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Trinity College

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Trinity College Bulletin

Centennial Number

The Geology of the Trinity Campus

HARTFORD, CONNECTICUT

April, 1923

TRINITY COLLEGE BULLETIN

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Centennial Number

The Geology of the Trinity Campus

By

Edward Leffingwell Troxell
Assistant Professor of Geology

Hartford : Connecticut

April, 1923

Prefatory Note

It seems appropriate that the Centennial Number of the Trinity College Bulletin should be an account of the Geology of the Trinity College Campus. It is a time when we are all talking in terms of the century just completed, and it is good, therefore, to have our time conception given a proper perspective by consideration of the records in the rocks upon which Trinity is built. The college itself proudly records a single century, while the rocks below register in silence thousands and millions of years.

It has long been a matter of common knowledge to geologists that Trinity College is singularly fortunate in having such an open book displayed here for her students. This being the case, we are glad to make a part of the permanent college records the account here given by Professor Troxell of the geology of our Trinity ridge. He has studied the formation with great care and has shown to class after class the evidences of the processes by which our world was made. This account will be of interest to many but especially to those who spent four years on this hill. It is to be hoped that as Trinity begins to add another century to her years, a study of the geology of her campus will fill each class with reverence for Him in whose sight a thousand years are as one day.

R. B. OGILBY,

President.

The Geology of the Trinity Campus

With the farthest stretch of the imagination one cannot grasp the significance of the changes that have been wrought during geological time. It is difficult to conceive, as we feel the comfort of the conservative New England environment, that the conditions were ever greatly different from those we know today. We can hardly realize, in a place of such present security, that there was once a time when great beasts stalked about the river flats, and living on luxuriant vegetation or devouring the flesh of their unfortunate prey, left their footprints on the sands. Who would suspect from our present equable surroundings that this region was once held in the frozen grip of an arctic climate through a long period of time, and that above us were piled thousands of feet of glacial ice pushed along from a northern center of accumulation? Still more difficult is it to picture in our minds the circumstances under which "an immeasurable force burst asunder the solid pavement of the globe," when the earth itself was opened up and streams of lava, not once but thrice, flowed over the land, overwhelming everything with floods of liquid fire.

All these things did take place and the result today is the escarpment, the high ridge, the eminence which seems to be as if prepared by nature to exalt one of man's noblest institutions, a college. We may read the story of these events in the rocks themselves, where the record, written in a surprisingly legible manner, challenges our diligent investigation.

The object of this description of the geological formations of the Trinity Campus, is to set forth the striking features in a way that may serve as a guide both for the student of geology and the chance visitor to this interesting place. The wealth of evidence of Earth-phenomena revealed in the small space deserves a treatment of this nature, and offers a practical laboratory for the study of the sciences of geology. Phenomena of geological history and structure, of metamorphism, of mineralogy, and of glaciation, illustrate many well established principles. This particular series of deposits has been mentioned in publications by Barrell, Rice, Gregory, Davis, Shepard, Percival and Silliman. Professor Silliman, as early as 1830, wrote a long description of the formation which had already been known as a valuable rock quarry for a hundred years. Dr. C. J. Müller, Trinity '17, has made a careful study of the mineral vein, and I have drawn freely from his copious notes in writing the paragraphs dealing with the mineralogy.

The Events of Geological Time

Cenozoic Era	**Pleistocene** or Glacial Period	Age of Man
	Pliocene, Miocene Oligocene, Eocene	Age of Mammals
Mesozoic Era	Cretaceous, Birth of Rocky Mountains	Age of Reptiles or Dinosaurs
	Comanchean, Rise of Modern Plants	
	Jurassic, First Archaic Birds	
	Triassic, Rocks of Trinity Campus and Connecticut Dinosaurs	
Paleozoic Era	Permian, Birth of the Appalachians	Age of Amphibians
	Carboniferous, Great Coal Beds	
	Devonian Silurian	Age of Fishes
	Ordovician Cambrian	Age of Invertebrates
	Complex Rocks	The Dawn of Life

General Geology

A glance at the table of geological periods shows us that the Age of Reptiles, the **Mesozoic** era, began with the Triassic and that this same period marks the time of origin of the rocks forming our escarpment; with the exception of Pleistocene glaciation, our attention will be directed to the Triassic almost exclusively.

Two distinct types of rock are easily distinguishable in the Triassic formations: first the sandstones and shales; and second the trap or **diabase,** of igneous origin, which is nothing other than cooled lava. The trap rock, which forms an extensive sheet covering hundreds of square miles in its wide distribution through the Connecticut Valley, lies on top of the red sandstones over which the lava flowed. We must remember that the separate outcrops of rock are but the visible evidence of one continuous rock mass spreading over the earth· the bedrock happens to be concealed for the most part under a mantle of soil and other loose material.

From a general survey of the whole Connecticut Valley we know that there were three distinct outwellings of lava and that the trap rocks here are a part of the last one, referred to technically as the **posterior sheet;** as a molten mass it was poured out upon the surface of the land in a very fluid state from some undiscovered vent in the earth's crust. The **sedimentary** rocks underlying the igneous sheet are made up of sandstones and shales, and as the name implies, were formed from sediments brought by currents of water and wind and accumulated in enormous quantities. That these deposits are continental in origin rather than of the sea, can be demonstrated by the absence of marine and the presence of fresh-water fossils, by the peculiar surface markings from ripples, drying, etc., by the presence of clastic mica and by the red and brown colors. The sands and silts are estimated to have reached a depth or thickness of 13,000 to 18,000 feet.

Topography.—The bold cliff of the westward facing escarpment extends in a long ridge from Trinity College past Goodwin Park and for several miles in a southerly and south-easterly direction, showing the influence of the hard rocks on the topography. The lava rock is more resistant to the processes of erosion and therefore furnishes a strong capping to protect the slightly softer and therefore more easily eroded shales and sandstones beneath.

All of these rocks slope or **dip** eastward with an inclination of eighteen degrees; therefore the rocks plunge far beneath the surface on the east side of the campus even where the land is at a lower level. The solid rock is covered, for the most part, with glacial material and is hidden from view except along the very edge of the escarpment.

Fig. 1. Above the contact plane the dominant lines of the igneous rock are vertical; below are the horizontal beds of the sandstone.

Because we find in other parts of the valley, ledges of the same Triassic rock similarly dipping eastward, we conclude that the original deposit was broken up into an harmonious system of eastward tilting, faulted blocks. The structure as a whole has been compared to a window shutter, where the separate slats or units are tilted equally and in the same direction. From the angle of dip and the distance between consecutive ridges in the valley, we can estimate the amount of movement between adjacent blocks, provided there are no intermediate and unseen faults; for this particular fault, which caused the escarpment at Trinity College we estimate that the displacement is about 5000 feet. The lines of breaking or faulting must extend for miles along the surface of the ground, and the simplest interpretation of the Trinity escarpment postulates a fault roughly parallel to the hill and extending a mile or more north and south. Davis, however, has continued this line on his map a distance of twenty miles further to the south-west!

The Igneous Rocks

The upper thirty or thirty-five feet of the escarpment near the Museum are composed of minutely crystalline rock, the product of an extensive flow of lava extruded over the red sandstones beneath, covering an area of hundreds of square miles. This is the third and upper flow or series of flows of igneous rock, already mentioned. Although this dark colored diabase melts more easily than lighter colored acidic lavas, yet it is estimated that the temperature required to produce the degree of fluidity necessary for such an extensive flow must have been 1300° C. (=2400° F.).

Physical Features.—The primary physical features, those which are inherent in the rock and were contemporaneous with its formation, may be summed up under **composition, texture,** and **structure.** The outstanding characteristics are the dark color of the freshly broken surface, indicating the iron-magnesian content, the minutely crystalline, almost dense texture, the presence of vesicles or bubbles in certain parts and the irregular, broken, flow structure in local areas. From all of these, except the dark color, it is reasoned that the flow was an **extrusive** one. The rapid cooling did not permit large crystals to grow as is the case in granite; furthermore it caused the rock to solidify while under no great pressure and accordingly preserved the vesicular and porous texture caused by the released gases. Particularly near the upper surface of the lava layer where the pressure from the super-incumbent weight was least, is it porous and scoriaceous. A few feet of rock pressure, with the greater depth of lava and the increased weight, however, was sufficient to compress the gases causing the main mass of rock to become more dense. At the very bottom the vesicles are again present and we assume that the thinner front of the rolling wave of hot material was quickly cooled here, preserving the impression of the jets of steam forced up from the moist sand beneath. Before the flow had reached its present depth, the rock cooled with the gases still present and expanded, and the gradual increase in depth of the flow and the added load did not suffice to obliterate the texture in these lower layers, after they had once solidified through partial cooling. Professor Silliman devoted

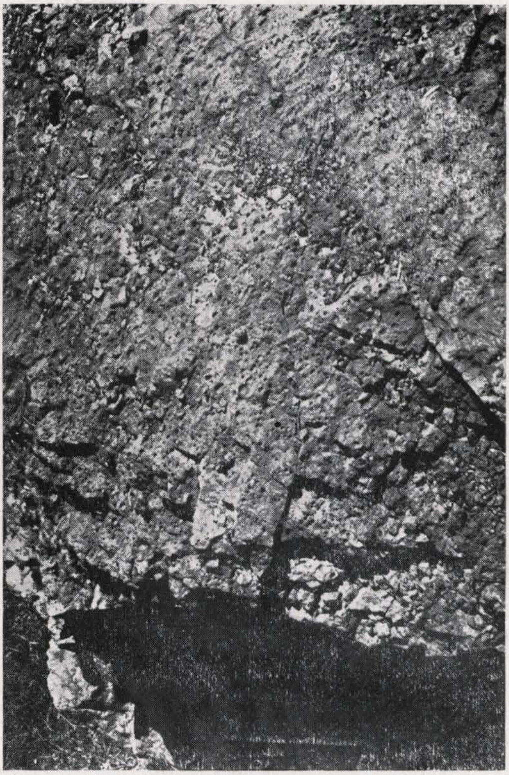

Fig. 2. Vesicular and scoriaceous texture of the lava caused by the included gases. This is a feature of surface flows.

several paragraphs to the description of this feature, which he traced through the lower two or three feet of the trap rock and for some distance into the underlying sandstone.

Contact Alteration.—The line of contact between the lava and the sand and clay beneath gives us an example of the mutual effect of the contrast in original temperatures and compositions. This result is called metamorphism, and affects a zone along the border line, which depends for its thickness on the depth of the flow, principally, and on the amount of heat given off by the lava. There is a gradual change as we approach the actual contact from either side; the lava seems to have assimilated some of the sandstone beneath and the latter is baked and profoundly altered by the penetration of liquids and volatile substances. The shale has become flinty, shows a conchoidal fracture, and its originally red and brown color is changed to blue or gray. Silica taken into solution by the hot waters may, on passing through, cement the sand grains into a hard quartzite. Baking may almost completely change the composition of the rocks near a contact like this one.

Jointing.—The jointing planes of the trap rock, which cut deeply into the mass and show plainly as lines of fracture on the upper surface, constitute one of the more important secondary features. These cracks have a tendency to divide the sheet of lava into polygonal pillars which are frequently hexagonal. The ideal prismatic structure is a result of the cooling from the surface downward, which gives rise to a differential shrinking. The shrinking is attained most easily when the cracks run out from a center at angles of 120° producing hexagons, thus releasing the maximum amount of stress and giving the greatest volume to each block for the least amount of fracturing. Other secondary features caused by weathering and glaciation may be noted. Chemical disintegration of the rock, induced by the atmosphere and percolating waters, changes the dark surface with a greenish tinge to one of dull orange or buff. This color is due in part to the formation of kaolin, from the alteration of feldspar, stained with iron oxide.

Trap Breccia.—A very unusual phase of the trap rock is seen near the St. Anthony Hall, east of Summit Street and beyond the northern limits of the campus. A breccia always consists of the broken angular fragments of a rock, recemented; here the binding material is of two sorts: it comes either from other molten lava itself or from an arenaceous or sandy substance filling all the interstices.

In the first place the fragments were formed from the shattering of the glassy rock through sudden cooling, through the explosive action of super-heated steam, or from the pulling apart of the crust formed on the surface of the lava, as a result of a revived flow. In the latter case the broken pieces might easily be rolled into and recemented by the remaining molten material.

Fig. 3. Brecciated or broken trap-rock, cemented by a filling of liquid lava or of sand, now consolidated.

A cement of indurated sandstone is not so easily explained; four hypotheses may be advanced: (1) The mixing of fragments of igneous rock with sand may take place along the front of a flow where the lava pushes over and mingles with a bed of sand. This seems to be a possible explanation, but with it one must assume that the lavas of the **posterior sheet** here at Hartford do not result from a single flow but rather from distinct outbursts with an intervening time of sedimentation, and this is doubtful.

(2) The mixture of sand with the trap rock may possibly take place in a large fault zone where both sandstone and the igneous diabase are involved. Observed slickensides support this hypothesis.

(3) Probably the most plausible theory of the origin of the breccia is that which presupposes an explosion, beneath the lava layer, resulting from the flow over wet sands and shales turning the moisture into steam. This action may be compared to that of a geyser. The great heat caused the steam to form in spite of the pressure above; it overcame all resistance, tore through the superincumbent load, lifted and shattered its 35 feet of rock, and left a pile of loose fragments. Such an explosion might have thrown fragments of shale or sandstone into the debris, one of which is actually seen at the present time: a piece of shale.

The filling of the interspaces in the breccia, according to this theory, might easily be accomplished by the settling of later wind- or water-borne sediments, which were spread over the top and gradually worked their way into the smallest crevices.

The deposits of calcite and quartz which appear as white spots on these rocks are thought to show conclusively the former presence of hot springs. The solutions emanated from the layers beneath.

A fourth explanation may be ventured, (4) that the peculiar breccia marks the proximity to the **vent** in the earth's crust through which the **magma** out-welled and in which it mingled with the wall-rock along its course; both might then have been extruded onto the surface together. This supposition, although far from proven, is a worthy working hypothesis and warrants further careful study. In this connection it should be noted, however, that *in the neighborhood of a vent, fragments of wall rock, sandstone for instance, ought to be surrounded by lava material.* Except for certain doubtful specimens of the rock, which have been collected, the reverse is true in every case observed.

There is a current rumor that this extremely interesting and instructive series of rocks, on the corner of Summit and Vernon Streets, is to be blasted away to facilitate building on the site. This is to be deplored, but if it must be done Trinity College, cooperating with the City of Hartford, should endeavor to secure some of the largest and most suitable blocks, and have them transported across to the public park or to the campus for preservation.

The Sedimentary Rocks

At the bottom of the cliff there lie red sandstones exposed for a vertical distance of ten feet or more; similar deposits are known to extend downward for over a thousand feet, before another trap sheet is encountered. The sedimentary rocks are not as resistant to erosion as the trap rock is, yet in places they are considerably indurated. Although commonly spoken of as the Triassic **red sandstones,** we frequently find distinct layers of red shale of very fine grain.

The material composing these bedded rocks, sand, silt, and mud, was derived from highlands and mountainous tracts, bordering the old river valley.

These mechanical products of erosion were swept onto the broad flats of an old intermontane flood plain, the surface continued periodically to subside through a vast age during which there accumulated the many thousands of feet of these coarse and fine sedimentary rocks, rich in fragmented mica and feldspar. The process was interrupted only by the occasions of igneous activity, interspersing the three great sheets of lava, one of which we see at Trinity College.

Primary Characters.—Most rocks which are products of erosion and deposition in water, are **stratified.** The original materials were subjected to a process of sorting by the moving waters, and are arranged in layers. Where one stratum ends and another series begins, there is a sharp break in continuity, represented by a line in the cross section, and an easy plane of cleavage in the rock, which we call a **bedding plane.** It happens that the sandstones underlying the campus are so much divided by bedding planes that they are practically unfit for building purposes, although great use of them has been made in the past.

Thin beds of fine-grained material result from the settling of sediment from quiet water. The supply of material may be brought in all at once by a strong current which then subsides, and a renewal of the supply may be produced in deep water by surface currents which carry only the finest materials and never disturb the bottom layers.

In a place where deposition has gone on, a change from finer to coarser sediments may indicate a withdrawal of the standing waters and a decrease in depth; but in a stream it may suggest renewed erosion and increased load following a flood, for rapidly flowing waters bring coarse material and for a time at least permit of no fine deposits.

The thickest beds of sandstone along the Trinity escarpment measure scarcely more than ten or twenty inches. Since bedding always shows a change of deposition, massive sandstones, without banding or streaks, may be due either to an enormously rapid rate of deposition, too rapid for sorting, or may be due to a remarkably uniform rate of accumulation.

Frequently one sees an irregular line running along the wall of rock cutting across the bedding planes. It resembles an **unconformity** and is sometimes referred to as a local unconformity. The line represents the intersection of the vertical plane with a former land surface made uneven by an impetuous stream cutting into its own deposits. New sediments had soon restored the evenness of the strata.

Another feature which breaks the regularity of the strata is the false or cross bedding. This may result: (1) through the formation of ripple marks which are advancing more rapidly than they are building; (2) through the building of a delta with the foreset beds on a steeper slope; or (3) finally in the building of a sand bar where material is carried over and dumped on the lee side. If the bedding is much crossed and extremely irregular, we think of rapidly changing or eddying currents at the time of deposition. Although there is a resemblance in each case, contemporaneous erosion such as this should not be confused with disconformity, neither should cross bedding be interpreted as nonconformity.

The consolidation of the beds from sands and muds to hard stone may have been effected at some considerable depth beneath the surface by heat and pressure working together, or it may have been brought about nearer the surface by the action of ground water dissolving calcite, silica, or iron oxide, and redepositing it about the small fragmental grains, cementing them firmly together.

Markings on the Sandstone.—Surface features may be secondary in origin, i.e., caused after the strata are formed; but if they are primary or contemporaneous, they may be of value in determining the origin, for then they show the inherent qualities.

Ripple marks are commonly seen on the exposed surfaces of the bedded rock; these consist of parallel ridges made by the wind or by currents in shallow waters, just as they are made today in sand dunes or along a sandy shore.

In the case of ripple marks made by water, seldom on slopes of more than a few degrees, the coarse grains are left in the trough and the finer material on the crest; the reverse is true when the marks are made by the wind, and here they may appear on slopes as steep as the angle of repose of the sand grains.

The shales are sometimes marked in an irregular way by the material filling **sun cracks.** Sun cracks are due to the shrinking of clay, which results in the formation of polygonal plates; these, like the columns in trap rock, are ideally of six sides. The shrinking results from the long exposure of mud or clay to the dry air on river flood plains and less frequently on tidal flats; the phenomenon is favored in semi-arid regions. The cracks between the blocks or cakes of sediment are easily filled in later on by wind- or water-borne sediments, converting the whole into a solid, continuous mass. The typical **intraformational conglomerate** made of these sun-dried, saucer-shaped cakes of clay surrounded by sand, is beautifully shown in places along the escarpment.

Not infrequently we find small impressions a fourth of an inch or less in diameter on the finest grained shales; these tell us of a prehistoric shower and are interpreted as **rain-drop imprints.** If the rim of the little crater-like impression is uniform and circular, no wind was blowing, but if the rim is pushed out and thickened on one side, it is apparent that the drop struck obliquely and that the wind was blowing from the opposite side.

No undoubted fossils have been reported from this locality, but a thorough search may yet reveal footprints or plant remains, for these are well known in other exposures of the Triassic sandstones. The probabilities of discovering the remains of vertebrates (dinosaurs, etc.) is indeed remote, although these too have been found a few miles east of Hartford.

Many of the peculiar markings which we see must be ascribed to mechanical causes simply, although they display a striking resemblance to footprints, shells, bones, and plants. These may be concretions, sun-crack fillings, false bedding, or marks made by floating objects—a branch dragging on the bottom muds.

Climatic Indications.—The red or brown color, peculiar to the sandstones generally, is universally ascribed to an iron oxide, particularly hematite which may occur when fine particles are disseminated, or it may appear as a coating around the sand grains. The hematite is formed under circumstances adverse to reduction, i.e., not in the presence of a reducing agent such as organic matter. It appears rather under conditions favoring oxidation, perhaps in the presence of air or at least with air occupying the open spaces in the sand. This implies aridity, and a low ground-water level.

We may ascertain important facts from the sediments about the physical aspects of the land from which they were derived. Coarse sediments and arkose from broken up granite tell us quite clearly of hills of steeper slope, rapid erosion under dry or cold climates, and no great distance of transportation. Fine materials, muds, etc., imply hills of low relief reduced almost to a plain (**peneplain**). Muds containing much kaolin (clay), with interbeds of sand, show that the preëxisting rocks were granite whose feldspars weathered under a relatively warm, humid climate.

Deposits made in an arid climate, which may be indicated by incompletely weathered products such as feldspar in arkose, by wind-blown rounded sands and dust, by sand coated with red iron oxide, by wind ripple marks and sun-cracking, are thought to suggest accumulation on the lee side of a mountain range which screened the prevailing winds, caught the precipitation on the adverse slope, and carried it away in the opposite direction.

This leads us to suppose that there existed a range of mountains to the westward in Triassic time, and that the rains fell on its western rather than its eastern slope.

Climate may also be shown by the general absence of fossils, which implies frigidity, turbidity, salinity, or aridity, at least for periods of time during deposition. Shells and other fossil remains are seldom found in sandstone, because of their grinding and wearing away in the sands themselves. Although the scarcity of fossils in sandstone results mainly from the destructive effect of mechanical erosion which reduces the organic material to small fragments at the time the sands are laid down, their absence may be due also to their dissolution by the chemical action of the underground waters. Finally, it is probable that the flats were not the favorite haunts of many of the animals, that their visits were infrequent, that few died here, and that no remains or traces were left in these deposits.

A Minor Fault and Mineral Vein

Besides the major faults or rifts in the Connecticut Valley, which broke the Triassic rocks into separate blocks and so profoundly influenced the topography, there are others of less

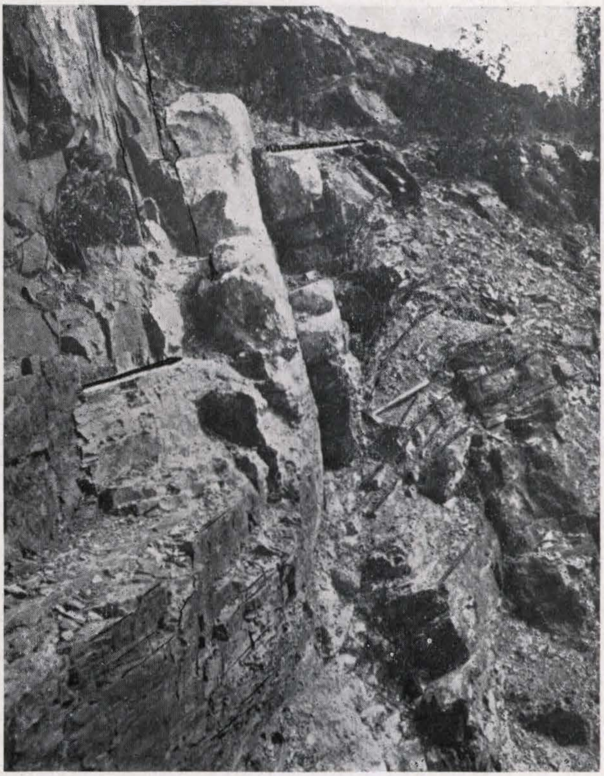

Fig. 4. A mineral vein of white barite now marks a fault plane. That one side has gone up relatively is seen by the offset of corresponding layers—note the black lines—and by the bending of the beds as they were dragged where the hammer now lies.

degree which are inconspicuous because of the slight displacement of their walls. One such is well shown near the stone steps leading up the cliff toward Vernon Street. Its plane of fracture is now conspicuously marked by a vein of white **barite** nearly two feet in thickness, which fills the opened space. This little fault penetrates the face of the cliff and trends in a general direction southward; for a distance the down-dropt eastern wall forms the face of the escarpment itself. Adjacent layers of the shale and sandstone are dragged by the movement along the fault plane, and the convex surfaces face in the direction of the movement, i.e., upward on the west side and downward on the opposite side. Since the plane leans toward the east or toward the down-thrown block we term it a **reverse fault** and assume that it is due to pressure from the sides. If, however, the fault was originally formed in the horizontal beds, and later tilted with them from a nearly vertical position, it might be considered a **normal** fault. It is evident that this fault was formed at a time later than the Triassic (for the Triassic rocks themselves were broken) and probably is one of the series made during and coincident with the general breaking up of the larger blocks of the system. Along the plane of this small fault one sees a zone of **crush breccia** made of fragments ground off the country rock and held together by vein minerals. In addition one sees polished and striated surfaces of rock which result from differential movement along lines of fracture; these are called **slickensides.** They lie in different attitudes showing that there were various movements in accommodation, perhaps, to the ones seen in the major faults.

Accompanying the faulting and the subsequent formation of the mineral vein a change occurred in the bordering shales and sandstones, extending several feet beyond the fault plane. The strata were impregnated with carbonaceous material and the most important effect has been to change the normally red beds to a dark slate color. They resemble now the black shales seen elsewhere in the valley at a lower horizon, which may indeed have been the source of the carbon. The borders of the altered zone are at times very distinct.

The Mineral Vein (From a study by Müller).—Along the fissure which marks the fault plane there appears a heavy vein of material consisting mostly of **barite,** with smaller quantities of **quartz, bitumen;** the copper sulphides, **bornite, chalcocite,** and **covellite;** the carbonates, **malachite** and **azurite;** together with the oxide of iron, **limonite.** The quartz appears both as white masses surrounded by the other minerals and as cementing material between the brecciated fragments of the vein. It also forms drusy surfaces lining small cavities, and in some cases is deposited on the other minerals in such a manner as to show a later origin. Bornite is the only copper sulphide mineral visible without a microscope. It is present mainly in the form of irregularly scattered grains in the quartz and barite gangue. Chalcocite and covellite are also found to be present. Malachite, the green carbonate of copper, appears as a powdery coating on the other minerals, or as silky tufts of radiating hair-like crystals. The vein was probably deposited while the rock formation was near the surface and results from the passage of mineral-bearing waters under low temperature and pressure. The deposit as a whole serves to show two types of solution: one is acidic and of ascending nature, from which the sulphides were deposited, and probably originated from the igneous rocks themselves; the other type is an alkaline solution coming from descending waters of surface origin, which furnish carbon-dioxide and oxygen and are oxidizing in nature.

Glaciation

Of all the geological events which here took place, none is more interesting than the sweeping movement of the great continental glacier which literally left its record inscribed on the stone surface, and then melting away, covered it with a mantle of its characteristic glacial drift. If we could clear away the layer of loose material, we could walk, no doubt, over many acres of glacially striated surface with its variety of markings, a great sculptured floor extending everywhere beneath the campus.

Glaciers in the past, as today, betoken abundant precipitation, mostly snow, in excess of that which melts during the summer; and glacial movement is inaugurated only after a period of long continued accumulation. The glacier or glaciers which invaded Connecticut in the Quaternary or Pleistocene age had a center of origin perhaps twelve to fifteen hundred miles further north, from which they spread. Even in its southern reaches, the ice may have measured a half mile in depth, and a mile or more in the deepest places in Canada.

The interpretation of glacial activity in past ages is founded on a broad study of existing ice masses in the Alps, in Greenland, Alaska, and Antarctica; and constitutes one of the latest additions to geologic science.

Glacial Sculpturing.—The sculpturing on the surface of the trap rock, for it was the uppermost layer and the only formation exposed here at that time, varies from that of a highly polished surface to that of an irregular tearing away of large blocks, and from hair-like scratches to deep grooves measuring several inches in cross dimension and many feet in length. The finer lines were engraved by sharp stones firmly imbedded in the ice, like a machinist's tool, and carried along with great force but with considerable uniformity. The direction of these lines, where not affected by local irregularities of topography, indicates the general trend of the glacier's course; but sometimes a system of secondary cross-lines, usually at low angles, tells us of two or more distinct ice movements or a change in the direction of the border flow while the glacier was advancing or retreating.

Fig. 5. The bed-rock smoothed and striated by glacial action. The ice moved toward the top of the picture.

It appears at times that the glacier, meeting a salient in the rock floor, dug and scraped in a less regular way, to the end that broad, rough scars were made, always on the north side, a few inches in length and terminating near the highest point. These are called **gouges** and are distinct from chatter marks.

Chatter marks are formed when, due to the elasticity of the ice or the bed rock, the engraving tool of stone as it advances is given a vibratory motion and leaves a series of indentations regularly spaced.

Fig. 6. The gouging here shown is in contrast to the slender and more delicate striations frequently seen.

Another easily recognized product of glacial sculpturing is the **roches moutonnées.** These are the rounded and smoothed bosses of bed rock, over which the ice has been gliding in its passage southward, and which, in certain cases, resemble the backs of sheep on a hillside, hence the name. Although they are in general shaped like the half of an egg, and the north side is smoothly rounded where it met the full force of the irresistible glacier; yet when the ice reached the crest it was too rigid to conform to the lee slope under the influence of gravity, so it passed on over without scouring. Its passing, however, was not without considerable effect; by a process called **plucking** it pulled out from the south side the loosened fragments frozen to it and left the roche moutonnée exceedingly jagged and irregular.

Fig. 7. A roche moutonnée rounded and scoured on the right by the advancing glacier, plucked and torn on the left by the ice mass as it passed on over.

Transported Material.—The **erratic** boulders so commonly seen in any glaciated region bear mute evidence of the tremendous transporting power of the ice. Regardless of their size, blocks large and small are pushed and carried along, sometimes for scores of miles and up the sides of steep slopes. One particularly fine illustration of this phenomenon, a large sandstone boulder, may be seen on the crest of the cliff several hundred yards south of the Museum. It lies upon the lava rock, perhaps thirty feet above the beds of similar material **in situ.** Its abnormal position and the fact that it is more massive than the near-by bedded red sandstones, force one to the conclusion that it came from some distant ledge. It shows the effect of a long journey in the flattened and striated faces and angular corners, and now lies, in all probability, where it was dropped by the last melting ice.

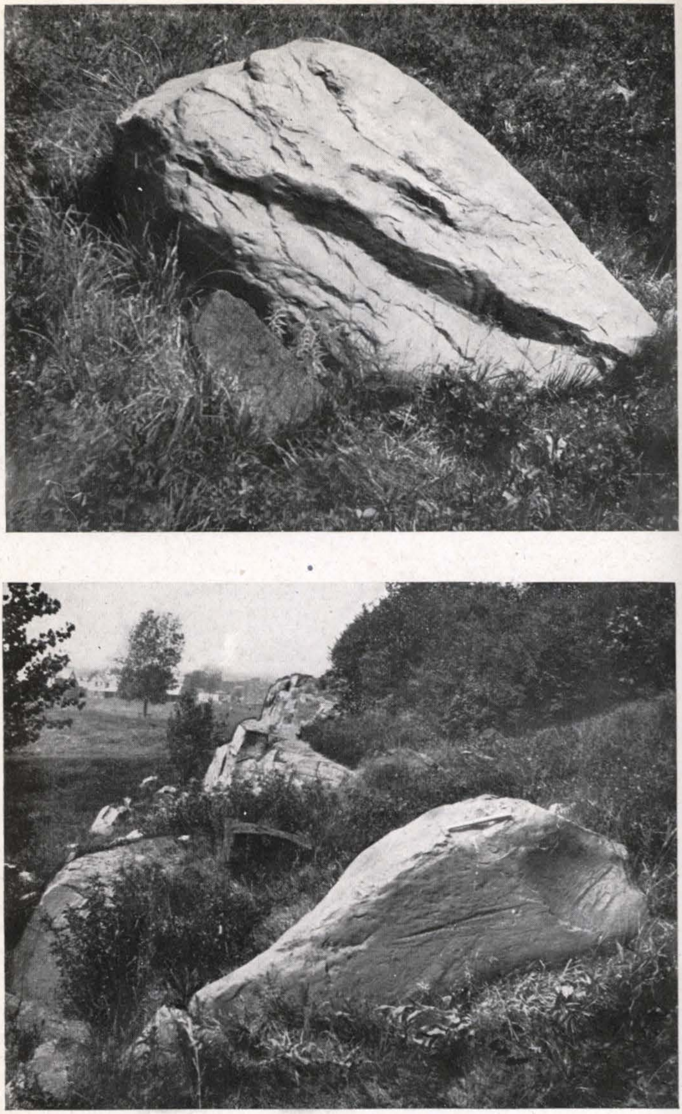

Fig. 8. Here is an erratic, a boulder of red sandstone weighing from two to four tons, shown in two views. Evidence for its movement by the ice lies in the striated, flattened faces and in its position above the ledge of trap rock.

The **glacial drift** or **till** consists of a heterogeneous mixture of boulders, gravel, sand, and clay, most of it carried within the ice-mass or on its surface and dropped without any regard to sorting or stratification as the ice gradually melted and disappeared. It is evident that this clastic material does not pertain to the rocks beneath, but like the erratics, is foreign and lies unconformably on the trap surface.

The thin veneer of glacial till has been so disturbed in recent years that it has lost any resemblance it might have had to a moraine in its superficial aspect. On the campus proper, much grading has been done, but south of the science buildings the topography has been altered little by artificial means, and seems to retain the gentle undulations of the last recessive moraine.

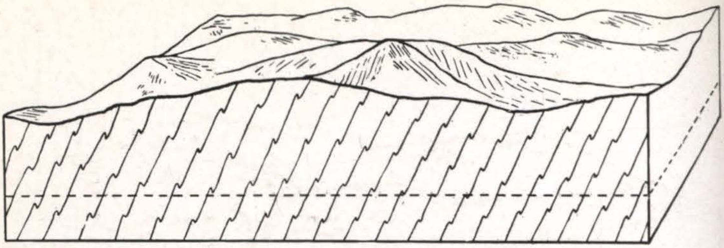

Fig. 9. At the close of the Paleozoic era, the "New England Alps" appeared, attaining an altitude of 10,000 feet or more. It is with this movement that the known geological history of the Connecticut Valley begins.

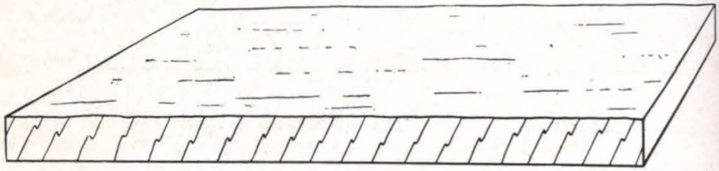

Fig. 10. With the early Triassic period, the mountains were cut down to a peneplain; there remain only the old crystalline foundations, but all is ready for the sediments of later Triassic time which are of such significance to us. The land settles gradually as the materials accumulate.

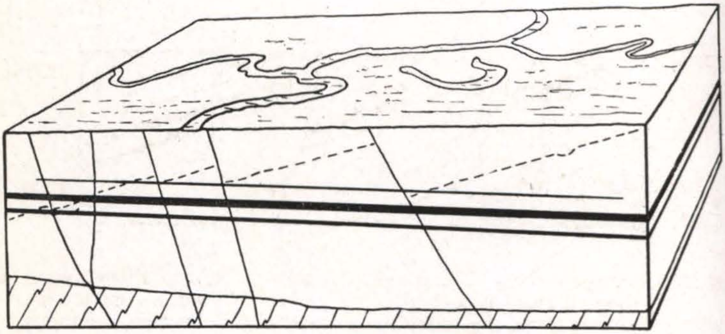

Fig. 11. The third diagram shows the completion of the Triassic rocks as they were originally formed. The heavy lines represent the three lava flows described in the text; the broken lines, the present surface of the ground.

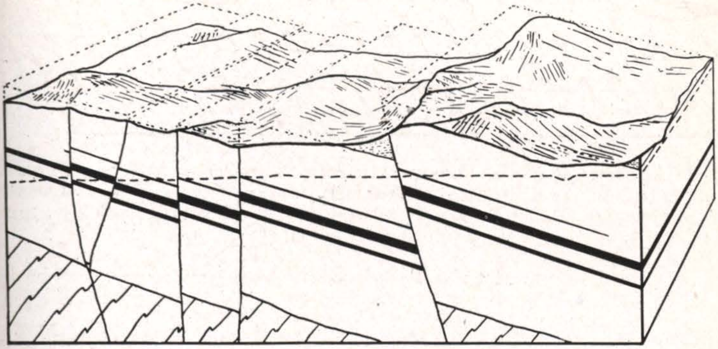

Fig. 12. Block faulting has made this a mountainous country again in Jurassic time. Each block was tilted eastward and took the position and attitude it retains today.

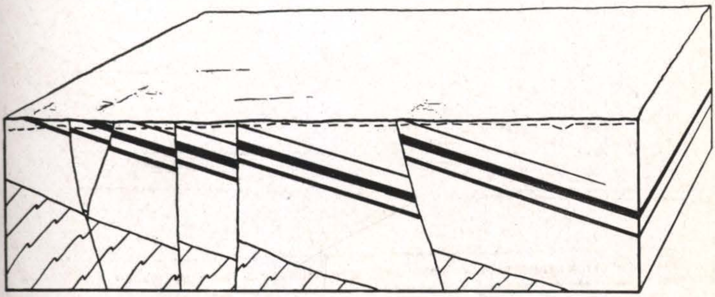

Fig. 13. Once again in the Cretaceous, the hills are cut to a level plain; the corners of the separate blocks were beveled and, except for further stream erosion, the conditions represented are as they are today.

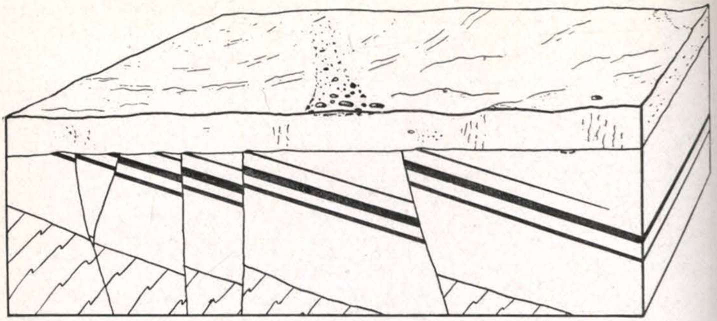

Fig. 14. A glacier covered the land in the Pleistocene to a depth of a half mile or more. Much loose material was carried by it and left where the ice melted.

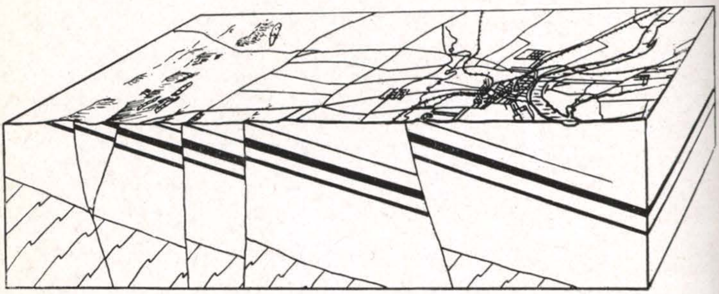

Fig. 15. This diagram represents the conditions as we know them now: the Connecticut River passes through Hartford on the right; the Talcott Mountains lie on the left; and the structure of the rocks are shown on the face of the block to a depth of two miles and a half.

The series of block diagrams here shown is drawn on a scale of three miles to the inch, without vertical exaggeration. Each section is therefore ten miles long and extends westward from a point, on the eastern or right-hand-side, one mile beyond the present Connecticut River.

The History Reviewed

Let us go back in our fancy and visit the place of the Trinity Campus eons before there were buildings or freshmen, before there were professors to thwart the natural course of events.

First Visit.—Let us take our first visit at the end of the splendid Paleozoic era. We see the magnificent New England mountains towering to the skies, surpassing our highest Appalachian peaks. The teeth of the frost and the wear of merciless streams are gashing the slopes and tearing away the superstructure; nothing endures. We tire as we watch the continuous process.

Second Visit.—We come to the same place in Triassic time; we see how well the eroding forces have done their task. The mountains are razed, their grandeur is gone, and the land is reduced to a monotonous plain. But look, yonder a peculiar thing is happening. Miles to the east of us the ground is sinking, and now beneath our feet and now farther westward. Streams are flowing in from the sloping valley sides, carrying much sediment; they nearly fill the depression and bring it to a general level.

At times more favorable animals appear, dinosaurs stalk on their hind legs, monarchs of the time; there are fish in the ponds and lakes bordered by vegetation; there may even be small mammals, but they are archaic and few. Now the benign sun is shining on this Triassic land, baking the muds and drying the air.

But see that dark flood smoking and steaming, which streams out the valley floor, sinister and hostile in its meaning. The wave of molten rock is killing and driving away all things living, and the pools are turned to boiling caldrons as the lavas mingle with the water.

Our visit is hastened by the vile gases which stop our breathing; but the view has taught us how the lavas come, why there are sun-cracks and ripple-marks, and whence the footprints on the shales.

Third Visit.—As we pass this way again, we feel vast, internal earth-forces, great strains are set up, severe earthquakes shake the whole region. There is a crushing and rending of the very foundations; blocks are heaved as on a troubled sea; the smooth strata are folded and broken and the parts are faulted and displaced and tilted toward the east. We are in the Jurassic period.

Fourth Visit.—It is a brief occasion in the Cretaceous, and once more there is presented to our view a leveled land. Even the rough edges of the huge blocks we knew are now beveled, and every rock is covered with its soil.

Fifth Visit.—We are here again in the Pleistocene; all has changed, all is unfamiliar. Instead of lavas or sediments or hills and valleys, nothing is seen but the surface of ice, a gloomy pile which the sun smites in vain. This is not, as at first you might suppose, a frozen river or lake, but a glacier thousands of feet in depth, and the land is hidden except for glimpses when the ice retreats and comes again. The skies are cloudy and a mist blurs the sharpness of the outline, but we discern the shapes of strange beasts, the mammoth and mastodon, horses, bison, caribou, and beaver; we believe we see members of the human race beyond the margins of the ice, awaiting its withdrawal and the end of winter years.

Sixth Visit.—Come with me once more; this is our final visit, for with our going now we may not come again; it is the year of Our Lord nineteen hundred and twenty-three, and of Trinity College the hundredth. We see the same rocks that Silliman saw when the college was but seven years old; there lies the ridge, the pleasant valley beyond. We see the surface mantle of till and soil from which spring grasses and trees, and men walk about, oblivious of the eventful past.

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