrace levels and the Tertiary peneplain near the latitude of Washington are shown in the following diagram:

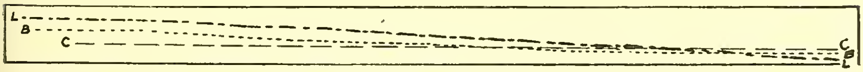

Figure 1. Diagram of earlier and later Columbia terrace plains and Tertiary peneplain near the Latitude of Washington. Vertical scale greatly exaggerated.

In the vicinity of Washington, where the relations are particularly well exhibited, the earlier Columbia terrace has an altitude from 215 to 180 feet, with the Lafayette formation on the Tertiary peneplain about 100 feet above. The later Columbian terraces are in a series, of which the highest averages about 100 feet in altitude. Both are separated by steep bare scarps, which are continuous for long distances. Florida, or Boundary Avenue, is at the foot of the younger scarp for several miles, and this scarp is a marked feature all about the Washington amphitheatre. The earlier Columbia terrace extends widely around Washington, and far up the Potomac valley, at first with rapidly increasing elevation. It is clearly exhibited in the Frederick valley at an altitude of 400 feet, and Mr. Keith has called my attention to extensive terracings in the Goose Creek valley and extending across to the head waters of the Occoquan, which are of earlier Columbia and Inter-Columbia age. In descending the Potomac, the altitudes of the earlier Columbia terrace are found to gradually decrease, and finally it passes beneath the later Columbia terrace and deposits, about thirty miles below Washington.

In the Baltimore region, the relations are very similar to those in the Potomac valley. The upper part of Baltimore is built mainly on the earlier Columbia terrace at altitudes from 140 to 200 feet. The terrace and its deposits have been found to extend up the Jones Falls depression to an altitude of 380 feet in eleven miles, and there are similar relations in the Gunpowder valley, where the same altitude is finally attained. This is a much steeper slope than exists in the Washington region, and the tilting here attains its maximum degree. Between Washington and Baltimore, there is a moderately wide depression, which holds areas of various sizes of early Columbia terrace at altitudes from 180 to 240 feet. This depression expands widely in the region between the Patuxent and the Patapsco, and towards the bay the altitudes gradually decrease to sixty feet near the bay shore. On the eastern shore of Chesapeake Bay, the deposits of the early Columbia terrace are overlain by the later Columbia deposits at an altitude from five to twenty-five feet above tide water, and to the eastward there is only a very gentle slope seaward. In the region south of the lower Potomac, the relations are similar to those east of the bay.

The later Columbia terraces extend in a wide belt along the ocean, covering all of the eastern shore of Maryland and Virginia, and extending up the tidal estuaries to and into the Piedmont region. They pass below tide level along the coast line and extend far out the submarine slope. To the westward, they gradually rise to from 60 to 100 feet in the depressions near the western margin of the Coastal Plain province. They extend up the Piedmont gorges for some distance, but are, of course, there greatly narrowed. Along the north side of the Potomac gorge above Washington, there is a narrow discontinuous shelf which gradually rises to 145 feet at Great Falls, where it becomes the floor of the valley. The inner gorge below the Falls has been cut through the later Columbia terrace. The later Columbia terrace extends up all the small valleys along the Coastal Plain, but is often considerably degraded in them.

PLEISTOCENE DEPOSITS.

The Pleistocene deposits consist of gravels, loams, and sands. In the typical development, there is a basal member containing gravels and bowlders, which merges upward into loams. On the earlier terraces, there is a formation of this character, which for the present may be designated "earlier Columbia." On the later terraces, there is a similar deposit which has long been known as the Columbia formation, and this for the present shall be differentiated as "later Columbia."

In the region to the west and north of Washington, where the earlier terrace is highly elevated, the earlier Columbia is at high altitudes, and the later Columbia deposits lie on the low terraces in the deeper portion of the depressions, but to the east and south, the later Columbia lies in regular succession on the earlier Columbia deposits. The evidences of the separateness of these two formations westward are the bare scarp of erosion intervening between the terraces, and, in a measure, the difference in degree of inclination. In some districts there are wide areas of bare slopes between the upper and lower terrace levels. In portions of the region eastward, a series of cross-bedded sands has been found to intervene between the earlier and later

Columbia deposits, which represents the products of the subærial erosion of the inter Columbia uplift in the region westward. In his report on the "Geology of the Head of Chesapeake Bay,"[1] McGee describes several exposures of this feature and represents it in his general section, but gives no suggestion as to its interpretation. It has been found to be general over a wide area, but is not everywhere equally distinct. The relations are shown in the following figure:

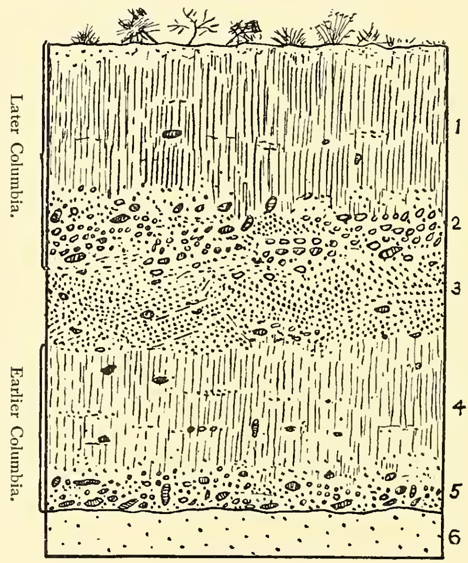

Figure 2. General section of Pleistocene deposits on the eastern side of Chesapeake Bay showing relations of cross-bedded sands between the earlier and later Columbia deposits. 1. Loam. 2. Gravel and bowlder bed. 3. Cross-bedded coarse sands. 4. Loam, with scattered pebbles, etc. 5. Gravel and bowlder bed. 6. Pre-Pleistocene formation.

The basal beds of each of the Pleistocene formations contain very coarse material to the westward which comprise bowlders, pebbles and sub-angular masses of quartzite, quartz, crystalline rocks, sandstones, and cherts, more or less closely packed in sands and loams. Some of the masses stand on end, and these

[1] U. S. G. S., 7th Ann. Rept., 1888. Pp. 537–646. Plates.

strongly suggest that they were carried by ice and dropped in their present attitudes. The loams contain scattered pebbles and bowlders, and pebbly and sandy streaks. Locally the formations consist entirely of pebbly sands. To the eastward, there is a gradual decrease in the coarseness of the materials. These statements apply about equally to the earlier and later Columbia deposits, but, on the whole, the materials of the earlier Columbia are often coarser than those of the later Columbia. Both formations contain local streaks of ferruginous conglomerate, but the earlier Columbia deposit presents much of this material, and east of Washington it is a conspicuous feature. In some portions of the regions between the valleys of the Potomac and Patuxent, and northeast of Baltimore, the earlier Columbia formation becomes very thin, and consists largely of local materials. The thickness of the later and earlier Columbia deposit averages twenty feet each.

The earlier Columbia deposit has been widely removed from the higher altitudes, and up the Piedmont gorges is represented by meagre fragments. The widest areas now constituting the surface are southeast of Baltimore, and south of Washington, west of the Potomac. In the upper part of Baltimore, and about Mount Pleasant, the upper part of Washington, there are moderately large areas. In the valleys north of Baltimore there are many thin patches of earlier Columbia gravels, and some of these widen considerably in the limestone valley of the Cockyville region. In the Rock creek valley, near Washington, there are many small areas of the deposits at from 195 feet to 205 feet, and an early Columbia delta at the broad intersection of the 200-foot terrace level with the gorge above.

The later Columbia deposit is not widely degraded, and it has only been removed over the area occupied by tide water, and narrowly trenched by the various small water ways.

POST-COLUMBIA RELATIONS.

The principal Post-Columbia features are the channels which have been cut through the Columbia terraces, recent alluvium, wash on slopes, and marsh. The Post-Columbia channels are in greater part flooded by tide water, which, to the southeastward, extends to slightly above the base of the Columbia formation. These channels have a depth of 150 feet in the deepest portion of Chesapeake Bay, but decrease in amount to the westward. They are excavated *through* the Columbia deposits and are not floored by that formation, as suggested by McGee. Throughout the region, the later Columbia deposit caps cliffs at the waters edge, and to the northward its base is usually considerably above tide water and various subterranes appear below. Many of these cliffs have been cut back more or less by lateral wave action, but there are numerous others which are due entirely to vertical erosion. All the tide water channels are cut deeply into formations underlying the Columbia deposits, and the base of the very lowest Columbia deposits southward is but a short distance below low tide. Several years ago I obtained a sample of the bottom of the Chesapeake bay in twenty feet of water, a mile from the west side of the lower bay, and it was typical Chesapeake clay containing a perfect, very fragile shell of a characteristic *tellina*. At Claiborne, on the east side of the bay, extensive dredgings were made for a long railroad dock, and the lower diatomaceous clays of the Chesapeake formation were found to be practically bare in the bottom. In Patapsco river, the dredgings out of the channel brought up typical Potomac clay at twenty-seven feet, which was overlain by a few feet of river mud. McGee[1] states that the boring on Spesutic island, near the head of the bay, was through 140 feet of sands and silts, which were thought to be neither Columbia nor Potomac. I believe, however, that in the lower portion of this well some Potomac sands may have been penetrated. The well, however, proves the existence of a deep channel here with a great mass of alluvial filling.

Owing to submergence now in progress, alluvial deposits are mainly laid down in tide water. In the Piedmont region, and in some of the smaller valleys, there are transient accumulations of alluvium on freshet planes. Throughout the region, there are

[1] Loc. cit.

overwash deposits, or talus, on slopes and in some small depressions. Marsh growth keeps pace with subsidence in many regions, and there are numerous large marsh areas along the principal tidal estuaries.

There are recent dune sands on the coast and older dunes inland in part of the eastern shore region, but I have given no special attention to their relations.

RESUME OF HISTORY.

The earliest event in the Tertiary history of which there is evidence was the deposition of the Pamunkey formation in Eocene times Its fine, glauconitic, highly fossiliferous sands were evidently deposited in moderately deep waters containing an abundant fauna. The extent of the maximum submergence by Pamunkey seas and the original extent and thickness of the formation are not known. As the formation represents but a small proportion of the total Eocene known in other regions, there either were long intervals in which this region was a land surface (and this was undoubtedly the case during the deposition of older Eocene formations elsewhere) or overlying formations, if deposited, were subsequently removed. Consequently the erosion interval between the Pamunkey and Chesapeake formations may have been inaugurated soon after the end of Pamunkey deposition, or it may have followed much more extensive deposition of later Eocene formations which were removed before Chesapeake deposition. It is ascertained that the entire present Coastal Plain region emerged before Chesapeake deposition and there was general planing or base-levelling, but the extent of uplift, the amount of tilting, and the depth of degradation which followed are not known. Some light may be thrown on these questions when the stratigraphy of the Pamunkey formation is more accurately determined. The emergence was followed by submergence during which the Chesapeake formation was deposited. As these deposits have a known thickness of 800 feet to the southeastward, and over 1,400 feet in New Jersey, and consist of very fine-grained materials, and are in part diatomaceous, their deposition occupied a very long period of deep submergence; but how deep and how wide-spread are not known. The western edge of the Pamunkey formation was widely overlapped, and it is probable that the older Miocene formations were also overlapped far to the eastward. The conditions of erosion and sedimentation differed considerably from those of Pamunkey times, for the fine sands and clays, diatomaceous in part, have had a different history from the glauconitic sands and marls of the Pamunkey formation. The uppermost members of the formation, which are found in the southeastern corner of Virginia, were laid down during the uplift of the Chesapeake formation, for the mingled sands and shell fragments indicate proximity to a shore. They are very young Miocene and contain a large number of Pliocene shells. This emergence was probably part of the general uplift and planing which followed Chesapeake deposition. It was a general base-levelling precisely similar to that of the Post-Pamunkey emergence, and there are similar limitations to our knowledge of the extent of uplift, amount of tilting, and depth of denudation. In both uplifts there was slight tilting from the westward. It was during Pamunkey and Chesapeake times that much of the base-levelling of the Piedmont region was effected, but if these formations were originally spread far westward over the surface of the crystalline rocks, their presence retarded the base-levelling for the time being.

Following Post-Chesapeake erosion there came a moderate amount of submergence and the deposition of the Lafayette formation. Another change had taken place in the conditions of erosion and sedimentation, for coarse sands and gravels were spread about by waves and currents over a wide zone in the vicinity of the shore. Farther eastward there were deeper waters and the sands and finer materials were deposited in them. How far west the waters spread is not known, but the shore deposits along the base of Catoctin Mountain indicate general submergence of the peneplain for at least a portion of the time. The great sheet of typical sediments was apparently not spread far beyond its present limits on the divides, but it widely overlapped the edge of the Chesapeake formation and many outliers of Potomac formation. It was from the lower and marginal beds of the Potomac formation that much of its material was derived.

Lafayette deposition was followed by relatively rapid uplift, during which there were carved the wide steep-sided troughs of the river valleys and a wide shelf along the coast to the east and north. It was at this time that the present topography of the Coastal Plain region was outlined for, in previous emergences, there had been only a general planing. It is thought that the irregular course of the rivers across the Coastal Plain, notably the southerly deflections of portions of the Delaware and Potomac rivers and the head of Chesapeake Bay and the local drainage relations, were due to the original contour of the surface of thc Lafayette deposits. This surface had a peninsular configuration similar to the submarine sand bars now existent along the ocean coast, and, with uplift, the "sloughs" determined the location of the water ways. The deflected courses of the rivers are not related to any orogenic influence so far discovered, as suggested by McGee, nor to the texture of the deposits they traverse. Post-Lafayette emergence was greatest in amount to the northward, and in northern Maryland, Delaware, and New Jersey, the formation was widely eroded, together with the underlying formations. All of this region was planed to a terrace level, and a wide depression was excavated along the western margin of the Coastal Plain region from Baltimore to Washington. Wide valleys and series of terrace plains were cut in the Piedmont region, especially in the areas of softer rocks in the Jura-Trias and limestone valleys adjoining the Susquehanna and Potomac depressions.

In figure 3 there are given a series of sections which illustrate the conditions at a number of periods following the Lafayette uplift.

In the second section in this figure is shown the relative amount of the erosion during the uplift following Lafayette deposition, along a line passing near the latitude of Washington.

To the northward the degradation extends farther and farther westward, and finally covered the entire width of the Coastal Plain. To the southward its amount diminishes gradually.

The next epoch was one of general subsidence by which the terrace plains of the last epoch were submerged to a moderate depth, and the earlier Columbia was deposited. The extent of this submergence is represented in the following figure, and some of its relations are shown in the second section in figure 3.

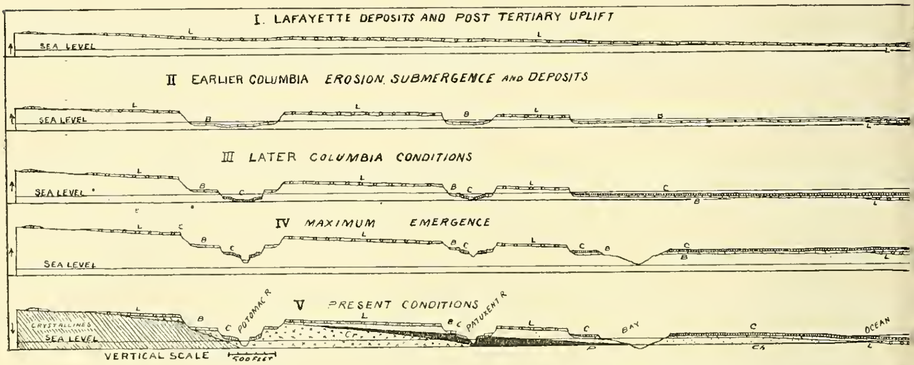

Figure 3. Sections near the latitude of Washington to illustrate the Post-Tertiary history of the Coastal Plain region. L. Lafayette formation. B. Earlier Columbia deposit. C. Later Columbia deposit.

In the earliest stage of earlier Columbia submergence, a heterogeneous mass of coarse material was deposited, but with increased depth of water the fine loams and sands were laid down. The coarsest materials were deposited near shore, and in the course of the estuarine channels of the rivers. Further off shore there were finer deposits, and out of the river currents, there was less deposition, and the deposits consist in larger part of local materials. This period is correlated with the first ice invasion of the glacial epoch.

Following the earlier Columbia deposition the general Post-Tertiary emergence continued to the northwestward, but to the south and east there was either no movement, or slightly increased submergence. The uplift northward was such that the area shown by the heavy rulings in Fig. 4 emerged, finally, to

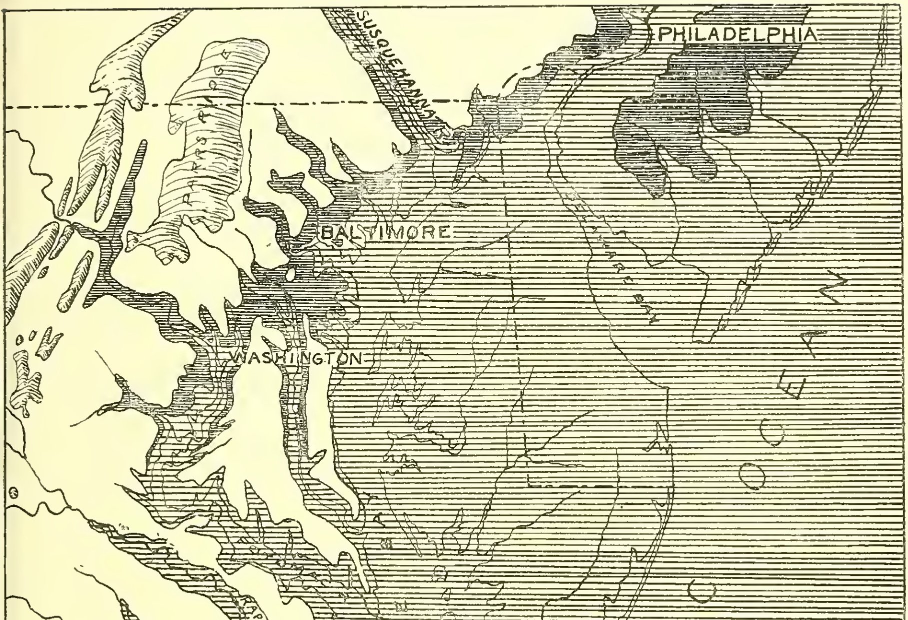

Figure 4. Map of the Middle Atlantic region to illustrate the extent of the Pleistocene submergence.

about 150 feet above the water in the portions westward. The streams in this region were revived and a terraced trough was cut within the earlier Columbia trough. That this uplift was also rapid is indicated by the steep sides of the trough, but the emergence was not so long continued as the Post-Tertiary uplift, for when base-level was reached the trough was widened only about half as far. The general nature of this trough in the Washington region and eastward is shown in the third section in figure 3. Farther northward the earlier Columbia terrace was more widely degraded, owing to the somewhat increased amount of uplift in that direction. During this epoch there was considerable erosion in the Piedmont region, shown mainly in the cutting of steep-sided inner gorges, and a general deepening of the drainage ways. As the cutting reached base level a series of wide terraces were cut in the vicinity of Washington, along the Delaware valley and around southern New Jersey, which were essentially continuous with those of the submerged region to the east and south. During the uplift this submerged region received the products of the degradation, and the coarse, cross-bedded sands, shown at 3 in figure 3, are just what we should expect under the conditions.

The widening of the Inter-Columbia troughs was terminated by general subsidence, during which the later Columbia deposits were lain down under conditions almost precisely similar to those of the earlier Columbia deposition; first, the coarse basal beds, and then the fine loams, with few scattered bowlders and fragments. They were deposited on the lower terrace plains of the depressions in the uplifted region, but to the eastward they were laid down in open waters over the earlier Columbia deposits and the intermediate deposit; 3 in figure 3. The later Columbia waters extended across the Coastal Plain region in the larger valleys and for some distance into the Piedmont region, but their western limits are not definitely known. In figure 4 the area of later Columbia submergence is represented, and some of its relations are shown in section 3, figure 3. The later Columbia terraces extend to the Great Falls in the Potomac, but the later Columbia waters do not appear to have extended beyond the Falls.

In the James river valley the Pleistocene submergence was continuous below Richmond. Either the earlier Columbia or later Columbia waters, or the continuous Pleistocene submergence

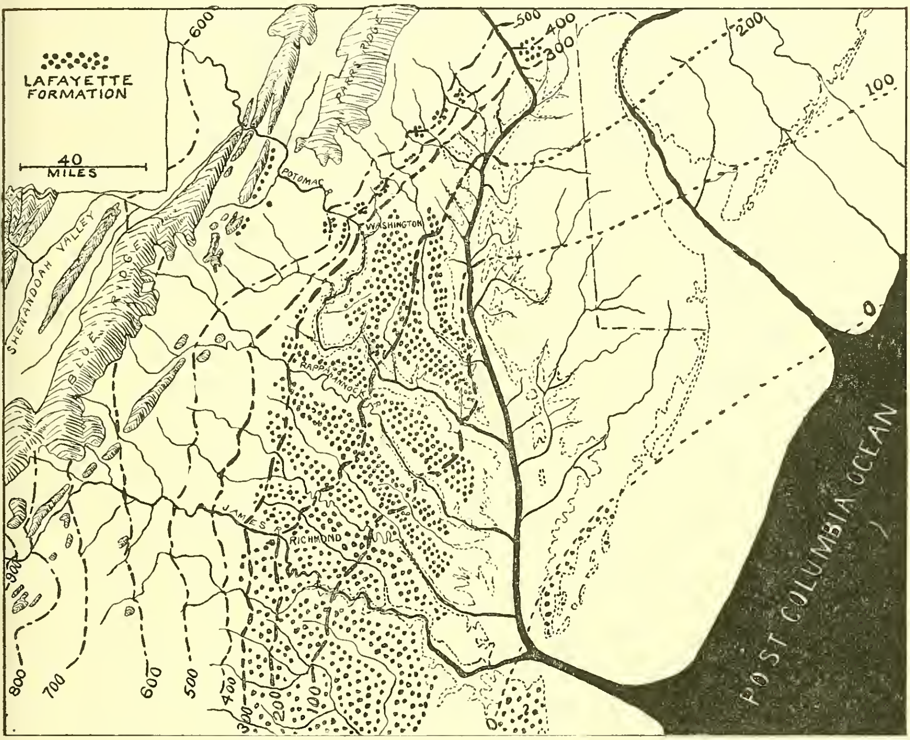

Figure 5. Map of the Middle Atlantic Slope, indicating the conditions in the time of Post-Columbia maximum uplift. There is also shown on the map the nature of the deformation of the Tertiary peneplain in 100 foot contours; and the present extent of Lafayette deposits.

may have extended far westward. Mr. Keith informs me that there is a succession of gravel-capped terraces along the valley in the Lynchburg region, and these may represent Lafayette, earlier Columbia, and later Columbia deposits, laid down in succession during oscillations in a general uplift, as in the

Washington and Baltimore region. The age of the high tilting of the Tertiary peneplain in the James river region in the Piedmont province has not been determined, and a study of these gravel terraces should throw much light on its history.

Following later Columbia deposition the uplift continued, but without much tilting. The entire Coastal Plain region was finally lifted from 100 to 150 feet above tide water, and deep channels cut through the later Columbia terraces. The drainage conditions at this stage are represented in figure 5 and in section 4, figure 3.

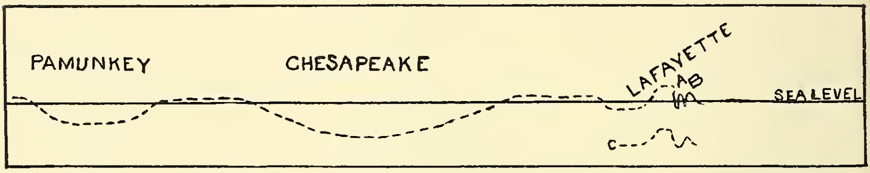

Figure 6. Diagram of Cenozoic oscillations of land and water in the Middle Atlantic Coastal Plain region. A. Earlier Columbia. B. Later Columbia, C. The conditions east and south of the area of inter-Columbia emergence.

This was the maximum degree of uplift, and was of short duration, for the valleys were not greatly widened, and they had a relatively steep inclination seaward. It was followed by subsidence, which is still in progress, and has resulted in the flooding by tide water of the larger Post-Columbia valleys of the Coastal Plain region. The total rate of this subsidence is not known, but on the coast of New Jersey its present rate has been estimated by Professor Cook at two feet per century. In many districts the incursion of tide water is kept pace with and even slightly exceeded by the deposition of silt and other detritus. These accumulations, in themselves, indicate subsidence, for the deposition is mainly due to slackening of currents in the shallower channels, due to tide-water incursion. Marsh growth keeps pace with subsidence in many portions of the region.

In the following diagram an attempt has been made to represent the nature of the oscillations of the Coastal Plain region, but, owing to the meagerness of quantitative data, is not very satisfactory.

Certain general relations in this diagram are founded on definite data. They are the relatively greater length of Chesapeake submergence, the shortness of Lafayette definition, and the relatively short submergence of Pleistocene times. The Post-Lafayette emergence is shown to be greater in vertical amount than the earlier emergences, by the sub-aerial trough-cutting which ensued, but there may have been similar or deeper gorges in earlier times, which were finally effaced by base-levelling. That the Inter-Columbia uplift was of shorter duration than the Post-Lafayette is indicated by the relative narrowness of the inner trough.

N. H. Darton.

U. S. Geological Survey.

THE METAMORPHIC SERIES OF SHASTA COUNTY, CALIFORNIA.

CONTENTS.

INTRODUCTION.

The stratigraphy of the metamorphic rocks of the Klamath mountains is destined to throw much light upon geologic problems in the West, but as yet very few geologists have made explorations in this region. The principal work has been done by John B. Trask, of the Geological Survey of California, under J. D. Whitney, by J. S. Diller and H. W. Fairbanks,[1] and their observations are recorded in the various papers cited below. This

[1] Acknowledgments are due Mr. H. W. Fairbanks, who gave information about nearly all the localities mentioned in this paper, and also supplemented by the loan of his collections of fossils the collections made by the writer.

paper deals chiefly with that part of Shasta county which borders upon the McCloud and the Pitt rivers, where the writer was during the summer of 1893.

STRUCTURE.

Folds. The region is preëminently a folded one, although the folds are obscure except along the water courses, and the anticlines are often overthrown. This, together with the scarcity of fossils in the shales, and the monotonous character of the rocks, renders the structure hard to unravel. These folds are seen chiefly in the siliceous shales of the Pitt formation, the Carboniferous limestone of the McCloud being chiefly an east-dipping monocline, and the Triassic limestone of Squaw creek appearing as a series of short monoclines, usually with an east dip, and with some imperfect folds. The siliceous shales are usually on edge, with a strike of 25° west of north. The folds are nearly all short, and since the streams run with the strike, a peculiar effect is seen—the streams are constantly cutting across the strike in running from one synclinal trough into another. The ends of the anticlines are soon worn down deeply, until one loses the effect of anticlinal "noses," and is inclined to think that the stream has cut directly through the axis by means of a fault.

East of the fork of Squaw creek, near Kelley's ranch in the space of one mile there were seen in the siliceous shales three small anticlines. In these cases the arches of the anticlines were actually seen, but in most cases the folds are so sharply jammed together, the erosion so great, and the rocks so similar throughout the section that it was impossible to see the detailed structure.

Faults. While faults have not had such a great influence on the general topography as folds, still they have influenced to a greater degree the local details. In the siliceous shales of the Pitt formation faults can not be distinguished, but only surmised. In the limestones, however, they can easily be found.

East of the McCloud river the Carboniferous limestone for a short distance forms two east-dipping monoclines, the repetition being caused by a dislocation parallel with the trend of the mountains. The Triassic limestone on Squaw creek also probably owes its preservation to parallel fault lines, for the limestone masses are often on edge, lying unconformably between beds of the older shales. And these limestone masses are never continuous for more than a few miles, there being always an offset between one ridge and the next one to the northward. The limestones were probably faulted down into troughs and thus preserved against erosion.

The trend of the Carboniferous limestone mountains is north and south, while the strike is always west of north, but exceedingly variable.[1]

Between Squaw creek and Pitt river there are at least three parallel north-south fault lines, for the Triassic limestone forms three ridges in which the same dip, order of succession of the various beds, and the same fossils were observed. To the eastward the Trias is cut off from the Jura by either a fault or an unconformity, for in some places much higher Triassic beds were found than at others at no great distance. But no unconformity by erosion was observed.

A glance at Fairbanks' geological map of Shasta county[2] shows that the system of faults must be younger than the folds. The Carboniferous limestone has a north and south trend; it is not however continuous, but disappears and then reappears in the same strike in a few miles. But the strike of the rocks is not parallel to the trend of the mountains, being northwest-southeast, while the general dip is to the northeast.

Since the Carboniferous limestone is in line with a general east dip, and the Triassic nearly parallel with it, also with a general east dip, it seems that the strata of this region were thrown into folds with a northwest-southeast strike, and that afterwards a system of north-south faults or fault troughs broke

[1] California State Mining Bureau, Eleventh Annual Report, 1893, 1894. H. W. FAIRBANKS: Geology and Mineralogy of Shasta County, p. 37.

[2] California State Mining Bureau, Eleventh Annual Report, 1893.

through ; the limestone was sunk down into these troughs and thus preserved against erosion, while the strata have been eroded away from the rest of the country.

These limestones are therefore not lenticular masses, where shales take their place in the strike, for at the ends of the limestone ridges only the underlying shales are seen, and frequently there are detached masses of limestone with strike directly across the main trend.

Stratigraphy.

The Sacramento Formation.[1]

Kennett limestones and shales. Along the Sacramento river, above Redding, is a thick series of dark contorted siliceous shales, with occasional masses of limestone. H. W. Fairbanks[2] describes these strata and mentions the occurrence of numerous corals in the limestones between Squaw and Backbone creeks, about four miles west of Kennett. This was the first discovery of Paleozoic fossils in Shasta county west of the Sacramento river. No fossils were found in the slates, and in the limestones only corals were found.

The writer did not visit this locality, but Mr. Fairbanks generously gave the use of his information and collections. The fossils proved to be:

Favosites canadensis, Billings.
Favosites conf. *hemisphæricus*, Troost.
Cladopora couf. *labiosa* Billings.
Cyathophyllum sp.
Chonophyllum (?)
Aulopora sp.
Alveolites sp.
Diphyphyllum conf. *archiaci* Billings.

This limestone therefore seems to be of Devonian age, and probably from the middle division, but this is by no means certain, since we know so little of the range of Paleozoic fossils in

[1] H. W. Fairbanks, Ms.

[2] California State Mining Bureau, Eleventh Annual Report, 1893. Geology and Mineralogy of Shasta County, pp. 47–49.

COLUMNAR SECTION OF THE METAMORPHIC SERIES OF SHASTA COUNTY.

CRETACEOUS.				Shasta-Chico formation.	
JURA.		Bend Formation.		Mormon sandstone of Big Bend.	Thickness ?
				Shales and shaly limestones of Big Canyon.	
TRIAS.	Upper Trias.	Cedar Formation.	Hosselkus Limestone.	*Spiriferina* beds, 50 ft. siliceous limestone.	Thickness 400 ft.
				Atractites beds, 100 ft. siliceous limestone.	
				Trachyceras beds, 50 ft. soft limestone.	
			Swearinger Slates.	*Halobia* slates, 100 ft. calcareous slates.	
				Monotis shales, 100 ft. argillites and tuffs.	
	Middle Trias.	Pitt Formation.	Pitt Shales.	Siliceous shales and conglomerates, at Silverthorn's ferry, and on Squaw creek, with *Trachyceras whitneyi, et cetera*, about 1,500 ft. below the Hosselkus limestone.	Thickness 2,000 ft.
				Several hundred feet of shales and conglomerates without fossils.	
CARBONIFEROUS.	Upper Carboniferous.		McCloud Shales.	Siliceous and calcareous shales and conglomerates, with Upper Carboniferous fauna at the base. Occurs on the McCloud river, about 20 miles north of the U. S. Fisheries.	Thickness 1,000 ft.
		McCloud Formation.	McCloud Limestone.	Massive limestones and marbles of the McCloud river; rich in corals and brachiopods.	Thickness 2,000 ft.
	Lower Carboniferous.		Baird Shales.	Siliceous black shales of the U. S. Fisheries at Baird; very fossiliferous in places.	Thickness 500 ft.
DEVONIAN.		Sacramento Formation.	Kennett Limestones and Shales	Limestones and shales near Kennett on Sacramento river, with Devonian corals.	Thickness ?

the West, which is often quite different from their range in the Eastern states.

A recent paper by J. S. Diller and Charles Schuchert[1] makes the Middle Devonian age of these rocks more certain, since they found several of these species and others more characteristic on Hazel creek and Soda creek, in Shasta county. They also found near Gazelle, in Siskiyou county, a younger Devonian fauna, with only one species in common with the Shasta localities.

The McCloud Formation.[2]

Occurrence and character. The McCloud formation is espe cially well developed in the region of the McCloud river in Shasta county, and from this it receives its name. The formation consists entirely of Carboniferous strata, the Baird siliceous shales, overlain by the heavily bedded McCloud limestone, with some beds of igneous rock. The thickness is estimated at about 2,500 feet, but this may be far from the true thickness.

The rocks are fossiliferous from bottom to top, and the faunas give divisions as well characterized as those given by the lithological characters. J. S. Diller[3] considers the strata of the McCloud formation as equivalent to those of the Caribou formation, as they certainly are in part. But the McCloud series is much more complete than any Carboniferous known in the Las sen Peak or the Taylorsville region, since the horizons of th Upper and the Lower Carboniferous are well defined faunally and stratigraphically.

These strata were first studied by Trask[4] who recognized them as Carboniferous, and thought the limestones belonged just below the Coal Measures, from the evidence of fossils collected by him near Stillwater. He noted too that the formation extends from Stillwater northward across the Pitt river, on both sides of

[1] "Discovery of Devonian Rocks in California," Am. Jour. Sci., Vol. XLVII., June, 1894, pp. 416–422.

[2] H. W. Fairbanks, Ms.

[3] Geological Atlas, U. S. Geological Survey, Lassen Peak Sheet, 1892.

[4] Report on the Geology of the Coast Mountains, 1855.

the McCloud, for about thirty miles above the junction of the two rivers.

The Baird Shales.

Distribution and fossils. The Baird shales consist of about 500 feet of black metamorphic siliceous shales, in places calcareous, and occasionally sandy. At the top, too, are beds of diabase and other eruptives, which, however, do not seem to make up any considerable thickness of the rocks. The Baird shales extend from near the junction of the Pitt and the McCloud rivers northward for about twenty miles along the McCloud, but they were studied by the writer only in the neighborhood of the U. S. Fisheries at Baird.

The strata have a general dip to the east, but this is very inconstant; their strike is approximately north and south. What underlies them could not be made out. They are certainly younger than the Kennett limestones, but what the interval between the two formations, and whether they are conformable or not, could not be ascertained. They are probably overlain conformably by the McCloud limestone, but the contact could not be observed, and the diabase which separates the two divisions may mark an unconformity.

Fossils were first cited from the Baird shales by Dr. C. A. White;[1] he described from the U. S. Fisheries: *Productus giganteus*, Martin, which is found in America only at this locality, if *P. latissimus*, Sowerby, cited by F. B. Meek[2] from Montana, should not prove to be a synonym, as Davidson is inclined to think it. Dr. White also mentions several other species:

Productus conf. *nebrascensis*, Owen.
Streptorhynchus conf. *crenistria*, Phillips.
Camarophoria sp.
Spirigera sp.
Fenestella sp.
Allorisma sp.
Euomphalus sp.

[1] U. S. Geol. Survey Terr., Twelfth An. Rep., Part I., p. 132.

[2] Bull. U. S. Geol. Survey Terr., Vol. II., No. 4, p. 354.

The first reference of the Baird shales to any definite horizon was made by Captain A. W. Vogdes,[1] who cites from Baird, *Proetus ellipticus*, Meek and Worthen, which, in the Mississippi valley, is characteristic of the Waverly.

Near the U. S. Fisheries at Baird the calcareous and sandy layers are rich in fossils, and in three days of collecting yielded the following fauna:

Proetus ellipticus, Meek and Worthen.
Nautilus sp.
Orthoceras sp.
Bellerophon cyrtolites, Hall.
Bellerophon conf. *galericulatus*, Winchell.
Cyclonema sp.
Dentalium sp.
Euomphalus conf. *luxus*, White.
Loxonema conf. *delphicola*, Hall.
Loxonema sp.
Murchisonia sp.
Pleurotomaria aff. *capillaria*, Conrad.
Aviculopecten conf. *affinis*, Walcott.
" conf. *carboniferus*, Stevens.
" *peroccidens*, Walcott.
" *interlineatus*, Meek and Worthen.
Crenipecten crenistriatus, Meek.
" *winchelli*, Meek.
Pterinopecten vertumnus, Hall.
Streblopteria similis, Walcott.
Actinoptera n. sp. aff. *A. boydi*, Hall.
Aviculopinna ?
Leptodesma conf. *spinigerum*, Conrad.
" conf. *protextum*, Conrad.
Pinna?
Pterinea pintoensis, Walcott.
Macrodon hamiltonæ, Hall.
" conf. *tenuistriatus*, Meek and Worthen.
Nucula insularis, Walcott.
Modiomorpha conf. *desiderata*, Walcott.
Schizodus chemungensis, Hall.
Schizodus curtiformis, Walcott.

[1] Proc. California Acad. Sci., 1893, Oct. 17, 1892, and Zoe, Vol. III., p. 274.

Schizodus deparcus, Walcott.
" *pintoensis*, Walcott.
Pleurophorus meeki, Walcott.
Astartella?
Conocardium alternistriatum, Herrick.
" conf. *pulchellum*, White and Whitfield.
Prothyris meeki, Winchell.
Cardiomorpha sp.
Grammysia arcuata, Conrad.
" *famelica*, Herrick.
Promacrus?
Sanguinolites æolus, Hall.
" conf. *clavulus*, Hall.
Sphenotus rigidus, White and Whitfield.
" conf. *valvulus*, Hall.
Edmondia medon, Walcott.
" sp.
Allorisma conf. *consanguinatum*, Herrick.
Allorisma conf. *costatum*, Meek and Worthen.
Palæanatina conf. *typa*, Hall.
Lingula mytiloides, Sowerby.
Discina sp.
Chonetes loganensis, Hall and Whitfield.
Productus flemingi, var. *burlingtonensis*, Ha
" *giganteus*, Martin.
" *nebrascensis*, Owen.
" *punctatus*, Martin.
" *semireticulatus*, Martin.
" *subaculeatus*, Murchison.
" sp.
Orthis michelini, Leveille.
Streptorhynchus crenistria, Phillips.
Athyris hirsuta, Hall.
" *lamellosa*, Leveille.
" *subtilita*, Hall.
Retzia radialis, Phillips.
Spirifer centronatus, Winchell.
" *lineatus*, Martin.
" *striatus*, Martin.
Spiriferina cristata, Schlotheim.
Camarophoria coöperensis, Shumard
Rhynchonella thera, Walcott.

Terebratula hastata, Sowerby.
Fenestella sp.
Rhombopora sp.
Crinoid stems.
Clisiophyllum gabbi, Meek.
Lithostrotion californiense, Meek.
" *sublæve*, Meek.

About nine miles north of Baird in siliceous shales on the McCloud river was found in addition to many of the above species:

Pterinopecten n. sp. aff. *P. dignatus*, Hall, of the Devonian of New York.

Affinities of the fauna. The list of fossils contains a total of 84 species, of which 19 were not specifically identified. Out of the 65 forms specifically determined 26 occur in the Waverly of the Mississippi valley, although 8 of these also occur in the Upper Carboniferous of that region. Fifteen are known to occur in the Devonian of the eastern states, but of these 6 also occur in the Waverly; thus there are only 9 forms that in the Mississippi valley, or east of it, would be considered as decidedly Devonian. Thirty-six are known from the Waverly and Lower Carboniferous of Utah, Nevada, and New Mexico; of these 29 correspond to forms described by Walcott from the Lower Carboniferous of the Eureka district, Nevada. Three species, *Aviculopecten carboniferus*, *Aviculopecten interlineatus*, and *Macrodon tenuistriatus*, have been considered characteristic of Upper Carboniferous.

With this assemblage of species one would not hesitate to place these strata low down in the Carboniferous, but whether they are equivalent to the Waverly is a question not so easily settled. Although about one-half of the species are found in the Waverly, and nearly one-fourth in the Devonian of the Mississippi valley, 29 of these, and a large number of others as yet unknown in California, were found by C. D. Walcott[1] in the Eureka district, Nevada, in strata of Lower Carboniferous age,

[1] Monograph VIII., U. S. Geol. Survey. Paleontology of the Eureka District.

but lying 3,000 feet above the Upper Devonian White Pine shale.

We do not know the age of the rocks immediately underlying the Baird shales, but the siliceous shales of the Sacramento river lie some distance below them, and are probably in part of Carboniferous age. It thus becomes probable that in California, as in Nevada, the Waverly fauna, with a few Devonian forms, lived on after the corresponding faunas had become extinct in the eastern region. A migration of these survivors into the Lower Carboniferous sea of the Mississippi valley may explain the supposed colony mentioned by C. R. Keyes[1] from the Burlington of Missouri, and observed in Arkansas by the Geological Survey of Arkansas.[2] In both places, in the midst of undoubted Lower Carboniferous faunas, there appears a group of fossils that, if found alone, would be classed as of Waverly age. They are not colonies in the sense in which Barrande used that word, but are simply migrations from one faunal region into another, due to shifting of physical barriers; these migrations have taken place during all time, and have complicated correlations, until we lose faith not only in the idea of synchronism as proved by fossils, but also in homotaxis, unless we can find the direction of the migration.

In the paleontological sense the Baird shales are homotaxial with the Waverly, while stratigraphically they probably are not, but would agree more nearly in position with the higher divisions of the Lower Carboniferous of the Mississippi valley.

The occurrence of *Productus giganteus*, Martin, in these strata is very interesting. This is a common Lower Carboniferous fossil in Europe, but in America is not found east of this place, unless *P. latissimus*, Sowerby, which F. B. Meek[3] has cited from Montana, on the western slope of the Rocky Mountains, is an equivalent of it. This fact has been used by the writer[4] as evi-

[1] Am. Jour. Science, December, 1892, p. 447.

[2] Journal of Geology, Vol. II., p. 198.

[3] Bull. U. S. Geol. Survey Terr., Vol. II., No. 4, p. 354.

[4] Journal of Geology, Vol. II., p. 200.

dence that the European Carboniferous species found in America migrated through the ocean that connected on the west the American with the European Carboniferous waters.

The McCloud Limestone.

Occurrence and character. Immediately above the Baird shales, and probably conformably with them, lies the McCloud limestone. This series is about 2,000 feet in thickness, uniform in bedding, and very siliceous in places. Some few beds are altered to a crystalline marble, but in the main the series is made up of a fine-grained hard grey limestone, which at the base contains few fossils besides corals, *Clisiophyllum gabbi*, Meek, and *Lithostrotion californiense*, Meek. But towards the top the beds become more fossiliferous and contain a varied assemblage of species, which however do not rival in number those of the Baird shales.

Trask[1] first visited this limestone at Bass' ranch near Stillwater, and recognized that it belonged to the Carboniferous formation and probably the upper division. The Geological Survey of California[2] afterwards visited the same locality and collected a number of fossils, that were described by F. B. Meek in Volume I. of the Paleontology of California. These were thought by Meek to indicate a horizon below the Coal Measures, although he leaves the question open, from the fact that many species that in the Mississippi valley or in Europe would be thought to indicate Subcarboniferous, in the West are found in the Upper Carboniferous.

The McCloud limestone is first seen at Bass' ranch near Stillwater, south of Pitt river. Where the Pitt river cuts through the limestone disappears, being probably faulted out of sight, or as Fairbanks[3] puts it, is "pinched out." But north of the Pitt, and east of the McCloud, the limestone starts up again, forming prominent mountains that rise 2,400 feet above the river. These

[1] Report on the Geology of the Coast Mountains, 1855.

[2] Geology of California, Vol. I., pp. 326–7.

[3] Geology and Mineralogy of Shasta County, p. 35.

limestone ridges are cut through by the McCloud river about nine miles above the U. S. Fisheries, but continue along the west bank of the river about ten miles further to the north. After that they reappear at intervals in the same strike as far as the county line, getting nearer to the Sacramento river. The geological map of Shasta county, published by H. W. Fairbanks,[1] shows the distribution and relations of the McCloud limestone. J. D. Whitney[2] estimates the thickness of the McCloud limestone at about 1,000 feet, and says that it lies conformably between metamorphic slates. H. W. Fairbanks[3] says that the thickness is nearer 2,000 feet, which agrees with the observations of the writer.

Fauna of the McCloud Limestone. From the locality at Bass' ranch F. B. Meek, in Volume I. of the Paleontology of California, cites the following species:

Fusulina cylindrica, Fischer.
" " var. *gracilis*, Meek.
" (*Schwagerina*) *robusta*, Meek.
Lithostrotion californiense, Meek.
" *sublaeve*, Meek.
" sp.
Clisiophyllum gabbi, Meek.
Orthis conf. *carbonaria*, Swallow.
Productus semireticulatus, Martin.
Rhynchonella sp.
Spiriferina conf. *cristata*, Schlotheim.
Spirifer lineatus, Martin.
Retzia compressa, Meek.
Euomphalus whitneyi, Meek.

Several days of collecting in the region of Baird failed to increase this list. Taken by itself the fauna would not be characteristic of Upper Carboniferous, and indeed it is arbitrary to draw the line at the base of the limestone. Even *Fusulina cylindrica*, which in the region east of the Rocky Mountains

[1] California State Mining Bureau, Eleventh Annual Report, 1893.

[2] Geol. California, Vol. I., p. 326.

[3] California State Mining Bureau, Eleventh Annual Report, 1893. Geology and Mineralogy of Shasta County, p. 36.

seems to be characteristic of Upper Carboniferous, in Nevada is found also in Lower Carboniferous. But the most decisive proof of the Upper Carboniferous age of these strata is their position so far above the Baird shales, which have been shown in this paper to be equivalent to the Lower Carboniferous of the Eureka district, Nevada, which is known to occur 3,000 feet above the base of the formation.

The McCloud limestone is probably equivalent to the limestone of the Caribou[1] formation of Plumas county. But J. S. Diller[2] thinks that they belong to a lower horizon than that assigned them by the writer. The Robinson[3] beds of the Taylorville section are probably higher up in the section, but nevertheless the McCloud limestone is, in part at least, equivalent to the Coal Measures.

The Pitt Formation.[4]

General character of the rocks. The Pitt formation overlies conformably the McCloud limestone, and consists roughly estimated of about 3,000 feet of siliceous and calcareous shales, conglomerates and tuffs. The rocks in most places are highly metamorphosed, very poor in fossils, and folded to such a degree that the stratigraphy is obscure. The general strike is north and south, and the dip generally toward the east, since most of the folds are overthrown.

The formation is largely developed in the region near the junction of the Pitt and the McCloud rivers. It contains both Carboniferous and Triassic rocks, in an apparently conformable series, both with a decisive fauna, the presence of Upper Carboniferous and Middle Trias being proved by fossils.

The Carboniferous argillites. The oldest fossiliferous strata of the Pitt formation are of Upper Carboniferous age, and are found on the east bank of the McCloud river, about nine miles

[1] U. S. Geol. Survey, Geological Atlas, Lassen Peak Sheet, 1892, J. S. Diller.

[2] Bull. Geol. Soc. Am., Vol. III., p. 375.

[3] Bull. Geol. Soc. Am., Vol. V., p. 247.

[4] H. W. Fairbanks, Ms.

above Campbell's ranch, and twenty miles above the U. S. Fisheries. The rock is a dark calcareous argillite, with strike a little west of north, and dip 30° E. This place is three miles east of the McCloud limestone, and considerably above it in the section.[1] The writer did not visit this locality, but Mr. H. W. Fairbanks, of the State Mining Bureau, obtained the information given, and also collected the following fossils :

Aviculopecten sp.
" aff. *crenistriatus*, Meek.
Streblopteria sp.
Conocardium sp.
Chonetes sp.
Productus multistriatus, Meek.
" *muricatus*, Phillips.
" *nebrascensis*, Owen.
" *semireticulatus*, Martin.
" *subhorridus*, Meek.
Orthis michelini, Leveillé.
Athyris subtilita, Hall.
Retzia radialis, Phillips.
Spirifer lineatus, Martin.
Spiriferina cristata, Schlotheim.
Rhynchonella sp.

These beds are the probable equivalents of the Robinson beds of the Taylorsville region, and of the Little Grizzly creek beds, Plumas county,[2] which seem to form the top of the Carboniferous formation. The boundary of these Carboniferous argillites could not be found, but they probably make up the lower thousand feet of the Pitt formation.

The Triassic shales and conglomerates. Triassic fossils that belong to the Muschelkalk, or Middle Trias, were found in the siliceous shales at Silverthorn's ferry on Pitt river, several hundred feet above the Carboniferous strata. The fossils found there were:

Trachyceras whitneyi, Gabb.
Popanoceras ?

[1] H. W. FAIRBANKS, Geology and Mineralogy of Shasta County, p. 38.

[2] H. W. TURNER, American Geologist, Vol. XIII., 1894, p. 231.

and one or two other ammonites that could not be determined generically.

About three and a half miles from the ferry, on the road towards Redding, in calcareous layers in the shales were found:

Nucula ?
Rhynchonella sp.
Trachyceras whitneyi, Gabb.

About two miles south of the last named locality were found in very metamorphic siliceous shales, near the contact with a porphyritic eruptive rock, *Pseudomonotis ?* and other indeterminable fossils.

On Squaw creek, twelve miles above Copper City, at Terrupchetta (cottonwood flat), were found in a black metamorphic shale, apparently in the same horizon at the beds at Silverthorn's ferry, *Nucula* sp., *Spiriferina* sp., and crinoid stems. This horizon is about 1,500 feet below the Upper Triassic limestone, which lies just to the east of Squaw creek. Near Madison's ranch on Squaw creek Mr. H. W. Fairbanks found in the same horizon *Myacites* conf. *humboldtensis* Gabb.

Age of the Triassic slates. The age of these slates is not fully settled by the occurrence of *Trachyceras whitneyi*, for Dr. E. von Mojsisovics[1] says that this horizon belongs to the Muschelkalk, an opinion concurred in by Professor Hyatt.[2] But in his later work, "Arktische Triasfaunen,"[3] Mojsisovics considers this horizon to belong to the Noric, although in this he has plainly confused the Trias of Taylorville, Plumas county, with that of the Star peak region in Nevada. It seems probable to the writer that both Muschelkalk and Noric strata are found in the Star peak region, for both *Trachyceras whitneyi*, Gabb, and *T. homfrayi*, Gabb, are found there, and in the Squaw creek region of Shasta county, California. But in Shasta county *Trachyceras homfrayi* is found just at the base of the *Halobia* slates, in rocks of undoubted Upper Triassic age, while *Trachyceras whitneyi* is

[1] "Cephalopoden der Mediterranen Triasprovinz," p. 141.

[2] Bull. Geol. Soc. Am., Vol. III., p. 400.

[3] Mem. Acad. Imper. Sc. St. Petersburg, VII. Ser., Vol. XXXIII., No. 6, p. 129.

found about 1,500 feet lower down, and not accompanied by any of the species that were found above.

The Triassic shales cover all the region near Silverthorn's ferry on Pitt river, and most of the country north of Copper City, on both sides of Squaw creek, and extend at least twenty miles to the north, but the country is nearly inaccessible, and almost no geological explorations have been made in it.

The Cedar Formation.

Distribution and character.—The Cedar formation was first named by J. S. Diller[1] to include the Upper Triassic slates and limestones of Indian valley, Plumas county, and Cedar creek, Shasta county. It therefore includes the original Trias described by Gabb[2] from "Gifford's ranch."

In the Pitt river region the formation is very similar to that in Plumas county, being composed of finely laminated shales overlain by massive limestone, each rich in fossils. It seems to overlie conformably the siliceous shales of the Pitt formation, but the contact could not be observed. The Pitt shales usually have a different dip and strike from the overlying limestones, but the region is faulted and folded, and massive limestones do not adapt themselves to contortions so readily as thin-bedded shales. Certain recognizable horizons were always found at the same distance below the limestone, and thus the conformity becomes probable.

The formation is first seen at Cedar creek, south of Pitt river, from which locality the formation was named. It has also been cited by J. S. Diller[3] from near Texas Springs, southwest of Redding. But the formation is best studied from Brock's ranch on Pitt river, northward across Squaw creek, and nearly to the McCloud river, a distance of over twenty-five miles. It is composed of the Swearinger slates, overlain conformably by the

[1] Geological Atlas U. S. Geol. Survey, Lasson Peak Sheet, 1892, Descriptive text.

[2] Paleontology of California, Vol. I.

[3] Bull Geol. Soc. Am. Vol. IV., p. 221.

Hosselkus limestone. The local names given by J. S. Diller[1] to strata in Plumas county are used here because in Shasta county the lithology and fauna are similar.

The Swearinger slates.—The Swearinger slates consist of about 200 feet of thin-bedded shales, at the top becoming very calcareous, and at the base containing beds of tuff. There are two main divisions, the *Trachyceras homfrayi* beds and the *Halobia* slates. The *Trachyceras homfrayi* beds contain great numbers of *Trachyceras homfrayi*, Gabb, *Lima* conf. *acuta*, Hyatt, and a few specimens of *Monotis subcircularis*, Gabb, *Pecten* sp., *Halobia rugosa*, Guembel, *Halobia superba*, Mojsisovics, *et cetera*. In some tuffs in this series were found: *Spiriferina* sp., and crinoid stems. The fauna is similar to that of the *Monotis* beds of Genessee valley, Plumas county, as described by Hyatt,[2] and is unquestionably of Noric age.[3] The genus *Monotis* is very rare in the Pitt region, although very common in the region of Taylorsville, but enough species were found to identify the horizon. The *Trachyceras homfrayi* beds with some tuffs make up the lower hundred feet of the Swearinger slates. The upper hundred feet of this division is made up of the *Halobia* slates. These strata are very calcareous, and usually rich in fossils, although these are mostly not well preserved. From their nature these beds are seen only as a fringe along the base of cliffs of the Hosselkus limestone, and are usually covered with talus, so that outcrops are rare. They are filled with casts of *Halobia superba*, Mojsisovics, with also a few specimens of *Rhynchonella* sp., *Polycyclus Trachyceras* conf. *ladinum*, Mojsisovics, *Eutomoceras*, *et cetera*. According to Mojsisovics,[4] *Halobia superba* is characteristic of the lower Karnic, and *H. rugosa* of the upper Karnic, but Dr. Rothpletz[5]

[1] Bull. Geol. Soc. Am. Vol. III., p. 372.

[2] Bull. Geol. Soc. Am. Vol. III., p. 397.

[3] The term Noric is used in this paper as it was used by Mojsisovics, and not Bittner.

[4] Abhandl. K. K. Geol. Reichsanstalt, Wien, Bd. VII., No. 2, p. 37.

[5] Palæontographica, 39 Band, 1892, p. 91, "Perm, Trias and Jura formation auf Timor."

says that the *Halobiae* are not confined to such distinct horizons as Mojsisovics thought. The stratigraphic position of these beds is the upper Noric, where Hyatt[1] placed them, while recognizing their transition character from the number of species common to them and to the Hosselkus limestone.

A somewhat similar fauna was found by the writer at the Rush creek mine, Rich Gulch, Plumas county, and in a similar stratigraphic position.

The Hosselkus limestone—The Hosselkus limestone has the same distribution as the Swearinger slates, being found always above them. There is a thickness of about 200 feet of these strata, of a rather uniform character. The rocks are usually siliceous, especially toward the top. Fossils are plentiful all through the strata, but are easy to get out only at the base; higher up the rocks are so silicified that it is almost impossible to get fossils out.

The Hosselkus limestone may be conveniently divided into three divisions, the lowest of which is the *Trachyceras* beds, so called from the large number of that genus found at this horizon. These beds are about 50 feet thick, and are composed of rather hard pure limestone, made up almost entirely of fossils; a large majority of all the Triassic species were taken from this horizon. The best collecting ground was found on the ridge between Squaw creek and Pitt river, about three miles northeast of Madison's ranch. The following fossils were collected at this locality:

Arpadites aff. *A. cinensis*, Mojsisovics.
Balatonites sp. group of B., Arietiformes.
" " B., Gemmati.
Polycyclus conf. *henseli*, Oppel.
Tirolites conf. *foliaceus*, Dittmar.
Trachyceras conf. *aon*, Muenster.
" aff. *aonides*, Mojsisovics.
" conf. *archelaus*, Laube.
" aff. *armatum?* Muenster.
" conf. *ladinum*, Mojsisovics?
" conf. *hylactor*, Dittmar.

[1] Bull. Geol. Soc. Am., Vol. III. p. 390.

Trachyceras sp. (like *Tirolites* in youth).
" sp. (with fine costæ in youth, coarse in age).
Tropites subbullatus, Hauer.
" sp. (with narrower coil than *T. subbulatus*).
" sp. (with smooth narrow coil).
" sp. (with rough narrow coil).
" *saturnus*, Dittmar.
" conf. *janus*, Dittmar.
Sagenites conf. *erinaceus*, Dittmar.
Halorites conf. *ramsaueri*, Gabb (not Hauer).
Eutomoceras conf. *sandlingense*, Hauer.
Eutomoceras, sp.
Acrochordiceras sp.
Ptychites ?
Nannites conf. *spurius*, Muenster.
Lecanites sp. ?
Arcestes conf. *californicus*, Hyatt.
Sageceras or *Beneckeia ?*
Nautilus triadicus, Mojsisovics.
" sp.
Orthoceras sp. ?
Atractites sp.
Aulacoceras sp.
Pecten sp.
Gervillia sp.
Halobia superba, Mojsisovics.
Posidonomya conf. *wengensis*, Wissmann
Modiola sp.
Capulus sp.
Natica sp.
Rynchonella conf. *solitaria*, Hyatt.
Terebratula sp.

About six miles north of the last named locality, at Terrupchetta on Squaw creek, the *Trachyceras* bed is well exposed, and many fossils were collected from this horizon, including most of the forms found at Madison's, and in addition a *Nautilus* with two sharp angles on the external sides like *Nautilus galeatus*, Mojsisovics, of the zone of *Trachyceras aonoides*, of the Karnic.

The Atractites beds.—These beds form the middle division of the Hosselkus limestone ; they are very hard and siliceous, and while fossils are very numerous it is almost impossible to get out good specimens. The thickness of these beds is about 100 feet, but this is often seemingly increased by faulting. The rock is cut through in several directions by joints, and the weathering of the strata along these lines of weakness has given a rugged outline to the ridges, of which the *Atractites* beds usually form the top.

At the locality three miles northeast of Madison's ranch the following fossils were collected from this horizon:

Polycyclus conf. *henseli*, Oppel.
Trachyceras (like *Tirolites* in youth).
" conf. *aon*, Muenster.
Tropites subbullatus, Hauer.
" sp. (with narower coil).
" sp. (with high ribbed whorl).
" *saturnus*, Dittmar.
Halorites conf. *ramsaueri*, Gabb.
Eutomoceras sandlengense, Hauer.
Eutomoceras, sp.
Acrochordiceras sp.
Lecanites sp.
Arcestes sp.
Nautilus triadicus, Mojsisovics.
Orthoceras ?
Atractites (very common).
Aulacoceras sp. (rare).
Gervillia sp.
Modiola sp.
Margarita sp.
Natica sp.
Rhynchonella conf. *solitaria*, Hyatt.
Nothosaurus sp. ?

The bones referred to *Nothosaurus* consist of a portion of the backbone about thirteen inches in length, together with several ribs, and fragments of other bones. Most of the species were found in much greater numbers and better preservation in the underlying *Trachyceras* beds, so that there is no great faunal distinction between the two horizons.

The Spiriferina beds.—These beds are made up of about 50 feet of limestone like that of the *Atractites* beds, but harder and more siliceous. They contain numerous fossils, especially brachiopods, which, however, cannot be got out without dissolving the matrix. The most common fossil is a *Spiriferina*, or more probably, two species of this genus. Besides these are found:

Rhynchonella conf. *solitaria*, Hyatt.
Terebratula sp.
Trachyceras sp.
Modiola sp.
Gervillia sp.
Pentacrinus sp.
Cidaris sp.

Relations of the fauna of the Hosselkus limestone.—The fauna of the lower part of the Hosselkus limestone is undoubtedly that of the zone of *Tropites subbullatus* and *Trachyceras aon* of the Tyrolean Alps, that is of the lower Karnic. Several species are identical in the two regions, and many others very closely related. More than this, the stage of development of the ammonites is identical, which is quite as good a proof of similarity in horizon as identity of species.

The fauna of the underlying *Halobia* slates has long been recognized as of Noric age, and Mojsisovics[1] is inclined to make the *Pseudomonotis* beds of the same age on both sides of the Pacific ocean.

The upper part of the Hosselkus limestone may correspond to the Raibler beds of the Tyrol, as described by Dr. S. von Wöhrmann[2]; no species common to the two were found, but the poverty in cephalopods, and greater number of brachiopods and lamellibranchs are characteristic of these horizons.

GEOGRAPHIC PROVINCES IN TRIASSIC TIME.

Of late years there has arisen much doubt as to the validity of the Juva and the Mediterranean Triassic provinces of Mojsisovics; but until recently the Arctic-Pacific Triassic province has gone unquestioned.

[1] "Arktische Triasfaunen," p. 149.

[2] Jahrbuch K. K. Geol. Reichsanstalt, Wien, 39 Band, 1889, pp. 181-258.

The Arctic-Pacific province was described by Mojsisovics[1] as including the Trias of Siberia, Spitzbergen, Japan, western North America, Peru, New Zealand, and New Caledonia. This province was characterized by the fact that in it in Lower and Middle Trias there were known no *Tirolitinæ*, but many *Dinaritinæ*, and by having during the two lower divisions a more or less close faunal connection with the Mediterranean province. In the Upper Trias, however, the Mediterranean elements have disappeared, and a strong influx of Juva types has taken place. The region was further thought to be characterized by the presence of *Popanoceras* even as high as Middle Trias, and by the prevalence of *Pseudomonotis* to the exclusion of *Monotis*.

But very recently A. Rothpletz[2] has shown that on Timor, right in the midst of the Arctic-Pacific region, in the Indian ocean, there occurs a Triassic fauna of genuine Alpine habitus, with several Tyrolean species. Of these, *Halobia lommeli* and *Monotis salinaria* also occur in North America. The Tyrolean species therefore had a path of migration directly through the supposed Arctic-Pacific Trias region.

While the Upper Trias of California shows an unmistakable preponderance of Juva elements, such as *Tropites subbullatus*, other members of the *Tropitidæ*, *Halobia superba* and others, still there is also a considerable admixture of Mediterranean types, identical with, or nearly related to species of southern Tyrol. If, then, there really existed in Triassic times a division into the Juva and the Mediterranean regions, we have an extension of their waters uniting in America, and thus a commingling of the two faunas. But recently Mojsisovics[3] himself has given up his two provinces, and acknowledged that the differences were due to corresponding beds being unfossiliferous in the two regions.

[1] Mem. Acad. Impér. Sc., St. Petersbourg, VII. Series, Tome 36, No. 5. "Arktische Triasfaunen," pp. 143–155.

[2] Palaeontographica 39 Band, 1892, "Perm Trias and Juraformation auf Timor und Rotti," pp. 90–91.

[3] Sitzungsb. K. Akad. Wissenschaften Wien., CI. Band; VIII. Heft 1892, pp. 769–780.

Professor W. Waagen[1] has also shown that the Alpine and the Himalayan Trias are similar, but that the Salt Range Trias belongs to the Arctic province. We have, then, in California a prolongation of the Alpine Trias province through the Himalaya region. The fossils of the Trias in British Columbia, described by J. F. Whiteaves,[2] look quite different from those known in California, but it is as yet impossible to say whether this difference is due to geographical separation, to climatic differences, or to difference in geological horizon.

THE BEND FORMATION.

The Bend formation was named by J. S. Diller[3] to include all the Jurassic deposits of the region of the Big Bend of Pitt river. In a later publication Mr. Diller[4] says that the Pitt river Jura corresponds to the Mormon sandstone, Middle Jura, of the Taylorsville region. About six miles west of Big Bend, in Big canyon, H. W. Fairbanks[5] discovered fossils in shaly limestones which, on examination by the writer, proved to be Jurassic and probably equivalent to the Hardgrave sandstone, Lower Jura, of Indian valley. The writer afterwards visited this locality and found the fossiliferous beds in place, in the bottom of the canyon. The joint collections yielded:

Montlivaultia sp.	*Pecten* sp.
Pholadomya nevadana, Gabb.	*Gryphaea* sp.
Entolium meeki, Hyatt.	*Lima* sp.

About nine miles west of Big canyon, on the east branch of Squaw creek, near the house of John Miles, the writer found in 1893 a shaly limestone with a few fossils that seem to belong to the Jura. Among these were some small gasteropods, a *Pecten*

[1] Jahrbuch K. K. Geol. Reichsanstalt Wien., 42 Band, 1892, pp. 384–385.

[2] Geol. Survey Canada, Contributions to Canadian Palaeontology, Vol. I. Part II. pp. 127–149.

[3] U. S. Geol. Survey, Geol. Atlas, Lassen Peak Sheet, 1892, J. S. Diller.

[4] Bull. Geol. Soc. Am. Vol. IV. 1893, p. 221.

[5] Eleventh Rep. California Min. Bu. 1893, Geology and Mineralogy of Shasta County, p. 29.

of unmistakable Jurassic habitus, and *Pentacrinus*, which was quite common.

These beds lie at no great distance above the Triassic lime stone of Squaw creek, and thus belong to the Jura, and probably the Lias.

THE JURA-CRETACEOUS UNCONFORMITY.

As has been shown by J. S. Diller in his various publications on northern California, the Cretaceous lies always unconformably upon the eroded edges of the metamorphic rocks of the Klamath mountains, sometimes upon older and sometimes upon younger strata, but always with a sharp line of erosion between the two series. The metamorphism of the older rocks took place in late Jurassic time and has not affected the Cretaceous.

It therefore becomes probable that the Klamath mountains, the Coast Range, and the Sierra Nevada are in reality parts of one great mountain system in which the main uplift and metamorphism of the strata took place before Cretaceous time. The Klamath mountains have been partly submerged during the Cretaceous and Eocene the Coast Range partly submerged during both Cretaceous and entire Tertiary times, while the Sierra Nevada has kept above the sea ever since its original uplift, and has only on its western flank slightly tilted deposits of Cretaceous and Eocene age.

JAMES PERRIN SMITH.

STUDIES FOR STUDENTS.

SUPERGLACIAL DRIFT.

I. ALPINE GLACIERS.

Lateral moraines.—On the surface of alpine glaciers, there is sometimes an abundance of stony material which takes the form of lateral moraines. The material composing these moraines is derived principally from the slopes above the ice. In its acquisition, the ice is for the most part passive. Alpine glaciers occupy the bottoms of valleys. So far as general topography is concerned, the valley in which a glacier lies may be said to have an ice bottom. From the slopes of the ice-bottomed valley, rock masses, large and small, descend. They may be loosened by the expansion and contraction due to rapid changes of temperature, by the wedge-work of ice forming in the crevices of the rock, or by the growth of roots in the same position. Once loosened, the blocks of rock begin their journey of descent. This may be accomplished rapidly or slowly, depending upon the steepness of the slopes, and other local conditions. Descending the slopes, the loose masses of rock may reach the bottom of the valley, that is, the surface of the glacier. Avalanches which sometimes descend the steep slopes of valleys, are likely to carry down considerable quantities of stony or earthy material. Where avalanches reach the surface of glaciers, the stony material they bear is deposited on the glacier near its lateral margin. A similar result may be effected by landslides. Locally the amount of material carried down by avalanches and landslides may be considerable but on the whole it is not great. The occasional torrents which come into existence during rain storms, or during the season when the snow of the higher mountains is being rapidly melted, descending from the slopes above to the ice below, carry larger or smaller quantities of rock material.

By any or all of these processes, stony or earthy material may descend into a valley which has no lgacier. It may there accumulate at the base of the slope, or it may be carried away by waters coursing through the valley. It may descend into a glacier valley below the end of the ice, when its fate is the same. If it descend into a valley above, but near the end of a glacier, it may fail to reach the surface of the ice, since near the lower end of a glacier, where melting is rapid, the ice often fails to fit snugly against the bounding slopes of rock. Under these circumstances, material descending from the slopes above is liable to fall between the glacier and the valley wall. It is only where the glacier fits snugly against the sides of its valley, that material descending from the slopes can reach its surface so as to contribute to a lateral moraine. In general, an alpine glacier fits snugly against its valley walls in its upper stretches only, and it is here, therefore, that lateral moraine material is most likely to be acquired in quantity, by the processes indicated.

It will be readily seen that steep slopes above the surface of a glacier favor the accumulation of moraine *débris* upon it. While expansion and contraction due to changes of temperature, and while freezing of water in rock crevices, need not be more effective on steep slopes than on gentle ones at the outset, material once loosened will be much more likely to travel down steep slopes than down gentle ones. Steep slopes, therefore, will be more likely to lose such incoherent material as develops upon them, and so be kept bare, while the gentler slopes will be more likely to retain the disrupted and disintegrated material to which they have given rise. On the gentler slopes, therefore, the rock surface will ultimately come to be protected against changes of temperature and other disrupting surface influences, by its mantle of unremoved débris. Thus it comes about that in the long course of time steep slopes above glaciers will contribute much more débris, than gentle ones for the making of lateral moraines.

Beyond a certain point, steepness of slope would not in all ways favor the development of lateral moraines. Beyond a certain point, steepness of slope does not favor avalanches, since snow and ice cannot accumulate in sufficient quantity to produce avalanches on slopes of too high gradient. The degree of slope would affect landslides in a similar way. If a slope be too steep there can be no slide of loose rock and earthy material, since such materials cannot accumulate in sufficient quantity to give rise to a slide. Since landslides and avalanches are at best no more than subordinate sources of lateral moraine material, lateral moraines are most likely to be well developed on those glaciers which are bounded by high mountains with steep slopes. All the drift which gains a superglacial position by any of the processes thus far mentioned, is superglacial from the beginning of its association with the ice.

It is possible that lateral moraine material may reach its position by another process. Where the bed of the ice is rough, it may chance that the lateral portion of the glacier passes over roughnesses of bed of considerable extent. If the lateral margin of the ice passes over elevations which project up into it nearly to its surface, those parts of the ice which pass around any given elevation will presently come together below the same, carrying with them some material from its slopes. Likewise the ice which passes over the summit of the rock prominence may have worn or torn away more or less rock material from its surface. Such material is at first subglacial, with reference to the ice which removes it, but it quickly becomes englacial as the ice moves on. Some of it may be near the upper surface of the ice, after the ice has united below the obstruction. Further down the valley, as a result of melting, the ice surface may be brought down to the level of this englacial material. When this happens, the englacial material becomes superglacial. This superglacial material which has passed through an englacial history may be an additional source of lateral moraine material. Not all superglacial material derived in this manner could enter into a lateral moraine. Only those portions which reach the surface of a glacier near its margins would be so available. It is possible that, above the differentiated alpine glacier, the ice of the snow-field may have passed over roughnesses of bed in such relations that englacial material there acquired may subsequently reach the surface of the ice in such a position as to be added to the lateral moraine material accumulated from above. This however is probably not an abundant source of lateral moraine material.

From the foregoing it will be seen that lateral moraine material belongs to two distinct classes. The first class, that descending from the mountain slopes above the surface of the ice, is strictly superglacial. This at least is true of all that portion of it which reaches the surface of the ice below the zone of accumulation. That which reaches it within the zone of accumulation may be temporarily buried by the snow of successive winters, until the ice which carries it passes from the zone of accumulation to the zone of wastage. While such material may have a brief englacial history, it still belongs, to all intents and purposes, with the first class of superglacial material. The second class, that which was taken from the summits of prominences which reached well up into the body of the ice, was at first subglacial, but quickly became englacial as the ice closed together beyond the prominence which gave rise to it. After a longer or shorter englacial journey, it became superglacial, as the result of surface ablation. Since the subglacial journey of such material was exceedingly brief in most cases, and the englacial and superglacial journeys doubtless much longer, it may be called englacial-superglacial drift. Englacial-superglacial bowlders should differ from bowlders which have been superglacial throughout their history, in that the former should show more evidence of wear. This might be inflicted both during their brief subglacial journey, and during their more protracted englacial history.

Medial moraines.—Wherever two mountain glaciers bearing lateral moraines unite, the lateral moraines belonging to the two margins which coalesce give rise to a medial moraine. Such a medial moraine is no more than two lateral moraines joined together. The derivation of the medial moraine material is therefore essentially the same as the derivation of the lateral moraine material.

It sometimes happens that there are considerable hills in a glacier's bed which the ice is unable to surmount, and it flows around them. Temporarily, an ice stream may be said to be divided into two by each prominence of this sort. These two streams unite below the rock prominence. If the rock prominence be high and steep, it may yield earthy and stony material to the surface of the ice on either hand, just as the slopes above an ordinary alpine glacier give rise to lateral moraine material. Such a boss of rock protruding through the ice may give rise to two lateral moraines, one on either side. These preserve their distinctness around the projecting hill. But where the ice streams on either hand coalesce below the prominence, the two lateral moraines unite and become a medial moraine. In such a case the ice passes over the lower slopes of the prominence which it surrounds. When the ice has closed round such a prominence, healing the wound which it made, some of the material plucked from the slopes of the hill below the surface of the ice, will be found in the ice above its base, that is in englacial position. Some of it may be very near the upper surface of the ice, and some of it will be at lower levels. As the ice passes on down the valley, its surface is subjected to rapid melting. When the uppermost twenty feet of the ice have been melted, all the material which was englacial in this part of the ice will have arrived at the surface, not because it was carried up to the surface, but because the surface was carried down to it. It will be seen that the greater the surface melting, the greater the amount of englacial material which will become superglacial, as the result of ablation. This superglacial material with an englacial history will first make its appearance along the line of the medial moraine which has been formed by the union of the two lateral moraines, since it is the ice along this line which, at the outset, carries englacial material nearest the surface. With surface melting, therefore, the medial moraine composed of superglacial drift and formed by the union of the two lateral moraines, will be augmented by the addition of englacial-superglacial drift. The effect will be to widen the medial moraine, as well as to increase its total volume, and this effect will be progressive with increasing distance from the hill which was the occasion of the whole phenomenon under consideration.

In many cases there are bosses of rock in the path of a glacier which the ice is able to override. They yield material to the bottom of that part of the ice which passes over them, but it is to be remembered that the bottom of the ice which passes over them may be near the surface of the glacier. When the ice has passed the prominence, the material which was borne from its top may find itself in an englacial position, and may be far above the bottom of the transporting ice. Subsequently, surface melting may bring the surface of the glacier down to its level. Such englacial material then becomes superglacial, and has the general position of a medial moraine. It would be, in fact, a medial moraine made up wholly of englacial-superglacial débris and not produced by the union of lateral moraines.

A lateral or medial moraine is likely to lose its distinctness as the end of the glacier is approached. Where such a moraine has sufficient body, it protects the ice beneath from melting. The ice beneath therefore assumes the form of a ridge, which is drift covered. Under these circumstances, the drift tends to slide down the sides of this ice-ridge. In time the drift may spread itself somewhat widely over a glacier sometimes even covering its whole surface, near its lower end.

The percentage of englacial material which will ultimately become superglacial is believed to depend upon its position in the ice, and upon the relative rates of surface and basal melting. If surface and basal melting be equal, the material of the upper half of the ice will ultimately come to be superglacial. If the rate of melting at the upper surface of the ice be greater than that at the lower, the englacial material carried by something more than the upper half of the ice will ultimately become superglacial, as the result of surface melting.

It is a mooted question whether glacial motion is of such a nature as to allow the transfer of material from the base of a glacier to its surface. It is often urged that drift may be transferred from a basal to a superficial position, without actually rising. In a mountain glacier, the bed of which is steeply inclined, basal drift would reach the upper surface of the ice if it were carried forward horizontally, or even if its forward path of motion declined at any rate less than that of the bed of the glacier. It has frequently been argued that this is the actual condition of things. While this conception does not involve a rise of material in terms of absolute altitude, it involves the rise of material through the ice which embeds it, or the rise of ice which embeds drift through that which surrounds it. That basal drift may rise through its embedding ice, or that ice embedding drift may rise through other ice in any such way as would be necessary to bring basal drift to the surface, has not been demonstrated. That stony material may be crowded up some slight distance into the ice from below by the help of other material beneath the ice, is readily understood, but in the present state of knowledge there is little warrant for counting upon the rise of material from the bottom of a glacier to its surface. If such rise were a general fact, there should be much more evidence of wear upon superglacial boulders than has yet been found. Indeed, the total absence from most Alpine glaciers of surface boulders showing any trace whatsoever of glaciation, seems to go far toward settling in the negative the question of the rise of basal drift through the ice.

The material which was superglacial at the outset would be likely to remain superglacial to the end, unless it fell into crevasses, or unless some other untoward accident befell it. The englacial-superglacial material must likewise have remained at the surface after once reaching it, unless it suffered some accidental fate.

Broadly speaking, the oldest ice of a glacier is at its lower end. Since the lower end of a glacier has had a longer time than any other part in which to gather superglacial material, and since surface melting has here been greatest, making possible the transfer of more drift from an englacial to a superglacial position at this point than elsewhere, it follows that the lower end of a glacier is likely to have more superglacial drift than any other part. Wherever it has not, it is because local conditions, such as extensive crevassing, have prevented its retention at the surface.

Superglacial drift of eolian origin.—Another sort of superglacial material sometimes arises through the agency of the wind. As glaciers advance into regions which are free from snow and ice, they advance into regions whence dust and sand may be blown upon them. Once lodged upon the ice, dust is not likely to be carried farther by the wind, since there is sufficient moisture to hold it. Once moistened, too, it is likely to freeze to the surface of the ice. Such dust is liable to removal by superglacial waters. If it escapes them, it is likely to remain upon the ice so long as the latter remains unmelted. It is believed that considerable quantities of dust reach the surface of existing glaciers in this way. Such dust as is blown upon the surface of the ice, within the zone of wastage, is superglacial from the beginning.

This process of dust accumulation goes on most actively near the ends of glaciers, since the surroundings here are best adapted to furnishing the dust. But the same process must go on to some slight extent throughout the whole gathering ground of existing glaciers. As the snow accumulates year by year, it contains a modicum of dust blown upon the snow-field. This dust becomes englacial. The embedding snow is presently converted into ice. As the ice moves toward the end of the glacier, passing from the zone of accumulation to the zone of wastage, its surface melts, and the dust contained in the part which is melted, appears at the surface. Some of it is doubtless washed away by the superglacial drainage resulting from rain and from surface ablation. Such as escapes this fate may remain upon the surface of the ice. The amount of dust which shows itself on the surface of a snow-field at the end of a melting season is sometimes considerable. As seen in section in a snow-field, the snowfalls of successive winters are seen to be clearly defined by the presence of these bands of earthy matter ("dirty ice") between them; these bands indicate the condition in which the surface of the snow found itself at the close of the successive seasons of melting. A small amount of dust descends from the atmosphere with the snow when it falls. As the snow and ice melt, this is set free, and, in its proper measure, swells the amount of dust which gathers upon the surface in other ways.

Surface melting has been greater at the end of a glacier than at any point above. If it has not been washed away, therefore, the amount of dust which has passed from an englacial to a superglacial position, as the result of surface melting, must be greatest at the end of the glacier. Since the amount of wind-borne superglacial dust which has had no englacial history is also greatest here, it follows that the total amount of superglacial dust which has come through the atmosphere, must be greatest near the ends of glaciers, unless conditions have prevented its preservation. The dust is most likely to remain where the surface of the ice is smoothest, and where there is little surface drainage. Material blown upon the ice is much finer than most of that which descends from the slopes above.

2. PIEDMONT GLACIERS.

Piedmont glaciers owe their origin to the fusion or coalescence of several alpine glaciers. All the material which was on the surface of the alpine glaciers which unite to make a piedmont glacier, will be at the surface of the latter from the beginning. All the englacial material which was carried by the contributing alpine glaciers in their upper parts will become superglacial on the piedmont glacier, so soon as surface melting has brought the surface down to its horizon. Since the only piedmont glaciers concerning which we have knowledge have little motion, surface melting must greatly predominate over basal melting, and the proportion of englacial drift which becomes superglacial must therefore be great. On the Malaspina[1] glacier, which stands as our representative of piedmont glaciers, superglacial drift is most abundant near the edge, where surface ablation has been greatest.

[1] Russell, expedition to Mt. Saint Elias. National Geographical Magazine, vol. III. pp. 53–204, also JOURNAL OF GEOLOGY, vol. I., No. 3, 1893.

At and near the centre, superglacial material is not abundant, because melting has not there been sufficient to carry the surface of the ice below the horizon of abundant englacial detritus. Wind-borne fine material might reach the surface of piedmont glaciers in the same way that it reaches the surface of alpine glaciers.

3. The Continental Ice-Sheets.

1. *Lateral moraines.* Wherever the edge of the continental ice-sheet found itself in a region of strong relief, ice-tongues thrust themselves forward into valleys beyond the main body of the ice. In very many respects such tongues of ice corresponded to alpine glaciers. Upon their surfaces lateral moraines may have accumulated just as in the case of mountain glaciers today. But the country invaded by the continental ice-sheet of North America was, for the most part, not mountainous. Marginal glaciers of the alpine type must have been restricted to those parts of the ice-sheet which invaded mountain regions, or at any rate to areas of marked relief. As the ice-sheet advanced and thickened, it presently covered the elevations which had earlier occasioned the lobation of its edge. So soon as it covered an elevation, this elevation ceased to give immediate origin to lateral moraines. Since on the whole the relief of the country covered by the North American ice-sheet was not great, there was little chance for the development of extensive lateral moraines upon it. While they doubtless existed on the alpine-glacier-like lobes of the ice-sheet's edge in regions of strong relief, they could have existed for considerable distances back from the margin in but few localities. As the ice invaded regions of slight relief, such as the larger part of the Mississippi basin, it could have acquired little superglacial material. No more than miniature lateral moraines could have come into existence. The same conditions which forbade the development of extensive lateral moraines on the continental ice-sheet, gave the ice little opportunity to acquire englacial material which could subsequently become superglacial by surface melting.

As the ice of the continental glacier closed round nunataks, the lateral moraines which had come into existence became medial; but medial moraines, arising by the coalescence of lateral moraines, could not have been more extensive than the latter. After the ice overtopped the nunataks which gave rise to lateral moraines, these same elevations might still yield englacial material to the over-riding ice. Later, part of this englacial material, perhaps became superglacial, by having the surface of the ice brought down to its horizon as the result of surface ablation. On reaching the surface, this material might assume the form of a medial moraine, as in alpine glaciers. As on mountain glaciers, lateral or medial moraines on a continental ice-sheet might readily lose their distinctive character during the melting of the surface ice. As in the case of alpine glaciers, the proportion of englacial material in a continental ice-sheet which must become superglacial as the result of surface melting would depend, 1), upon the position of the englacial material in the ice; and, 2), upon the relative rates of basal and superficial melting. The higher the elevations from which the englacial material was derived, the nearer will it be to the upper surface of the ice at the beginning of its history. The nearer it is to the upper surface of the ice, the better its chance of becoming superglacial. The amount of englacial-superglacial material would therefore be greatest in a region of strong relief, and especially in a country where the relief was great, relative to the thickness of the ice. A region of 2,000 feet relief, beneath an ice-sheet 5,000 feet thick, might yield little englacial material which would ultimately become superglacial. If the ice over the same region were but 2,500 feet thick, a much larger proportion of its englacial drift would be likely to reach the surface of the ice. Since the ice-sheet was always thinnest at its margin, the relief of any given region was always greater, relative to the thickness of the overlying ice, when the marginal part of the ice overlay it, than at any other time. Advance of the ice means the thickening of the ice at all points back of the margin. With increasing thickness of the ice, a less and less proportion of the englacial material derived from any given elevation would stand a chance of becoming superglacial, because there must be progressively more and more surface-melting, in order to bring the uppermost portion of the englacial material to the surface. Meanwhile basal melting has been going on, and will have brought some of the englacial material to the bottom of the ice, that is, to a subglacial position. Because of its thinness, therefore, the marginal part of the ice-sheet was likely to secure more englacial material capable of becoming superglacial, than any other part.

The ratio of surface melting to basal melting is probably greater at the margin of the ice than elsewhere, so that the upper surface of the ice is here lowered more rapidly than elsewhere. It follows that, as a result of surface melting, a greater proportion of the englacial material acquired by the margin of the ice would be likely to become superglacial, than of that acquired by any other part. Considered from the standpoint of the ice, there are, therefore, two reasons why the marginal part of an ice-sheet should possess more englacial-superglacial drift than any other part.

There is another set of reasons why superglacial material, derived from an englacial source, must be more abundant near the margin of the ice than elsewhere. They relate to the surface over which the ice passes. The passage of glacial ice over a region of rough topography tends to smooth it. It is when the ice first invades a region that its topography is roughest. Later, after the passage of much ice, the rugosities of surface have been reduced, and from the smoother surface the ice is able to get less detritus. Furthermore, quite apart from considerations of topography, it is when the ice first invades a region that there is most loose surface material in a condition to be removed. Later, after longer passage of the ice the materials antecedently loosened by surface agencies have been taken away, and any further acquisition the ice may make must be made from the more solid rock beneath. Considered from the standpoint of the surface over which the ice passed therefore there are two valid reasons for believing that the marginal part of an advancing ice-sheet is more favorably situated for acquiring englacial material than any other. If the marginal part of an advancing ice-sheet acquired more englacial material than any other part, and if a larger proportion of that which it acquired became superglacial, it will be seen that this part of the ice had great advantage over other parts in the matter of superglacial drift. Apart from all considerations of topography, surface material, thinness of ice, and rate of surface melting, an advancing ice margin has an advantage over a receding margin in the acquisition of material, because of its greater vigor of movement.

Not only must englacial-superglacial material be most abundant at and near the margin of the ice, but, under most conditions, it must be more abundant at the margin of an ice-sheet during its earliest advance than at any other time, since it is the first advancing margin which in general finds the roughest topography, and the most loose material ready for removal. A qualification to the first part of this statement, and a partial exception to the last, should be stated. If the interval since the ice has retreated from a given region be long, a rough topography may have been developed since the earlier passage of the ice. In this event, the first advancing margin might have no advantage over the second in securing englacial drift which may become superglacial. When the ice re-advances over a surface from which it has receded, it may find a large supply of loose material in the form of drift, ready for removal.

In summation it may be said that the advancing margin of a continental ice-sheet must have been more abundantly supplied with superglacial material than the receding, because (1) the motion was more vigorous, favoring the acquisition of more englacial material capable of becoming superglacial; (2) the surface over which the advancing margin spread was, on the whole, better supplied with material which might become superglacial, either directly or indirectly; (3) the topography of the country as the ice invaded it, was such as to allow it to acquire material more readily than at any other time. The first of these conditions applies with equal force to a first or a later ice advance. The second and third apply with greater force to the first advance of the ice, unless the interval between the first and second was sufficiently long to develop a rough and essentially non-glaciated topography. The conditions most favorable for the acquisition of superglacial material are, (1) a rough country, with (2) much loose material upon its surface, affected (3) by an advancing ice margin. Whenever the edge of the ice was stationary, the elevations which were yielding superglacial material, or englacial material which stood a chance of becoming superglacial, were elevations which had already been worked over by the advancing ice, so that they were less productive than when the ice first reached them. When the ice was retreating, its surface would have had still less superglacial material than when stationary.

As noted in connection with alpine glaciers, the drift which has been superglacial from the outset should differ from the englacial-superglacial drift by showing less wear. The difference might be great or slight, depending in part upon the duration of the englacial history of the englacial-superglacial drift.

From what has been said it is clear that the englacial-superglacial drift acquired by the thin margin of an advancing ice-sheet had a shorter englacial history than that acquired by any other part of the ice-sheet. It should, therefore, show less wear than the corresponding drift picked up by the ice back from the margin. The amount of material which was superglacial from the outset must also have been greatest at the margin of the ice during its advance, and this had little or no opportunity of suffering wear. The aggregate of superglacial drift at the margin of an advancing ice-sheet must, therefore, be much more free from wear than that of any part of the ice back from the margin. Since the superglacial drift of a receding ice margin may be mainly or wholly englacial-superglacial, and since it may have been mainly or wholly acquired by ice of considerable thickness, attaining its superior position only after a long englacial course, it follows that the surface drift of an advancing ice margin must be more free from wear than that of a receding margin.

There must have been another difference between the superglacial drift acquired by an advancing ice margin, and that acquired by other parts of the ice. The advancing margin of an ice-sheet invades territory the surface of which is likely to be provided with the products of decomposition. It is these products of decomposition which in considerable part enter into the composition of the superglacial drift, and into the composition of the englacial drift which is shortly to become superglacial. It follows that the superglacial and englacial-superglacial drift of an advancing ice margin is made up more largely of the products of rock disintegration than the surface drift of any other part of the ice. The drift of a stationary or receding margin constitutes no exception to this general statement, since, as already noted, much of it was originally acquired some distance back from the margin, and from surfaces over which much ice had passed, and from which, therefore, the disintegrated products had been earlier removed.

It should be further noted that it is not merely an advancing ice-sheet, the superglacial drift of which is largely disintegrated and oxidized, but an advancing margin which is invading territory hitherto unglaciated, or unglaciated for a long period of time. During the forward phase of an oscillatory movement, the edge of the ice may be moving over territory which had been but recently abandoned, and which might therefore be free from the products of rock disintegration.

Dust might be blown upon an ice-sheet as upon an alpine glacier, but the thickness which it might attain on the former is far greater than on the latter. The ice of a continental glacier is much thicker than the ice of a mountain glacier. It has been much longer in process of accumulation, and presumably contains more dust. Above the zone of wastage, this is chiefly englacial. In the zone of wastage, it gradually becomes superglacial. Since there is a much longer period of surface melting in an ice-sheet than in a mountain glacier, and so a much greater amount of surface melting, more dust must finally rest on the surface of an ice-sheet than on the surface of a lesser body of ice. Unless carried away by surface drainage, superglacial material having an eolian origin should appear at the upper (inner) margin of the zone of wastage, and should increase to the very edge of the ice. It should be most abundant in this position, since most ice has here been melted, leaving its dust behind.

To the fine material which was left on the surface by the melting of the upper ice, was added such as blew upon the surface within the zone of wastage, and which was never englacial. Like the former, this latter material must have been most abundant at the extreme edge of the ice.

It is not definitely known how important (quantitatively) wind drift was on the North American ice-sheet. But it is believed that its amount was far greater than has been commonly recognized.

DEPOSITION OF SUPERGLACIAL MATERIAL.

If the margin of an ice-sheet thins to an edge, the englacial drift must ultimately become either superglacial or subglacial. Either basal melting will bring it to the bottom of the ice, or surface melting will bring it to the top. There is no third alternative. If the drift rise or sink through the ice, the case is in no wise altered, so far as the final result is concerned. If an ice-sheet terminates with an abrupt front, it is manifest that some englacial material may be deposited from its englacial position. Since the ice-sheet is believed to have thinned virtually to an edge, it is clear that essentially all the englacial material was either superglacial or subglacial in its final deposition.

While the superglacial drift is being carried forward on the surface of the ice, the edge of the ice is being continually melted back. When it is melted back as rapidly as it advances, the edge of the ice is stationary in position. When the rate of edge melting exceeds that of forward flowage, the edge recedes. When the wastage falls short of the advance, the edge moves forward. In any case the edge of an ice-sheet is being melted off continually. In the first case, the extreme edge is in the same place from year to year, but the ice which is at the extreme edge this year is not the same ice which was in the corresponding position last year. That ice has been melted. The ice which is now at the edge was then back from the margin the distance of one year's melting. All the drift covering carried by that ice which has been melted during the year has been dropped, and dropped on the surface over which the ice lay when it melted. The superglacial drift on the ice which is now at the front, is the superglacial drift which last year was back from the edge the distance of one year's melting, together with such material as was then englacial, but which surface melting has meantime allowed to become superglacial.

While the edge of the ice remains stationary in position, all deposits of superglacial drift must take place in a narrow belt at its edge. These deposits would tend to build up a marginal ridge, or dump moraine. For reasons already given, a stationary ice margin must have less surface drift than an advancing margin, other conditions being equal.

The case is somewhat altered if the edge of the ice be advancing. If the ice moves forward 500 feet per year, while it is melted back 400 feet, it makes a net advance of 100 feet. But the 400 feet which were at the front last year are gone, and the superglacial material which this 400 feet of ice carried has been deposited where the ice which carried it melted, that is, *on ground now occupied by the ice.* The ice has already worked over in part, and buried in part, the superglacial material deposited from the 400 feet of ice which have been melted off during the year. When the ice has advanced still further, it will have covered the particular superglacial drift referred to more deeply, and will have modified it more completely. At no considerable distance from the margin, the larger part of it would probably have lost every trace of its earlier superglacial character, by having been worked over beneath the ice, and so converted into subglacial drift. Such part as did not suffer this fate might be buried, and, in genesis, would be *superglacial material* (superglacial till). In position it would be *beneath the subglacial drift deposited by the same ice-sheet.*

At every stage in the advance of the ice-sheet, there would be a narrow margin of ice covering the superglacial deposits made at the edge of the ice just before. Such superglacial deposits might for a time retain their superglacial characteristics, even though buried by the ice. So long as this remained true, their classification might be open to question. But it is not apprehended that this condition of things commonly existed for any considerable distance back from the ice's edge. This statement, which is believed to be true as a general statement, is not to be construed to mean that superglacial material, deposited by an advancing ice-sheet, may not in exceptional cases be buried by the subglacial deposits of the ice at a later and more advanced stage of its development, without being in any way changed, beyond being compacted by the pressure of the over-riding ice.

The ice at any stage whatsoever in the period of its advance, must have worked over, or in exceptional cases buried, all the superglacial material which had been deposited up to that time. What had been superglacial material thus became subglacial, as the ice advanced. However great the amount of superglacial material acquired and deposited by the advancing edge of a continental ice-sheet as it passes over rough surfaces, essentially all of it must subsequently be reworked beneath the ice, must lose its superglacial characteristics in the process, and must have impressed upon it the features which ice impresses upon materials worked over beneath itself. That is, all superglacial and englacial-superglacial drift deposited by an advancing ice-sheet must be transformed later from superglacial into subglacial drift. It has already been shown that it is the advancing margin of an ice-sheet which is most favorably circumstanced for carrying a heavy load of superglacial material. The conditions of glacier motion and melting determine the continuous deposition of this material, while the ice is still advancing. It follows that the heaviest deposits of superglacial material which an ice-sheet can make at any period of its history, cannot retain their superglacial character, but are necessarily converted into subglacial drift.[1]

Such superglacial drift as was deposited by the melting of the ice at the time of its maximum extension, and later, after the recession began, would not become subglacial except by a subsequent advance of the ice. But oscillations of the ice-edge are probably frequent, even during the recession of a continental glacier, and it is only the superglacial drift left by the ice in any given locality at the time of its final withdrawal from that locality, which can properly be classed as superglacial drift. In view of this fact, and in view of the further fact that receding ice has little superglacial drift to deposit, it would seem that there was little chance for the presence of much superglacial drift in such a region as that from which our continental ice-sheet withdrew, unless, indeed, there was actual transfer of drift from a basal to a superglacial position. Not only would the amount of superglacial drift deposited by the receding ice be slight, compared with the deposits of an advanced or advancing margin, but it would be composed of fresher material, which had been subjected to more wear. It would, therefore, be less distinct from the subglacial drift, so far as these characteristics are concerned, than the superglacial drift deposited by the extreme margin of the ice.

It is no part of the purpose of this paper to discuss the criteria for the recognition of superglacial drift in glaciated regions. This may be the subject of a later paper. But it may not be useless to point out that such superglacial material as was deposited by the ice at and near the limit of its maximum advance, may have been largely acquired by the advancing margin of the ice while working over territory which had not been glaciated hitherto. So far forth, it may have been largely composed of oxidized, and disintegrated materials. Here, and here only, it is

[1] This statement leaves out of consideration the effect of possible unequal rates of advance and recession of the ice. Such inequality might slightly change the result. It also leaves out of consideration the drift which is thought by some to rise through the ice during its motion.

conceived, was the superglacial drift notably more oxidized and disintegrated than the subglacial at the time of its deposition. It is not believed that this belt of notably oxidized and disintegrated superglacial drift could have been many miles in width, even when the ice-sheet with which it was connected was wide. Toward the direction whence the ice came, the character here noted would gradually disappear.

ROLLIN D. SALISBURY.

EDITORIALS.

THE scope of the work of the United States Geological Survey was enlarged the present year by the adoption of an amendment to the appropriation bill providing for the gauging of the water supply of the United States, and for the investigation of the artesian water areas. The demands made upon the Survey from time to time for information concerning the water resources of the country are far greater than it is able to meet. The demand is especially from the West ; but numerous calls also come in from the East relative to the available water supply for power, and in some areas for irrigation. Response to the inquiries made requires not only a broad knowledge of the topography, geological structure, and meteorological conditions of the regions involved, but also more or less familiarity with the local conditions governing the distribution and character of the available water. These inquiries are made by all classes. They come from farmers seeking to provide water for domestic use, and for irrigation ; from individuals seeking artesian water supply and water power ; from municipal organizations ; and from members of congress having in view legislation concerning the utilization of streams flowing across state boundaries.

The general government has absolute title to nearly one third of the area of the United States, excluding Alaska. With the exception of certain areas within the Indian Reservations, the public lands of the West are mainly within the arid or semi-arid region. There is only enough water for the irrigation of a small proportion of the rich soil. Whether it be received from artesian sources or from precipitation direct, the government is still far from knowing the total amount available, or the best method of its utilization.

In order to throw light upon one of the many phases of the inquiries concerning the water resources, a thorough investigation was made, under the direction of Major Powell, as to the population of the lands of the national domain. The result shows that settlement has followed the streams of the great west to a remarkable degree, and that it has clustered about the foothills of the higher mountain ranges, which, from their abruptness of topography, insure a perennial supply of water for irrigation. There is hardly a spring, creek, or small river, whose waters are not utilized by the farmer. As a consequence, the surface of the great desert of arid land is everywhere dotted with oases. The water which is thus utilized is that which is most readily available. There is much that is still unemployed. Both the great supply of storm waters, and the underground supply, are scarcely touched. The utilization of this unappropriated water is the first condition for the further development of the arid and semi-arid lands. In order that it may be utilized, a careful investigation should be made, in order to furnish the information which is needful before new enterprises can safely be entered upon.

In the past, the hydrographic work of the Survey has been limited, because of the small sum available for gauging the streams, and for studying the various problems involved. Such results as have been secured were rather an incidental result of the brief irrigation survey which was practically suspended in 1891. The scope of the requests for information shows the popular appreciation of the best work in this direction. From this standpoint the inquiries are encouraging. At the same time they are embarrassing, in that it is assumed that the Survey has extended its investigation over the whole field, when, as a matter of fact, the work has been carried on in a restricted way in but a few of the more important localities.

The nation as a whole is interested in the question of its water resources, as vital to the future of the public lands. It is also interested in the general question of water for domestic purposes, especially in thickly settled districts. The economic and effective search for waters for this purpose involves a knowledge of all of the factors entering into a thorough hydrographic investigation. In the search for artesian waters, thousands of dollars have been wasted in places where a thorough knowledge of the geological structure would have prevented such waste. Each year this fact is being better appreciated, and expert opinion is more and more sought, both in connection with the search for artesian water, and in the utilization of water power.

The hydrographic work is not only intimately related to geology and topography, but also demands data from the records of climatic oscillations. The latter may be obtained from the records of the Weather Bureau, but in other respects the work is essentially a survey, and should be prosecuted in the most economic manner possible. The organization of the department of hydrographic work under the present limited appropriation is under the charge of Mr. F. H. Newell, who is assisted by Mr. Arthur Davis. Both of these gentlemen are trained topographers, and have had long experience in such hydrographic work as is contemplated by the Survey. At present they are largely engaged upon the special study of the water supply of the great arid and semi-arid region of the interior, employing local assistance wherever parties are found who are interested in the work. A large amount of this assistance is voluntary, so that they are able to obtain much more extensive results than would otherwise be possible with the resources at command. The railroads, especially, are giving much assistance by having their bridge tenders read the river gauges that have been set up under the direction of Mr. Newell.

The value of this work is beyond question, and since it is so closely related to geology, it appears to be strictly germane to the work of the Survey. R. D. S.

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THERE is another project under consideration by the Director of the Survey that will be of practical value to the people of the country. It is proposed to establish a laboratory for the study of materials entering into the construction of highways. At present there is a decided movement in the country towards the betterment of roads. This movement has not yet taken a national character, but it is believed that, by establishing a laboratory in connection with the National Survey, where information can be given as to the character of the material best adapted to road construction, a great impulse may be given to the improvement of highways.

It is well known that in many districts great expense has been incurred in building roads, with the result of producing dusty roads in summer and muddy roads in winter. This outcome is the result of ignorance in regard to the character of the rock necessary for the production of good roads. Inferior materials have sometimes been used, when, in the immediate vicinity, there were other materials which, alone or in combination, would have produced a solid road-bed. Such failure results in discouragement, and is detrimental to further progress. The requirements which relate to the building of a road are not more complicated than those which relate to the building of a roof. The main questions have to do with the choice and manipulation of materials. It is clearly within the province of the Survey to gather and distribute accurate information concerning the value and location of rocks which may serve a good purpose in the construction of roads. To a great extent these inquiries can be made in the ordinary work of the Survey, with but a small addition to the present cost of its operations.

A large part of the country, including the greater portion of the southern states, and some portions of the Mississippi basin, has been thought to be essentially destitute of materials suitable for the construction of good roads. The inquiries that have been made by geologists, especially by Professor Shaler, have shown that in many places within these regions there are hidden deposits of gravel, and other sorts of rock, which, when properly used, might give excellent highways, and that around the margin of this great area, often within the limits of convenient railway distribution, there are abundant supplies of rock well fitted for such use. It only remains to discover the supply of such stone as is cheapest and best for the use of each region.

This information can only be obtained in practical form for each district, as the work of the Survey advances. Professor Shaler has prepared a paper on the subject of geological highways, which will be printed in the annual report of the Director of the Survey for 1893–4. For more detailed information, it is proposed that the various road commissioners send to the Survey samples of such rocks and gravels in their immediate vicinities as are believed to be valuable for road construction.

A laboratory for inquiry into the value and use of materials which may be useful in the construction of highways was established in connection with the Massachusetts Road Commission at the scientific department of Harvard University. This was established especially to meet the needs of Massachusetts. The results of the first year's work have shown clearly that the laboratory will be of great service to the people. It is possible that each state should establish a laboratory, though this would lead to great expense, since the amount of work to be done after a year or two of study would be relatively small in each, and the results obtained by divers observers and methods would lack the unity which give a national value.

The work of the laboratory should be arranged so as to obtain information (1) as to the resistance of the material to blows such as are inflicted by the feet of draft animals and by carriage wheels; (2) as to the cementation value of the dust which is made when the bits of stone are placed upon the road and driven together by the weight of the roller; (3) as to the extent to which the stone is likely to be penetrated by water, which, on freezing, will break and disturb the road-bed. When preliminary tests have shown that any given material is likely to be valuable, it may be desirable to make further and more thorough tests by paving a square rod of some street where the amount of traffic is sufficient to give it a thorough trial.

Experience has shown that many kinds of rock which are not suitable for road building when used alone, may be combined with other materials in such wise as to give good results. Thus certain quartzites, which, though very hard, do not, when crushed, form a binding cement of good quality, may be made to do good service in road construction when mixed with a small quantity of rock powder obtained from some other stone. As this powder need not exceed one tenth of the material used in road construction, it need not involve great cost, even if brought from a considerable distance.

Professor Shaler has called attention to the use of bricks for highways. They have been used for centuries in Holland, and it now seems likely that in the lowlands of the South this kind of pavement may come to be of great value. This makes it important that the laboratory should include in its investigations a careful study of the clays of the country, with reference both to distribution and burning qualities. Much information is at hand concerning the clays of the country, but little attention has been paid to this phase of their use.

During the present year an officer of the Survey will be detailed to take charge of the investigation of highway material in the laboratory at Cambridge, Mass. The establishment of a national laboratory will be brought to the attention of congress, and a request made for a suitable appropriation. The entire expense would probably not exceed $15,000 for the first year, and $10,000 a year thereafter. It would seem that such a laboratory would speedily become a source of public information concerning highways, and that it would prove to be of great value to the country.

R. D. S.

Reviews.

SOME RECENT ALPINE STUDIES.

Beiträge zur Lehre von der Regionalmetamorphose. L. MILCH (Neues Jahrbuch für Mineralogie u.s.w., Beilage Band IX., 1894).

Zur Classification der unorganogenen Gesteine. L. MILCH (same journal).

Études dans les Alpes Francaises. MARCEL BERTRAND (Paris, 1894).

Through the classic works of Heim and Lehman in 1878 and 1884, the problems of metamorphism were clearly set forth and attention was called to the fact that nowhere in the world were the conditions more favorable for their solution than in the Alps. In this region all gradations were to be found from the least metamorphosed sediments to the most highly altered clastics and eruptives. Investigators of marked ability were attracted to the field and a very copious literature on Alpine metamorphism has resulted. Their success led to similar work in numerous other fields where these same problems had been considered as incapable of solution. These workers look with interest to all contributions to the knowledge of Alpine geology, for they are sure to contain valuable suggestions for the prosecution of work on the crystalline schists the world over.

During the past few months Dr. Milch of Breslau has published a second paper on the dynamic phenomena of the Verrucano. In a former paper[1] he discussed the subject of the dynamic metamorphism of the eruptive rocks, and in the present paper he gives some results of a study of the metamorphism of the sediments as bearing on the general subject of regional metamorphism.

Many of these altered sediments show typical clastic grains, while others have lost all trace of such character. Such rocks are divided according to the nature of the alteration into the following groups :

[1] Reviewed in JOURNAL OF GEOLOGY, Vol. I., No. 8, p. 850.

I. *a. Allothimorphic fragments*, with the composition and form of unaltered clastic constituents.

b. Authimorphic fragments, with the composition of the clastic constituents unchanged, but the form altered.

II. *a. Allothimorphic pseudomorphs*, with the composition changed in a manner depending on the nature of the former substance, but with unchanged form; dependent new products with old allothimorphic form.

b. Authimorphic pseudomorphs, with the composition changed as above, but with altered form; dependent new products formed with new, authimorphic form.

III. *Eleutheromorphic new products*, with composition and form altered; true authimorphic products.

Under the division of authimorphic fragments two classes are distinguished; those which have become adapted to the altered conditions are designated as *kamptomorphic;* the others are called *authiclastic*. All of the categories above tabulated are observed in the rocks of the Murgthal. The first and second divisions are observed especially in the quartz, feldspar, and mica, while the third is best seen in the sericite and iron hydroxide masses. In the latter case, there is a varied arrangement of the leaves and fibres. Where the new products are radically arranged around the larger minerals, the structure is designated as *eleutheromorphic-lenticular* (flaserig). If these new formations wind around the larger mineral components, the structure is called *mechanical-lenticular* (flaserig). In the first case, the single leaves are not deformed and they show no optical disturbance, while in the second instance these leaves are bent. The former are analogous to the links of a twisted chain, and the latter to the strands of a cable.

The author compares with the altered sandstones of the Murgthal, the curved lenticular gneiss of the Rhine valley. These rocks have been strongly contrasted by all previous students, but Dr. Milch regards the difference between them as one of degree rather then kind. In both the original unaltered material was allothimorphic. The present authimorphism has been produced by chemical and mechanical means. The cause has usually been regarded as pressure alone. This explains the mechanical alteration of the components, but the chemical alteration is only to be explained by a transfer of substance through the agency of water. Dislocation and faulting are not necessary to produce these changes, for pressure and high temperature are sufficient.

In a discussion of regional metamorphism two divisions must be recognized, *pressure* and *dislocation* (dynamic) metamorphism. The former alters all rocks, while the latter is dependent on the nature of the rocks, and it is confined to certain areas. Both build similar minerals and they have a common cause for mineral alteration. The tests for distinguishing regionally metamorphosed rocks are varied. While Credner and Dathe emphasized the point of the presence or absence of mechanical phenomena as the clue, Milch regards the absence of such effects as no proof against dynamic metamorphism. A second distinction is the entrance of magnesian minerals of the mica and chlorite groups. In regionally metamorphosed rocks chlorite is more important, while in the true crystalline schists biotite is the important mineral.

Clastic structures are often lost and so cause an outward resemblance of many gneisses to eruptive rocks, but that this is only external is easily proven by the chemical composition.

In pressure metamorphism, the pressure is at first weak but increases slowly through the successive geological periods, and it produces especially kamptomorphous forms. The condition for dislocation metamorphism is a sudden pressure working in a limited time with varying intensity and direction. This pressure does not form gneisses but mica schists. In a rock under a slight pressure, clastic phenomena are abundant, but as this pressure is increased, the forms become kamptomorphous. Finally, with great loading and small motion, gneisses are formed resembling those produced by pressure metamorphism. Thus the two divisions are bound together by numerous transitions. The great force is pressure which sometimes produces greater mechanical changes, under other conditions, more chemical alterations. Mechanical changes, especially the crushing and formation of small components, characterize dislocation (dynamic) metamorphism.

Dr. Milch, in the second article, presents a new rock classification which depends essentially on the source of the material of the rock constituents and the cause of their present form. It is fourfold and conformable to the four divisions of igneous rocks, chemical precipitates, mechanical sediments, and crystalline schists. Its advantage over this old system is the placing of the products of contact and regional metamorphism in a fixed place.

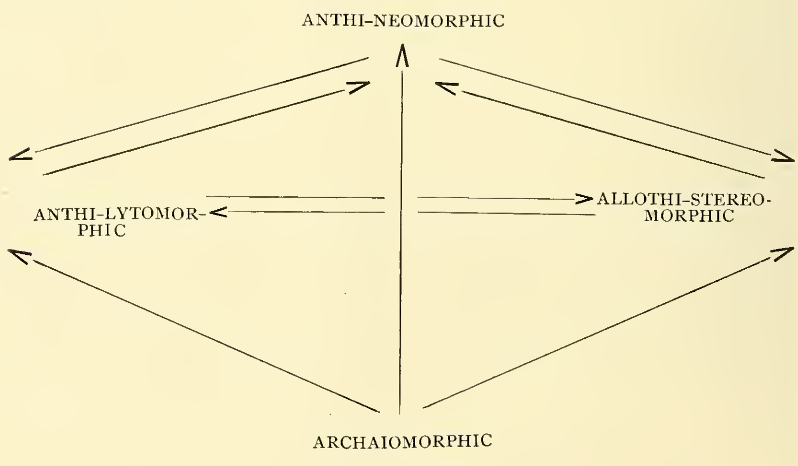
Group 1) includes rocks composed of components whose material separated out of the original molten sea, in the form of the present rock. Such types are called *archaiomorphic*. To this group belong all the eruptive rocks. Through alteration, transport, and reconsolidation new groups are formed, known as *neomorphic*, which are further divided according to the manner and condition in which the material has been transported, and the way in which the constituents have acquired their present form. There are three groups of these neomorphic rocks.

Group 2) includes rocks whose material was in another form and in another part of the earth's crust, but the form of whose constituents has been acquired without outside influence. These are the chemical precipitates and are designated as *authi-lytomorphic*.

Group 3) includes rocks which originated in another place but through transportation have been brought in a solid condition to the present location and united into a new rock with the old form. These are the mechanical sediments, and they are called *allothi-stereomorphic*.

Group 4) includes rocks composed of constituents whose material was originally deposited on the place where they are now found, but which have in a mechanical or chemical manner built a new rock on the old place. Here are placed the products of contact and regional metamorphism and weathering, and they are designated as *authi-neomorphic*.

Each of these three neomorphic divisions under altered conditions passes over into the other two, but all originate from the first division, or archaiomorphic. The various possibilities are shown in the directions of the arrows in the following diagram given by Dr. Milch :



Professor Bertrand has extended the work to the westward, and brings together in two papers the results of his four years' work in the French Alps. The first paper describes the structure and metamorphism, while the second is devoted to a discussion of the *lustrous schists.*

The structure is that of the fan with the folds on the west dipping toward France and on the east toward Italy. In the neighborhood of St. Maurice and Briancon, the axis of the fan is formed of Carboniferous rocks; while farther south, it is formed of Eocene layers inclining in the same way. While the Carboniferous zone on its western border forms a curve regular and parallel to the axis of the chain, the interior folds are remarkable for their irregularities. The cause of this difference is the presence of elongated lenses occurring in the synclines and anticlines. Such an arrangement resembles the augen (amygdaloidal) gneiss, so the name *amygdaloidal* (augen) *structure* is proposed. To illustrate the importance of these lenses, Mt. Blanc is found to be one large lens or augen rising from a synclinal area.

All this region of the Alps during Carboniferous, Triassic, and probably Jurassic time has been the seat of continuous sedimentation. The later movements have restored to light these ancient sediments and have shown the depths to which they have been buried.

While in one case the lustrous schists seemed to be of Palæozoic age, in all other places they are better interpreted as Triassic. The very great development of green rocks of apparently Triassic age seemed exceptional, but they were found in other places associated with fossils. The author regards the Hudson river group in the United States, as described by Walcott, as the first instance comparable to these lustrous schists. Similar bodies of schistose rocks as a facies of fossiliferous beds occur in Scandinavia and the Pyrenees. It is, then, a general fact that on the site of the important mountain chains, before their formation was complete, there was active sedimentation with a schistose facies limited to the synclines and usually of basic rocks. In this region there was a rapid filling up of the geosynclines in the flysch periods. The Triassic *flysch* was formed at the centre of the chain before the first submergence. The Eocene *flysch* was deposited on the border of the chain already emerged, and this was followed by active denudation which resulted in a recent rupture of the equilibrium. That the age of these lustrous schists is Triassic there is but little doubt, a conclusion which agrees with the observations of Lory.

G. Perry Grimsley.

Analytical Abstracts of Current Literature.

Eastern Boundary of the Connecticut Triassic. By W. M. Davis and L. S. Griswold. Bull. Geol. Soc. Amer., Vol. 5, pp. 515–530. April, 1894.

Some New Red Horizons. By Benjamin Smith Lyman. Proc. Amer. Philos. Soc., Vol. 33, pp. 192–215. June, 1894.

The "Triassic" of Davis and Griswold and the "New Red" of Lyman are the same series of strata, the series for which Redfield proposed the non-committal name "Newark."

The first paper is introduced by an outline of the geologic history of the district, the main points of which had been previously published by Davis. The Triassic beds were deposited unconformably on crystalline and metamorphic rocks to a depth of at least 11,000 or 12,000 feet. Their sequence is interrupted by trap sheets, partly contemporary and partly intrusive. They were uplifted, faulted, tilted and degraded, being reduced to base level in Cretaceous time. Uplift and further extensive degradation followed in Tertiary time, and the work of Pleistocene ice modified topographic details.

The eastern boundary of the Triassic area is determined by five faults. Three trend north and south and have downthrow to the west. Two trend northeast and southwest, intersecting the others, and have downthrow to the northwest. Points of intersections are marked by two salient and reëntrant angles in the boundary. The transverse faults are identified with faults observed in the centre of the area and there found to involve displacements of 2,000 and 1,000 feet respectively. One of the meridinal faults shows a maximum displacement of not less than 9,000 feet. Great pains are taken to explain the nature of the evidence on which these results are founded.

The second paper is based primarily on a minute survey of the New Red in Montgomery and Bucks Counties, Pa., where the series is composed of five formations, the Pottstown (youngest), Perkasie, Lansdale, Gwynedd and Norristown, with a total thickness of at least 27,000 feet. The formations dip toward the northwest and their outcrops are partly duplicated by a great fault (described in an earlier article by the same author). Their representatives are conjecturally identified in other counties and states, partly from stratigraphic descriptions, partly from structural studies conducted by comparing reported dips with topographic details represented on the contour maps of the New Jersey and United States Surveys. Hypothetic maps and sections are given of the New Red in New Jersey, New York, Connecticut and Massachusetts. The structure ascribed to the Connecticut field differs radically from that of Davis and Griswold, being characterized by folds instead of faults. All trap sheets are held to be contemporaneous.

With the aid of these maps and other conjectures ninety-one localities of fossils, ranging from Massachusetts to North Carolina, are classified with reference to the five formations discriminated in Pennsylvania; and lists are given of the species reported from the several localities. It is thought that the uppermost and lowermost beds may differ widely in age, the Norristown being possibly as old as Permian.

The paper is emphatic, not to say eloquent, in its characterization of the fatuity of the opinions it controverts, but the dangers which lurk in rhetoric are minimized by the suppression of names.

It is only through extrapolation that the two researches are made to appear discordant. If the structural results of elaborate field study in Pennsylvania be compared with the results of similar work in Connecticut, substantial agreement is found. In each district the series is very thick, has a dominant dip in one direction and is expanded in outcrop by faulting. G. K. G.

The Optical Recognition and Economic Importance of the Common Minerals Found in Building Stones. By LEA McI. LUQUER. (School of Mines Quarterly, Vol. XV., No. 4, July, 1894).

The microscopic examination of thin sections of building stones was first recommended by Cordier in 1816, and H. C. Sorby was one of the first to successfully put it in practice. The facts determined by the microscope are divided into two classes: 1. Mineralogical, including (*a*) the component minerals, (*b*) the chemical composition of the minerals, (*c*) the condition of the minerals. 2. Physical or structural, including (*a*) porosity, (*b*) cohesion, (*c*) homogeneity. Thirty-eight rock-forming minerals are described, and a short bibliography is given of the articles consulted in the preparation. T. C. H.

Landscape Marble. By BEEBE THOMPSON (The Quarterly Journal, Geological Society, Vol. L., Part 3, No. 199, August, 1894, pp. 393–410).

The first published description of the landscape marble occurs in a work by Edward Owen in 1754. The name "Cotham Stone" comes from Cotham House, near which it was quarried. The stone is described as a close-grained argillaceous limestone with no distinct evidence of concretionary origin. The upper surface is often much wrinkled, the interior characterized by dark markings. Two landscapes are shown in some specimens. The microscopic and chemical characteristics and mode of occurrence are briefly described. The following theories, proposed by others to account for the peculiar markings, Mr. Thompson considers inadequate: (1) Escape of imprisoned air; (2) gaseous emanations; (3) infiltration of dark mineral matter; (4) shrinkage of the stone. He thinks they are due to interbedded layers of vegetable matter. Experiments were made to reproduce the characteristics of the landscape marble, and an imaginative word-picture is drawn of the conditions under which the writer supposes the stone to have been formed. T. C. H.

The Famous Connecticut Brownstone. By BURTON H. ALLBEE (Stone, Vol. IX., No. 1, June, 1894, pp. 1–31).

The famous Connecticut brownstone quarries at Portland have been operated for more than 200 years, and at the present time are worked on a gigantic scale. Mention is made of these quarries in the official records of Middletown, September 4, 1665, and in 1690 six acres were sold to the town by the Middlesex Quarry Co. The quarrying is done at present by three companies, who utilize more than 1,000 acres, and employ 1,000 to 1,200 men. The annual production varies from 1,700,000 to 2,000,000 cubic feet, half of which is high-grade dimension stone and the remainder used for piers, foundations, etc. The quarries are located on the bank of the Connecticut river, stretching for two miles along its course. Channelers, steam drills, and blasting are employed in the quarry. Average blocks are from two to five feet thick, but blocks measuring 128 feet by 20 feet by 11 feet have been loosened. The quarries are now 200 feet deep.

The stone is of Triassic age, and has long been noted for the bird and bird-like serpent tracks which occur in it. Chemical analysis shows it to contain 70.11 per cent. silica, 13.49 per cent. alumina, and a small per cent. each of iron oxide, manganese, lime, magnesia, soda, and potash. It has a specific gravity of 2.35 and weighs 150.75 lbs. per cubic foot. It has a crushing strength of 10,000 to 10,900 lbs. per square inch.

The stone has been used to some extent for monuments but is primarily a high-grade building stone, and as such has been shipped to all parts of the United States. Its great durability is shown by the fact that on tombstones which have been standing more than 200 years the lettering is still distinct. The article is illustrated by thirty full-page plates, one a representation of the brownstone in colors. T. C. H.

The Lake Superior Sandstones. By H. G. ROTHWELL (Stone, Vol. IX., No. 1, June, 1894, pp. 59–61).

The article is supplementary to an earlier one published in the proceedings of the Michigan Engineering Society for 1891. The quarries at or near

Ashland and on the island of Bayfield produce an excellent building stone, yet not without defects. From one of the quarries the largest block of sandstone ever quarried was taken.

The Portage-Entry red sandstone is very popular on account of its fine grain, easy splitting and sawing qualities, and easy manipulation under the tool. In some localities it loses its bright color and becomes streaked. The Marquette Raindrop stone is rapidly growing in favor. It is of Potsdam age and older than the preceding stone. The sandstone from Keweenaw Bay took first prize at Philadelphia and Chicago for building sandstone. Analyses and crushing strength of the different varieties are given. T. C. H.

The Great Bluestone Industry. By HENRY BALCH INGRAM (Popular Science Monthly, July, 1894).

The writer states that New York City, which uses such large quantities of North or Hudson river bluestone flagging, has the finest sidewalk pavements in the world. The bluestone is a fine-grained, compact sandstone, extremely hard and made up of microscopic crystals of the sharpest sand. The stone occurs in a belt stretching from the Helderberg Mountains in Albany county diagonally across the southeastern portion of the state into Pike and Wayne counties, Pennsylvania. The belt varies in width, being in the shape of a scalene or obtuse triangle. The best quality of stone found along this belt is in Ulster county, where it has a medium to dark blue color. In the north part of the belt it has a gray color, and in the south part a deep red. So far as known the first quarry of this stone was opened near Kingston, in 1826. It is now one of the important industries of the state, the product of the quarries amounting annually to nearly $3,000,000. One quarry at West Hurley, known as the Lawson quarry, is said to have produced more than $4,000,000 worth of bluestone. The stone occurs in blocks piled up like cardboard, which are wedged off, lifted out, and cut up into the sizes required. Some are too small for flagging and are used for coping, pillar caps, etc. Sometimes monoliths of great size are obtained; one being 20 × 24 feet and 9 inches thick. The bluestone in Ulster county, New York, belongs to the Hamilton period, while that quarried in the other counties belongs to the Catskill group of Devonian age

T. C. H.

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GLACIAL STUDIES IN GREENLAND.

During the past summer it was the privilege of the writer to visit Greenland as geologist to the Peary Auxiliary Expedition, and to study some of the glaciers of its middle and northern portions. A sketch of the observations made, so far as they are deemed worthy of publication, and a discussion of their bearings will be attempted in a series of articles to which this is introductory. While the itinerary form, which is quite the fashion in Arctic literature, will not be followed, an outline of the journey may perhaps give some glimpses of Arctic conditions that will be of interest, and possibly of service, to those who have occasion to consider the ways and means of studying in the far north. Incidentally, it will be convenient to introduce some miscellaneous observations made on the way, which would not readily find place in a formal description or discussion of the glaciers.

Provision was made for the expedition by Lieutenant Robert E. Peary, Civil Engineer, U. S. N., last year, before leaving the United States on his third trip to Greenland. Its primary object was to communicate with his party, with the alternative purpose of supplementing its outfit, if necessary, should it remain, and of offering it a means of return, should its work be finished. A collateral object was to do such independent scientific work in geographical, biological, ethnological, and glacial lines as time and conditions might permit.

The expedition was organized and directed by Mr. Henry G. Bryant, Secretary of the Geographical Club of Philadelphia, whose exploration of the Grand River of Labrador is well known. The party was limited to seven, the six additional members being: Professor William Libbey, Jr., of Princeton University, geographer; Dr. Axel Ohlin, of Sweden, zoölogist; H. L. Bridgman, of Brooklyn, historian; Emil Diebitsch, of Port Royal, S. C., civil engineer; Dr. H. Emerson Wetherell, of Philadelphia, surgeon; and the writer. It was arranged that on reaching Inglefield Gulf my work might be conducted independently of the rest of the party, who proposed to make such examination of the coast of Ellesmere Land and Jones Sound as the condition of the ice would permit.

The party assembled at Brooklyn on June 20th, and took passage for St. Johns, Newfoundland, on the regular coasting steamer, Portia, of the Red Cross line. A few hours' stop was made at Halifax, which gave a little opportunity to see the interesting drift at that point. St. Johns was reached on June 25th without noteworthy event, unless it be that an iceberg south of Newfoundland, two at the entrance of St. Johns Harbor, and three or four on the distant horizon, gave a feeble prophecy of the ice conditions that were in store for us at the north. We remained at St. Johns awaiting the fitting out of the Falcon, a sealing steamer which had been chartered for the trip, until the 7th of July. The larger part of the interval was spent in the study of such geological formations as were accessible, especially glacial deposits. By the kindness of Dr. Taite I was able to see the interesting formations between St. Johns and Petty Harbor. Through the good offices of Mr. James P. Howley, government geologist, and the signal generosity of the Messrs. Reid, builders and operators of the Newfoundland Western & Northern Railway, Dr. Ohlin, Dr. Wetherell, and myself were permitted to spend four days in the interior, with all the facilities and comforts which a special train, under the personal direction of Superintendent Reid, could give, and with the added felicity of the lucid explanations of Mr. Howley, covering not only the region immediately traversed, but very much beyond. The road is in process of building for the government, and most of the excavations are fresh and unmodified. Our trip extended about 250 miles into the interior. I hope to give some of the results in the JOURNAL during the year.

It is worthy of more than passing note that Mr. Howley, as government geologist, was entrusted with the location of the preliminary line for this road, and, though it bisects the island, passing through a wooded and almost wholly unsettled region, he was able to lay it down with such fullness of knowledge and good judgment that only slight departures were found advisable on fuller surveys. It is equally gratifying to make note of a government reposing the determination of the most important feature of its greatest commercial undertaking in the hands of its scientific adviser. The builders and operators of the road, the Messrs. Reid, appear equally appreciative of Mr. Howley's knowledge and counsel. The road is to terminate at the southwestern angle of the island, traversing the coal beds of the southwestern portion which Mr. Howley has recently exploited with favorable results. The completion of the road and the establishment of a steam ferry to Cape Breton will very greatly improve the now very poor communication between the mainland and St Johns, the point of departure, directly or indirectly, of so many Arctic expeditions.

On the 7th of July the Falcon, a stanch, full-timbered sealing steamer, specially fitted for ice work, and commanded and manned by experienced Arctic navigators, was ready, and the start was made.

Our course was direct to Cape Desolation, South Greenland. The voyage was almost without incident to that point, very little ice being seen. On the day after departure I noticed only two small masses of ice, on the day following, only one, and on the next two days, none at all. When this is compared with the much larger amount of ice reported off the coast of Labrador and Newfoundland by other vessels, and with the observations made on our return voyage, it seems to warrant the inference that the berg-bearing current was comparatively narrow, and that it hugged the mainland coast somewhat closely. If this is a general fact, the total amount of ice drifting south is liable to be exaggerated in estimates based on the reports of coasting vessels. My observations farther north lend support to this; but of course the observations of a single voyage are much too slender to justify a conclusion.

Early on the morning of the 12th we sighted Cape Desolation, which lies about 150 miles west-northwest of Cape Farewell. The first glimpse of the topography of Greenland was full of suggestiveness. The aspect of its coastal mountains at once arrested attention on account of their marked ruggedness and angularity. The sky lines were strongly serrate, and the lower angles generally sharp and harsh, except, in some measure, near the base. Flowing contours did not much enter into the general view, though they might be found here and there by search. The dominant lines of sculpture lay in vertical, not in horizontal, planes. The inference was, therefore, close at hand that they owe their fashioning to the familiar meteoric agencies that work vertically, and not to the horizontal rasping of ice flowing out from the interior. This may not be wholly true of the lower contours which could not be seen to good advantage. Glimpses of the great inland ice cap were caught at intervals between the mountain peaks. According to the charts of Greenland, the border of the inland ice here lies but a few miles back from the coast line, and this nearness intensifies the significance of the unsubdued angularity of the coastal mountains. The bearing of this angular topography upon the problem of the former extension of the ice, and especially upon the broad question whether the ice sheet of Greenland once crossed the Baffin basin and became the source of the North American glaciation, as held by some geologists, at once presented itself, and stimulated as careful a scrutiny of the coastal topography as was practicable. This line of observation was continued assiduously throughout the whole length of coast followed, from Cape Desolation to Inglefield Gulf, as far as the circumstances of the voyage permitted, both going and coming. Fogs and night made many breaks in the series, but out of the something more than 1100 miles of coast skirted, sufficient was seen to afford a fairly good basis for drawing a conclusion, so far as this kind of inspection would justify one at all. As I hope to discuss these observations collectively, they will not be further referred to in this sketch.

We had little more than come near enough for a clear view of the coast of Greenland before we encountered the outer edge of the East Greenland ice pack. It is an interesting fact that the well-known Arctic current which flows southward along the eastern coast of Greenland, bearing a formidable ice pack, curves around Cape Farewell and follows the western coast *northward* for several degrees of latitude, though it becomes broadened and scattered somewhat in this portion of its course. It then gradually recurves to the west and south and descends the Labrador coast, its burden of ice being progressively melted and dispersed. The charts name Holstensborg, which lies about seven degrees north of Cape Farewell, as the limit of this north-flowing current.

We found this stream of floe ice very compact and closely hugging the coast south of Cape Desolation. An estimate of its breadth by an officer of the vessel was fifteen or twenty miles, but a liberal allowance for probable error should doubtless be made. It is reported to be often much wider than this. At the point we encountered it the outer edge was quite sharply defined, and although the sea was unusually calm, the presence of the pack was announced at some distance by a continuous roar arising from the action of the ocean swell on the border of the crowded floes of ice. Outside of this compact stream, small masses of much eroded ice were scattered over a narrow belt, forming a slight bordering fringe. The ice of the main pack was quite firm and solid. To a large extent it retained its original tabular form, but not a few of the masses were reduced to very irregular and often very picturesque shapes. The melting to which all had been subjected was notably more rapid at the edge of the water than either above or below, and the result was a girdling incision at the water level tending to reduce the mass to a double tabular form, which was sometimes carried so far as to approach the hour-glass form. The thinner, and usually smaller, table was naturally above, and the thicker and larger below, for the obvious reason that the greater mass of the ice was submerged. The breaking away of segments of these tables and various other inequalities of reduction often resulted in the tilting of the mass and the establishment of a new zone of maximum melting, leading on to further inequalities. While other agencies participated in forming the odd shapes assumed by the larger masses of ice, they appear to have been chiefly due to the superior rate of melting at the water's edge. It was only when the process of dissolution had reached an advanced stage that the more unique and fantastic forms were usually assumed. These were naturally most prevalent among the scattered masses on the border that were more freely bathed by the warmer surface water of the open sea.

The odd forms usually have, as a common feature, a submerged, massive base from which irregularly eroded portions stand forth. This base is the remnant of the lower table already mentioned, which retains much of its massiveness after the air and surface water and direct sunlight have wasted the upper part. To these massive bases the floes often owe their preservation long after their own slenderness and ill-balanced proportions would have wrought their destruction. Fragile columns, with or without entablatures, slender pinnacles, and delicate forms of various types, stand forth from these submerged bases, giving, at a little distance, an impression of such fragility as to lead one to wonder how they retained their integrity, until a near approach revealed the substantial base. A great variety of imitative forms are observable. Often the exserted portions resemble the limbs of an inverted animal. Not uncommonly the more massive projections from the submerged base stand forth like the prows and poops of oriental ships. Resemblances to mythological creatures, to architectural structures, to sea birds, to plants, and likenesses of all sorts might be imagined without much exercise of the fancy. These odd forms, however, were quite subordinate in size and number to the simpler thick pans merely worn more or less about their edges. The aggregation of these made up the great mass of the ice pack.

The ice of the floes was often very thick, and, although no measurements were made, it seemed within safe limits to estimate the depth at fifteen to twenty feet and occasionally more. It retained so much of its integrity of structure as to give exquisitely beautiful tints of green and blue. The blue tones appeared to be chiefly due to light transmitted from the sky, the green to light that arose from beneath the water, thrown back by submerged, projecting shelves. The intergradation of tints was beautiful beyond expression.

A few, but only a very few, icebergs were embraced in the ice pack; from which the inference is drawn that either the East Greenland glaciers do not freely put forth icebergs, or that they still remained locked up in the icebound harbors of the coast. The same inference must be extended, I suppose, to the glaciers of the west side so far as skirted by this current. The process of developing fantastic forms among the icebergs was apparently identical, in large part, with that involved in the sculpturing of the ice floes.

But I have run ahead of my narrative somewhat. On encountering the border of the pack off Cape Desolation about nine o'clock on the morning of the 12th, the course of the vessel was turned westward and skirted its edge until midday, when the pack was found more scattered, and the Falcon entered it, worming her way from opening to opening, for the greater part, but forcing a passage by direct collision when necessary. The floes, however, continued to be measurably thickset, particularly toward the coast. A direct crossing of the stream seemed to grow more difficult as it was penetrated, and towards evening the course of the vessel was directed to the westward to escape the closer packed ice near the coast. Several hours were required to reach the more open portion, and during the night, and most of the following day, there were frequent encounters with belts of ice. These were usually separated by tracts of open water. The northern limit of the ice pack, as seen by us, lay nearly opposite the Frederickshaab glacier, Lat. 62°30′. This gives an extent along the coast north of Cape Desolation of about three degrees.

The wrapping of the East Greenland ice pack about the southern extremity of the island greatly affects the climate of the coast, and doubtless the glaciation of the interior. The harbors of this part of the coast are reached only with difficulty during the early part of the summer; indeed, during June and July the coast between Lat. 60° and 65° is less accessible than that between Lat. 65° and 70°. We found East Greenland ice still in the inlets and among the islands about Goodhaab (Lat. 64°) on our return in the early part of September.

As previously remarked, comparatively few icebergs were seen among the floes from East Greenland. Soon after our escape from the pack, a feeble train was observed nearly opposite the Frederickshaab glacier. Only a dozen rather small icebergs composed the procession. Beyond these, few icebergs were seen until, two days later, we encountered a grand procession streaming out from Disco Bay.

While we were immediately opposite the Frederickshaab glacier, the coast was shrouded in low clouds and fog. But these cleared away before we were out of the range of vision, and, through the aid of field glasses, we had a measurably satisfactory, though distant, view of this most beautiful glacier. Our position was such as to make its magnificent profile, as it issued from among the peaks of the coastal mountains and stretched, with a gentle decline, far out on the lowlands that form the immediate shore, the most striking element presented. Notwithstanding its great massiveness, its freedom from constriction, and its relatively gentle decline, it was strongly crevassed at some points on its flanks, and on its crest line. On its lateral border vertical ice-walls appeared, but from our position I could not detect any at the extremity.

On the evening of July 15th, we encountered a grand procession of icebergs moving southwesterly from Disco Bay, into which they had been discharged (with perhaps few exceptions) by the Jacobshaven glacier. Thirty were in sight at once. It was not so much the number, nor the size, as the variety and picturesque beauty, that commanded admiration. The Jacobshaven icebergs are noted for their pinnacled and angulated forms. It is even held by Greenlanders that they may be distinguished from the bergs of other glaciers by their distinctive forms. From what I saw, I should think this measurably true.

Early on July 16th, we arrived at Godhaven, on the south side of Disco Island, and, after the customary formalities of entrance to a Greenland port, visited the lower glacier in Blase Dale,

FIG. 1. Iceberg off the Crimson Cliffs, northern part of Baffin's Bay. Characteristic floe-ice of the region in the foreground.

which creeps down from a local ice cap covering the southwestern uplands of the island. This glacier was again visited on our return, forty-eight days later, and this constitutes the longest interval afforded me for the study of seasonal effects on the surface of the same glacier. Disco Bay was found thickly dotted with Jacobshaven icebergs, and presented a most enchanting picture, set off, as the picturesque ice masses were, by a calm, blue sky, a clear, genial atmosphere, and the red-brown cliffs of Disco Island. While at Godhaven we were fortunate enough to secure specimens of the famous "Ovifak" iron.

Leaving Godhaven on the evening of July 17th, we skirted the west coast of the island, and on the afternoon of the 18th encountered a magnificent procession of icebergs emanating from the Umanak Fjord. These were much larger, but more tabular and less picturesque, than those derived from the Jacobshaven glacier. Thirty or forty of the larger order were in view at the same time, besides many smaller ones. They probably came from the great Karaiak glacier. Their drift was southwestward. A more scattered procession moved parallel to this on the north. It appeared to come from the straits between Ubekyendt Island and the Svarten Huk Peninsula, and was doubtless chiefly derived from the Kangerdluksuak glacier.

During the night of the 18th the first northern pack ice was encountered at a point south of Upernavik, between latitudes 72° and 72° 30′. This ice was much thinner and more completely tabular than that of the East Greenland pack previously described. It lay lower in the water, and was usually confined, even in its most solid portions, to a thickness of from three to five feet. Except where broken up at the edges by the collision of the pans, it presented little relief from the water's surface. The general expression throughout the whole of the northern portion of Baffin's Bay, so far as seen by us, was not unlike that of ordinary river or lake ice when broken up, save in its greater expanse. In this respect it contrasted somewhat markedly with the East Greenland ice, which, by reason of the tilting of the thick masses, due to irregular melting, presented a quite unequal surface. These differences, which spring from original differences in the thickness of the parent ice sheets, doubtless point to different conditions of origin and history. The floe ice of the upper part of Baffin's Bay is chiefly the product of a single season, that of East Greenland may be inferred to be the product of several seasons' cumulative work, or else to come from a region of much more intense cold, and more prolonged season of low temperature; the former more likely than the latter.

On the 19th much ice was met, which to the experienced officers of the ship clearly foretold the unusual amount of ice which we subsequently met to the northward. A most charming view of the "midnight sun" was presented that night, as the vessel zigzagged its way through the ice floes that filled the whole horizon and gave a strange, wintry aspect to the whole scene.

The hope of the captain was that, turning away from the coast near Upernavik, he might be able to effect the "middle passage" across Melville Bay, direct to Cape York, but early on the morning of the 20th, after about a day's struggle with the ice, the attempt was abandoned, and the Falcon turned back toward the coast. All day she worked about through the leads, or bunted

FIG. 2. Icebergs of Cape York; still held in the bay ice that remains attached to the shore. The point of view is about two miles off Cape York, which lies a little to the left of the picture. Cape York Eskimos in the foreground.

her way from one to another, in the endeavor to reach the more persistent lanes of water that are usually developed between the moving ice of the bay and the stationary ice that still remains attached to the shore. Success in this was reached during the evening, and the sail of the 21st was a continuous delight, as the vessel followed a broad lane concentric with the coast of Melville Bay, affording a rare opportunity of studying with our glasses the undulating slope of the inland ice that forms the horizon throughout almost the entire circuit of the bay. From the extensive ice walls at its margin numerous large icebergs had broken away, but were still detained in the fixed bay ice. A series of promontories and nunataks break the continuity of the ice border. The most remarkable of mirages occupied large segments of the horizon nearly all day, and limited the field of good observation, but their extraordinary character (there being two, three, and even four reflecting horizons superposed on each other, giving rise to imitations of castellated structures of the most fantastic and beautiful forms) was some compensation for the illusions they constantly threw over large portions of the landscape.

That afternoon, when within sight of Cape York, and in the highest spirits over the delightful passage of so much of the dreaded Melville Bay, the lane we had followed to so great advantage led away from the land, and became broken and intricate. During the night the ice closed upon the vessel while trying to force her way through a narrow passage, and she was nipped astern and her rudder severely strained, but not permanently injured. The vessel was held fast, with a strong "list," all the following day, which was Sunday, and so, by no virtue of ours, the day became "a day of rest" and, I need scarcely add, of more than puritanical sobriety. About three o'clock next morning, however, the ice relaxed, the vessel settled back to her normal position, and again began threading and ramming her way through the pack with such success that by ten o'clock she was in a wide lane leading to Cape York, which was reached at noon; or, to speak more accurately, the fixed ice, which extended about two miles out from the cape, was reached. During a short stop here specimens of the rock in place (gneiss) and of the drift (gneisses, granites, syenites, red and white quartzites, etc.) were collected, photographs of the glaciers and the icebergs were taken, and a few general observations made. The bay east of the cape was full of icebergs derived from the glaciers that debouch into it, and at its mouth there was a very notable cluster, probably aground. Numerous large icebergs also lay along the coast northwest of Cape York, skirting the "Crimson Cliffs" as far as Conical Rock. As we sailed along these Crimson Cliffs (their color is due in part to "red snow," *protococcus nivalis*, and in part to red lichens, and not to the hue of the rock) I noted eleven glaciers, or glacial lobes, coming down from ice caps whose heights did not exceed three thousand feet. A few miles beyond lies the Petowik glacier, about seven miles wide. It descends by a gentle inclination from the inland ice, its course being unusually direct, and its surface smooth and unruptured by crevasses. In general

FIG. 3. *Contrasted Topographies.* No. 1.— Dalrymple Rock, near the Greenland coast at the mouth of Wolstenholme Sound, about 77° N. Lat. Formed of hornblendic gneiss. Illustration of angular outlines.

habits and relations, it resembles the great Frederickshaab glacier, but it is smoother, less massive, and much less impressive.

On the morning of the 24th we were off the mouth of Wolstenholme Sound. A landing was made at Dalrymple Island, one of the notable nesting haunts of the eider duck. While the hunters of our party made a generous addition to our provisions, I secured an excellent set of specimens from the finely foliated series of hornblendic gneisses that form the island. Saunders Island, which lies not far to the north, was an interesting object, as it is composed of conspicuously stratified red rock (with little doubt sandstone) banded with gray layers. As almost the whole of the coast to the southward is composed of crystalline rock, the introduction of the clastic series here commands an interest it would not otherwise possess. Wolstenholme Island, to the southeast, presents the same appearance as the "Crimson Cliffs," which are gneissic. Distant views of the glaciers in and

FIG. 4. *Contrasted Topographies.* No. 2.—Southeastern Carey Island. Situated in the midst of the northern part of Baffin's Bay, thirty or forty miles from the Greenland coast, W., N. W. from Dalrymple Rock, and formed of almost identical rock. Illustration of rounded outlines.

north of Wolstenholme Sound, and of the ice cap covering the adjacent plateaus, were afforded.

One of the missions of the expedition was to search for further information respecting the missing Swedish naturalists, Björling and Kallistenius, who were wrecked on the southeasternmost of the Carey Islands, two years ago. The course of the Falcon was therefore turned westward toward them. A landing was effected during the afternoon, and the search continued until midnight, with no better results than the mournful satisfaction of finding many relics of the unfortunate party, and of collecting, and re-interring with burial service, the bones of one of the party, which had been disinterred from their shallow grave and scattered about, apparently by burgomaster gulls. Collections of rocks were made from the islands, which are gneissic. Foreign drift was found on them, the significance of which is quite important taken in connection with other data gathered with reference to the former extension of the ice. This will be discussed later.

Early on the morning of July 25th, the date named for reaching Inglefield Gulf by Mr. Bryant in his prospectus, the Falcon entered Whale Sound, the southern entrance to the gulf. Finding the inner portion of the sound covered with unbroken ice, the vessel passed between the Northumberland and Herbert Islands into Murchison Sound, the northern entrance to the gulf. This was also found covered with ice, and after searching in vain for a practicable way through it, the Falcon was made fast to the ice, only some forty odd miles from her primary destination, which she would have reached on schedule time but for the unusual tardiness of the breaking up of the ice. The persistence of the ice here, and along the coast of Ellesmere Land, and in Jones Sound on the west side of Baffin's Bay, rendered the geographical work contemplated by Mr. Bryant almost fruitless. It very considerably modified my own work, and caused some loss of time, but was not without its very considerable compensations, so far as my part of the work was concerned. By reason of their detention I became much indebted to the other members of the party, and particularly to Professor Libbey, for hearty and very considerable aid. Thwarted in their own immediate plans, they turned cordially to the other scientific work which was available; and it is well-nigh impossible to be detained at any point on the coast north of Cape York where glaciers and ice caps profitable for study are not near at hand. To Professor Libbey's rare skill in photography science will be indebted for many choice views of glaciers which the kodak, my own rather uncertain dependence, might not have furnished, though this proved better than I had reason to expect, and out of the 350 views taken I shall find ample illustrative material.

On the day following our arrival a base line was measured on the ice under the superintendence of Professor Libbey, and with the assistance of Mr. Bridgman and Dr. Wetherell, with a view to the more accurate mapping of the surrounding region. This was abandoned the next day, however, for the ice having relaxed and a lane having opened northward, the Falcon moved to a point close in to the north shore, opposite the Igloodahomyne glacier,

FIG. 5. The Igloodahomyne Glacier, near mouth of Murchison Sound, North Greenland. A dependency of the inland ice.

in the hope of finding broken ice and a practicable passage along the north shore. The Igloodahomyne glacier was examined by Professor Libbey, Dr. Wetherell, and myself on the following day. During the next two days the vessel was advanced several miles into Inglefield Gulf, where it was again arrested opposite the glaciers of the Red Cliff peninsula, which furnished a profitable field of study until August 4th. Meanwhile, communication had been opened over the gulf ice with Lieutenant Peary's headquarters, and we learned with extreme regret that the extraordinary severity of the spring storms on the ice cap had so nearly destroyed his dog team, and had so far crippled his men, as to compel a return to headquarters and a postponement of his exploration of the extreme borders of Greenland until next year.

On August 4th, by invitation of Lieutenant Peary, I accompanied him to his headquarters, Anniversary Lodge, on Bowdoin Bay, (Lat. 77° 44′), and made that a working centre until August 23rd. Here, with the great ice cap near at hand, the local ice cap of the Red Cliff peninsula directly opposite, and nine glaciers of varying forms and habits within a half dozen miles, I enjoyed every facility which the phenomenal situation and the great kindness of Lieutenant Peary and his party could furnish. In no small degree the misfortune that turned them back was my gain. Lieutenant Peary's intimate knowledge of the region, his wide observation upon the glaciers of middle and northern Greenland, his counsel and his personal guidance, and his ample equipment for northern work, all of which were freely placed at my service, were of incalculable aid to me. Mr. E. B. Baldwin, meteorologist to the party and an enthusiast in exploration, was my nearly constant guide and companion, and did all in his power to aid in the work. One would be indifferent indeed, if, under these circumstances, he did not press the work to the utmost limits of physical and mental endurance, for the continuous daylight put no limit to daily hours.

I learned with gratification that Lieutenant Peary had undertaken the mapping of the geographic features of a large territory adjacent to Inglefield Gulf, and that he had commenced systematic observations on certain of the glacial phenomena, among others the measurement of the rate of glacial motion by stakes and transit, and by a series of photographs. This proved peculiarly fortunate, under the circumstances, for, though I went with a full instrumental outfit for measuring glacial movement, and for making such geographic determinations as might be necessary for plotting the glaciers studied, the adversities of the season that made it necessary to leave the Falcon thirty miles from the main field of work, and to make the journey by foot or by sledge over uncertain bay ice, much broken by leads, rendered the transportation of the outfit impracticable. The geographic outlines which I shall be permitted to use in these articles are chiefly the contribution of Lieutenant Peary. The fuller data which he will himself publish in due time, relative to glacial distribution, movement, and many other features, will be an important accession to glaciology.

A detailed narrative of the excursions made from Anniversary Lodge to the ice caps and to the adjacent glaciers does not seem to me to possess sufficient interest, apart from the results, which will be fully described, to warrant giving it a place here.

Between the 23rd and the 26th of August, the Falcon, which had previously reached the Lodge, visited several points at the head of Ingefield Gulf, and an opportunity was afforded to see, at hand, two of its great glaciers, the Leidy and the Hubbard, and to view from near points a complete panorama of the remarkable group that gathers about the head of the gulf. These lie about one hundred miles back from the general line of the west coast and are opposite the greatest breadth of Greenland's ice cap.

On the 26th of August the return trip was begun, and, besides further studies of coastal topography, a visit to two additional glaciers on Disco Island, and some study of a coastal plain, very analogous to that of Norway recently described in the Journal by Dr. Reusch, the journey possessed little of scientific interest. Floe ice was still abundant along the "Crimson Cliffs" and the coast east of Cape York, but the northern part of Baffin's Bay was free from floes on the line of our passage, and almost free from icebergs. On the coast of Labradors, which we somewhat closely approached, only a few icebergs were seen. We arrived at St. Johns, Newfoundland, on September 15th, which may be said to be schedule time. Here I parted with my aid, Mr. Z. Butler, who had rendered faithful service throughout the trip. Leaving the Falcon at St. Johns in company with Mr. Bridgman, with whom I parted at Halifax, I returned by way of Canada, stopping two days to see the interglacial formations at Toronto, which promise such important evidence bearing on the diversity of the glacial period.

T. C. Chamberlin.

ON A BASIC ROCK DERIVED FROM GRANITE.

WHILE studying the hematite deposits of St. Lawrence and Jefferson counties, New York, under the direction of Dr. James Hall, State Geologist, the writer had occasion to examine some interesting rocks associated with the ores, which are worthy of note.

A brief description of the rocks is given in the report on the region presented to Dr. Hall, in which especial attention is paid to their relation to the problem of the origin of the iron ores. The aim of the present paper is to supplement that report with a more complete account of one phase of these rocks, occurring at the Old Sterling mine, in Antwerp, Jefferson county.

Mode of occurrence of the rock.—The mine consists of a large open pit, together with considerable underground workings. The surface rock is Potsdam sandstone, beneath which the ore, a red hematite, occurs in large irregular masses, intimately associated with a rock of entirely different character, which is the subject of this paper. The contact between this rock and the ore is extremely irregular, as is well shown in the open pit where the ore has been removed leaving the rock in projecting knobs, ridges, and walls, with intervening pockets and hollows. In the underground workings it is not uncommon for the ore to be suddenly cut off by the rock and to appear again after passing through a greater or less thickness of it. The contact is evidently irruptive and is precisely like the contacts of granite and limestone which are common in the region, although the rocks involved have a very different appearance. Emmons,[1] who has given the only detailed account of the ore and associated rock, considered them both igneous, and called the rock serpentine, a name which has clung to it ever since. The facts adduced by Emmons

[1] Geology of New York. Second District, p. 97.

to prove the igneous nature of the rocks were hardly of a character to justify the conclusion, and that he was right in regard to the so-called serpentine must be regarded as a mere matter of chance.

Description of the rock.—A hasty examination of many specimens of the rock would seem to warrant Emmons' determination of it as serpentine. It is dark green or black, massive, and very fine grained or quite aphanitic, with rather waxy lustre, and abundantly slickensided. Thus far it is precisely like serpentine, and many specimens show no other prominent features. But most of the rock is mottled with abundant white, vitreous spots, of extremely variable size. Where these are large enough to be clearly seen (and they may reach three or four inches in diameter), it is evident that they are fragments of quartz. Specimens in which the grains are small and evenly distributed closely resemble a porphyritic rock with glassy or aphanitic groundmass. In the presence of this quartz, there is a marked divergence from the ordinary character of serpentine.

The slickensides which are so abundant in hand specimens are developed on a large scale in the rock exposed in the mine pit. They run in every direction, and on this account most of the exposed surfaces are slickensided, being, as a rule, curved and showing a beautiful polish. Such surfaces measuring more than one hundred square feet are not uncommon. A good example appears in the centre of the pit upon a dome-like mass of rock.

Origin of the rock.—Accepting the evidence afforded by the contact, that the rock must be igneous, a difficulty is met at once in its apparently contradictory features. Its serpentinous aspect suggests derivation from a basic rock, but conflicting with such a supposition is the presence of much quartz. This mineral is, moreover, so distributed that it cannot be accounted for as inclusions, or, to any great extent, as secondary. These facts, noted in the field, led the writer to a close examination of the exposures in the hope of finding some portion of the rock which, through less complete alteration, would give some clue to its origin. The examination resulted in the finding of several small patches, which, though considerably altered, still retain enough of their original character to show conclusively that they are granite. The transition between the fairly fresh granite and the serpentine-like rock is very gradual, the feldspar losing its fresh appearance and passing over into a green aggregate, while the quartz decreases in quantity, till in some specimens it is wholly lacking. To the naked eye no other minerals are visible, the original granite having been a coarse, pegmatitic variety.

The alteration of an acid granite into a nearly black, apparently basic, rock is an exceptional phenomenon, and yet in this instance the field evidence alone is of such conclusive nature that there can be no doubt that such is the case. Furthermore, the operation has taken place on a large scale, for there are hundreds of tons of the altered rock in sight, and it is impossible to tell how much is underground.

Additional evidence that the rock is an alteration of granite is afforded by the fact that at the bottom of the underground workings the ore rests upon a granite which differs only in freshness from the material of the least altered patches in the serpentine. But even this granite shows the beginnings of the alteration.

Megascopical aspect of the alteration.—A specimen of granite from the bottom of the shaft is a decidedly coarse-grained rock, made up of quartz and feldspar, the latter predominating. Besides these distinct minerals there is a limited amount of greenish material which fills the interstices between the essential minerals. The latter have very irregular outlines, the feldspar occurring in decidedly larger individuals than the quartz. The former mineral generally has bright cleavage faces; less often they are dull and earthy. The color is gray with a very faint pink tinge. The quartz is colorless and clear, with the usual vitreous lustre.

The granite of the least altered patches in the "serpentine" differs from such a specimen in having a larger amount of the green aggregate, and in the color of the feldspar. This color is a decided pink or red, but there can be no doubt that it is itself a result of alteration, having replaced an original gray like that of the feldspar of the specimens from greater depth. These patches of comparatively little altered granite are only a few feet in diameter, and shade off into the typical serpentine-like rock on all sides. The passage is gradual as a whole, but more rapid in some spots than in others, so that, while it is impossible to draw any line of demarcation in the stages of the process, lines uniting equally altered portions around a granite core would be extremely irregular.

From the centre of such a core outward the green aggregate increases, while the feldspar gradually disappears, till finally there remains a waxy, deep green mass holding fragments of quartz. In some highly altered specimens the quartz is very conspicuous against the dark groundmass; in others it is entirely absent, though this is never true of large masses. In still other cases lumps of quartz several inches in diameter occur. These always lie close to one another and usually along definite zones, showing clearly that they are fragments of crushed veins.

In the slightly altered granite cores there are no conspicuous indications of disturbances, the slickensides being confined to the highly altered phases of the rock, in which, as stated above, they are very prominent. This fact, together with the great irregularity in the direction of the slickensides, suggests that the movements which have formed the polished surfaces may have resulted from changes of bulk in the rock attendant upon the alteration, as in the case of true serpentines.[1]

It should be noted; however, that the granite cores are so small that they might fail to give evidence of considerable movements in the mass as a whole, and such movements may account for the slickensides, as they do for the crushing of the quartz in veins and scattered through the rock. That the latter

[1] J. S. DILLER, Geology of the Lassen Peak District, 8th Ann. Rept., U. S. G. S., p. 401.

is the case is clearly shown by the microscopic structure of the rock, as stated below.

Microscopical details of the alteration.— A microscopical examination of sections illustrating all of the phases of alteration shows some variation in the intermediate stages of the process, but considerable uniformity in the final results.

Sections of the least altered granite show it to consist of orthoclase, microcline, and quartz, with occasional stout prisms of apatite and irregular masses of tourmaline. Granite of this character is quite common in the region, and has been previously described by the writer.[1] The feldspar has the common dull and cloudy appearance. The quartz contains abundant fluid inclusions and great numbers of the hair-like bodies usually considered rutile. Undulatory extinction is constant, and much granulation is shown in nearly all sections.

Alteration begins with the development of a greenish aggregate in the feldspar. This may form irregular masses, or may be confined to cracks. Very often quite large portions of the aggregate have angular outlines formed by cleavage cracks of the feldspar. Where the aggregate has formed in a zone of crushing, it usually contains small, angular fragments of feldspar which at first sight look like crystals of some newly formed mineral. The areas of the aggregate are very unequally distributed in the granite, one portion of a specimen being greatly changed, while another portion remains unaltered. In some cases this is clearly due to the arrangement of cracks and crushed zones, but often there is no apparent reason for it. As the alteration proceeds the areas of the aggregate gradually extend until they entirely replace the feldspar, leaving no trace of its former presence.

At the same time the quartz is attacked, but, as a rule, it yields much more slowly than the feldspar. In the absence of cleavage the alteration proceeds along the borders of the grains and in the irregular cracks. The areas of alteration product

[1] C. H. Smyth, Jr.: Petrography of the Gneisses of the Town of Gouverneur, N. Y. Trans. N. Y. Acad. Sci., XII., p. 210.

thus formed never have the sharp, angular outline that they have in the case of the feldspar. Irregular tongues of the aggregate eat their way into the quartz, gradually spreading, cutting across, and separating grains originally continuous, and finally entirely replacing them. Such complete replacement of the quartz is, however, exceptional, and seldom extends through any considerable mass of the rock. Although the quartz usually lags behind the feldspar in the process of alteration, the degree of change in the two minerals has no constant relation. For, on the one hand, a section whose feldspar is completely replaced by the aggregate may retain most of its original quartz, while, on the other hand, a section with quite fresh feldspar may show much alteration in the quartz. Not uncommonly the alteration proceeds most rapidly along the contact between the quartz and feldspar. It is hardly probable that this results from chemical causes; it must, rather, be due to the more ready circulation of solutions along these contacts. This may, perhaps, be accounted for by a tendency for quartz and feldspar to separate under mechanical strains.

The extreme result of the alteration is a mass of the greenish aggregate with no trace of either quartz or feldspar. But more commonly the rock consists of the green aggregate with a greater or less number of quartz grains.

Under low powers the aggregate has a felt-like appearance, and a green or yellowish color. With crossed nicols it shows aggregate polarization of varying intensity, the most thoroughly altered sections being nearly isotropic.

With higher powers the aggregate is seen to be made up of small, irregular scales, with a single pronounced cleavage. These scales are quite pleochroic in green and yellow, have a parallel extinction, and low double refraction. From these facts it is very probable that the scales consist of some member of the chlorite group, or of one of the nearly related hydrous silicates. An absolute determination of species is out of the question, and it is, moreover, probable that more than one species enter into the composition of the aggregate. Some sections show mingled with, or replacing, the green scales, colorless scales with similar cleavage, but no pleochroism, and having strong double refraction. In this case the mineral is probably muscovite. It is much less abundant than the chloritic mineral and disappears as the alteration becomes more complete. By this it is not meant to imply that the muscovite is an essential step in the process of change, as in most cases there is no trace of it, even in the earlier stages of alteration. Other substances are present in minor quantity, and generally of undeterminable character. In many cases they are evidently the result of the alteration of the normal green aggregate by ordinary surface agents, with the production of iron oxide, carbonates, etc. Such weathering often brings out very clearly a wavelike banding in the sections, which very closely resembles flow structure. When this structure appears in a section of the most highly altered rock, composed of the very low, doubly refracting aggregate, the likeness to a section of a glassy volcanic rock is striking.

Cataclastic structure is very pronounced in most sections, when the alteration has not proceeded so far as to hide it, and there can be no doubt that the crushing played an important part in the process of change.

Chemistry of the process.—As microscopical study gives no definite information in regard to the chemical composition of the altered granite, an analysis has been made of a carefully selected sample. For this purpose a specimen was chosen representing the extreme result of the process of alteration, being nearly free from quartz, with a deep green color and waxy lustre. A thin section cut from the specimen shows a mingling of green and yellow aggregates, with no trace of feldspar or quartz. The results of the analysis are shown in column I. No analysis has been made of the fresher granite, because even the best specimens are so much altered that the results obtained would give no clearer idea of the original composition of the rock than can be gathered from a consideration of its mineralogical composition.

	I.	II.	III.	IV.
SiO_2	29.70	26.88	29.45	46.90
Al_2O_3	17.03	17.52	18.25	35.73
Fe_2O_3	—[1]	—	8.17	—[1]
FeO	27.15	29.76	15.12	2.48
MgO	10.66	13.84	15.32	0.83
CaO	1.68	—	0.45	0.45
Na_2O	0.56	—	—	0.48
K_2O	0.10	—	—	6.41
H_2O	11.79	11.33	12.57	5.00
	98.63	99.33	99.33	98.88

I. Greatly altered granite, Old Sterling mine.

II. Prochlorite, St. Christophe.[2]

III. Delessite, Zwickau.[3]

IV. Alteration product of doubtful origin (probably derived from granite), Caledonia mine.

It has been shown that the original rock was an acid granite, consisting almost wholly of orthoclase, microcline and quartz, with no ferromagnesian constituents. From this there can be no doubt that it contained not less than 70 per cent. of silica, with a large content of alumina and alkalies, and little iron, magnesia, and lime. The analysis shows that the process of alteration consisted of a decided decrease in the percentage of silica and alkalies, with an equally marked increase of iron and magnesia, and the addition of much water. Moreover, this has not been a mere removal of some constituents, leaving relatively increased proportions of the others, but, on the contrary, there has been an actual addition of material from a foreign source. It is hardly necessary to say that the composition of this alteration product is totally unlike that of the product that would result from the alteration of such a granite under ordinary conditions. Of course the analysis represents, as already stated, the extreme result of alteration, but it is not probable that the results would

[1] The iron in I. and IV. is all calculated as ferrous, but there can be no doubt that some of it is in the ferric condition.

[2] Dana's System of Mineralogy, p. 654.

[3] *Ibid.*, p. 660.

be very different for an average sample. The silica would be increased by the grains of quartz, but would hardly exceed 40 to 50 per cent.

The results of the analysis and of the microscopical study bring into question the propriety of applying to the rock the name serpentine. Modern usage seems to justify the use of the designation "serpentine" for rocks composed largely of the mineral serpentine. But the analysis of the green aggregate composing the larger part of the rock under discussion shows a composition so different from that of serpentine, that there can be no doubt of the impropriety of applying this name to the rock. Analyses of different portions of the green aggregate would probably yield decidedly different results, so that it seems useless to attempt to identify it as a whole with any mineral species; but the analysis given, as well as the optical properties, indicates a much closer relationship with the chlorites than with serpentine. This relationship is illustrated by analysis II. and III., which are very similar to I., the difference being no greater than would naturally result from the variability in the composition of the minerals concerned.

Cause of the alteration.—In endeavoring to ascertain the cause which has led to such a complete change in the granite, it is evident that search must be made among the class of processes to which Roth[1] gives the name of "complicated weathering." For the alteration is not of a kind that could be produced by the simple agents of the normal weathering of rocks, nor do the facts indicate that it is a result of ordinary dynamic metamorphism, though, as stated above, crushing of the rock has been an important factor. The granite must have been attacked by some powerful chemical agent, whose action was not general, but, on the contrary, limited to this particular locality, and to such others as show analogous alteration products. A clue to the nature of the agent is afforded by the composition of the alteration product, and by the character of the associated rocks. From the analysis it is clear that the alteration has been brought about

[1] J. ROTH, Allgemeine und Chemische Geologie, Vol. I., p. 2.

by the removal of certain constituents of the granite, and the addition of a great amount of iron, with less magnesia and much water. The association of the altered granite with iron ore, suggests that the latter is in some way connected with the process of alteration. That such a connection does exist is shown by the fact that rocks similar to the altered granite, and sometimes of like origin, occur at all of the ore mines of this vicinity; while, on the other hand, nothing of the kind is found away from the ore, although granite is a very common rock.

Accepting the connection between the alteration of the granite and the presence of the iron ores, two hypotheses are suggested to account for the phenomena. The discussion of these two hypotheses involves the whole question of the origin of the iron ores, which is considered at some length in the report to which reference has been made. For present purposes only a very brief summary of the most salient points is necessary.

According to one hypothesis the granite is younger than, and has been intruded into, the iron ore. As a result of this intrusion the granite has undergone marked endomorphic changes, during, and subsequent to, the intrusion, becoming heavily charged with iron and assuming its present form. But this hypothesis is rendered doubtful (aside from its inherent weakness) by the absence of any contact phenomena in the iron ore, and by the presence of an analogous serpentine-like rock at another ore mine, which is derived from a finely laminated gneiss, instead of a granite. In fact, there is nothing to indicate that the change in the granite associated with iron ore is, in any way, the result of the action of heated solutions generated at the time of intrusion, while much evidence is at hand to prove that this is not the case. There is more probability in a modification of this hypothesis, by which it is assumed that the ore was originally siderite and that oxidizing meteoric waters changed it to the peroxide, with the production of much carbon dioxide, which, being carried in the percolating waters, might be a sufficiently powerful agent to bring about the alteration of the granite. This explanation would account for the alteration of gneiss as well as of granite, but does not remove the difficulty afforded by the lack of metamorphism in the iron ore at the Sterling mine. There are, moreover, other facts which need not be discussed here, indicating that the ore is probably a secondary concentration younger than the granite. Upon this supposition is based the second, and, in the writer's opinion, more probable hypothesis to account for the alteration of the granite.

This hypothesis assumes that at the time of the granitic intrusion the ore had not been formed, its present place being occupied by other rocks, chiefly limestone. The ore was formed by the gradual replacement of the limestone, through the agency of solutions which at the same time produced the alteration of the granite. This explanation requires that a source shall be found for the solutions supposed to bring about the whole series of changes. It is believed that such a source exists in a ridge of gneiss which rises a few rods west of the mine. The rock of this ridge is highly pyritiferous and contains also much magnetite. As the result of weathering, the surface becomes rusty, and the pyrite almost wholly disappears, leaving the rock light and porous. While this pyritiferous rock is not shown directly at the mine, there can be no doubt of its presence, as its strike is such as to carry it very close to the ore body.

The oxidation of the pyrite yields solutions containing iron sulphates and sulphuric acid. These solutions must be capable of producing very marked chemical effects, and are just the sort of agent required to account for all the phenomena under consideration. Working down the dip and coming in contact with limestone and granite, they would change the former to an iron ore, with the consequent formation of solutions of lime and magnesia sulphates. These solutions, as well as those derived directly from the pyrite, would attack the granite, and, being very different from the common agents of alteration, the product of their action would naturally be of an unusual character, as is the case with the rock under consideration. The solutions would have much more powerful chemical action than the ordinary agents of weathering and would supply the elements which, as analysis shows, have been added to the rocks.

While it is impossible to trace this process with precision, and there is no positive proof that it is what has actually occurred, still the explanation has much to commend it. It accounts for the association of the altered granite with the ore, and its absence elsewhere in the region, by assigning the alteration of the granite and the formation of the ore to a common cause. It explains the very unusual character of the alteration as the result of an unusual agent. Evidence of a general nature bearing in the same direction is afforded by the fact, stated by Roth,[1] that several of the hydrated silicates of iron and magnesia, to which the green aggregate of the altered granite is quite similar, are formed where the products of the weathering of pyrite act upon silicates. These facts seem sufficient to warrant the tentative acceptance of the hypothesis as a reasonable explanation of the phenomena observed.

Similar rocks elsewhere in the region.—As previously stated, the ore at all the mines of the region is associated with rocks more or less similar to that at the Old Sterling, and generally called serpentine. That these rocks have been subjected to a process of alteration analogous to that of the granite has already been suggested as probable, but it has not been found possible always to determine their original character. At the Dixon mine the "serpentine" is plainly an altered granite, like that of the Old Sterling. The "serpentine" at the Clark and Pike mines is an altered gneiss, but at the Caledonia mines its nature is somewhat uncertain. Here it is an aphanitic mass, showing, as a rule, no trace of its original minerals or structure. By Shepard[2] it was included in his mineral species Dysyntribite, whose variable nature was afterwards shown by Smith and Brush.[3] Its relation to the ore is such as to suggest an intrusion, but the

[1] J. Roth, Allgemeine und Chemische Geologie, Vol. I., p. 238.

[2] R. U. Shepard, Am. Jour. Sci. (2) XII., p. 209. Treatise on Mineralogy, p. 146.

[3] J. L. Smith and G. J. Brush, Am. Jour. Sci. (2) XVI., p. 50.

data are scanty and unreliable. The composition of the rock, shown in IV., is so different from that of the Old Sterling rock, as to raise some doubt of a unity of origin. This is particularly true when it is considered that the Caledonia rock, if derived from a granite, has generally lost all trace of its quartz, and yet has suffered less chemical change than has the Old Sterling rock, in which much quartz still remains. This fact might, however, be accounted for by some difference in the solutions causing the alteration, or by a more complete crushing of the granite. The latter explanation is particularly probable, as the granite of the region not uncommonly runs over into very fine granulitic phases. There are, moreover, very pronounced indications of crushing and shearing in the rock of this locality. Some specimens of the rock, however, contain quartz, and in thin sections closely resemble the Old Sterling specimens. Examination of these sections makes it difficult to avoid the conclusion that the Caledonia "serpentine" is also an altered granite. The microscopical evidence in favor of such a conclusion is very strong, though not affording, as in the case of the Sterling rock, a complete demonstration.

From the facts at hand it may be stated that the so-called serpentine of the various mines is derived from different rocks, whose character must be determined in each case. There is nothing to indicate that the original rock was, in any instance, a basic intrusion, but, on the contrary, where it has been found, it is decidedly acid. Moreover, the alteration products are not sufficiently uniform in character to be grouped under a specific name, and, even were this done, the term serpentine, which has always been applied to them, would have to be supplanted by something more in accord with their composition.

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THE QUARTZITE TONGUE AT REPUBLIC, MICHIGAN.

I.

On Major Brooks' geological and topographical map of Republic Mountain and vicinity, Plate VI. of the Atlas of the Geological Survey of Michigan, 1873, a tongue of the upper quartzite (his formation, XIV.) is correctly represented as forking from the main mass of the same rock, and running northwest along the top of the Republic bluff, a thin wedge of the underlying specular jasper (his formation, XIII.) being interposed between them.

No explanation of this singular occurrence was given by Brooks in the text of the Michigan report.

Dr. M. E. Wadsworth[1] in 1880, as the result of personal examination, concluded that the supposed quartzite tongue was really a granite dike, intruding the jasper.

In consequence of later studies[2] by himself and his assistants, Dr. Wadsworth has recently decided that his former determination of the tongue as a dike of granite was erroneous, and that it is in fact quartzite. In this latest publication he endeavors to explain the peculiar relations by the assumption that the interposed wedge of specular jasper does not belong to the lower series, but to the upper, and was deposited later than the quartzite tongue.

In the autumn of 1891, in the course of extended work on the surface and underground at Republic, I studied this question in some detail, and concluded that the phenomena were due entirely to faulting.

[1] Notes on the Geology of the Iron and Copper Districts of Lake Superior, 1880, pp. 34-35.

[2] Report of the State Board of Geological Survey, Lansing, 1893, pp. 129-130.

II.

For the purposes of this article it is unnecessary to give a detailed description of the Republic rocks, as their character is sufficiently indicated by the names attached to the several formations in the table below, which shows, with some slight modifications, the divisions, the order of succession, and the nomenclature as determined and used by Brooks, Wadsworth, and the United States geologists, respectively.

I. Brooks.	II. Wadsworth.	III. U. S. Geologists.
Huronian	*Holyoke Formation*	*Upper Marquette Series*
Quartzite XIV.	Quartzite	Quartzite
	Unconformity	Unconformity
Ferruginous Jasper, XIII.		*Lower Marquette Series*
Specular and Magnetic	Republic	Specular Jasper
Ore Formations XII.		Magnetite-Actinolite-
Magnetic Siliceous	Formation	Schist
Schist X., VIII., and VI.		
Quartzite V.		Quartzite and Conglomerate
Unconformity	Unconformity	Unconformity
Laurentian	Cascade Formation	Archean

I have omitted from column I., the succession according to Brooks, the diorites VII., IX., and XI., which are now known to be later intrusive sheets and dikes. That Brooks should have divided the ferruginous rocks between the quartzites V. and XIV. into what we now think an unnecessary number of formations, is easily understood, when it is remembered that his classification was a provisional one for field use, which the exigencies of hurried publication forced him to retain in his final report.

In column III. I have made two divisions of the ferruginous rocks. These are sharply separated in aspect, and in the western part of the Marquette district at least, each has its own place in the stratigraphical column. The specular jasper when present, always overlies the magnetite-actinolite-schists. No theory of difference in origin is implied, and the distinction is entirely one of convenience.

Dr. Wadsworth has not, I believe, published a detailed section of the rocks at Republic.

III.

All the rocks of the Upper and Lower Marquette series have been closely folded in the Republic area into a syncline, about seven miles long, the axis of which runs about northwest and southeast. The present fold for most of its length is sunk deeply into the Archean, the axis being practically horizontal. South of Smith's Bay, however, the axis rises with a pitch of nearly 45°, the several formations swing around successively in horseshoe form through an angle of 180°, from the northeastern to the southwestern side, and the fold, so far as it affects the bedded rocks, abruptly terminates. Through the greater part of the length of the trough the rocks on the two sides of the axial plane have been squeezed nearly into parallelism. On the eastern side, few of the many surface observations show in the upper quartzite a dip less than 80°, which is the average to a depth of more than 900 feet in No. 8 shaft. On the western side the dips are somewhat lower, but will average nearly 80°.

The formations in the unconformably underlying Lower Marquette series on the eastern side of the trough dip at uniformly higher angles, and stand either vertical, or show a slightly overturned dip towards the east. There is then a pretty constant upward convergence of the two series along the contact, averaging perhaps 15°.

The distance in which the turn is made at the southeast end of the trough, or at the bottom as it really is, is relatively very short. The radius of the generalized curve into which the

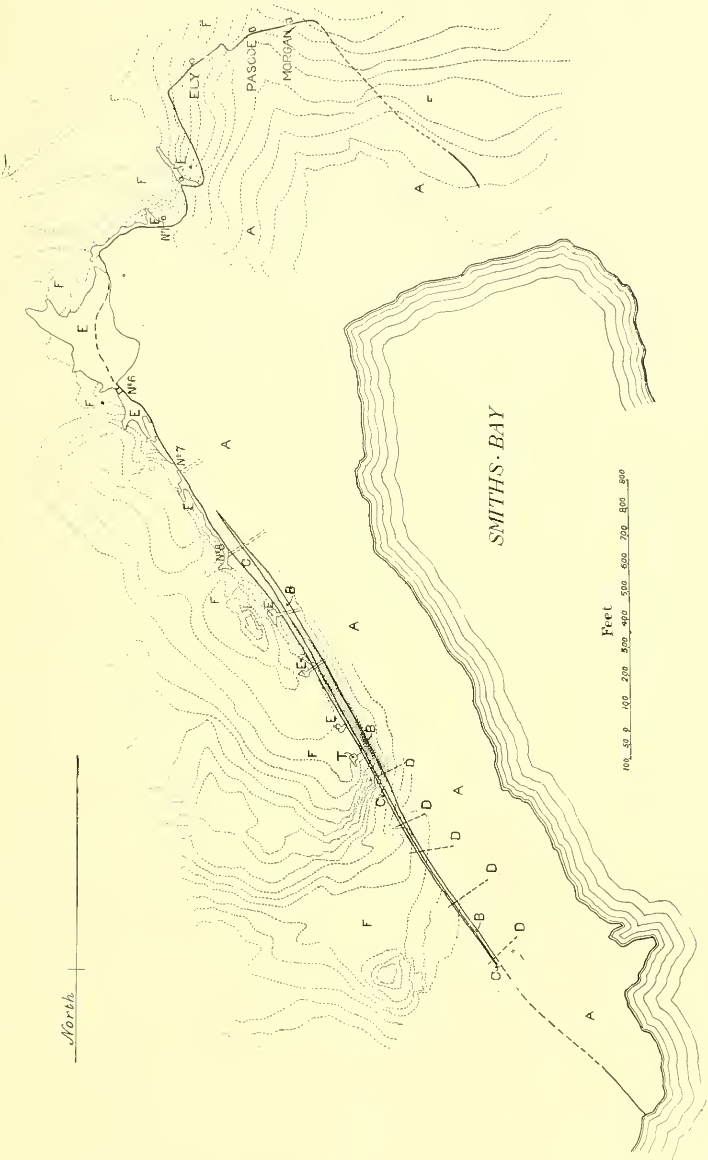

FIG. 1.—The Vicinity of the Republic Mine. A, A = Area underlaid by the Upper Marquette quartzite. B, B = Jasper Wedge. C, C = Quartzite Tongue. D, D = Diamond-drill holes. E, E = Open pits. F, F = Area occupied by the Lower Marquette Jasper. T = Thompson pit. Contours (from Brooks) at ten-foot intervals. The heavy black line is the outcrop of the base of the Upper Marquette Series. When dotted it is covered, or not precisely determinable.

base of the upper quartzite has been thrown, can be very little greater than the thickness of that formation. Field study shows clearly that the neutral surface of the folded material lay below the base of the upper quartzite, and included a considerable portion of the actinolite-schists. This is proved by the severely contorted condition (showing compression) of the thinly bedded jaspers, and by the same structure on a larger scale in the more heavily bedded quartzite. The crowding of the rocks above the neutral surface into a constricted space has resulted in the formation of three important synclines, separated by two anticlines, all subordinate to the main fold. The most eastern of the synclines occurs at the great open pit of the Republic mine; the middle, in the ground opened by the Morgan, Pascoe and Ely shafts; the westernmost in the neighborhood of the Swamp shaft[1] (Fig. 1). These larger subordinate folds are accompanied by a multitude of smaller anticlines and synclines, of various dimensions. They are smaller, more numerous, and more closely compressed in the iron-bearing member than in the overlying quartzite.

The upper quartzite, which is a massive and heavily bedded rock, yielded to the compression by differential movements of one bed over another, and doubtless also by thickening. The effects of the movement of bed on bed are strikingly shown at numerous points in the horseshoe, perhaps particularly well in the small open pit east of the Ely shaft. Here the individual quartzite layers, from one foot upwards in thickness are separated by parallel selvages of ground-up quartzitic material, varying in thickness usually from two to four inches. In the case of one, the measured thickness is eleven inches. These selvages, known locally as a variety of "soap-rock," show frequently a vertical pressure-cleavage.

It is certain, then, that the original sheet of sediments, which varied in character from thinly leaved jaspers below to heavily bedded quartzites above, and aggregated, for the area under discussion, upwards of half a mile in thickness, has been bent back

[1] The Swamp shaft falls outside of the limits of Figure 1.

upon itself, and that the neutral surface of division between the portion above, that was subjected to compression, and the portion below, that underwent tension, lay well beneath the heavily bedded quartzite. The part of the sheet above the neutral surface was confined within a progressively narrowing space, to which it had to accommodate itself by thickening the beds, by plicating them, and also by relative movement of each bed on that below it. That the accommodation thus necessitated by

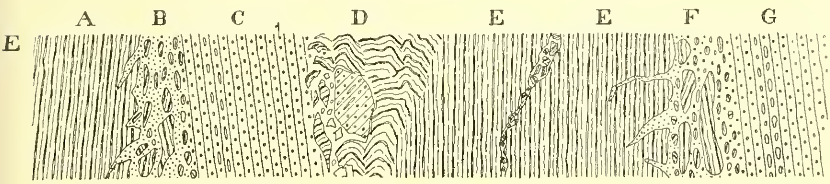

FIG. 2.—Section north of the Thompson Pit. A = Lower Marquette Jasper. B = Conglomerate. C = Quartzite tongue. D = Breccia. E = Jasper Wedge. F = Conglomerate. G = Quartzite. One inch = 20 feet.

the mechanical conditions actually did take the form of slipping along bedding planes, is, in the case of the quartzite, clearly shown.

IV.

I will now consider the quartzite tongue. The best exposures of the conglomerate at the base of the upper quartzite tongue, the included jasper wedge, and the main mass of jasper, including all contacts, may be seen on the natural cross-section afforded by the breaking down of Republic Mountain north of the Thompson pit. This section is represented in Figure 2, and a sketch plan of the outcrops is given in Figure 3. The conglomerate at the base of the main mass of quartzite is exposed on the steep western face of the bluff, from its north end almost to No. 8 shaft. It holds pebbles of jasper, of banded jasper and ore, of ore, and of quartz, which last with ferruginous matter forms the cement. The jasper inclusions are often large and angular, and in many cases it is difficult to see that they are completely detached from the main jasper body of the tongue. The conglomerate cement, which is largely made up of grains of blue quartz, fills cracks in the underlying aspe wedge, often in directions transverse to the banding (Fig. 4). Some of these cracks may be traced for several feet back from the contact. In many places the general course of the contact cuts the banding of the jasper of the wedge at a considerable angle. Altogether the conglomerate is unmistakably basal, and was clearly laid down upon an irregularly eroded surface.

From this contact for about sixteen feet to the east the jasper wedge comes in. The great mass of this rock cannot be distinguished, either by the eye or under the microscope, from the specular jasper of the Lower Marquette iron-formation. It is very rich in iron ore, the jasper bands often showing the tendency to break up into oval-shaped units that indicates an advanced stage towards concentration. Occasionally, however, within the solid body of the jasper, small patches of quartzite may be observed, which occur singly, or several together along the same general line. These patches are not interbanded with the jasper bands, but often cut them off squarely at their margins (Fig. 5). They recall the sand-pockets which occur similarly in the banded ore at the Mountain Iron Mine on the Mesabi range.[1] Here, doubtless, as there, the sand has been introduced from above, at a time subsequent to the development of the banded structure.

With the exception of these rare quartzite pockets the jasper wedge contains no foreign fragmental material. Through it, however, run several fault lines, which are indicated by narrow breccias, the materials of which are entirely derived from the jasper itself, and by displacement of the jasper bands at the walls. Some of these breccias run nearly parallel with the banding, while others cut across it at considerable angles.

The jasper wedge terminates to the east in a very distinct fault breccia some five feet in width, at its widest point north of the Thompson pit. This breccia consists of large angular pieces of jasper (one measured one by three feet), of quartzite, of quartz and of iron ore, and many pebble-like forms of all

[1] Compare Bulletin No. X., Minnesota Geological Survey, p. 205, Fig. 20.

these, surrounded by more or less ferruginous, chloritic and siliceous cement, in which many grains of blue quartz occur. The jasper wedge is not separated from the breccia by any sharp line of division. The layers, which in the solid body of

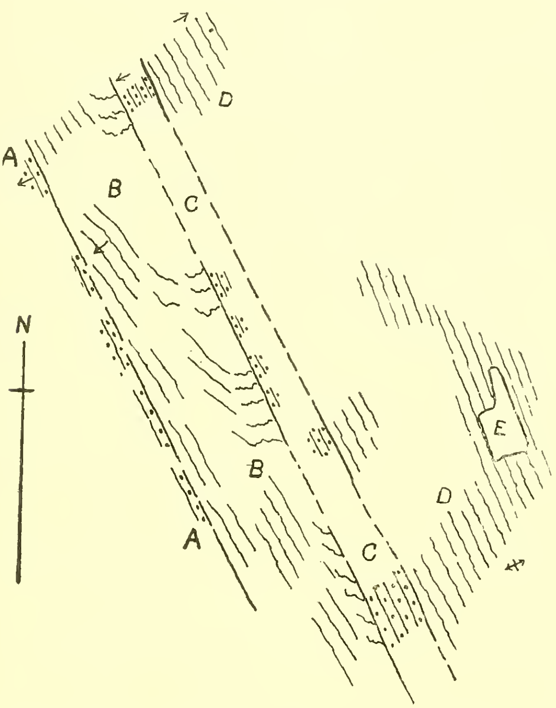

FIG. 3.—Sketch plan of the outcrops in the vicinity of the Thompson Pit. A, A = Conglomerate at the base of the main mass of the Upper Marquette Quartzite. B, B = Jasper Wedge. C, C = Quartzite tongue. D, D = Lower Marquette Jasper. E = Thompson Pit. One inch = 50 feet.

the wedge stand nearly vertical, become contorted near the breccia and bend towards it, the convex side of the little arches being upward on vertical sections and towards the south on the horizontal exposures (Figs. 2 and 3). This indicates that the material west of the fault, towards the interior of the trough moved relatively upwards, and had also a southerly horizontal component.

Next east of this breccia about six feet of westerly dipping quartzite comes in, constituting the quartzite tongue. South of the Thompson pit this quartzite steadily increases in thickness, and in about 300 feet attains a width of twenty-five feet. The quartzite shows the plainest marks of its sedimentary origin, and it is almost incredible that any other could have been attributed to it. It contains thin layers of conglomerate that may be followed for considerable distances. These layers are composed of nicely rounded pebbles of jasper, of specular and magnetic ore and of quartz, as well as of larger flat slabs of banded jasper. Where the quartzite becomes thicker, a little north of No. 8 shaft, the conglomerate layers in the upper portion hold a few pebbles of magnetite-actinolite-schist. In the bedding planes the pebbles have a roughly parallel inclination of 30–40° to the north, which is nearly the general pitch of the trough. A system of parallel normal joints having the same inclination also affects the quartzite as well as the jasper, and seems to have had some influence in localizing ore-concentration, since the small body at the scram immediately north of No. 8 rests upon one of them.

The quartzite tongue is also in places gashed with a parallel system of narrow quartz veins which dip south about 40°, and so are nearly normal to the pitch. These are confined to the massive quartzite, and stop short at the conglomerate layers in it, nor do they extend into the jasper wedge above or into the main jasper body below. It may be that they represent open spaces where the massive quartzite was pulled apart, possibly at existing joints, by the drag of the upper members along the fault.

Below the quartzite on the line of section follow three or four feet of conglomerate entirely similar to the conglomerate which overlies the jasper wedge, and having identical unconformable relations with the specular jasper of the Lower Marquette series, which continues in an unbroken body to the east.

The significant facts along this section (and they are equally evident at many points south), which seem clearly fatal to the idea that the jasper wedge is an interbedded member of the upper series are these: (1) It is not interbedded. (2) The main body of Upper Marquette quartzite to the west is as clearly separated from the jasper wedge by an erosion interval as the quartzite tongue is from the main body of Lower Marquette jasper upon which it rests. The jasper wedge cannot belong to the upper series unless there are two upper series. (3) The jasper of the wedge is not a fragmental rock, and no contemporaneous fragmental material has been recognized in it. It disappears a

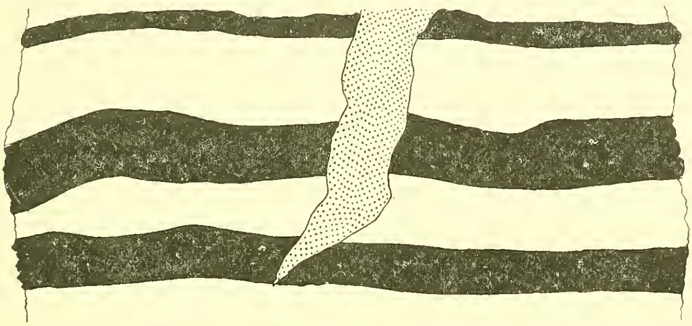

FIG. 4.—Plan showing quartzite filling a crack in the Jasper Wedge. The black bands are specular hematite; the uncolored are red Jasper. The locality is ten feet south of the suspended ladder. About one-sixth natural scale.

short distance south of No. 8 tunnel, and the two quartzites come together. If it were a member of the upper series, it must have been laid down at the same time that a rather coarse fragmental rock was being deposited a few hundred yards away, in which case it is hardly conceivable that clastic material should not have been largely included in it.

V.

While the relations of the quartzite tongue are correctly represented on Brooks' map, the better surface exposures of the present day, and the large amount of exploration done by the Republic Company, enable its position now to be fixed with much greater precision. Several diamond-drill holes north of the Thompson pit have shown that it extends 500 to 600 feet north of the point where it terminates on Brooks' map. It becomes steadily narrower, and as it does not appear at the Kingston and Kloman exposures on the west side of the river, there can be little doubt that it gradually dies out, and that the jasper wedge finally merges into the main body of specular jasper (Fig. 1).

Therefore, the facts to be explained appear to be these: A quartzite tongue branches in the south from the main mass of similar quartzite, and after continuing substantially parallel with it for a long distance, finally tapers to a point in the north in a

FIG. 5.—Elevation showing part of a quartzite "pocket" in the interior of the Jasper Wedge. The black bands are specular hematite; the uncolored are red Jasper. The locality is about 100 feet northwest of the Thompson Pit. About one-twelfth of the natural scale.

mass of specular jasper. The quartzite tongue includes between itself and the main quartzite mass, an exactly similar jasper tongue which starts in the north from the mass of specular jasper, and tapers to a point in the south in quartzite, the two tongues interlocking. The quartzite in each case, in the tongue and in the main mass, has similar and unusual relations (those marking a time-break) with the jasper of the tongue and of the main mass. And between the jasper wedge and the quartzite tongue extensive faulting has taken place.

These facts point towards if they do not demonstrate the identity in age of the two jaspers, and of the two quartzites, and indicate that their present relations are due to faulting.

Recurring now to the mechanical conditions which affected the rocks during the folding, we have seen that the material above the neutral surface yielded to the compression, in part, by slipping along the bedding planes. If for any reason such movement could take place more easily along any one surface, the neighboring surfaces would be relieved, and one of maximum movement would result. It is readily conceivable that in the same way one local maximum might relieve several neighboring maxima, and so a large amount of movement might be accumulated along a single surface. A maximum movement, starting in the specular jasper would, on account of the slight upward convergence of dip, necessarily tend to cut across the quartzite at the contact. The quartzite might be traversed until a surface of maximum movement in it was reached, which would then be followed. The result would be a fault, along which the material on the side towards the interior of the trough would be displaced relatively upwards, and which, in the direction of the strike, might easily pass from one rock to the other more than once. The wedge of specular jasper included between the surface of movement and the contact surface would move relatively upward with the main body of quartzite, while the corresponding wedge of quartzite above the line along which the contact surface was traversed would remain relatively at rest with the main mass of jasper.

A break formed under such conditions, accompanied by displacement sufficient to bring these two wedges together, and followed by sufficient denudation, would result in the surface relations that may now be observed on Republic Mountain.

HENRY LLOYD SMYTH.

CAMBRIDGE, MASS.

A SKETCH OF GEOLOGICAL INVESTIGATIONS IN MINNESOTA.

PRIOR to the beginning of geological investigations in Minnesota there was a period of exploration and travel, in the published accounts of which are some references to the strictly geological features of the state,[1] and others from which some inferences can be drawn bearing upon the natural features and often upon the geology. Omitting the references made by Champlain in 1615 to the "Grand Lac" and the explorations made by Grosselliers and Radisson between Hudson's Bay and Lake Superior in 1659, and the maps of Franquelin dated 1688, and Beauharnois, dated 1737, it is sufficient here to mention only the discovery of the Falls of St. Anthony by Father Hennepin who accompanied Accault in an expedition up the Mississippi, sent out by La Salle, in 1680. Hennepin's original account of the falls has been used as a datum from which to calculate the amount of recession from their discovery to 1857. This important geological phenomenon was viewed through the eyes of a religious enthusiast, and he named them in honor of St. Anthony of Padua, his adopted patron saint. Sieur Du Luth about the same time was making some additions to the known geography of the state. In 1683 Le Sueur made the earliest examination of the valley of the Minnesota. He mentioned a "green earth," which he supposed to be carbonate of copper, at a point near Mankato, and a large mass of native copper on Lake St. Croix. Jonathan Carver traveled extensively in Minnesota in 1766. He gave a full description and an illustration of the Falls of St. Anthony, which have served to

[1] There is a "sketch of explorations and surveys in Minnesota" in Vol. I. of the final report of the present "Geological and Natural History Survey" of the state. This deals largely with the early explorations. In Bulletin No. 1, of the same survey, will be found some account of the institution and progress of the present survey.

fix their position at that date. He makes the first mention of the red pipestone, or catlinite, of the southwestern part of the state.

Following these early travels was a period of territorial exploration, extending from 1783 to 1858. When the War of the Revolution closed the area which now comprises the state of Minnesota was divided between the French and the United States. From 1783 till the expedition of Lieutenant Z. M. Pike, of the United States army, which took place in 1805, the Upper Mississippi region was left almost as it had been under the British, whose fur-traders still overran the region and still floated the British flag at their trading-posts or "forts." During this period, however, an indefatigable English geographer crossed the northern part of the state and recorded his observations of latitude, depositing his notebooks with the Northwest Fur Company, by whom he was employed, These records have remained unpublished until recently.[1] The work of this geographer, whose name was David Thompson, resulted in determining the fact that the northern source of the Mississippi was not north of the Lake of the Woods, where it was assumed to be by the treaty of 1783. He reached Turtle Lake, the "Julian sources" of the Mississippi, according to Beltrami, twenty-five years before that gentleman saw the lake, and recorded the latitude of the Mississippi at Red Cedar (now Cass) Lake. Lieutenant Z. M. Pike in 1805 measured and described the Falls of St. Anthony. This description, as it is accompanied by a map of the river and cataract, has served to fix the position of the falls at that date. He also described briefly the Falls of Pokegama. In 1871 Major S. H. Long again visited and described the Falls of St. Anthony, giving some notes on the nature of the rocks that cause them. In 1820, and again in 1832, Mr. H. R. Schoolcraft was in Minnesota in the employ of the United States government. He was the first to give a geo-

[1] E. D. NEILL. History of Minnesota, fourth edition, p. 866. Minneapolis, 1882. Mr. J. B. TYRRELL has more recently published these notes in the Proceedings of the Canadian Institute, March (published October), 1888.

logical account of the lower valley of the St. Louis River. The rock at the Falls of St. Anthony he considered Lower Carboniferous; *i. e.*, of the same age as the lead-bearing Mountain Limestone of England. In 1832 he discovered the source of the Mississippi River and named it Lake Itasca, an imaginary name of an imaginary Indian divinity, constructed by him for the occasion from the two Latin words *veritas*, truth, or true, and *caput*, head, by taking two syllables of the former and one of the latter. By this he intended to indicate that Lake Itasca is the *true head* of the Mississippi. Beyond this signal discovery and a picture of the Falls of St. Anthony, Schoolcraft added but little to the geography or geology of the state. He should, however, have credit for noting the occurrence of crystalline rocks at several points in the Mississippi River below the Falls of Pokegama.

Keating's narrative of Major Long's expedition in 1823 to the source of the St. Peter's River contains much on the geology of the route. Besides an account of the Falls of St. Anthony, Professor Keating gives the first geological description of the valley of the Minnesota River (then called St. Peter's) and of the *coteau des prairies*. Descending the Red River of the North to Winnipeg, this party turned eastward, crossed the Lake of the Woods, ascending Rainy River and Rainy Lake, thence following the international boundary line to the east end of Sturgeon Island where they turned more northward, in order to reach Fort William by another route. Keating was a chemist and a mineralogist, and his notes on the crystalline rocks of the route afford the first instance of the application of the correct and careful methods of modern science to the investigation of the geology of the state. It was a reconnoissance simply, and but few facts could be noted, but such as they are they have been found, in the main, to be reliable.

Lieutenant James Allen, who accompanied Schoolcraft in 1832, rendered an independent report of the expedition, in which he gives brief descriptions of the topography and general features, including the dalles of trap-rock on the St. Croix river.

G. W. Featherstonhaugh was the first professional geologist, so far as known, who made the state a visit. He was an English gentleman and was commissioned "U. S. Geologist" by Col. J. J. Abert, of the bureau of topographical engineers. He was accompanied in 1835 by Mr. W. W. Mather who afterwards became known as a geologist of the state surveys of Ohio and New York, but they parted by reason of some disagreement, and Mather returned alone from some point on the upper waters of the Minnesota river. It is possible that Mr. Featherstonhaugh's geological report suffered materially in thus being deprived of the services of Mr Mather who retained his geological notes. The manuscript of Mr. Mather, not published, was said to have been in existence for some years after the report of Mr. Featherstonhaugh was issued, but for many years it has been lost. Mr. Featherstonhaugh's report, published at Washington, was largely a general treatise on geology, but contains many new and interesting facts relating to the physical features of the country, including an account of the Falls of St. Anthony. He visited the place of Le Sueur's "copper mine," but concluded that the discovery of copper, as reported by Le Sueur, was one of those fables which the early French travelers sometimes invented in order to gain influence at the court of France. The "Carboniferous limestone" he supposed to extend as far as the bluffs of the Minnesota at Mankato. He ascended the *coteau de prairie*, but he failed to visit the red pipestone quarry situated in the extreme southwest corner of the state.[1]

It remained for George Catlin, in 1836, to bring away from its native place, a sample of the red pipestone. This was submitted to Dr. C. T. Jackson, of Boston, who after analysis and description, gave it the name of catlinite.

Joseph Nicolas Nicollet,[2] from 1836 to 1843 prosecuted geo-

[1] Mr. Featherstonhaugh's report is entitled: "Report of a geological reconnoissance made in 1835 from the seat of government by the way of Green Bay and Wisconsin territory to the *coteau des prairies*, an elevated ridge dividing the Missouri from the St. Peter's River," printed in 1836.

[2] Additional facts about Nicollet. H. V. WINCHELL, American Geologist, Vol. XIII., p. 126, Feb., 1894.

graphical researches in the Northwest. Incidentally he aided greatly in determining some parts of its geology. It was through him that T. A. Conrad obtained fossils from the lead-bearing formations of the Upper Mississippi by which he, first of all, correctly assigned that limestone to the age of the Trenton of New York.[1] Professor James Hall, but little later, examined it in the field, and came to the same conclusion.

The chief event connected with the territorial investigation of the geology of Minnesota was the survey of D. D. Owen, extending from 1847 to 1850, which also covered much contiguous territory. This survey had the resources and the corps of men which enabled it to pronounce finally on some of the mooted questions of the geology of the Upper Mississippi valley, and it was continued long enough to complete at least a reconnoissance of a large area. Its fine quarto volume,[2] published at Philadelphia by Lippincott, Grambo and Co., contains, besides the report of Dr. Owen, reports by J. G. Norwood, B. F. Shumard, C. Whittlesey and R. Owen. It embraces also a memoir by Joseph Leidy on the extinct mammalia and chelonia of Nebraska Territory, and several valuable appendixes. Dr. Owen's other assistants were J. Evans, B. C. Macy. A. Litton, G. Warren, H. Pratten, F. B. Meek and J. Beal. From this report may be said to date the systematized geology of the state. It laid accurately a broad base on which all future geologists of the state must build. About this time the New York State survey was in vigorous action, and some of its results had been published. Hall, Conrad, Emmons, and Mather, with Hitchcock of Massachusetts contributed indirectly to the final conclusions at which Dr. Owen arrived. The form of the volume is similar to that of the final report of the New York survey, but its breadth of scope is greater and its typographic execution superior. Its illustrations

[1] Observations on the lead-bearing limestone of Wisconsin and descriptions of a new species of trilobites and fifteen new Silurian fossils. T. A. CONRAD. Proc. Acad. Nat. Sci., Philadelphia, Vol. I., 1841–43.

[2] Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and incidentally of a portion of Nebraska territory, by DAVID DALE OWEN, United States geologist, 1852.

and its maps are first-class. It is a well-known work, and can still be seen sometimes offered for sale by dealers. It constituted at that time one of the largest and most expensive publications of the United States government, a monument at once to the learning, the zeal and the wise management of Dr. Owen. It is not necessary here to go into the scientific merits of this volume, since its contributions to the geology of Minnesota and of the Northwest are well known and have entered into the geological literature of the country in many forms.

After this territorial period, ending in 1858, the new state made early attempts at a geological survey, but met with poor success. The first legislature ordered a reprint of portions of the geological report of Professor Daniels on the survey of Wisconsin, Minnesota having formerly been embraced in the territory of Wisconsin. The second legislature instituted a plan for establishing a thorough survey. Messrs. Charles L. Anderson and Thomas Clark were appointed commissioners to report on the geology of the state and on a plan for such survey. They rendered a report the following year, making an octavo pamphlet of twenty-six pages, outlining the proper scope and methods of such a survey. But the legislature took no action, probably because of the objections of Governor Ramsay who considered that the state was not able at that time to bear the cost which the survey would entail. In 1864 a law was passed by the sixth legislature authorizing the governor to appoint and direct a state geologist. The first appointee under this law was Dr. Aug. H. Hanchett. His assistant was Thomas Clark. But little or nothing of value was done by Dr. Hanchett, but Mr. Clark rendered a report of seventy octavo pages on the physical features of that portion of the state bordering on Lake Superior. The next two years the survey was conducted by Mr. H. H. Eames who had his brother, Richard M. Eames, for assistant. Two small annual reports were rendered by Mr. Eames, who was devoted to prosecuting a "mineral hunt" in the northern part of the state. This was apparently in accordance with instructions from Governor Miller. Excitement soon arose over the discovery of small amounts of gold in the schists at Vermilion Lake, and a genuine "boom" (so-called in later years) centred on that region. Much prospecting was done and much money squandered, but little geology resulted from these two years of the administration of Mr. Eames. The state survey collapsed ingloriously, and was not revived till the commencement of the present survey in 1872.

From other sources, however, the geology of Minnesota was kept in a state of progress. Professor James Hall visited the state in 1865, and examined the St. Croix valley with reference to its prospects for copper in the vicinity of Taylor's Falls. This visit was prolonged for the purpose of examining the reputed coal beds of southwestern Minnesota which he found to belong to the Cretaceous system. The next year a report of the trip to the southwestern part of the state was made by Professor Hall. It is published in the Transactions of the Philosophical Society of Philadelphia. This paper embraces the first geological observations ever made on a very large area in the region southwest from the Minnesota River, and may be said to have supplemented and extended the observations of Keating and of Featherstonhaugh. In 1866 also were published the field observations of Colonel Charles Whittlesey made in northern Minnesota in the years 1859 and 1864. These also embodied some more detailed descriptions of the region north of Pokegama Falls, resulting from the survey of D. D. Owen whose assistant Whittlesey was. The papers of James Hall and of Charles Whittlesey constitute the most valuable contributions to the geology of the state during the period following the territorial exploration, and preceding the present survey. There were, however, some later surveys. One was a topographical survey of the Minnesota valley by General G. K. Warren, under the United States government. His reports are to be seen in the Report of the Chief of Engineers for 1867, 1868, and 1874. He first published, with full demonstration, the idea that the valley of the Red River of the North was formerly covered by a freshwater lake which embraced the region of Lake Winnipeg. Professor Henry Youle

Hind had already announced such a hypothesis, but General Warren mapped the area of the lake and assigned a cause for the former drainage toward the south.[1] In 1871 Messrs. W. D. Hurlbut and J. H. Kloos contributed to the geology of Minnesota, the former in the southern part of the state and the latter in the northern. Their papers were published in the *Minnesota Teacher*, although Mr. Kloos contributed an article, in 1872, to the *American Journal of Science*, giving particulars of the discovery of Cretaceous beds with lignite in the valley of the Sauk River, adding palæontological determinations by F. B. Meek.

Professor A. Winchell was appointed by Governor Horace Austin in 1871 to make an examination of the vicinity of Belle Plaine, in Scott county, where indications of brine were said to exist. This was in accordance with an Act of the Legislature of 1870. The report was printed by the Legislature of 1872. It gives a sketch of the geology of the region, including notes on the drillings from the Belle Plaine well, and concludes that probably brine does not exist at Belle Plaine, nor in the rocks below.

The present survey.—The law of the present survey was approved by the governor, March 1, 1872. It is the first instance in which a systematic survey has been placed by any state of the Union, under the direction of the regents of the State University, with requirement to make constant examination and stated reports. It has often happened that the professor of geology in a state institution has been the state geologist, but in those cases he has been directed by some other state board or by the governor. The arrangement which prevailed in Alabama, during the incumbency of Professor Tuomey, of the State University, was in some respects similar, but it was not inaugurated at the instance of the state legislature. It was an incident of his professorship as ordered by the trustees,[2] and when it was recog-

[1] See the American Naturalist for November, 1868.

[2] E. A. SMITH, Geological Surveys in Alabama. JOURNAL OF GEOLOGY, Vol. II., p. 275.

nized by the legislature the explorations were still carried on at the expense of the University of Alabama. When the state later appropriated money to conduct the survey, Professor Tuomey resigned his position in the university. The present survey of Alabama was instituted by law in 1873, although the trustees of the university had required the professor of geology the year previous to revive the plan which was established under Professor Tuomey. The survey as such is not under the direction of the university trustees. The governor, the secretary of state, and the state geologist constitute the board of control.

The plan of the Minnesota survey was recognized at once as a new departure and was thus referred to by a high authority:[1]

"We spoke in the June number of the *Popular Science Monthly* of the advantages that would arise from connecting the scientific exploration of the several states with their higher educational institutions. We have been since reminded that this is an accomplished fact in at least one of the states, and we hasten to give credit to Minnesota for having taken this new departure in scientific education. It is one of the youngest states in the Union, and a generation ago was but a land of savages, an indefinite tract in the great "Northwest Territory," beyond the "Wisconsin," beyond the distant Mississippi, that we now see taking the lead of the older states in organizing the new education by devoting her university to the comprehensive and practical study of nature. This step has been but recently taken, and its benefits are prospective, but if thoroughly carried out there can be but little question of the advantages that must arise to the people of the state. . . . . The movement in this case, it is evident, has been initiated mainly in the interest of the geological survey, but it is to be hoped that the larger objects of education to which it is a means will not be lost sight of. The university will undoubtedly be benefited by taking the responsibility of the work, but the movement will fall greatly short of the good it might accomplish if it is not vitally connected with the educational system of the state."

This survey has been in uninterrupted progress under its original law from the date of its establishment to the present. It requires the regents not only to conduct a purely geological survey, but also to make a natural history survey, including botany and zoölogy, to construct a topographical map of the state, and to investigate its meteorology. The law establishes a

[1] Editorial in the Popular Science Monthly, Vol. III., p. 391, 1873.

museum at the university, which is ordered to be kept in good order and accessible to the public, and provides for the exchange of specimens with other institutions. This law was drafted by President W. W. Folwell, of the University of Minnesota, and is still in force in all its provisions. It was introduced in the Senate by Hon. J. S. Pillsbury, of St. Anthony. The legislature has sometimes passed supplementary laws to facilitate the execution of the main law, or directing the methods of publication of the survey reports, but has in no way changed the original law.

To accomplish this survey *an annual appropriation of one thousand dollars was made by the legislature!* The writer was appointed to conduct it in July, 1872, and tendered his first report December 31, 1872. The funds being so meager, the state geologist was required to earn the greater part of his salary by teaching the natural sciences in the State University, and he held the chair of geology and mineralogy and discharged all its functions, in addition to the work of the survey, until 1878, when the regents made other provision for such instruction. It is apparent, on the slightest consideration, that a state survey based on such a fund would go so slowly that more than a century would lapse before its completion, and that it would not be apt to receive the respect of the people, nor maintain its rank amongst such enterprises. In casting about for some means to establish the survey on a better footing, the writer, when engaged in the field work of the first year's campaign, was much with Hon. W. D. Hurlbut, of Rochester, Minn., and received from him the suggestion that the state lands known as Salt Spring lands, might be made to support the survey. This United States land grant had been the prey of various chimerical schemes for developing imaginary natural resources, and it appeared evident that it would be entirely absorbed by unprincipled and ambitious designers unless it were taken care of by the legislature in such a way as to put the lands beyond their reach. The suggestion of Mr. Hurlbut may have resulted from conversations with the state auditor, Hon. O. P. Whitcomb, who was his townsman, and who was also friendly to the survey. It is probable, further, that the auditor had conferred with Hon. A. J. Edgerton, then state railroad commissioner, and with the senator (Pillsbury) from St. Anthony, as has been claimed, and that there was, prior to the writer's knowledge, a concerted agreement to devote these lands to the support of the survey.[1] However that may be, the first report of the survey presented the suggestion to the legislature that these lands could be devoted, consistently with the terms of the United States grant, to the maintenance of the survey ordered by the previous legislature. The law that was passed turned these lands over to the custody and control of the regents of the university, with instructions to sell them and devote the proceeds to the support of the geological and natural history survey. Thus the survey was put on a financial basis which promised for it a reasonable duration. When later it was found that there was a large deficit in these lands due to the negligence of the United States officers, and the state was allowed to make re-selections in other portions of its domain, and when such re-selected lands were also devoted by the state to the same purpose, the fund became sufficient, with economy, to keep the enterprise in working activity for several years, and apparently to complete the geological portion. These lands, thus augmented, amounted to 38,643 acres, which could not be sold, according to existing law, for less than five dollars per acre.

In addition to this financial foundation the legislature increased the annual appropriation named in the original law to two thousand dollars, the same to continue until the annual proceeds from the Salt Spring lands should amount to that sum. It was discontinued in 1879. As the sales of the Salt Spring lands did not furnish sufficient revenue the survey became indebted to the university. The legislature, in 1887, appropriated ten thousand dollars. In 1891 it appropriated fifteen thousand dollars, and in 1893 ten thousand dollars.

[1] The writer gives these details because some complaint has reached him that due credit had not been given by him, in an earlier account, to the prior conferences of these public officials.

TOTAL COST OF THE MINNESOTA SURVEY.

Annual appropriations at the commencement of the survey,	$15,000.00
Proceeds of the Salt Spring lands to July 31, 1888,	46,105.07
Legislative appropriation, 1887,	10,000.00
" " 1891,	15,000.00
" " 1893,	10,000.00
Proceeds of the Salt Spring lands from July 31, 1888, to July 31, 1892,	27,621.09
Total,	$123,726.16

This covers the expenses of all departments of the survey, which lately has been rendered more active in the lines of botany, zoölogy, and topography than formerly. It also embraces the expenses of the museum and the library, and includes $12,510.80 expended for the department of instruction in the university prior to 1878. It does not cover the cost of publication of the reports and bulletins. These are executive documents of the state, emanating by law, from the State University, and their publication is provided for by estimates for public printing which are presented to each session of the legislature.

The field work of this survey began in the southern counties and progressed northwardly. But little technical work was attempted at first, the aim being to render work done, as expressed in the reports, acceptable to the people of the state, and thus to the legislature on whose good-will the firm establishment of the enterprise depended. Quicker geological returns were possible in the southern and central counties, which are principally of prairie and settled, than in the northern, which are forested and were then largely in their primeval state. Still the annual reports do not record a steady progress northward, but embrace miscellaneous and often unclassified matter derived from all parts of the state. They average about 250 pages octavo, and have many illustrations. Twenty-two annual reports have been issued. In 1884 the first volume of the "final report" required by the law of the survey, was issued. It is a quarto of 700 pages and 43 plates. It embraced the work of about ten years, so far as it could be made conformable with the plan of publication adopted. The second volume of the final report, of the same size and style as the first, was published in 1888. This covered subtantially the central third portion of the state. These volumes contain no palæontology, but are devoted to a description of the geological features, with frequent references to the economic resources of the areas described. The state is being mapped by counties, and each chapter of these reports is accompanied by a colored and contoured map of the county it describes. There is to be no large atlas in sheets three or more feet square, but a book-atlas, in quarto size, will constitute one of the final volumes, made up of all the county maps, or plates, with brief descriptive text for each. The third volume of the final report has been under way for two or three years. It is devoted to the palæontology of the Lower Silurian, *i. e.*, the formations above the St. Peter sandstone and up to and including the Galena limestone. If there be no interruption of the survey, it will be concluded in the same style by the publication of one other volume (fourth) of the final report, which will present the geology and lithology of the northern part of the state.

In addition to the annual and the final volumes a third serial is maintained, appearing in independent parts at irregular intervals, embracing more carefully considered investigations, which arise in the progress of the general research, which, yet, cannot be accepted as finished, but ought to be preserved. Of these occasional publications, which are called "bulletins," ten have been issued, and the eleventh is in preparation.

The administration of the survey, in all its departments, was, till 1891, in the hands of the writer, but at that date the botanical, the zoölogical, and the topographical departments were erected into independent surveys, and different members of the faculty of the university were appointed to conduct them. It has been the policy of the writer to conduct the survey, as far as possible, in the interests of the people of the state, in the immediate and economical sense. The plans that have been adopted have been almost always submitted to the regents, or their executive committee, prior to their execution. In some instances certain public or widespread want for information, expressed in correspondence, or in the public press, such as the demand for information concerning the grasshopper plague and the ways and means for alleviating the evil, the call for peat fuel on the woodless prairies, the ravages of insects injurious to horticulture, the general belief in the existence of coal in the state, the demand for authoritative statements founded on scientific data touching the nature and extent of our forests, or the quality of our soils, or the probability of brine for the manufacture of salt, or the existence of the necessary conditions for artesian water or burning-gas, or the quality of our native building stones, or the extent of iron ore deposits and their qualities,—these have all been elements that have influenced the plans formed from year to year. While answering these purposes as nearly as possible, the survey has been rendered useful to numerous individuals by private correspondence, preventing the useless expense of misguided exploration in many instances, and directly influential in promoting economic industry in every case where its aid was solicited and its data could be employed.

In this policy the usefulness of the survey has been brought home to the people of the state, and they have come to regard it as an indispensable adjunct to the university and to the progressive development of the state in its natural resources. This course was politic as well as just. There was nothing more evident, when the survey began, than that it must have the confidence of the people. The people then lived largely in the southern and central portions of the state. The annual reports embraced common, patent facts, and description cast in a semi-scientific mould. As the survey became grounded in the good-will of our own citizens, it was strengthened for doing more advanced work, and at the same time it found a constituency ready to welcome more scientific publications. It is highly probable that if such a moderate course had not been pursued, the legislature, instead of always manifesting a good-will and determination to have the work well sustained, would have refused the financial aid that has been asked of it, and the enterprise might have had the short-lived existence that has been the fate of so many other state surveys.

Coöperation of the U. S. Coast and Geodetic Survey.—Under a law of Congress, passed many years ago, the Coast and Geodetic Survey coöperated with such states as had either geological or topographical surveys in progress. This aid consisted in the determination of the latitude and longitude of certain points and the establishment of others by triangulation preparatory to correct mapping. Through the agency of Governor L. F. Hubbard, in 1884, this matter was brought to the attention of the Superintendent of the Coast and Geodetic Survey, and this law of Congress was made operative for the State of Minnesota, and has continued so to the present. That furnished the commencement of the topographical survey which the state law orders. By the combined operation of these laws such triangulation and other field work is authorized as will eventuate in a complete topographical mapping of the state in the most approved methods. This articulation between the two surveys was practically established by Major C. O. Boutelle, an officer of the Coast and Geodetic Survey, and the subsequent conduct of the survey has been under the direction of Professor W. R. Hoag, of the University of Minnesota. This plan not only carries on, with little expense, the required topographical survey, but furnishes to the department of engineering in the university an object lesson in the use of the nicest instruments and some employment for its advanced engineering students—for in all departments of the state survey the law requires the employment of the professors and students of the university when they can be found competent.

The scientific progress of this survey it is not necessary to enter upon, and the writer might not be the best judge if he should attempt to set it forth. Its reports are widely distributed, and its agency, such as it is, in the recent development of the geology of the state, and of the Northwest, is well known.

Conclusion.—It is the custom to "finish" such surveys, but no one who has been cognizant, for twenty years, of the incompleteness of the work which such surveys have to be satisfied with, and who reluctantly relinquishes from time to time some line of research, or some unsettled problem, in order to devote his energy to the passing events of the general work, will be willing to employ the word *finish* in any other sense than that his time and resources are exhausted, and he must hasten to put in order such data as he may have gathered, ere they be lost by the limitations of human life. Every such survey constitutes a stepping-stone, and only a stepping-stone, to the *finishing* of the geology of the area surveyed, but the end is in the far future, and perhaps in the infinite future. The future stepping-stones toward that end may not be in the manner of formal surveys; but in many ways now unknown, largely through the activity of the professors in the various state institutions who will wrestle with the problems now left unsolved, the intricacies of the geology of the state will be explained more fully. More enlightened public sentiment will furnish multiplied ways and means for more minute work, and the increase of exact knowledge, combined with greater demand for scientific data, will yet carry the geology of the state to a degree of exactness of which we at present can have but a faint conception.

N. H. Winchell.

Studies for Students.

THE DRIFT—ITS CHARACTERISTICS AND RELATIONSHIPS.

Contents.

Definition of the drift. The northern part of the United States, as well as a large part of the Dominion of Canada, is covered by a mantle of incoherent materials composed of clay, sand, gravel and bowlders. These various materials are sometimes intimately commingled, and sometimes more or less distinctly separated from one another. The separation may be either lateral or vertical. One region may be covered by well-assorted gravel or sand, while a contiguous area may be covered by bowlder-bearing clay, or by an unassorted mixture of bowlders, gravel, sand and clay; or layers of sand and gravel may alternate with layers of unassorted bowlder-bearing material in the same vertical section. Where bowlders, gravel, sand and clay are associated without trace of separation or arrangement, any one of them may predominate over the others to any extent, or all may be commingled in approximately equal proportions.

Through this mantle of unconsolidated material the underlying rock often projects. Many natural and artificial sections likewise reveal the rock beneath. From these sections, and from the general relations of the drift to the underlying rock, it is seen that the surface materials are not restricted to any particular sort of rock. They occur on limestone, sandstone, shale, gneiss, granite, or any other sort of rock, with apparent indifference.

Another feature which at once attracts attention is the fact that the body of material overlying any particular kind of rock contains many fragments or bowlders of rock which could not have been derived from it. Where the underlying rock is limestone, bowlders of gneiss, granite, sandstone, or diabase are often found in abundance in the overlying mantle of loose materials. Such bowlders cannot be supposed to have come from the disruption of the limestone, for limestone does not contain the materials of which they are composed. In like manner, the covering of unconsolidated material which overspreads the surface of gneiss within the area specified, often contains bowlders from a great variety of other formations, such as limestone, sandstone, and shale. Disintegration or disruption of the gneiss could by no possibility have given rise to limestone or sandstone or shale, since gneiss contains nothing from which these rocks could come by any simple process of disintegration or disruption. Not only does the composition of the loose materials overlying the solid rock in the northeastern part of the United States forbid the idea of their origin by the decay of the underlying rock, but in addition to this, the physical condition of the bowlders has a like significance, since many of them show no signs whatever of disintegration. They often look as fresh as if quarried but yesterday from their parent formations.

This aggregate of surface material which overlies different formations indiscriminately, and which is composed of materials which could not have been derived wholly from the underlying rock, is called *drift*. It was long since recognized that the materials of which it is composed did not originate where they now lie, and that, in consequence, they sustain no definite genetic relationship to the formations of the territory over which they are spread. Long before the drift received special attention at the hands of geologists, it was believed that it had been transported from other localities to those where it now occurs. The early conception was that it had been brought or "drifted" to its present position from some outside source by means of water. It is to this conception of its origin that the formation owes the name *drift*. In the early days of geology this surface material, which often effectually conceals the rock beneath, was regarded as uninteresting in itself, and an obstacle to the study of the underlying formations, which were regarded as the proper field of geological inquiry. So long as the drift was looked upon in this way, it received but little attention; but within recent years it has been the object of critical investigation, and there are now few departments of geology which are attracting a larger share of professional attention, and few departments which have yielded, or are yielding, more interesting and more important results. The accessibility of the drift, and its importance in shaping the details of the surface throughout so wide an area, have made it a favorite subject of study for a large number of students.

Thickness of the Drift.

In general. The thickness of the drift varies greatly. Over large areas its depth is so slight and so unequal that the underlying rock is frequently exposed. This is much more generally true in mountainous and hilly regions than in plane ones, though regions are not wanting where frequent rock exposures are associated with a topography of but slight relief. The mountains of New England, the Adirondacks, the Catskills, the Highlands of Northern New Jersey, and the adjacent parts of New York and Pennsylvania, may serve as examples of mountainous regions where the underlying rock is but poorly concealed by the mantle of drift. Areas of plane or gently undulating topography where the drift is so thin as to allow the underlying rock to be exposed frequently are by no means rare in the drift-covered area, but within the area of the United States, they are not generally of great extent.

Over wide areas the drift is so thick that the underlying rock is rarely seen except where natural or artificial excavations of great depth have been made. In such cases, excavations afford the only means of knowing the thickness of the drift. In still other regions the covering of drift is so massive that even the deeper valleys and the wells fail to penetrate it to its base. Over considerable areas in Northwestern Minnesota, for example, the older formations are so deeply buried by the drift that they have not been reached by the deepest excavations and borings that have there been made, though this does not mean that they are beyond the reach of deep borings. The drift is also very deep in many parts of Iowa, Illinois, Indiana, Ohio, Michigan, and New York. Depths of something more than five hundred feet have been recorded in a few places. Such thicknesses are rare; but thicknesses of two hundred or three hundred feet are by no means uncommon. The average thickness throughout the drift-covered area is much less, but no very accurate estimate can be made on the basis of present knowledge. The average thickness for the Upper Mississippi basin has been estimated to be not less than 100 feet.[1] For the eastern part of the United States, this figure is probably much too high.

The variations in thickness may be great within short distances. One hill may have barely drift enough to cover the rock, while the next may be composed of drift from base to summit. The drift may be thin on the hills, and deep in adjacent valleys, or, less commonly, the reverse may be the case. Thicknesses varying from nothing to one hundred or two hundred feet are not rare within a single square mile, and sometimes occur within much narrower limits. The natural sections exposed along the sides of valleys, and along the cliffs of seas or lakes, sometimes illustrate the abruptness of the variations in thickness. At one point along the course of a river valley the total face of

[1] CHAMBERLIN: Geikie's "The Great Ice Age," 3d edition, 1894.

the bounding bluffs, scores and perhaps hundreds of feet in height, may be of drift, while at adjacent points close at hand the entire faces of the bluffs may be composed of rock alone, or of rock no more than drift-coated. It follows that the surface of the subjacent rock is sometimes very uneven, and that its irregularities do not always stand in definite relation to the present topography. Where extensive excavations are favorably situated, it may sometimes be shown that the roughnesses of the rock surface beneath the drift are due to the existence of deep valleys excavated in the rock surface before the drift was deposited, and that these valleys do not now appear at the surface because they have been filled by the drift, and thus obliterated as surface features. Since the deposition of the drift, the rain and the rivers have in many places carved out new valleys in its surface. Sometimes these valleys, developed since the deposition of the drift, have sunk themselves through it, and into the rock below.

While abrupt variations in thickness characterize the drift of certain regions, and especially regions of considerable relief, they are not universal. Over large areas its thickness is nearly uniform. This is more likely to be true in plane areas than in areas of marked relief. If the thickness of the drift be approximately uniform in flat regions, it follows that the surface of the underlying rock must be approximately level. Where the depth of the drift is uniform, or nearly so, it may be scores or even hundreds of feet, or it may be very slight, affording no more than a thin soil and subsoil. It is even true, now and then, that areas a few or many miles in extent are nearly free from drift within the very heart of larger tracts, which, with these exceptions, are deeply covered. While the thickness or thinness of the drift is measurably independent of both altitude and topography, it is rather more commonly thick in low and nearly level regions than on high and rough areas. Apart from all considerations of altitude and topography, the distributi on of thick bodies of drift is not altogether fortuitous. Regarding the drift sheet as a unit, its greatest average thickness is neither at its extreme edge nor at its centre, but somewhere between the two positions and distinctly nearer the former than the latter. This is not to be construed to mean that the drift is not often thick both without and within the zone here specified, or that it is never thin in this zone.

Any theory of the drift must take account of these facts. The agent or agents to whose activity it is to be attributed must have been able to leave many small patches, not always higher or lower than their surroundings, essentially without drift. They must have been such as could have left the drift now in thick beds, and now in thin, over limited or extensive areas, without close dependence on topography or altitude, yet without complete independence of either.

Thickness of the drift along its borders. At its margin, the drift sometimes thickens so as to constitute a considerable ridge. This is the exceptional condition of things rather than the general. In other cases the drift grows thinner and thinner toward its edge, its limit being still well defined, and constituting a definitely traceable line. In still other cases the drift feathers out at its edge, ceasing to exert any observable influence on topography. In such cases the border may become so ill defined that it is traceable only with difficulty.

Driftless Areas.

Besides the many small patches of bare or nearly bare rock over which the drift forces acted without leaving deposits of much thickness, there is, far within the outermost limit of the drift-covered country, an area several thousand square miles in extent, where drift is altogether absent. This area lies mainly in southwestern Wisconsin, but embraces small adjacent areas in Illinois, Iowa, and Minnesota. The absence of even a meager coating of drift from this area has led to the conclusion that the agency or agencies which produced the drift were not here operative. There is probably a second, smaller driftless area, also, in the axis of the Mississippi basin, occupying a part of the elevated land between the Illinois and Mississippi rivers, near their junction. This area is much nearer the border of the drift, and appears much less anomalous than the other. Neither of the driftless areas are notably higher or lower than their surroundings, though both are notably rougher.

In considering the origin of the drift, we are forced to exclude as the sole or principal agents such as would not allow the existence of driftless areas, neither notably higher nor lower than their surroundings, within the very heart of the great sheet of drift.

Constitution of the Drift.

Physical heterogeneity. It is certainly a striking fact which confronts us when we see huge bowlders, sometimes many tons in weight, imbedded in earthy material as fine as that which our most sluggish streams are carrying in suspension. Between these extremes of coarseness and fineness, there are materials of all grades. The proportions of coarse and fine materials are not at all constant. The fine may predominate at one point, the coarse at another. From predominance of fine to predominance of coarse the changes may be abrupt, and frequently repeated. Any one of the constituents of the drift—bowlders, gravel, sand or clay—may predominate over any or all the others to almost any extent. It follows that any one of these may nearly or quite exclude the others, though the drift is rarely composed of large stones only. While, therefore, the drift is remarkable for its physical heterogeneity, and while this heterogeneity is a general characteristic, still there are localities where it is not extreme. There are localities, indeed, where the drift is remarkably homogeneous. In such cases its constituents are more commonly fine than coarse, and rather more commonly of sand than of clay, although drift made up principally of the fine, earthy material which is popularly called "clay," is by no means rare.

From the physical heterogeneity of the drift, it is clear that the agent or agents to which it owes its origin, or to which at any rate much of it owes its origin, must have been able, under some conditions, to carry and deposit at one place and at one time, materials as fine as the finest particles of silt or mud, and bowlders many tons in weight, while they were competent, under other circumstances, to make deposits of much less extreme diversity.

Lithological heterogeneity. The drift of any given area generally contains pieces of some such assemblage of rocks as the following: shale, sandstone, limestone, quartzite, gneiss, schist, porphyry, diabase, and gabbro. Not all these types of rock are represented in the drift of every locality, and some localities contain rock fragments of other types. But if all the foregoing kinds of rock are represented in the drift of a given locality, the drift containing them cannot be looked upon as possessing unusual lithological heterogeneity. Any type of rock represented in the drift may be represented by masses as large as the largest bowlders which the drift contains, and, at the same time, by the smallest particles which will allow of identification. In other words, the physical heterogeneity of any given sort of rock represented in the drift may be about as great as the physical heterogeneity of all.

The various types of rock represented in the drift of any locality are not generally in equal proportions. It is often true that some one type predominates, and this predominance is often striking. But in spite of this, the lithological heterogeneity of the drift is a well-nigh universal characteristic. Any hypothesis which essays to explain its origin must take account of this fact.

We must suppose that the granite of the drift came from some place or places where granite is the native surface rock, since we know of no other possible source for it. We suppose that the shale, sandstone, and limestone of the drift came from regions where shale, sandstone, and limestone severally occur, as the uppermost formations beneath the drift. But so many sorts of rock as frequently occur in the form of loose bowlders in the drift of a given place, do not often occur as surface formations in closely contiguous localities. Within the area covered by the drift there are rarely more than a limited number of rock formations appearing at the surface in closely associated areas. From its lithological heterogeneity, therefore, we must conclude that the sources of the drift were various and wide-spread; and if we conclude that its sources were wide-spread, we have no alternative but to conclude that the agencies which were concerned in its production were capable of wide-spread action.

Not only do we conclude from the lithological heterogeneity of the drift that it came from wide-spread sources, but we may reach positive conclusions concerning the minimum areal limits of these sources. By a careful study of the lithological character of the stones of the drift at any given point, and by comparing them with the formations of solid rock in all directions from this point, it is generally possible to determine the exact formation from which many of them came. If the surface exposures of the formations from which the identifiable bowlders came be very small, we are able to draw definite and positive conclusions concerning both the direction of transport of the bowlders in question, and the distance which they have journeyed. If the surface exposures of the formation whence they came be large instead of small, the conclusion which could be drawn would be confined within less narrow limits.

If the determination of the direction and distance of transport rested on the identification of a single type of rock, it would be necessary, in order to make the conclusion absolute, to prove that there is no second source, seen or unseen, whence the given type of bowlders could have come. Manifestly this might be a very difficult thing to do. But if identity can be established between various and diverse types of rock found in loose pieces in the drift of a given locality, and an equal number of formations in beds or *in situ* elsewhere, the case becomes much stronger, for it is almost beyond belief that two complex but lithologically dentical series of rock formations, embracing bowlders of so many types as frequently occur in the drift, exist in different directions from any given area. It follows that where identity can be established between a wide-ranging series of bowlders and rock fragments in the drift, and an equally complex succession of diverse formations *in situ* lying in a common direction from the drift which contains the identified types of rock, the conclusion that the former came from the latter is so highly probable as to amount to moral certainty. The known facts concerning the distribution of geological formations make it incredible that a complex succession of identical formations may lie similarly in a second direction from the given locality of drift, and yet be wholly concealed.

It is not to be understood that it is possible to trace every bowlder of the drift to its exact source. Far from it. It is often impossible to tell from what formation a bowlder came. An unfossiliferous Cambrian sandstone may be indistinguishable from an unfossiliferous sandstone from various other formations. Even if it be possible to determine the formation from which a given bowlder came, it does not follow that its exact or even its approximate geographic source can be determined. It may be possible, for example, to say that a given bowlder of the drift came from the Laurentian formation. But the Laurentian formation is exposed over so great an area that it might not be possible to tell, even approximately, the direction whence the bowlder in question came, or the distance it has journeyed. In spite of these limitations, there are some types of rock, and some associations of types of rock, which are available for the determinations here suggested. Drift bowlders derived from any formation possessing distinctive characteristics, and exposed in a small area only, give very definite information concerning both the direction and the distance of their movement. Where complex associations of bowlders occur, their joint testimony may be tolerably definite on these points, even when that of each type, taken singly, fails to be so.

The fine material of the drift. The fine, earthy material of the drift is popularly called clay. If it be critically examined, it teaches significant lessons. It is found to differ in some essential respects from the mineral matter which makes up the soil and subsoil of driftless territory. The latter is composed principally of the insoluble ingredients of decomposed rock, while the former is often nothing more nor less than pulverized rock, the soluble constituents as well as the insoluble being present. If it be examined under the microscope, tiny particles of all the principal minerals which enter into the composition of any of the bowlders of the drift of the same locality may be recognized In the clayey part of the drift, the dolomite and calcite of the limestone, the sand grains of the sandstone, the quartz, orthoclase, plagioclase, mica, hornblende, augite, olivine, magnetite, etc., and even the rarer apatite, tourmaline, zircon, garnet, etc., of the crystalline rocks, may generally be found in microscopic particles, if bowlders containing these minerals are at all plentiful. In general, the minerals which are abundantly represented in the drift bowlders of any locality, are relatively abundant in the fine earth of the drift of the same locality, while the rarer minerals of the bowlders are correspondingly rare in the accompanying clay. To this general statement there are some exceptions. The mineral particles of which the fine parts of the drift are composed often appear as fresh as if but just broken from the crystals of undecomposed rock. Where the particles are large enough so that their forms and surfaces can be distinctly made out, they are seen to be predominantly angular in shape, and to be bounded by fracture faces. They are just such particles as might result from grinding up together various sorts of rock. Furthermore, the fine earthy matter of the drift of any locality is of such mineralogical composition as to suggest that it was largely made from the grinding up of just those sorts of rock which are now represented in the large and small stones of the drift. The physical nature of the earthy matter of the drift, taken together with its mineralogical and chemical constitution, leaves no room for doubt that it is nothing more nor less than "rock flour," the product of mechanical grinding. The agencies which produced the drift must have been able to pulverize rock. No theory which does not take this into account can be acceptable.

Structure of the Drift.

Stratification. Much of the drift is distinctly stratified, and much of it is altogether devoid of stratification. Its structure is altogether independent of lithological heterogeneity, but is intimately connected with physical heterogeneity. Extreme physical heterogeneity implies absence of stratification, but absence of extreme physical heterogeneity does not imply stratification. In many cases drift composed almost wholly of earthy material, so fine as to be popularly called clay, is wholly without stratification. In such cases there are generally some stones associated, even though they be small. Heterogeneity exists, but is not extreme. In some places, though rarely, drift composed almost wholly of sand, and therefore not remarkably heterogeneous physically, is still without stratification.

While the unstratified drift may be nearly homogeneous physically, the stratified drift never reaches extremes of heterogeneity. It may be either coarse or fine, but the very coarse and the very fine do not coexist. While there are occasional beds of bowlders the relations of which suggest stratification, the usual limit to the coarseness of stratified drift is coarse gravel. Now and then large bowlders occur in the stratified gravel, sand, or silt, but these bowlders cannot be regarded as partaking of the stratified character which affects the matrix which encloses them. They interrupt the stratification, as may often be distinctly seen. They are accidents in the stratified deposits. No part of the drift, as that term is generally understood, appears to be so fine and so homogeneous as to fail of stratification because of its fineness and homogeneity. The single apparently well-marked exception to this statement (some parts of the loess) need not be here considered.

It is sometimes the case, as fresh cuttings through the drift show, that lenses or pockets of stratified gravel or sand occur in the midst of thick beds of unstratified drift. The reverse is also sometimes true, considerable masses or chunks of unstratified drift being now and then found in the midst of extensive stratified deposits. This association, however, is much less common than the other. Where the stratified drift occurs in extensive beds, it may overlie or underlie the unstratified, or the two may alternate with each other repeatedly in vertical succession in a single section.

In some regions, the unstratified materials predominate greatly over the stratified. In other regions the reverse is true. On the whole, stratified material is more abundant in valleys, and on low areas adjacent to high ones, than elsewhere, but there is no hard and fast topographic relation between the two types. The associations of the two phases of drift are often such as to leave no room to doubt the essential contemporaneity of their origin. The lithological likeness of their materials leaves no room to doubt that the two phases of the drift came from the same general source. From these considerations we conclude that the drift agent or agents must have been capable of producing deposits which were sometimes stratified and sometimes unstratified, and that in many places the deposition must have occurred under such circumstances as to allow of the frequent change from the one phase of deposition to the other.

Foliation of the unstratified drift. While the finer part of the bowlder-clay — the matrix in which the bowlders are set — shows no stratification, it frequently has a sort of structure which may be termed foliation. Roughly speaking, it is comparable to the foliation of gneiss, though of course without the crystallinity of the latter, and without differentiation of its mineral constituents. The foliation is always somewhat irregular, but is usually approximately horizontal, or approximately parallel with the surface. The regularity of its development is usually interrupted where it comes in contact with a bowlder. The foliation lines have a tendency to curve up over, and down beneath, the same, while at the centre of the sides of the bowlder they are rarely developed. The study of this foliation structure suggests that much of it is the result of pressure. In this case, the approximate horizontal direction of the parting planes suggests that the pressure was not far from vertical. In some cases the foliation is such as to suggest that it is the result of a shearing movement in the fine, earthy material. The position of the horizontal cleavage planes suggests that the pressure inducing the shear must have had a horizontal element.

Foliation is restricted to the unstratified portion of the drift, though even here it is by no means universal. It is rarely so distinct as to be obtrusive, and may easily escape the observation of those whose attention has not been called to it. The true theory of the drift must be one which will allow much of the unstratified drift to have been subject to great vertical pressure, and perhaps to shearing, at the time of its formation, or since.

Shapes and Markings of the Stones in the Drift.

If the stones in the drift be carefully examined, they are found to possess significant features. If a goodly number of them be collected from the unstratified drift, it will be seen that, while their surfaces are often smooth, their forms are, on the whole, somewhat unlike those of stones rounded by rivers or by waves. While some of them are round or roundish, many others are many-sided. Their faces are often beveled. They have been worn, but the wear appears to have been effected by planing rather than by rolling. The planed sides may meet each other at any angle, though the angle along the line of junction of two faces is rarely sharp. With these planed and sub-angular bowlders and stones there are associated few or many well-rounded ones showing none of the characteristics just noted. With them also, there are occasional angular masses of rock bounded by fracture faces, which do not appear to have suffered notable wear.

If an equally large number of stones from the stratified drift be selected for examination, it will be found that rounded, water-worn forms predominate. On the other hand, specimens of the many-sided, plane-faced forms, though much less common than in the unstratified drift, are not always altogether wanting. This distinction affects large and small stones alike. It characterizes bowlders a foot in diameter, if so large stones occur in the stratified drift, and it characterizes fragments less than an inch in diameter. In case large bowlders occur in the stratified drift, they are rather more likely to have the sub-angular form than the smaller ones.

Another peculiarity goes along with the foregoing. The planed, sub-angular bowlders and rock fragments which characterize especially the unstratified drift, are often distinctly marked with one or more series of lines or scratches on one or more of their faces. The lines of each series are parallel with one another, but the lines of separate series may cross each other at any angle. Multiple series on a single face are not rare, though less common than single series. Multiple series on multiple faces are rather infrequent, yet every student of the drift has seen them many times. Similar markings are not unknown on the well-rounded stones of the drift, though they are here much less abundant than are those of sub-angular forms.

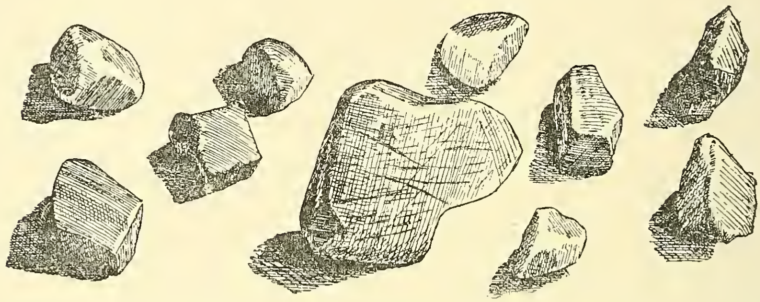

Fig. 1. Characteristic forms of small stones taken from unstratified drift. The contrast in form between these and water-worn pebbles is evident at a glance.

These markings, or *striæ*, as they are called, do not affect all the stones, or even all the sub-angular stones of the drift. If fifty per cent. of those occurring in the unstratified drift of any locality are striated, this is to be looked upon as a large proportion. On the other hand, even the unstratified drift locally contains so few striated stones that a single one is hard to find, even when good exposures are at hand. So far as concerns abundance of striæ, something depends on the relative proportions of coarse and fine materials. Much also depends on the differences in hardness between the various constituents. The striæ are much more abundant on the softer stones, such as limestone, than on the harder, such as quartzite. In much of the stratified drift, striated stones are rarely found. But in certain phases of it, they are no rarity. Where they are abundant, their forms are likely to be sub-angular, just as in the unstratified drift. Striation of surface, and sub-angularity of form, seem to go together.

The true theory of the drift must involve the action of an agent or of agents which, under normal conditions were capable of planing and beveling and striating many stones, especially the softer ones of the unstratified drift, while rounding and leaving unstriated most of those of the stratified. But the agents must have been such that under certain circumstances their activities failed, on the one hand, to leave more than a very small percentage of the stones of the unstratified drift beveled and striated, while, on the other hand, they sometimes permitted the stratification of gravels containing many sub-angular, plane-faced, striated stones, varying in size from pebbles to bowlders.

The Sources of the Drift.

Direction and distance of transportation. By tracing identifiable constituents of the drift back to their sources, it has been found that the general direction of drift transportation in the United States was from north to south. From this general direction there are many and considerable local deviations, both to the the east and west. Generally speaking, it has been found that the larger part of the drift of any locality has not been transported any great distance, though a small part of it has usually traveled far. Even at the southern margin of the drift, bowlders are sometimes found which have come from territory north of our national boundary. Those materials which have come farthest are generally of hard rock. These general statements are not without local and striking exceptions.

The forces which are responsible for the drift, therefore, must have moved, in .general, from north to south, and must have been capable of local and considerable deviation both to the east and west. They must have been active over an extensive area. They must have been forces capable of gathering and carrying materials in such wise that, at the time of their deposition, the larger part had been transported but a few miles, and in such wise that the contributions of various formations to the drift of any locality are, in a rough sort of way, inversely proportional to their distance. The drift forces must have been able also to carry large blocks of rock, and preferably hard rock, great distances, at the same time that they frequently carried a large proportion of the fine materials deposited at any given point, trivial distances only.

Size of bowlders in relation to distance from their source. Bowlders of a given type can sometimes be referred to a single source of very limited area. In such cases, it has been repeatedly noticed that the average size of the bowlders becomes less with increasing distance from their source, though individual exceptions to this rule are sometimes striking. This might be accounted for, conceivably, on either of two suppositions. Either the drift forces were not able to move the large bowlders so far as the smaller ones, or their size was reduced in the process of movement. If the latter conjecture be the correct one, the smaller bowlders, which are farther from their source, should show evidence of greater wear than the larger ones, which have not been carried so far. This might also be the case if the first supposition be the true one. For even if the drift agents could carry only the smaller bowlders considerable distances, these smaller bowlders might be worn more in their longer journey, than the larger ones, in their shorter. Between the two hypotheses the greater wear of the smaller bowlders might not therefore be decisive. But the extreme physical heterogeneity of the drift clearly indicates that the drift agents were, on the whole, very independent of the size of the materials handled. Bowlders many tons in weight were sometimes carried scores of miles. In view of this, the conclusion that the decrease in size of bowlers with increasing distance from their source is the result of wear suffered during the transit, seems the more probable. If this conclusion be correct, the drift force or forces must have been able to wear effectively the materials carried, during the process of their movement.

ROLLIN D. SALISBURY.

[To be continued.]

EDITORIALS.

THE sixth International Geological Congress is of the past. It was arranged that it should be in Zurich, but a more proper statement would be that it was in Switzerland, for the real work of the Congress was done in nearly all parts of that republic,—in the Jura at the northwest, in the great valley separating the Jura and the Alps, in the Alps, and on the Italian lakes to the south.

The officers in charge of the Congress, with admirable judgment, decided that the important matters were not acts of legislation in reference to geology, but an opportunity for the geologists of the world to gain an acquaintance with the geology of Switzerland, and the methods of work of the Swiss geologists. With these as the controlling thoughts, a series of excursions was arranged, running over a month or more. In planning these, while the geological interest of the localities was a controlling factor, care was taken that the visitors should enjoy the magnificent scenery of Switzerland. The excursions had such variety and scope that each geologist was able to find at least one before the sessions at Zurich, and one after, which covered his particular line of work, and this whether he were a palæontologist, a structural geologist, a glacialist or a petrographer. The excursions were further divided into two classes : the first provided for those who did not care for, or were not able to endure physical hardship, and therefore were largely by carriage, steamboat, and railway ; the second class, largely on foot, provided for those who were able to take long walks and endure severe climbing. The rendezvous for the excursions before the sessions were at various places in Switzerland. They were all well arranged so as to converge naturally at Zurich. After the Congress another set of excursions diverged from Zurich and converged at Lugano. Those before the Congress were in the Jura, those after in the Alps. All who went on one journey before and one after the Congress were able to obtain a good general idea of these two grand mountain systems, and the great valley separating them.

In order that the excursions should have the greatest success, there were published in advance a new geological map of Switzerland by Heim & Schmidt, a number of special memoirs by various geologists, and an excellent official guidebook, an octavo volume of over 300 pages, with numerous figures, maps, and sections. This book has a large number of parts, each one pertaining to a particular excursion. In most cases each part has a general statement of the geology of the district traversed and a detailed account of the phenomena to be seen on each day of the journey.

If one may judge by the two excursions which the writer was able to attend, the conductors were masters of the geology of the area covered, and eager to make the expeditions both pleasant and profitable to all participating. Not only is this true, but the citizens of Switzerland seemed to regard the Congress as a national affair, and wherever the parties went, they were treated with the greatest consideration and entertained with lavish hospitality.

At the sessions at Zurich there was no attempt whatever to legislate on any scientific question of geology. The meeting differed chiefly from other gatherings of geologists in that it was international, and was therefore attended by an unusually large number of eminent men. At the general sessions exceptionally valuable papers were presented by some of the more prominent geologists. Papers of a more special nature were read before the several sections of General Geology, Stratigraphy and Palæontology, Mineralogy and Petrography, and Applied Geology. One could therefore listen to the papers which were of particular interest to him, without being under the necessity of hearing others.

The excursions and sessions afforded an excellent opportunity for mutual acquaintance and interchange of ideas. It will doubtless be the experience of each geologist who attended the Congress, as he reads the works of men with whom he has become acquainted, that they will bring to him the image of the person who created the works. The friendships formed and the consequent sympathy with one another cannot fail to be a stimulus to mutual kindly criticism and helpful suggestion. The widening acquaintance in the past few years of many of the geologists of the world is without doubt one of the chief causes of the decline of unpleasant controversy. This bringing men together from all lands, and the formation of personal relations between them may perhaps be considered one of the most important functions of the International Congress. In this particular, if this be true, the last session was unsurpassed in importance by any previous one.

The only feeling of discontent which one brought away was grounded on the human limitation of indivisibility, for many interesting things were occurring at the same time. One wished not only to accompany one excursion before and another after the sessions, but two or more, and many found it very difficult to decide between them. The same may be said of the sessions. But this criticism is one which our brothers in Switzerland will doubtless take without hostility. The writer, and I have no doubt all other geologists foreign to Switzerland who came only with a desire for the advancement of geology, went away with a warm feeling of gratitude toward the Swiss geologists, who labored so long and faithfully to make the Congress what it was,—a high success.

C. R. V. H.

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THE explorer that enters a field whose sensational phases excite extreme popular interest must often pay the penalty of misinterpretation. His chief motive is easily supposed to spring from the sources of chief popular concern. It is not easy for the masses to suppose that he is stimulated by any higher interest than that which appeals most strongly to them. The discomfort of this is offset, in a certain way, by the popular tribute which is accorded him solely because his endeavor is misconstrued. His true purpose would be received with indifference. It is only when those whose interest takes a higher form share in the popular interpretation, without sharing in the popular interest and applause, that the penalty becomes a proper source of concern. When, for instance, in lieu of an effort to prove the insularity of Greenland, a race for the "fartherest north" appears as the prime motive of an expedition, the masses are all agog, but scientists become indifferent. An adventurous rush for the pole, and an effort to determine the rotundity of the ice cap, awaken diametrically opposite sentiments among the two classes. The interest of the one rises as that of the other falls.

As motives in all endeavors are doubtless more or less mixed, it will be fortunate if each class can find in every laudable enterprise a purpose congenial to its own point of view, provided always the hazard of the endeavor does not bar it out from legitimate undertakings. Beyond question, popular interest in Arctic exploration centres about the "fartherest north" and the attainment of the pole, and is grounded in the human factors of competitive courage, strength, sagacity, and luck ; while scientific interest is chiefly centred upon the physical and biological features of the region considered as elements of our great environment, to know every part of which is prerequisite to knowing any part well. In so far, therefore, as proper endeavor falls within the limits of legitimate hazard, the conjunction of popular with scientific interest is a helpful source of support and promotion, and, in view of this, the true explorer may be challenged to ake courageously the good and ill of personal interpretation until time shall bring its due, and presumably its true, adjudication.

The scientific factors in the work of Lieutenant Peary are worthy of note, quite apart from any admiration which his courage and perseverance may awaken. It should be more generally known that, during those portions of the season when his party have not been engaged in his great endeavor to complete the outlining of the northern and eastern coasts of Greenland and of the archipelago which is presumed to constitute its extension northward, they have been employed in the mapping of the western coast on a more detailed and accurate basis. This has not been confined to the portion near the headquarters of the party on Inglefield Gulf. Many additions have been made to existing knowledge of the coast all the way from Melville Bay to Cape Alexander, and even beyond. Inglefield Gulf and its dependencies, which on our charts are little more than a caricature, have been outlined with considerable accuracy, the leading points about Bowdoin Bay being fixed by triangulation. Mr. Astrup has made a new map of Melville Bay, which, notwithstanding the prominent and grewsome part it has played in northern navigation, is laid down on the charts with great inaccuracy. The outlines of the inland ice, and the glacial tongues which protrude from it, have been delineated with much greater approach to accuracy than heretofore. Other geological features have received attention. As elsewhere indicated, in addition to the geographical features of the glaciers, some of their physical characteristics, including their rates of movement, have been studied.

The meteorological observations, in the hands of Mr. E. B. Baldwin, formerly in the United States Weather Service, have been commendably complete in plan and successful in execution. In kind and grade they have been essentially the same as those required at our weather stations of the first order. The barograph and the thermograph were not only successfully manipulated at headquarters, but were kept in operation upon a sledge during the journey on the inland ice in the stormy months of March and April, as was also the anemometer. *Continuous* records of the temperature and of the atmospheric pressure and movements were thus secured. This is, we believe, quite beyond precedent. Perhaps nothing can better show that Lieutenant Peary's expedition was something more than an adventurous rush for the "fartherest north," or even for mere extent of coastal exploration, than this successful attempt to carry delicate instruments of continuous and exact record on a perilous trip, where every pound of burden and every expenditure of effort were matters of moment to the outcome.

This is not the place for an extended sketch of the scientific work of the expedition, but the citation of these items may aid in giving to genuine scientific interest and appreciation a tangible basis, quite apart from the humanistic phases of the enterprise that most attract the general attention. T. C. C.

Reviews.

The Great Ice Age. By Professor James Geikie. Third edition. London: Edward Stanford, 1894, pp. xxviii + 850. xvii plates.

The progress of glacial geology has been so great during the last few years that a new edition of this classic work is most welcome. Much the larger part of the volume has been rewritten. Even those parts which are only revised are so modified that they read as if now written for the first time. Apart from the alterations which the studies of recent years have made necessary, the general scope of the volume is somewhat changed. In the present edition, the glacial phenomena of the continent of Europe have received much fuller and much more systematic treatment than in the preceding. The glacial phenomena of Asia, Africa, Australia and South America also come in for their share of attention. The chapters which deal with the glacial phenomena of North America (52 pages) were contributed by Professor Chamberlin, and suggest much that is new in the way of classification and correlation. Another important change is the transfer of the discussion of the causes of the glacial period to the end of the volume. This arrangement seems to make this chapter much less than heretofore an organic part of the volume, and it is distinctly pointed out that the general facts and relations set forth in the rest of the volume are not dependent on any particular theory of glacial climate. Many of the minor changes of the volume are significant, and not the least point of significance is the fact that they are very generally brought into harmony with the results of recent research in our own country.

By way of illustration it may be mentioned that kames and åsar are now sharply distinguished from each other, and that the discussion concerning their origin is somewhat changed. It is interesting to note that Professor Geikie believes the åsar to be, for the most part, the products of subglacial, not of superglacial streams. In connection with kames some interesting facts concerning their distribution and relations are indicated. In Scotland they are said to be especially abundant "opposite the mouths of our larger valleys." Quoting Mr. Jamieson, Professor Geikie points out that kames are often grouped in belts which "lie across valleys in long sinuous lines, forming curves or segments of a circle, the concavity of which is presented to the head of the valley, and their convexity toward the sea or downward end, as in terminal moraines." Outside these belts and groups of kames, there are frequently found wide flats of gravel and sand, sustaining the same relation to the kame-belts that similar deposits sustain to moraines, and, more rarely, to belts of kames in our own country. Professor Geikie does not fail to note the close relationship between certain aggregations of kames and terminal moraines. It was just this moraine-like habit of certain kame belts, moraine-like both in themselves and in their relations, which led the writer to propose for them the name *kame-moraines.*[1]

Apropos of the question which has been raised, on this side of the water, as to the reality of the existence of rock basins produced by glacier erosion, it may be noted that Professor Geikie asserts that the "largest and most important lakes of Scotland" as well as a "vast number of mountain tarns" lie in rock basins. There is no hesitation in ascribing these rock basins to the work of glacier ice.

Important as many of the minor changes in the new edition are, the chiefest interest is likely to centre in the discussion concerning the succession of glacial epochs. In Scotland Professor Geikie finds what he regards as evidence of five glacial epochs. In England the Weybourn and Chillesford crags are believed to represent the deposits of a still earlier epoch when the climate was arctic in Britain, and when considerable glaciers were in existence, though the crag deposits themselves are not looked upon as the direct product of ice. These crag deposits, together with the overlying Cromer forest beds, are referred to the Pliocene. According to this interpretation, the beginning of the glacial period is not coincident with the beginning of the Pleistocene.

Instructive maps are given, showing the extent to which the ice covered Great Britain and Ireland, and the continent as well, in the second, third, and fourth glacial epochs. During the second epoch, Ireland, Scotland, and Wales were completely covered by ice, and glaciation extended essentially to the valley of the Thames. On the continent the ice is represented as having extended so far south as to cover

[1] Annual Report of the State Geologist of New Jersey, 1892, page 93.

all of Holland and part of Belgium. In Germany it extended to the Erz and Carpathian Mountains. It reached its southernmost extension in the valley of the Dneiper, somewhat below latitude 50°. A further point of interest is the representation of an independent ice sheet of considerable extent in northeastern Russia and the adjacent parts of Asia, about the Timan and Ural Mountains. The ice sheet which centred here is mapped as extending westward until it came in contact with the ice sheet which spread eastward from Scandinavia. This subordinate ice sheet had an area about as great as that of France. According to the map, the edge of the ice during this epoch was markedly lobate, especially to the eastward. Expression is also given to the idea that some of the mountain ridges well within the area of the *mer de glace* exerted, even at the time of maximum glaciation, a considerable influence on the direction of ice movement. The mountains of Great Britain, of Ireland, and of Eastern Scandinavia are represented as having never been so deeply covered with ice but that they continued to exert an influence upon the direction of its movement. They served as local centres of glaciation while the ice sheet was developing, and as such would seem never to have altogether lost their identity.

During the next glacial epoch (the third) ice again covered all of Scotland, but failed to override the southern extremity of Ireland. It left a considerable part of Wales uncovered, and encroached upon the borders of England only at the north, northwest, and northeast. On the continent, the ice failed to reach its earlier limit. Hamburg, Berlin, and Warsaw lie near the limit of its advance, and there was no independent ice sheet in the region of the Urals. The Scandinavian and British ice sheets were again confluent. During the fourth epoch, glacier-ice in Britain was largely confined to the mountain valleys of Scotland, though the valley glaciers sometimes came down so as to coalesce on the low lands, making somewhat extensive "district" or piedmont glaciers. On the continent, the ice covered the eastern half of Denmark, and reached southward to the Baltic ridge. It failed to cover all the southern part of Sweden, and did not encroach far upon Russian soil. The British and Scandinavian ice sheets were not confluent. During the fifth and sixth epochs, the development of ice was still more restricted, the glaciers of the last being less extensive than those of the fifth.

What is the basis on which the subdivision of the glacial period is based ? There would seem to be no question as to the distinctness of the Weybourn crag from the oldest glacial formations of the British Isles. The only question would seem to be concerning the glacial character of the Weybourn crag epoch. In favor of this view Professor Geikie seems to make a strong case. Between the drift of the second and third glacial epochs, the "lower" and "upper" bowlder clays of England, there seems to be a well marked interglacial horizon. This horizon represents an interval during which the land surface of Britain was considerably elevated. During the time of elevation the climate changed from arctic to temperate, and the land surface became well clothed with vegetation, and was occupied by man and Pleistocene mammalia. Following this condition of elevation, there was submergence of the land to an undetermined extent. During the submergence the climate changed from cold-temperate to arctic. The increase in the severity of climate accompanying the submergence resulted in a second *mer de glace*. Thus a very considerable period of time, accompanied by a very considerable amelioration of climate, and by very considerable changes of level, separated the lower drift of Britain from the upper.

The evidence on the basis of which the third epoch represented in Scotland (the fourth of the full series) is separated from the preceding, is drawn from several sources. (1) The mountain valley lake basins are believed to represent the work of advancing ice, not the work of the receding ice (valley glaciers) of the third epoch. (2) The bowlder clay in the mountain valleys possesses a topography which is fresher (less eroded) than that of the bowlder clay of the surrounding country. (3) Above the valley moraines which are thought to mark the termini of the glaciers of this epoch, there is an absence of till in the bottoms ot the valleys, and on their lower slopes. Higher up the slopes bowlder clay is present, as also in the same valleys below the moraines. The absence of bowlder clay in the situations specified is attributed to the erosive work of the mountain glaciers of the third (Scotland) epoch. (4) The moutonnées, striæ, etc., in the areas thought to have been covered by the local glaciers of the third epoch are fresher than the corresponding features elsewhere. (5) The coincidence of direction of ice movement with the courses of the valleys in the third epoch is striking, while during the preceding epoch the direction of ice movement was independent of topography. (6) It is thought that after the last great ice sheet (that of the third ice epoch) withdrew from Scotland, there were considerable changes of level, before the ice of the next epoch reached its greatest development.

The evidence brought forward along these lines in support of the separation of the epoch of the "district" glaciers of Scotland from the epoch of the preceding *mer de glace* is such as to make it clear that the former was in some measure distinct from the latter. The ice of the so-called fourth epoch would seem to mark a distinct stage in glacial history, a stage when the ice was more active than for a time preceding. But the evidence is not such as to make it clear that the epoch of "district" glaciers was so far separated from the last *mer de glace* of Scotland as to entitle it to the rank of a separate epoch, as that term is used in America. If local glaciers of the dissolving ice sheet tarried long in the mountain valleys, their persistence would seem to explain some of the phenomena cited as evidence of the separation of the epochs. A temporary and relatively slight re-advance of such glaciers during the general dissolution of the ice sheet might bring them again into vigorous action. Such recrudescence would at least help to explain such phenomena as call for advancing ice. The coincidence of the direction of striæ in the mountain valleys with the slopes of the surface, and the independence of striæ with reference to slopes elsewhere, does not seem to the writer strong evidence of an independent ice epoch during which the ice was largely confined to the valleys. It is believed that existing striæ were very often, if not very generally, made by the later phases of ice movement in the regions where they occur. It seems rational to believe that while Scotland was covered with ice to great depths, the movement of the same was largely independent of topography; but that later, when the ice was undergoing dissolution, when the highlands had become bare, and when the valleys were still occupied by ice, its motion was in correspondence with the local slopes. Such striæ as were developed at that time would necessarily be in harmony with the direction of the valleys. It is believed that a re-advance might take place sufficient in vigor to explain the phenomena cited from Scotland, without being of sufficient extent, or of sufficient importance from other points of view, to be regarded as a distinct glacial epoch. If, on the strength of the evidence presented, we are not altogether convinced that the third glacial epoch represented in Scotland (the fourth of the full series) was sufficiently distinct from its predecessor to be ranked as a distinct epoch, as we have been accustomed to use that term, it does not follow that new evidence may not yet lead to this conclusion. If the fourth epoch of Professor Geikie be no more than an episode, as terms are used in America, the recognition of its proper measure of distinctness is still important. An episode may ultimately come to possess a significance scarcely less than that of an epoch. Even if the "district" glaciers represented but a very moderate re-advance of the ice, this re-advance is worthy of differentiation since it helps to emphasize the general fact of the complexity of the glacial period as a whole.

When we come to the separation of the fifth from the fourth glacial epoch, and of the sixth from the fifth, it must be confessed that the evidence presented is very far from convincing, if the word epoch is to retain the meaning which has been attached to it in this country. From the written page it does not appear that the so-called fifth and sixth glacial epochs of Scotland necessarily amount to more than considerable recrudescences of glaciers which were previously retreating. But even if these recrudescences be of minor extent only, they should be recognized for what they are. If they be not separate epochs, in our sense of the term, there can be no doubt that they represent more or less distinct advances of the ice, and their separate recognition helps to emphasize what seems to be the fact in America as well as in Europe, viz., that the glacial period was long and complex. To this conclusion detailed work on both continents seems to be surely leading.

The drift of Southern England, "rubble drift," "head," etc., is ascribed to torrents connected in time with the ice epoch. The material, if we understand Professor Geikie rightly, is not for the most part material that was worked over by the ice, but rather the product of rock disintegration in cold climates. It is believed that the frozen surface outside the ice prevented the penetration of the rain water. Under these conditions, precipitation and drainage might give rise, especially in the warmer seasons, to considerable floods. Such waters, it is believed, bore the rubble from its native place and spread it upon the plains to the south. If this interpretation be correct, it may have an important bearing on gravel deposits outside the glacial drift in other countries.

On the continent, "upper" and "lower" series of drift deposits are recognized on all hands. There are numerous beds which have been more or less generally classed as interglacial. They are found at intervals over a stretch of country extending from the North Sea to Moscow. Many of the continental geologists have been in the habit of putting them together, and of regarding them as the great division plane between the "upper" and "lower" tills. Independently of the interglacial beds, an "upper" till is sometimes seen to be distinctly unconformable on a "lower," the relations being such as to indicate that the lower was exposed for considerable periods, and subject to extensive erosion, before the upper was deposited on it. This relationship does not necessarily indicate great recession of the ice between the times of deposition of two bodies of till. So far as the physical relations are concerned, the upper body of till might be the work of an advancing ice sheet which had previously retreated but a short distance, but which remained long in retreat.

It is surely most significant that the same general conclusions concerning the multiplicity of ice epochs are reached, whatever part of the continent be examined, provided it be within the glaciated area. Thus in Northern Norway, after an epoch of glaciation there appears to have been an epoch of submergence until the sea stood 63 meters higher than now. Then the land rose so that the sea stood about 35 meters higher than now. Then followed another epoch of glaciation. Between the deposits of these glaciations there are marine beds containing fossils. In Southern Sweden there are non-glacial fossil-bearing beds overlain and underlain by ice deposits. In Schleswig and the Danish Islands there are similar beds in similar relations. Of the eighteen species found in these beds, eleven have a southern range, four have a wide range north and south, while three species only are distinctly northern. Again in Eastern Holstein, and on the islands of Rügen and Bornholm, there are similar beds, similarly situated.

The interglacial beds are best developed in Eastern and Western Prussia, where they are of greater thickness, and occupy greater areas than elsewhere. They include sand, peat, etc. Some of them are marine, while some are of fresh-water origin. They have yielded many fossils. The general facies of their molluscan faunas, both marine and fresh water, denotes a temperate climate. All the marine molluscs are North Sea forms, and still live in the Kattegat. Most of them are now living in the western Baltic. The testimony of the fossil land mammals confirms that of the molluscan faunas as to the temperate climate of the continent between successive glaciations.

Considered as a whole, the character of the "interglacial" fossil beds of Northern Europe is such as to indicate that if they belong to one epoch, that epoch must have been one of considerable length and complexity. Interglacial peat beds in Holstein sometimes alternate with sand, and contain floras which denote considerable changes of climate, from cold to temperate and back again to cold. The mammalian remains likewise indicate fluctuations of climate. In Central Russia there are fossil beds overlying the drift of the most extensive ice sheet. These fossil beds are not buried by till, since they are beyond the limit of the later advance of the ice, but they are clearly neither post- nor pre-glacial. They are thought to represent a climate more humid and more mild than that which now exists in the same region.

Evidence for the existence of multiple ice epochs is not confined to the fossil beds, strong as their testimony is. In Germany there is an "upper" bowlder clay different in physical and lithological constitution from the "lower." This implies a difference in direction of movement of the ice which formed the two beds of till. Thus in Western Germany, the "lower" till was deposited by ice moving from north to south, while the "upper" till was deposited by ice moving from north of east to south of west. This two-fold division of the bowlder clay exists south of the region of the great Baltic ridge, though the southern limit of the "upper" till south of this ridge seems not to have been accurately determined.

As in Britain, so on the continent, Professor Geikie finds evidence that the ice-sheet which reached farthest south, and which deposited the "lower" till of Western Germany, is not the oldest ice-sheet which affected Northern Europe. In Southern Sweden there is a till or ground moraine older than that produced by the most extensive ice-sheet. This oldest bed of drift, so it is affirmed, was deposited by ice moving from the southeast to the northwest. The overlying drift is the product of ice which moved from north-northeast to south-southwest, or nearly at right angles to the direction of the first movement. No interglacial beds are found here, but the diversity of movement is so great that, taken in connection with the extraordinary direction of the first, its significance cannot be trifling. It is to be noted that the foregoing interpretation does not involve three periods of drift deposition in Southern Sweden. The "lowest" ground moraine is referred to the first epoch (the time equivalent of the Weybourn crag), while the "upper" must be made to include the deposits of the second and third, if deposits of both exist. Some corroborative evidence of a great "Baltic" glacier, which antedated the most extensive *mer de glace* of the continent and of Britain, is thought to be found in certain fossil beds of Central Germany, though for their own particular region these fossil beds are thought to be pre-glacial. The "lower" till of Central Germany is correlated with the "lower" till of Britain (second glacial, but first Pleistocene glacial epoch). The "upper" till of Central Germany (south of the Baltic ridge) is separated from the "lower" by beds containing the remains of a temperate fauna and flora. For the distinctness of the epochs of these two sheets of drift, the evidence is certainly strong. The "upper" till is correlated with the drift of the second Pleistocene *mer de glace* of Britain.

The great Baltic ridge of North Germany is regarded as a huge terminal moraine, on the outer part of which are the *End-moräne* or *Geschiebewälle* of the Germans. This moraine is looked upon as the southern margin of a sheet of drift which overlies the "upper" till of Central Germany. Some of the fossil beds of North Germany are believed to lie between this third sheet of drift and the second, the second being the equivalent of the "upper" till of the region south of the Baltic ridge.

The "lower" till of Schleswig within the Baltic ridge, is thought to correspond with the "upper" till of Middle and Western Germany. This implies that the direction of movement during the time of the great Baltic glacier, was notably different from that during the production of the "upper" till of Middle Germany. Furthermore, the so-called "lower" till of Schleswig is known to be underlain by a still lower till separated from it by fossil beds indicating a temperate climate. It is therefore concluded that the till of Schleswig is referable to three distinct epochs. The basis for the reference of the drift sheet limited on the south by the Baltic ridge to a separate epoch — the fourth — is threefold: (1) The fossil beds between it and the next lower drift-sheet; (2) the change of level which these fossil beds imply; and (3) the differences in direction of movement. The drift which is limited by the Baltic ridge in Germany is correlated with the epoch of the "district" glaciers in Scotland.

Evidence for a fifth glacial epoch, that is, an epoch later than that of the great Baltic glacier, has not heretofore been recognized in Scandinavia. The mountain valley moraines of that peninsula have been regarded as moraines of recession. From this conclusion Professor Geikie is inclined to dissent. He is disposed to think that these moraines may represent a minor ice epoch or ice epochs, corresponding with the latest epochs of Scotland.

It is interesting to note, though too much weight must not be attached to the analogy, that the outermost border of the drift in

Europe, as in America, is not characterized by terminal moraines; that the limit of the drift deposited during the second advance of the ice in Europe, as in America, is not commonly marked by well-defined moraines, though moraines are not altogether wanting; that the great body of loess in Europe, as in America, seems to be connected with the ice advance which succeeded the greatest; and that the ice during the next succeeding advance (the second after the greatest), both in Europe and America, developed the great terminal moraines, and that these terminal moraines are bordered on the outside by plains and valley trains of sand and gravel, denoting more vigorous drainage than during the earlier stages of the ice.

A chapter is devoted to the glaciers of Middle Europe. Nearly all the mountains of this part of Europe had their glaciers during one or more of the glacial epochs. In some of these regions, as in the Vosges Mountains of Alsace, there is more or less evidence of separate epochs with inter-current non-glacial conditions.

In Switzerland details concerning the glacial formations have been worked out in great detail by several geologists, among them Messrs. Penck, Brückner, Böhm, and Du Pasquier. Much of the work in Switzerland has been done independently, but the conclusions reached appear to be nearly the same in whatever part of the Alpine country the areas investigated lie. Three thoroughly distinct series of glacial deposits are recognized, separated by interglacial beds representing genial climatic conditions. The intervals between the successive glaciations were long, perhaps longer than the time since the last. This evidence is not confined entirely to the regions which were actually covered by the ice. It is also found in territory which ice did not cover. The evidence outside the areas actually glaciated is drawn from three series of gravel deposits. The oldest series of gravels, which Professor Geikie calls the "plateau" gravels, were deposited during the first recognized epoch of glaciation in the Alps. After the deposition of these gravels there was a long period of erosion. Streams cut deep and broad valleys through these gravels, and into the rock upon which they rest. During this erosion interval the Inn, for example, deepened its valley several hundred feet.

In the valleys thus formed, a later deposit of glacier gravel was made. This gravel constitutes the so-called "high terraces." There is direct evidence that this gravel was connected in time and origin with the second glacial epoch of the Alpine region. Subsequent to the deposition of this second series of gravels, there was a long period of erosion and weathering, during which deep valleys were cut in the high terrace gravels. This period of erosion corresponds with the second interglacial epoch of the region. Later, a third series of glacial gravels was deposited in the valleys cut out of the second series. This third series may be traced into direct connection with the terminal moraines in the mountain valleys. The foregoing sequence was first established by Penck for Upper Bavaria, but it has been found to hold for all the Alpine *Vorland* between the Rhine and the Traun. By Professor Geikie these three glacial epochs of Switzerland are believed to correspond to the first three glacial epochs of Northern Europe.

The argument for the tripartite division of the glacial deposits of Switzerland as stated by Professor Geikie, seems strong. The evidence has been gathered with great care by those on whose conclusions we have learned to rely. Until it is decided how far the ice must have retreated, relative to earlier and later advances, and how long it must have stayed in retreat, in order that a re-advance shall constitute a new ice epoch, there is of course chance for discussion as to whether these separate series of glacial deposits represent distinct glacial epochs. But from Professor Geikie's exposition, there can hardly be a doubt that the three subdivisions of the Alpine drift are thoroughly distinct, distinct enough to make their reference to separate epochs the most natural method of classifying them.

Later than the three glacial epochs, as determined by Penck and his associates, there are said to be two later sets of moraines in Switzerland. To these Professor Penck assigns a "post-glacial" age. Geikie thinks they may belong to the fourth and fifth epochs, according to his general classification for the whole of Europe. This would make five glacial epochs in Switzerland, according to Geikie, two of which are "post-glacial," according to Penck.

Evidence of the same general import is likewise found in the Auvergne. It will thus be seen that the evidence for the existence of multiple glacial epochs is not confined to one area, or even to a few closely associated areas. The evidence is drawn from widely separated sources, and is found in all regions which were extensively affected by glaciation.

Concerning the general question of the division of the glacial period into epochs, it may be said that too much reliance is not to be placed on specific bits of evidence, or on specific lines of evidence.

Specific bits of evidence, or even whole lines of evidence, which are cited in support of separate epochs, might be interpreted in some other way. But in dealing with such questions we have always to remember that several lines of evidence, no one of which is absolutely conclusive, may together be so strong as to carry conviction. The question is not whether this or that bit or line of evidence *might be* explained in some other way than by the theory of distinct glacial epochs, but whether, as a matter of fact, the aggregate of evidence compels the adoption of this theory. The question is not *what might have been*, but *what was*.

According to Professor Geikie the sequence of events during the prolonged glacial period is as follows: (1) A glacial epoch, preceded by a period of increasing cold. At this time ice filled the basin of the Baltic. The Alpine lands were swathed in snow and ice, and great glaciers came out from the mountains, making moraines on the low ground at their bases. The mountain regions of Britain were probably ice-clad, though of this there is no direct evidence. In France there were glaciers from the volcanic cones of Auvergne and Cantal, which descended so as to deploy upon the plateaus. (2) Then followed the first interglacial epoch. The southern part of the North Sea became land, and a temperate flora, comparable to that of England today, covered corresponding latitudes. A luxuriant deciduous flora occupied the valleys of the Alps, and flourished at heights which it no longer reaches. (3) The first interglacial epoch was succeeded by a second glacial epoch. During this time the northern *mer de glace* reached its greatest extent. At the same time, the Alpine glaciers reached their greatest extension, while in the other mountains of Europe snow fields and glaciers came into existence. (4) The dissolution of this ice sheet was followed by a second interglacial epoch. The climate of Northern and Central Europe again became temperate, a temperate flora and fauna finally replacing the arctic forms which first tenanted the land after the ice disappeared. The plants which occupied Germany and the central plains of Russia indicate a less extreme climate than is now experienced in these regions. Later, the climate became more rigorous. The amount of erosion accomplished during this second interglacial interval was such as to testify to its great duration. (5) A less extensive, but still great ice sheet overwhelmed a large part of the British Islands, and spread itself widely upon the continent. As in the preceding epoch the Scandinavian and British ice sheets were confluent. From the Alps great glaciers descended to the lowlands. (6) Eventually the ice of the third epoch disappeared and temperate conditions succeeded. Of this change the best evidence is furnished by the younger interglacial beds of the Baltic coast-lands. (7) The fourth glacial epoch succeeded the third interglacial. During this epoch the Lowlands of Scotland were submerged to a depth of 100 feet. The Highlands of Scotland had their glaciers, which in places reached the sea. The Alpine glaciers flowed for long distances down the great valleys, but fell far short of the dimensions reached by those of the earlier epochs. From Scandinavia, the ice moved south to the Baltic ridge in Germany. (8) Following the fourth glacial epoch there was a fourth interglacial epoch, when deciduous trees spread far north into regions where such trees no longer flourish. The Baltic was converted into a great lake. Submergence followed, and the Baltic became an arm of the sea, with a fauna indicative of a warmer climate than the present. (9) During the fifth glacial epoch there were local valley glaciers in the British Isles, the position of which shows that the snow line in Scotland had an average height of 2500 feet. During this epoch Scotland was submerged to an extent of about fifty feet. In the Alps, the fifth glacial epoch is marked by moraines of the second so-called "post-glacial" stage. (10) The fifth interglacial epoch was marked by the re-emergence of the land and the retreat of the valley glaciers. Britain's area became wider than at present, but it is not known that connection was made with the continent. (11) During the sixth glacial epoch Scotland was submerged twenty or thirty feet more than at present. The snow line then stood at an elevation of something like 3500 feet in Scotland, and a few small glaciers existed in the lofty mountains. It is to be noted throughout, that elevation and amelioration of climate go together, while colder conditions accompany subsidence.

Concerning the origin of the loess Professor Geikie takes no uncertain ground. He believes that it was primarily an aqueous deposit, made during the closing stages of more than one glacial epoch, but that the principal body of it was connected with the closing stages of the third epoch. Subsequent to its first deposition, it is held that the wind shifted it from the position in which it was left by the water, on a somewhat extensive scale. The fossils of the loess seem to indicate that an arctic fauna was succeeded by a sub-arctic, and this in turn by a temperate one.

In his chapter on extra-European countries, our author recounts evidence to the effect that there were extensive glaciers in most of the mountain ranges of Asia during the glacial period. At this time glaciers are believed to have been much more extensive than now, in regions where they now exist, and to have existed in many places where they are not now found. The glacial deposits of Asia have been little studied, and have not thus far yielded evidence of recurrent epochs. In Africa there is evidence that there were somewhat extensive glaciers in the Atlas Mountains, where there are said to be large moraines at an elevation of not more than 6000 feet. There is evidence, too, that glaciers descended much lower than at present from some of the mountains near the equator. Thus about Mt. Kenia (18,370 feet) glaciers have at some time descended between 5000 and 6000 feet lower than at the present time. In South Africa, likewise, there are traces of glaciers in the mountains at elevations ranging from 1000 to 5000 feet. In the Australian Alps, glaciers are found to have descended to a level little more than 3000 feet above the sea. There is evidence also of glaciation at points in South Australia. Within this province the effects of ice action are observable down to within forty feet of the sea level about St. Vincent Gulf, latitude 35° south. There are also evidences of former glaciers in Tasmania, and the ice in New Zealand is known to have been much more extensive at some earlier time than now. Kerguelen Island, it is believed, has at some time been completely smothered by ice. In South America, too, glaciers were formerly much more extensive than now.

Professor Geikie makes no specific statement looking to the time correlation of the glacial conditions in these various countries with those of Europe and North America, but the implication, perhaps unintentional, is that they fall within the limit of the glacial period of those countries. Until the cause of the glacial period is known, it would seem to be unfortunate to assume that the glaciation of different continents was synchronous.

The chapters devoted to the drift of North America are more than a summary of the drift phenomena of our continent. They are written from the standpoint of Pleistocene history and embody new suggestions on many points.

Professor Chamberlin calls attention to the fact that the known history of glaciation practically begins with the time when the ice reached its outermost limit. The earlier glacial history is largely lost, and that which is not altogether lost, is greatly obscured. A distinct innovation is suggested in the chronological classification of the drift. Instead of referring to a given drift deposit as belonging to the first, second, or third glacial epoch or episode, it is proposed to designate the deposits made during the more distinctly marked stages of the glacial period, by the names of type localities. Thus it is proposed to apply the name *Kansan* to the deposits made by the most extensive sheet of ice. This formation is now uncovered only along the southern border of the drift. As now exposed, it finds extensive development in Kansas, Missouri, Illinois, Iowa, Nebraska, and Dakota, and lesser development in several other states. In general, this formation is thin at its outer edge, its terminus not being marked by morainic accumulations. It has suffered much erosion. In many regions, remnants only have escaped destruction at the hands of erosive agencies. The rock surface underlying the exposed part of this formation was in general little modified by the ice.

The Kansan formation is overlapped by another sheet of drift, the *East Iowan*, which encroached upon it from the north, leaving only its southern margin exposed. Between the two formations there is a widespread body of soil, which is in many places thick. It was probably as well developed as the soils of the present surface. It is known to extend fully fifty miles back from the outer border of the East Iowan formation. The plant remains which this soil contains have not been studied in great detail, but they are such as to indicate a temperate climate. The interval of deglaciation therefore was important. This interval of deglaciation is called the post-Kansan interval. Some estimate of its length is also based on the amount of erosion which the Kansan formation has suffered, compared with that which has affected the next succeeding formation.

Like the Kansan, the East Iowan formation was once widespread, but as a rule only that part of it which was not covered by later drift can now be certainly differentiated. Like its predecessor the East Iowan formation is not generally bordered by distinct terminal moraines. With the East Iowan formation, the main body of the loess seems to have been connected in time of origin.

Following the East Iowan formation, it would appear that there was an interval of deglaciation sufficiently long "to permit a notable change in the configuration and conditions of the land — the development of capacious valleys; the general carving of the surface into an erosion topography; the production of vegetal beds and soils, and the deep penetration of weathering."

Following this period of deglaciation, the ice again advanced, making, and finally leaving, the body of drift which it is proposed to designate the *East Wisconsin* formation. As now exposed this formation is much more extensive than either of the preceding, though it is less extensive than either of the others were before they were buried and disturbed or destroyed by later incursions of the ice. It is characteristic of the East Wisconsin formation that it is bordered by great moraine loops. It is also characteristic of this formation that extensive gravel plains, in distinction from silt and loess plains, border its moraines on the outside. It is in connection with this formation that drumlins, kames, and osar are best developed. The East Wisconsin formation is by no means simple. During its development there were repeated oscillations of the ice edge. Some of them may have been considerable, but they are not believed to mark more than minor stages in the history of the glacial period.

At several closely associated points in the vicinity of Toronto there are fossil beds of stratified drift between beds of till. These fossil beds have yielded a rich flora and fauna, which have recently been studied by Messrs. Coleman, Townsend, and others. The character of the fossils is unequivocal. They indicate a climate milder than that of the present time in the same region. The molluscan fauna would be appropriate to Southern Illinois, the flora to Southern Ohio. Unfortunately, the position of the fossil bed in the great drift series is not certainly known. It is hardly probable that it belongs between the Kansan and the East Iowan formations. It is more probable that it lies between the East Iowan and the East Wisconsin formations. On the other hand, it may lie between the East Wisconsin formation, and the deposits of a later ice epoch which, within the United States, has not been differentiated from the preceding. If the fossil bed occupies the position last mentioned, there would be reason for separating the drift series into four principal formations, rather than three.

Professor Chamberlin is very conservative with reference to the chronological importance of the several subdivisions which he proposes. He does not assert that the three main subdivisions for which he proposes names, are of equal importance. It is left an open question which of the two deglaciation intervals between these formations is the more important. It is left an open question, so far as affirmation is concerned, whether either one or both of these intervals is of sufficient importance to constitute the succeeding ice advance a separate glacial epoch. It is clear, however, from the discussion, that the author believes in at least a bi-fold division of the glacial formations of sufficient importance to allow each to be assigned to a separate epoch. It is also clear that he is hospitable to a threefold division each with the rank of an epoch, and the way is left open for recognition of a fourth.

In this connection Professor Chamberlin makes some suggestions of general interest concerning the subdivisions of the drift. He says:

"If the ice age consisted of distinct glaciations separated by climatic conditions as genial as those of today, they might as properly be called periods as epochs of glaciation. If the intervals of ice retreat, whether they amounted to complete disappearances or not, were comparable to the post-glacial period in duration, in the amount of erosion, weathering, soil production, vegetal accumulation, orographic movement, or other work done, or in the geniality of their climate or the character of their life, they are surely entitled to be recognized as marking epochs. If the intervals fall notably short of this, it is doubtless best to regard them as marking episodes, rather than epochs. The need for recognizing them would still remain, however, if we are to decipher and delineate the intimate history of the Ice Age."

We suspect that many glacialists would not be willing to follow the above suggestion in full. We suspect that many of them would hold that an interval of deglaciation might fall "notably" short of the post-glacial interval, and still the re-advance of the ice constitute a separate glacial epoch, especially if the retreat and the subsequent re-advance of the ice were very considerable. If, for example, the ice retreated so far from its extreme position as to free the territory of the United States, and if, during this retreat, the region freed became temperate, a subsequent advance of the ice to the limit of the East Iowan formation might perhaps not improperly be regarded as a distinct glacial epoch, even if the deglaciation interval were notably shorter than the post-glacial epoch. Especially would this be true, if the ice remained long in retreat, and if other events, such as changes of continental attitude, intervened. Even on the basis which Professor Chamberlin has proposed, there is in the minds of many geologists no doubt but that at least two, and very likely three distinct glacial epochs have affected the North American continent.

Professor Chamberlin very properly insists that just at present it is a matter of subordinate importance whether the several divisions of the ice period be called epochs or episodes; that the thing which is important is the recognition of the complexity and the protracted character of the glacial period as a whole. Until this is recognized, it will be difficult to prosecute work intelligently along the lines which must ultimately determine whether the rank of the several subdivisions is epochal or episodal.

A single word may be added with reference to Professor Geikie's chapter concerning the "Cause of the Glacial Climate." It has already been noted that the discussion of this subject has been relegated to the last chapter of the volume. In the course of this discussion it is evident that Professor Geikie holds much less strongly than heretofore to Croll's hypothesis of glacial climate. While he indicates that this hypothesis probably "contains a large element of truth" he does not regard it as a full solution of the vexed question. He further indicates that the complex phenomena of Europe "are evidence of a succession of changes too manifold, and perhaps occupying too short a space of time, to be accounted for by the cause to which Croll appealed." Professor Geikie's attitude seems to be well expressed in one of his closing sentences: "The primary cause of those remarkable changes is thus an extremely perplexing question, and it must be confessed that a complete solution of the problem has not yet been found."

ROLLIN D. SALISBURY.

Papers and Notes on the Glacial Geology of Great Britain and Ireland. By the late HENRY CARVILL LEWIS. Edited from his unpublished MSS., with an introduction, by HENRY W. CROSSKEY. Pp. lxxxi+469. Maps x., figures 83. London: Longmans, Green & Co., 1894.

Dr. Crosskey and the devoted wife of the late Professor Henry Carvill Lewis have placed all who are interested in glacial phenomena under lasting obligations by the publication, in elegant form, of the papers and notes of one who was among the most active and enthusiastic of American glacialists. It would have been a pleasure to the writer to have made earlier notice of this work, had not his absence from the country prevented. The book embraces papers on (1) Comparative Studies upon the Glaciation of North America, Great Britain and Ireland; (2) The Terminal Moraines of the Great Glaciers of England; (3) On some Important Extra-Morainic Lakes in Central England, North America, and elsewhere, during the period of maximum glaciation, and on the Origin of Extra-Morainic Bowlder Clay; (4) The Supposed Threefold Division of the Drift; (5) The Direction of Glaciation as ascertained by the Form of the Striæ; (6) Notes of observations made in the field, with their associated references, and with maps of routes and of the glaciated areas; (7) Memoranda and Brief Essays on various subjects connected with Glacial Geology; and, as appendices, (A) Extracts from the MSS. of Mr. Percy F. Kendall, and (B) Field Notes in Switzerland, Italy, South Germany, Belgium, and Holland. These papers and notes are presented as nearly in the form in which they were left by Professor Lewis as could be done consistently with a proper preparation for the press, Dr. Crosskey believing that this was both wiser and more loyal to his friend than any essential revision would be.

A peculiar interest attaches to the field notes of Professor Lewis, as they are thus frankly presented to us, because they open without reserve the door to his inner thoughts and impressions as they arose from day to day in the course of his rapid contact with new phenomena. We are permitted to see the advances, the oscillations and the occasional retreats of conviction that marked the application of his dominant working hypothesis to the problems he had undertaken. All who have had like experiences of oscillating conviction—and who has not—will find a sympathetic chord touched in the perusal of these notes.

Professor Lewis' method was distinctively that of the working hypothesis. While he entertained many supplementary hypotheses, and was by no means negligent of opposing hypotheses, there was one that was dominant and guided his work. The distributive affection that characterizes the system of multiple working hypotheses finds little expression in his investigations. With a strong faith in his chosen method, he sought to disentangle the intricate drift deposits of the British Isles by its energetic application. His working hypothesis sprang from his previous studies. During the decade preceding his notable work on the moraine of Pennsylvania, certain of the now older students of the drift, east and west, had detected a series of terminal moraines that had been previously overlooked or neglected, and had inaugurated the morainic method of discriminating and delineating the stages of glacial history. In the east the chief terminal moraine lay near the limit of the drift and was, for the time, supposed to be essentially coincident with it; in the west the chief moraines lay at some distance back from the drift margin, and were not supposed to represent the full extent of the ice advance except locally, although correlated with those of the east. At the east, by virtue of the near coincidence of the moraine with the border of the drift, the word "terminal" came to have a double significance, in which *terminal to the drift* grew to be more prominent than *terminal to the ice* that formed it. It is needless to say that the latter is the original and true sense of the term, and that up to this time it had been employed almost exclusively in this sense in its application to the moraines of the Alps and elsewhere. Almost none of the previously recognized terminal moraines were marginal to the glacial deposits. The strength and definiteness of the outer terminal moraine in the Atlantic region, and the inconspicuousness of the drift outside it—which was almost overlooked for the time—naturally brought into great prominence the marginal position of the moraine, and fostered the development of the imported sense of the word "terminal." More than this, it led to the conviction that such a moraine was *characteristic* of the outer border of the glacial drift, if, indeed, it was not a necessary feature, and that by seizing upon it, and following it persistently, the precise limit of the ice advance might be definitely traced out and the true glacial drift distinguished from outlying drift transported by other agencies. It was this view, thus derived, that stimulated and directed the work of Professor Lewis in Great Britain and Ireland. His supreme effort was to detect and trace across the British Isles a moraine marginal to the true glacial drift, and to distinguish from this the outlying deposits which he believed to be formed by means other than direct glacier action.

The book sets forth by maps and clear descriptions the course of the moraine as traced by Professor Lewis, and also the nature and extent of the glacial movements that gave rise to it. It also presents the distribution of the marginal waters in Great Britain, by whose agency, in Professor Lewis' judgment, the extra-morainic drift was chiefly deposited. These were, in his opinion, mainly fresh waters, ponded back into lakes by the glacial obstruction of valleys and basins sloping *toward* the ice. He was led to very moderate views respecting the marine submergence of the land.

It must be left to British glacialists to say how far the delineations of Professor Lewis are likely to stand, but without doubt the introduction of the morainic method, and the definite mapping which he presented, must be regarded as a very stimulative contribution. The writer of this note does not agree with him in the belief that the *border* of the glacial drift is necessarily any more amenable to the morainic method than other portions; indeed, we think that European as well as American experience has already shown that it happens to be less so, as a major fact. The moraine-developing habit was most pronounced during the later part of the glacial period. More than this, we think it has been amply demonstrated that the border of the drift was formed at different times, and that the moraines that are marginal to it in one portion depart widely from it in other portions, one moraine lying on the border in one region, and another in another region, and that along a large portion of the border there is no conspicuous ridging of the drift. Nevertheless it is valuable to trace out any terminal moraine, whether it borders the drift or whether it separates drifts older from drifts younger, for it becomes, in any case, if successfully done, a tangible datum line for correlation.

Professor Lewis came to recognize, so far as England is concerned, that there was an earlier drift outside the moraine he mapped. Concerning this he says, p. 69 (*Postscript added to abstract printed in "Geological Magazine," November, 1887, p. 516*): "Since the paper [Extra-Morainic Lakes of England] was read of which the above is an abstract, I have found traces of the existence of a very much older series of glaciers than those here described.

"Since the period of these ancient glaciers, which in many places were more extensive than the modern ones, earth movements have occurred and erosion has removed almost all their deposits, and generally obliterated striæ, so that the region subject only to the older glaciation now resembles a non-glaciated area.

"The glaciers and their bordering lakes, described above should therefore be considered as belonging to the second or last glacial epoch."

And again, p. 390: "Recently I had found in the 'fringe' region of England evidence of a much more ancient glaciation; so old indeed that erosion had removed almost all the deposit and obliterated the striæ. Perched erratics occur above any possible lake. Is not this still due to an old glacier, and the red clay to an extra-morainic lake? Are they contemporary deposits? I find that the glaciers of the first epoch came from more southern centres than those of the second ice period."

T. C. Chamberlin.

The Colorado Formation and its Invertebrate Fauna. By T. W. Stanton. Bull. U. S. Geol. Surv., No. 106, 288 pp., 45 plates. Washington, 1893.

In the preparation of this memoir the author has made extensive field studies in Colorado and Utah, and has had the benefit of certain unpublished notes by Mr. Walcott on the Kanab valley. In addition a careful review of previous papers and collections has been made with the satisfactory result that, whereas previously but twenty-five or thirty species had been definitely referred to the Colorado formation, one hundred and fifty are now listed. The greater portion of these, including some thirty-nine new forms, are described in this paper.

The history and definition of the Colorado formation is introduced by Meek and Hayden's Upper Missouri section, which has so long been the starting point for all work on the interior Cretaceous. The evolution of this section from the original five numbered formations to the present form is briefly sketched.

The Cretaceous is considered by regions, beginning with Iowa, and continuing through Kansas, Upper Missouri region, Colorado, New Mexico, and Utah. The portion devoted to Colorado and Utah is particularly full and interesting.

The Colorado fauna is compared with those of other marine Cretaceous formations. There are fourteen identical or very closely related forms which occur in both the Colorado and Montana. The Eagle Ford shales contain twelve typical Colorado forms, and the Austin limestone thirteen. Seven species are found in British America, and eight in Manitoba. A comparison with European formations shows the relations to be closest with the Turonian.

The species described are well figured, and the descriptions clear and concise. A large number of changes in nomenclature are made, many of which result from the changes in classification adopted by recent European writers. Few of the changes made will be more widely noticed than that of *Inoceramus problematicus* Schlot, the best known and most widely distributed Colorado form, to *Inoceramus labiatus*, a form described earlier (1813) by the same author. Another of the changes which deserves notice is the recognition of the western forms hitherto known as *Gryphæa pitcheri* Morton as belonging to an independent species which is christened *newberryi*. Still another change of importance is the recognition of Meek's American species

Prionocyclus woolgari as identical with the European form described by Mantell, now known as *Prinotropis woolgari*.

The bulletin shows a very happy combination of stratigraphic and palæontologic work. It will be welcomed by all students of the interior Cretaceous as a valuable aid.

H. F. Bain.

Analytical Abstracts of Current Literature.

The Relation Between Baseleveling and Organic Evolution. By J. B. Woodworth. (American Geologist, October, 1894, Vol. XIV., No. 4, pp. 209–234.)

In the historical sketch the writer speaks of the former strong belief of the British geologists in marine action as the origin of baseleveling, due in large measure to their insular position. They have recently been awakened by the work of the continental geologists in regard to baseleveling by meteoric agents.

In America, Powell, Gilbert, Davis, McGee, and others have established a cycle of existence for rivers and their valleys, ranging from youth, in a newly elevated country, through adolescence, maturity, and so on into old age, when, the land remaining stable, a peneplain will be formed. An uplift will revive the streams and start a new cycle. Many other points of interest are brought out by these writers in regard to the history of river systems.

Under the general effect of river changes on fluvial faunas, the important relation of the topographic history to the distribution of fresh-water fish and mollusks is shown. This may be through (1) head-water division, (2) antecedent streams, (3) alluviation, (4) slight submergence, (5) elevation and revival of streams.

Effect of baseleveling of a mountainous region is discussed, including the fading away of divides, the degradation of uplands, spread of lowland conditions, the peneplain as an open field for land life, uplift and dissection of the peneplain. The Jura-Cretaceous peneplain is discussed at length, both in its topography and its influence on life. It forms a conspicuous topographic feature in eastern North America, and traces of it occur on the Pacific coast. It is well developed in New England, Middle Atlantic states, and southward. At the close of the Cretaceous the peneplain was elevated when streams began to cut valleys, and another Tertiary baselevel had almost been completed when a new uplift caused rejuvenation.

The influence of the peneplain on life is most pronounced, being most favorable for reptiles, which abound in such great numbers. Reptiles are characteristic lowland forms. They can endure the cold of high altitudes or latitudes only by falling into a torpor. The conditions being so favorable, they thrive in such vast numbers and are of such great size that the mammals are virtually driven to the uplands and almost extinguished. Several theories are advanced for the extinction of these large reptiles. Professor Verril regards lack of parental care as a cause; Professor Marsh thinks the small brain, highly specialized characters, and huge bulk, prevented them from adapting themselves to changing conditions. Wood attempts an explanation in the geographic changes. The flora, it is shown, changed almost as much as the fauna.

In attempting to extend his theories to periods of baseleveling antecedent to the Mesozoic, the writer finds a check in the insufficiency of knowledge concerning the early land forms. Comparison of meteoric baseleveling with glaciation and submergence shows that only the first is conducive to land life, that both glaciation and marine invasion are sterilizing in their effects.

T. C. H.

Tertiary and Early Quaternary Baseleveling in Minnesota, Manitoba, and Northwestward. By W. Upham. (American Geologist, Vol. XIV., No. 4, October, 1894.)

This paper forms an excellent supplement to the preceding one, taking up the history where the other leaves off. The area, character, vertical extent, etc., of the baseleveling of the northwestern plains during the Tertiary area is followed by a discussion of the renewed elevation and partial baseleveling at the close of the Tertiary. Attempt is made to correlate this period of leveling with one in Pennsylvania, New Jersey, the southern states, and in the West. The origin of the Red River valley is found in this later erosion. Topographic features of Minnesota and Manitoba, due to the cycles of baseleveling, are discussed, also the direction of the Tertiary and early Quaternary drainage. The last uplift, that at the beginning of Quaternary times, he says, raised the area 3000 to 5000 feet higher than it is now, as shown by the fjords and submarine valleys of the North Atlantic, Arctic, and North Pacific coasts. It was the culmination of this uplift that brought the great snow accumulations of the glacial period, under whose weight the land sunk below its present level, causing the ice to melt. His approximate measures of the denudation, along with some of his former estimates, give the duration for different periods as follows: Tertiary, two to four million years; the Lafayette, 60,000 to 120,000 years; Glacial period, 20,000 to 30,000 years; and the Recent period, 6,000 to 10,000 years.

T. C. H.

Proof of the Presence of Organisms in Pre-Cambrian Strata. Mr. L. Cayeux. (Bull. de la Soc. Geol. de France, Ser 3*e*, tom 22*e*, June, 1894, pp. 197–228.)

Stratigraphy.—Radiolaria occur in beds of siliceous schists (phtanite of Haüy) and quartzites of North Belgium, the position of which has been determined by Professor Charles Barrois. Their horizon is shown to be constant in a series of schists and graywacke corresponding in point of ages with the *phyllades de Saint Lô* (pre-Cambrian).

Preservation.—The radiolaria were, as is usual with the Palæozoic forms, very badly preserved, so that a great many sections were necessary to obtain a few good specimens. Even these were so delicate and so surrounded and filled with fragments of carbonaceous material as to greatly increase the difficulty of observation. The outlines and details of structure were nevertheless, as the plates indicate, so complete in many instances as to leave no doubt as to the nature of the organisms. The skeletal silica is often found in the form of opal, often replaced by carbon.

Forms found.—Among the number of forms whose generic place could be determined beyond doubt are mentioned: Cenosphæra, Carposphæra, Xiphosphæra, Stanrosphæra, Acanthosphæra, Cenellepsis, Spongurus, Tripocalpis, Tripilidium, Tripodiscium, Archicorys, Cyrtocalpis, Dictyocephalus, Sethocapsa, Dicolocapsa, Theocampe; representing the sub-orders, Sphæroidea, Cyrtoidea, Prunoidea and (not determinable as to genus) Discoidea.

Criticisms.—The author takes up in detail objections that have been raised against the existence of radiolaria in pre-Cambrian strata as (1) the invisibility of the reticulated, skeletal structure, (2) the impossibility of seeing the siliceous tests imbedded in quartzite, (3) the uniform regularity of the figures observed and the size of the observed forms in comparison with known radiolaria, (4) the contact or intergrowth of the pre-Cambrian forms, (5) their similarity to foraminifera.

Character of the fauna.—A discussion of the grouping and comparative abundance of various species follows, and then a comparison of the pre-Cambrian fauna with the radiolaria of the Silurian and of the present. E. C. Q.

The Niobrara Chalk. By SAMUEL CALVIN, Iowa City, Iowa. (American Geologist, September, 1894.)

The presence of the Niobrara chalk has been demonstrated at various points in Iowa as far east as Auburn, in Sac county, while fossils in the drift indicate its former existence at points much farther east than this. The paper deals chiefly with the characteristics of the formation as exhibited eastward from the mouth of the river from which it takes its name. In their typical development the strata are soft, calcareous deposits lying in massive beds, and exhibit all the characteristics of chalk. The beds represent the final stage in a progressive subsidence, when the mechanical sediments gave place to those of organo-chemical origin, with waters clear and moderately deep, and the shore line probably a hundred miles to the eastward. An upward movement began before the close of the Niobrara age. The most conspicuous invertebrates are *Inoceramus problematicus* and *Ostrea congesta*. Numerous citations are given showing that the general attitude of American geologists has been against the recognition of chalk in the American Cretaceous.

"The characteristics of the Niobrara chalk are such that exhaustive investigations with the microscope may be carried out with very little difficulty." Foraminifera are abundant, and in places constitute from one fourth to one third the volume of the chalk. Coccoliths are most abundant, though the small, rodlike rhabdoliths may also be detected with a high-power objective. The genera and species represented vary somewhat with the locality and the beds from which they were obtained. *Textularia globosa* is represented by a large and a small form, which grade into each other. The latter has been regarded as a distinct species, *Textularia pygmæa*, by Dawson. Differences in development are correlated with the probable conditions relative to depth and the amount of earthy sediments. The identity of the Niobrara with the English chalk is well established. C. H. G.

A Study of the Cherts of Missouri. E. O. HOVEY. (American Journal of Science, November, 1894, p. 401.)

Thirty-eight specimens from different parts of the state were examined in fifty thin sections, about one-half from the Lower Magnesian (Ozark of Broadhead) Series, and about one-half from the Lower Carboniferous.

Petrography and fossil remains.—The cherts consist mostly of chalcedony, with quartz and opal present to some extent. Careful search failed to reveal any indication of radiolaria or sponge spicules, with the exception of certain slender, cylindrical rods in one specimen, which showed nuclei of a brown substance surrounded by clear chalcedony. Many of the fossiliferous cherts from the Lower Carboniferous showed sections of brachiopods, crinoids, and corals, and in some cases of Stromatopora.

Chemistry.—Analyses showed the non-fossiliferous cherts to be nearly pure silica with more or less alumina and iron. The "altered" and "unaltered" cherts are shown to be chemically very nearly identical. The very small percentage of water in the pure cherts would indicate a small amount of opal.

Origin.—The theories of Prestwich, Hull, and Hardman, Irving and Van Hise, Renard and Hinde are reviewed, and the author concludes that the cherts studied by him "are due to chemical precipitation, probably at the time of the deposition of the strata in which they occur, or before their consolidation." E. C. Q.

Recent Publications.

—Blake, William P.

Notes on the Structure of the Franklinite and Zinc Ore Beds of Sussex County, New Jersey. 4 pp.—From the Trans. of the Am. Institute of Mining Engineers.

—Call, R. Ellsworth.

A Contribution to a Knowledge of Indiana Mollusca. 43 pp.—From Proc. Ind. Academy of Sci., Vol. III., 1893.

—Darton, N. H.

Artesian Well Prospects in Eastern Virginia, Maryland, and Delaware. 26 pp., 2 plates.

—Dawson, George M., C.M.G., LL.D., F.R.S., F.G.S.

The Progress and Trend of Scientific Investigation in Canada—Presidential Address for 1894.—Royal Soc. of Canada.

—Geological Surveys :

Arkansas—J. C. Branner, State Geologist.

An. Rep., 1891, Vol. II., Miscellaneous Reports: Benton County, by F. W. Simonds and T. C. Hopkins; Elevations, by J. C. Branner; Observations on Erosion above Little Rock, by J. C. Branner; Magnetic Observations, by J. C. Branner; Mollusca, by F. A. Sampson; Myriopoda, by C. H. Bollman; Fishes, by Seth E. Meek; Dallas County, by C. E. Siebenthal; Bibliography of the Geology of Arkansas, by J. C. Branner. 349 pp.; illustrated; 2 maps. An. Rep., 1892, Vol. II., Tertiary, G. D. Harris. 207 pp.; illustrated; 1 map.

Minnesota—N. H. Winchell, State Geologist.

Preliminary Report of Field Work during 1893 in Northwestern Minnesota. 40 pp.—Arthur Hugo Elftman. Part XII. of Twenty-second An. Rep.

Missouri—Arthur Winslow, State Geologist.

Coal Report—Sheet Report, No. 2 Bevier Sheet, Map and Sections, including portions of Macon, Randolph, and Chariton Counties, with Descriptive Report. 75 pp.—C. H. Gordon, Assistant Geologist.

Iron Mountain Sheet—Sheet Report, No. 3, Map and Sections—including portions of Iron, St. Francis, and Madison Counties, with Descriptive Report. 85 pp.—Erasmus Haworth and Frank L. Nason, Assistant Geologist.

Pennsylvania—J. P. Lesley, State Geologist.

Geological Maps of the State and of Schuylkill, Carbon, Huntington, Dauphin, Lebanon, Bucks, and Montgomery Counties, and of the Bituminous Collieries.

Topographical Maps of the Blue Mountain at Port Clinton, in two sheets; the South Mountain District, three sheets; and of Buck and Montgomery Counties.

South Australia.

Annual Report of the Government Geologist, for year ending June 30, 1894, with Maps. 26 pp., 3 Plates.

—King, F. H.

Destructive Effects of Winds on Sandy Soils and Light, Sandy Loams, with Methods of Protection. Illustrated. 29 pp.—From Agricultural Bulletin, No. 42, University of Wisconsin.

—Merriam, J. C.

Ueber die Pythonomorphen der Kansas Kreide. 39 pp., 4 Plates.

—Russell, Israel C.

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—Scudder, Samuel H.

The Effect of Glaciation, and of the Glacial Period, on the past Fauna of North America. 8 pp.—From Am. Jour. Sci., Vol. 48, Sept., 1894.

—Thwaites, Reuben Gold.

Early Lead Mining in Illinois and Wisconsin. 6 pp.—From An. Rep. Am. Historical Association, 1893.

—Ward, Lester F.

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GEORGE HUNTINGTON WILLIAMS.

As our thoughts turn to George Huntington Williams and we endeavor to express in some fitting form our appreciation of his character as a man and of his ability as a teacher and investigator, we are embarrassed by the sense of our bereavement at his death and of our bewilderment at those inscrutable laws that sometimes deprive us of what we hold best. It would be impossible for one who enjoyed the intimate friendship of such a nature as George Williams possessed to approach his memory by any other avenue than that of the affections, or to recite the achievements of his brilliant mental activities without first recalling those amiable traits that won him a place in the hearts of all his associates.

Gifted with the grace of personal attractiveness that commended him to the favor of new friends and in no way belied his disposition, he was also endowed with a ready adaptability to the conditions and interests of those with whom he was brought in contact, which was greatly enhanced by that happy faculty of letting others share his own interests and of considering them both worthy of his confidence and capable of entering into his pleasures and pursuits. These fundamental elements of good fellowship distinguished him to a marked degree. But he was more than genial; the buoyancy of his spirit which kept him company through periods of anxiety, making him hopeful in adversity, carried him at other times to heights of enthusiasm. The sanguine expectations and superlative qualities that sprang into being at the magic touch of his unrestrained enthusiasm were irresistible. This quality of his nature contributed very largely to the success of his intellectual labors, and to the inspiriting influence he exerted over his pupils. More than this, it enabled him to carry forward cheerfully the plan of his successful career against the early discouragement of those in authority over him, who subsequently recognized his ability and heartily coöperated to enlarge his opportunities.

One recalls with delight the vivacity and enthusiasm with which he disclosed some new observation, or unfolded schemes that opened up alluring vistas of possible research. But happier yet must always remain the recollection of George Williams as the historian of his own varied experiences. Times without number have we been carried away in merriment over the narration of his last humorous adventure until it seemed that all the incidents of his life must have worn the comic masque. His sense of humor was keen and never deserted him. By it ordinary events became amusing, and the more notable ones ludicrous. Whether his experience was in the class room or the study, dining room or nursery, some one or some thing furnished the text for a humorous anecdote. His excursions often brought him into laughable situations, and his more considerable expeditions became adventures alive with mirth or with ridiculous incidents.

But while stranger and friend alike paid tribute to his humor, his power of interpretation did not transgress the bounds of fairness, or expose its subjects to unjust ridicule. It lacked the sting of satire, and reflected the nobler characteristics of his nature. For above all other traits there shone the strong light of his unselfishness, raised into prominence by a spirit destitute of jealousy. Often did he prove by actions more than words his freedom from jealousy; his generous treatment of his students in their work; the helpful elaboration of their ideas, or of their plans; his successful navigation of those dangerous straits that separate the provinces of director and worker, of principal and assistant—waters in which so many craft become disabled, so many undertakings are hopelessly wrecked; his magnanimous conduct toward his junior associate, whose advancement he earnestly advocated and materially hastened, and between whom and himself there always existed the closest affiliation and heartiest concord. And when, about to venture upon untried ground, the present writer sought his friend's advice, he found a generous counselor, one ever ready to communicate ideas, observations, and valued knowledge, who seemed incapable of secreting for some fancied gain anything that might benefit another. But higher yet must be recorded the purity of his life—his honor without reproach; his affections above suspicion.

Turning to his career as teacher and investigator we have first to note those faculties he happily inherited, which showing themselves from time to time during his early development at last became his strength and power. Among these was a great love for books, his frequent companions when a child. He was not only fond of studying them, but attempted making them, and soon developed correct habits of reading—close observation and discriminating analysis. These, combined with a good memory, also discriminative, proved invaluable aids to his success as a teacher, as well as to the completeness of his literary work, in which fullness of bibliography and strength of historical treatment are characteristic features.

He had also a faculty for acquiring languages that not only made him proficient in German and French, and well versed in Latin and Greek, but gave him a command over English which was evident in his writings and even more so in his speech. His conversation was fluent, and his ability to express his ideas in a clear, forcible manner rendered him an excellent lecturer and an attractive speaker. His skill in drawing and illumination developed during his school days, and turned his thoughts toward architecture, his choice of professions at the time of his entering college at eighteen. This talent served him well in after life, and contributed no little to his descriptive powers. A healthy inquisitiveness and the habit of close observation supplied the necessary elements of an original investigator, who needed only an introduction to some of the many fascinating and alluring problems of Nature to become a zealous searcher after her hidden laws. He was the fortunate possessor of good judgment and a logical reason, and exhibited an energy that was constantly taxing his physical endurance.

With this endowment he entered Amherst College, and in time became attracted toward geology, remaining after graduation to pursue its study with Professor Emerson; then to Europe where he visited regions that had become geologically classic; settling in Heidelberg to devote himself to microscopical petrography under Professor Rosenbusch; acquiring at the same time a knowledge of crystallography and mineralogy. Graduating from Heidelberg in 1882, he returned to this country to find an opening for his stored-up energies in the Johns Hopkins University, where he undertook the labors of an Associate in 1883, being made Associate Professor in 1885. From this time on he led his dual life of teacher and investigator, apparently as eager to pursue the one line of activity as he was to carry on the other. And while they maintained the closest relationship to one another, proceeding conjointly, they may without violence be considered separately.

As a teacher he was eminently successful, judged by the interest taken in his courses, and by the character of the students who have graduated in his department, and who now occupy honorable positions, both in the faculties of universities and on the staffs of geological surveys. His methods were advanced and rational. The liberal use of laboratory practice and frequent excursions into the surrounding country brought his pupils in contact with problems as they exist in Nature. And the actual investigations they were themselves able to carry on under his direction rendered them not merely hearers of his words but doers of them; acquiring experience and self-reliance that enabled them to enter at once upon new fields of geological activity.

His influence as a teacher was not limited to his classes, but reached a much larger audience through the medium of his writings; whether in advocacy of the intimate connection between crystallography, physics, and chemistry; or in proclaiming the achievements of microscopical research in the realm of geology; or in the substantial aid to the study of crystallography which he has bequeathed us in his text-book on the Elements of Crystallography. His natural impulse to disseminate knowledge showed itself in the many reviews and notices of other works, which were thus brought to the attention of a wider circle of readers. His last writings were in connection with Johnson's Universal Cyclopædia and the Standard Dictionary. A complete list of his publications will appear in the current volume of the Bulletin of the Geological Society of America, through the kindness of Professor Wm. B. Clark.

As an investigator he was naturally influenced by the character of his environment, though his researches were in no sense limited or narrow. In a country where geological problems present themselves on every hand, it is likely that an investigator will attack those that are most accessible. And he will be fortunate if he finds himself in a region as diversified and interesting as that in which Professor Williams began his investigations. But while his work took color from its local surroundings, it was by no means confined to the borders of a limited area, or even of the state in which he lived. His interests and acquaintances in other parts of the country, his proximity to Washington, and his early connection with the United States Geological Survey enabled him to carry on his studies in distant places, and in this way to enlarge the field of his observation. Thus, while the major part of his work was prosecuted in Maryland, it extended into Virginia and North Carolina on the one side, and into Pennsylvania on the other. His researches in the Menominee-Marquette region of Michigan, and in the vicinity of Peekskill, N. Y., besides his travels through some of the most instructive regions of Western America, Canada, and Norway, further enriched his geological experience.

This wide range of opportunity furnished him material in part purely mineralogical, in part petrographical, and toward the latter period of his career broadly geological. And while, by reason of the greater demands on his time of university duties, his earlier investigations lacked comprehensiveness, yet his treatment of whatever material was at hand was thorough and systematic, and his methods of presentation are models of logical arrangement and concise statement. Even his more fragmentary researches often contributed to the elucidation of principles of fundamental importance and of general application. Thus his study of some remarkable pyroxenes led him to the demonstration of the possibility of hemihedrism in the monoclinic crystal system; while his study of certain hornblende and its gliding planes contributed in no small degree to the proper crystallographic orientation of this mineral with reference to pyroxene.

In the realm of petrography he improved every opportunity, whether small or great, to advance the boundary and efficiency of this growing science. The accidental notice of an obscure body of serpentine in Syracuse, N. Y., long since buried by town improvements, and its investigation by modern microscopical methods, led to the complete refutation of the elaborate theory of Dr. T. Sterry Hunt, so far as it related to the chemico-sedimentary origin of this once well-known occurrence of serpentine. The identification of a glass-breccia, now metamorphosed, in the pre-Cambrian crystalline rocks of the Sudbury district, Canada, demonstrated the existence in this region at that geologically early date of volcanic action, whose products differed in no appreciable manner from those of modern volcanoes.

Soon after his establishment in Baltimore he began the study of the rocks of the neighborhood, selecting from among the crystalline schists those most closely allied to massive igneous bodies, and examining their transitions into more and more metamorphosed forms. In thus early attacking the problem of metamorphism he showed the influence of his environment, which received a powerful impetus from the work of Johannes Lehmann, published the year following, in 1884. This he eagerly assimilated, and, appreciating its great value, brought it to the notice of his fellow countrymen in two reviews. Subsequently he received from Professor Lehmann a suite of specimens demonstrating the correctness of his conclusions, and by this means he became fully alive to the importance of similar methods of investigation for unraveling the complications of metamorphic rocks. This he expressed in his report on the Menominee-Marquette region in the following words: "The recent multiplicity of refined methods for the investigation of crystalline rocks, has opened an almost new field of geological inquiry. The difficult and obscure problems here presented may now be attacked by truly scientific methods. The prophecies which Hermann Vogelsang made in 1867 for the new departure in geology have been more than realized within the last twenty years. The almost new science of petrography may be said to have proved itself capable of rendering, in the study of the crystalline rocks, a service equal to that which palæontology has already given in the deciphering and correlating of the fossiliferous strata."[1]

Later his convictions as to the mission of petrology and the part it is to play in the advancement of geological science found expression in his address before the Worcester Polytechnic Institute, in which he said: "The recent development in the science of the earth consists of the return to the work begun by its earliest pioneers. The old petrographers were right. If we would know the life history of our planet, we must learn the origin, structural relations, and composition of our rocks. We must discover the forces — chemical and physical — which work in and upon them, and we must see *how* they work." Then catching inspiration from that eloquent advocate of the universality of life in matter, Professor John W. Judd, he adds: "It is a question how far the popularly received distinction between dead and living matter can be made amenable to strict definition as long as we know so little of what the so-called 'life force' is. As far as we can judge of the phenomena presented by the organic and mineral worlds, they differ rather in degree than in kind. . . . .

[1] Bulletin 62, U. S. Geological Survey, p. 34.

There is, however, nothing among the recent discoveries of the microscope in regard to rocks so surprising as their delicate adjustment to their environment. We are accustomed to look upon the masses of our mountains as the very type of what is stationary and eternal; but in reality they are vast chemical laboratories full of activity and constant change. With every alteration of external conditions or environment, what was a state of stable equilibrium for atoms or molecules ceases to be so. Old unions are ever being broken down and new ones formed. Life in our planet, like life in ourselves, rests fundamentally on chemical action. The vital fluid circulates unceasingly through the arteries of the oceans and the currents of the air; it penetrates the rocks through the finest fissures and invisible cracks, as the human blood penetrates the tissues between artery and vein, producing, with the help of heat and pressure, like changes in the histology of the globe."[1]

The establishment of these convictions became the ruling motive of his later work. The more important of his petrographical studies include those on the gabbro and diorite in the neighborhood of Baltimore; on the massive rocks of the Cortlandt series in New York; and on the greenstone schists of the Menominee-Marquette region.

As his interests extended into the broader domain of general geology the scope of his investigations widened, and we find him at work on the petrography and structure of the Piedmont plateau in Maryland, and on the occurrence and distribution of the ancient volcanic rocks along the Atlantic seaboard. His work in coöperation with others on the geology of Maryland occupied a large share of his time in recent years, and appeared in various editions of the map of the state, the last of which is now in press.

In recognition of the value of his services to the Johns Hopkins University he was appointed Professor of Inorganic Geology, in 1892. The same year he was honored by the Geological Society of London by being made a foreign correspondent. He was one of the judges of award in the department of mineralogy at

[1] Popular Science Monthly, September, 1889, pp. 640–648.

the World's Columbian Exposition; and was a vice president of the Geological Society of America.

At the height of his effectiveness and in apparent vigor of manhood he was cut off—leaving the fields of his activity to other workers, and leaving us to mourn the loss of an illustrious associate, whose lovable character mellows the memory of his fruitful life.

Another day is ended.—A brilliant sun has set, illumining the clouds that would darken heaven with a vivid coloring, whose varied hues are but reflected fragments of the white light of noon.

JOSEPH P. IDDINGS.

GLACIAL STUDIES IN GREENLAND. II.

The Glaciers of Disco Island.

Very much of the deep interest felt in the glaciation of Greenland springs from the light it throws upon the former glaciation of our own country and of Europe. In the region of the old drift of the middle latitudes, the only glaciers that now exist belong to the small mountain type. These very imperfectly represent the modes of action of continental glaciers. It is natural therefore to turn for light to the polar ice-fields, which alone approach continental dimensions. But this approach to equality in dimensions and similarity in general habit is attended by a possible, if not a probable, difference in the special effects of latitude. If, to be sure, the ancient glaciations were caused by changes of latitude, these differences might not exist. But this hypothesis, like all other hypotheses relative to the origin of ancient glaciation, is at present open to very serious sources of doubt. It is not safe, therefore, to assume like latitudes. The peculiarities of glacial action due to latitude are therefore to be sought out, and, if need be, taken account of in drawing comparisons between the ancient glaciation of low latitudes and the present glaciation of high latitudes.

It is not difficult to find a partial basis for the elimination of these special effects. The great ice-field of Greenland ranges through something more than twenty degrees of latitude, *i. e.*, it stretches from about Lat. 60° N. to a limit but partially known, somewhere beyond Lat. 82° N., according to Lieutenant Peary. The former glaciation of the United States reached somewhat south of Lat. 38° N. It hence appears that the old glaciation stretched just about as far south of the southernmost extremity of the present ice-field of Greenland, as this ice-field now stretches north of that point. The difference between the more southerly and the more northerly glaciers of Greenland may therefore give us a clue to what may have been the effects of double that range in former times.

The southern extremity of Greenland is, however, affected by the presence of the polar current of East Greenland and its heavy ice pack, which wraps about Cape Farewell and flows up the west coast several degrees, as already described. On this account a comparison between the more genial tracts immediately north of this and those of higher latitudes may be as representative as one drawn between the extreme portions. At any rate, this is the only comparison I can make, as my observations south of Disco Island were extremely limited. So far, however, as their very slight value goes, it appears that the Disco Island glaciers are of the same type as the glaciers of like dimensions in the more southerly region. In the following descriptions an endeavor will be made to call attention to all those peculiarities which seem to be serviceable in distinguishing the special effects of latitude. Among these special effects it is not meant, of course, to include those general influences of low temperature simply as such, to which the glaciation is due, but rather those which are inherent in the latitude as an astronomical relationship; such effects, for example, as may be attributed to the low angle of incidence of the sun's rays, or to its constancy above the horizon, or to similar phenomena involving peculiar effects aside from low temperature.

Politically speaking, Disco Island belongs to "Northern Greenland." Godhaven, the capital of the "northern inspectorate," is located on its southern border. In reality, however, Disco lies south of the middle latitude of Greenland. It ranges in latitude between 69° 15′ and 70° 20′ and in longitude between 51° 70′ and 54° 80′. The glaciers we are to study lie just north of Lat. 69° 15′ N. They are therefore but little within the Arctic circle. They are eight and one-half degrees south of those which we shall study a little later on Inglefield Gulf.

Disco is the largest of the known islands associated with

Greenland. Should the mass of land seen by Lieutenant Peary, north of Independence Bay, prove to be an island, as is highly probable, it will doubtless be found to surpass Disco in extent. The island is essentially a lofty plateau, ranging in height between 2000 and 4000 feet, with peaks rising to 5000 feet. Its borders are generally precipitous, but broken by valleys which are usually narrow and steep, penetrating but short distances. On the western side, however, there are developed very notable amphitheaters by the broadening and mesa-like recession of the upper parts of the valleys. On this side also there are three notable fjords, the Disco, Mellem, and North fjords. The first of these reaches nearly half across the southern portion of the island. The southern face of the plateau, as seen on the approach to Godhaven, is bold but not angular nor serrate. A somewhat symmetrical wall rises precipitously from near the water's edge to the height of 2000 to 2500 feet, where it is surmounted by an undulating plain that appears to represent an ancient surface. The face of the wall is broken at frequent intervals by steeply descending ravines, cut by small streams. The boldness of the frontage appears to be due to the work of the sea, but sea action has not recently been so effective as to prevent the accumulation of very large masses of talus along the foot of the cliffs, accompanied by a measurable recession of the upper part of the wall. The topography plainly indicates an ancient process of leveling, with a base-plane some 2000 feet higher than the present. It also indicates that this did not reach completion, and that a very long interval of greater elevation followed, during which a lower plain now near the sea level was partly developed at the expense of the older one. In this the fjords and deeper channels were cut. The present boldness of frontage toward the sea is probably due to the sea's action subsequent to the formation of the lower plain as may be inferred from its freshness and steepness.

The geological structure in the vicinity of Godhaven is quite simple. At the water's edge, and rarely rising more than 100 feet above it, lies a series of gneisses, resembling in all general respects those of the Laurentian formation. A low hook of this gneiss running out from the base of the cliffs, and embracing an arm of the sea, forms the little harbor of Godhaven. Although here confined to the horizon of the sea level, it is evident that the gneissic series is more than a simple basement of the island, for the glaciers that come down from the ice cap bring bowlders of gneiss, from which the inference is safe that the series rises to the summit at no great distance back from the sea frontage. Apparently the later rocks are built about a nucleus of ancient gneiss.

Resting unconformably upon the gneissic series is a mass of irregular basic igneous rock, largely a volcanic agglomerate, rising somewhat more than a third of the way to the summit. This is exceedingly irregular in structure. Some parts of it are but a rude agglomeration of very coarse volcanic fragments of the roughest type. Although but obscurely bedded, taken as a whole it constitutes a rude stratum upon which, in turn, rises a very regularly bedded igneous series which constitutes the upper and more symmetrical portion of the cliffs. This series appears to consist of very uniform basaltic flows, separated by clastic volcanic material, a portion of which is a bright red silt-rock, whose high color gives distinctness and conspicuousness to the bedding. This regularity of bedding and the symmetrical degradation of the series, with its brownish aspect, gives it, at a distance, much the appearance of some of the Triassic and Tertiary terranes of brown sandstone.

The sandstone series that is well known to occur in the island was not observed in the immediate vicinity of Godhaven, but a few miles north, in the valley of Blase Dale, it appears abundantly in the drift in places, and may be occasionally seen *in situ.*

Along the sides of the valleys which cut back into the plateau the bedded volcanic series at the top usually gives rise to vertical or steeply sloping faces, while the rough massive agglomerates form irregular embossments in the lower slopes and bottoms of the valleys. The bedded series degrades the more rapidly, and retires by stopes, mesa-fashion, with a notable tendency to form amphitheatres. The valleys are therefore well suited to receive and develop glaciers.

The most notable of these valleys in the vicinity of Godhaven is the Blase Dale or Windy Valley. Through this flows the Red River, whose waters are tinged by the débris of the reddish shales and the red part of the igneous series. This valley is perhaps a mile in width, measured between the bluff faces, and is stiffly joined on either hand at nearly right angles by valleys of considerable breadth, but short length. The Blase Dale reaches back almost due northward, with moderate acclivity, for perhaps fifteen or twenty miles. Its full length was not seen, and the maps of the interior are imperfect.

Into the tributaries of this valley three glaciers descend from the west and two from the east, within eight miles of its mouth. The first three are derived from the snow cap which covers the southwestern portion of the plateau; the last two come from a much smaller snow cap on a dissevered portion of the plateau on the opposite side of Blase Dale. The snow cap on the west side of the valley so nearly occupies the plateau immediately overlooking Godhaven, that its border may be seen from the village through a short valley cut by a brook in the face of the escarpment. The base of the ice cap, according to the charts and the descriptions of Dr. Rink, is about 2500 feet above tide. At the time of our visit, both in July and September, it was covered with fresh snow to its very edge. We did not therefore climb to it, as it seemed more profitable to spend our limited time in the examination of the better exposed portions of the glacial tongues derived from it. Three of these glacial tongues were visited. They descend from the snow cap by cataracts across the horizon of the bedded igneous rocks, until they reach the broader, gentler portion of their respective valleys, where they reshape themselves into plump, solid glaciers, and creep on down to points varying from 900 feet to 1500 feet above the sea.

We shall perhaps encounter in their most natural order those features in which students of American and European drift are most interested, if, instead of beginning our study here, we start at the sea level and follow up the valley until we reach the ends of the present glaciers, as we shall thus see the work formerly done by the once more extensive ice.

The gneissic rocks at the sea level, especially those that surround the harbor of Godhaven and stand out somewhat from the bluffs, are thoroughly smoothed after the well-known fashion of glaciers. They are so well subdued as to constitute an aggregation of fairly well-formed *roches moutonnées.* The ice movement was here from the *eastward,* not from the overhanging ice-crowned cliffs to the north. In other words, the line of motion was tangent to the southern shore of the island, not normal to it. Extremely little drift or débris of any kind has been left upon the surface here. There is abundant evidence of "plucking," and numerous little basins cover the low peninsula south of the harbor, but the material so derived was almost wholly borne away. The principal part of what remains is of the same nature as the rock on which it rests, and hence the erratic material gives us little aid in determining whether the ice movement which wrought upon the surface came down from the interior of the island through Blase Dale, as far as its mouth, and then turned westward at right angles, and crossed this low outlying hook, or whether the movement was part of a more general one from the eastward, caused by a former extension of the great inland ice cap of Greenland, which now has its border some fifty miles to the east. The latter seems to be much the more probable hypothesis, for reasons that will appear later.

On entering the mouth of Blase Dale, it is remarkable that the drift is found to be very scant. This can be attributed to no inability of the valley to retain drift, for its slopes are sufficiently gentle and its streams sufficiently confined to definite channels to permit the retention of drift if it were ever lodged there. Nor can it be attributed to any uncertainty of observation, for the surface is essentially bare. Occasional clumps of willows occur, mosses are somewhat abundant, and there are not a few flowering plants, all the more noticeable and grateful for their persistent blossoming in spite of the hostile elements, but none of these, nor all together, essentially obscure the surface. Portions of the valley well suited to retain drift are almost entirely free from it. Here and there are some small aggregations, and in some of the valleys there are considerable accumulations, although in some of these instances it is uncertain what part is due to stream action, what to local disaggregation, and what to glacial transportation. But whatever may be the result of a strictly correct analysis of such mixed deposits, the general fact remains that the glacial drift in the valley is exceedingly scant. That there is some, however, is beyond question, for, besides other evidence, there are here and there gneissic bowlders which are sharply distinguishable from the igneous rocks that form the entire bottom and sides of the valley, and these are perched in such situations and have such forms and markings as to show that they are the relics of a glacier that formerly occupied the valley.

The contours of the bottom and lower slopes of the valley have taken on phases consonant with the scant drift. While in general the outlines are referable to meteoric and aqueous erosion, and their general configuration is of the usual degradation type, they are slightly rounded and subdued, after the glacial fashion. A few shallow basins occur, for which no assignable agency other than ice seems available. Nowhere, however, are the spurs, ridges, or other embossments of the valley subdued to a distinct moutonnée type. No glacial striæ were observed, except in the immediate vicinity of the present glaciers. These characteristics prevail throughout the valley up to the immediate vicinity of the present glaciers. No terminal moraine was found stretching across the valley at any point below, but at the ends of the present glaciers notable terminal moraines are being formed. The scantiness of the marks of this former glaciation of Blase Dale, compared with the strong markings on the little Godhaven peninsula, affords grounds for the view already expressed that the glaciation of the latter was a part of a more general and more powerful movement from the east rather than an extension of the local glaciation of the island.

Ascending Blase Dale amid such feeble tokens of former ice action, and turning to the left into the wide mouth of the first tributary valley, we reach the lowest of the Blase Dale glaciers at a height of about 1500 feet above the sea.

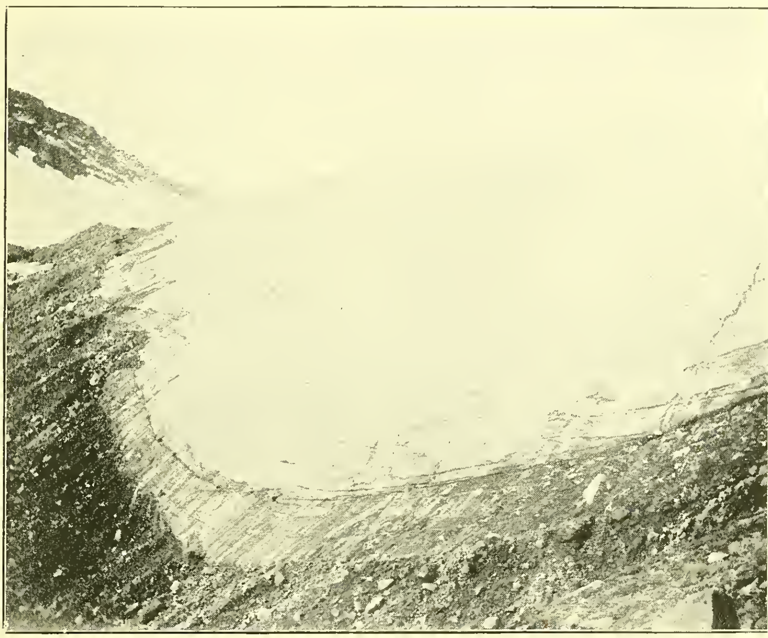


FIG. 6.—Portion of the end of Lower Blase Dale glacier in the west valley, showing terminal slope and the relations of the ice to the morainic material.

Lower Blase Dale Glacier.—This glacier descends from the ice cap by a steep, much-crevassed cataract. An embossment of rock in the center causes the ice to break over it and fall in fragments to the base of the declivity, where it again solidifies and moves on with the branches on either hand that succeeded in descending without complete disruption. These branches correspond to the heads of two valleys that jointly make up the common valley. These diverge gently below the cataract, leaving a broad, low ridge between them. But the glacier is sufficiently massive to embrace them both, and bridge over the intervening divide. The effect of the ridge, however, is a slight incurving of the frontal margin of the glacier in passing over it, and the development of two imperfect terminal lobes, one occupying each valley.

FIG. 7.—Nearer view of a portion of the extremity of the Lower Blase Dale glacier shown in Fig. 6, illustrating the superposition of the ice upon its morainic material.

At the time of our first visit, on the 16th of July, the edge of the ice and the terminal moraine on this divide were not only concealed by snow, but so deeply buried that the limit of the ice and even the existence of the terminal moraine could only be inferred from adjacent exposed portions. On reaching the crest of the glacier, we found that the larger part of its surface also was still buried in snow. In places it even then retained a depth of three feet or more, which greatly impeded progress, not to say observation. In September, this had entirely disappeared, but, as already remarked, snow still covered the ice cap above and lay upon the cataracts, and to some extent upon the higher lands adjacent, as will be seen by referring to the photographic illustrations. These particulars, which have little importance in themselves, are introduced here to show the climatic conditions under which these glaciers are formed and maintained. They illustrate the extreme shortness of the season

FIG. 8.—Portion of the end of the Lower Blase Dale glacier on the divide between the two valleys, showing the relation of the ice to the morainic material.

during which effective wastage is brought to bear upon the glacier proper. The full inference from this, however, should doubtless not be drawn, because the season appears to have been somewhat more than usually severe.

At the later date, the character and relations of the terminal moraine were fully revealed. On the saddle between the two valleys the moraine was sharply developed as a little ridge lying immediately against the present ice and rising a few feet — rarely the height of a man — above it. In the valleys, the glacier pushed out upon its moraine, and lay above it, and, at points. even projected over it, so that it was quite impracticable to walk along the edge of the ice on the débris. Figs. 6 and 7 show the relations of the ice to its moraine in the westernmost of the two valleys. Fig. 8 shows the relation of the glacier to its moraine on the divide between the two valleys. In the latter it will be seen that the terminal moraine is but a small bowldery ridge, formed at the immediate foot of the glacier. A little of the snow drift that obscured the whole moraine in July may still be seen at the right of the picture. In the former it will be observed that the morainic material lies directly beneath the edge of the ice. The glacier even projects a little in the central portion, so that the streamlets of water fall free in front of the drift beneath (Fig. 7). There is a débris-bearing horizon in the ice, about fifteen feet above its base, as shown in the figure. This is but the outcropping edge of a layer of dirty ice, which, besides silt, carries pebbles and stones of moderate size, and an occasional bowlder. Below this there is some débris in the ice, but its amount is small. The wash of the silt over the surface as it melts gives an exaggerated impression of its amount in the photographs. A similar statement may be made of the débris on the whole terminal margin of the glacier. At some points there are layers of ice a few inches thick, which are well set with erratic material. This, as it comes to the surface, gives rise to little heaps or ridges upon the ice, at points a few feet back from the moraine. These heaps or ridges present the appearance of having been forced out from the ice, but this is in part due to the fact that the débris covers the ice and retards its melting, so that it comes to take the conical form so well known on Alpine glaciers. When the loose material is cleared away, the débris is usually found to be confined to a thin layer solidly imbedded in the ice. In some instances, however, the débris was found set free by melting for some distance back between the layers of purer ice, and hence it may have been subject to outthrust by the movement of the ice. Certain instances were found in the Inglefield Gulf region where this had undoubtedly taken place. But, for the most part, this apparent outthrust was seemingly due to differential melting.

Little needs to be added to the photographic illustrations to make clear the nature and disposition of the terminal material. It is aggregated immediately at and under the ice edge. On its external face it is usually heaped about as steeply as the material will lie. It is composed of rocky material mixed with clay. Gravel is occasionally present, but is only a very minor constituent. The mixture of rock and clay is indiscriminate and varying. It differs little from the well-known stony till produced

FIG. 9. Illustration of the bruising, de-angulation and partial rounding of the bowlders of the terminal moraine.

by Alpine glaciers, where the rock element is abundant and the grindings take the form of clay rather than sand, as is the case with most basic igneous rocks. The bowlders are commonly bruised and de-angulated in various degrees. They are sometimes, but not usually, well rounded. In a moderate degree they are polished and striated in typical glacial fashion. The amount of wear, however, is only moderate. It is far less than the average wear suffered by the bowlders of our Pleistocene drift, as would be expected from the shorter transportation. Fig. 9 illustrates fairly well the nature and degree of reduction. This was taken on the outer slope of the terminal moraine. A few rods from this point an exposed surface of the underlying rock exhibited characteristic grooving and polishing [Fig. 10].

The waters produced by the melting of the edge of the glacier flow over the terminal moraine in little streamlets at various points along its course. To some slight extent, the waters gather between the edge of the ice and the inner side of the moraine, and run for short distances parallel to the ice edge until they find a lower point in the moraine, when they pass across it. As they descend the outer slope, they separate some of the smaller

FIG. 10. Striated surface just outside of the terminal moraine.

fragments from the mass and slightly round them, producing incipient gravel, but, owing to the rockiness of the morainic material and the shortness of the outer slope of the moraine, this work is very trivial. It however, represents a work that attained very great importance on the outer side of some of our ancient moraines.

The formation of the moraine is in itself a demonstration of the movement of the ice, but it gave no indication of vigor of movement. No opportunity was offered for instrumental measurement, but the natural signs of movement were sought with little result. At the time of our first visit, as already remarked, an immense snow drift covered the border of the ice, the moraine, and a portion of the rock surface outside, yet I saw no signs of the crushing or crumpling of this bridging drift, such as might have been expected had the ice pushed forward to any notable degree during the existence of the drift. And again, our tracks, impressed upon the soft crest of the little moraine only a few feet back from the border of the ice during our July visit, remained intact and undisturbed on our visit in September. I could not see any clear signs of thrust or disruption in the interval. Beyond question some motion must have taken place, but it was so slight as to fail to indicate itself by such signs as these.

Ascending from the moraine to the glacier, the terminal slope of the ice becomes a matter of interest, in view of the comparisons we shall have occasion to make with the glaciers of Inglefield Gulf, eight and a half degrees farther north. On the saddle between the two minor valleys, or, in other words, in the central part of the end of the glacier, the terminal slope of the ice is so moderate as to admit of easy ascent. In the valleys on either hand the slope is such as to forbid ascent except by resort to the ice axe. On the lateral borders the ascent is again more gentle. In no case however, is there a vertical wall of ice; the line of ascent is a beautiful curve. Attention is especially invited to this because it is in consonance with glaciers of lower latitudes, but in contrast with the prevailing habit in the far north.

Within a few rods of the border, a much gentler slope is reached which gradually grows lower until at a distance of perhaps half a mile, it seems even to be reversed and to descend toward the cataract on the border of the ice-capped plateau. Instrumental measures do not however confirm the impression, but such descents in a direction opposite to the movement of the ice do occur, as we shall see presently.

After leaving the immediate vicinity of the terminal moraine the surface is found to be practically free from pebbles and bowlders. A small amount of dust discolors the surface, a part of which has doubtless been blown upon it and a part of which is probably derived from the ice. A few crevasses traverse the portion of the glacier visited; but these are mostly small and longitudinal. In the main they are old and snow-filled.

In a word of summary, it may be remarked that the glacier conforms to the usual habit of Alpine glaciers of low latitudes. Its surface and terminal contours are of the same type. Its débris, where it does not take the form of lateral and medial moraines, is found in the basal portion of the ice, and does not appear at the surface except in the immediate terminal zone.

The Middle Blase Dale Glacier.—To pass from the glacier just described to the next on the west side of the Blase Dale, it is not necessary to descend to the bottom of the valley. A moderate climb over a low intervening spur and a corresponding descent brings us into the open valley partly occupied by the middle glacier. The precipitous sides of this valley diverge at a wide angle. Its bottom is a broad platform stretching from cliff to cliff and extending a half mile perhaps in front of the glacier beyond which it descends by a steep terrace into the Blase valley. The general form and relations of the glacier and its moraines are so well shown in the photographic illustration, Fig. 11, that little need is left for verbal description. In all its essential characteristics it belongs to the same type as the lower glacier. Its moraine is much more massive and better developed. The point of observation is such as to make the moraine in the central and left portions appear to be rather lateral than terminal, but the little medial moraine at the left shows that the direction of movement is essentially normal to the margin, except at the extreme left. The profile shows the crest and terminal slope of the ice, but it fails to bring out the undulatory nature of the ice surface. On ascending the eastern or right hand portion to the first crest, we were surprised to find an actual descent into a very considerable valley, from which the surface again rose to a second crest. In this valley a little lakelet had accumulated. Fig. 12 shows imperfectly the depression of this valley into which one of my companions had descended so far that only his head and shoulders remained visible. Of course the trustworthiness of the illustration depends on the accuracy of the leveling of the instrument, but the formation of the lakelet, and the descent of the streams into it,

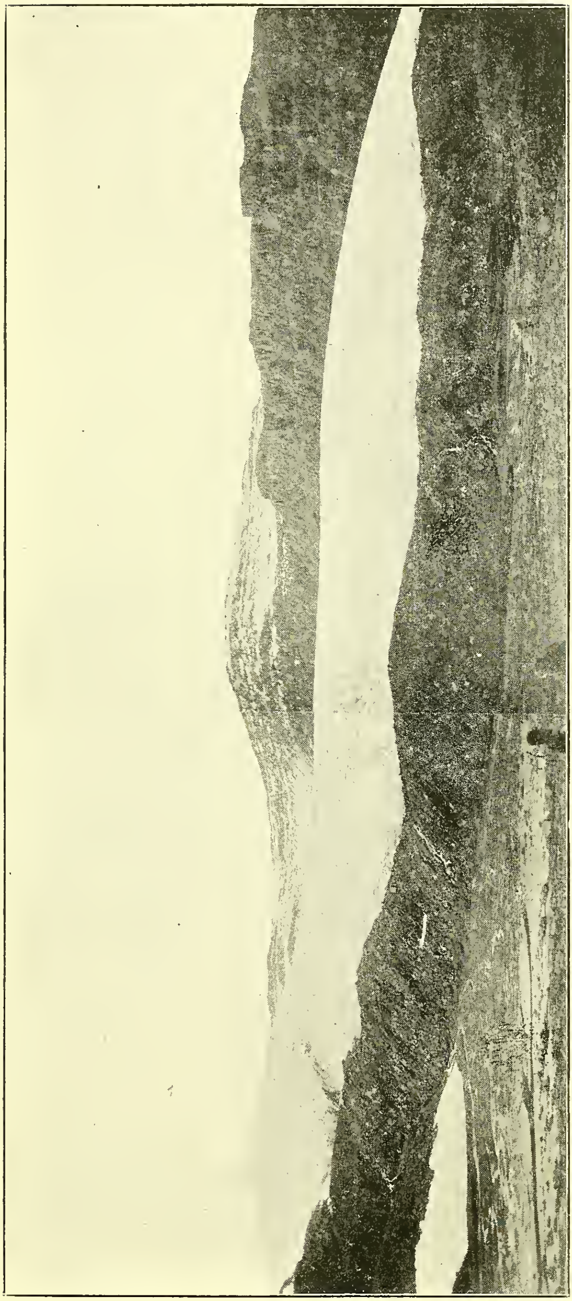


FIG. 11. General view of the Middle Blase Dale glacier and its moraine.

are sufficient evidence that its surface slopes in a direction *opposite* to the movement of the ice. An instance will be given later, in the Inglefield Gulf region, where very considerable surface streams were found flowing *directly opposite to the motion of the ice.*

As in the preceding case, almost no drift occurs upon the surface of the glacier except where there are medial moraines.

FIG. 12. View of a portion of the middle Blase Dale glacier showing the undulation of its surface involving a backward inclination.

The material from which the terminal moraine is built is derived from the base or basal layers of the glacier. The elevation of the end of the gracier is approximately 1600 feet above the sea.

Upper Blase Dale Glacier.—Without either descending to the bottom of Blase Dale or climbing over the heights, it is possible to pass up the valley to the next glacier by taking advantage of a terrace shelf that passes along the face of the cliffs. Beyond it connects with a much more considerable terrace which gradually broadens until it is wider than the Blase valley itself. At a distance of about three miles, a tongue of ice, very much more massive than either of the preceding, descends from the ice cap through a broader and deeper incision of the plateau face, and stretches entirely across the broad terrace just mentioned, and descends its face almost to the bottom of Blase Dale. At the point where it emerges from the cliffs of the upper plateau it develops strong lateral moraines which extend entirely across the high terrace, and even down its edge into the axis of the Blase valley. The outer lateral moraine on the right, bears evidence of greater age than the terminal moraines of the two glaciers already described. It is notably weathered and covered with vegetation in the partial fashion of the region. There is nothing to indicate age beyond a few hundred years, but it is notably older than the exceedingly fresh moraines we have already encountered, as it is also notably more ancient than the fresh lateral moraine that lies within it. Its material is very rocky and angular. Between it and the edge of the ice there is a more complex moraine consisting of several parallel ridges. The inner edge of this is so intimately associated with the margin of the ice, and its material extends out upon the border of the ice to such an extent as to make it difficult to determine just where the one ends and the other begins.

A very notable medial moraine is borne on the back of the glacier some distance out from its southern margin, but it joins the lateral moraine before reaching the terminus of the glacier. The crevasses of this glacier are more notable than those of the preceding, and besides the true crevasses, there are numerous fracture lines traversing some portions of the surface which seem to be due to internal strains that do not demand the opening of the crevice when once formed. They cross the laminæ, or blue bands, of the ice (which here run parallel to the sides) taking a course obliquely *forward* but curving toward the center of the glacier. Their course is thus seen to be the opposite of that of the normal crevasses on the border of a glacier. They are obviously a fine subject for investigation, and I much regret that time did not permit me to make more full and critical observations.

This glacier terminates on the steep terrace face shortly before reaching the axis of the Blase valley, and does not develop as distinct a terminal moraine as the two lower glaciers. The lateral moraines maintain great strength down to the terminal curvature, and in some degree close in at the end of the glacier. The terminal face of the ice is steep, but not vertical. Débris embraced in the lower part of the ice comes to the surface on this terminal slope as in the preceding cases, but apart

FIG. 13.—View of the Circumvallate glacier, with the Upper Blase Dale glacier and its lateral moraine in the foreground.

from this and the lateral and medial moraines, the surface is generally free from rocky material.

A circumvallate glacier.—Just north of the Upper Blase Dale glacier, and almost overhanging it, is an interesting little glacial lobe, snugly walled in by a sharp, serrate terminal moraine. This will be seen in the central part of Fig. 13, in the saddle between the prominences at the right and left. The view was taken from the south side of the Upper Blase Dale glacier. It is notable chiefly for the sharpness and symmetry of the moraine, and the contrast between it and the rocky surface around it. Outside of this moraine on the right, it will be observed, there is a wind drift accumulation of snow. This is of little moment here, but it is a phenomenon that acquires much importance in north Greenland, and will invite special consideration because of its peculiar effects on the formation of the terminal moraine. Here it does not appear to exert any influence on the moraine. It illustrates the persistence of the deeper winter snows throughout the summer. There had been a recent fall of snow, as the residue on the adjacent heights testifies, but this accumulation was obviously not due to it. The photograph was taken on September 2.

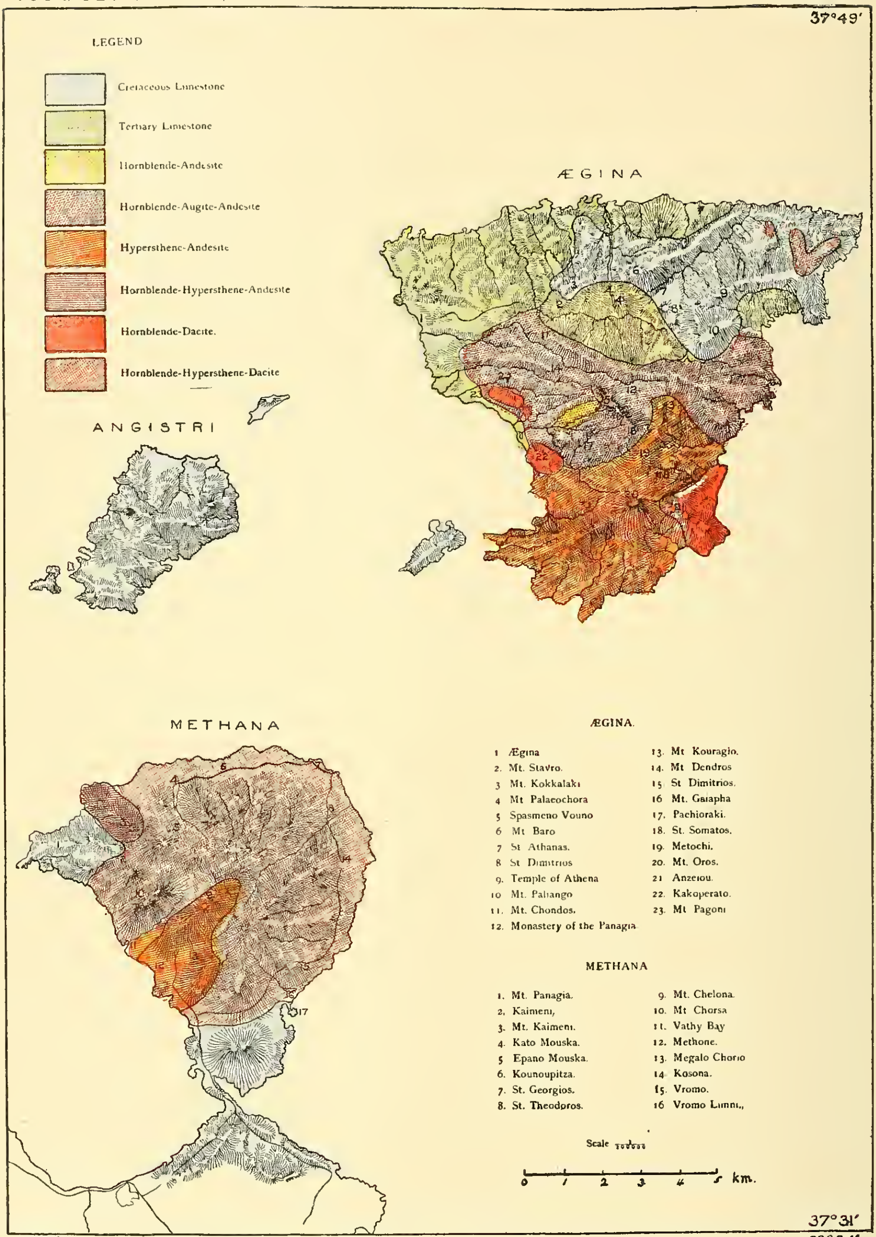
FIG. 14.—Distant view of the upper east side glacier, seen from the back of the Upper Blase Dalê glacier, looking eastward across the Blase Dale valley.

The east side glaciers. — Time did not permit me to visit the glaciers on the east side of the Blase Dale, but Fig. 14 is introduced to show the general aspect and relationships of the uppermost of the two seen on that side. The view was taken from the back of the Upper Blase Dale glacier, looking eastward across the valley. The view also illustrates in some degree the summit topography of the region and the nature of the broad upper valleys into which the ice lobes descend from the still higher ice caps. The east side glaciers give the impression of great thinness and flatness as compared with those of the west side. This was more notably true of the lower one. They nevertheless have lateral and terminal moraines of small dimensions, but no moraines were seen in the valleys below them.

Comparative features.—The general characteristics of the glaciers of Disco Island are closely similar to the southern Alpine type. They present the same forms of lateral, medial and terminal moraines; the same surface contours; the same terminal slopes; the same freedom from drift on the general surfaces, except as medial moraines, are superposed, or internal drift comes out to the surface on terminal slopes. There is the same habit of forming cataracts on steep descents, and of crevassing at points of more moderate strain. The Disco glaciers differ from typical Alpine glaciers in their less obvious activity. They also differ in that they come from ice caps on relatively flat plateaus instead of amphitheaters or mountain slopes or ravines. This distinction is not absolute, for ice caps occur among Alpine glaciers.

It does not, therefore, appear that these glaciers present any distinctive effects of latitude beyond the results of the low temperature that makes them possible at such moderate elevations. If we shall find a difference in the Inglefield Gulf region, its cause will be one that comes into play chiefly between the Arctic circle and the region far within it, rather than between the Arctic circle and the middle latitudes.

It is prudent to note, however, that these are but local ice caps and local glaciers. The great ice cap of southern Greenland and its dependencies may not have the same habit. At the far north, however, the local ice caps and their dependencies have the same habits as the great inland field and its dependencies. This gives ground for the belief that the features displayed in the Disco region are representative of southern Greenland generally. I have not found the descriptions of the southern Greenland glaciers sufficiently detailed on the points in question to warrant a wholly confident interpretation, but I do not recall anything inconsonant with this. T. C. CHAMBERLIN.



GEOLOGICAL MAP OF ÆGINA AND METHANA
BY HENRY S. WASHINGTON.

A PETROGRAPHICAL SKETCH OF ÆGINA AND METHANA.

PART I.

Introduction.

During several visits to Greece the volcanic island of Ægina and promontory of Methana, which are plainly seen from the Acropolis of Athens, had always presented themselves as a promising field for petrographical investigation. The attractions they held out were enhanced by the fact that since 1867 they have been unvisited, or at least undescribed by a geologist; and as the progress of petrography since that date has been so great, they seemed capable of furnishing much new and perhaps interesting material. An opportunity presented itself in March, 1893, when I was able to devote a week to Ægina and Methana together, with part of a day at Poros. This too short visit was supplemented by a second week spent at the same localities in March, 1894. A day was also devoted to visiting and collecting at Kolautziki, near Kalamaki on the Athens-Corinth Railroad, and at the neighboring valley of Sousaki, with its interesting mofetti. The collections made on these two excursions, which form the basis of this paper, are quite complete and typical of the various eruptive rocks of the region; the total number of hand specimens amounting to 122.

The predominantly petrographical character of the paper here given will explain the very cursory and imperfect way in which many of the geological and stratigraphical features are treated, only such a short sketch and description being given a may bc necessary to give the reader a sufficient idea of the general structure.

For the accompanying geological map there was used as a basis the British Admiralty Chart No. 1514, which in Ægina is very accurate in its delineation of the orographical and topographical features, but leaves more to be desired in the case of Methana. Some names have been altered and some new ones inserted, in accordance with my own notes, but otherwise the map is essentially the same as the original. It is much to be regretted that the construction of a complete and accurate geological map was out of the question, and in its geological features the present map does not claim any great accuracy, and must be regarded as merely an attempt to give the reader a general idea of the relations of the various rock masses, whose boundaries are in many cases more or less hypothetical. Though the roads are bad, traveling (on horseback) is easy, the people are kind and hospitable, and the only impediments are the extreme roughness of the accommodations and the absolute necessity of some acquaintance with the modern Greek language, an accomplishment not very difficult to learn. It must be added that the hypsometric figures, which are expressed in metres, are taken from the Admiralty Chart and from the work of Reiss and Stübel, to be mentioned later.

In conclusion, I must express my warmest thanks to Professor Zirkel for his very kind advice, to Dr. H. Lenk of the University of Leipzig for making the specific gravity determinations for me, and to Dr. A. Röhrig of Leipzig for the care and zeal he showed in making the chemical analyses.

Literature.—A short sketch of the previous geological descriptions of the region must be given, as they will be often referred to. The writings of the travelers prior to 1800 I have not consulted, since their descriptions, while matters of interest, would be of no petrographical value. Among the earliest in this century was Dodwell,[1] who spent a day at the Acropolis of Methana, recognized the volcanic origin of the peninsula, and recommends it to future geologists for investigation. The first really geological investigation was that made by MM. Boblaye and Virlet[2]

[1] DODWELL: Tour Through Greece. London, 1819. II., pp. 281, 284.

[2] Expéd. Scient. de Morée. Sect. des Sci. Physiques. Paris, 1834. Tome II., 2me Part. Géol. et Miner. par Boblaye et Virlet, pp. 239–258 and 364–370. Atlas, 1re Série, Pl. I., III., V., 2me Sér., Pl. IV., V. Referred to as "B. & V."

during the French expedition to the Morea in 1832. Partly owing to its early date their geological descriptions are unsatisfactory, and from several indications, such as speaking of a lava stream at Kaimeni on Methana only as reported by M. de Vaudrimey, they seem not to have explored the region very thoroughly; and their geological sections, both of Ægina and Methana, show many signs of a too free use of the imagination and of the imperfect methods of observation of the time.[1] They express the view (p. 240) that the "trachyte" masses have been raised (*soulevées*) "in a solid or scarcely pasty condition," preceded by the deposition of Tertiary beds. Their descriptions of the various rocks are naturally quite superficial, and in many cases not in accordance with subsequent observations, as when they unite the widely different rocks of Palæochora, Mt. Chondos, and Mt. Oros under one group of "*Trachyte bleu porphyroïde*" (p. 252), and state that the "Domite" (the light gray compact hornblende-andesite of Mt. Stavro) owes its character to a discoloration of the blue trachyte (p. 254). In accordance with L. von Buch's theory of Craters of Elevation they attribute this origin to the Spasmeno Vouno, and in part to Methana.

The next geographical traveler was Fiedler,[2] who confined his observations in Ægina to those made on a trip to the temple ruins from the harbor, and at Methana to those made during a sail round the promontory. In the former he devoted his attention chiefly to the clays occurring on the island, though he gives a good description with an illustration (Pl. III.) of Spasmeno Vouno. In Methana he describes one or two of the hot springs, speaks of the Kaimeni stream, placing the crater whence it flowed to the north of it, as he says it is now covered by the sea, and describes the Mt. Panagia, where he states that serpentine occurs. Russigger's account[3] I was unfortunately unable to consult, and the description of Curtius,[4] whose work is largely

[1] Cf. PHILIPPSON, Der Peloponnes., p. 5, who severely criticises their work.

[2] Reise durch Griechenland. Leipzig, 1840. I., pp. 256–278, II., pp. 541–552.

[3] Reisen in Europa, Asien und Afrika. Stuttgart, 1843 and 1848, I., p. 79, IV., pp. 246–251.

[4] Peloponnesos. Gotha, 1851. I., pp. 40–42, II., pp. 438–443.

archæological, is chiefly taken, as far as the geology is concerned, from the writers just quoted.

It was not till 1866 that the region was again visited by geologists, but in this year Fouqué, as well as Reiss and Stübel, on their return from study of the Santorin eruption, examined the localities. Fouqué's account of Methana[1] is short, but he gives an excellent description of the Kaimeni eruptive centre, whose crater he was the first to discover, and which he identified as the site of the eruption mentioned by Strabo, Pausanias, and Ovid.

Reiss and Stübel[2] spent a day on Ægina, going from the harbor to the temple, thence along the eastern slope of the East Ridge to the summit of Mt. Oros, and thence to Perdika; and a little longer time on Methana, of which they explored the northwestern part, including Kaimeni and Mt. Chelona. Their account is very readable, their descriptions, as far as they go, very good, and the conclusions they draw from their observations in general, just. A short petrographical description of the rocks collected by them is given by v. Fritsch, which, being based almost entirely on a megascopical examination, is necessarily imperfect and unsatisfactory. They also give a geological map, which, however, does not go into details, and which is not correct in its orographical features, their changes of the British Admiralty Chart (which they complain of) being much for the worse. They are incorrect also in assigning the limestone mountain masses of the north of Ægina to the Tertiary rather than to the Cretaceous period. Neumann and Pertsch[3] devote some space to this region, but their account is entirely taken from the three preceding writers, as is the case with Philippson,[4] whose field of study did not include Ægina, and who did not visit Methana.

[1] Les Anciens Volcans de la Grèce. Revue des deux Mondes, LVIII., 1867, 470. Also cf. C. R. LXII., 904, 1121.

[2] Ausflug nach Ægina und Methana. Heidelberg, 1867, 84 pp. Ref. in Neu. Jahrb., 1868, 212.

[3] Phys. Geogr. v. Griechenland. Breslau, 1885.

[4] Der Peloponnes. Berlin, 1892.

GENERAL DESCRIPTION.

Ægina.—This island, whose culminating point, the summit of Mt. Oros, lies in Lon. 23°30′ E., and Lat. 37°42′ N., has almost the shape of an equilateral triangle, the north coast running east and west. The length of each of the sides is about 13 kilometres, and the total area about 85 sq. kilometres. The view presented by the island from the sea is striking, the dark gray bare slopes rising steeply from the low northern shore to the central heights, which in turn are joined by a fine curve with the sharp dominant peak of Mt. Oros, the last falling away in a long regular slope to the sea at Cape Pyrgos. The chief port and only town, likewise called Ægina, lies near the northern end of the western shore, the small harbor, formed by two jetties, being crowded with the gaily painted feluccas and other craft of the sponge fishers. It is a picturesque, prosperous little town of some 2500 inhabitants, one of the chief seats of the sponge fisheries of the Ægean Sea, and the centre of quite an extensive native trade in pottery, the Ægina jugs and vases being highly esteemed throughout Greece.

Geologically the island is divisible into five distinct districts, the first being the low fringing shore land on the north and northwest, the latest in point of geological time. The second is the mountainous region of the north and northeast, made up of Mts. Kokkalaki, Baro, the Temple Ridge, and Mt. Paliango, which are all of hard crystalline limestone of undoubted Cretaceous age. The next district is that comprising Mts. Stavro, Palæochora, and Spasmeno Vouno, and may be called for convenience the Stavro District. It is entirely composed of eruptive material, the characteristic rock being a light gray hornblende-andesite. The fourth district is the most complex, both topographically and lithologically. It embraces the ridges of Mts. Chondos, Dendros, Pagoni and Gaiapha, with some outlying spurs, as well as perhaps the north and south running line of hills called Mt. Kourágio. This district, which includes all the central part of the island, may be called the Monastery District (from the Monastery of the Panagia or Virgin in the centre). Lithologically it is chiefly characterized by the abundance of hornblende-augite-andesite. The fifth and last district, made up of Mt. Oros and its outliers, and to be known as the Oros District, occupies the whole southern angle of the island. Orographically, the subordination of the outlying members to a main central mass is much more clearly marked here than in the other cases. The main rock mass is an augite-hypersthene-andesite with later eruptions of dacite.

It may be mentioned here that neither on Ægina nor on Methana did I meet with any dikes, sheets, or other such intrusive bodies: the bearing of which point on the eruptive character of the region will be discussed later.

The north and northwest shores are low and flat, rising very gradually to the foot of the east and west running mountain range. This shore land, which is of late Tertiary age, is composed of horizontal beds of marl and a soft cream-colored limestone, such as is known throughout Greece as "Poros Stone" (πώρινος Λίθος), which is extensively used for building purposes, being soft and easily cut when first quarried, but hardening considerably on exposure. Along the north coast these beds give place to a breccia of limestone blocks cemented by a soft calcareous cement, which occupies the foot of the mountain range just mentioned.

This range, which belongs to the second district, embraces the mountains of Kokkalaki, Baro (199 m.), and the ridge (191 m.) on which stand the well-known ruins of the ancient Greek temple of Athena. These mountains are carved out of nearly horizontal beds of the gray or yellowish crystalline Cretaceous limestone (containing rudistes) which forms such a prominent geological feature of this part of the Balkan peninsula. The southern side of Mts. Kokkalaki and Baro is quite steep, the lower part being in places almost perpendicular—evidently an old shore cliff, the lower part of which is now invisible. On the south slope of Mt. Baro there crops out a horizontal stratum of dark red shale, and a similar, though smaller outcrop is seen near the west end of Mt. Kokkalaki. (Cf. Fiedler, I., 273.)

The limestone is continued to the southeast, as far as Mt. Paliango, forming horizontal beds, in places one or two metres thick, overlying clays. The small hill on which stands the chapel of St. Dimitrios is formed of beds of this same clay, capped by a thick bed of limestone, and not, as Fiedler says,[1] of reddish trachyte. The lower slopes of the Temple Ridge are covered with an andesitic breccia, similar to that described below, the andesite probably being derived from hills to the northeast, east, and south, which lack of time forbade my visiting, but which had the appearance of being andesite and not limestone. A ready means of discrimination is furnished by the small pine trees, which seem to grow best on a limestone soil. Both in Ægina and Methana the limestone mountains are either covered or plentifully overgrown with the common small Aleppo pine (*Pinus Halepensis*), while the mountains of eruptive material are almost, if not quite, devoid of them. The soft late Tertiary limestone is met with below the temple on the road to the Bay of St. Marina. To the southwest rises the long ridge of Mt. Paliango (or Paraliago), 292 m. above the sea, built up of gray limestone beds, dipping 15° to the southwest. The top is covered with pines, but the sides are steep and rugged, and the lower slopes covered with talus.

With the exception of some small alluvial and beach deposits, the rest of the island is of eruptive origin. These Cretaceous limestone masses must have formed, prior to the eruptions, a small island group, the presence of the breccia of water-worn andesite blocks, and late Tertiary beds of marl, etc., showing that elevation has since taken place. The surrounding smaller islands, Augistri, Moni, Metofi, Lagosa, etc., are to all appearances, made of the same hard Cretaceous limestone.

As we approach, coming from Ægina, the mountains south of the northern limestone ridge we find the Neogene limestone and marls gradually giving place to a coarse breccia of rounded blocks of andesite cemented by a soft white limestone of Tertiary age. These blocks, which vary in dimensions from the size of one's fist to larger than one's head, are of the same rock as that which

[1] Op. cit. I., 274.

forms the neighboring mountains, and seem to represent in part an ancient talus, worn by the action of the sea and subsequently cemented by the travertine-like material which partially forms the shore deposits. This sort of breccia is to be found up to heights of 200 metres.[1]

The most northerly mass of eruptive rock is that of the Stavro District, including the domes of Mts. Stavro (311 m.), Palæochora, and Spasmeno Vouno, and much of the lowest slopes of these is formed of the breccia just described. Mt. Stavro (Cross Mt.), which is formed of a compact mass of hornblende-andesite, presents some interesting peculiarities of structure. As we pass along the west side of the valley, between it and Palæochora we see that its east face, which is very steep above but more sloping below, is cut here and there by vertical joints running east and west. In one place two of these parallel joints are only four metres apart, and the intervening mass has slipped down some two metres, giving rise to slickensides on the two faces of the adjoining rock. The side walls show a columnar structure perpendicular to the vertical face. This columnar structure is very well developed around the whole east and north sides of Mt. Stavro, the irregular columns varying from 15 to 50 cm. in diameter, and on the northeast side dipping towards the southwest. They are cut by many transverse, but not decidedly "ball and socket" joints, one effect being that the east slope of the mountain is quite free from débris, while the north and northeast sides have their lower slopes thickly covered with a talus of angular fragments broken off from the columns above. The columns are often curved, and in some places a sub-spherical structure is developed. The upper part of the north face of the mountain is quite vertical, and shows a peculiar structure which, as it seems rather out of the ordinary, may be briefly described. Two straight vertical joints, running north and south, cut the rock face, and on each side of both of these is a secondary system of curved joints which meet the vertical joints at angles of 45° to 60°, curving downwards and approaching a ver-

[1] B. & V., 258, R. & S., 15.

tical direction as they recede from the latter. These oblique columns are divided transversely by a tertiary joint system, cutting them about at right angles to their direction. The effect of these three systems of cracks is to give to the rock mass a "feather-like" columnar structure. As one goes farther to the northwest along this cliff the andesite is seen to be more and more disintegrated, till finally it becomes a pulverulent andesitic mass, resembling tufa, forming a low saddle running toward the limestone of Mt. Kokkalaki. The south slope of the eastern part of Mt. Kokkalaki is flanked by a mass of gray andesite, like that of the "feathered" cliff. Though covered with vineyards, it has the appearance of being a lava stream which flowed from the Stavro Centre and was hemmed in by the limestone ridge on the north.

The hill of Palæochora (Ancient Village), about 300 m. above the sea, is a striking feature of the landscape; rather conical in shape, with slopes of about 30°, it is covered with the ruins of an old town dating from about the end of the sixteenth century, which was built during the period of Turkish occupation as an inland refuge from the numerous pirates that then infested these seas.[1] It is a picture of desolation; the old house walls, built of the gray andesite, still standing though roofless, and interspersed among the houses are numerous chapels, the largest of which, that of St. Cyriacus, containing some interesting frescoes, is still in use. The lower part of this hill is mainly an andesite conglomerate, but the upper part is compact andesite, though cracked and split into a roughly columnar structure.

Immediately to the southeast of this hill, partly resting on its flank, is one of the most remarkable geological features of the island, the so-called Spasmeno Vouno (Broken Mountain). This is a volcanic dome 300 to 400 m. in diameter, and rising from 50 to 60 m. above the valley to the south of it, which was originally well-shaped, of an almost hemispherical form, with gently curving sides, whose average slope varies from 20° to 30°. It is entirely composed of a coarse breccia of light horn-

[1] Lacroix. Iles de la Grèce. Paris, 1881. p. 513.

blende-andesite, somewhat similar to that of Mt. Stavro, in large angular blocks, with a cement of small pieces and paste of the same material; the whole being rather soft, considerably weathered, and showing no signs of stratification. Many of the blocks show the peculiar sub-vitreous lustre which seems to be characteristic of lava when cracked and broken while cooling from a highly heated condition. The original dome is now to a great extent destroyed, the sides being cut by cracks and deep ravines with precipitous sides, the largest of these running quite across the hill from north to south, while the interior is quite hollow, forming a sort of amphitheatre with precipitous walls of rock. This amphitheatre is a scene of wild beauty, pinnacles and buttresses rising on all sides to heights of six to twenty metres, those towards the south being the highest. Two cases of faulting were seen, the throw being vertically downwards and the slip in one case being a couple of metres. Fiedler[1] apparently attributes the condition of the dome largely to explosive agencies, as he calls it "eine zerborstene Felskuppe." Judging from two examinations of the place, this explanation does not appear to me to be the correct one. For one thing, the surface of the dome and the surrounding ground are quite free from large blocks such as could naturally be expected to have been dropped there by an explosion. Again, the presence of tall slender pinnacles of the not very coherent breccia is quite incompatible with such an explanation. Spasmeno Vouno must be regarded then as a volcanic dome, formed by the outpouring of a partially solidified lava stream, the interstices between the blocks being filled chiefly by more liquid matter or by disintegration of the upper part. The mass cracked on cooling, such as we see a similar andesitic mass to have done at Stavro and Palæochora, and the fissures thus formed served as starting points for subaërial erosion. That this erosion is still going on here at quite a rapid rate is shown by the presence of a niche for the reception of a votive tablet, such as are very frequently met with in Greece, near the top of a slender buttress near the north side of the amphitheatre. This niche, which must

[1] Op. cit., I., 274.

date from Hellenic times, is now quite inaccessible. Much of the eroded material is now to be seen forming a terrace to the south and southwest of the dome, probably the "*sol bombé*" of the French geologists.[1] The deeper erosion of the southern part is explained by the fact that Spasmeno Vouno is formed on the southeast flank of the more compact Palæochora dome, the easily eroded mass of the later outflow being hence deeper toward the south.

The central part of the island is separated sharply from the districts just described by a straight, rather broad valley running about east and west almost across the island, at the bottom of which there flows during the wet season a small stream. In its western part the lower part of this valley is cut in the light hornblende-andesite breccia, while further east it is in limestone. This central part of Ægina — the Monastery District — is chiefly composed of two parallel ridges, having a trend of about North 60° West. The most northerly, called (at least its western half) Mt. Chondos (Near Mountain), runs almost clear across the island, ending at the east in Cape Peninda. Its sides are steep (over 30°) and the upper parts bare and rocky, while the lower slopes are often devoted to vines. As seen from the map the lower part of the north slope is composed of a hornblende-andesite like that of Stavro, while the rest of the ridge is chiefly composed of a compact hornblende-augite-andesite. The relation of the two could not be clearly made out in my somewhat hurried trips, but it seemed probable in places that the former rock overlies the latter. On the north side, near the west end and opposite Mt. Stavro, are beds of gray, pulverulent, fine-grained tuff which overlie the fringing andesite breccia. The dip of these beds varies, in one place being 30° southeast, while in another they are horizontal. A bed of compact brown rock which seems to be silicified tuff is also found farther east near the crest of the ridge, and according to Reiss and Stübel[2] a tuff occurs near the base of the east end, south of Mt. Paliango. A

[1] B. & V., 254.

[2] R. & S., p. 17.

little west of north of the Monastery the ridge of Mt. Chondos is made up of rounded masses of andesite which split up into more or less perfect concentric shells on hammering (perhaps an effect of weathering[1]), and which are cemented by a paste of the same material. Almost due north of the Monastery the top of the ridge has quite the appearance of a lava stream of the type that one sees at Giorgio Kaimeni in Santorini, being composed of sharp, angular blocks tumbled together in great confusion.

The southern ridge, called Mt. Dendros (Tree Mountain) is much shorter, ending at the east in a peak on which stands another chapel to St. Dimitrios. It then bends round to the southeast, enclosing, with Mt. Chondos, a small fertile plain in the northwest corner of which stands the Monastery of the Panagia (Holy Virgin). This plain, which is roughly triangular in shape, is bounded on the east by a ridge which bears the name of Mt. Kourágio, to be described presently. The plain is drained by a stream flowing through a deep valley in its northwest angle. Although at first glance it looks as if this Monastery plain were the site of an ancient crater, yet closer examination of the region fails to confirm this impression.

The branch of Mt. Dendros which bounds the plain on the south is called Mt. Gaiapha and has a height above sea level estimated at 500 metres. The inner (north) side of this is very steep, a mound of talus below and steep cliffs above, the rock being split by vertical cracks running southwest and northeast. The rock is a light reddish hornblende-augite-andesite carrying many of the segregations to be described later. It weathers very easily and is hollowed on the northern face into caves and pockets, some of which are two metres across. The southern slopes are covered with angular blocks and overgrown with grass, thyme, and scrub-oak.

The ridge which bounds the Monastery plain on the east bears the name of Mt. Kourágio, though here as in so many other places the mountain peaks and ridges do not possess very definite names and are often called by different names by differ-

[1] Cf. REYER, Die Enganeen, Wien, 1877, p. 20.

ent inhabitants. The sides are steep and covered with large angular blocks of a compact dark pyroxene-andesite, almost identical with that of Mt. Oros. So great is the similarity that petrographically it belongs to the latter district, while topographically it should be placed in the Monastery district, as it terminates sharply and steeply at its southern end on the 250-metre high saddle connecting the central Monastery district with Mt. Oros. Besides the mountains just described there are a number of subordinate spurs and ridges which belong to this district, such as Mt. Pagoni (Peacock Mountain) and the dacitic ridge near St. Vasili on the west coast.

The southern part of the island is connected with the district just described by the above-mentioned saddle which is flanked by two valleys running respectively west and east. This angle of Ægina is occupied by the dominating mass of Mt. Oros, 540 metres high, with its outlying spurs. This mountain is of quite regular conical shape, near the top the sides sloping at angles of about 35°, and at the south running down to the sea in a long slope of about 15°. The area at the summit of the mountain is not large, and chiefly taken up by a small chapel of St. Elias, this uppermost platform being bounded on the south by steep, but not high declivities. No indications of a crater were to be noted, and the topmost rock is a fine-grained, dark gray pyroxene-andesite, with a quite well developed, phonolite-like system of joints, the rock splitting easily into thin slabs. This structure is also met with in the augite-andesite of St. Somatos on the north-east foot, where are some well-preserved Hellenic walls. The flanks of the mountain are covered with angular blocks, making the ascent and descent very fatiguing. As seen from the map the lowest slopes of the mountain are made up of radiating ridges, most of which seem to be due to erosion, while some may be of the nature of lava streams. A small eruptive dome exists on the east flank near the hamlet of Anzeiou, forming a hill 297 metres high. This is formed of a compact dark hornblende dacite, as is the hill of Kakoperato, another later flank eruptive centre, on the northwest flank near the shore.

Methana.—The promontory of Methana, also called in antiquity Methōnē, lying about 7.5 km. southwest of Ægina, is almost an island, being joined to the mainland by an isthmus barely 0.3 km. wide. Its otherwise almost circular outline is broken on the northwest by the projection formed by the hill of the Panagia, a mass of gray Cretaceous limestone, 210 metres high, and on the south by a similar limestone mass, of which the isthmus is a prolongation. Its shores in general are rocky, though beaches occur in places. The general appearance is extremely rugged and forbidding, the rocky slopes coming down to the water's edge at angles of 25° to 35°, and the whole promontory being a confused agglomeration of bare peaks rising gradually but irregularly to the not very prominent mass of Mt. Chelona in the centre. This exterior impression is heightened on closer examination, arable land being very scarce and the few and poor inhabitants wringing a scanty subsistence out of the stony slopes.

The chief harbor and village is on the southeast coast at Vromo Limni (Stench Harbor), so called on account of the hot sulphur springs (temperature 27° C.), where there is a summer bathing establishment—the only place where tolerable accommodations can be secured. Hot sulphur springs also exist on the northeast coast near Agios Giorgios. Near the shore, on the southwest, are the small walled acropolis and other scanty remains of the ancient Greek capital of the district, which for the sake of clearness will be referred to as Methone, its ancient name, the modern village of Megalo Chorio (Large Village), being perched on the mountain slopes above. The other villages are merely clusters of wretched houses.

Geologically the promontory is simpler than Ægina. The Neogene limestone formation, including the flanking breccias, is wanting, which may be partially explained by the fact that Methana lies in an area of subsidence. Cold[1] has shown that the east coast of the Peloponnesos from Cape Matapan to Hermione has subsided in historical times, and as my guide described columns and ruins lying beneath the sea near Methone, it seems

[1] Cold: Küsten Veränderungen im Archipel. München, 1886, p. 14 and map.

that this line of subsidence must be extended farther north to Methana. We find, as already noted, the same gray Cretaceous limestone as in Ægina, at Mt. Panagia and at the southern end near the isthmus. The junction of this with the eruptive rock in the former place is quite sharp though obscured by talus, but I could find no traces of the metamorphic action of the lava on the limestone which Fiedler describes. The junction on the south is covered by a broad, shallow alluvial valley devoted to cultivation.

The rest of Methana is entirely composed of eruptive material, and, while apparently simpler and not divisible into districts, is less clean cut and well defined in its orographical features than is the case on Ægina. The highest point is the summit of Mt. Chelona (760.7 m.) in the centre, which, however, hardly overtops several of the surrounding peaks. The summit is formed of a ridge of huge angular fragments of rock running east and west. This rock is a hypersthene-andesite, dark gray in color, and very compact and fine grained, though several fragments show a coarse scoriaceous structure, which was probably the reason why the English officers labeled the peak "extinct volcano" on the chart. The same rock is found at Methone and at Megalo Chorio, and, though the stratigraphical relations were difficult to make out in the short time at my disposal, this mass of rock seems to be older than the surrounding masses of dacite.

On the south, Mt. Chelona is separated from the mountain above Vromo by a broad valley which runs down to the small Vathy (Deep) Harbor on the west coast. The topmost ridge, just spoken of, forms the southern boundary of a small plain in which are the remains of a "bee-hive" tomb similar to those at Mycenæ and elsewhere. This plain slopes down to a long valley on the north which separates Mt. Chelona from several peaks almost as high as itself, on one of which are the ruins of an old castle and town as at Palæochora on Ægina, and also bearing the same name. To the east lie several peaks, and in passing from the summit down to Kosona on the east coast one crosses a level plain of some size and almost circular shape, surrounded by high hills.[1] It has not, however, the appearance of a crater. In the centre of this is a low, flat, circular rocky eminence, about 10 m. high by 80 m. in diameter, composed of a much decomposed pulverulent eruptive rock, originally probably a dacite, carrying many small rounded segregations. Here we have undoubtedly a late centre of eruption. The ridge separating this plain from the sea on the east is covered with large angular blocks of dacite, while the slope below is composed of a dacitic breccia, the cement being a fine-grained tuff-like paste of the same materials.

There remains to be described one more locality which, for several reasons, offers the most important and interesting features of any on the peninsula. This is the hill lying on the northwest coast, east of the limestone of Panagia, called Kaimeni (Burnt); here we have the seat of the most recent eruption of the whole Ægina-Methana region.

The Kaimeni is a ridge about two km. long running northwest from near the hamlet of the same name, forming a promontory in the sea. Its highest point is 416.9 metres above sea level and 206 metres above the small valley at its southern end.[2] Its flanks, which have a slope of 37°, are composed of large and small angular blocks of andesite with some scoria, the latter being especially abundant near the bottom of the southwest flank. At the top is an oval depression, 60 to 80 metres deep and measuring perhaps 100 by 150 metres, its long axis lying parallel with the crest of the ridge. The walls of this depression are very steep, in many places perpendicular, of large blocks of rock or solid cliffs split in places by wide cracks, some of these being fifteen metres deep. The bottom is covered with angular fragments of andesite. This hollow is undoubtedly an explosion crater, but the character of the eruption need not be discussed here. Beyond this crateral cavity the lava stream runs to the northwest projecting into the sea. This seaward part of

[1] This is not the circular "crater-like" plain described by Reiss and Stübel (p. 34), which lies to the northwest of Chelona, and whose crateriform character did not strike me, though I passed through it.

[2] R. & S., pp. 24.

the stream is quite distinct from that just described, being brown and apparently scoriaceous, and weathered into tall pinnacles rendering it almost inaccessible.

This Kaimeni is undoubtedly the site of the last and only historical eruption of the whole region, which occurred during the reign of Antigonus Gonatas, King of Macedonia, 227–239 B. C., and which has been spoken of by Strabo, Pausanias, and Ovid. Pausanias[1] is very brief and merely speaks of hot springs, 20 stadia (2.5 miles) from the small city of Methana, which started during the reign of Antigonus, the water not appearing first, but being preceded by an eruption of fire from the ground. Strabo's[2] account is more explicit and runs as follows: "Near Methone, which is on the Hermionic Gulf, a mountain seven stadia high was cast up during a fiery eruption. During the day it could not be approached on account of the heat and the sulphurous smell, but by night it emitted an agreeable odor and appeared brilliant at a distance; the heat was so great that the water of the sea boiled for five stadia around and was turbid at a distance of twenty stadia. On the hill were found masses of rock as large as towers." Ovid[3] is much more fanciful, and he describes poetically how the winds enclosed in interior cavities, seeking an outlet, finally elevated a mass of rock like a bubble, which was still standing in his day. This poetical description has been brought forward by Humboldt and others in support of von Buch's theory of craters of elevation.[4]

The identification of the site of this historical eruption, which as we have seen is due to Fouqué, is of great importance for many reasons. In the first place it shows us the character of at least one eruption of the region with clearness and certainty. It also, by the state of preservation at the end of the two thousand years which have elapsed since the eruption, furnishes a measure of comparison for the other eruptive centres, and it also gives

[1] PAUSANIAS, II., 34. 1.

[2] STRABO, I., 3. 18.

[3] OVID: Metamorph., XV., 296–306.

[4] Cf. DAUBENY: Volcanoes, London, 1848, p. 327.

us specimens of what we know to be definitely the latest products of eruption.

The fact of an eruption having taken place here in historical times raises the question whether the volcanic forces of the region are extinct, or merely dormant. The hot springs of Methana and probably the mofetti of Sousaki are apparently the last visible signs of volcanic activity, and it seems almost certain that the volcanic forces of Ægina and Methana are quite extinct. But on the other hand, when we recall the long periods of absolute repose that we know to have lasted in some cases between two volcanic eruptions, as that of about seventeen centuries at Ischia, we cannot feel absolutely sure that some time the dormant forces will not be roused, and that we shall not have a fresh chapter to add to the vulcanological history of Methana.

Poros.—The only part of this island (which lies immediately to the southeast of Methana) which is of interest in the present connection is the small promontory on the south coast on which the town of Poros stands, connected with the main part of the island (composed chiefly of Cretaceous slates and limestones) by a low sandy isthmus. This small peninsula is a bare rocky hill, a mass of gray and reddish hornblende-andesite, the difference between the two colors being due only to weathering, as Philippson[1] has pointed out. No traces of a crater are to be seen, and the hill is evidently due to an eruption of the domal type which probably took place in the Quaternary period.[2] Some well-stratified tuff beds, with a dip about 20° to the north, are to be seen near the shore in the town.

Kolautziki.—As my examination of the occurrences of eruptive rock on the mainland of Greece was confined to collecting at the railroad cutting west of the small village of Kolautziki I shall draw largely on Philippson's description.[3] Near Kalamaki, which is on the east side of the Isthmus of Corinth, there is found an eruptive rock which Philippson calls a quartz-trachyte,

[1] Op. cit., p. 46.

[2] PHILIPPSON: op. cit., p. 433.

[3] Op. cit., pp. 21 ff.

but which, judging from the specimens collected farther east is probably more correctly to be called a dacite. The range of hills (chiefly of late Tertiary marls and conglomerates) in which this rock is found runs east parallel with the north shore of the Saronic Gulf and only a few kilometres distant from it. In these hills is the valley of Sousaki[1] with its mofetti. The rocks of this valley are of serpentine and less altered gabbro, and Reiss and Stübel are inclined to attribute the emanation of CO_2 and the other phenomena of the mofetti, not to volcanic agencies, but to the decomposition of the gabbro. Philippson combats this view, and I think correctly, though this is not the place to enter into discussion of the matter. Southeast of this, between the range of hills and the sea, is a low hill land, which is mostly "quartz-trachyte" with marl and conglomerate of late Tertiary and Quaternary age. A little to the west of the hamlet of Kolautziki, nine kilometres east of Kalamaki, the railroad cuts through a mass of this dacite, the width of the cut being 112 metres. This mass of eruptive rock is in general solid and compact, though in places made up of a coarse breccia cemented by finer material of the same nature. No scoriæ was to be seen. As Philippson says, it seems to be the end of a lava stream flowing from the west, though he was unable to find its place of origin. This stream is overlaid by late Tertiary limestone, and hence belongs to the same period as the earlier outflows of Ægina and Methana

CHARACTER AND DATE OF ERUPTIONS.

Before passing on to the petrographical description of the various rocks some space must be devoted to the conclusions that may be drawn from the facts observed by myself and others in regard to the character of the eruptions which formed the masses of Ægina and Methana, their geological date, and the order in which the various rocks were poured out.

In taking up the question of the character of the eruptions we shall start from the most definitely known and least denuded

[1] For descriptions of this interesting and little visited locality cf. Philippson, op. cit., p. 22, and the references there given.

focus, that of the Kaimeni on Methana. Here we have an example of that type of eruption so happily called by Fouqué[1] "cumulo volcanoes." The type specimen of this class of volcanoes is the cone of Giorgio Kaimeni in Santorini, produced by the great eruption which began in February, 1866, and whose formation was closely watched and studied by scientific observers from the beginning to the end.[2] The succession and character of the phenomena in this eruption were briefly as follows: The eruption began as a submarine outpouring of lava and lava blocks, accompanied by few or no explosions. As the mass reached the surface of the sea it was seen that the outflow consisted of a stream of solid angular lava blocks, pouring out slowly and with no explosions till they gradually heaped themselves above sea level, forming a "cone" quite different from any of the well-known types, there being no crater, no stratification of any kind, no tuff, scoriæ, nor ashes, and no flow of liquid lava. It was simply the quiet exudation of a mass of solid angular blocks of eruptive rock, whose rate of progress was slow, not forming streams such as liquid lava forms, but a comparatively short and high agglomeration of loose blocks. Such a cone is also quite different from the also craterless typical *Kuppen* of the Rhine, *puys* of Auvergne or *mamelons* of the Island of Réunion, which are due to the exudation of liquid but pasty material.

A suggestion put forward by Professor J. D. Dana[3] in regard to certain lava streams of Mauna Loa and Kilauea, offers a good explanation of the structure just described. The lava streams called in Hawaii *aa*, are likewise composed of loose angular blocks, and Dana suggests that this structure is due to the lava stream flowing over a region containing subterranean moisture in quantity sufficient to cool and fracture the lava and not be evaporated by the first hot portions of the stream.[4] In the case of

[1] FOUQUÉ: Santorin, Paris, 1879, p. xv.

[2] Cf. FOUQUÉ: Santorin, Cap. II.

[3] DANA: Characteristics of Volcanoes. New York, 1890, p. 243.

[4] I have observed such an action in the glass works at Murano, where a large mass of molten glass was poured into water, with the result that it was cracked into large pieces, much resembling the lava blocks of Giorgio Kaimeni.

the first submarine outpourings at any considerable depth the conditions must be quite different, partly owing to the important factor of the great pressure here involved. But when the lava mass has reached nearly to, or a short distance above, the surface of the sea we get a condition of affairs similar to that suggested by Dana, resulting in the cooling and cracking of the lava stream into solid blocks which are forced upward and onward by the outpouring stream below, forming a cumulo volcano. That there are few or no explosions during this phase of such a submarine volcano may be accounted for by the action of the sea water in cooling and condensing a large part of the imprisoned water vapor, as well as by the presence of the numerous cracks in the mass, serving as so many vents for its outlet.

"Stone streams"[1] due to such a cause differ radically from the ordinary lava streams made up of loose blocks, such as one meets with on Vesuvius or Etna, which are due to a simple mechanical breaking up of the solidified scoriaceous crust by the movement of the mass and the frequent subsequent flowing away of the liquid material.

The eruption may cease at this stage, as at the May Islands in Santorini; or when a certain quantity of lava blocks has been extruded, their mass and height above water varying with the special conditions, the character of the eruption may change, as at Giorgio Kaimeni, to the ordinary type, a crater being formed and explosive ejections of ashes and lapilli, or the pouring out of liquid lava, following.

Now, to return to the Kaimeni of Methana, whoever has seen the two volcanic masses produced by the eruptions of 1866 at Santorini and *ca.* 250 B. C., at Methana, cannot doubt for an instant that the earlier eruption was of the same type as the later. We find at Methana the same short high stream composed of a wild confusion of angular lava blocks, with little scoria. There is also a crater hollow at Methana, which however differs from that at Giorgio Kaimeni[2] in being deeper and with more precipitous

[1] JUNGHUHN: Java, II., p. 762.

[2] For plan of this crater cf. Fouqué: Santorin., Pl. XXX. and Ann. d. Sc. Géol., VII., Pl. 7.

walls, pointing to the fact that at the former place the eruption ceased with the explosion which produced the crater; a conclusion strengthened by the absence of ashes and lapilli, with which the crater and the upper part of the cone of Giorgio Kaimeni are covered.

Such then may be taken as the mode of formation of the earliest and lowest portions of the two areas. As Reiss and Stübel have so well described,[1] we must consider the first eruptions to have formed a cluster of small islands in the sea near the preëxistent limestone islands, such as we find in the analogous case of Santorini at the small Kaimeni Islands in the centre of the bay. These earliest submarine eruptions and some of the later ones took place either just before, or more probably during, the later Tertiary period,[2] as is shown by the andesitic breccias cemented by Neogene limestone.

The analogy between Santorini and our region, however, ceases with the formation of the smaller cumulo volcanoes, for at the former place a large, thoroughly typical strato-volcano was formed, while in the latter the later eruptions seem to have belonged to a different type. These later eruptions were chiefly subaërial and were continued into the following geological period, and even, on Methana, into historical times. They were nearly all eruptions of the dome (*Kuppe*) type—the exudation of large masses of pasty material, accompanied by few explosions and with little formation of tuff or scoriæ, forming high steep mountains or short thick streams. These eruptions did not take place at one centre, but at various points of the region and along fissures forming the complex of hills and mountains that we now see.

That the main mass of both Ægina and Methana is made up of such a complex of volcanic domes, and is not the denuded wreck of a strato-volcano is clearly shown by the following facts: The chief of these is the absence of inter-stratified beds of lava and tuff, and of lava sheets, such as form the chief characteristic

[1] R. & S., p. 39.

[2] Cf. Neumayr. Geol. Bau. d. Insel Kos., etc. Denkschr. d. K. Akad. d. Wiss., Vol. XL., 1880, p. 264; Philippson, Peloponnes., p. 433.

of strato-volcanoes, built up of explosive ejection of fragmentary material and the pouring out of liquid lava streams, of which Vesuvius and Etna are taken as types. Tuff exists, it is true, in some places on Ægina, as we have seen, but here it exists on the surface, overlying the massive rock at the flanks of the mountain, and it is well known that such deposits do accompany volcanic domes. Lava sheets are, however, quite lacking. It is evident from an examination of the region that the denudation has not been very extensive, so that the absence of tuff cannot be explained on this ground; any amount of which, moreover, would not explain the absence of inter-stratified tuff beds and lava sheets. The denudation has not been nearly as extensive as that which has taken place in the somewhat similarly formed Euganean Hills near Padua in Northern Italy, where the eruptions ceased in post-Eocene time,[1] though it must be remarked that the climate is here more favorable to denudation than in our region. The main valleys between the mountain masses must hence be looked on as original intercolline spaces, enlarged, though slightly, by erosion.

The forms of the mountain masses and their mutual positions are decidedly those to be looked for in the case of eruptions of the kind supposed, and different from those produced by the erosion of a strato-volcano. While not of the regular "bell" shape that is seen in such perfection in the "*puys*" of the Auvergnes or the "*mamelons*" of Réunion, yet the shape of the ridges is eminently such as would be produced by the extension of a mass of viscid lava (without the formation of explosion craters) at many points along a fissure, such as have been described by Scrope[2] and Hartung.[3] The masses are higher and shorter than those which would be formed by liquid lava streams, and they do not, except in the case of Mt. Oros, radiate from a common centre.

The character of the lavas also is eminently favorable to the

[1] REYER, Die Enganeen, Wien, 1877, p. 48.

[2] SCROPE, Volcanoes, 2nd ed., 1862, p. 134.

[3] HARTUNG, Beobacht. über Erhebungskrater, etc., Leipzig, 1872, p. 57.

production of domes. Being porphyritic andesites and dacites of medium to rather high acidity they were, when ejected, in a pasty rather than a very fluid condition,—the state of viscosity which is essential to the production of domes and masses of great height as compared with their lateral extensions.

Another fact in favor of the view here held is the total absence of dikes, which are rare in dome eruptions, but common and characteristic in those of the other type. This might, perhaps, be explained by the small amount of denudation, inasmuch as dikes, when present, are much more numerous and of larger size near the base than in the upper layers of volcanoes of whatever type.[1] Their *total* absence, however, cannot reasonably be so explained and, taken in connection with the facts above mentioned, must be regarded as a confirmation of the present view. It may be added that the columnar structure of Mt. Stavro and the laminated structure of Mts. Oros and Chondos, which are characteristic of *Kuppen*, point in the same direction.

It is probable, however, that in some places, streams of more liquid lava were poured out, as east of Mt. Stavro, and perhaps in some of the ridges to the south and east of Mt. Oros, which I was unable to examine. As has already been suggested, there also may have been true craters on Methana, though it does not appear probable to me. These, however, would be secondary phenomena, and we must regard it as certain that the great majority of the eruptions which formed the two regions were of the dome type, as defined by von Lubach,[2] based on a substructure of cumulo-volcanoes, which have also been formed in some of the later flanking secondary eruptions.[3]

Relative age of the various lavas.—It has already been briefly noted, and we shall see at greater length later on, that lavas of quite diverse chemical and mineralogical composition were

[1] Cf. GEIKIE, Text-Book of Geology, 1893, p. 233.

[2] Z. d. d. Geol., Gesell. XVIII., 644.

[3] It is noteworthy that the eruptions of andesites, very similar to those described in this paper, which occurred at Milos (according to Ehrenberg) and at Smyrna, Sipylos and Pergamon (according to my own observations) were all decidedly of the domal type.

erupted at different points of the region under examination, and it is an important matter to ascertain the relative age of these various outflows. To this problem, unfortunately, I can not furnish a very satisfactory or absolutely certain solution, owing to reasons already spoken of and to the scarcity of good exposures and sections; so that the following remarks merely indicate what I believe (though on slight evidence) to be the true state of affairs. I may express the hope that some future observer will decide the question definitely.

In the case of Ægina it is probable that the eruptive activity shifted, as a whole, from south to north. That is, the Oros district is the oldest, followed by the formation of the masses of the Monastery district, and that last of all the hornblende-andesites of the Stavro district were ejected, the formation of Spasmeno Vouno closing the period of eruptive activity on Ægina. This is the general plan, but it is very likely that some of the smaller eruptions, such as those of Anzeiou or Kakoperato, took place during periods when, or between which, the main eruptions of another district were taking place, a fact frequently observed in volcanic regions.

In Methana the sequence of events is less clear than on Ægina, but from analogy with the Ægina rocks and for other reasons, I am inclined to believe that the main andesitic mass of Mt. Chelona was first formed, and that the peaks surrounding it were subsequently ejected. On chemical grounds, which will be discussed on a later page, it seems probable that Methana is, on the whole, younger and more recently formed than Ægina.

HENRY S. WASHINGTON.

(To be continued.)

THE BASIC MASSIVE ROCKS OF THE LAKE SUPERIOR REGION.

IV. THE PERIPHERAL PHASES OF THE GREAT GABBRO MASS OF NORTHEASTERN MINNESOTA.[1]

A. Introduction.

In 1886 Professor J. W. Judd[2] described a series of basic rocks from the Inner Hebrides and the adjoining mainland of Scotland and Ireland, that in mineral composition are closely allied to the gabbros with which they are associated. Their structure, however, is quite peculiar. The most notable difference between it and the structure of a normal gabbro lies in the character of the olivine and diallage constituents. These have "more or less rounded outlines, and are imbedded in a plexus of lath-shaped crystals of feldspar; in polarized light these grains are seen not to be parts of one large crystal, but to have very different orientations. The form of the individuals of pyroxene and olivine at once recalls the structure seen in the granulites" (p. 68). It was therefore called by Judd the "granulitic structure." True gabbros, with the granitic structure, were found only in the central portions of great bosses and flows. On the edges of flows and along their upper and lower surfaces the granitic structure gives place to the ophitic or the granulitic structures. The best examples of the last two types were found: the first in dike rocks; the second in lava flows. Hence the conclusion was reached that "the only type of rock absolutely characteristic of intrusive rocks is the granitic; but ophitic varieties and varieties with skeleton crystals in their base abound in, though they are not confined to, intrusive rocks; while rocks of granulitic structure and those with short and rounded microlites in their groundmass are especially abundant among the

[1] Quart. Jour. Geol. Soc., February, 1886, p. 49.

[2] Continued from Vol. I., p. 716.

lavas" (p. 75). The cause of the granulitic structure was thought to be the crystallization of the rock's components during a period before the internal movements of the rock-mass had ceased. The granitic and the ophitic structures occur only in masses of considerable dimensions, where the original molten magma yielding the gabbro or the diabase, existed for some time in a state of perfect internal equilibrium. It is when crystallization goes on in a mass that is in actual motion, or one whose portions are in motion relatively to each other, in consequence of strains set up in the magma, that a granulation of the augite and olivine results.

The rocks so ably described by Judd in the article referred to, have their exact counterparts in northeastern Minnesota. The great mass of the gabbro constituting the "basal flow" in this region has the typical granitic structure. Along its northern edge, however, near the bottom of the mass, occurs a series of rudely bedded rocks, that differ so markedly from the gabbro that they have been regarded as distinct types by most geologists who have seen them in place. Many of them are dense, heavy, vitreous-looking rocks, others are fine-grained, dark gray ones with a sandy texture and often a resinous lustre, while still others have the appearance of a very fresh, brilliant magnetite. Although they mark the northern limit of the gabbro area throughout its entire extent, their best developments are in the neighborhood of Akeley Lake, in Sec. 29, T. 64 N., R. 5 W.; along the north shore of Iron or Mayhew's Lake, in Secs. 29 and 30, T. 65 N., R. 2 W.; and Sec. 36, T. 65 N., R. 3 W.; in the country between Little Sasaganaga and Gabamichigamak Lakes, in the northwest portion of T. 64 N., R. 5. W., and on the north shore of the lake last named, in Secs. 31 and 32, T. 65 N., R. 5 W. In the reports[1] of the Minnesota survey these rocks are called by various names, such as muscovado, quartzite, iron ore, and in the field notebooks of the members of the United States Geological Survey, quartzites, silicified gabbros, etc. The mere recital of these names is enough to

[1] 15th Ann. Rept., pp. 183, 351, etc. 16th Rept., p. 355, etc.

suggest the obscure relationships of the rocks designated by them.

A rapid glance at the sections of the rocks composing the beds indicates that they may be separated into three classes, of which one, the non-feldspathic gabbros, corresponds to the peridotites[1] associated with the Scottish gabbros. The other two classes embrace granulitic rocks whose structure is similar in all essential respects to the structure of the Scottish rocks referred to above.

The members of one of these two classes are granulitic gabbros, corresponding in their important features with the granulitic gabbros of Professor Judd. The other class of granulitic rocks comprehends a series of quartzose members, composed of quartz and olivine, of quartz and hypersthene, or of the three minerals mentioned. The quartz is evidently not secondary, for the olivine associated with it is almost entirely unaltered in many cases. It has crystallized in its present position, and in most specimens after the olivine was formed. It has been suggested that these peculiar rocks were originally quartzites that have been altered by the great gabbro mass south of them. Many of them appear to have had this origin. They are probably metamorphosed sediments, but of such a unique character that a critical study of them is demanded before a positive decision as to their genesis can be given.

The present communication deals only with the basic and the granulitic gabbros, rocks that are unquestionably phases of the normal gabbro.

B. The Non-Feldspathic Gabbros (Peridotites).

In choosing the group name "non-feldspathic gabbros" for these rocks, in preference to the more usual one "peridotites," emphasis is placed on the fact that the rocks included under it are nothing more nor less than gabbros in which feldspar is lacking. The magma which gave rise to them was undoubtedly a portion of that which, under the ordinary circumstances

[1] J. W. JUDD: Quart. Jour. Geol. Soc :Vol. 41, 1885, p. 357.

prevailing during the period of its cooling, produced the coarse-grained gabbro that covers so many hundreds of miles in northeastern Minnesota. Under certain conditions this same magma yielded the very basic rocks here described, but these form such a small mass as compared with that of the great gabbro, that it does not seem wise to designate them by any name that will not at once indicate their very close relationship to the gabbro. Peridotite as the name of a group of rocks produced by the slow cooling of a very basic magma is well enough, but as a name for the aggregation of basic minerals from a comparatively acid gabbro magma it would be as much out of place as the use of the same name for the olivine-diallage concretions of a basalt.

The rocks of this class occur, as has been said, along the north boundary of the gabbro area, where they are found alternating with the granulitic gabbros of the several varieties. The thickness of the bands ranges from twenty or more feet down to a fraction of an inch only. In a single thin section may sometimes be discovered several of them. The line of separation between the bands is nowhere very distinct, and in the thin section it is seen to be quite gradual. Many times the rocks are so charged with magnetite as to have suggested their being worked for ore. Professor N. H. Winchell,[1] in his discussion of the iron ores of Minnesota, classes this magnetite with that occurring in the normal gabbro under the group name "gabbro-titanic-iron group." The difference between the magnetite of the quartzose beds under the gabbro and of the basic rocks associated with the gabbro is recognized.

A specimen of one of the basic rocks was submitted to Dr. Hensoldt[2] for microscopic study. In the section examined basic and acid bands occur alternately. The basic portion of the rock (M. 1339), which is from the Akeley Lake region, is described as a compact lherzolite, chiefly composed of yellowish-

[1] The Iron Ores of Minnesota, Bull. No. 6, Geol. and Nat. Hist. Survey of Minn., pp. 123–126.

[2] Ib., p. 127.

green enstatite, olivine and magnetite. "Even in the same hand specimen it passes from a fine schistose condition into a coarse crystalline one, while in some of its modifications it assumes the character of a regular quartzite." The schistose portion "shows an admixture of well-defined tabular plates of yellowish-green enstatite, and granular or 'fractured' olivine of a paler shade. The enstatite exhibits an exceedingly fine striation, and it contains no enclosures, except a few grains of magnetite. It polarizes brilliantly, but shows no pleochroism. The olivine is more abundant than the pyroxene. It is present in the form of angular masses and grains, which have a fragmental appearance as if crushed by mechanical pressure or in consequence of a sudden thermal disturbance. The magnetite occurs in rounded grains and crystals, varying from dust-like minuteness to aggregates equaling in size the largest of the enstatite tablets."

Titaniferous Magnetites.—The specimens in the possession of the United States Geological Survey all contain a large proportion of magnetite, which in some cases runs so high as to constitute 90 per cent. of the entire rock. These latter rocks have the bright metallic lustre of magnetite and usually a finely granular texture. The lustre frequently becomes very brilliant and the specimen takes on the peculiar pinkish tinge of ilmenite. A careful inspection of such specimens as seem to be pure ore, reveals the presence in them of tiny yellowish green grains of olivine, but these are so rare that they produce but little impression on the general aspect of the rock. When the magnetite makes up practically its entire body, the rock is much jointed, and, consequently, it easily breaks into small irregular or cuboidal fragments, as Winchell has already noted, and these are not unfrequently natural magnets. Tests of magnetites of this kind from the shores of Little Sasaganaga Lake, N.W. ¼ Sec. 7, T. 64 N., R. 5 W., prove them to be very rich in titanium, as was surmised from their pinkish tinge.

Professor Winchell[1] cites several analyses of titaniferous magnetites from the north edge of the gabbro area, that show from 2.23

[1] Bull. No. 6, Minn. Geol. Survey, p. 141.

per cent. to 16.03 per cent. of TiO_2. He gives no account of their associations, but refers to them simply as gabbro-magnetites. In the same group he includes the magnetite occurring as sand on Black Beach, near Beaver Bay. The rock of Beaver Bay is, however, not a portion of the great gabbro mass that we are now discussing, but it is probably a portion of a sheet or "sill" intrusive in the Keweenawan strata, and occurring at a much higher horizon than that at which the rock which is the subject of the present series of papers, occurs.

Olivine-Pyroxene Aggregates.—When magnetite is scarce in the basal beds of the gabbro, the rocks are usually very fine-grained, sugary aggregates of yellowish green olivine, and a dark brilliant substance that upon examination is found to be a pyroxene. Occasionally a large plate of pyroxene or of hornblende is imbedded in the fine aggregate, but this so rarely happens that it does not affect the general appearance of the rocks. On the other hand it is not uncommon to find in what is apparently a fine-grained mass many large areas of irregular shapes that reflect light uniformly. These evenly reflecting surfaces are the cleavage faces of large grains of pyroxene or of amphibole that are so completely saturated with inclusions as to appear as heterogeneous in structure as the aggregate in which they lie. The entire fracture surface of specimen M. 453H, for instance, is made up of interlocking areas with evenly reflecting surfaces, each covering about a sixteenth of a square inch, and yet so full of little inclusions are they that the rock must be described as possessing a finely granular texture. In very rare cases the thinner bands are very coarsely granular, when they consist almost exclusively of pyroxene with now and then a little magnetite. In all cases the structure is obscurely schistose, and large pieces tend to break more easily along their bedding planes than transversely thereto.

In the most olivinitic phases of these rocks olivine comprises nearly their entire mass. The mineral here occurs in irregular interlocking grains of a pale yellowish green color, crossed by cracks and fissures in which a little limonite or other brown iron hydroxide has separated. Its inclusions are not abundant. A few tiny grains of plagioclase, a rounded grain of quartz and an occasional mass of leucoxene or flake of pyroxene, besides small irregular grains of magnetite are the only ones noticed.

Here and there, between the olivines, is a plate of pink augite, which is slightly pleochroic and which in most of its characteristics approaches the diallage of the normal gabbro, except that it never contains the gabbroitic inclusions. Its outlines are irregular and its contours are moulded by those of the olivine, so that it is undoubtedly younger than this component. Locally the diallage has acquired a fibrous structure due to alteration into a very pale yellow or colorless mineral supposed to be tremolite (or actinolite).

Most of the latter substance forms groups of fibres, whose relation to the augite can be inferred only from the fact that they occur between the olivine grains, with the contacts between the two minerals quite sharp. The olivine has undergone little, if any, decomposition, so that the fibres must be due to the alteration of the pyroxene, if they are secondary rather than primary in origin. The little groups or bundles of these fibres are very compact except at their ends, where they are frayed out into single fibres whose extinction is sometimes parallel to their long axes, and sometimes is slightly inclined to them. Their double refraction is strong and their polarization colors are brilliant. The axis of least elasticity is nearly parallel to the longitudinal direction of the needles, which are therefore negative, if the orientation of the optical axes is as it is in normal hornblende. Two cleavages are discernible, one parallel to the long axes of the needles and one (a parting) transverse to them. Cross sections of the bundles were not seen, so that it is impossible to say positively that the mineral is a hornblende, but its similarity to certain fibres in other rocks,[1] that are certainly hornblende, is so strong that there can be little question that these are hornblende as well.

[1] Cf. description of actinolite in actinolite-magnetite schists, Amer. Jour. Sci., XLVI., 1893, p. 176.

As to the origin of the supposed tremolite there is a doubt. The assumption of fibrosity by the diallage in some cases, would seem to point to a secondary origin for the bundles of hornblende since this is the only fibrous mineral in the rock. The little bundles, however, are so compact and their situation within the thin section is so remote from that of the diallage that the supposition of a primary origin for them seems to be demanded.

The magnetite, which is much more abundant in these rocks than in the normal gabbro, occurs as inclusions in all their constituents. It is more commonly an attendant of the tremolite, however, than of either the diallage or the olivine. It occurs as small irregular grains between the fibres of the bundles and in the exterior portions of the fibrous groups, and in nearly all cases the longer directions of the grains are parallel to the long axes of the fibres.

In mineral composition these rocks are wehrlites, but their structure is quite different from that of any rocks of this character heretofore described. The diallage and tremolite act as interstitial substances inclosing olivine grains, where the first two minerals are in sufficient quantity to serve this purpose. Where they are absent the rock consists entirely of a mosaic of interlocking grains of perfectly fresh olivine. Since both the olivine and the diallage are identical in characteristics with the same minerals in the normal gabbro, we are led to suspect that the rock is a special phase of the latter, in which the acid constituent — plagioclase — is lacking.

Pyroxene Aggregates.— In other beds the olivine is in less quantity than in those just described, and the rock composing them is slightly different. The olivine is in the same small grains, but these no longer form mosaics. They are in greater part included within large irregular plates of green pyroxene, whose ragged edges extend out for some distance between other surrounding olivine grains. The material of the plates is bright green in color, and it is slightly pleochroic. Its highest observed extinction is 36°, and its most common inclusions are grains of magnetite and masses of limonite. Most of the magnetite is between the olivine grains and the pyroxene, or in the interstices between the plates of the latter mineral, though some large grains are included within the olivine.

In the non-olivinitic types of these basic rocks, pyroxene and magnetite are the principal components. These types are perhaps more common than the olivinitic types, but their variety is so great that a description of them would be little else than a description of individual specimens. Pyroxene forms the greater part of all these rocks, but the character of the pyroxene changes for each individual bed, so that it is impossible to classify their material with any degree of success. It must therefore suffice to study one of the most striking types, and to leave the others with the statement that they are composed exclusively of some form of pyroxene and of magnetite.

The most interesting of the pyroxene-magnetite rocks is that already referred to as exhibiting lustre-mottling (M. 453 H). In this the pyroxene is present in two forms. It occurs as large, strongly pleochroic green plates, and as small, slightly pleochroic green grains, the latter included in the former. The lustre mottling on the hand specimen is due to the reflection from the large plates, and the fine-grained texture of the rock is the result of the uniform distribution of the small grains within the larger ones. The entire area of a slide is often occupied by four or five of the pleochroic plates, with their inclusions. They interlock with irregular sutures, and thus completely cover the thin section. When examined over the lower nicol the plates are yellowish-pink transverse to their prominent single cleavage and light green parallel to this. The axis of least elasticity in sections showing parallel cleavage lines is in the direction of this cleavage, and the extinction is consequently also parallel thereto. In cross sections the pyroxene cleavage is plainly apparent. Here the pleochroism is in yellowish pink and light wine-yellow tints, the latter in the direction of the smaller of the two lateral axes of elasticity. The absorption is consequently $\mathfrak{c}$=green$>\mathfrak{a}$=yellowish pink$>\mathfrak{b}$=wine yellow. The mineral is in all probability hypersthene.

The small grains included within the hypersthene are bright green in all positions. Now and then slight changes in the shade are noticed, indicating very weak pleochroism. The color is so nearly like that of the green ray of the hypersthene, that the presence of the grains in the latter mineral can be detected only with the greatest difficulty, when the slide is in such a position that the parallel cleavage of this mineral runs in the direction of the vibration plane of the lower nicol. In most of the included grains a well-marked coarse cleavage is noticed, the maxium extinction against which is 41°. In addition to the coarse cleavage there is often observed a second and finer series of cleavage lines, whose direction is parallel to that of the coarser ones. The properties of this pyroxene are those of diallage.

The magnetite in this rock is very abundant. It is in large and small grains imbedded in the pyroxenes, the larger ones usually in the hypersthene and the smaller ones in the diallage. Many of the grains are irregular in shape, but quite a number show crystal forms. There is no evidence that any of the mineral is of secondary origin. It all seems to be original. A portion of the magnetite separated from the powdered rock by digestion with hydrochloric acid was tested for titanium with a negative result, although specimens from other similar rocks contain this element.

The only other constituent observed in the section was a bright green hornblende, whose extinction is not known to be greater than 13°. It occurs in but a few flakes with irregular and indefinite outlines that fade off into the surrounding pyroxenes. It is probably secondary.

A comparison of the descriptions of the types of rocks above given indicates that the hypersthene in the last described type has taken the place of the olivine in the others. The green diallage in both cases is the same, though in the first two instances it surrounds the olivine, *i.e.*, it is younger than this mineral, while in the other instance it is surrounded by the hypersthene — it is older than the latter. A study of the granulitic phases of the gabbro points to the same conclusion, viz., that the hypersthene and olivine occupy similar places in the rock's constitution. Where the one is present the other is usually absent. They seem to be complementary components. It is also noticeable that when hypersthene is present and olivine absent the rock contains more magnetite than in the case where the conditions are reversed.

In some of the beds the percentage of the iron oxide increases as has already been said, until it reaches 80 per cent. or even 95 per cent. of the rock mass. In some of the sections made from these rocks nearly the entire field of the microscope may be occupied by a single mass of compact magnetite. On its edges this mass often breaks up into small grains that are cemented together by a large plate of green pyroxene. This observation is valuable as showing that the beds composed almost exclusively of magnetite have the same origin as those in which this mineral constitutes only a small part of the rock mass. The latter are certainly phases of the gabbro, hence the former must also be phases of the same rock. Whether most of the magnetite in these varieties is primary or secondary cannot be told. Much of it is certainly primary.

Granulitic Pyroxene Rock.—An interesting variety of the basic rocks is No. M. 1334. It is slightly schistose, and is composed almost exclusively of colorless pyroxene and green hornblende, in small grains with rounded contours. Its structure is granulitic. A brief description of the rock is given in the chapter on the granulitic gabbros.

The Relation of the Basic Rocks to the Normal Gabbro.—From the descriptions that have preceded, it is seen that the basic rocks along the northern periphery of the gabbro are composed almost exclusively of the more basic constituents of the normal rock—viz., magnetite, olivine, and pyroxene. The feldspar of the main mass of the gabbro is entirely lacking in them. The accumulation of the basic portions of the gabbro-magma on its periphery may be accounted for by its differentiation during cooling. Such a differentiation of a gabbro-magma has been described a number of times. Matthew[1] has noted it in a gabbro area near St. Johns, New Brunswick, while Vogt[2] has described it at a large number of places in Norway, Sweden, and other European countries. A notable feature in connection with the phenomena described by Vogt is the association of oxide and sulphide ores with the basic portions of the differentiated rocks. Many of the magnetite deposits of Norway are shown by this author to be peripheral phases of gabbro. The occurrence in Minnesota is similar to the Norwegian occurrences, and hence the author concludes that the ores of Winchell's "gabbro-titanic-iron group" have a similar origin. It has been shown by the descriptions that this is the case; the basic aggregates on the northern border of the gabbro area are peripheral phases of the coarse-grained olivine gabbro, whose composition and structure are so uniform throughout most of its extent, and the ores associated with these aggregates are only more basic phases of the same magma, by whose differentiation, after its intrusion into its present position, olivine gabbro, pyroxene-olivine aggregates, and almost pure titaniferous magnetite beds were formed.

W. S. BAYLEY.

[1] W. D. MATTHEW: Trans. N. Y. Acad. Sci.

[2] J. H. L. VOGT: Bildung von Erzlagerstätten durch Differentiationsprocesse in basischen Eruptivmagmata. Zeits. f. prakt. Geologie, Januar, 1893.

(To be concluded.)

THE GEOLOGICAL SURVEYS OF ARKANSAS.

The Owen Survey.—The subject of a state geological survey of Arkansas was first brought to public attention by Governor Elias N. Conway in his message to the legislature in 1856. Upon his recommendation the matter was taken into consideration and the first geological survey of the state was begun under an act passed January 4, 1857. This act provided for the appointment of a state geologist by the Governor, and an appropriation of $4,800 per annum, out of which all expenses were to be paid. Dr. David Dale Owen, then state geologist of Kentucky, was appointed state geologist of Arkansas, and entered upon his duties October 1, 1857. The results of the work done in 1857 and 1858 are given in Owen's "First report of a geological reconnoisance of the northern counties of Arkansas," Little Rock, 1858.

In his message to the legislature of 1858–9 Governor Conway recommended more generous support of the survey. There were those in the legislature, however, to whom the collecting of fossils and the examination and location of rocks seemed a ridiculous occupation for state officers to say nothing of its being a waste of the state funds, and every effort was made by them to defeat the appropriation bill.[1]

[1] Some idea may be had of the ridicule heaped upon it from the following extracts from amendments offered to the survey bill.

"Mr. * * * offered to amend by adding the following after section 11, viz:

"SEC, 12. The same amount which is appropriated to the State Geologist, shall likewise be appropriated to a phrenologist, * * * * and a like amount to an ornithologist, and their several assistants who shall likewise be appointed by the Governor, and shall continue in office fifty-four years * * *; and the Secretary of State shall forward one copy of each report to the Governor of each state in the Union, except such as may be known to be black republican governors; also, one copy to the Queen of England, and to the Emperors of France and Russia; also, a copy to the Queen of Spain: provided that government will sell Cuba to the United States on reasonable terms."

"SEC. 14. It shall be the duty of the phrenologist to examine and report upon the heads of all the free white male and female citizens in the state, and their children, except such as may refuse to have their heads examined."

The bill providing for the continuation of the survey passed in February, 1859; by its provisions the state geologist's salary was raised from $1,800 to $2,500, and an appropriation of $6,000 per annum was made for the survey work. Under this act Dr. Owen was again appointed state geologist. Before the next legislature convened Dr. Owen died (November 13, 1860) and his "Second report of a geological reconnoisance" was edited by his brother, Dr. Richard Owen, and Prof. J. P. Lesley and was printed at Philadelphia in 1860.

Dr. Owen's efforts were devoted entirely to the work of reconnoissance, the first report treating the region north of the Arkansas River, and the second that south of the river. In the main his ideas of the geological structure of the state were correct, and his facts have been of great service in working out the details of the structure and the areal geology. Errors were made, but they were few and unimportant, especially when we take into consideration the limited time and small means at the disposal of the survey. It may be well to mention the more fundamental of these errors, because they have so long been current:

I. It was thought that the Arkansas coals belonged to the Lower Coal Measures. Coal does occur in the Lower Coal Measures north of the Boston Mountains, and the generalization was made from these beds. The coal of the Arkansas valley is in an altogether different position — near the top of the Coal Measures.

II. It was thought that the novaculites, now known to be Silurian, were Carboniferous. No fossils had then been found in or near the novaculites.

III. The theory of northeast-southwest metalliferous veins across the state, although advanced only as "probable," led to much searching for silver and lead, much loss of time and money, and to much disappointment.

The civil war broke out shortly after the publication of Owen's second report, and all such work was necessarily suspended in the southern states. No steps were taken to finish the geological survey of Arkansas until after the close of the war.

The Reconstruction Surveys.—In the General Assembly of 1866 a bill was passed by the Senate providing for a geological survey of the state, but it was rejected by the Lower House.[1]

In his message to the General Assembly of 1868 General Powell Clayton, then Governor of the state, recommended the continuation of the survey begun by Owen, but the committee to which the matter was referred reported that "owing to the unsettled state of the country and the lack of funds to prosecute the above work" the bill should be indefinitely postponed.

In the legislature of 1871 a survey bill was passed (and approved March 28, 1871) appropriating $15,000 for two years work. Under this act Governor O. A. Hadley appointed W. F. Roberts, Sr., of Pennsylvania, state geologist. The records in the office of the Secretary of State do not show how long Mr. Roberts held office, but he was appointed June 5, 1871, and in his message to the General Assembly in 1873 Governor Hadley says that he returned to Pennsylvania "last July, and I have not heard from him since."

Dr. George Haddock, then of Arkadelphia, was, upon Governor Hadley's recommendation, appointed Mr. Roberts' assistant, and went with him through the western part of the state.

Mr. Roberts' report was never delivered to the Governor, but, according to his own statement,[2] it was deposited in a bank, because the state was unable to print it. A series of articles, however, was subsequently published by Mr. Roberts in the *Age of Steel* of St. Louis, Missouri (1887–88), and it is probable that these articles represent his views of the geology of the state, and give the results of his work. They are largely a repetition of the results given by Owen.

[1] This bill appropriated $13,000 for the survey for two years — 1867 and 1868. The vote in the House was 30 to 27 against the bill; in the Senate it was 17 to 6 in its favor.

[2] Made to the writer in 1888.

In 1873 Dr. George Haddock, who had been Mr. Roberts assistant, published at Little Rock a pamphlet of 66 pages entitled "Report of a Geological Reconnoisance of a part of the State of Arkansas made during the years 1871–72." This paper gives the only results of the work done under this appropriation.[1] It is of but little or no importance and adds nothing to the work done by Owen.

The General Assembly of 1873 passed a bill for the continuation of the survey, and made an appropriation of $15,000 for it.[2]

Under this act the following state geologists were appointed: *George Haddock*, appointed May 15, 1873, removed from office January 14, 1874. Mr. Haddock, who is said to have been a Scotchman, had been assistant geologist under Mr. Roberts the year before; he made no report except the one published under a former appropriation and mentioned above. *William C. Hazeldine*, appointed January 14, 1874, and removed June 29, 1874. Mr. Hazeldine was an Englishman by birth; he had been sent to the State Legislature from Richmond, Little River county, in 1871. Later he was circuit Judge of the Second District of Arkansas, and lived at Augusta, Woodruff county. As state geologist he made no report, and, so far as can be ascertained, did no field-work. *Arnold Syberg* was appointed June 29, 1874, and remained in office to the end of the term. Mr. Syberg is a native of Prussia; he was at one time a captain in the regular army of the United States, afterwards state engineer of the State of Arkansas, and still later engineer in the Confederate army. He still lives at Little Rock. Mr. Syberg says that he made no report, and that the only work he did was to receive and examine specimens sent or brought in from various parts of the state.

The total amount appropriated for the 1873–74 survey—

[1] The books in the Auditor's office show that $10,700 of this appropriation was drawn out, and that the remaining $4300 was carried over to the next survey account.

[2] For minority report against the appropriation see *Senate Journal*, 1873, p. 450, *et seq.*

$15,000—was spent, and, in addition thereto, the Legislature voted $2386[1] in a deficiency bill.

The failure of the surveys for years 1868 to 1875 to yield any geological results must be attributed to the general demoralization of the state government during the reconstruction period.

No further efforts were made to carry on a geological survey until the year 1881, when bills for such work was defeated in both branches of the General Assembly.

In the Assembly of 1883 the only legislation passed relating to geological work was a Senate concurrent resolution "authorizing and directing the Governor to make application to the Secretary of the Interior of the United States for a geological survey of the State of Arkansas." Nothing seems to have come of this effort to obtain help from the national government.

The Branner Survey.—The last survey of the state was publicly suggested by Governor Simon P. Hughes in his message to the General Assembly in January, 1887, and on January 19th of that year Hon. Elias W. Rector, Representative from Garland county, introduced in the Lower House an act providing for a geological survey of the State of Arkansas.[2]

This bill provided for a state geologist and three assistants. The geologists were to be paid from the appropriation for the state officers, and printing, stationary, postage, fuel, and lights were to be paid for out of funds to furnish supplies and to do printing for state officers, while $10,000 was appropriated in the survey bill proper to pay contingent expenses. The bill required that the survey should be completed in two years. Under this act J. C. Branner, at the time professor of geology in the University of Indiana, was appointed state geologist; he entered upon the duties of his office June 24, 1887.

At the next meeting of the General Assembly, in 1889, there was much and violent opposition to the continuance of the

[1] The biennial report of the State Treasurer for 1874 shows that he paid $19,628 to the state geologist.

[2] It was referred to the Committee on Judiciary, reported back favorably, fully discussed and passed February 24, 1887, by a vote of 53 to 19; the same bill passed the Senate by a vote of 28 to 1, and was approved by Governor Hughes, March 5, 1887.

survey, due chiefly to the fact that the survey had declared fraudulent certain so-called gold mines in the western part of the state; but, under the leadership of Mr. Rector, a bill for its continuation was passed. This new bill was in the form of an amendment of the bill of 1887, and was so worded as to make it unnecessary for subsequent assemblies to do more than vote the money required for the general appropriations. This amendment fixed the contingent fund at $10,000 for two years, and gave the state geologist four assistants in place of the two previously provided for. Under this bill J. C. Branner was re-appointed state geologist. The General Assembly of 1891 made the same appropriations as the previous one, and the same state geologist was again appointed. When this last appropriation was made, it was stipulated that it should finish the survey's work, and that the survey should be brought to a close by the end of March, 1893. When the Assembly met, therefore, in 1893 the field-work had been finished, or as nearly so as possible, and the only appropriations asked for was one to be used to complete the preparations of the reports. For this purpose an appropriation of $4000 was made to be expended under the direction of the Governor. It was understood also that the former state geologist should prepare the reports without expense to the state beyond the assistance he might need in office and clerical work, and that the printing, engraving, and binding of the reports should be paid for as before out of the general appropriations to pay for that work for the state. The reports of the survey are now all published except the four volumes mentioned below.

Some wonder is occasionally expressed that a state geologist should undertake to bring the work of a survey to a definite close, instead of insisting upon the fact that a state geological survey is an essential, and should be a permanent, part of every state government. Whether every state should maintain a permanent geological survey depends upon circumstances and conditions that cannot be discussed in this place. So far as the case in hand is concerned, it seemed, and still seems, better that with fair appropriations and salaries the work should be pushed energetically and brought to a definite end, rather than that appropriations should dwindle to a point forbidding creditable work. Believing that the people are entitled to what they pay for, it has been the aim of the present survey to meet the reasonable expectations of the people of the state in giving them practical and economic results, and at the same time to do all the purely scientific work that the means at the survey's disposal would admit of, or that the study of economic problems demanded.

The reports are mainly in the form of monographs of the subjects treated: thus all the facts gathered relating to the manganese are brought together in the manganese report; those relating to the novaculites are given in the report on novaculites, and every thing known of the igneous rocks of the state is given in the report on igneous rocks, etc. Besides the evident advantage of having the subjects thus grouped in monographs, this method has kept down the number of volumes, has prevented the publication of undigested field notes, and has greatly reduced the cost of printing. The disadvantages of such a sytem are that the bulk of the work upon a given subject must be done by one person, and, in the case of formations that extend over wide areas and require much detailed study, it is impossible to bring out the results promptly. The clay report, for example, has been in hand since 1887, and is not yet published. The delay in publication is also liable to work injustice to assistants by their results being anticipated. This can be prevented to a certain extent by publishing results of special interest in scientific periodicals.

In the case of the Arkansas survey this method of publication has not been carried out without legal difficulties. The law establishing the survey says: "Section 4. It shall be the duty of said geologist, on or before the first Monday in December of each year . . . . to make a printed report to the Governor of the results and progress of the survey, accompanied by such maps, profiles, and drawings as may be necessary to exemplify the same, which reports the Governor shall lay before the General Assembly."[1]

Annual reports are the only ones provided for, and it is for this reason that the volumes, instead of being numbered consecutively, are given as annual reports, and divided into volumes, one volume generally being devoted to a single subject.

The greater part of the topographic maps made by the survey will accompany the final report on coal. They embrace an area of 3240 square miles; the maps are on a scale of one mile to the inch, the contour interval is twenty feet. The total area mapped topographically is 4,500 square miles, while topographic sketch maps have been made of about double that area, and special areas have been mapped on scales varying from 300 to 1,000 feet to the inch.

The following are the reports published under the Branner survey.[2]

Annual Report for 1887.—Administrative (pamphlet). Pp. 15.

Annual Report for 1888.

- Vol. I.—Gold and silver. Pp. 320 + xxxi; 2 maps.
- Vol. II.—Mesozoic. Pp. 319 + xiv; illustrated; 1 map.
- Vol. III.—Coal (preliminary). Pp. 120 + x; illustrated; 1 map.
- Vol. IV.—Washington county; Plant list. Pp. 262 + xiv; illustrated; 1 map.

Annual Report for 1889.

- Vol. II.—Crowley's Ridge. Pp. 283 + xix; illustrated; 2 maps.

Annual Report for 1890.

- Vol. I.—Manganese. Pp. 642 + xxvii; illustrated; 3 maps.
- Vol. II.—Igneous rocks. Pp. 457 + xv; illustrated 6 maps.
- Vol. III.—Novaculites. Pp. 443 + xx; illustrated; 2 maps.
- Vol. IV.—Marble. Pp. 443 + xxiv; illustrated; atlas of 6 maps.

Annual Report for 1891.

- Vol. I.—Mineral waters. Pp. 144 + viii; 1 map.
- Vol. II.—Miscellaneous — Benton county; Elevations; River observations; Magnetic observations; Mollusca; Myriapoda; Fishes; Dallas county. Pp. 349 + xii; illustrated; 2 maps.

Annual Report for 1892.

- Vol. I.—Iron deposits. Pp. 153 + x; 1 map.
- Vol. II. Tertiary. Pp. 207 + xiv; illustrated; 1 map.

[1] Acts of Arkansas, 1887, p. 58.

[2] A bibliography of the Geology of Arkansas is given in Vol. II An. Rep. Geol. Survey of Arkansas, 1891, pp. 319-340.

There are also in press or in manuscript four volumes, as follows: The final report on coal; the report on the Lower Coal Measures; the report on clays, kaolins and bauxites; the report on zinc.[1] A bulletin upon the palæontology of the state is being prepared by Dr. H. S. Williams, of Yale University; it will be published by the United States Geological Survey.

The following are some of the general economic results of the Survey's work:

1. The areal and structural geology of the state in so far as the subdivisions are known. (The exact parting between the Carboniferous and Lower Carboniferous along the southern margin of the Carboniferous is not known; indeed it is not known whether the Lower Carboniferous comes to the surface south of the Arkansas River.)

2. Reporting upon the reputed gold mines of the state.

3. Outlining the coal area.

4. Determining and pointing out the adaptabilities of the various coals, and the best methods of mining and marketing them.

5. Showing the extent, value and method of locating manganese deposits.

6. Mapping and calling attention to the character, extent and distribution of the marbles and other limestones.

7. Discovery of chalk, giving its distribution, and suggesting uses to which it may be put.

8. Chemical analyses of the mineral waters.

9. Showing the character of the iron ores.

10. Discovery of bauxite and giving its distribution.

11. Pointing out the character, distribution, and availability of the clays of the state.

12. Determining by tests the character of the granites and giving their distribution.

[1] The survey reports are distributed by the writer to his correspondents at his personal expense and on his own account. Copies can generally be had, however, by geologists and capitalists by addressing the Honorable Secretary of State, Little Rock, Arkansas. It is necessary to state, on making application, that one is a capitalist or a geologist, and interested in the geology of Arkansas, and to prepay all postage or to order the reports sent by express at his own expense.

13. Analyses and distribution of the zinc ores.

Some of the more comprehensive geologic problems that yet remain to be solved, relate to :

1. The palæontology of the state.
2. The physical geography.
3. Quaternary history.
4. Relation of the palæozoic beds to those of the other parts of the continent and to those of the world.
5. The divisions of the Silurian beds.

RESUMÉ OF APPROPRIATIONS AND PUBLICATIONS.

TERM.	GEOLOGIST.	APPROPRIATION.	REPORTS PUB.	VOLS.	PAGES.	MAPS
1857–8	D. D. Owen	$ 4,800	First survey	1	256	0
1858–60	D. D. Owen	12,000	Second survey	1	431	1
1871–3	W. F. Roberts, Sr.	15,000	Haddock's pamphlet	1	63	0
1873–4	Geo. Haddock, W. C. Hazeldine, A. Syberg	19,628	None	0	0	0
Former surveys, seven years.		$51,428		3	750	1

TOTALS OF BRANNER SURVEY.

1887–9	J. C. Branner	$27,800	Reps. for '87–8	5	1105	5
1889–91	J. C. Branner	32,600	Reps. for '89–90	5	2373	21
1891–3	J. C. Branner	32,600	Reps. for '91–2	4	887	5
1893–5[1]	J. C. Branner	4,000	In preparation	4	about 2000	38
	Total,	$97.000[2]		18	6365	69

Engraving, printing, and binding are not included in the total for the period 1887–95. Those items and the cost of fuel, lights,

[1] No field work was done after 1892; the appropriation was made in 1893 for completing the reports.

[2] A deficiency bill for $2,340 was passed by the legislature in 1889. This sum, however, should not be added to the total amount appropriated because a somewhat larger amount reverted to the treasury that year from the appropriation for salaries. It is but just to add, moreover, that the work represented by the state geological reports was not all paid for by the state : about $8000 worth of work was contributed by volunteer assistants; about $5000 was spent on precise levels by the U. S. Coast and Geodetic Survey; about $25,000 was spent in topographic work by the U. S. Geological Survey; about $7000 worth of engraving was done by the U. S. Geological Survey, and a deficiency of about $3000 was paid by the State Geologist.

stationery, and postage would probably bring the total expenditures of the Branner survey up to about $120,000, and the total cost of all the state geological surveys up to $171,428.

When all the conditions are considered, it must be recognized that great credit is due the people of the State of Arkansas for the liberality with which they have supported geological work.

John C. Branner.

Stanford University, California,
November 8, 1894.

STUDIES FOR STUDENTS.

THE DRIFT—ITS CHARACTERISTICS AND RELATIONSHIPS.[1]

CONTENTS.

THE TOPOGRAPHIC RELATIONS OF THE DRIFT.

The body of the drift. The drift is not confined to any topographic situation. Its vertical range may be hundreds of feet within a single mile. It occurs on the tops of mountains thousands of feet high, as well as on their slopes and at their bases. It covers hills of lesser magnitude, and mantles high plateaus and low plains with apparent indifference. It is found down to the level of the sea in some places, and is known to pass beneath it. Throughout all these topographic situations it maintains a tolerably constant character. Stratified drift often extends beyond the margin of the general drift-sheet. In such cases it is generally confined to the valleys leading out from the drift area. The stratified drift which is beyond the edge of the general drift-sheet is thus seen to maintain a definite relation to topography. As a general fact, the northern part of the drift-covered territory is higher than the southern, although elevated areas are not wanting near its southern limit.

[1] Continued from page 724.

The topographic relations of the great sheet of drift make it clear that the agencies which produced it must have been measurably independent of topography over the greater part of the drift area, but forces which were dependent upon topography carried stratified drift into valleys far beyond the borders of the area which is generally drift-covered.

Topographic terminus of the drift. Remembering that most of the drift was transported in a general southerly direction, it is a not insignificant fact that the line marking its southern boundary is largely independent of present topography. The drift does not rise to a given altitude and then fail; neither does it descend to a certain level below which it does not occur. In general, its southern boundary may be said to be lower than the larger part of the area which it covers to the north. In view of the direction in which it was transported, its distribution with relation to present topography is such as to indicate that in the process of distribution it was frequently stopped on a downward slope. The only escape from this conclusion would seem to lie in the assumption that the land surface has been extensively deformed since the drift was deposited, an assumption for which we have no warrant. In detail, the terminus of the drift is now on level lowland, now on level highland, now on a surface sloping toward the direction whence the drift came, and now on a surface sloping in the opposite direction. At some points, the terminus is found upon hilltops, while at others closely adjacent it is in the bottoms of valleys. The margin of the drift is therefore far from being horizontal. If it were allowable to suppose that the drift-covered area to the northeast had been elevated since the drift was formed, or that the driftless territory to the south had been depressed since that event, we might suppose that some more definite relationship than now appears formerly existed between altitude and topography on the one hand, and drift distribution on the other. But no general northward elevation or southward sinking will account for the topographic irregularity of the border of the drift. The character of this irregularity is such that, taken in connection with its surroundings, it is clearly not the result of any post-drift alterations of level. The topographic irregularity of the drift border was original. It follows that the activities of the drift-producing agencies were not confined to a horizontal line along the outermost limit of their reach.

Topography of the Drift.

The topographic expression of a drift-covered country can hardly be said to be identical with the topographic expression of the drift, since the former is largely dependent on the topography of the subjacent rock. Strictly speaking, the topography of the drift is the topography which it possesses independently of its bed. It is the topography which it might assume if deposited on a plane surface. It should not be understood, however, that the topography of the underlying rock exerts no influence on the topography of the drift. Suffice it here to say that the topography of the drift varies within wide limits. Both stratified and unstratified drift may have surfaces which are nearly plane, though such surfaces are rather more characteristic of the former than of the latter. A plane surface of stratified drift is almost sure to have a slight inclination, tolerably constant both in degree and direction for any limited area. This cannot be said of the plane surfaces of unstratified drift, where such exist. By all degrees of gradation plane surfaces of either phase of drift may depart from planeness by taking on shallow depressions; but a plane topography interrupted only by depressions is much more characteristic of stratified than of unstratified drift. Again, the depressions in the surface of the stratified drift are more likely to be circular in form and more sharply defined than those in the surface of the unstratified, where such exist. In the latter case depressions are almost always accompanied by slight elevations, the counterparts of the depressions, the profiles of which are very gentle. If, along with the depressions, swells affect the surface of the stratified drift, as they sometimes do, they are likely to be more abrupt than the corresponding features of the unstratified drift. They generally have smaller bases for equal heights.

Either the stratified or the unstratified phase of drift may have a topography of moderate relief and gentle profiles. But this is more characteristic of the unstratified than of the stratified phase. Either phase may have a rough topography, rough rather by virtue of the small size, steep slopes, and close juxtaposition of the elevations and depressions. than because of great relief. Extreme roughness of drift topography is perhaps as characteristic of certain special phases of stratified drift as of unstratified, but it is more characteristic of intimate associations of stratified and unstratified drift than of either alone.

If the average thickness of the drift be no more than one hundred feet, the average amount of relief for which it can be responsible is manifestly not great. The greater its thickness, the greater the variations of surface which it can produce, if irregularly disposed. Reliefs of one hundred feet or so, attributable to the drift alone, are not rare along certain belts of thick drift. Such differences in altitude may occur within the space of a few rods, but they do not characterize any considerable fraction of the drift-covered area. Reliefs of much greater range, belonging wholly to the drift, are seldom met with. Where so great relief occurs within narrow geographic limits, it is usually where deep, abrupt, kettle-like depressions are associated with equally abrupt hillocks.

The topography of the drift is not defined or described when its range of relief is indicated. Nothing more need be said concerning it at this point, than to indicate that one of its notable characteristics is the presence of multitudes of depressions which have no surface outlet. These depressions may have any depth up to a hundred feet or more. Reference is here made only to those depressions which affect the surface of drift, not to those for whose existence the irregularities of the surface of the underlying rock is largely or wholly responsible.

The depressions may be of any form, regular or irregular. They may be of any area, up to many square miles. Their slopes may have any degree of steepness, limited only by the angle at which loose material like the drift will lie. They may be closely grouped or widely scattered. Thousands and tens of thousands of these depressions are marked by the swamps, ponds, and lakes of the northern part of the United States. Indeed, these features are so nearly co-extensive with the drift, that the line marking the limit of the latter may almost be said to be the line marking the limit of the former. The principal exceptions to this statement are the marshes and shallow ponds along coasts and sluggish streams outside the drift.

If it be remembered that the depressions in the surface of the drift have a wide range in the matter of area, shape, depth, and

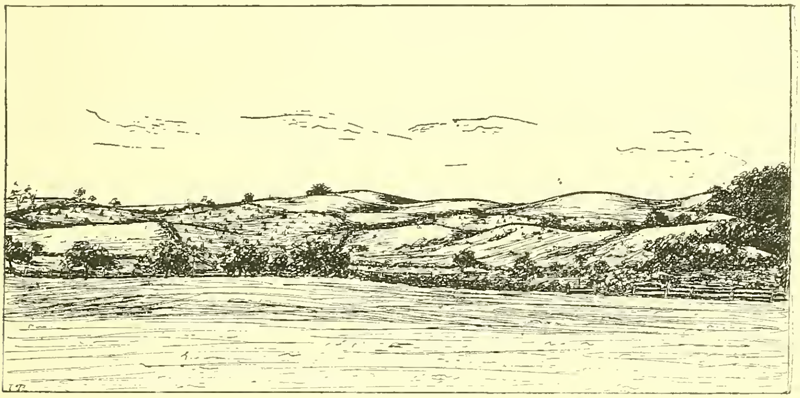


Fig. 2. One type of drift topography. Drawn from photograph of drift surface, near Hackettstown, N. J.

abruptness of slope, a rough sort of idea of drift topography may be acquired by imagining at least an equal number of hills, of equally diverse sizes, shapes, and slopes, interspersed between the depressions. It is not to be understood that the depressions and hills are everywhere existent in the drift-covered area, or that they are everywhere striking, where they exist. It is to be remembered that there are areas of drift of great extent, the topography of which is essentially plane, and that there are other areas of equal extent where the topography is but gently rolling, and where the elevations and depressions are therefore not obtrusive. It is to be remembered further that in many parts of the drift-covered territory, the controlling element in the surface topography is the topography of the underlying rock. Yet, in spite of all these exceptions, the presence of undrained depressions associated with elevations which, roughly speaking, are their counterparts, is one of the most distinctive features of drift topography. The topography of the drift is in sharp contrast to the topography developed by river erosion, for in regions whose surfaces are fashioned by river erosion the depressions are valleys, and each has an outlet. Every tributary valley leads to a lower, and the lowest leads to a lake, to an inland basin, or to the sea.

When the surface of the drift is rough, the roughness is dependent in part on the amount of relief, but more especially on the abruptness of the hills and hollows, and the closeness of their association areally. Where they have steep slopes and are close-set, even with but moderate relief, the topography appears rough. Where they are farther from one another, and possess gentler slopes, the topography may appear much less rough, even though the relief within broader areal limits be equally great. The topography of the drift, could it be distinctly separated from the topography of drift-covered areas, would be found to be measurably independent of the topography of the subjacent rock.

The Topography of the Drift-Covered Areas.

It is of consequence to distinguish between the topography of driftless and drift-covered territory. The topography of the latter is often, but not always, strikingly unlike that of the former. The topography of driftless territory varies within certain limits, and the topography of drift-covered territory varies within certain other limits. Sometimes the two types of topography vary toward a common limit. Under such circumstances they may closely simulate each other. In general it may be said that the most distinctive difference between the topographies of drift and driftless areas is the more perfect and more systematic development of the drainage lines upon the latter. This is made obvious in one way by the abundance of marshes, ponds, and lakes in the drift area, in contrast with their scarcity without.

It is made obvious in another way by the definite and systematic relations which exist between the elevations and depressions. In non-mountainous driftless regions, the depressions are usually river valleys, and the elevations inter-stream ridges. The common relationship of these features is such as to show that the inter-stream ridges are but remnants of a surface which has been roughened by the excavation of the valleys. In the drift-covered areas, on the other hand, this relationship does not always exist, and even where it can be made out, it is often obscure.

It is also of consequence to distinguish between the topography of drift-covered areas and the topography of the drift. The topography of the drift, it will be remembered, is the topography which it possesses independently of its bed. It is the topography which it might have if deposited on a plane surface. The topography of drift-covered areas is due partly to the topography of the drift *per se*, and partly to the topography of the rock below the drift. Either one of these elements may be the controlling one. Where the drift is thin and uniformly distributed, the topography of the drift-covered territory corresponds closely with that of the rock beneath. Where the drift is thick and irregularly disposed, the topography of the area it covers may be very unlike that of the subjacent rock. In extreme cases, and for limited areas, the drift may be so thick and so irregularly disposed that the surface affected by it preserves none of the topographic features of the underlying rock. In any case the existing topography is the resultant of the two elements. If the topography of the underlying rock has a relief greater than the average thickness of the drift, it will still determine the larger features of the resultant topography, though perhaps not its details. If the topography of the underlying rock possesses a relief which is slight in comparison with the average thickness of the drift, the latter may determine both the major and minor features of the resultant topography.

The drift and drift-free surfaces present many differences. Where there is no drift the valleys are likely to be more nearly straight. Here, too, the tributary valleys join their mains in a more regular way, and at a more nearly uniform angle, forming more symmetrical systems. Abrupt turns and striking detours of streams are, on the whole, less frequent,[1] though this is not illustrated by limited areas everywhere. Within the drift area of North America, rapids, falls, and other evidences of youthful drainage are much more common than in adjacent driftless areas of comparable altitudes. The elevations between the valleys are more continuous in the driftless areas, unless the drainage system is so far advanced in its life-history as to have notched the inter-stream ridges, or to have cut them into isolated hills. The elevations and valleys stand in more definite and constant relations to each other; that is, the topography of the driftless country is a topography the details of which have been fashioned mainly by running water.

If it be true, as, on the whole, it probably is, that the drift territory has less relief than the driftless for corresponding altitudes, it is also true that its surface is often more "choppy," the hills being shorter and more noticeably huddled together. This characteristic is popularly recognized in such names as "short hills," "knobs,"[2] etc., names which have been locally used because of the striking contrast in shape between the discontinuous hills of drift, and the associated hills of greater length composed of solid rock (see Fig. 2). The choppiness of surface is by no means co-extensive with the drift. Where it is present, the drift, rather than the underlying rock, is the controlling element in the present topography. Drift hills are sometimes low and symmetrical in form, and their slopes gentle. They are sometimes more or less systematic in arrangement over considerable areas, but even then their forms do not generally stand in any definite relation to river valleys. Hills which are only drift-coated may bear a more or less obvious relation to the valleys, but hills composed entirely of drift are measurably independent of them.

[1] The abrupt turns of streams in their flood plains is not here taken into account.

[2] The name "Short Hills" has been given to a village in New Jersey where the surface is of the character here referred to. The term "knobs" is frequently applied to the abrupt and closely set drift hillocks. This term has also been popularly used in other relations to designate a very different type of topography.

In some regions, and over considerable areas, river erosion has so far modified the topography developed at the time of deposition of the drift as to reproduce a topography comparable in kind to that which affected the subjacent rock before the drift was deposited. In this case the characteristic features of drift topography have been destroyed. River erosion topography has been superimposed on the topography of the drift-covered area. Ridges and hills fashioned by streams working upon the drift, stand in that relationship to adjacent valleys which the laws of stream erosion determine.

Plane tracts may be brought into existence in very different ways. They occur in driftless as well as in drift-covered areas, Flatness, therefore, cannot be regarded as diagnostic, either of drift or of driftless regions.

It follows from the foregoing that the drift forces must have been such as were able to develop plane surfaces at some points, surfaces marked by more or less symmetrical drift hills which are measurably independent of valleys at others, and short, choppy hills, in still others. They must have been such as were able to modify, to all degrees, the pre-existent rock topography.

Relation of Drift to the Underlying Rock.

Where fresh exposures show the contact between any considerable bed of drift and the underlying rock, it may be seen that the drift does not generally grade into the rock. Especially where the underlying rock is hard, the plane of contact between it and the drift is generally sharply marked. Where the underlying rock is not indurated, the plane of contact is sometimes less well defined. Furthermore, where the underlying rock is hard, its surface is commonly firm and fresh. Signs of weathering are absent. Any weathered surface it may once have had before the drift was deposited was completely removed during that process. This relationship is shown in the accompanying diagram (Figure 3). It should not be inferred that the relationship between the drift and the underlying rock expressed in the diagram is universal, even where the drift is thick. It frequently does not obtain where it is too thin to protect the rock beneath from considerable changes of temperature, and from the effects of those other disintegrating agencies which affect the surface to a depth of a half dozen feet. In such situations the surface of the

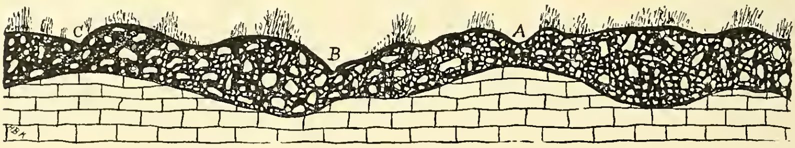


Fig. 3, illustrating the relation of drift to underlying rock. The line of contact is distinct, and the rock surface is not roughened by decay.

underlying rock may be much broken and weathered. If the rock be of such a character as to successfully resist weathering, its surface may be smooth and firm where the thickness of drift is very slight, or even where it is altogether absent.

The relation which the drift sustains to its underlying rock bed is therefore distinctly unlike that which the residuary earths of driftless regions sustain to the rock upon which they rest. In the latter case, as the designation "residuary earth" implies, the soil and subsoil have arisen chiefly from the decomposition and disruption of the underlying rock. All rock beds lack homogeneity to such an extent that their surfaces weather unequally. Their weathered surfaces are therefore uneven. The weathered

Fig. 4 shows relation of soil to rock, where the former has arisen by the decay of the latter. The line of contact is indefinite because of the irregular decay of the rock surface.

product of the rock—the subsoil—fills the little hollows on its surface, and penetrates the fissures and cracks, while the prominences of the uneven rock surface project up into the subsoil. The relationship referred to is illustrated in Figure 4, where the upper darker portion represents the residuary earths, and the lighter part below the underlying rock whence the earths were derived. As shown in the figure, the upper surface of the rock is often so much broken, and so much mingled with the more earthy subsoil, as to make it very difficult to locate the plane of contact between them.

The true theory of the drift must explain its relation to the rock beneath. Any hypothesis which fails to explain this relationship must be incomplete at the very least. Any hypothesis with which this relationship is inconsistent, must be false.

Significant Features of the Surface of the Rock Underlying the Drift.

Striation and planation of the bed rock. Besides the characteristics referred to in the last paragraph, the rock surface beneath the drift, and especially beneath the unstratified drift, is frequently found to be polished and striated. Sometimes it is polished without being striated, but the two things usually go together. While these features are found at many points throughout the drift-covered area, and at all elevations at which drift occurs, they are not found everywhere where there is drift, and are rarely found beyond its limits. Where similar striæ on bed rock are found outside the limits of the great drift area, it is not without significance that they occur in lesser areas of drift. In North America, these lesser bodies of drift, with their striated stones, and with striated bed rock beneath, are in the lofty mountain regions of the west. The smoothings and the markings on the bed rock beneath the drift are identical in kind with those already noted as occurring on the bowlders of the drift. So exact is the correspondence, that community of origin cannot be doubted. The drift agencies, therefore, must have been capable of striating the rock beneath the drift, as well as the stony materials of the drift itself.

The striæ on the bed rock beneath the drift are generally approximately parallel in any given locality, and tolerably constant in direction over considerable areas. In a general way, the direction of striæ corresponds with the direction in which the drift has been transported. When large areas are studied, the striæ are sometimes found to be far from parallel. Less commonly, this is true for small areas. Divergent and inharmonious as these various directions sometimes seem to be, fuller knowledge discovers a system in their arrangement. In many areas, the striæ are found to arrange themselves in systems. Within each system the striæ are found to be divergent from a common axis. Such axis is not generally a mountain range, or even a ridge. It is oftener a broad valley.

The systematic arrangement of the striæ, as developed in some regions, is illustrated by the accompanying figure (Figure 5), which represents, in a diagrammatic way, the arrangement of striæ on the rock surface beneath the drift of eastern Wisconsin. The striæ on the right-hand side of the figure appear to represent the marginal part of a second system, the axis of which is in the trough of Lake Michigan. In other localities, also, two similar systems of striæ lie side by side.

Within any single divergent system there may be local divergences from the common direction. In such cases, the divergences are almost uniformly associated with local topographic features. The striæ often have such a direction as to indicate that the agent which made them had a tendency to go around a hill or ridge, instead of passing directly over it. This tendency of striæ to veer round elevations may sometimes be observed about large and abrupt hills, while in the same locality lower hills with gentler slopes do not appear to have influenced the course of the striating agent.

Striæ are not confined to horizontal or gently inclined surfaces. They sometimes occur on steep slopes, on the vertical faces of cliffs, and, occasionally, even on the under side of overhanging rock masses. They sometimes occur in still more anomalous positions. In the face of the high bluff overlooking Cayuga Lake, for example, a horizontal groove in a vertical face is striated on its upper, lower, and interior sides. The groove in which the striæ occur retires eight inches into the face of the vertical cliff.[1]

Where striæ are absent from the surface of the rock beneath

[1] Seventh Annual Report, U. S. Geol. Survey, pp. 170, 173.

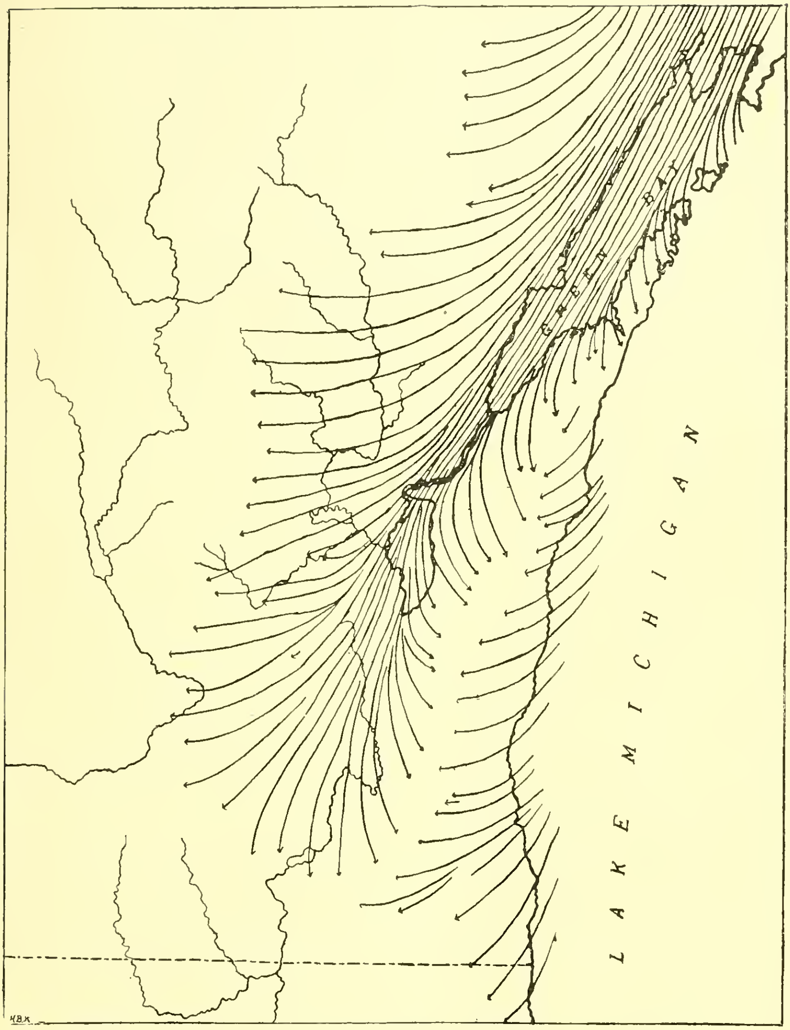


FIG. 5. Illustrating the general arrangement of striæ in Eastern Wisconsin.

the drift, their absence must be due to one of two things; either they were never formed, or they have been destroyed. Where the character of the underlying formation is such as to unfit it for receiving striæ, they could never have been developed. This would be true where the underlying formation is loose sand or gravel. Where the underlying rock is such as not to favor the development of striæ, but not such as to prevent their formation altogether, they may be rare. This might be true of rock which is unusually hard, and for this reason difficult of striation, or it might be true of rock which is very fragile and easily crushed. Where the underlying rock is ill-adapted for retaining striæ, they could not be expected to remain in great numbers, even if once developed. This would be the case where the rock is plastic, like clay, or where the rock is readily disintegrated. Again, striæ which once existed on rock adapted to receiving and retaining them may have been destroyed because of adverse conditions. Thus limestone received and has preserved striæ quite as well as any formation where the striated surface has remained deeply covered with drift. Where little or no covering has protected it, the striæ are absent, or ill-defined. It is reasonable to suppose that such surfaces were once striated, but that weathering has destroyed the marks.

The foregoing considerations help to explain why the striæ are not found at all points beneath the drift, even if the drift agencies and the polishing and striating agencies were the same, as we must believe they were. But there are places, and not a few of them, where striæ and polishing do not appear to have existed, even though the bed rock is of such a nature as to have favored their development and retention. In such cases the drift is often seen to rest, not on the solid rock, but on a layer of residuary material which originated in the decomposition of rock beneath. In this case the immediate substratum of the drift is really an incoherent earth, incapable of receiving striæ. In other areas where striæ and polishing are not known, their absence is probably apparent only. This is true in regions where the rock is so deeply buried that it is rarely seen.

Any acceptable theory of the drift must account for the divergent systems of striæ, for the local deflections from the general direction within these systems, and for the association of such deflections with local topographic features. It must also account for the occurrence of striæ on steep slopes, on vertical faces, on the under side of overhanging rock masses, and on the lower, upper, and interior surfaces of horizontal grooves in vertical cliff faces. It must be consistent with the absence of striæ and polishing on the rock surface at many points within the drift-covered territory, and must be mindful of the absence of the same sort of markings on the surface of the rock formations outside the drift. The phenomena of the striæ show that the drift agent or agents, or some of them, must have been such as could, under some circumstances, work with a large measure of independence of topography, at the same time that they were, under other conditions, locally influenced or even largely controlled by it. They must have been such as could have sometimes operated at great altitudes, as in the mountains of the west, without affecting the lower levels surrounding.

The shape of the rock hills projecting through the drift. In many places within the drift-covered area, but not everywhere, the rock knobs which project through the drift, or which are but slightly covered by it, possess certain characteristics which are not without significance. Such bosses of rock frequently have smoothed and rounded forms which are so distinctive that they have received a special name, *roches moutonnées*. In some regions each rock-prominence seems to be a *roche moutonnée*. In such cases, one side of each boss seems to be worn more than the others, and in any limited area it is generally the same side of each hill which shows the greatest wear. This fact must be taken into account in any attempt to explain the drift, for it is a phenomenon about as widely distributed as the drift itself, though not by any means to be seen at all points. The sides which are most worn are those facing the direction from which the drift forces moved, as shown by the direction of striæ, and by the direction in which material has been transported.

ROLLIN D. SALISBURY.

(To be continued.)

EDITORIAL.

In a personal letter from Bernard B. Smyth, of the Kansas Academy of Science, certain phenomena of the margin of the drift are described, which afford a criterion of age that is new, so far as we know. Mr. Smyth has recently been engaged in tracing the border belt of the drift in the vicinity of Topeka. This consists of a distinct well-defined train of bowlders with very little other drift. This had been traced to a point southwest of Topeka, where it disappeared. On making another attempt to recover the lost train, Mr. Smyth was surprised to find it in an unexpected place, resting on the bed-rock of the bottom of the valley of Shunganunga creek, covered up "*with about twenty feet of native prairie earth washed from surrounding hills.*" Further tracing showed that the train makes a sinus two miles deep and a mile and a half wide, beyond which it resumes its general course. This embayment Mr. Smyth attributes to the influence of a high point of land, which affected the ice rather by the reflection of the sun's rays than by physical opposition, since the line of bowlders does not approach the hill closer than one-third of a mile, generally not nearer than one-half of a mile. Analogous behavior of the ice in the vicinity of prominences was observed by the writer in Greenland. The point of most especial interest, however, is the burial of the border train of bowlders under so great a depth of native prairie earth from the surrounding hills. This indicates either that very favorable conditions are offered by this valley for the derivation and deposition of prairie earth, or that the bowlder belt has a very considerable age. At any rate, here is a basis of estimating both the actual and the relative ages of glacial deposits when so situated that the burying material may be discriminated as ordinary surface wash. From this region to Montana, the surface outside the drift border slopes toward it, and affords a wide field for the application of the method. T. C. C.

Reviews.

Hussak's Geology of the Interior of Brazil. The Constitution of Brazil provides (Act 3) that: "An area of 14,400 square " kilometers is reserved to the Union on the central plateau " of the Republic, which shall be duly laid out, and in it " the future federal capital shall be established." In 1892 a commission was appointed to locate, explore, and report upon the region referred to. Dr. Luiz Cruls, director of the astronomical observatory at Rio de Janeiro, was chief, and Dr. Eugene Hussak, geologist of the commission. A preliminary report has been published under the title, *Relatorio parcial da commissão exploradora do planalto central do Brazil;* Dr. Hussak's résumé of the geology of the region is given on pages 105–130.

In view of the little known of the origin of diamonds in Brazil, what he says on this subject is of special interest. Agua Suja is a diamond mine in the southwestern corner of the state of Minas Geraes, four leagues south of Bagagem, the place where the famous diamond, the "Estrella do Sul", was found.

In the region between Uberaba and Rio Paranahyba the streams have cut down through sandstone to the underlying highly inclined mica schists. These schists contain masses and veins of quartz rich in tourmalines. The horizontally bedded sandstone resting upon the schist is unfossiliferous, easily decomposed, somewhat argillaceous and probably of later age than Carboniferous. In some places eruptive rocks (augite porphyry) overlie the schists, and in others they are contemporaneous with or later than the sandstone. The country is covered almost everywhere with recent water-worn gravels, sometimes loose, sometimes cemented. In the newly opened diamond washings these gravels form horizontal beds more than thirty-five feet thick, and divisible lithologically into four groups. The lowest of these groups rests upon the sandstone, and contains the heavy materials, big water-worn bowlders four to five decimeters in diameter, enclosed in fine sand, and a great quantity of cobbles of augite porphyry, the size of one's fist at most. The big bowlders are of muscovite granite rich in tourmaline, of augite porphyry, of mica schist, of soft yellow sandstone, etc. The diamonds are found only in the sand containing cobbles of augite porphyry. The diamonds thus far found are small, but they are all of the first water. The following minerals are found with the diamonds: rutile, magnetite, tourmaline, pyrope, a single ruby, and, most abundant of all, limonite. Magnetite is the most characteristic of these minerals.

In regard to the original matrix of the diamonds found at Agua Suja certain circumstances suggest that they have originated in a manner analogous to those of South Africa. Hitherto it has been thought that the diamonds of eastern Minas were derived from the mica schists. The African diamonds, on the other hand, are from rocks of eruptive origin. The following are Dr. Hussak's reasons for believing Agua Suja diamonds to have an origin similar to the African ones:

I. The absence or rarity of many of the minerals that accompany the diamonds found about Diamantina.

II. The presence of others, such as the pyrope garnets, that are characteristic of the African mines, which, in a certain sense, indicate the presence of eruptive rocks, but which are rare or altogether wanting in the Diamantina washings.

III. The abundance and character of the magnetite pebbles indicate a highly basic rock of eruptive origin, and related to the African peridotite.

On the other hand it is admitted that the abundant fragments of mica schists and granite show that these have furnished materials to the Agua Suja gravels, and in the absence of positive proof to the contrary it is admissible that either of them may have furnished the diamonds.

The remainder of Dr. Hussak's report contains an interesting sketch of the general geology of the high plateau of Brazil. The rocks of the region traversed — southwestern Minas and southeastern Goyaz — he divides into two groups: first, the crystalline schists which consist of mica schist and itacolumite. These are cut by eruptive granites and are auriferous. Second, sandstones and Palæozoic clay shales, the latter enclosing gray limestones.

Those portions of Minas and Goyaz traversed—part of the great central plateau of Brazil—form a typical plateau of transgression.

After the formation of the fundamental complex of schists, which here consists of metamorphosed marine sediments, there were orographic movements which lifted, folded, and metamorphosed them; these movements were probably accompanied by granitic eruptions producing granitic zones and pegmatite dikes.

The granitoid gneiss zone of the Paranahyba valley and Entre Rios and the amphibole schists probably represent later granitic and basic eruptions connected with and modified by orogenetic movements.

After an interval of denudation came the sedimentary deposits which, upon elevation, form the region of schists, sandstones, and Palæozoic limestones between Santa Luzia and Formoza, and further to the north the lofty (1500 meters), flat-topped Veadeiros.

This second uplift closed the cycle of great geologic events for this region, and it has ever since been undergoing denudation. In the surrounding region, however, to the north and to the west in the Tocantins-Araguaya and the Xingú and Paraguay basins, to the east in the basin of the São Francisco, and to the south in that of the Paranan, enormous sedimentary deposits were laid down, which, by transgression, covered the margins of the old Goyaz island and extended over enormous areas in the basins mentioned. The later deposits have remained in a horizontal position. They seem to have begun in Devonian times and to have gone on with certain interruptions up to Mesozoic times. In the mining area about Uberaba the rocks are soft sandstones, and augite porphyries belonging to this great horizontal series. The sandstone is the continuation of the beds which in São Paulo overlie fossiliferous Carboniferous or Permian rocks; it is probably Triassic.

The characteristic feature of this formation in the Paranan basin is the abundance of eruptive rocks, suggesting a very active volcanic epoch. Denudation has deeply trenched the plateau, leaving a characteristic topography. Wherever erosion has cut down to the harder itacolumites these are left as high and rugged foothills with steep flanks. The limestone also resists erosion better than its associated rocks.

The last and newest formation of all these is the top dressing of gravel, which is not a marine deposit, however, but the result of atmospheric agents and the deposits of modern streams.

J. C. Branner.

Einleitung in die Geologie als historische Wissenschaft. By Johannes Walther. Jena, 1893–4.

In this new work of Professor Walther the inductive method receives a new and highly interesting treatment in its application to historical geology. There are, we are told, four principal methods of attacking the historical phases of geology, (1) the astrophysical method which begins with the earth as star-dust and studies its development from the speculative and mathematical standpoint of the astrophysicist; (2) the tectonic method which studies the structure of the crust and strives to reconstruct therefrom the changes which have taken place in it; (3) the experimental method in which geological phenomena are reproduced on a small scale in the laboratory; (4) the ontologic method.

The experimental method can, evidently, but rarely become a demonstration in the study of geologic phenomena, because we cannot often reproduce all the natural conditions and we know that the same results may often be produced by different methods. Thus coal may be procured by the rubbing or pressure of wood or by its imperfect combustion or by the action of acid upon cellulose tissue or by burning oil of turpentine. So also we may easily produce dolomite in the laboratory but to produce it from limestone and sea-water, observing the same conditions as those under which it is produced in nature has been the object of a great deal of unsuccessful experimentation. In many cases it is impossible for us to discover all the conditions under which the natural phenomena occur.

The experimental method must, therefore, be enlarged and at the same time held in check and corrected by a fourth method, the *ontologic method* as it is here called. This method consists in a word in making the earth our laboratory, in studying the processes by which geological history *is being made now*, and in making this study the point of departure for (introduction to) the study of historical geology. "We determine the origin of dead volcanoes by studying the formation of those now building; we form a basis for understanding the history of a fossil coral reef by examining a living reef; and the depth of water at which a fossil oyster bank was formed is approximated by a determination of the depths at which the genus *Ostrea* is now found living." (Introduction, p. xiii.)

Before entering further into the application of this method we should bear in mind that like every other method it has limitations which the author does not fail to recognize. The most important of these seem to be the following: (1) Our observations of phenomena are often very limited. In spite of the numerous expeditions and deep sea dredging how small a fraction of the whole territory has been explored; (2) an important difficulty arises from the scattered condition of the literature of the subject which has been already greatly reduced by the present compilation; (3) more vital is the difficulty of studying forms which have no living representatives as the graptolites and the blastids and the fact that in general the farther back we go in geologic time the more difficult does it become to apply the ontologic method; (4) the most important limitation to this method, however, arises from the assumption which lies at the very root of it, namely, that factors affecting organic life and inorganic movement have remained the same in all ages. Can we be certain that the oyster now commonly found in from one to two hundred and fifty feet of water lived at the same depth in the Jurassic, or can we be sure that new factors have not entered in or old factors been lost which affected the mode of life and the deposition of strata? It becomes necessary then for the ontologically working historical geologist to be keenly alive to these possibilities of error and search in all his work to reduce the probable error to a minimum. If approached in this spirit this last objection would not prove as formidable as might at first be supposed and will decrease as *our knowledge of the laws of earth-history* become more and more complete.

Proceeding to the body of his theme the author agreeable to the nature of the ground to be covered divides his work into the study (1) of the formation of rocks, especially the sedimentary ones, (2) the mode of life of the marine organisms, and (3) the relations of the first to the second or the outside conditions of life and their effect upon the organisms (Bionomy); though for conventional reasons these topics are taken up in the reverse of this their more natural order.

Under the title "Bionomy of the Ocean" the author considers the distribution and conditions of life of marine organisms. As plants alone have the power to organize inorganic substances, it is important that we first study their conditions of life. They need light, water, carbonic acid, and chromophyll, without which the processes of assimilation cannot take place. As experiment has shown that light waves capable of effecting chemical changes do not penetrate the water deeper than 400 meters and as the other conditions of assimilation are met above this line, it is proposed to distinguish a *diaphanic* region including the land and the water to a depth of 400 m. and inhabited by assimilating organisms and an *aphotic* region including the ocean and lakes below the assimilation-line and the dark caves of the crust, where plant life is impossible. Temperature limits — 85° C. to 3° C. for water organisms — restrict greatly the distribution of life in the diaphanic region.

Upon a somewhat different basis of classification are next considered the life-zones of the ocean (divided first into oceanic basins and second into shore, shallow, and deep sea zones), and the kind of life inhabiting each (the author following Haeckel in dividing the ocean forms (Halobios) into Benthos, or bottom forms, Nekton or active, swimming forms and Plankton or passive, floating forms with numerous subdivisions).

Intimately connected with the question of environment in its relation to life is the facial development of the ocean bottom. Thus we find that certain forms as Mytilus and Mactra are found upon a mud bottom, other forms as Anomia and Spondylus love a gravel bottom. A change in bottom from any cause will cause a change in the fauna — a migration. The influence of the bottom extends, however, not only to the plants and animals living directly upon it but also to the Nektonic forms which feed upon certain plants and further to the animals of prey who live upon the animals (of both Benthos and Nekton) who frequent the same region. Further than this the fact that fish pick out a certain kind of bottom on which to lay their eggs causes them to frequent certain places during the spawning season.

A great many interesting questions relative to the effect of environment are discussed and by numerous facts illustrated in the following sections on the influence of light, of temperature, of salt percentage, and the effects of tides, waves, and circulation of the water upon the living organisms. The formation of oceanic islands and all those movements of the earth's crust which alter its position and cause a relative or absolute change in the sea-level have an immediate and vital influence upon all life within the region of change, because it affects at once the various conditions under which the organisms have been living. This constant change of environment by compelling the faunas and floras to migrate, or die, or by modifications to adapt themselves to their surroundings becomes a powerful factor in the production of new varieties and the origin of new species.

Part II. takes up the mode of life of the marine fauna, especially from the standpoint of their importance to the palæontologic geologist. In order that the working geologist may not underrate the sources of error in his work the author very wisely discusses first the various zoölogic groups to show what ones are by reason of the absence or the unstable nature of the hard parts incapable of preservation. The following sections discuss for the most part the conditions favorable to the life of the various animals which are taken up in their zoölogic order beginning with the Foraminifera. In this section of the book the tables showing the maximum and minimum depths at which various species have been found by dredging are an especially prominent and valuable feature. In the section on the Cephalopods especial attention is called to the fact that the shells having air chambers by being able to float for long periods may be readily driven to great distances after the death of the animal and become fossils in a totally different region from that inhabited by the animal during life and in varying sorts of rock according to the nature of the bottom upon which the shell chances to drift. He points to the fact that the living *Spirula* and *Nautilus* are restricted to narrow boundaries on the sea bottom and that the animal is rarely seen. At the same time the shells of the dead *Nautilus* and *Spirula* are found widely scattered on tropical strands far from the home of the living animal. These thoughts applied to the very important fossil group of the Ammonites mean that their shells *tell us nothing* of the conditions under which the Ammonites lived but give us most valuable means of making exact correlations; for if as we suppose the Ammonite shell on the death of the animal rose to the surface and was carried for many days hither and thither and finally filled and sank, the shells would be scattered here and there over the entire ocean bottom and deposited in sediments *all of the same* age. So confident is the author of this that he believes that the Ammonite shells mark *not only homotaxial but actually homocronial periods.*

Part III. considers the formation of rocks upon the present surface of the earth. According to their mode of formation mechanical, chemical, volcanic and organic deposits are distinguished, and the distribution of the various rock facies over the earth's surface is indicated. This portion of the book which makes up the major part of Part III. (pp. 543–966) is largely systematic and classificatory in its nature and is filled with a large array of facts and observations on the formation of recent rocks and their distribution which cannot fail to be of great value to the working geologist. Here again the author calls brief attention to the alterations which the recent rock formations undergo in becoming fossil the knowledge of which is essential to the understanding of fossil deposits. Two classes of such changes are distinguished,—*metamorphism* and *diagenism*. By metamorphism is understood alterations caused by mountain pressure and volcanic warmth; and diagenism is defined (p. 693) as "all those physical and chemical changes which occur in a rock after its deposition without the action of mountain pressure and volcanic warmth." The book appropriately closes by outlining the possibilities of a *comparative lithology*. Throughout the book is urged the necessity of the historical geologist giving equal prominence to the study of the conditions of formation of the rocks and the conditions of growth of organisms. We make prominent the study of the correlation of faunas in historical geology and we should not neglect the study of the correlation of deposits. As comparative anatomy based upon the correlation of organs is the most important aid to palæontologic work of reconstruction, comparative lithology based upon the correlation of rock formations would prove a valuable aid to the study of historical geology and the reconstruction of earth history.

In the chapters on equivalence of the rocks, correlation of facies and changes in facies the author points the way to a scientific study of comparative lithology and lithological correlation of sediments and indicates some of the laws governing the deposit of sediments, which complicated as they are, are important enough to be worthy of careful investigation.

On the whole the work is a thoughtful and carefully worked out presentation of his theme, evincing long and careful work of observation and compilation and a just appreciation of the peculiar advantages and the disadvantages of ontologic methods of research in historical geology. The two factors—the history of fossils and the history of the rocks—are given equal prominence, and it is everywhere emphasized that the one cannot be studied successfully without the aid of the other.

E. C. QUEREAU.

Geologische und geographische Experimente. Heft III., Rupturen, Heft IV., Methoden und Apparate. By E. REYER, Leipsic, 1894.

In connection with Professor Walther's book it is interesting to note the appearance of the last pamphlet by Professor E. Reyer, of Vienna, representing the *experimental method* in geology. The two preceding papers, which appeared two years ago, and which will be more or less familiar to the reader (*Ursachen der Deformation und der Gebirgsbildung*, Leipsic, 1892; *Geologische und geographische Experimente über Vulkanische- und Massen-Eruptions*, Leipsic, 1892), introduced Professor Reyer's experimental work, especially in the reproduction by artificial means of the phenomena accompanying mountain-building and eruption. The last paper, just received, comprises two sections. The first deals with the various phenomena of cracking and gaping of the crust caused by torsion, lateral pull, lateral pressure, or vertical movement. The phenomena of rupture found in regions of crustal movement or of metamorphism are reproduced here on a small scale. These experiments recall those of Daubrée, but are an improvement over his work in so far as in the present case the materials used correspond more nearly to the materials in nature. In the second part of this paper, where the author gives to the public his methods of experimentation, and the apparatus constructed and employed by him in his laboratory, we find that clay, loess, loam, and gypsum, or some adhesive substance, are the most prominent constituents used, and that ice, glass, or harder substances, do not find a place. The advantage in using softer substances is obvious, for the smaller the scale of the experiment the finer must be the material used and the less, therefore, should be its cohesion in order to make the relation of cohesion to the natural forces, as gravity, correspond to their relations in nature. If the relation be a correct one the action of gravity for instance will produce the same result (of faulting, flexure, etc.) in the reduced laboratory experiment as in the large process in nature. In experiments of torsion with harder substances, as glass or ice, gravity alone produces no effect because the cohesion of the glass is so great. If, however, we have a mixture (of fine-grained silt or gypsum with water) of the proper consistence arranged in thin layers (strata) and leave one part unsupported, the action of gravity alone produces the desired flexure, faulting, or twisting as Professor Reyer has shown.

Unfortunately the lateness of the receipt of the paper prevents a more special account of apparatus and methods. The field, however, is full of promise. It would seem that at present a chief desideratum in this kind of work is to so choose the conditions of experimentation in the laboratory that, if not the same, they may be at least comparable to natural conditions as far as possible, that the results may be suggestive less of how the process may take place and more of how in nature it did take place. The work of Professor Reyer has been of undoubted value, and will, we hope, stimulate to further careful investigation in this direction.

E. C. Quereau.

Analytical Abstracts of Current Literature.

Verlauf Der Grönland-Expedition der Gesellschaft für Erdkunde. Dr. Erich von Drygalski. Verhandlungen der Gesellschaft für Erdkunde zu Berlin, 1893, Nos. 8 u. 9.

This article is mainly a sort of itinerary with little geological detail. The glacial investigations referred to were carried on chiefly on the mainland east of Disco. The author emphasizes the fact that the surface of the inland sea near its edge is much dissected by valleys cut by surface streams, and that there are upon the ice many pools and little lakes due to melting of the ice beneath patches of dust. In the warm season there are many lakes about the border of the ice held in on one side by the ice. With the first sharp cold the ice cracks so as to let the water escape. The author's microscopic study failed to discover any essential difference in structure between glacial ice and lake ice, though the fjord ice was somewhat unlike both. Dr. von Drygalski thinks that the contained water alone gives to glacier ice the power of movement, and that, therefore, there is no motion without a melting temperature. It is thought that the melting temperature maintains itself at the bottom of the ice by virtue of the transfer of heat from the upper surface during the melting season. Since the upper part of the ice must be below the melting point during a large part of the year, it is thought that movement depends more on the lower than on the upper layers. The author is doubtful of the truthfulness of the comparison between ice streams and rivers. The temperature of the mass is thought to fluctuate about the freezing point, and its work and motion are thought to depend upon the change from a solid to a fluid condition, and *vice versa.*

R. D. S.

The Geology of Angel Island. F. Leslie Ransome. (Bulletin Geological Department of University of California, Vol. 1, No. 7.)

Angel Island is about a square mile in extent, and lies in San Francisco Bay, three and one half miles northeast of San Francisco. The larger portion of the island is occupied by the San Francisco sandstone, which contains an abundance of plagioclase and other non-quartzose fragments. Interbedded with the sandstone are numerous masses of jaspery rock elsewhere denominated "bedded jaspers," but the discovery of an abundance of remains of siliceous organisms makes the term "radiolarian chert" more applicable. Both sandstone and chert have been locally metamorphosed by the invasion of eruptive rocks. The term Fourchite is doubtfully applied to an intrusive sheet or sill invading the San Francisco sandstone, some portions of it consisting of a breccia, other portions having an imperfect spheroidal structure, while the main body is massive evidently representing a true sill and not an interbedded flow. Bright blue amphibole, with pleochroism of glaucophane is a noticeable feature. It is also remarkably free from the usual accessory minerals of basic eruptive rocks. Alteration along the contact zone has resulted in the development of a glaucophane schist. Serpentine which occurs as a large dike traversing the island from northwest to southeast was derived from a rock composed wholly or mainly of diallage and incloses masses of a gray rock resembling diabase. The glaucophane schists were formed from the San Francisco sandstone by metamorphism. Evidence controverts the view that the radiolarian cherts (bedded jaspers) represent ordinary shales silicified by regional metamorphism. The serpentine is in no sense a metamorphosed sediment. The appendix contains descriptions of radiolarian remains found in the chert.

C. H. G.

Geological Survey of Missouri. Report on the Bevier Sheet. By C. H. GORDON. J. E. TODD and H. A. WHEELER, contributors. Report on the Iron Mountain Sheet. By A. WINSLOW, E. HAWORTH, and F. L. NASON.

The above reports, issued by the Missouri Survey under the direction of Arthur Winslow, State Geologist, constitute the second and third of the series of sheet reports, of which the Higginsville Sheet was the first. The present reports are issued in large octavo, uniform with the other publications of the survey, instead of the same size as the atlas sheets, as was at first planned. Each sheet comprises an area of one fourth of a square degree. The scale is 1 : 62500, or about one inch to a mile. The topography is indicated by twenty feet contours. A sheet of cross and columnar sections accompanies each map. The work has evidently been carefully done.

The Bevier sheet comprises the southwestern part of Macon county, with portions of Chariton and Randolph. The topography is due entirely to stream erosion. The rivers have sunk their valleys to a moderate depth in a wide stretching plain, the remnants of which are still well preserved in the broad inter-stream surfaces.

The stratified rocks of the region belong to the Coal Measures series, the deposits of the Middle and Lower stages being represented. Within the state, however, no widely recognizable horizon separating the two has been identified. The strata dip gently to the southwest, but there are local departures from this dip. Five beds of coal are recognized, two of which—the Bevier and the Mason City beds—can be profitably worked. The former of these is the most important. Its estimated available tonnage within the limits of this sheet is 336,000,000 tons.

The report on the Quaternary geology is by Professor Todd. Three divisions are noted, viz.: 1. Pre-glacial or basal clay, a light gray clay, without northern pebbles, and of no great surface extent. 2. Drift or till. The erratics comprise granites, greenstones, and a red quartzite identical with the Sioux quartzites. The last seems not to be distributed much further east than the area of this sheet. 3. A gray, loamy clay, which is intimately mixed with fine sand, and contains a few well-worn pebbles and calcareous concretions. This formation is McGee's "gumbo." Professor Todd considers it the equivalent of the higher loess into which it appears to grade. Much detailed information is given by Professor Wheeler concerning the economical values of clays and shales of the region.

The rocks present in the area covered by the Iron Mountain sheet are, 1) crystalline, massive Archean rocks, which are divisible into basic eruptives, occurring in the form of dikes, and acid eruptives, including both granites and porphyries; 2) crystalline stratified Algonkian rocks, chiefly conglomerates and slates, including the iron ore bed of Pilot Knob; 3) clastic Paleozoic limestones and sandstones. The economic interest of the region centers chiefly in the iron ores and building stones. Thorough exploration has shown that the Iron Mountain ore deposit is practically exhausted. The same may also be said of the Pilot Knob deposit.

H. B. K.

The Granites of Cecil County in Northeastern Maryland. By G. PERRY GRIMSLEY. (Jour. Cin. Soc. of Nat. Hist., Vol. XVII., Nos. 1 and 2, April, July, 1894. Thesis for Doctorate, Johns Hopkins Univ.)

The rocks of this region are holocrystalline with a northeast strike and a highly inclined dip to the southeast. The rock is of a light color with dark biotite arranged in more or less parallel lines. This foliation runs northeast while the dip is nearly vertical. Toward the gabbro contact on the north the feldspar of the granite is replaced in part by hornblende and biotite along with an increased amount of magnetite. Near the contact, bowlders of sheared and squeezed chloritic rock occur, together with dark oval patches of basic constituents. The latter are considered basic segregations rather than inclusions of foreign rock. Other rock types are diorite and staurolitic mica schist.

As a result of dynamic action, old minerals have been more or less metamorphosed and new ones developed, with the production of a secondary foliated structure. Of new minerals epidote is especially well developed. In the replacement of feldspar by epidote, the host apparently exerts no orienting influence on the epidote as is often stated to be the case. The epidote is often arranged in zones and sometimes is concentrated in a rim within the feldspar individual. The explanation of this is sought in variations of chemical composition within concentric zones of a single feldspar crystal. The alteration of feldspar to muscovite is much less frequent than to epidote.

The staurolitic mica schist separating the areas represents a sedimentary deposit more ancient than the granites and probably owes its highly crystalline character to contact metamorphism.

The study of granite soils with the aid of the miner's pan showed the presence of a number of minerals not noticed in the thin sections.

C. H. G.

Erosion in the Hydrographic Basin of the Arkansas River above Little Rock. By J. C. BRANNER. (An. Rep. Geol. Surv. of Ark., 1891, Vol. II.)

The observations on the erosion in the Arkansas River basin, while not as exhaustive as the State Geologist desired them, owing to limited resources at his command, they nevertheless furnish a valuable addition to the literature on this subject. The physical and chemical character of the sediment is described, and a number of analyses given. The tabulated results of the amount of material carried in suspension and the amount carried in solution for each month in the year are given.

More than twenty-one million tons are carried in suspension and nearly seven million tons, or nearly a third as much in solution. In November during very low water, the amount in solution was six times that in suspension, while in May and June during high water, the amount in suspension was more than five times that in solution. The results are compared in part with those of other rivers.

Other papers in the same volume are Elevations, Magnetic Observations, and Bibliography, by J. C. Branner; Mollusca, by F. A. Sampson; Myriopoda, by C. H. Bollman; Fishes, by S. E. Meek; The Geology of Benton County, by F. W. Simonds and T. C. Hopkins; and Geology of Dallas County, by C. E. Siebenthal.

The Dallas County report is accompanied by a topographic map, and contains a discussion of the topography and the general geologic features; but the chief point of interest is the description of the potter's clays. It contains numerous analyses, a list of the occurrences of the clay deposits and a history of the pottery industry in the county. The pottery clays of other parts of the state, along with the other valuable clays of the state, will be described in a forthcoming volume on clays by the State Geologist.

T. C. H.

The Tertiary Geology of Southern Arkansas. By G. D. HARRIS. (An. Rep. of the Geol. Surv. of Ark., 1892, Vol. II., pp. 207; 1 map.)

All the Tertiary deposits of Southern Arkansas are classed in the Eocene series and subdivided into the Midway, Lignitic, Claiborne, and Jackson stages, using the nomenclature of the neighboring states. These correspond, in part, at least, with the Lafayette formation of McGee and the Orange sands of Hilyard, but Professor Harris prefers, for reason given, not to use these terms. Each of the stages is discussed in detail as to distribution, topography, and organic remains. The oldest known Tertiary deposits in the state are included in the Midway stage and contain a fauna similar to the Midway limestone in Alabama. The Lignitic stage lacks molluscan remains, but fossil leaves are abundant. Molluscan remains are not abundant in the Claiborne stage, but are in the Jackson stage. The Tertiary-Cretaceous border is changed in a number of places from Hill's map in 1888. The Cretaceous is found farther to the northeast than formerly supposed. Seven plates of typical fossils are given and thirty-four figures illustrating the stratigraphy of the area. The purely economic features of the area will be discussed in a future volume of the Survey publications. T. C. H.

Recent Publications.

—Cannon, George L. Jr.

The Geology of Denver and Vicinity. 36 pp.

—Carter, Oscar C. S.

Anthracite Coal near Perkiomen Creek. 5 pp.—From Journal of the Franklin Institute, August, 1894.

—Curtis, George E.

A Problem in Mechanical Flight. 11 pp.—From Annals of Mathematics Vol. VIII., No. 6.

—Geological Surveys:

New South Wales.

Records of Geological Survey, Vol. IV., Part II., 1894. Department of Mines and Agriculture. 74 pp., 2 Plates, and Catalogue of Mining Maps.

—Grimsley, George Perry.

The Granites of Cecil county in Northeastern Maryland. (A thesis accepted for the degree of Doctor of Philosophy, by the Johns Hopkins University, June, 1894.) 50 pp. with Plates.—From the Journal Cin. Soc. Nat. Hist., April and July, 1894.

—Hovey, E. O.

A Study of the Cherts of Missouri. 9 pp.—From the Am. Jour. Sci., Vol. XLVIII., November, 1894.

—James, Joseph, F., M.Sc., F.G.S.A., etc.

Remarks on the Genus Arthrophycus, Hall. 5 pp.—From Jour. Cin. Soc. Nat. Hist., July–October, 1893.

Knowlton, F. H.

A New Fossil Hepatic from the Lower Yellowstone in Montana. 2 pp. and Plate.—From Bull. of the Torrey Botanical Club, Vol. XXI., No. 10, October 24, 1894.

—Leffingwell, Albert, M.D.

Physiology in Our Public Schools. 4 pp.—From Journal of Education, Boston, Mass.

—Quereau, E. C. Ph.D.

Ueber die Grenzzone zwischen Hochalpen und Freiburger Alpen im Bereiche des oberen Simmethales. 7 pp.—Separat-Abdruck aus Berichte der Naturforschenden Gesellschaft zu Freiburg, Band IX., Heft 2, 1894.

Die Klippenregion von Iberg im Osten des Vierwaldstätter-Sees — Die Exotische Schichtenfolge — Inaugural-Dissertation zur Erlangung der philosophischen Doktorwürde vorgelegt der hohen philosophischen Fakultät der Universität Freiburg i. B. 54 pp.

—Steinmann, G.

Das Alter der paläolithischen Station vom Schweizerbild bei Schaffhausen und die Gliederung des jünger Pleistocän. 11 pp.—Separat-Abdruck aus Berichte der Naturforschenden Gesellschaft zu Freiburg, Band IX., Heft 2, 1894.

—See, T. J. J.

The Locus of the Center of Gravity for a Homogeneous Ellipsoid of Revolution. 6 pp., 1 Plate.—Reprint from Astronomy and Astro-Physics.

—Wright, Albert A.

The Ventral Armor of Dinichthys. 8 pp., 1 Plate.—From the Am. Geologist, Vol. XIV., November, 1894.

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