Alexander Winchell

Walks and Talks in the Geological Field

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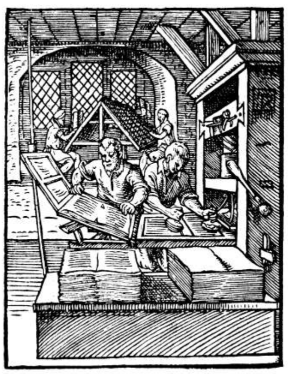

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PREFACE.

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This work attempts to hold a position between text-books and books of light reading. The formal text-book would not suit the class of readers addressed. The style of light reading would have been unworthy of the theme, and would not have supplied the substantial information here intended. The writer has often felt that graphic illustrations would have rendered portions of the text more intelligible, and therefore, more entertaining; but these would have enhanced the cost of the book beyond limits which for other reasons seemed desirable.

The method of treatment is simple. The reader begins with the familiar objects at his very door. His observations are extended to the field, the lake, the torrent, the valley, and the mountain. They widen over the continent until all the striking phenomena of the surface have been surveyed. Occasionally, trains of reasoning suggested by the facts are followed out until the outlines of geological theories emerge. The course of observation and reasoning then penetrates beneath the surface. The various formations and their most striking fossils are described, first in descending order, to the oldest. We find here indications of heat which stimulate speculation and bring out the grounds of a nebular theory of world-origin. From this starting point, the treatment now handles the subject in historical order, weaving into a narrative, the dry facts previously noted. Reaching the end of the history, the treatment pauses for retrospect and reflection; and here are brought to view some of the higher and more abstruse thoughts connected with the subject of the book.

It is hoped the perusal of this work may impart some clear conceptions of that grand range of scientific truths with which it deals. It is hoped, also, that a relish may be stimulated which will seek its gratification in the scholarly study of works of higher range and more exacting method.

THE AUTHOR.

Ann Arbor, March, 1886.

WALKS AND TALKS.

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I.
FACTS;
OR, THE RECORD GIVEN US TO READ.

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AMONG THE ROCKS.

I. The Geology at our Doors.

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SURFACE MATERIALS.

Come, John and Jennie—come, George and Julia—let us have a talk about Geology. Come, John's mother and aunt—come every body that wishes—we shall find some of the most delightful things to talk about which any body ever heard of. Now "Geology" may sound like a hard word; and perhaps you have no curiosity to know any thing about it. But do not decide too soon, for if you know nothing about Geology, you can't know what interest there is in it. Take my word for to-day—you will find the subject easy and delightful.

We shall travel all over the world. We shall climb over mountain-cliffs and descend into deep mines. We shall go down under the sea, and make the acquaintance of creatures that dwell in the dark and slimy abysses. We shall split the solid rocks and find where the gold, the silver, and the iron are hidden. We shall open the stony tombs of the world's mute populations. We shall plunge through thousands of ages into the past, and shall sit on a pinnacle and see this planet bathed in the primitive ocean; boiled in the seething water; roasted in ancient fires; distorted, upheaved, moulded, and reshaped again and again, in a long process of preparation to become fit for us to dwell upon it. We shall see a long procession of strange creatures coming into view and disappearing—such a menagerie of curious beasts and crawling and creeping and flying things as never yet marched through the streets of any town. And what is most wonderful of all, we shall plunge through thousands of ages of coming events, and sit on our pinnacle and see the world grow old—all its human populations vanished—its oceans dried up—its sun darkened, and silence and midnight and Winter reigning through the entire province in which a sisterhood of planets at present basks in the warmth and light of a central and paternal sun.

Do you feel no curiosity over these wonderful themes? These all belong to Geology. Come, let us begin.

But we must begin at the beginning. Those who go on long and pleasant journeys have to start from their own door-steps. Geology tells all about this world. The world is *here*—under our feet. It is in the garden and along the road-side, and in the field, and on the shore where the summer ripples sing lullabies to the sleepy crags, and winter storms tear them from their resting-places. No summer ripples or wintry storms are here; but the solid land is here. Let us walk up this hill-slope and sit where we may get an outlook over a little piece of the world's surface.

What is there, now, within reach of our vision that we can distinguish and describe and say that it belongs to the world—is a part of the world? Whatever it may be, it is a geological fact. It is a part of the science of geology. Now, here is this hill-slope, and the soil and stones which make it.

Back of us the hill rises to a higher level. Perhaps brown cliffs frown near its summit; and there are huge, heavy trees upborne five hundred feet above the town. But, in the opposite direction, there is the landscape. That is a geological fact. With all its scenic beauty, that is geology, at foundation. The houses and the herds, the wheat-fields and the gardens—these are accessories. But the dark, beetle-browed ridge which skirts the horizon—that is nature's. The green forest which glides down to the field borders; the stream which winds across the landscape, and rises and falls with the rains; the low swells and the valleys between; the outcropping ledge in the field, and the loose stone by the road-side—these belong to nature. There, in the distance, flies the train of steam-cars, its iron-bound way has been cut through hill and rock-mass, and opens to our view something of the hidden material which goes to form the world. There is the meadow, with its green turf and deep, dark soil. The gully scored in the hill-side by the summer storm, and the train of stones and sand at its foot—which the water tore from their hiding-places beneath the soil. Up the stream we see the tamarack swamp or the open marsh, through which the head-waters flow—the head-waters of the main stream or of some small tributary. There, just beyond, is the little lake or pond, sleeping in its green-fringed nest, and looking out on the grass-covered slopes and the blue sky.

How charming is all this scenery! How many times, imbued with the love of nature, we have strolled on the borders of this quiet lakelet, or lounged on the green slope, which seemed set, like an amphitheater, to accommodate the visitor, who loves to look upon the scene. Perhaps, as urchins straying from school, or getting the most out of a

Saturday holiday, we have angled along this brook, or paddled our skiff over this pond. Perhaps in wonderment we have seen the artist from the city, with easel and brush reproducing on canvas the beauty of this simple landscape, thinking to win a prize in the Academy of Art, or at least to afford the pent-up dwellers in the dusty town the luxury of knowing how lavishly the beauties of nature are strewn before the gaze of those who dwell here in this agricultural vale—in this quiet hamlet which Providence has made our home.

This is all geology. We are in the midst of it. We have been enchanted by it before we knew its name. We have admired the forms fashioned in beauty by the hands of the geological forces before we knew that it had a geological origin, or possessed any geological significance, or had passed through long ages of preparation. We have been like children born in the parental dwelling, reared in the midst of its comforts and adornments, without once thinking that, before we were born, some mind planned the dwelling, some hands reared its walls, laid its floors, and fashioned every doorway and casing. Now, this terrestrial dwelling, with all its beauties and conveniences, its wonders and sublimities, is something to set us thinking; just as we reflected, when the thought first came into our minds, that father's house has had a history, and was the product of study and labor, which we had never before considered. The green slope was made; the pretty lake was scooped out; the swelling hill was shaped; the dark mountain was upbuilt, its foundations were laid, its vast weight has been sustained and is to-day sustained by some support, with strength proportioned to the requirement. It is time for us to come to a realization of these facts.

We may begin in this very spot to inquire how this terrestrial home was fashioned. It was made without hands, but not without the use of the same forces of nature and properties of matter as were employed in the building of our paternal dwelling. Its plan was not drafted on paper and carried out under the direction of a builder, who issued his orders in audible tones; but our terrestrial abode is built under a plan just as real and just as intelligible, and is just as truly a fit subject for study. There is this difference, that we may arrive at a complete understanding of the plan, and purposes, and modes of construction of the paternal home; but of the terrestrial home we can only arrive at an incomplete understanding. As far as we proceed, the methods of understanding and interpreting are the same; but the whole plan, in its depth, and breadth, and complications surpasses our powers, and we must, like young children, content ourselves with a comprehension of some of the most obvious things—sure that if our powers were loftier, we might proceed in the same way to understand more difficult things in the plans and methods of world-making.

If we decide to interest ourselves in the inquiry, How the world was made and what it has become, we must first give attention to the *materials* of which it is composed. It is a stone dwelling; it is imperishable—at least as imperishable as granite foundations and massive courses of masonry can render a structure. Here are, indeed, beds of gravel and sand, overspreading the greater part of the country. These are not firmly consolidated, and are easily moved out of place. But they are like the gravel used on the roofs of some buildings—a very insignificant part of the whole. Underneath these loose materials we shall find the solid and enduring foundations. But the study of the loose surface materials is full of interest, because their presence renders the earth habitable. What sort of a home for man or beast would this planet be, if all the loose surface beds were cleared off down to the rocky floor on which they rest? Did you ever hear that question asked before? We must, by all means, begin with the stones, and sands, and clays, which lie upon the surface, or near the surface, and try to ascertain what they are and how they are arranged, and of what use they are to man. Do you think we had better proceed?

II. Lost Rocks.

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BOWLDERS.

Who cares for a cobble-stone? It is a kind of nuisance anywhere—so most people think. The farmer would be glad to have every one of them carted from his fields. I have seen land so thickly covered by them as to be almost impossible to cultivate. In some regions near the coast, in New England, the loose rounded stones lie so close over hundreds of acres that I have traveled by simply stepping from stone to stone.

You will notice that cobble-stones are of various sizes. In fact, it is difficult to state where a cobble-stone is small enough to be called a "pebble," and just where it is too large to be a cobble-stone. Pebbles differ from them only in size. Pebbles are hard and rounded, and seem formed of the same kinds of rocks; and the large, rounded, loose stones, which lie scattered over the earth's surface, are in every respect only a larger style of cobble-stones. It is plain that these are all *one class of rocks*. So it has been decided; and geologists call them *bowlders*. This is an old name used by common people before the science of geology existed, because these stones are rounded like balls or *bolls*; and, being loose on the surface, are apt to be *bowled* about. Even grains of gravel and sand appear to be of the same nature as bowlders. You will also notice, especially, that these rocks are all separate and detached, as well as rounded, and they are of various colors and mixtures of colors. They are apparently different kinds of rocks, which by some means have been brought promiscuously together. Ledges of rock, which you must have noticed many times, are generally all one kind of rock. They extend long distances, and continue under the earth. Should a ledge of rocks become broken up, and the fragments, large and small, have their angles rounded off, and the whole then be scattered over a township, far from the ledge, the result would be much like what we see in our actual bowlders. From all we know of rocks we are constrained to believe that our bowlders are rounded fragments of broken up ledges. But where are the ledges? Not in the next township or county. Perhaps not in the next state or province. They have strayed far away from their native ledges. They are "lost rocks." Now, it would be very interesting to know where the parent ledges are; and it is curious how these fragments have been transported so far, and how they became so rounded, instead of remaining angular, like the stones blasted from a quarry.

Indeed, the more we think about this, the more astonishing the facts appear; for we call to mind that just such bowlders are scattered all over our northern states, and they lie buried beneath the surface in countless numbers. And the very sand and gravel, to the depth of many feet, is only the same kind of material in a finer state. What an incalculable amount of work has been accomplished in transporting all these materials so far that the places from which they came have been lost, and can not be found. Suppose it were necessary to cart all the loose stuff on a township to a distance only one mile further, on what terms do you think the contract would be taken? But all that stuff has been moved—not one mile alone, but many miles, to a certainty. And not alone the stuff on a township, but the stuff on ten thousand townships. The work was not done, you say, by the slow process of hauling in carts. No, indeed; but it was done somehow, and it is the same job whether performed by Nature's method or by human muscle. Think of that.

Now, what do you imagine was Nature's method? Would it not be a grand discovery if we could find out? It was Agassiz that ascertained this, and the discovery gained him great fame. But there were others who came very near to the same discovery. Suppose we could stand by and see Nature in the midst of the job—carting and dumping on the bare surface of the rocks, the gravel and sand and clay so indispensable to render the surface of the earth habitable for man or beast or plant. I think we should consider it a grand revelation of the method and mind of the Author of nature. I am happy to assure you that we have found out pretty precisely how this immense and beneficent work was done; and this knowledge is a part of geology, and we are intending to talk these matters over until you grasp the knowledge. That is, we shall put you where you will be as a bystander gazing on the progress of the great work as Nature herself carries it on.

Many bowlders attain to dimensions which are truly enormous. The largest are found in northern New England and Canada. As we proceed southward, the average size diminishes, and south of the parallel of Cincinnati, bowlders are entirely wanting, except along the Appalachians. In New Hampshire are many immense bowlders, which have excited the wonder of all who have seen them. Several of these have been described and figured by Professor C. H. Hitchcock in his Report on the Geology of New Hampshire. The Churchill Rock of Nottingham is 62 feet long, 40 feet wide and 40 feet high. It contains 75,000 cubic feet, and weighs 6,000 tons. Close by is Chase Rock, 40 feet long, 40 feet high and 30 feet wide. Vessel Rock, in Gilsum, now split by frost, weighed 2,286 tons. The Green Mountain Giant, in Whittingham, Vermont, weighs 3,000 tons; and a bowlder formerly existing at Fall River, Massachusetts, weighed 5,400 tons. At St. Ignace, in the Upper Peninsula of Michigan, lies a porphyry bowlder 25 feet in height. Mr. G. M. Dawson, in his report on the geology of the North-west Territory, describes a quartzite bowlder 42 feet long, 40 feet wide and 20 feet high, and another nearly as large. It appears that the greater part of North America, down to the latitude of Cincinnati, is overstrewn by incoherent materials containing bowlders. The situation is similar in Europe; and there, also, certain “lost rocks” or “erratics” attain vast dimensions. The “Pierre à bot” (or Toad-stone), on the Jura Mountains, about two miles west of Neufchâtel, contains 40,000 cubic feet, and weighs 3,000 tons. As far south as the Lake of Como, bowlders of large size are very frequently encountered.

Often these lost rocks lie perched on the summits of sharp cliffs; and sometimes we find them so nicely poised that the strength of a man suffices to give them a tilt. They are then called “rocking stones.” In Hanover, New Hampshire, half a mile east of Dartmouth College, is a rocking stone 12 feet long, 10 feet wide, 5½ feet thick, containing 480 cubic feet. In Goffstown is one 8 feet high and 42 feet in circumference. In Barre, Massachusetts, is one having a smaller bowlder on its back, which, when in motion, suggests the idea of a child’s rocking horse. One in Fall River, poised on granite, weighs 160 tons.

We find bowlders at various altitudes, from the level of the sea, to the height of perhaps six thousand feet; but above this, though rock fragments are extremely numerous, they are mostly angular, and appear to be derived from rocky ledges close by. They are not "lost rocks." The summit of Mt. Washington is covered by a bed of angular fragments, and such fragments are common for two thousand feet below the summit. Lower than this, rounded bowlders are abundant. Professor C. H. Hitchcock, however, thinks he finds real transported rocks to the very summit. The great quartzite bowlder in the North-west Territory, Canada, is 3,250 feet above sea-level. Many others in that part of the continent are up to 4,400 feet in elevation; and, in one region, attain 5,280 feet. Some erratics on the flanks of the Sweet Grass Hills lie at an elevation of 4,660 feet. The Pierre à bot, in Switzerland, is 800 feet above Lake Neufchâtel, which lies itself 1,427 feet above sea-level.

We observe, in passing over the country, that the larger bowlders are northward; while toward the south, their average size diminishes to cobble-stones, and finally, all indications of transported rocks disappear. Since we have concluded that all these lost rocks have been removed from extensive ledges somewhere, it seems probable that the direction of these ledges is to the north. We notice also, that bowlders of any particular kind become more numerous, as well as larger, as we proceed northward. In fact, in some cases, by following up a train of bowlders of a particular kind, we trace them to their origin. That origin is often sixty or one hundred miles, or even two hundred miles away. Such are the distances to which the forces of Nature have moved much of these incoherent materials.

It is not always possible to trace bowlders to their source by following back a train. But we can always consider where is the nearest locality of bed-rocks of the same kind as any particular bowlders. For instance, in Connecticut, we can find bed-rocks sometimes, in the near vicinity, but at other times, not farther away than Massachusetts. In Ontario, the nearest sources of the bowlders are in the regions east and north of Georgian Bay. At Chautauqua, the nearest bed-rock for the hard bowlders is beyond Lake Ontario and Lake Simcoe. In Michigan, the nearest source is north of Lake Huron and south of Lake Superior. So in Indiana, Illinois, and the north-west generally, we must go northward to find rocks in place which are of the same sorts as the bowlders. This is plainly demonstrated in the case of bowlders of *native copper*, which are frequently found in Wisconsin, Illinois, Indiana, Michigan, and Ohio. There is no other credible source than the native copper region south of Lake Superior. So, in the case of the *Pierre* à bot, near Neufchâtel, the nearest credible source is the Mont Blanc chain of Alps, seventy miles distant, and separated by the valley of Switzerland and the Lake of Geneva.

We seem authorized to conclude, therefore, that the bowlders have been transported generally from the north; that many of them have been moved one or two hundred miles; that they have sometimes been borne over regions which are now lake-basins; that they have been carried, at times, to higher levels than their origin, and much higher than valleys over which they passed; that a vast mass of sand, gravel, and clay was moved with them, since they lie imbedded in these accumulations, to the depth, sometimes, of one or two hundred feet.

These conclusions will be borne in mind when we come to seek for the nature of that tremendous agency which could have performed so vast a work over all the northern half of at least two continents. (Talks IV and XLVII.)

III. The Gravel Pit.

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ARRANGEMENT OF THE DRIFT.

Shall we proceed? This subject has its alphabet, like most others; and every child can testify that there is little inspiration in the alphabet. A few more letters of our alphabet will be found in the *arrangement* of the loose materials which cover the surface of the northern states. These materials are called *Drift*. The bowlders are a part of the Drift. Now we wish to know more about the internal constitution of this deposit. This will be easy, for the Drift is all about us, and numberless deep excavations have been made for sundry purposes. Let us visit a gravel pit, or some deep railroad cut through a pile of these incoherent materials.

Do you find these loose sands and gravels arranged in regular courses? Yes, you say; and then you hesitate; and well you may; for the semblance of courses is exceedingly interrupted. Here is indeed, a layer or bed, or stratum of sand, but it thins out in one direction, and in the other, loses its upper and lower boundaries, and merges in a general mass of sand. Here is a bed of gravel, but it lies at a different inclination from the last, and in one direction it changes to sand, while in the other, it becomes split up into a number of subordinate layers which bend down and lose themselves. This bed also is composed of many oblique laminæ, coarser and finer in alternation, which are cut off completely by the upper and lower surfaces of the bed or stratum. What is singular, the very next bed below this, which is also obliquely laminated, has its laminæ tilted in the opposite direction. And then next to this is a long straight course of cobble-stones and pebbles. Is not this a correct description of what you have all seen somewhere?

In some places are large beds of fine sand, which are taken out and used for mortar-making. In others we find extensive deposits of gravel and pebbles, which are used for paths and streets. Mixed in the sands are some cobble-stones and large bowlders. Here and there, too, are some beds containing much clay; and these are impervious to water. Now, all this is not a regular nor a perfect bedding or stratification. We may say the Drift here is semi-stratified. You can all recall some locality where this arrangement of materials occurs.

This cut or exposure, however, extends only fifteen or twenty feet down. How is the arrangement below? There are places where the bed-rock is not reached in less than a hundred or two hundred feet. There are wells fifty to eighty feet deep, without reaching bed-rock. Those who have seen such wells have observed the deeper structure of the Drift; and they report it much like what we see in the gravel-pit. I will tell you how we shall ascertain the arrangement to the depth of perhaps two hundred feet. Go to the lake-shore, or the sea-shore. Of course it must be a place where the shore is not formed of bed-rocks. Here the whole thickness of the Drift may be cut through, exposing at the bottom the solid foundation on which the Drift reposes. Well, here we find two kinds of Drift. The semi-stratified Drift passes down into a sheet of Drift quite unstratified. It consists of blue clay and a large quantity of imbedded bowlders. These are rounded like those at the surface. They are in every respect the same thing—made, apparently, by the same agency; transported in the same company. This is the Bowlder Clay or *Till*.

We must state, however, that in some situations the semi-stratified Drift rests directly on the bed-rock. Perhaps in these places the Bowlder Clay was washed off before the semi-stratified Drift was laid down. Again, there are many places where the semi-stratified Drift does not rest on the Bowlder Clay—perhaps because it was never laid down; but more probably because it has been removed. In such places the stiff, blue clay is exposed over the surface, and the soil is full of bowlders. Can you not call to mind such a place?

The sheets of sand and gravel, often obliquely laminated, which we saw in the gravel-pit, were there cut through in a vertical section presented edgewise. You must think of these sheets as extending into the earth a certain distance, but very irregular in extent as well as in form and position. Some of them are flat; some are concave upwards, and some are convex. Now and then one is nearly horizontal, but most are considerably inclined.

Did you ever see a huge mound of rock-rubbish at the foot of a torrent rushing down a steep ravine to the open, level land—a torrent sometimes suddenly swollen to a terrific and maddened volume, which tears stones and trees from their fastenings? And have you ever seen such mound cut through for a highway or other purpose? If you have, you have witnessed a semi-stratified order of deposition somewhat like that in the Drift. Those who have thought on this resemblance have reached the conclusion that the semi-stratified Drift must have been moved and laid down by some kind of *torrential action*.

But however this was, the origin of the bed of Bowlder Clay must have been very different. Here is no sort of bedding. The whole is in a state of uniform confusion. Evidently, then, Nature employed two kinds of action successively in transporting and dispersing the Drift. In the semi-stratified Drift, water in tumultuous movement may have been the chief agent. In the Bowlder Drift water was *not* the chief agent, since here is none of the assortment and stratification due to water, and here also are rock-masses moved scores or hundreds of miles, and these results are not ascribable to water.

Let us take another glance over the general distribution of the Drift. We have seen the bowlders increasing in bulk and abundance northward. We have seen the whole Drift formation terminating southward on about the parallel of

Cincinnati. We find incoherent surface deposits in Kentucky and southward; but they contain no bowlders; and they have mostly resulted from the disintegration and decay of the bed-rocks in place. The Drift, then, is a *northern* phenomenon.

If we notice more carefully the detailed distribution of bowlders, we find that, while they have generally moved southward, there has also been a radial distribution from high mountains. In New Hampshire the bowlders move east and west from the White Mountains, as well as south. In Switzerland, the *Pierre à bot* and thousands of other bowlders moved north-westward from the Mont Blanc range—though on the opposite sides of Mont Blanc the movement was in the opposite direction. In the Rocky Mountains and the Sierra Nevada, the movement of the bowlders was east and west from the mountain axis. So, too, the southward distribution of bowlders was greatest along mountain elevations.

Thus the distribution of Drift materials sustains a relation to altitude similar to that which it sustains to latitude. What factor, or force, or agency exists in altitude which exists identically in latitude? Temperature, certainly. To ascend a high mountain range is the same as to ascend to a high latitude. All high mountains support animals and plants related to species farther north. On the summit of Mount Washington are the butterflies and plants of Labrador. Ascending the Andes, you have tropical products at the foot, temperate products at ten thousand feet, and arctic conditions at the summit. The distribution of the Drift, then, has relation to heat and cold. Greater cold has been accompanied by larger results. Bowlders are more numerous and more massive in northern and in elevated regions, because the cold is there more intense.

Now, how does cold act to effect transportation of rock-fragments? Our thoughts run over the world to scrutinize the modes of action of cold. Much cold implies much snow and ice, if moisture and water are abundant. Most far northern regions and high mountain summits are covered much of the year, or the whole of it, by a sheet of snow. Winter snow, under the action of thawing and freezing temperatures in alternation, becomes granular, as we often observe in old snow, especially in early spring. With a more advanced stage of granulation, the icy grains coalesce into larger grains, and finally merge completely into a solid mass of ice. This, also, we have often noticed in the last lingering patches of last winter’s snow.

We have many observations of this kind on a large scale. On high mountains broad fields of granular snow come into existence, and at a certain elevation the average annual temperature is not sufficient to dissolve it before autumnal snows begin to increase the amount. The old snow becomes a permanent granular sheet on the high slopes. In the Alps the Germans designate it *Firn*, and the French, *Névé*. When the firn-masses are accumulated in valleys, the amount of snow is so great that it may reach to a much lower altitude before finding a temperature which will suffice to melt it all away before the next winter. So tongues of granular snow stretch down the mountain valleys, and being, like our late spring snow, exposed to increased action of warmth, these valley prolongations of the upper firn become completely changed into solid ice. This is now a *glacier*.

We may reason a step further from facts of observation. All substances expand with increase of temperature, and contract with reduction of temperature. The glacier is certainly at a lower temperature in winter than in summer—though it can never be warmed above thirty-two degrees Fahrenheit, which is the thawing temperature. The surface of the glacier is also at a lower temperature during the night than during the day. The glacier, therefore, must sometimes expand and sometimes contract. Now, when it expands, the whole expansion will be developed at the free lower border, since the upper border is frozen to the earth, and pressed also, by the snows beyond. Also, if both were free, *most* of the expansion would be developed below, because gravity aids motion downwards. Next, when the glacier contracts, the lower border does *not* retreat, because the ice is not strong enough to bear the pull of the mass up the slope. The ice breaks in innumerable little cracks. These are soon filled with water, which freezes, and thus restores the complete solidity of the glacier. Thus, when the next expansion takes place, the glacier takes another slide down the valley. So the glacier travels. So, if a whole state should become glacier-covered, the ice-sheet would have a motion from higher to lower, and from colder to warmer. Every thing on its surface would be transported; every loose object beneath it or in front of it would be pushed forward.

Now, here are some hints toward an explanation of the method of transportation of our millions of bowlders. If we go to the Alps we find exactly such glaciers, on a small scale, performing precisely such work. Thus our theory receives confirmation. We can not pretend that glacier action explains all the phenomena of the Drift. Nor do we pretend that any thing more than a hint has been given toward an explanation of transportation. The action which arranged the semi-stratified Drift must have been exerted by water rather than ice. But we leave the subject now to your thoughts. You may speculate as much as you please for the purpose of forming a complete theory. You will find such occupation interesting and profitable. By and by we shall come upon this subject again from another direction. (Talk XLVII.)

IV. Among the Glaciers.

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GEOLOGICAL ACTION OF GLACIERS.

Perhaps it is best to pause at once and contemplate a fuller sketch of some living glaciers. We indulged in a little speculation about the cause of the Drift. We argued that glaciers must perform a work pretty nearly such as the Drift required; and I cited you to Alpine glaciers as actually exemplifying this kind of work. But come, now, let us take a closer look at Alpine glaciers. The scenes are abundant in picturesque interest as well as instruction.

About fifty miles from Geneva lies the “vale of Chamonix”—the classic valley of classic glaciers. Its axis lies nearly east and west, and the Arve, taking its rise from the east, flows through the length of the valley, and bends north to the Lake of Geneva. On the north, the valley is bounded by the sharp pinnacled Aiguilles Rouges (A-ghee-Roosj); on the south rises the stupendous mass of the Mont Blanc (Blahnc) range, nearly sixteen thousand feet above sea level. The rounded summit of the monarch mountain is silver white with perpetual snow. On one shoulder rises the Dome du Goûter, and on the other the Aiquille de Goûter (A-ghee-du-Goó-tay). For three thousand feet below the summit, compact snow covers the surface to an unknown depth. In one region below the Aiguille de Goûter, may be seen a long perpendicular cliff of snow left by a slide. It looks like a vast entablature to the glittering dome. This is said to be fifteen hundred feet in height. At the foot of the final dome stretches a fathomless crevasse, in which a number of persons have been lost. This is the "Grande Crevasse," and for a long time it prevented all successful approach to the mountain’s summit. Sometimes a temporary bridge is stretched across by drifting snow. Occasionally it becomes sufficiently solid to serve for a passage over, but it is always treacherous, and once precipitated an English lady and her companion to a depth from which they were never recovered.

From the Grande Crevasse stretches a gentle slope called the Grand Plateau at an elevation of thirteen thousand feet. This is covered with granular *névé*. Along its lower limit the snow-mass is broken into tumultuous confusion, and the passage over it is difficult and dangerous. Below this is the Little Plateau, ten thousand feet above sea-level; and then come other broken belts of snowy precipices. Now, the upper limits of two glaciers are reached in the downward flow of the ice. This common ice-field is a scene of grand confusion. The mountain slope beneath the ice-sheet presents many irregularities of pitch, and many projecting bosses. Over all these the ice-stream flows toward the lower level. In one place, nine thousand feet above sea-level, a vast pinnacled mass of rock rises some hundreds of feet above the ice. This divides the wide stream, but the parts completely coalesce again around the lower side. In other places, the underlying inequalities break the sheet by fractures large and small. Some of these crevasses extend up the general slope, and others are transverse. The ice-mass is therefore broken into innumerable prismatic fragments. The tremendous mashing together which they experience through the movements of the flow, squeeze numbers of them out of their places; and they stand as huge pyramids and columns ten, twenty, and forty feet above the general surface. The columnar forms are called *séracs*. The afternoon sun acts on them, and some are sharpened to a point; others are worked out at the sides, and stand with broad flat caps. Finally they tumble down or waste away, while new ones rise in other places. Though the ice is continually shattered by crevassing, the fissures are continually closing together, when changes in underlying configuration permit. Two fractured surfaces pressed tightly unite again as one mass; and a patch shivered into ten thousand fragments becomes solid and transparent under the lateral squeezing to which it may become subjected. So, to whatever extent the ice-sheet may be shattered, it is continually healing, and tends to return to the condition of a sound and solid mass. Thus the tourist, picking his way among the séracs, and jumping the bottomless chasms, hears frequently the detonation of some new split, which is echoed back from the red pinnacles of Mont Maudit, which rises on his left. These themselves hurl down rocky fragments to keep alive the watchfulness of the traveler, and place material on the back of the glacier to be borne gradually but steadily down toward the valley.

The common glacier-field just mentioned strikes the sharp upper limit of a mountain salience, which slopes down to the valley of Chamonix, and separates two mountain valleys. This prominent dividing point is the Aiguille de la Tour. As the common ice-mass impinges against it, the ice parts to the right and left like a river. Down the western valley flows the ice-stream known as the Glacier de Taconnay. Down the eastern valley flows the greater stream known as the Glacier des Bossons, having the little village of Bossons at its foot. Another valley lies still farther west, and the common ice-field of Mont Blanc fills it with a stream known as Glacier de la Gria.

These three glaciers descend to the valley on the west of the pretty village of Chamonix. On the east are three others. The nearest is the celebrated Mer de Glace, the lower part of which is called the Glacier des Bois, with the little village of Bois at its foot. The snowy eastern slope of Mont Blanc and Mont Maudit (Mo-deé) feeds an enormous glacier which, to an observer from the valley of Chamonix, lies behind the pinnacled summits of Charmoz and Midi. This is the Glacier du Géant, and it forms the western tributary of the Mer de Glace. Into the head of the Mer de Glace comes the Glacier de Léchaud (La-shó), fed by the snow-fields of the Grandes Jorasses. On the east, the Léchaud is reinforced by the broad triangular Glacier de Talèfre (Tah-lefr'), in the midst of which, at an elevation of 9,143 feet, is the Jardin, an island of land-surface, walled in on all sides by lofty mountains, and adorned in August with a display of several species of Alpine flowers.

Beyond the Mer de Glace is the Glacier of Argentière—a fine long river of ice, almost equal to the Mer de Glace itself.