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Art. XLIII.—*Topographic Development of the Triassic Formation of the Connecticut Valley;* by William Morris Davis.

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Contents :—Itinerary of Harvard Summer School of Geology—Faults in the Meriden region—Cross-section of the District—Means of detecting the unfaulted sequence of Triassic beds—Mechanism of monoclinal faulting—Topographic development of the Triassic belt—Initial constructional stages represented by the faulted blocks of Southern Idaho—Mountain ranges of the Great Basin equivalent to a later Jurassic Stage—The whole region base-leveled in late Cretaceous time—The present valleys worn in the Cretaceous base-level plain after its elevation—Polygenetic topography—The origin of the Connecticut river outlet via Middletown—The Connecticut river was originally consequent on the monoclinal faulting, and still persists near the course then taken, but has entered a second cycle of life as a result of the elevation of the lowland that was produced in its first cycle.

Since presenting two years ago a suggestion to account for the mechanical origin of the faulted Triassic monocline* I have visited the region about Meriden with the Harvard Summer School of Geology during its sessions of 1887 and 1888. An itinerary of the excursions made by the school in

* This Journal, xxxii, 1886, 342–352; Proc. Amer. Assoc., xxxv, 1886, 224–227; Seventh Ann. Report U. S. Geol. Survey, 1886, just issued.

deciphering the structure of the district together with maps and sections to illustrate the facts of observation and a detailed consideration of the arguments leading to certain conclusions is now in press in the Bulletin of the Museum of Comparative Zoölogy at Cambridge. The structural problems of the region afford excellent opportunity for practical instruction in geology. A brief summary of the results reached is presented here.

The small black square in figure 1 indicates the position of the Meriden district in central Connecticut and in the southern part of the New England Triassic area. Figure 2 is the same

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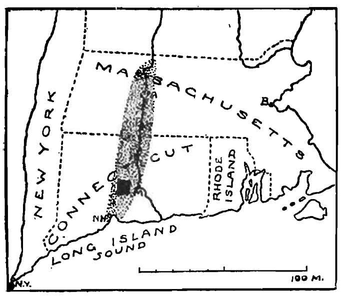

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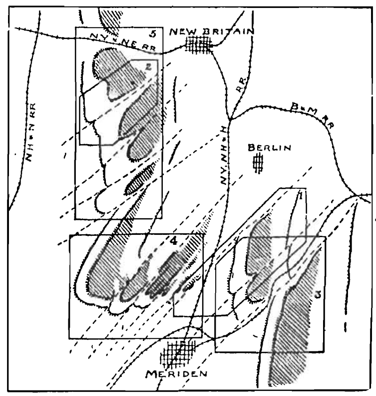

district on a larger scale. The main trap sheet, whose monoclinal ridges dominate the relief of the region, is shaded with oblique lines; the subordinate ridges formed on the anterior and posterior trap sheets are indicated by lines on either side of the main ridges. The chief faults of the region are drawn in broken lines, and their general southwest trend is clearly seen. The several enclosed spaces numbered 1 to 5 mark the areas represented on maps of still larger scale in the Bulletin above referred to. The "mountains" formed by the main trap sheet are, beginning on the southeast: Higby (or Besick) Mountain, Chauncy Peak and Lamentation Mountain, the Hanging Hills group northwest of Meriden (consisting of Cat-hole Peaks, Notch Mountain and West Peak), Short Mountain, High Rock and Shuttle Meadow Mountain, and Bradley's Mountain, before coming to Cook's Gap, a pass followed by the New York and New England railroad westward from New Britain. The evidence seems to me very strong that the faults separating all these blocks were produced after the trap sheets had taken their place in the stratified series, all the sheets here shown being extrusive surface flows, poured out during the accumulation of the aqueous strata.

A cross-section of the district from northwest to southeast, on the scale of figure 2, is given in figure 3; but its construction is not very accurate as to the values of dip and dislocation. The heave of the faults is on the southeast in every case, with the single exception of the fault between High Rock and Short Mountain, where the heave is on the other side; this departure from the prevailing rule of dislocation being indicated by a corresponding departure from the prevailing rule of topography. In passing northward across a fault of the ordinary kind, the repeated portion of a ridge is found in what Percival called "advancing order," that is, farther west than before; but here the repeated ridge is found in "receding order," and hence the fault is known to have a reverse throw. The distinct topographic effect of the faults is illustrated in two figures. The first (fig. 4.) is a view southwestward through a gap in the anterior trap ridge, on the line of the fault that

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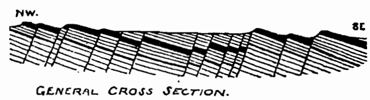

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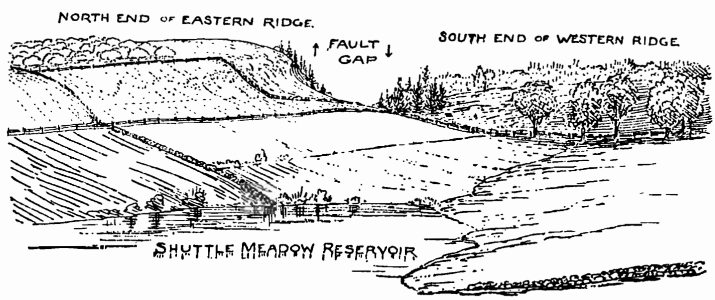

runs from New Britain through Shuttle meadow reservoir. The heaved side of the fault is on the left (southeast), where the back of the ridge is shaded by an apple orchard and its outcrop bluff is clothed with hemlocks: the thrown side is on the right, where the trap sheet lies lower, but rises westward to another ridge like the first; an old pasture field on its back, and a bold cliff facing the broad Southington valley beyond. This cliff runs two or three miles north, but shortly turns around the southern end of the ridge where it is terminated by the oblique fault; the other ridge falls away to the left of the view as it approaches the fault, but continues southward till it is again broken by another fault, and the topographic dislocation is repeated.

The second view (fig. 5.) is of larger range: it is taken from a hill about a mile east of Berlin, looking south to two masses of the main trap sheet. Lamentation Mountain is on the right with the slightly detached Chauncy Peak rising a little over its farther end; and Higby (Besick) Mountain rises on the left. The strong fault that passes a little east of Meriden separates

5.

HIGBY AND LAMENTATION MOUNTAINS.

these two mountains, while the greater fault which runs west of Meriden cuts off the north end of Lamentation. The view of these mountains is highly suggestive.

The extension of the faults to the northeast and southwest of the trap ridges is seldom traceable very far. Southwest of the anterior trap ridge, the country is generally soon covered with drift; but occasionally certain beds of conglomerate serve to indicate the course of a fault, as is the case with the great fault between the Hanging Hills and Lamentation Mountain, which may be followed two miles southwest of Meriden. To the northeast, the occurrence of a second posterior ridge in certain localities may in time serve to unravel the fault lines, as it has already for the fault between Chauncy Peak and Higby Mountain, which is thus traced about three miles to the northeast of the gap that it produces in the main sheet. All these localities are given in detail in the itinerary of the summer school, as above.

The systematic arrangement of the faults in this district, already mentioned in earlier papers, is thus confirmed. When this is once perceived, it is evident that the normal sequence of the Triassic beds can be found only by crossing the monocline obliquely to the northeast, always keeping within the limits of a single fault-block. This seems to me to be the key to the structure of the region. The remainder of this paper is occupied with considerations not discussed in the Bulletin.

The mechanism suggested to account for the production of a monocline with its system of faults thus arranged has been in the mind of other writers. Some fourteen years ago, Mr. G. K. Gilbert conceived its essential features, and gave a brief account of it in his description of the Great Basin Ranges.* He made the theoretical suggestion "that in the case of the Appalachians, the primary phenomena are superficial; and in that of the Basin Ranges they are deep-seated, the superficial being secondary; that such a force as has crowded together the strata of the Appalachians—whatever may have been its

* Wheeler's Surveys west of the 100th Meridian, iii, 1875, 62.

source—has acted in the Ranges on some portion of the earth's crust beneath the immediate surface; and the upper strata, by continually adapting themselves, under gravity, to the inequalities of the lower, have assumed the forms we see. Such a hypothesis, assigning to subterranean determination the position and direction of lines of uplift in the Range system, and leaving the character of the superficial phenomena to depend on the character and condition of the superficial materials, accords well with many of the observed facts, and especially with the persistence of ridges where structures are changed." The essential peculiarities of the method for the production of a faulted monocline is here clearly stated, although no opportunity is noted for independent verification of the suggestion, such as appears in Connecticut in the correspondence between the course of the faults and the trend of the underlying schists.

In my previous paper concerning the origin of the faulted monocline, no special consideration was given to the cause of the discordance between the course of the faults and the strike of the beds in the Meriden region, which now appears as so strong a structural characteristic. It may be suggested that this is the result of a force of compression acting on the whole mass of crystalline and overlying rocks in a direction oblique to the strike of the schists, whose structure determines the course of the faults. The schists trending northeast and the compression being exerted from west to east so that movement of any point in the schists must take place in an east and west vertical plane, a result such as that which here obtains might be produced. A consequence of this would appear in the much greater uplift given to the southwestern than to the northeastern part of any block thus obliquely tilted; but the unworn surface of any block would slope eastward, in the direction of the dip of its beds. When deeply eroded, the older members of the series of tilted beds would be revealed in the southwestern part of the block; while the newer still remain in the northeastern part, as we find them.

The topographic development of the Meriden region and indeed of the valley as a whole, may be briefly sketched. Its early structural topography, such as would have resulted from its dislocation without erosion, finds modern illustration in the tilted lava blocks of Southern Idaho, as described by Russell. This writer, from whose vivid descriptions we derive so clear a picture of our western country, says that the whole of the Great Basin—the "immense region lying between the Sierra Nevada and the Rocky Mountain systems has been broken by a multitude of fractures, having an approximately north and south trend, that divide the region into long, narrow, orographic blocks. These have been tilted so as to form small but extremely rugged mountain ranges, often from fifty to a hundred miles in length, with a width of but a few miles."—The fractures by which the blocks are separated "are of a comparatively recent date, and present bold scarps, that are frequently but slightly scarred by erosion, while the most recent examples of all were unquestionably formed within the past few years, and are yet unclothed by vegetation." . . . "The exhibition of fault-scarps, tilted blocks, and sunken areas, to be seen at the southern end of the Warner Lakes, is the most interesting of its kind that it has ever been our privilege to examine. In this narrow zone, the orographic blocks of dark volcanic rock are literally tossed about like the cakes of ice in an ice-floe; their upturned edges forming bold palisades that render the region all but impassable." . . . "These fault-scarps rise in sheer precipices that overshadow the Warner Lakes throughout their entire extent. Toward the northern end of the valley the great fault-scarp forming its eastern wall sends off a number of branches, at quite regular intervals, with a general northwest trend. The blocks thus separated pass under the lake beds that floor the valley, and appear again on its western border, where they form cliffs of considerable height." . . . "It is between the high walls enclosing the southern portion of the valley that the greatest confusion of the minor blocks is to be seen. Many of these fragments measure a mile or so on their edges and are tilted in various directions, leaving narrow rugged valleys between their upturned margins. The diverse tilting and the numerous fault-scarps that rise without system into naked precipices combine to make this a region of the roughest and wildest description." (Fourth Ann. Report U. S. G. S., 443, 445, 446.)

It is apparent from these extracts and from others that could be quoted that while southern Oregon has a more complicated structure than that of the Connecticut Trias, it nevertheless serves admirably as a picture of the early stages of the latter, when its faults were still growing: except in the matter of diverse displacement and in the amount of erosion suffered, the description of these long narrow blocks might apply to those of the Connecticut valley.

The blocks in Idaho have been dislocated so rapidly and so recently that they preserve their constructional topography with insignificant alteration, and in this they are the best examples of any region yet described. Nowhere else can we find so good an illustration of a mountain system in its infancy—almost in its birth. A similar constructional topography probably once existed in Connecticut; but it has long since disappeared. The upper surface of the Triassic region being of shales or sandstones, instead of hard sheets of lava, presumably allowed erosion to follow displacement rapidly, but it seems highly probable that the topography of the region was for a considerable time closely consequent on the deformations that closed the period of deposition and ushered in the long cycle of erosion that has since then endured with little interruption.

As time went on and the forces of deformation slackened, the forces of erosion made better headway in reducing the region to a water-sculptured topography; we find existing illustration of this stage of the history of central Connecticut, in the present form of the central ranges of the Great Basin. The following description is also condensed from accounts by Russell.

The central ranges of the Great Basin are structurally composed of long narrow blocks of bedded, aqueous and igneous rocks separated by faults and tilted into monoclinal attitudes; but the simple original structural form that they may once have had is now no longer immediately apparent; the orographic blocks here have been long enough exposed to denudation to reduce them to a water-sculptured form, in which the slopes are trenched by numerous ravines, and the ridges are notched by passes which break the crest-line into peaks, and everywhere develop topographic detail dependent on the unequal hardness of the bedded components of the mass. Much of the detritus taken from the upper portions is now lodged in the depressions between the adjacent ranges. Variety of form has thus been gained, and a marked feature of this variety is that it all tends to the better collection and discharge of the rain that falls upon the ranges. The topographic variety is now near its fullest development, and with further denudation it must lose strength; the ravines will consume more of the mass, the passes will be lowered and the peaks will be attacked and reduced from all sides. The original structural form will be then even less distinct than now, and a continually closer approach will be made to the ultimate featureless base-level lowland, to which all land forms are in time reduced, if no disturbance, such as elevation, interrupt the normal simple progress of their geographic evolution.

Some mountainous variety of form must in a similar manner have obtained for a time in central Connecticut and Massachusetts, when the strongly faulted monoclinal blocks were laterally furrowed by ravines and notched by passes. This may be provisionally called the Jurassic stage of the evolution of our district. But even mountainous ridges are not permanent. Given time enough, and the faulted ridges of Connecticut must be reduced to a low base-level plain. I believe that time enough has already been allowed, and that the strong Jurassic topography was really worn out somewhere in Cretaceous time, when all this part of the country was reduced to a nearly featureless plain, a "*peneplain*," as I would call it, at a low level; a plain that was broadly uplifted in early Tertiary time—or thereabouts—and thus thrown into another cycle of destructive development, and whose elevated remnants are now to be recognized in the crystalline uplands on either side of the present Triassic valley of Connecticut and Massachusetts (Emerson), and in the crest-line summits of the main trap ridges. The general equality of upland altitude on very diverse structures is the essential argument for the base-leveling of the region; but it is not intended to discuss this in detail at present. The post-cretaceous elevation that lifted the ancient lowlands was greater in the interior than near the coast, and our present valleys are deeply sunk and broadly opened in it. An extension of the same ancient lowland, now similarly elevated and dissected, is to be found in northern New Jersey. Standing on a commanding point of view, such as the fine drumlin a mile or more southeast of Meriden, whence the main trap ridges may be seen for many miles north and south, one must in imagination refill the low ground with the shales, sandstones and conglomerates that have been worn away, and thus raise the surface up to the level of the main trap ridges, or even a little higher, in order to perceive the form attained by the land in the late stage of the degradation of the dislocated Triassic blocks, when all this region stood lower. It was only after the close of this first cycle of degradation and after the elevation of the country to something like its actual altitude at a later date that the beginning of the present or second cycle of valley-making was reached. Some unmeasured part of the Tertiary and later time has been allowed for this part of the work. In the crystalline rocks, the valleys are narrow and steep sided, as is so finely shown in the expressive topographic map-sheets of western Massachusetts; but in the Triassic area, where the sandstones are relatively soft, the valleys have been widened out into broad lowlands, only the thicker trap-sheets retaining still some indication of their former altitude. The latest touches have been given to their form by glacial action, both destructive and constructive, as well as by river deposits in the valley bottoms and by estuary deposits in the coastal districts. Except in terrace and gorge cutting, post-glacial erosion is insignificant. If this sketch be correct, we may conclude that the present topography is not an immediate product of erosion on the Jurassic deformations of the Triassic beds; it is an uncompleted advance in a second cycle of development, with recent complications by glacial action and slight changes of level. Like mountains of repeated growth, this topography may be called "polygenetic." The present form of the region is modeled with reference to at least two base-levels.

Just as southern Idaho and central Nevada furnish illustration of the initial and somewhat advanced topographic forms assumed in the development of our Connecticut district, so there will doubtless be found somewhere on the earth, regions of similar structure, presenting actual illustrations of its later stages, when its stronger forms were subdued and finally worn down to the featureless surface or peneplain of its old age. Thus the evolution of the region will be better understood. By this process of comparison,* we may not only restore in some measure the past history of our region, but may as well look into its possible future. When later elevation raises our eastern continental slope to still greater altitude and exposes the mass of the land to still deeper attack by erosive forces, it may happen that the base-level will take such a position as to allow the discovery of the ridges of fundamental crystallines between the fault lines at the base of the Triassic trough; and this stage has its forerunner in a district of northern China (Shantung), described by Richthofen.† The structure of the district is summarized as consisting of crystalline schists of steep dip, unconformably overlain by Cambrian sediments; this compound mass is broken by a system of sub-parallel faults running east or southeast, with upthrow on the southern side, and with a tilting of the faulted blocks by which the uncomformable cover of Cambrian sediments dips southward toward the faults. The deformation is ancient, and subsequent denudation has exposed the fundamental crystallines in long narrow ridges, which by their superior hardness have become water sheds (whether they have always been so or not does not appear, as the successive cycles of river history from the first to the present are not deciphered), while the Cambrian sediments remain in narrow monoclinal strips between every ridge and the next fault to the south. The bottom of our Connecticut trough may some day be worn into similar ridges and valleys.

* During the preparation of this paper, I have had pleasure in meeting evidence of the value of the method here outlined in an essay by Dr. V. Hilber of Graz, Austria In discussing the origin of cross-valleys, he suggests an inductive illustration of their development, as follows: "Auch eine Methode welche in der vergleichende Erdkunde noch kaum Anwendung gefunden hat, welche aber auch für andre Fragen derselben berücksichtigenswert erscheint . . . . ist das Aufsuchen derjenigen Oberflächenformen, welche als Entwickelungsstadien der vollendeten Erscheinung betrachtet werden können." Die Bildung der Durchgangsthäler, Pet. Mitth, xxxv, 1889, 15.

† China, II, 239, Fig. 56. See also Philippson, Studien über Wasserscheiden, 119.

There is a peculiarity of the drainage of the Triassic belt that perhaps finds explanation through considerations such as the above. The Connecticut river from where it receives the Passumpsic between northern New Hampshire and Vermont, follows a line of ancient slates that lead it southward with direct course to the Triassic formation in northern Massachusetts; it crosses this State with tolerably direct southern course and continues in much the same line across Connecticut as far as Hartford; but there it turns to the southeast, and at Middletown it leaves the soft Triassic rocks and enters the hard crystallines, which it follows through a deep and rather steep-sided valley to the Sound at Saybrook. This departure from the low escape now open to the river along the line of easy grades that is followed by the Consolidated railroad from Hartford to New Haven, calls for some special explanation. It is evidently an example of the same kind as those described by Jukes in his famous paper, "On the mode of formation of some of the river valleys in the south of Ireland." But it remains to be seen why the Connecticut should turn from the Triassic belt of soft sandstones which here might lead it to the sea, and why if so turning it should take a course to the southeast rather than to the southwest.

Let it be admitted for the moment that the present course of the river is in the main inherited from the course that it had at the end of the development of the Cretaceous lowland; and that the course that it had during this early cycle of development was consequent upon the original dislocations of the Triassic surface. It is natural enough that the initial drainage of a faulted area should be consequent; we have excellent illustrations of immediately consequent drainage in the lava block country of southern Idaho, already referred to. Now if we can independently determine the probable direction of consequent drainage immediately after the time of dislocation in the lower Connecticut valley, and if this correspond to the present course of the Connecticut where it turns from the Triassic to the Crystalline rocks, the explanation offered may be at least deemed worthy of further examination.

The simplest method of determining the direction of the initial consequent drainage of the dislocated Triassic surface involves a reconstruction of the primitive form that the surface would have had if its dislocation had not been accompanied by erosion; the "structural surface" of la Noë and Margerie. This may be done most easily by developing the surface of the great lava flow that we now call the main trap sheet; restoring its lost portions by extending it upwards into the air along the plane of its dip, and stripping it bare where still covered; but limiting every part of the reconstructed surface by the fault planes that bound the several blocks. The original surface of the uppermost bed of sandstone would have been essentially parallel to this surface of the trap sheet, but a few thousand feet higher.

Percival long ago called attention to the great curve of the main trap sheet from the Hanging Hills to Mount Holyoke in Massachusetts. The restored surface of the sheet, although somewhat interrupted by faults, forms a great half-boat, with the keel along the line joining the ends of the curve and the western side of the boat following the main trap ridge. The boat may be enlarged by extending the sheet southeast from the Hanging Hills through Lamentation, Higby (Besick), Paug and Toket Mountains to the eastern margin of the Triassic formation north of Branford. In this portion of the curve, the faults are much stronger than farther north; but viewed in a large way, the whole sheet from Toket to Holyoke may be regarded as a somewhat broken half-boat, in the attitude already described, with the bow at Belchertown, Massachusetts, and the stern above Branford, Connecticut. Before the Cretaceous base-leveling was completed, the western side of the half-boat reached much higher into the air than the crests of the main ridges reach now.

The upper surface of the Triassic formation would have had a form similar to this, if not eroded. A drainage-system established upon it must have found outlet not to the west or south, where the side and the stern of the boat prevented discharge, but to the east, where the boat was open, and the location of the discharge would be somewhere about the lowest point of the keel. In other words, the chief stream of the region, during the early development of the dislocated country, would have run out to the east, some distance north of the point where the main sheet now reaches the crystalline rocks on the eastern margin of the formation. This corresponds with the general course of the Connecticut closely enough to give some degree of acceptance to the explanation; and the lower Connecticut may therefore be tentatively classified as an originally consequent stream, which has lived far through one cycle of life, and has now in obedience to the general elevation of its drainage area, entered a second cycle in which it is well advanced, still persisting more or less closely in the course chosen in its first cycle.

Thus explained, it may be called in this portion of its valley a revived river of originally consequent course. It is not intended to imply that the dislocated Triassic region ever had a purely "structural surface;" but only to indicate that the summation of all the movements of deformation, which would produce such a surface, sufficed to throw the drainage of the region into the area of least elevation.

The objection to the explanation does not seem to me to be in its inherent improbability, for I believe that every step in the process may find its homologue in the present stage of other regions of similar structure but less age. The objection lies rather in a difficulty not yet named; namely in the occurrence of a strong fault or series of faults, by which the eastern margin of the formation is determined, and whose upthrow is on the east. The drainage from the centripetal slopes of the Triassic half-boat must have surmounted this barrier in order to flow to Saybrook, and in doing so may have formed a large lake in the bottom of the boat, to be drained later on when the outlet was deepened. Whether suppositions so transcendental as these shall be approved remains to be seen.

Cambridge, Mass., February, 1889.