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THE

NATIONAL GEOGRAPHIC MAGAZINE.

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THE RIVERS AND VALLEYS OF PENNSYLVANIA.*

By William Morris Davis.

"In Faltensystemen von sehr hohem Alter wurde die ursprüngliche Anordnung der Langenthäler durch das Ueberhandnehmen der transversalen Erosionsfurchen oft ganz und gar verwischt."

Löwl. Petermann's Mittheilungen, xxviii, 1882, 411.

CONTENTS.

* The substance of this essay was presented to the Society in a lecture on February 8th, 1889, but since then it has been much expanded.

PART FIRST. *Introductory.*

1. *Plan of work here proposed.*—No one now regards a river and its valley as ready-made features of the earth's surface. All are convinced that rivers have come to be what they are by slow processes of natural development, in which every peculiarity of river-course and valley-form has its appropriate cause. Being

fully persuaded of the gradual and systematic evolution of topographic forms, it is now desired, in studying the rivers and valleys of Pennsylvania, to seek the causes of the location of the streams in their present courses; to go back if possible to the early date when central Pennsylvania was first raised above the sea and trace the development of the several river systems then implanted upon it from their ancient beginning to the present time.

The existing topography and drainage system of the State will first be briefly described. We must next inquire into the geological structure of the region, follow at least in a general way the deformations and changes of attitude and altitude that it has suffered, and consider the amount of denudation that has been accomplished on its surface. We must at the same time bear in mind the natural history of rivers, their morphology and development; we must recognize the varying activities of a river in its youth and old age, the adjustments of its adolescence and maturity, and the revival of its decrepit powers when the land that it drains is elevated and it enters a new cycle of life. Finally we shall attempt to follow out the development of the rivers of Pennsylvania by applying the general principles of river history to the special case of Pennsylvania structure.

2. *General description of the topography of Pennsylvania.*—The strongly marked topographic districts of Pennsylvania can hardly be better described than by quoting the account given over a century ago by Lewis Evans, of Philadelphia, in his "Analysis of a map of the middle British colonies in America" (1755), which is as valuable from its appreciative perception as it is interesting from its early date. The following paragraphs are selected from his early pages:

"The land southwestward of Hudson's River is more regularly divided and into a greater number of stages than the other. The first object worthy of regard in this part is a rief or vein of rocks of the talky or isinglassy kind, some two or three or half a dozen miles broad; rising generally some small matter higher than the adjoining land; and extending from New York city southwesterly by the lower falls of Delaware, Schuylkill, Susquehanna, Gun-Powder, Patapsco, Potomack, Rapahannock, James river and Ronoak. This was the antient maritime boundary of America and forms a very regular curve. The land between this rief and the sea and from the Navesink hills southwest . . . . . may be denominated the Lower Plains, and consists of soil washt down from above and sand accumulated from the ocean. Where these plains are not penetrated by rivers, they are a white sea-sand, about twenty feet deep and perfectly barren, as no mixture of soil helps to enrich them. But the borders of the rivers, which descend from the uplands, are rendered fertile by the soil washt down with the floods and mixt with the sands gathered from the sea. The substratum of sea-mud, shells and other foreign subjects is a perfect confirmation of this supposition. And hence it is that for 40 or 50 miles inland and all the way from the Navesinks to Cape Florida, all is a perfect barren where the wash from the uplands has not enriched the borders of the rivers; or some ponds and defiles have not furnished proper support for the growth of white cedars. . . . . .

"From this rief of rocks, over which all the rivers fall, to that chain of broken hills, called the South mountain, there is the distance of 50, 60 or 70 miles of very uneven ground, rising sensibly as you advance further inland, and may be denominated the Upland. This consists of veins of different kinds of soil and substrata some scores of miles in length; and in some places overlaid with little ridges and chains of hills. The declivity of the whole gives great rapidity to the streams; and our violent gusts of rain have washt it all into gullies, and carried down the soil to enrich the borders of the rivers in the Lower Plains. These inequalities render half the country not easily capable of culture, and impoverishes it, where torn up by the plow, by daily washing away the richer mould that covers the surface.

"The South mountain is not in ridges like the Endless mountains, but in small, broken, steep, stoney hills; nor does it run with so much regularity. In some places it gradually degenerates to nothing, not to appear again for some miles, and in others it spreads several miles in breadth. Between South mountain and the hither chain of the Endless mountains (often for distinction called the North mountain, and in some places the Kittatinni and Pequélin), there is a valley of pretty even good land, some 8, 10 or 20 miles wide, and is the most considerable quantity of valuable land that the English are possest of; and runs through New Jersey, Pensilvania, Mariland and Virginia. It has yet obtained no general name, but may properly enough be called Piemont, from its situation. Besides conveniences always attending good land, this valley is everywhere enriched with Limestone.

"The Endless mountains, so called from a translation of the Indian name bearing that signification, come next in order. They are not confusedly scattered and in lofty peaks overtopping one another, but stretch in long uniform ridges scarce half a mile perpendicular in any place above the intermediate vallies. Their name is expressive of their extent, though no doubt not in a literal sense. . . . . . The mountains are almost all so many ridges with even tops and nearly of a height. To look from these hills into the lower lands is but, as it were, into an ocean of woods, swelled and deprest here and there by little inequalities, not to be distinguished one part from another any more than the waves of the real ocean. The uniformity of these mountains, though debarring us of an advantage in this respect, makes some amends in another. They are very regular in their courses, and confine the creeks and rivers that run between; and if we know where the gaps are that let through these streams, we are not at a loss to lay down their most considerable inflections. . . . . .

"To the northwestward of the Endless mountains is a country of vast extent, and in a manner as high as the mountains themselves. To look at the abrupt termination of it, near the sea level, as is the case on the west side of Hudson's river below Albany, it looks as a vast high mountain; for the Kaats Kills, though of more lofty stature than any other mountains in these parts of America, are but the continuation of the Plains on the top, and the cliffs of them in the front they present towards Kinderhook. These Upper Plains are of extraordinary rich level land, and extend from the Mohocks river through the country of the Confederates.* Their termination northward is at a little distance from Lake Ontario; but what it is westward is not known, for those most extensive plains of Ohio are part of them."

These several districts recognized by Evans may be summarized as the coastal plain, of nearly horizontal Cretaceous and later beds, just entering the southeastern corner of Pennsylvania; the marginal upland of contorted schists of disputed age; the South Mountain belt of ancient and much disturbed crystalline rocks, commonly called Archean; a space between these two traversed by the sandstone lowland of the Newark formation;† the great Appalachian valley of crowded Cambrian limestones and slates; the region of the even-crested, linear Paleozoic ridges, bounded by Kittatinny or Blue mountain on the southeast and by Alleghany mountain on the northwest, this being the area with which we are here most concerned; and finally the Alleghany plateau, consisting of nearly horizontal Devonian and Carboniferous beds and embracing all the western part of the state. The whole region presents the most emphatic expression not only of its structure but also of the more recent cycles of development through which it has passed. Fig. 1 represents the stronger ridges and larger streams of the greater part of the central district: it is reproduced from the expressive Topographic Map of Pennsylvania (1871) by Lesley. The Susquehanna flows down the middle, receiving the West Branch from Lock Haven

* Referring to the league of Indian tribes, so-called.

† Russell has lately recommended the revival of this term, proposed many years ago by Redfield, as a non-committal name for the "New red sandstones" of our Atlantic slope, commonly called Triassic.

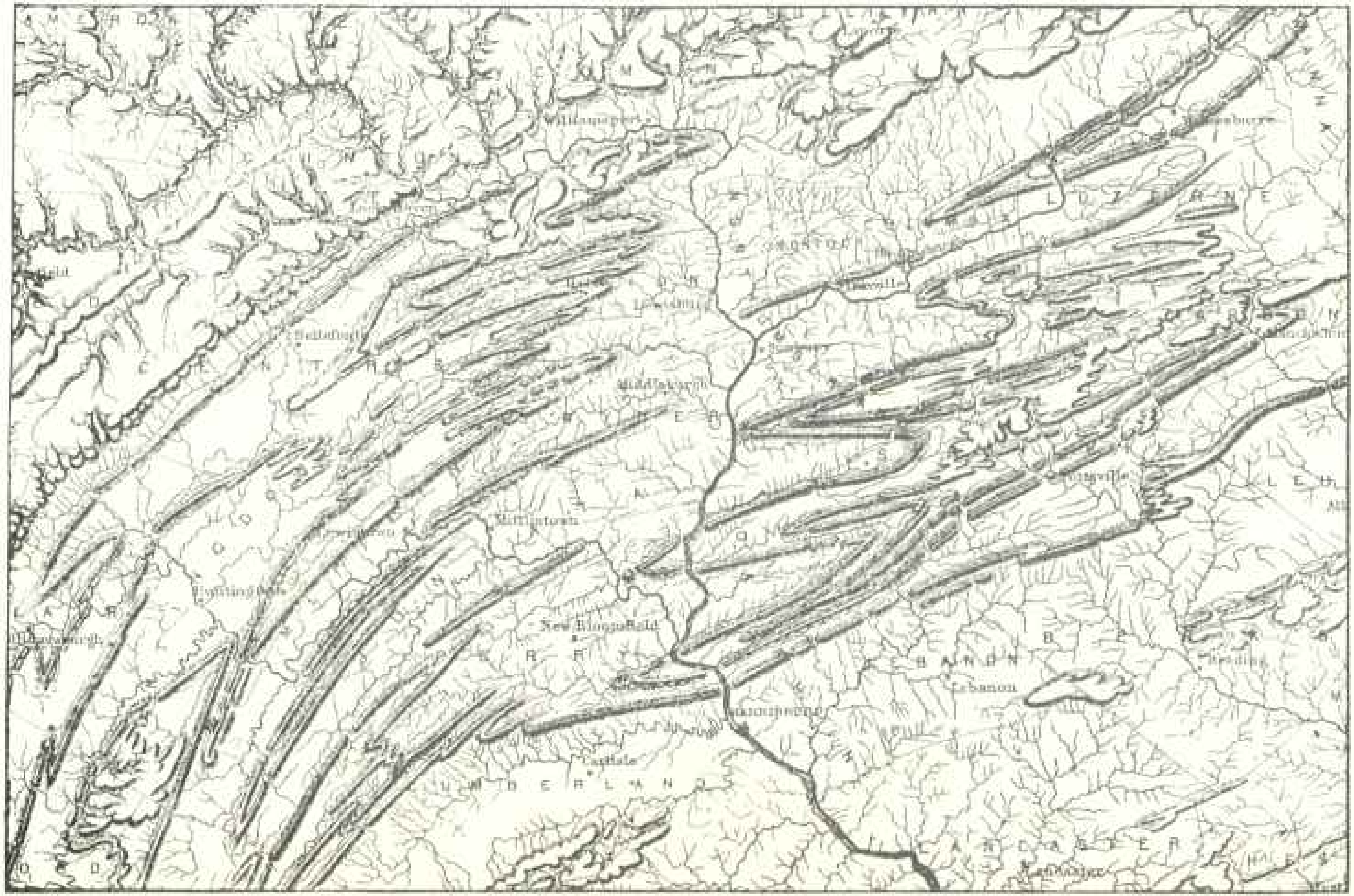


Fig. 1. Part of Topographic Map of Pennsylvania, by J. P. Lesley (1871).

and Williamsport, the East Branch from Wilkes-Barre in the Wyoming basin, and the Juniata from the Broad Top region, south of Huntingdon. The Anthracite basins lie on the right, enclosed by zigzag ridges of Pocono and Pottsville sandstone; the Plateau, trenched by the West Branch of the Susquehanna is in the northwest. Medina sandstone forms most of the central ridges.

3. *The drainage of Pennsylvania.*—The greater part of the Alleghany plateau is drained westward into the Ohio, and with this we shall have little to do. The remainder of the plateau drainage reaches the Atlantic by two rivers, the Delaware and the Susquehanna, of which the latter is the more special object of our study. The North and West Branches of the Susquehanna rise in the plateau, which they traverse in deep valleys; thence they enter the district of the central ranges, where they unite and flow in broad lowlands among the even-crested ridges. The Juniata brings the drainage of the Broad Top region to the main stream just before their confluent current cuts across the marginal Blue Mountain. The rock-rimmed basins of the anthracite region are drained by small branches of the Susquehanna northward and westward, and by the Schuylkill and Lehigh to the south and east. The Delaware, which traverses the plateau between the Anthracite region and the Catskill Mountain front, together with the Lehigh, the Schuylkill, the little Swatara and the Susquehanna, cut the Blue Mountain by fine water-gaps, and cross the great limestone valley. The Lehigh then turns eastward and joins the Delaware, and the Swatara turns westward to the Susquehanna; but the Delaware, Schuylkill and Susquehanna all continue across South Mountain and the Newark belt, and into the low plateau of schists beyond. The Schuylkill unites with the Delaware near Philadelphia, just below the inner margin of the coastal plain; the Delaware and the Susquehanna continue in their deflected estuaries to the sea. All of these rivers and many of their side streams are at present sunk in small valleys of moderate depth and width, below the general surface of the lowlands, and are more or less complicated with terrace gravels.

4. *Previous studies of Appalachian drainage.*—There have been no special studies of the history of the rivers of Pennsylvania in the light of what is now known of river development. A few recent essays of rather general character as far as our rivers are concerned, may be mentioned.

Peschel examined our rivers chiefly by means of general maps with little regard to the structure and complicated history of the region. He concluded that the several transverse rivers which break through the mountains, namely, the Delaware, Susquehanna and Potomac, are guided by fractures, anterior to the origin of the rivers.* There does not seem to be sufficient evidence to support this obsolescent view, for most of the water-gaps are located independently of fractures; nor can Peschel's method of river study be trusted as leading to safe conclusions.

Tietze regards our transverse valleys as antecedent;† but this was made only as a general suggestion, for his examination of the structure and development of the region is too brief to establish this and exclude other views.†

Löwl questions the conclusion reached by Tietze and ascribes the transverse gaps to the backward or headwater erosion of external streams, a process which he has done much to bring into its present important position, and which for him replaces the persistence of antecedent streams of other authors.‡

A brief article§ that I wrote in comment on Löwl's first essay several years ago now seems to me insufficient in its method. It exaggerated the importance of antecedent streams; it took no sufficient account of the several cycles of erosion through which the region has certainly passed; and it neglected due consideration of the readjustment of initial immature stream courses during more advanced river-life. Since then, a few words in Löwl's essay have come to have more and more significance to me; he says that in mountain systems of very great age, the original arrangement of the longitudinal valleys often becomes entirely confused by means of their conquest by transverse erosion gaps. This suggestion has been so profitable to me that I have placed the original sentence at the beginning of this paper. Its thesis is the essential element of my present study.

Phillipson refers to the above-mentioned authors and gives a brief account of the arrangement of drainage areas within our Appalachians, but briefly dismisses the subject.‖ His essay contains a serviceable bibliography.

If these several earlier essays have not reached any precise

* Physische Erdkunde, 1880, ii, 442.

† Jahrbuch Geol. Reichsanstalt, xxviii, 1878, 600.

‡ Pet. Mitth., 1882, 405; Ueber Thalbildung, Prag, 1884.

§ Origin of Cross-valleys. Science, i, 1883, 325.

‖ Studien über Wasserscheiden. Leipsig, 1886, 149.

conclusion, it may perhaps be because the details of the geological structure and development of Pennsylvania have not been sufficiently examined. Indeed, unless the reader has already become familiar with the geological maps and reports of the Pennsylvania surveys and is somewhat acquainted with its geography, I shall hardly hope to make my case clear to him. The volumes that should be most carefully studied are, first, the always inspiring classic, "Coal and its Topography" (1856), by Lesley, in which the immediate relation of our topography to the underlying structure is so finely described; the Geological Map of Pennsylvania (1858), the result of the labors of the first survey of the state; and the Geological Atlas of Counties, Volume X of the second survey (1885). Besides these, the ponderous volumes of the final report of the first survey and numerous reports on separate counties by the second survey should be examined, as they contain many accounts of the topography although saying very little about its development. If, in addition to all this, the reader has seen the central district of the state and marvelled at its even-crested, straight and zigzag ridges, and walked through its narrow water-gaps into the enclosed coves that they drain, he may then still better follow the considerations here presented.

PART SECOND. *Outline of the geological history of the region.*

5. *Conditions of formation.*—The region in which the Susquehanna and the neighboring rivers are now located is built in chief part of marine sediments derived in paleozoic time from a large land area to the southeast, whose northwest coast-line probably crossed Pennsylvania somewhere in the southeastern part of the state; doubtless varying its position, however, by many miles as the sea advanced and receded in accordance with the changes in the relative altitudes of the land and water surfaces, such as have been discussed by Newberry and Claypole. The sediments thus accumulated are of enormous thickness, measuring twenty or thirty thousand feet from their crystalline foundation to the uppermost layer now remaining. The whole mass is essentially conformable in the central part of the state. Some of the formations are resistent, and these have determined the position of our ridges; others are weaker and are chosen as the sites of valleys and lowlands. The first are the Oneida and Medina sandstones, which will be here generally referred to under the latter name alone, the Pocono sandstone and the Pottsville conglomerate; to these may be added the fundamental crystalline mass on which

the whole series of bedded formations was deposited, and the basal sandstone that is generally associated with it. Wherever we now see these harder rocks, they rise above the surrounding lowland surface. On the other hand, the weaker beds are the Cambrian limestones (Trenton) and slates (Hudson River), all the Silurian except the Medina above named, the whole of the Devonian—in which however there are two hard beds of subordinate value, the Oriskany sandstone and a Chemung sandstone and conglomerate, that form low and broken ridges over the softer ground on either side of them—and the Carboniferous (Mauch Chunk) red shales and some of the weaker sandstones (Coal measures).

6. *Former extension of strata to the southeast.*—We are not much concerned with the conditions under which this great series of beds was formed; but, as will appear later, it is important for us to recognize that the present southeastern margin of the beds is not by any means their original margin in that direction. It is probable that the whole mass of deposits, with greater or less variations of thickness, extended at least twenty miles southeast of Blue Mountain, and that many of the beds extended much farther. The reason for this conclusion is a simple one. The several resistant beds above-mentioned consist of quartz sand and pebbles that cannot be derived from the underlying beds of limestones and shales; their only known source lay in the crystalline rocks of the paleozoic land to the southeast. South Mountain may possibly have made part of this paleozoic land; but it seems more probable that it was land only during the earlier Archean age, and that it was submerged and buried in Cambrian time and not again brought to the light of day until it had been crushed into many local anticlines* whose crests were uncovered by Permian and later erosion. The occurrence of Cambrian limestone on either side of South Mountain, taken with its compound anticlinal structure, makes it likely that Medina time found this crystalline area entirely covered by the Cambrian beds; Medina sands must therefore have come from farther still to the southeast. A similar argument applies to the source of the Pocono and Pottsville beds. The measure of twenty miles as the former southeastern extension of the paleozoic formations therefore seems to be a moderate one for the average of the whole series; perhaps forty would be nearer the truth.

* Lesley, as below.

7. *Cambro-Silurian and Permian deformations.*—This great series of once horizontal beds is now wonderfully distorted; but the distortions follow a general rule of trending northeast and southwest, and of diminishing in intensity from southeast to northwest. In the Hudson Valley, it is well known that a considerable disturbance occurred between Cambrian and Silurian time, for there the Medina lies unconformably on the Hudson River shales. It seems likely, for reasons that will be briefly given later on, that the same disturbance extended into Pennsylvania and farther southwest, but that it affected only the southeastern corner of the State; and that the unconformities in evidence of it, which are preserved in the Hudson Valley, are here lost by subsequent erosion. Waste of the ancient land and its Cambro-Silurian annex still continued and furnished vast beds of sandstone and sandy shales to the remaining marine area, until at last the subsiding Paleozoic basin was filled up and the coal marshes extended broadly across it. At this time we may picture the drainage of the southeastern land area wandering rather slowly across the great Carboniferous plains to the still submerged basin far to the west; a condition of things that is not imperfectly represented, although in a somewhat more advanced stage, by the existing drainage of the mountains of the Carolinas across the more modern coastal plain to the Atlantic.

This condition was interrupted by the great Permian deformation that gave rise to the main ranges of the Appalachians in Pennsylvania, Virginia and Tennessee. The Permian name seems appropriate here, for while the deformation may have begun at an earlier date, and may have continued into Triassic time, its culmination seems to have been within Permian limits. It was characterized by a resistless force of compression, exerted in a southeast-northwest line, in obedience to which the whole series of Paleozoic beds, even twenty or more thousand feet in thickness, was crowded gradually into great and small folds, trending northeast and southwest. The subjacent Archean terrane doubtless shared more or less in the disturbance: for example, South Mountain is described by Lesley as "not one mountain, but a system of mountains separated by valleys. It is, geologically considered, a system of anticlinals with troughs between. . . . . . It appears that the South Mountain range ends eastward [in Cumberland and York Counties] in a hand with five [anticlinal] fingers."*

* Proc. Amer. Phil. Soc., xiii, 1873, 6.

It may be concluded with fair probability that the folds began to rise in the southeast, where they are crowded closest together, some of them having begun here while coal marshes were still forming farther west; and that the last folds to be begun were the fainter ones on the plateau, now seen in Negro mountain and Chestnut and Laurel ridges. In consequence of the inequalities in the force of compression or in the resistance of the yielding mass, the folds do not continue indefinitely with horizontal axes, but vary in height, rising or falling away in great variety. Several adjacent folds often follow some general control in this respect, their axes rising and falling together. It is to an unequal yielding of this kind that we owe the location of the Anthracite synclinal basins in eastern Pennsylvania, the Coal Measures being now worn away from the prolongation of the synclines, which rise in either direction.

8. *Perm-Triassic denudation.*—During and for a long time after this period of mountain growth, the destructive processes of erosion wasted the land and lowered its surface. An enormous amount of material was thus swept away and laid down in some unknown ocean bed. We shall speak of this as the Perm-Triassic period of erosion. A measure of its vast accomplishment is seen when we find that the Newark formation, which is generally correlated with Triassic or Jurassic time, lies unconformably on the eroded surface of Cambrian and Archean rocks in the southeastern part of the State, where we have concluded that the Paleozoic series once existed; where the strata must have risen in a great mountain mass as a result of the Appalachian deformations; and whence they must therefore have been denuded before the deposition of the Newark beds. Not only so; the moderate sinuosity of the southeastern or under boundary of the Newark formation indicates clearly enough that the surface on which that portion of the formation lies is one of no great relief or inequality; and such a surface can be carved out of an elevated land only after long continued denudation, by which topographic development is carried beyond the time of its greatest strength or maturity into the fainter expression of old age. This is a matter of some importance in our study of the development of the rivers of Pennsylvania; and it also constitutes a good part of the evidence already referred to as indicating that there must have been some earlier deformations of importance in the southeastern part of the State; for it is hardly conceivable that the great Paleozoic

mass could have been so deeply worn off of the Newark belt between the making of the last of the coal beds and the first of the Newark. It seems more in accordance with the facts here recounted and with the teachings of geological history in general to suppose, as we have here, that something of the present deformation of the ancient rocks underlying the Newark beds was given at an early date, such as that of the Green Mountain growth; and that a certain amount of the erosion of the folded beds was thus made possible in middle Paleozoic time; then again at some later date, as Permian, a second period of mountain growth arrived, and further folding was effected, and after this came deeper erosion; thus dividing the destructive work that was done into several parts, instead of crowding it all into the post-Carboniferous time ordinarily assigned to it. It is indeed not impossible that an important share of what we have called the Permian deformation was, as above suggested, accomplished in the southeastern part of the State while the coal beds were yet forming in the west; many grains of sand in the sandstones of the Coal Measures may have had several temporary halts in other sandstone beds between the time of their first erosion from the Archean rocks and the much later time when they found the resting place that they now occupy.*

9. *Newark deposition.*—After the great Paleozoic and Perm-Triassic erosions thus indicated, when the southeastern area of ancient mountains had been well worn down and the Permian folds of the central district had acquired a well developed drainage, there appeared an opportunity for local deposition in the slow depression of a northeast-southwest belt of the deeply wasted land, across the southeastern part of the State; and into this trough-like depression, the waste from the adjacent areas on either side was carried, building the Newark formation. This may be referred to as the Newark or Trias-Jurassic period of deposition. The volume of this formation is unknown, as its thickness and original area are still undetermined; but it is pretty surely of many thousand feet in vertical measure, and its original area may have been easily a fifth or a quarter in excess of its present area, if not larger yet. So great a local accumulation seems to indicate that while the belt of deposition was

* These considerations may have value in showing that the time in which the lateral crushing of the Appalachians was accomplished was not so brief as is stated by Reade in a recent article in the American Geologist, iii, 1889, 106.

sinking, the adjacent areas were rising, in order to furnish a continual supply of material; the occurrence of heavy conglomerates along the margins of the Newark formation confirms this supposition, and the heavy breccias near Reading indicate the occurrence of a strong topography and a strong transporting agent to the northwest of this part of the Newark belt. It will be necessary, when the development of the ancestors of our present rivers is taken up, to consider the effects of the depression that determined the locus of Newark deposition and of the adjacent elevation that maintained a supply of material.

10. *Jurassic tilting.*—Newark deposition was stopped by a gradual reversal of the conditions that introduced it. The depression of the Newark belt was after a time reversed into elevation, accompanied by a peculiar tilting, and again the waste of the region was carried away to some unknown resting place. This disturbance, which may be regarded as a revival of the Permian activity, culminated in Jurassic, or at least in post-Newark time, and resulted in the production of the singular monoclinal attitude of the formation; and as far as I can correlate it with the accompanying change in the underlying structures, it involved there an over pushing of the closed folds of the Archean and Paleozoic rocks. This is illustrated in figs. 2 and 3,

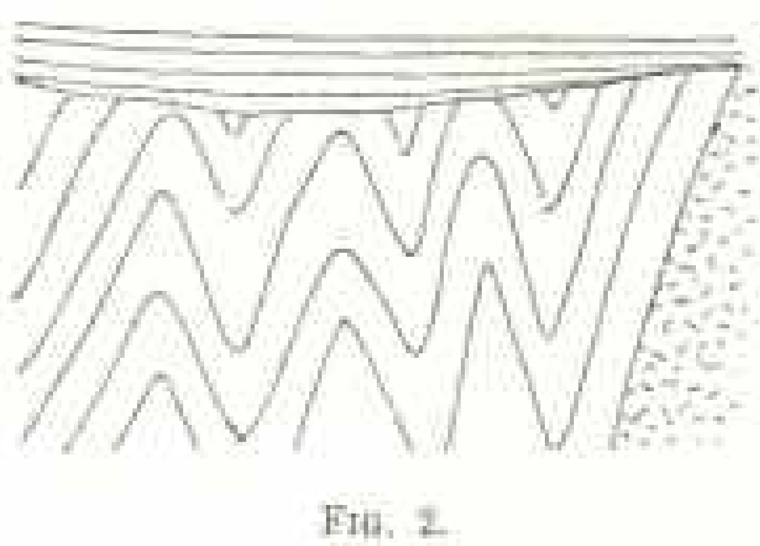


FIG. 2.

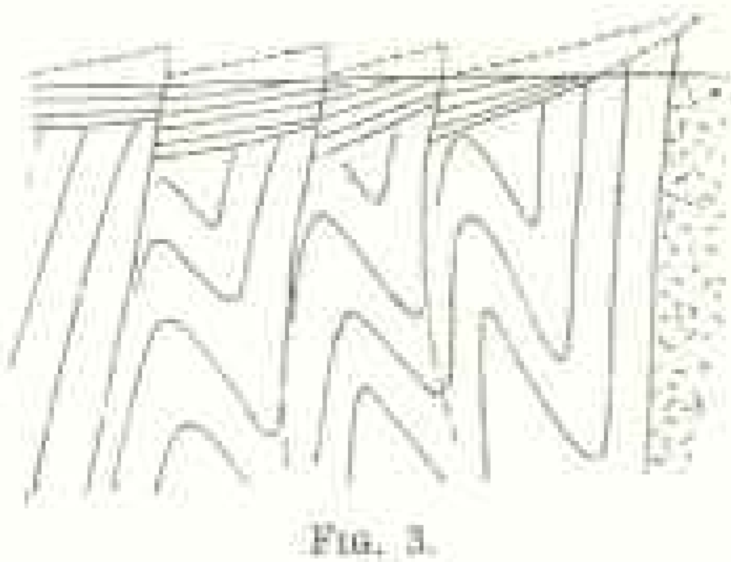


FIG. 3.

in which the original and disturbed attitudes of the Newark and the underlying formations are roughly shown, the over-pushing of the fundamental folds causing the monoclinal and probably faulted structure in the overlying beds.* If this be true, we might suspect that the unsymmetrical attitude of the Appalachian folds, noted by Rogers as a characteristic of the range, is a feature that was intensified if not originated in Jurassic and not in Permian time.

* Amer. Journ. Science, xxxii, 1886, 342; and Seventh Ann. Rept. U. S. Geol. Survey, 1888, 486.

It is not to be supposed that the Jurassic deformation was limited to the area of the Newark beds ; it may have extended some way on either side ; but it presumably faded out at no great distance, for it has not been detected in the history of the Atlantic and Mississippi regions remote from the Newark belt. In the district of the central folds of Pennsylvania, with which we are particularly concerned, this deformation was probably expressed in a further folding and over-pushing of the already partly folded beds, with rapidly decreasing effect to the northwest ; and perhaps also by slip-faults, which at the surface of the ground nearly followed the bedding planes : but this is evidently hypothetical to a high degree. The essential point for our subsequent consideration is that the Jurassic deformation was probably accompanied by a moderate elevation, for it allowed the erosion of the Newark beds and of laterally adjacent areas as well.

11. *Jura-Cretaceous denudation.*—In consequence of this elevation, a new cycle of erosion was entered upon, which I shall call the Jura-Cretaceous cycle. It allowed the accomplishment of a vast work, which ended in the production of a general lowland of denudation, a wide area of faint relief, whose elevated remnants are now to be seen in the even ridge-crests that so strongly characterize the ce tral district, as well as in certain other even uplands, now etched by the erosion of a later cycle of destructive work. I shall not here take space for the deliberate statement of the argument leading to this end, but its elements are as follows : the extraordinarily persistent accordance among the crest-line altitudes of many Medina and Carboniferous ridges in the central district ; the generally corresponding elevation of the western plateau surface, itself a surface of erosion, but now trenched by relatively deep and narrow valleys ; the generally uniform and consistent altitude of the uplands in the crystalline highlands of northern New Jersey and in the South Mountains of Pennsylvania ; and the extension of the same general surface, descending slowly eastward, over the even crest-lines of the Newark trap ridges. Besides the evidence of less continental elevation thus deduced from the topography, it may be noted that a lower stand of the land in Cretaceous time than now is indicated by the erosion that the Cretaceous beds have suffered in consequence of the elevation that followed their deposition. The Cretaceous transgression in the western states doubtless bears on the problem

also. Finally it may be fairly urged that it is more accordant with what is known about old mountains in general to suppose that their mass has stood at different attitudes with respect to base level during their long period of denudation than to suppose that they have held one attitude through all the time since their deformation.

It is natural enough that the former maintenance of some lower altitude than the present should have expression in the form of the country, if not now extinguished by subsequent erosion. It is simply the reverse of this statement that leads us to the above-stated conclusion. We may be sure that the long maintained period of relative quiet was of great importance in allowing time for the mature adjustment of the rivers of the region, and hence due account must be taken of it in a later section. I say relative quiet, for there were certainly subordinate oscillations of greater or less value; McGee has detected records of one of these about the beginning of Cretaceous time, but its effects are not now known to be of geographic value; that is, they do not now manifest themselves in the form of the present surface of the land, but only in the manner of deposition and ancient erosion of certain deposits.* Another subordinate oscillation in the sense of a moderate depression seems to have extended through middle and later Cretaceous time, resulting in an inland transgression of the sea and the deposit of the Cretaceous formation unconformably on the previous land surface for a considerable distance beyond the present margin of the formation.† This is important as affecting our rivers. Although these oscillations were of considerable geological value, I do not think that for the present purposes they call for any primary division of the Jura-Cretaceous cycle; for as the result of this long period of denudation we find but a single record in the great lowland of erosion above described, a record of prime importance in the geographic development of our region, that will often be referred to. The surface of faint relief then completed may be called the Cretaceous base-level lowland. It may be pictured as a low, undulating plain of wide extent, with a portion of its Atlantic margin submerged and covered over with a relatively thin marine deposit of sands, marls and clays.

* Amer. Jour. Science, xxxv, 1888, 367, 448.

† This statement is based on a study of the geographic evolution of northern New Jersey, in preparation for publication.

12. *Tertiary elevation and denudation.*—This broad lowland is a lowland no longer. It has been raised over the greater part of its area into a highland, with an elevation of from one to three thousand feet, sloping gently eastward and descending under the Atlantic level near the present margin of the Cretaceous formation. The elevation seems to have taken place early in Tertiary time, and will be referred to as of that date. Opportunity was then given for the revival of the previously exhausted forces of denudation, and as a consequence we now see the formerly even surface of the plain greatly roughened by the incision of deep valleys and the opening of broad lowlands on its softer rocks. Only the harder rocks retain indications of the even surface which once stretched continuously across the whole area. The best indication of the average altitude at which the mass stood through the greater part of post-Cretaceous time is to be found on the weak shales of the Newark formation in New Jersey and Pennsylvania, and on the weak Cambrian limestones of the great Kittatinny valley; for both of these areas have been actually almost baselevelled again in the Tertiary cycle. They will be referred to as the Tertiary baselevel lowlands; and the valleys corresponding to them, cut in the harder rocks, as well as the rolling lowlands between the ridges of the central district of Pennsylvania will be regarded as of the same date. Whatever variations of level occurred in this cycle of development do not seem to have left marks of importance on the inland surface, though they may have had greater significance near the coast.

13. *Later changes of level.*—Again at the close of Tertiary time, there was an elevation of moderate amount, and to this may be referred the trenches that are so distinctly cut across the Tertiary baselevel lowland by the larger rivers, as well as the lateral

FIG. 4.

shallower channels of the smaller streams. This will be called the Quaternary cycle; and for the present no further mention of the oscillations known to have occurred in this division of time need be considered; the reader may find careful discussion of

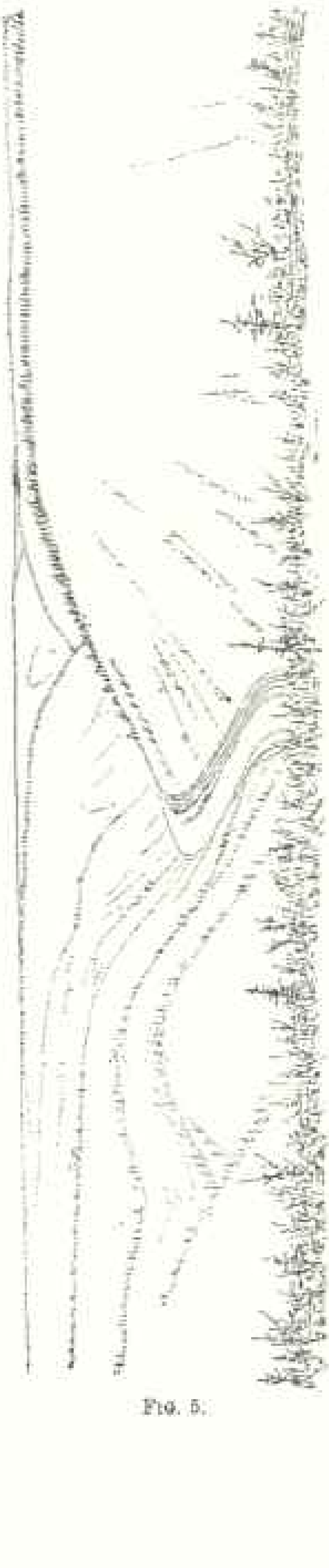


Fig. 5.

them in the paper by McGee, above referred to. It is proper that I should add that the suggestion of baselevelling both of the crest-lines and of the lowlands, that I have found so profitable in this and other work, is due largely to personal conference with Messrs. Gilbert and McGee of the Geological Survey; but it is not desired to make them in any way responsible for the statements here given.

14. *Illustrations of Pennsylvanian topography.*—A few sketches made during a recent recess-trip with several students through Pennsylvania may be introduced in this connection. The first, fig. 4, is a view from Jenny Jump mountain, on the northwestern side of the New Jersey highlands, looking northwest across the Kittatinny valley-lowland to Blue or Kittatinny mountain, where it is cut at the Delaware Water-gap. The extraordinarily level crest of the mountain preserves record of the Cretaceous baselevel lowland; since the elevation of this ancient lowland, its softer rocks have, as it were, been etched out, leaving the harder ones in relief; thus the present valley-lowland is to be explained. In consequence of the still later elevation of less amount, the Delaware has cut a trench in the present lowland, which is partly seen to the left in the sketch. Fig. 5 is a general view of the Lehigh plateau and cañon, looking south from Bald Mountain just above Penn Haven Junction. Blue mountain is the most distant crest, seen for a little space. The ridges near and above Mauch Chunk form the other outlines; all

rising to an astonishingly even altitude, in spite of their great diversity of structure. Before the existing valleys were exca-

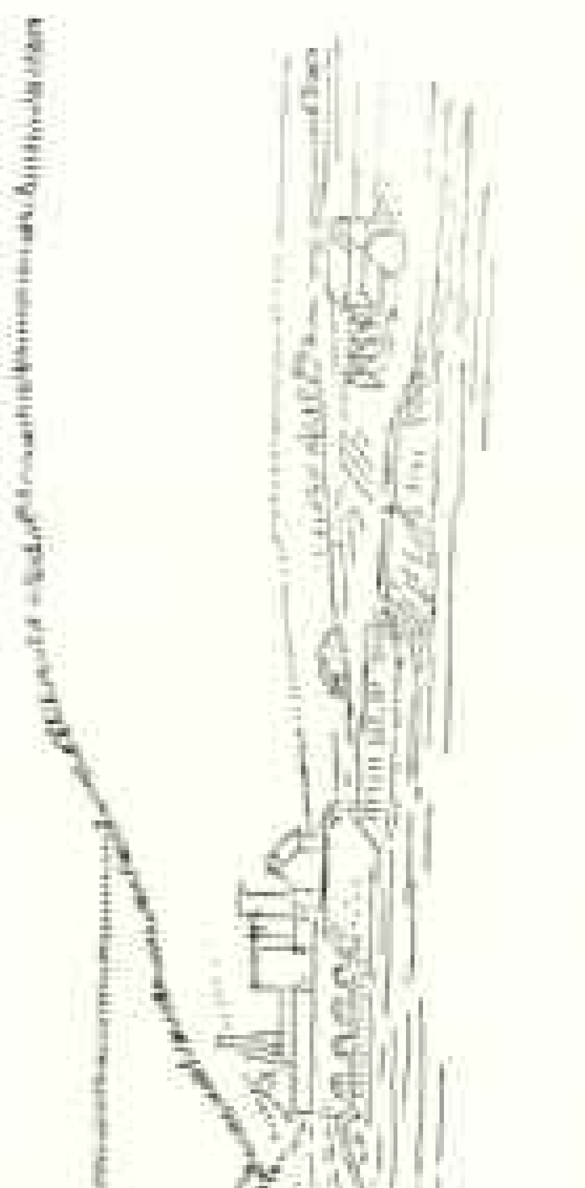


Fig. 6.

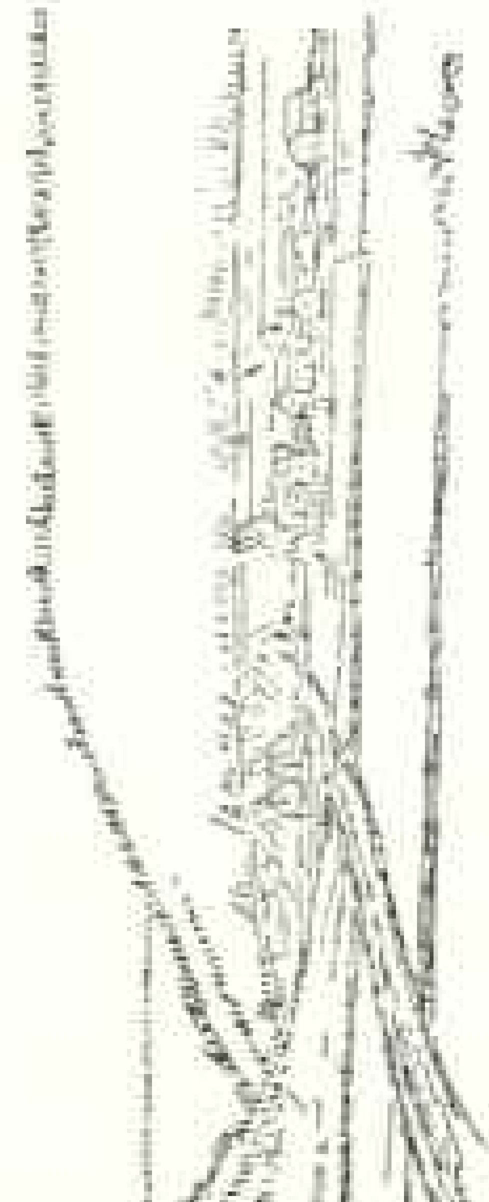


Fig. 7.

vated, the upland surface must have been an even plain—the Cretaceous baselevel lowland elevated into a plateau. The valleys cut into the plateau during the Tertiary cycle are narrow here, because the rocks are mostly hard. The steep slopes of the cañon-like valley of the Lehigh and the even crests of the ridges manifestly belong to different cycles of development. Figs. 6 and 7 are gaps cut in Black Log and Shade mountain, by a small upper branch stream of the Juniata in southeastern Huntingdon county. The stream traverses a breached anticlinal of Medina sandstone, of which these mountains are the lateral members. A long narrow valley is opened on the axial Trenton limestone between the two. The gaps are not opposite to each other, and therefore in looking through either gap from the outer country the even crest of the further ridge is seen beyond the axial valley. The gap in Black Log mountain, fig. 6, is located on a small fracture, but in this respect it is unlike most of its fellows.* The striking similarity of the two views illustrates the uniformity that so strongly characterizes the Medina ridges of the central district. Fig. 8 is in good part an ideal view, based on sketches on the

FIG. 8.

upper Susquehanna, and designed to present a typical illustration of the more significant features of the region. It shows the even crest-lines of a high Medina or Pocono ridge in the background, retaining the form given to it in the Cretaceous cycle; the even lowlands in the foreground, opened on the weaker Siluro-Devonian rocks in the Tertiary cycle; and the uneven ridges in the middle distance marking the Oriskany and Chemung beds of intermediate hardness that have lost the Cretaceous level and yet have not been reduced to the Tertiary lowland. The Susquehanna flows distinctly below the lowland plain, and the small side streams run in narrow trenches of late Tertiary and Quaternary date.

If this interpretation is accepted, and the Permian mountains are seen to have been once greatly reduced and at a later time worn out, while the ridges of to-day are merely the relief left by

* Second Geol. Surv. Pa., Report T_3, 19.

the etching of Tertiary valleys in a Cretaceous baselevelled lowland, then we may well conclude with Powell that "mountains cannot remain long as mountains; they are ephemeral topographic forms."*

PART THIRD. *General conception of the history of a river.*

15. *The complete cycle of river life: youth, adolescence, maturity and old age.*—The general outline of an ideal river's history may be now considered, preparatory to examining the special history of the rivers of Pennsylvania, as controlled by the geological events just narrated.

Rivers are so long lived and survive with more or less modification so many changes in the attitude and even in the structure of the land, that the best way of entering on their discussion seems to be to examine the development of an ideal river of simple history, and from the general features thus discovered, it may then be possible to unravel the complex sequence of events that leads to the present condition of actual rivers of complicated history.

A river that is established on a new land may be called an original river. It must at first be of the kind known as a consequent river, for it has no ancestor from which to be derived. Examples of simple original rivers may be seen in young plains, of which southern New Jersey furnishes a fair illustration. Examples of essentially original rivers may be seen also in regions of recent and rapid displacement, such as the Jura or the broken country of southern Idaho, where the directly consequent character of the drainage leads us to conclude that, if any rivers occupied these regions before their recent deformation, they were so completely extinguished by the newly made slopes that we see nothing of them now.

Once established, an original river advances through its long life, manifesting certain peculiarities of youth, maturity and old age, by which its successive stages of growth may be recognized without much difficulty. For the sake of simplicity, let us suppose the land mass, on which an original river has begun its work, stands perfectly still after its first elevation or deformation, and so remains until the river has completed its task of carrying away all the mass of rocks that rise above its baselevel. This lapse of time will be called a cycle in the life of a river. A complete

*Geol. Uinta Mountains, 1876, 196.

cycle is a long measure of time in regions of great elevation or of hard rocks; but whether or not any river ever passed through a single cycle of life without interruption we need not now inquire. Our purpose is only to learn what changes it would experience if it did thus develop steadily from infancy to old age without disturbance.

In its infancy, the river drains its basin imperfectly; for it is then embarrassed by the original inequalities of the surface, and lakes collect in all the depressions. At such time, the ratio of evaporation to rainfall is relatively large, and the ratio of transported land waste to rainfall is small. The channels followed by the streams that compose the river as a whole are narrow and shallow, and their number is small compared to that which will be developed at a later stage. The divides by which the side-streams are separated are poorly marked, and in level countries are surfaces of considerable area and not lines at all. It is only in the later maturity of a system that the divides are reduced to lines by the consumption of the softer rocks on either side. The difference between constructional forms and those forms that are due to the action of denuding forces is in a general way so easily recognized, that immaturity and maturity of a drainage area can be readily discriminated. In the truly infantile drainage system of the Red River of the North, the inter-stream areas are so absolutely flat that water collects on them in wet weather, not having either original structural slope or subsequently developed denuded slope to lead it to the streams. On the almost equally young lava blocks of southern Oregon, the well-marked slopes are as yet hardly channeled by the flow of rain down them, and the depressions among the tilted blocks are still undrained, unfilled basins.

As the river becomes adolescent, its channels are deepened and all the larger ones descend close to baselevel. If local contrasts of hardness allow a quick deepening of the down-stream part of the channel, while the part next up-stream resists erosion, a cascade or waterfall results; but like the lakes of earlier youth, it is evanescent, and endures but a small part of the whole cycle of growth; but the falls on the small headwater streams of a large river may last into its maturity, just as there are young twigs on the branches of a large tree. With the deepening of the channels, there comes an increase in the number of gulleys on the slopes of the channel; the gulleys grow into ravines and these into side valleys, joining their master streams at right angles (La Noë and Margerie). With their continued development, the maturity of the system is reached; it is marked by an almost complete acquisition of every part of the original constructional surface by erosion under the guidance of the streams, so that every drop of rain that falls finds a way prepared to lead it to a stream and then to the ocean, its goal. The lakes of initial imperfection have long since disappeared; the waterfalls of adolescence have been worn back, unless on the still young headwaters. With the increase of the number of side-streams, ramifying into all parts of the drainage basin, there is a proportionate increase in the surface of the valley slopes, and with this comes an increase in the rate of waste under atmospheric forces; hence it is at maturity that the river receives and carries the greatest load; indeed, the increase may be carried so far that the lower trunk-stream, of gentle slope in its early maturity, is unable to carry the load brought to it by the upper branches, and therefore resorts to the temporary expedient of laying it aside in a flood-plain. The level of the flood-plain is sometimes built up faster than the small side-streams of the lower course can fill their valleys, and hence they are converted for a little distance above their mouths into shallow lakes. The growth of the flood-plain also results in carrying the point of junction of tributaries farther and farther down stream, and at last in turning lateral streams aside from the main stream, sometimes forcing them to follow independent courses to the sea (Lombardini). But although thus separated from the main trunk, it would be no more rational to regard such streams as independent rivers than it would be to regard the branch of an old tree, now fallen to the ground in the decay of advancing age, as an independent plant; both are detached portions of a single individual, from which they have been separated in the normal processes of growth and decay.

In the later and quieter old age of a river system, the waste of the land is yielded slower by reason of the diminishing slopes of the valley sides; then the headwater streams deliver less detritus to the main channel, which, thus relieved, turns to its postponed task of carrying its former excess of load to the sea, and cuts terraces in its flood-plain, preparatory to sweeping it away. It does not always find the buried channel again, and perhaps settling down on a low spur a little to one side of its old line, produces a rapid or a low fall on the lower slope of such an obstruction (Penck). Such courses may be called locally superimposed.

It is only during maturity and for a time before and afterwards that the three divisions of a river, commonly recognized, appear most distinctly; the torrent portion being the still young headwater branches, growing by gnawing backwards at their sources; the valley portion proper, where longer time of work has enabled the valley to obtain a greater depth and width; and the lower flood-plain portion, where the temporary deposition of the excess of load is made until the activity of middle life is past.

Maturity seems to be a proper term to apply to this long enduring stage; for as in organic forms, where the term first came into use, it here also signifies the highest development of all functions between a youth of endeavor towards better work and an old age of relinquishment of fullest powers. It is the mature river in which the rainfall is best lead away to the sea, and which carries with it the greatest load of land waste; it is at maturity that the regular descent and steady flow of the river is best developed, being the least delayed in lakes and least overhurried in impetuous falls.

Maturity past, and the power of the river is on the decay. The relief of the land diminishes, for the streams no longer deepen their valleys although the hill tops are degraded; and with the general loss of elevation, there is a failure of rainfall to a certain extent; for it is well known that up to certain considerable altitudes rainfall increases with height. A hyetographic and a hypsometric map of a country for this reason show a marked correspondence. The slopes of the headwaters decrease and the valley sides widen so far that the land waste descends from them slower than before. Later, what with failure of rainfall and decrease of slope, there is perhaps a return to the early imperfection of drainage, and the number of side streams diminishes as branches fall from a dying tree. The flood-plains of maturity are carried down to the sea, and at last the river settles down to an old age of well-earned rest with gentle flow and light load, little work remaining to be done. The great task that the river entered upon is completed.

16. *Mutual adjustment of river courses.*—In certain structures, chiefly those of mountainous disorder on which the streams are at first high above baselevel, there is a process of adjustment extremely characteristic of quiet river development, by which the down-hill courses that were chosen in early life, and as we may say unadvisedly and with the heedlessness and little foresight of

youth, are given up for others better fitted for the work of the mature river system. A change of this kind happens when the young stream taking the lowest line for its guide happens to flow on a hard bed at a considerable height above baselevel, while its branches on one side or the other have opened channels on softer beds: a part of the main channel may then be deserted by the withdrawal of its upper waters to a lower course by way of a side stream. The change to better adjustment also happens when the initial course of the main stream is much longer than a course that may be offered to its upper portion by the backward gnawing of an adjacent stream (Löwl, Penck). Sometimes the lateral cutting or planation that characterizes the main trunk of a mature river gives it possession of an adjacent smaller stream whose bed is at a higher level (Gilbert). A general account of these processes may be found in Phillippson's serviceable "Studien über Wasserscheiden" (Leipzig, 1886). This whole matter is of much importance and deserves deliberate examination. It should be remembered that changes in river courses of the kind now referred to are unconnected with any external disturbance of the river basin, and are purely normal spontaneous acts during advancing development. Two examples, pertinent to our special study, will be considered.

Let AB, fig. 9, be a stream whose initial consequent course led it down the gently sloping axial trough of a syncline. The constructional surface of the syncline is shown by contours. Let the succession of beds to be discovered by erosion be indicated in a section, laid in proper position on the several diagrams, but revolved into the horizontal plane, the harder beds being dotted and the baselevel standing at 00. Small side streams will soon be developed on the slopes of the syncline, in positions determined by cross-fractures or more often by what we call accident; the action of streams in similar synclines on the outside of the enclosing anticlines will be omitted for the sake of simplicity. In time, the side streams will cut through the harder upper bed M and enter the softer bed N, on which longitudinal channels, indicated by hachures, will be extended along the strike, fig. 10 (La Noë and Margerie). Let these be called "subsequent" streams. Consider two side streams of this kind, C and D, heading against each other at E, one joining the main stream lower down the axis of the syncline than the other.. The headwaters of C will rob the headwaters of D, because the deepening of the channel of D is retarded by its having to join the main stream at a point where the hard bed in the axis of the fold holds the main channel

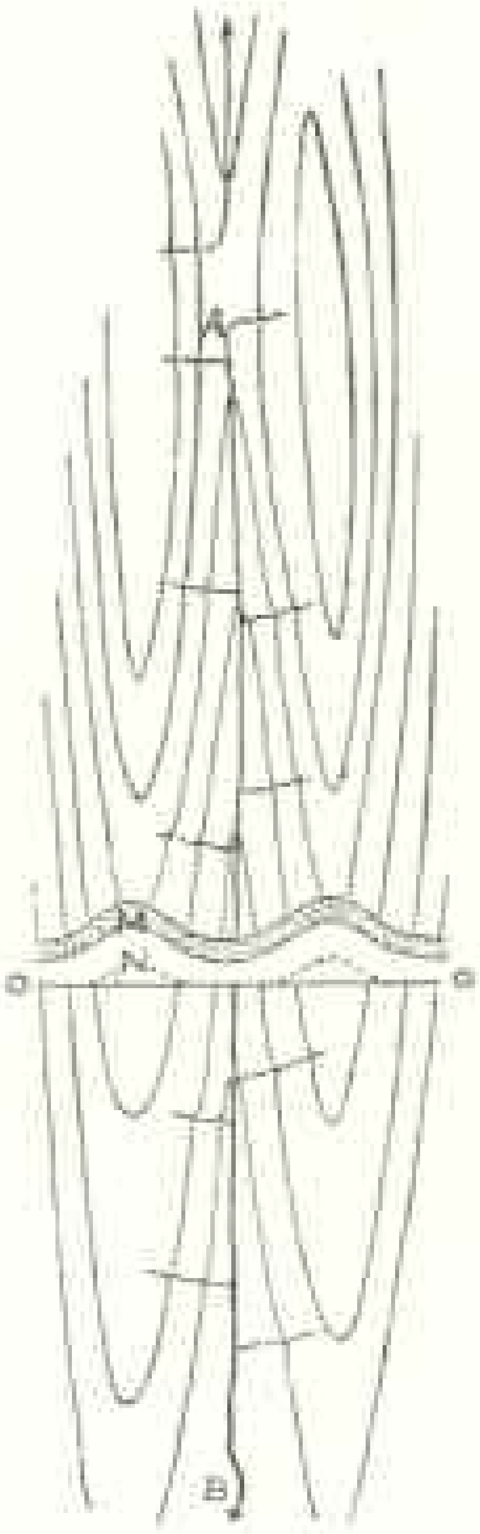


Fig. 9.

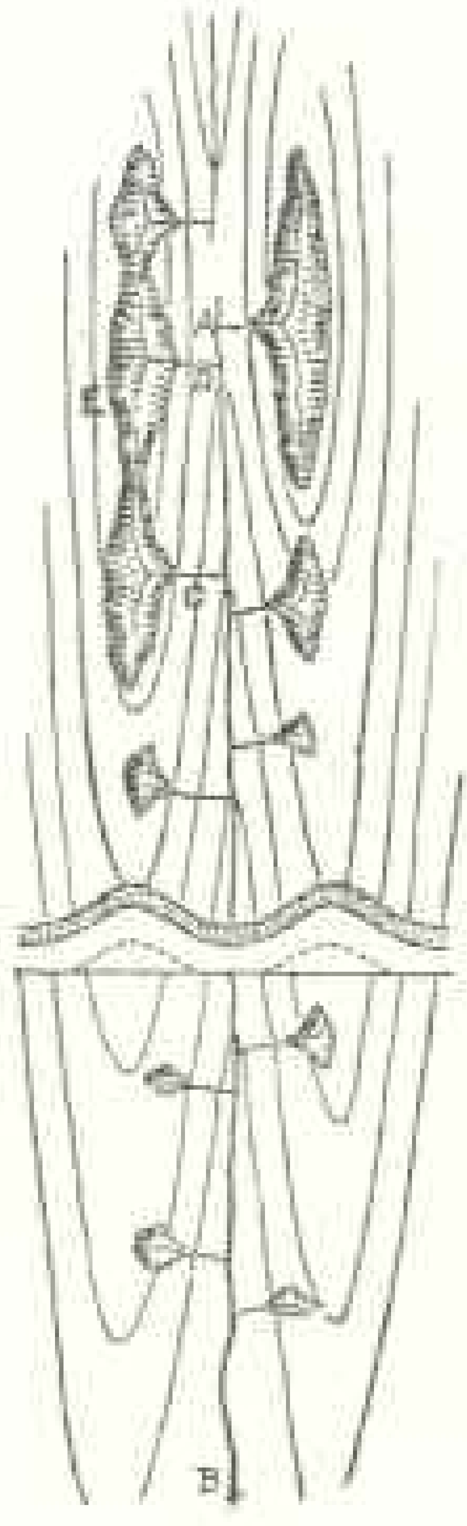


Fig. 10.

well above baselevel. The notch cut by D will then be changed from a water-gap to a wind-gap and the upper portion of D will find exit through the notch cut by C, as in fig. 11. As other subsequent headwaters make capture of C, the greater depth to which the lateral valley is cut on the soft rock causes a slow migration of the divides in the abandoned gaps towards the main stream, and before long the upper part of the main stream itself will be led out of the synclinal axis to follow the monoclinal valley at one side for a distance, fig. 12, until the axis can be rejoined through the gap where the axial portion of the controlling hard bed is near or at baselevel. The upper part of the synclinal trough will then be attacked by undercutting on the slope of the quickly deepened channels of the lateral streams, and the hard bed will be worn away in the higher part of the axis before it is consumed in the lower part. The location of the successful lateral stream on one or the other side of the syncline may be

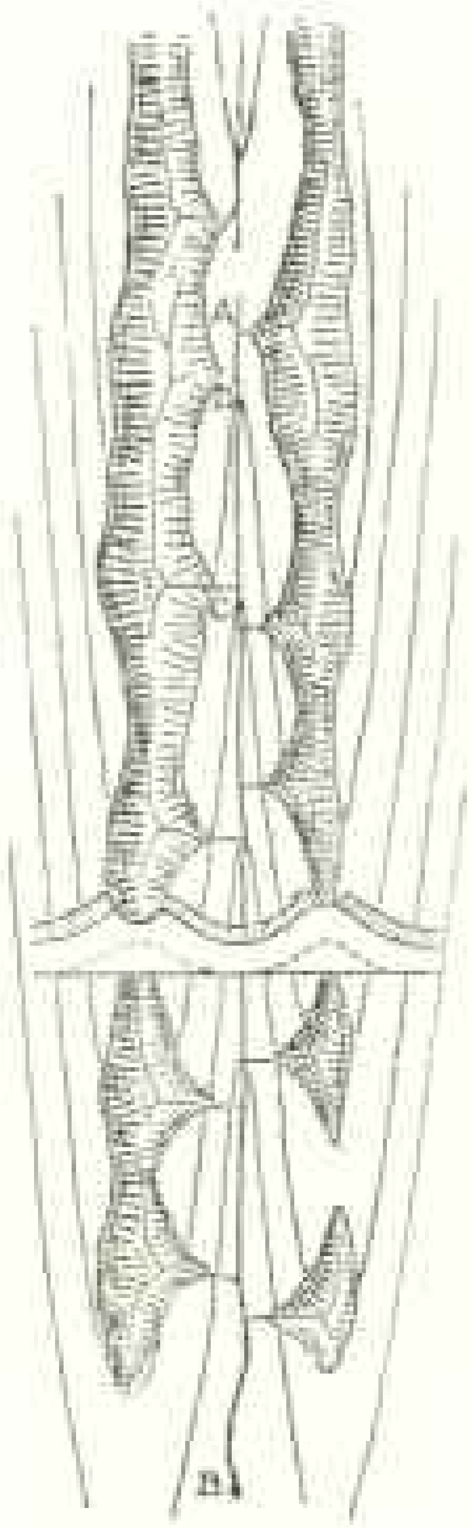


FIG. 11.

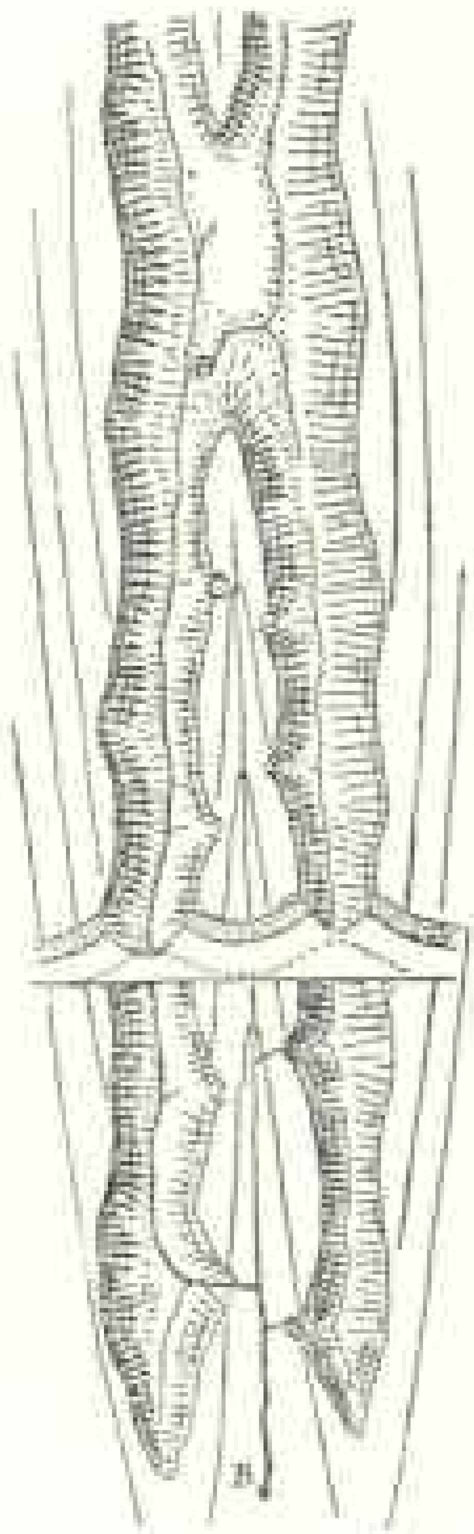


FIG. 12.

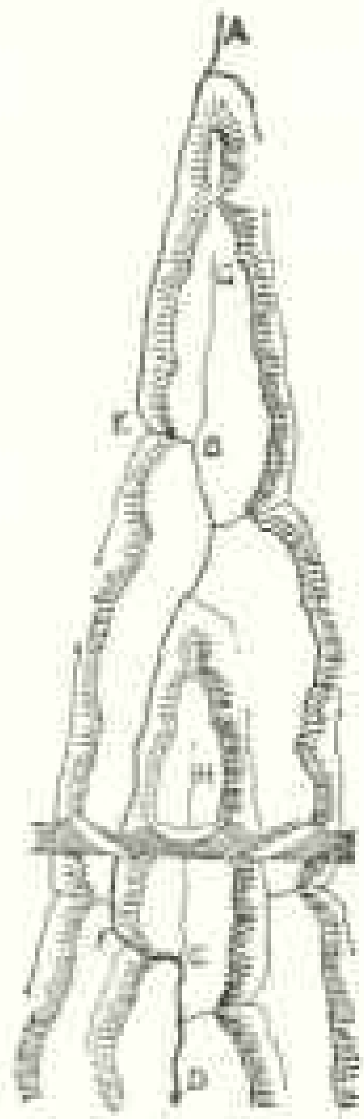


FIG. 13.

determined by the dip of the beds, gaps being cut quicker on steep than on gentle dips. If another hard bed is encountered below the soft one, the process will be repeated ;- and the mature arrangement of the streams will be as in fig. 13 (on a smaller scale than the preceding), running obliquely off the axis of the fold where a hard bed of the syncline rises above baselevel, and returning to the axis where the hard bed is below or at baselevel ; a monoclinal stream wandering gradually from the axis along the strike of the soft bed, AE, by which the side-valley is located and returning abruptly to the axis by a cataclinal* stream in a

* See the terminology suggested by Powell. Expl. Col. R. of the West, 1875, 160. This terminology is applicable only to the most detailed study of our rivers, by reason of their crossing so many folds, and changing so often from longitudinal to transverse courses.

transverse gap, EB, in the next higher hard bed, and there rejoining the diminished representative or survivor of the original axial or synclinal stream, GB.

17. *Terminology of rivers changed by adjustment.*—A special terminology is needed for easy reference to the several parts of the streams concerned in such an adjustment. Let AB and CD, fig. 14, be streams of unequal size cutting gaps, H and G, in a ridge that lies transverse to their course. CD being larger than AB will deepen its gap faster. Of two subsequent streams, JE and JF, growing on the up-stream side of the ridge, JE will have the steeper slope, because it joins the deeper master-stream. The divide, J, will therefore be driven towards AB, and if all the conditions concerned conspire favorably, JE will at last tap AB at F, and lead the upper part, AF, out by the line FEGD, fig. 15,

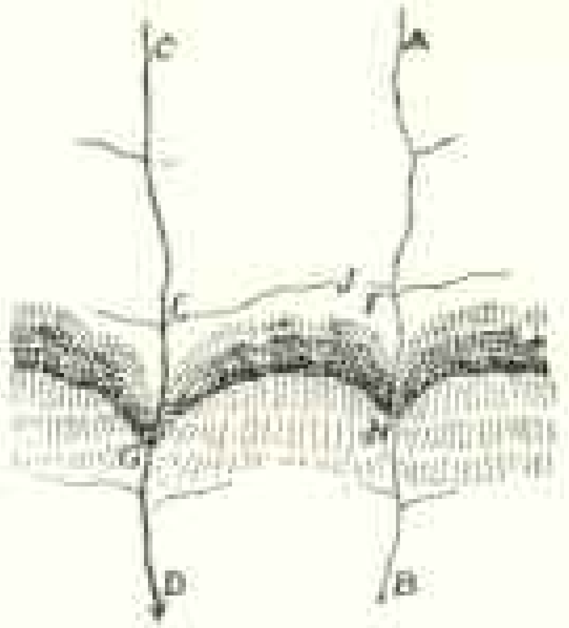


FIG. 14.

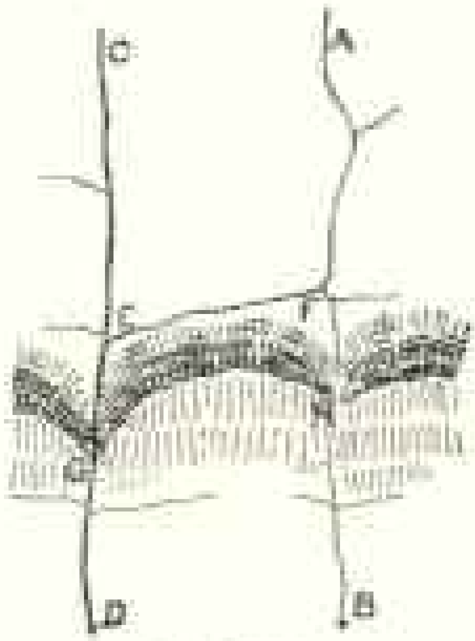


FIG. 15.

through the deeper gap, G. We may then say that JE becomes the *divertor* of AF, which is *diverted*; and when the process is completed, by the transfer of the divide from J, on the soft rocks, to a stable location, H, on the hard rocks, there will be a short *inverted* stream, HF; while HB is the remaining *beheaded* portion of the original stream, AB, and the water-gap of AB becomes a wind-gap, H. It is very desirable that geographic exploration should discover examples of the process of adjustment in its several stages. The preparatory stage is easily recognized by the difference in the size of the two main streams, the difference in the depth of their gaps, and the unsymmetrical position of the divide, J. The very brief stage of transition gives us the rare examples of bifurcating streams. For a short time after capture of the diverted stream by the divertor, the new divide will lie between F and H, in an unstable position, the duration of this time depending on the energy of the process of capture.

The consequences resulting from readjustments of this kind by which their recent occurrence can be detected are: a relatively sudden increase of volume of the divertor and hence a rapid deepening of the course of the diverting stream, FE, and of the diverted, AF, near the point of capture; small side-streams of these two being unable to keep pace with this change will join their masters in local rapids, which work up stream gradually and fade away (Löwl, Penck, McGee). The expanded portion, ED, of the larger stream, CD, already of faint slope, may be locally overcome for a time with the increase of detritus that will be thus delivered to it at the entrance, E, of the divertor; while the beheaded stream, HB, will find itself embarrassed to live up to the habits of its large valley [Heim]. Geographic exploration

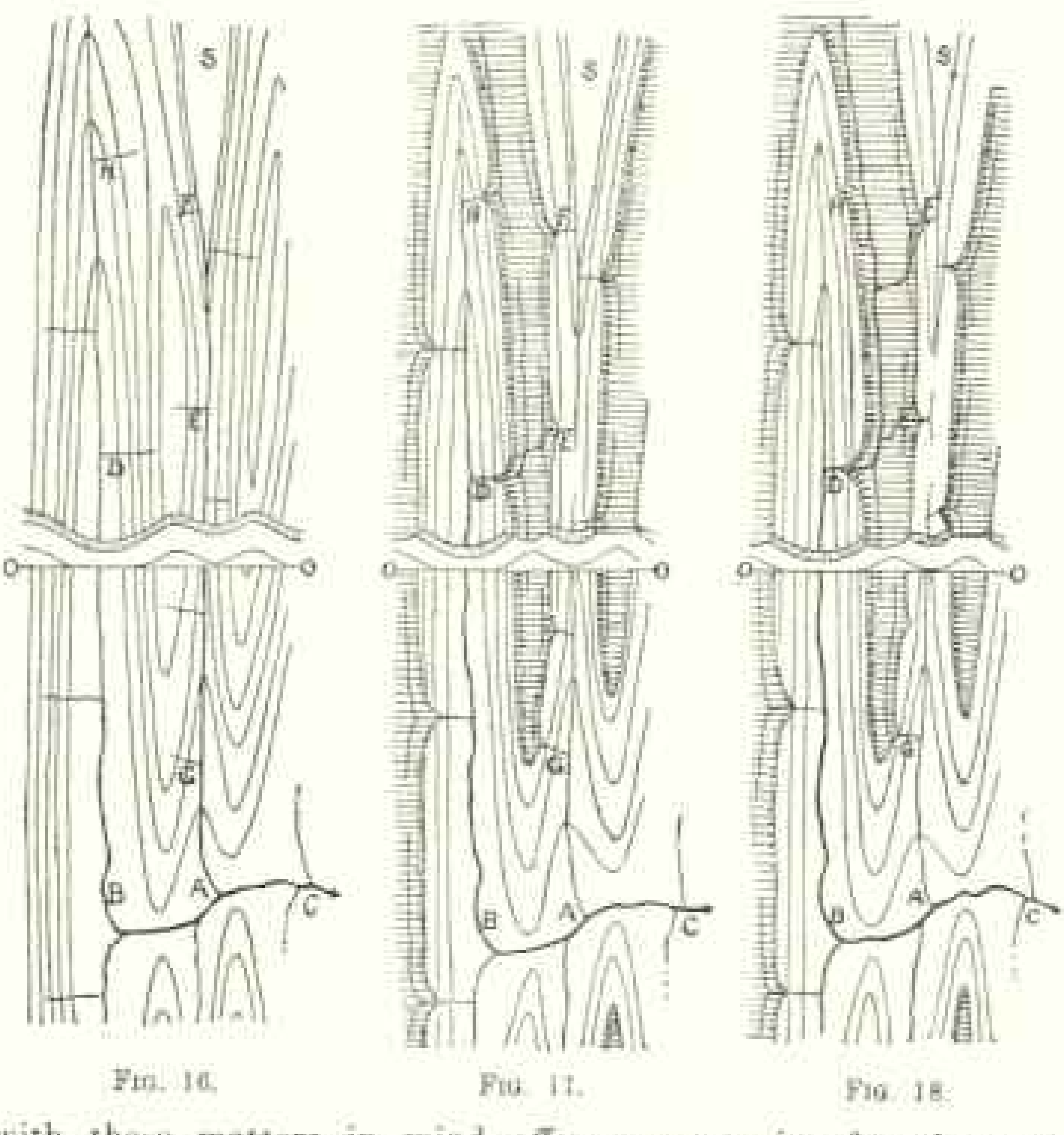


Fig. 16. Fig. 17. Fig. 18.

with these matters in mind offers opportunity for the most attractive discoveries.

18. *Examples of adjustment.*—Another case is roughly figured

in the next three diagrams, figs. 16, 17, 18. Two adjacent synclinal streams, EA and HB, join a transverse master stream, C, but the synclines are of different forms; the surface axis of one, EA, stands at some altitude above baselevel until it nearly reaches the place of the transverse stream; while the axis of the other, HB, descends near baselevel at a considerable distance from the transverse stream. As lateral valleys, E and D, are opened on the anticline between the synclines by a process similar to that already described, the divide separating them will shift towards the stream of fainter slope, that is, towards the syncline, EA, whose axis holds its hard beds above baselevel; and in time the upper part of the main stream will be withdrawn from this syncline to follow an easier course by crossing to the other, as in fig. 17. If the elevation of the synclinal axis, AES, take the shape of a long flat arch, descending at the further end into a synclinal lake basin, S, whose outlet is along the arching axis, SA, then the mature arrangement of stream courses will lead the lake outlet away from the axis by some gap in the nearer ascending part of the arch where the controlling hard bed falls near to baselevel, as at F, fig. 18,* and will take it by some subsequent course, FD, across the lowland that is opened on the soft beds between the synclines, and carry it into the lower syncline, HB, at D where the hard beds descend below baselevel.

The variety of adjustments following the general principle here indicated is infinite. Changes of greater or less value are thus introduced in the initial drainage areas, until, after attaining an attitude of equilibrium, further change is arrested, or if occurring, is relatively insignificant. It should be noticed that the new stream courses thus chosen are not named by any of the terms now current to express the relation of stream and land history; they are neither consequent, antecedent nor superimposed. The stream is truly still an original stream, although no longer young; but its channel is not in all parts strictly consequent on the initial constructional form of the land that it drains. Streams thus re-arranged may therefore be named original streams of mature adjustment.

It should be clearly recognized that the process of adjustment is a very slow one unless measured in the extremely long units

* This figure would be improved if a greater amount of wasting around the margin of the hard bed were indicated in comparison with the preceding figure.

of a river's life. It progresses no faster than the weathering away of the slopes of a divide, and here as a rule weathering is deliberate to say the least, unless accelerated by a fortunate combination of favoring conditions. Among these conditions, great altitude of the mass exposed to erosion stands first, and deep channeling of streams below the surface—that is, the adolescent stage of drainage development—stands second. The opportunity for the lateral migration of a divide will depend on the inequality of the slopes on its two sides, and here the most important factors are length of the two opposite stream courses from the water parting to the common baselevel of the two, and inequality of structure by which one stream may have an easy course and the other a hard one. It is manifest that all these conditions for active shifting of divides are best united in young and high mountain ranges, and hence it is that river adjustments have been found and studied more in the Alps than elsewhere.

19. *Revival of rivers by elevation and drowning by depression.*—I make no contention that any river in the world ever passed through a simple uninterrupted cycle of the orderly kind here described. But by examining many rivers, some young and some old, I do not doubt that this portrayal of the ideal would be found to be fairly correct if opportunity were offered for its development. The intention of the sketch is simply to prepare the way for the better understanding of our actual rivers of more complicated history.

At the close or at any time during the passage of an initial cycle such as the one just considered, the drainage area of a river system may be bodily elevated. The river is then turned back to a new youth and enters a new cycle of development. This is an extremely common occurrence with rivers, whose life is so long that they commonly outlive the duration of a quiescent stage in the history of the land. Such rivers may be called revived. Examples may be given in which streams are now in their second or third period of revival, the elevations that separate their cycles following so soon that but little work was accomplished in the quiescent intervals.

The antithesis of this is the effect of depression, by which the lower course may be drowned, flooded or fjorded. This change is, if slow, favorable to the development of flood-plains in the lower course ; but it is not essential to their production. If the change is more rapid, open estuaries are formed, to be transformed to delta-lowlands later on.

20. *Opportunity for new adjustments with revival.*—One of the most common effects of the revival of a river by general elevation is a new adjustment of its course to a greater or less extent, as a result of the new relation of baselevel to the hard and soft beds on which the streams had adjusted themselves in the previous cycle. Synclinal mountains are most easily explained as results of drainage changes of this kind [Science, Dec. 21st, 1888]. Streams thus rearranged may be said to be adjusted through elevation or revival. It is to be hoped that, as our study advances, single names of brief and appropriate form may replace these paraphrases; but at present it seems advisable to keep the desired idea before the mind by a descriptive phrase, even at the sacrifice of brevity. A significant example may be described.

Let it be supposed that an originally consequent river system has lived into advanced maturity on a surface whose structure is, like that of Pennsylvania, composed of closely adjacent anticlinal and synclinal folds with rising and falling axes, and that a series of particularly resistant beds composes the upper members of the folded mass. The master stream, A, fig. 19, at maturity still resides where the original folds were lowest, but the side streams have departed more less from the axes of the synclinals that they first followed, in accordance with the principles of adjustment presented above. The relief of the surface is moderate, except around the synclinal troughs, where the rising margins of the hard beds still appear as ridges of more or less prominence. The minute hachures in figure 19 are drawn on the outcrop side of these ridges. Now suppose a general elevation of the region, lifting the synclinal troughs of the hard beds up to baselevel or even somewhat above it. The deepening of the revived master-stream will be greatly retarded by reason of its having to cross so many outcrops of the hard beds, and thus excellent opportunity will be given for readjustment by the growth of some diverting stream, B, whose beginning on adjacent softer rocks was already made in the previous cycle. This will capture the main river at some up-stream point, and draw it nearly all away from its hard path across the synclinal troughs to an easier path across the lowlands that had been opened on the underlying softer beds, leaving only a small beheaded remnant in the lower course. The final re-arrangement may be indicated in fig. 20. It should be noted that every capture of branches of the initial main stream made by the diverting stream adds to its ability for further encroachments, for with increase of volume the channel is deepened and a

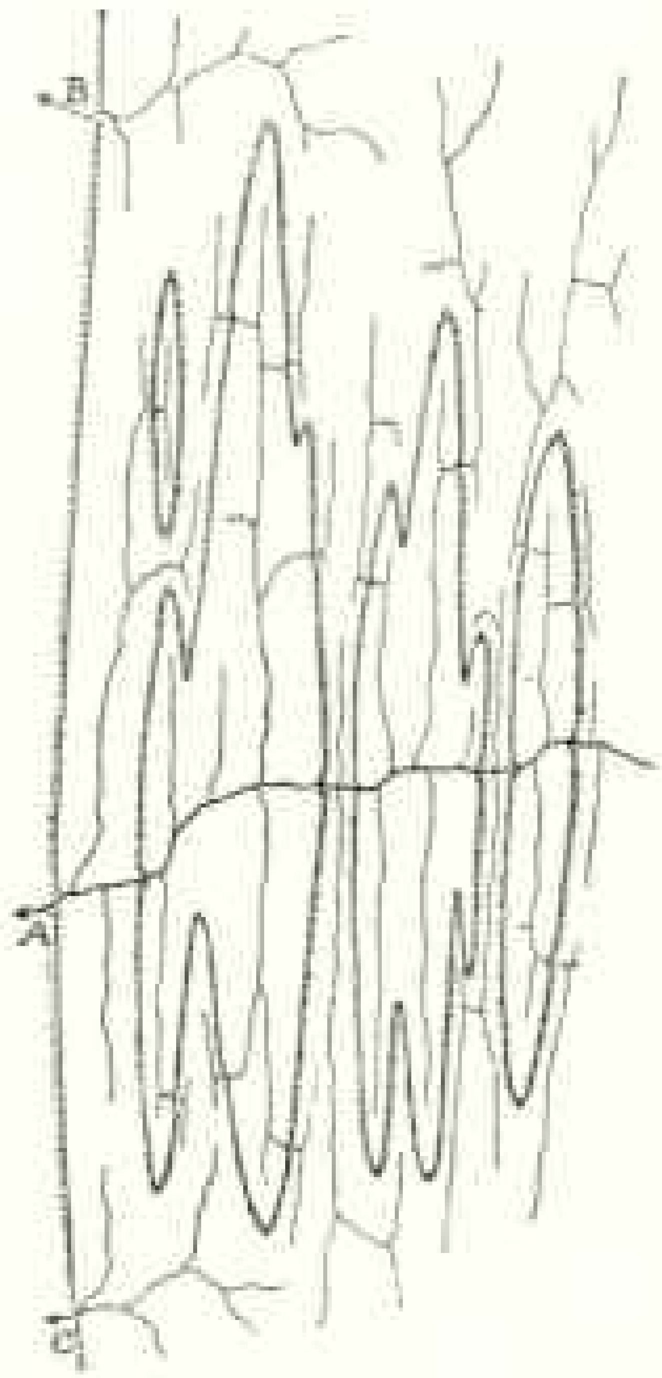


FIG. 19.

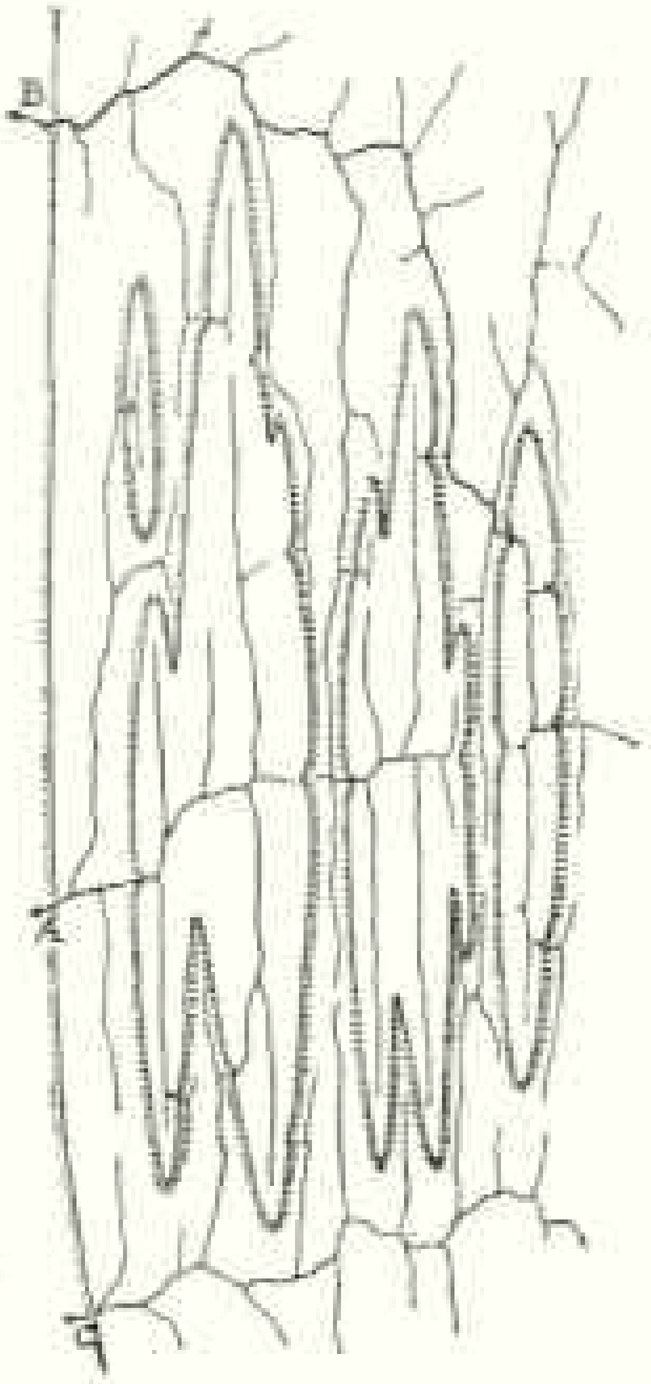


FIG. 20.

flatter slope is assumed, and the whole process of pushing away the divides is thereby accelerated. In general it may be said that the larger the stream and the less its elevation above baselevel, the less likely is it to be diverted, for with large volume and small elevation it will early cut down its channel so close to baselevel that no other stream can offer it a better course to the sea; it may also be said that, as a rule, of two equal streams, the headwaters of the one having a longer or a harder course will be diverted by a branch of the stream on the shorter or easier course. Every case must therefore be examined for itself before the kind of re-arrangement that may be expected or that may have already taken place can be discovered.

21. *Antecedent and superimposed rivers.*—It not infrequently happens that the surface, on which a drainage system is more or less fully developed, suffers deformation by tilting, folding or faulting. Then, in accordance with the rate of disturbance, and

dependent on the size and slope of the streams and the resistance of the rocks, the streams will be more or less re-arranged, some of the larger ones persisting in their courses and cutting their channels down almost as fast as the mass below them is raised and offered to their action. It is manifest that streams of large volume and considerable slope are the ones most likely to persevere in this way, while small streams and large ones of moderate slope may be turned from their former courses to new courses consequent on the new constructional form of the land. Hence, after a disturbance, we may expect to find the smaller streams of the former cycle pretty completely destroyed, while some of the larger ones may still persist; these would then be called antecedent streams in accordance with the nomenclature introduced by Powell.* A fuller acquaintance with the development of our rivers will probably give us examples of river systems of all degrees of extinction or persistence at times of disturbance.

Since Powell introduced the idea of antecedent valleys and Tietze, Medlicott and others showed the validity of the explanation in other regions than the one for which it was first proposed, it has found much acceptance. Lowl's objection to it does not seem to me to be nearly so well founded as his suggestion of an additional method of river development by means of backward headwater erosion and subsequent capture of other streams, as already described. And yet I cannot help thinking that the explanation of transverse valleys as antecedent courses savors of the Gordian method of explaining a difficult matter. The case of the Green river, to which Powell first gave this explanation, seems well supported; the examples given by Medlicott in the Himalayas are as good: but still it does not seem advisable to explain all transverse streams in this way, merely because they are transverse. Perhaps one reason why the explanation has become so popular is that it furnishes an escape from the old catastrophic idea that fractures control the location of valleys, and is at the same time fully accordant with the ideas of the uniformitarian school that have become current in this half of our century. But when it is remembered that most of the streams of a region are extinguished at the time of mountain growth, that only a few of the larger ones can survive, and that there are other ways in which transverse streams may originate,† it is evi-

* Exploration of the Colorado River of the West, 1875, 153, 163–166.

† Hilber, Pet. Mitth., xxxv, 1889, 13.

dent that the possibility of any given transverse stream being antecedent must be regarded only as a suggestion, until some independent evidence is introduced in its favor. This may be difficult to find, but it certainly must be searched for; if not then forthcoming, the best conclusion may be to leave the case open until the evidence appears. Certainly, if we find a river course that is accordant in its location with the complicated results of other methods of origin, then the burden of proof may be said to lie with those who would maintain that an antecedent origin would locate the river in so specialized a manner. Even if a river persist for a time in an antecedent course, this may not prevent its being afterwards affected by the various adjustments and revivals that have been explained above: rivers so distinctly antecedent as the Green and the Sutlej may hereafter be more or less affected by processes of adjustment, which they are not yet old enough to experience. Hence in mountains as old as the Appalachians the courses of the present rivers need not coincide with the location of the pre-Permian rivers, even if the latter persisted in their courses through the growth of the Permian folding; subsequent elevations and adjustments to hard beds, at first buried and unseen, may have greatly displaced them, in accordance with Löwl's principle.

When the deeper channelling of a stream discovers an unconformable subjacent terrane, the streams persist at least for a time in the courses that were determined in the overlying mass; they are then called superimposed (Powell), inherited (Shaler), or epigenetic (Richthofen). Such streams are particularly liable to readjustment by transfer of channels from courses that lead them over hard beds to others on which the hard beds are avoided; for the first choice of channels, when the unconformable cover was still present, was made without any knowledge of the buried rock structure or of the difficulties in which the streams would be involved when they encountered it. The examples of falls produced when streams terrace their flood-plains and run on buried spurs has already been referred to as superimposed; and the rivers of Minnesota now disclosing half-buried ledges here and there may be instanced as illustrating the transition stage between simple consequent courses, determined by the form of the drift sheet on which their flow began, and the fully inconsequent courses that will be developed there in the future.

22. *Simple, compound, composite and complex rivers.*—We

have thus far considered an ideal river. It now seems advisable to introduce a few terms with which to indicate concisely certain well marked peculiarities in the history of actual rivers.

An original river has already been defined as one which first takes possession of a land area, or which replaces a completely extinguished river on a surface of rapid deformation.

A river may be simple, if its drainage area is of practically one kind of structure and of one age; like the rivers of southern New Jersey. Such rivers are generally small. It may be composite, when drainage areas of different structure are included in the basin of a single stream. This is the usual case.

A compound river is one which is of different ages in its different parts; as certain rivers of North Carolina, which have old headwaters rising in the mountains, and young lower courses traversing the coastal plain.

A river is complex when it has entered a second or later cycle of development; the headwaters of a compound river are therefore complex, while the lower course may be simple, in its first cycle. The degree of complexity measures the number of cycles that the river has entered.

When the study of rivers is thus attempted, its necessary complications may at first seem so great as to render it of no value; but in answer to this I believe that it may be fairly urged that, although complicated, the results are true to nature, and if so, we can have no ground of complaint against them. Moreover, while it is desirable to reduce the study of the development of rivers to its simplest form, in order to make it available for instruction and investigation, it must be remembered that this cannot be done by neglecting to investigate the whole truth in the hope of avoiding too great complexity, but that simplicity can be reached safely only through fullness of knowledge, if at all.

It is with these points in mind that I have attempted to decipher the history of the rivers of Pennsylvania. We find in the Susquehanna, which drains a great area in the central part of the state, an example of a river which is at once composite, compound and highly complex. It drains districts of divers structure; it traverses districts of different ages; and it is at present in its fourth or fifth degree of complexity, its fourth or fifth cycle of development at least. In unravelling its history and searching out the earlier courses of streams which may have long since been abandoned in the processes of mature adjustment, it will be seen that the size of the present streams is not always a measure of their previous importance, and to this we may ascribe the difficulty that attends the attempt to decipher a river's history from general maps of its stream lines. Nothing but a detailed examination of geological structure and history suffices to detect facts and conditions that are essential to the understanding of the result.

If the postulates that I shall use seem unsound and the arguments seem overdrawn, error may at least be avoided by not holding fast to the conclusions that are presented, for they are presented only tentatively. I do not feel by any means absolutely persuaded of the correctness of the results, but at the same time deem them worth giving out for discussion. The whole investigation was undertaken as an experiment to see where it might lead, and with the hope that it might lead at least to a serious study of our river problems.

PART FOURTH. *The development of the rivers of Pennsylvania:*

23. *Means of distinguishing between antecedent and adjusted consequent rivers.*—The outline of the geological history of Pennsylvania given above affords means of dividing the long progress of the development of our rivers into the several cycles which make up their complete life. We must go far back into the past and imagine ancient streams flowing down from the Archean land towards the paleozoic sea; gaining length by addition to their lower portions as the land grew with the building on of successive mountain ranges; for example, if there were a Cambro-Silurian deformation, a continuation of the Green Mountains into Pennsylvania, we suppose that the pre-existent streams must in some manner have found their way westward to the new coast-line; and from the date of this mountain growth, it is apparent that any streams then born must have advanced far in their history before the greater Appalachian disturbance began. At the beginning of the latter, as of the former, there must have been streams running from the land into the sea, and at times of temporary elevation of the broad sand-flats of the coal measures, such streams must have had considerable additions to their lower length; rising in long-growing Archean highlands or mountains, snow-capped and drained by glaciers for all we can say to the contrary, descending across the Green Mountain belt, by that time worn to moderate relief in the far advanced stage of its

topographic development, and finally flowing across the coal-measure lowlands of recent appearance. It was across the lower courses of such rivers that the Appalachian folds were formed, and the first step in our problem consists in deciding if possible whether the streams held their courses after the antecedent fashion, or whether they were thrown into new courses by the growing folds, so that a new drainage systen would be formed. Possibly both conditions prevailed; the larger streams holding their courses little disturbed, and the smaller ones disappearing, to be replaced by others as the slopes of the growing surface should demand. It is not easy to make choice in this matter. To decide that the larger streams persisted and are still to be seen in the greater rivers of to-day, only reversed in direction of flow, is certainly a simple method of treating the problem, but unless some independent reasons are found for this choice, it savors of assumption. Moreover, it is difficult to believe that any streams, even if antecedent and more or less persistent for a time during the mountain growth, could preserve till now their pre-Appalachain courses through all the varying conditions presented by the alternations of hard and soft rocks through which they have had to cut, and at all the different altitudes above baselevel in which they have stood. A better means of deciding the question will be to admit provisionally the occurrence of a completely original system of consequent drainage, located in perfect accord with the slopes of the growing mountains; to study out the changes of stream-courses that would result from later disturbances and from the mutual adjustments of the several members of such a system in the different cycles of its history; and finally to compare the courses thus deduced with those now seen. If there be no accord, either the method is wrong or the streams are not consequent but of some other origin, such as antecedent; if the accord between deduction and fact be well marked, varying only where no definite location can be given to the deduced streams, but agreeing where they can be located more precisely, then it seems to me that the best conclusion is distinctly in favor of the correctness of the deductions. For it is not likely, even if it be possible, that antecedent streams should have accidentally taken, before the mountains were formed, just such locations as would have resulted from the subsequent growth of the mountains and from the complex changes in the initial river courses due to later adjustments. I shall therefore follow the deductive method thus indicated and attempt to trace out the history of a completely original, consequent system of drainage accordant with the growth of the central mountain district.

In doing this, it is first necessary to restore the constructional topography of the region; that is, the form that the surface would have had if no erosion had accompanied its deformation. This involves certain postulates which must be clearly conceived if any measure of confidence is to be gained in the results based upon them.

24. *Postulates of the argument.*—In the first place, I assume an essential constancy in the thickness of the paleozoic sediments over the entire area in question. This is warranted here because the known variations of thickness are relatively of a second order, and will not affect the distribution of high and low ground as produced by the intense Permian folding. The reasons for maintaining that the whole series had a considerable extension southeast of the present margin of the Medina sandstone have already been presented.

In the second place, I shall assume that the dips and folds of the beds now exposed at the surface of the ground may be projected upwards into the air in order to restore the form of the eroded beds. This is certainly inadmissible in detail, for it cannot be assumed that the folded slates and limestones of the Nittany valley, for instance, give any close indication of the form that the coal measures would have taken, had they extended over this district, unworn. But in a general way, the Nittany massif was a complex arch in the coal measures as well as in the Cambrian beds; for our purpose and in view of the moderate relief of the existing topography, it suffices to say that wherever the lower rocks are now revealed in anticlinal structure, there was a great upfolding and elevation of the original surface; and wherever the higher rocks are still preserved, there was a relatively small elevation.

In the third place, I assume that by reconstructing from the completed folds the form which the country would have had if unworn, we gain a sufficiently definite picture of the form through which it actually passed at the time of initial and progressive folding. The difference between the form of the folds completely restored and the form that the surface actually reached is rather one of degree than of kind; the two must correspond in the general distribution of high and low ground and this is the chief consideration in our problem. When we remember how accurately water finds its level, it will be clearer that what is needed in the discussion is the location of the regions that were relatively raised and lowered, as we shall then have marked out the general course of the consequent water ways and the trend of the intervening constructional ridges.

Accepting these postulates, it may be said in brief that the outlines of the formations as at present exposed are in effect so many contour lines of the old constructional surface, on which the Permian rivers took their consequent courses. Where the Trenton limestone is now seen, the greatest amount of overlying strata must have been removed; hence the outline of the Trenton formation is our highest contour line. Where the Helderberg limestone appears, there has been a less amount of material removed; hence the Helderberg outcrop is a contour of less elevation. Where the coal beds still are preserved, there has been least wasting, and these beds therefore mark the lowest contour of the early surface. It is manifest that this method assumes that the present outcrops are on a level surface; this is not true, for the ridges through the State rise a thousand feet more or less over the intervening valley lowlands, and yet the existing relief does not count for much in discussing the enormous relief of the Permian surface that must have been measured in tens of thousands of feet at the time of its greatest strength.

25. *Constructional Permian topography and consequent drainage.*—A rough restoration of the early constructional topography is given in fig. 21 for the central part of the State, the closest shading being the area of the Trenton limestone, indicating the highest ground, or better, the plases of greatest elevation, while the Carboniferous area is unshaded, indicating the early lowlands. The prevalence of northeast and southwest trends was then even more pronounced than now. Several of the stronger elements of form deserve names, for convenient reference. Thus we have the great Kittatinny or Cumberland highland, C, C, on the southeast, backed by the older mountains of Cambrian and Archean rocks, falling by the Kittatinny slope to the synclinal lowland troughs of the central district. In this lower ground lay the synclinal troughs of the eastern coal regions, and the more local Broad Top basin, BT, on the southwest, then better than now deserving the name of basins. Beyond the corrugated area that connected the coal basins rose the great Nittany highland, N,

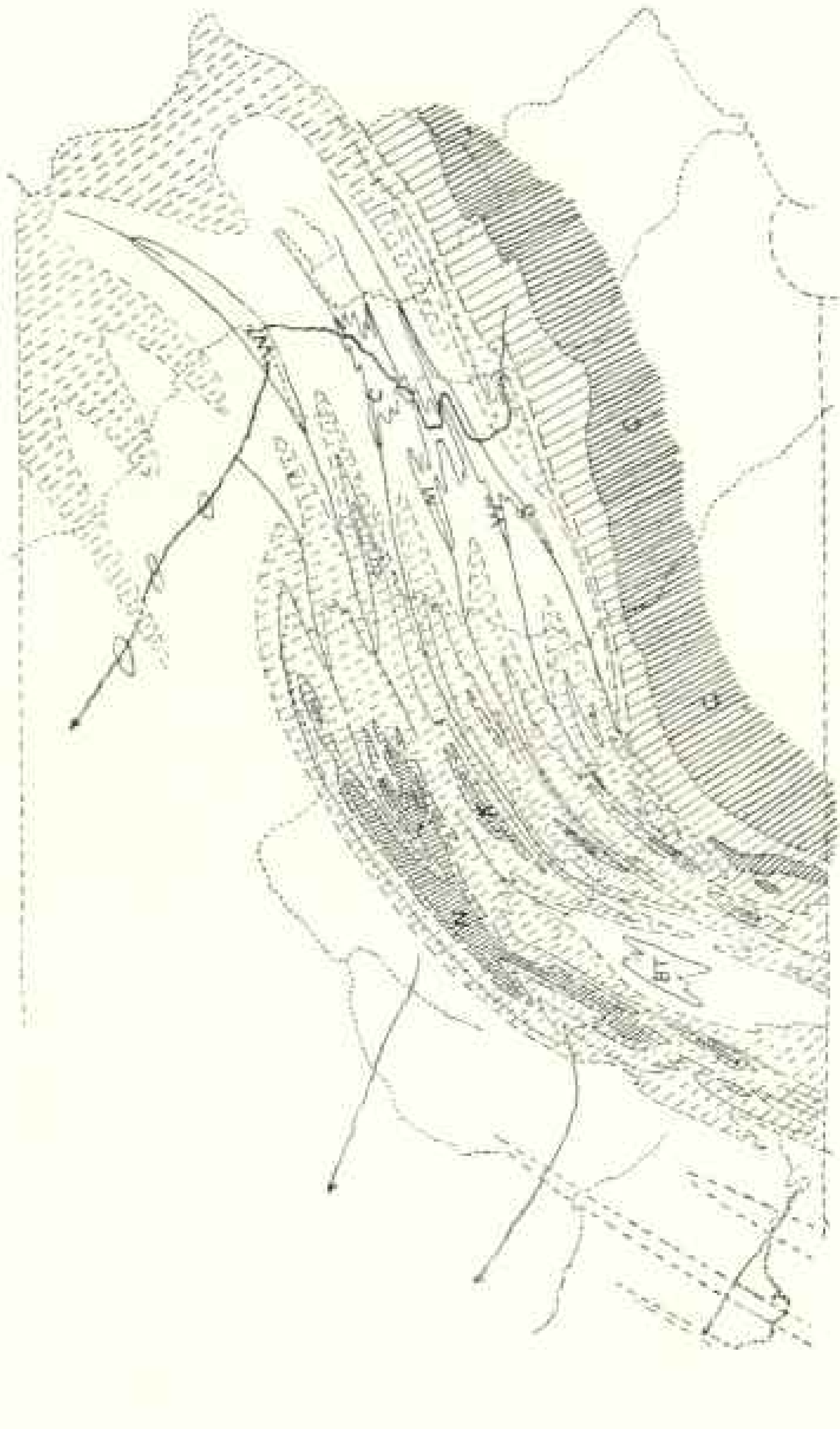


Fig. 23. Constructional Permian topography of Pennsylvania.

and its southwest extension in the Bedford range, with the less conspicuous Kishicoquilas highland, K, in the foreground. Beyond all stretched the great Alleghany lowland plains. The names thus suggested are compounded of the local names of to-day and the morphological names of Permian time.

What would be the drainage of such a country? Deductively we are led to believe that it consisted of numerous streams as marked in full lines on the figure, following synclinal axes until some master streams led them across the intervening anticlinal ridges at the lowest points of their crests and away into the open country to the northwest. All the enclosed basins would hold lakes, overflowing at the lowest part of the rim. The general discharge of the whole system would be to the northwest. Here again we must resort to special names for the easy indication of these well-marked features of the ancient and now apparently lost drainage system. The master stream of the region is the great Anthracite river, carrying the overflow of the Anthracite lakes off to the northwest and there perhaps turning along one of the faintly marked synclines of the plateau and joining the original Ohio, which was thus confirmed in its previous location across the Carboniferous marshes. The synclinal streams that entered the Anthracite lakes from the southwest may be named, beginning on the south, the Swatara, S, fig. 21, the Wiconisco, Wo, the Tuscarora-Mahanoy, M, the Juniata-Catawissa, C, and the Wyoming, Wy. One of these, probably the fourth, led the overflow from the Broad Top lake into the Catawissa lake on the middle Anthracite river. The Nittany highland formed a strong divide between the central and northwestern rivers, and on its outer slope there must have been streams descending to the Alleghany lowlands; and some of these may be regarded as the lower courses of Carboniferous rivers, that once rose in the Archean mountains, now beheaded by the growth of mountain ranges across their middle.

26. *The Jura mountains homologous with the Permian Alleghanies.*—However willing one may be to grant the former existence of such a drainage system as the above, an example of a similar one still in existence would be acceptable as a witness to the possibilities of the past. Therefore we turn for a moment to the Jura mountains, always compared to the Appalachians on account of the regular series of folds by which the two are characterized. But while the initial topography is long lost in our old mountains, it is still clearly perceptible in the young Jura,

where the anticlines are still ridges and the longitudinal streams still follow the synclinal troughs; while the transverse streams cross from one synclinal valley to another at points where the intervening anticlinal arches are lowest.* We could hardly ask for better illustration of the deductive drainage system of our early Appalachians than is here presented.

27. *Development and adjustment of the Permian drainage.*— The problem is now before us. Can the normal sequence of changes in the regular course of river development, aided by the post-Permian deformations and elevations, evolve the existing rivers out of the ancient ones?

In order to note the degree of comparison that exists between the two, several of the larger rivers of to-day are dotted on the figure. The points of agreement are indeed few and small. Perhaps the most important ones are that the Broad Top region is drained by a stream, the Juniata, which for a short distance follows near the course predicted for it; and that the Nittany district, then a highland, is still a well-marked divide although now a lowland. But there is no Anthracite river, and the region of the ancient coal-basin lakes is now avoided by large streams; conversely, a great river—the Susquehanna—appears where no consequent river ran in Permian time, and the early synclinal streams frequently turn from the structural troughs to valleys located on the structural arches.

28. *Lateral water gaps near the apex of synclinal ridges.*—One of the most frequent discrepancies between the hypothetical and actual streams is that the latter never follow the axis of a descending syncline along its whole length, as the original streams must have done, but depart for a time from the axis and then return to it, notching the ridge formed on any hard bed at the side instead of at the apex of its curve across the axis of the syncline. There is not a single case in the state of a stream cutting a gap at the apex of such a synclinal curve, but there are perhaps hundreds of cases where the streams notch the curve to one side of the apex. This, however, is precisely the arrangement attained by spontaneous adjustment from an initial axial course, as indicated in figure 13. The gaps may be located on small transverse faults, but as a rule they seem to have no such guidance. It is true that most of our streams now run out of and not into the

* This is beautifully illustrated in the recent monograph by La Noë and Margerie on "Les Formes du Terrain."

synclinal basins, but a reason for this will be found later; for the present we look only at the location of the streams, not at their direction of flow. As far as this illustration goes, it gives evidence that the smaller streams at least possess certain peculiarities that could not be derived from persistence in a previous accidental location, but which would be necessarily derived from a process of adjustment following the original establishment of strictly consequent streams. Hence the hypothesis that these smaller streams were long ago consequent on the Permian folding receives confirmation; but this says nothing as to the origin of the larger rivers, which might at the same time be antecedent.

29. *Departure of the Juniata from the Juniata-Catawissa syncline.*—It may be next noted that the drainage of the Broad Top region does not follow a single syncline to the Anthracite region, as it should have in the initial stage of the consequent Permian drainage, but soon turns aside from the syncline in which it starts and runs across country to the Susquehanna. It is true that in its upper course the Juniata departs from the Broad Top region by one of the two synclines that were indicated as the probable line of discharge of the ancient Broad Top lake in our restoration of the constructional topography of the State; there does not appear to be any significant difference between the summit altitudes of the Tuscarora-Mahanoy and the Juniata-Catawissa synclinal axes and hence the choice must have been made for reasons that cannot be detected; or it may be that the syncline lying more to the northwest was raised last, and for this reason was taken as the line of overflow. The beginning of the river is therefore not discordant with the hypothesis of consequent drainage, but the southward departure from the Catawissa syncline at Lewistown remains to be explained. It seems to me that some reason for the departure may be found by likening it to the case already given in figs. 16–18. The several synclines with which the Juniata is concerned have precisely the relative attitudes that are there discussed. The Juniata-Catawissa syncline has parallel sides for many miles about its middle, and hence must have long maintained the initial Juniata well above baselevel over all this distance; the progress of cutting down a channel through all the hard Carboniferous standstones for so great a distance along the axis must have been exceedingly slow. But the synclines next south, the Tuscarora-Mahanoy and the Wiconisco, plunge to the northeast more rapidly, as the rapid

divergence of their margins demonstrates, and must for this reason have carried the hard sandstones below baselevel in a shorter distance and on a steeper slope than in the Catawissa syncline. The further southwestward extension of the Pocono sandstone ridges in the southern than in the northern syncline gives further illustration of this peculiarity of form. Lateral capture of the Juniata by a branch of the initial Tuscarora, and of the latter by a branch of the Wiconisco therefore seems possible, and the accordance of the facts with so highly specialized an arrangement is certainly again indicative of the correctness of the hypothesis of consequent drainage, and this time in a larger stream than before. At first sight, it appears that an easier lateral capture might have been made by some of the streams flowing from the outer slope of the Nittany highland; but this becomes improbable when it is perceived that the heavy Medina sandstone would here have to be worn through as well as the repeated arches of the Carboniferous beds in the many high folds of the Seven Mountains. Again, as far as present appearances go, we can give no sufficient reason to explain why possession of the headwaters of the Juniata was not gained by some subsequent stream of its own, such as G, fig. 18, instead of by a side-stream of the river in the neighboring syncline; but it may be admitted, on the other hand, that as far as we can estimate the chances for conquest, there was nothing distinctly in favor of one or the other of the side-streams concerned; and as long as the problem is solved indifferently in favor of one or the other, we may accept the lead of the facts and say that some control not now apparent determined that the diversion should be, as drawn, through D and not through G. The detailed location of the Juniata in its middle course below Lewistown will be considered in a later section.

39. *Avoidance of the Broad Top basin by the Juniata headwaters.*—Another highly characteristic change that the Juniata has suffered is revealed by examining the adjustments that would have taken place in the general topography of the Broad Top district during the Perm-Triassic cycle of erosion. When the basin, BT, fig. 22, was first outlined, centripetal streams descended its slopes from all sides and their waters accumulated as a lake in the center, overflowing to the east into the subordinate basin, A, in the Juniata syncline along side of the larger basin, and thence escaping northeast. In due time, the

breaching of the slopes opened the softer Devonian rocks beneath and peripheral lowlands were opened on them. The process by which the Juniata departed from its original axial location, J, fig. 22, to a parallel course on the southeastern side of the syncline, J, fig. 23, has been described (fig. 18). The subsequent changes are manifest. Some lateral branch of the Juniata, like N, fig. 23, would work its way around the northern end of the Broad Top canoe on the soft underlying rocks and capture the axial stream, C, that came from the depression between Nittany and Kishicoquillas highlands; thus reënforced, capture would be made of a radial stream from the west, Tn, the existing Tyrone branch of the Juniata; in a later stage the other streams of the western side of the basin would be acquired, their divertor constituting the Little Juniata of to-day; and the end would be when the original Juniata, A, fig. 22, that once issued from the subordinate synclinal as a large stream, had lost all its western tributaries, and was but a shrunken beheaded remnant of a river, now seen in Aughwick creek, A, fig. 24. In the meantime, the

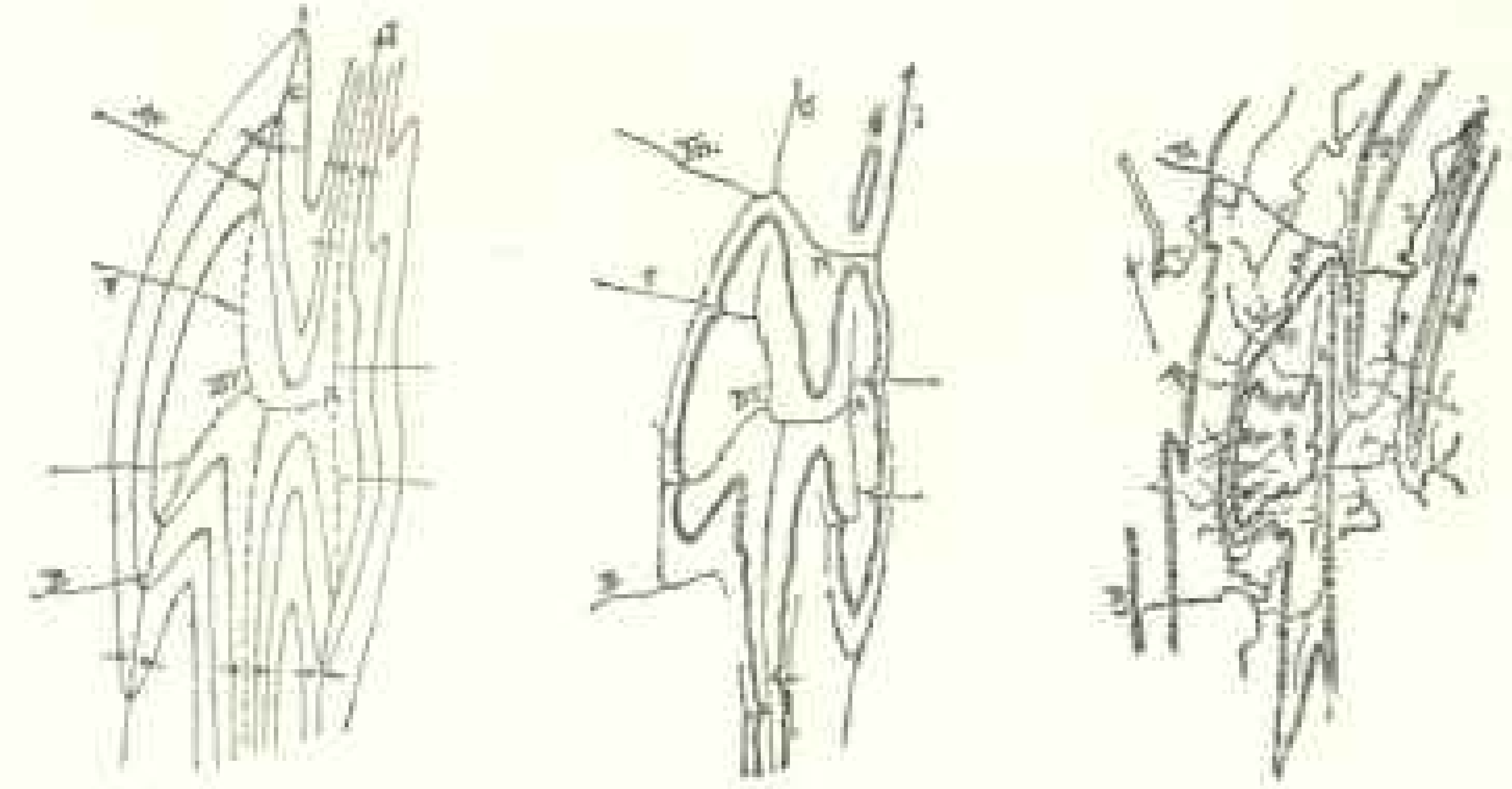


FIG. 22. FIG. 23. FIG. 24.

former lake basin was fast becoming a synclinal mountain of diminishing perimeter. The only really mysterious courses of the present streams are where the Little Juniata runs in and out of the western border of the Broad Top synclinal, and where the Frankstown (FT) branch of the Juniata maintains its independent gap across Tussey's mountain (Medina), although diverted to the Tyrone or main Juniata (Tn) by Warrior's ridge (Oriskany) just below. At the time of the early predatory growth of the initial divertor, N, its course lay by the very conditions of its growth on only the weakest rocks; but after this little stream had grown to a good-sized river, further rising of the land, probably in the time of the Jurassic elevation, allowed the river to sink its channel to a greater depth, and in doing so, it encountered the hard Medina anticline of Jack's mountain; here it has since persisted, because, as we may suppose, there has been no stream able to divert the course of so large a river from its crossing of a single hard anticlinal.

The doubt that one must feel as to the possibility of the processes just outlined arises, if I may gauge it by my own feeling, rather from incredulity than from direct objections. It seems incredible that the waste of the valley slopes should allow the backward growth of N at such a rate as to enable it to capture the heads of C, Tn, F, and so on, before they had cut their beds down close enough to the baselevel of the time to be safe from capture. But it is difficult to urge explict objections against the process or to show its quantitative insufficiency. It must be remembered that when these adjustments were going on, the region was one of great altitude, its rocks then had the same strong contrasts of strength and weakness that are so apparent in the present relief of the surface and the streams concerned were of moderate size; less than now, for at the time, the Tyrone, Frankstown and Bedford head branches of the Juniata had not acquired drainage west of the great Nittany-Bedford anticlinal axis, but were supplied only by the rainfall on its eastern slope (see section 39)—and all these conditions conspired to favor the adjustment. Finally, while apparently extraordinary and difficult of demonstration, the explanation if applicable at all certainly gives rational correlation to a number of peculiar and special stream courses in the upper Juniata district that are meaningless under any other theory that has come to my notice. It is chiefly for this reason that I am inclined to accept the explanation.

31. *Reversal of larger rivers to southeast courses.*—Our large rivers at present flow to the southeast, not to the northwest. It is difficult to find any precise date for this reversal of flow from the initial hypothetical direction, but it may be suggested that it occurred about the time of the Triassic depression of the Newark belt. We have been persuaded that much time elapsed between the Permian folding and the Newark deposition, even under the most liberal allowance for pre-Permian erosion in the Newark belt; hence when the depression began, the rivers must

have had but moderate northwestward declivity. The depression and submergence of the broad Newark belt may at this time have broken the continuity of the streams that once flowed across it. The headwater streams from the ancient Archean country maintained their courses to the depression ; the lower portions of the rivers may also have gone on as before ; but the middle courses were perhaps turned from the central part of the state back of the Newark belt. No change of attitude gives so fitting a cause of the southeastward flow of our rivers as this. The only test that I have been able to devise for the suggestion is one that is derived from the relation that exists between the location of the Newark belt along the Atlantic slope and the course of the neighboring transverse rivers. In Pennsylvania, where the belt reaches somewhat beyond the northwestern margin of the crystalline rocks in South mountain, the streams are reversed, as above stated ; but in the Carolinas where the Newark belt lies far to the east of the boundary between the Cambrian and crystalline rocks, the Tennessee streams persevere in what we suppose to have been their original direction of flow. This may be interpreted as meaning that in the latter region, the Newark depression was not felt distinctly enough, if at all, within the Alleghany belt to reverse the flow of the streams ; while in the former region, it was nearer to these streams and determined a change in their courses. The original Anthracite river ran to the northwest, but its middle course was afterwards turned to the southeast.

I am free to allow that this has the appearance of heaping hypothesis on hypothesis ; but in no other way does the analysis of the history of our streams seem possible, and the success of the experiment can be judged only after making it. At the same time, I am constrained to admit that this is to my own view the least satisfactory of the suggestions here presented. It may be correct, but there seems to be no sufficient exclusion of other possibilities. For example, it must not be overlooked that, if the Anthracite river ran southeast during Newark deposition, the formation of the Newark northwestward monocline by the Jurassic tilting would have had a tendency to turn the river back again to its northwest flow. But as the drainage of the region is still southeastward, I am tempted to think that the Jurassic tilting was not here strong enough to reverse the flow of so strong and mature a river as the Anthracite had by that time come to be; and that the elevation that accompanied the tilting was not so powerful in reversing the river to a northwest course as the previous depression of the Newark basin had been in turning it to the southeast. If the Anthracite did continue to flow to the southeast, it may be added that the down-cutting of its upper branches was greatly retarded by the decrease of slope in its lower course when the monocline was formed.

The only other method of reversing the original northwestward flow of the streams that I have imagined is by capture of their headwaters by Atlantic rivers. This seems to me less effective than the method just considered; but they are not mutually exclusive and the actual result may be the sum of the two processes. The outline of the idea is as follows. The long continued supply of sedimentary material from the Archean land on the southeast implies that it was as continually elevated. But there came a time when there is no record of further supply of material, and when we may therefore suppose the elevation was no longer maintained. From that time onward, the Archean range must have dwindled away, what with the encroachment of the Atlantic on its eastern shore and the general action of denuding forces on its surface. The Newark depression was an effective aid to the same end, as has been stated above, and for a moderate distance westward of the depressed belt, the former direction of the streams must certainly have been reversed; but the question remains whether this reversal extended as far as the Wyoming basin, and whether the subsequent formation of the Newark monocline did not undo the effect of the Newark depression. It is manifest that as far as our limited knowledge goes, it is impossible to estimate these matters quantitatively, and hence the importance of looking for additional processes that may supplement the effect of the Newark depression and counteract the effect of the Newark uplift in changing the course of the rivers. Let it be supposed for the moment that at the end of the Jurassic uplift by which the Newark monocline was formed, the divide between the Ohio and the Atlantic drainage lay about the middle of the Newark belt. There was a long gentle descent westward from this watershed and a shorter and hence steeper descent eastward. Under such conditions, the divide must have been pushed westward, and as long as the rocks were so exposed as to open areas of weak sediments on which capture by the Atlantic streams could go on with relative rapidity, the westward migration of the divide would be important. For this reason, it might be carried from the Newark belt as far as the present Alleghany front, beyond which further pushing would be slow, on account of the broad stretch of country there covered by hard horizontal beds.

The end of this is that, under any of the circumstances here detailed, there would be early in the Jurassic-Cretaceous cycle a distinct tendency to a westward migration of the Atlantic-Ohio divide; it is the consequences of this that have now to be examined.

32. *Capture of the Anthracite headwaters by the growing Susquehanna.*—Throughout the Perm-Triassic period of denudation, a great work was done in wearing down the original Alleghanies. Anticlines of hard sandstone were breached, and broad lowlands were opened on the softer rocks beneath. Little semblance of the early constructional topography remained when the period of Newark depression was brought to a close; and all the while the headwater streams of the region were gnawing at the divides, seeking to develop the most perfect arrangement of waterways. Several adjustments have taken place, and the larger streams have been reversed in the direction of their flow; but a more serious problem is found in the disappearance of the original master stream, the great Anthracite river, which must have at first led away the water from all the lateral synclinal streams. Being a large river, it could not have been easily diverted from its course, unless it was greatly retarded in cutting down its channel by the presence of many beds of hard rocks on its way. The following considerations may perhaps throw some light on this obscure point.

It may be assumed that the whole group of mountains formed by the Permian deformation had been reduced to a moderate relief when the Newark deposition was stopped by the Jurassic elevation. The harder ribs of rock doubtless remained as ridges projecting above the intervening lowlands, but the strength of relief that had been given by the constructional forces had been lost. The general distribution of residual elevations then remaining unsubdued is indicated in fig. 25, in which the Crystalline, the Medina, and the two Carboniferous sandstone ridges are denoted by appropriate symbols. In restoring this phase of the surface form, when the country stood lower than now, I have reduced the anticlines from their present outlines and increased the synclines, the change of area being made

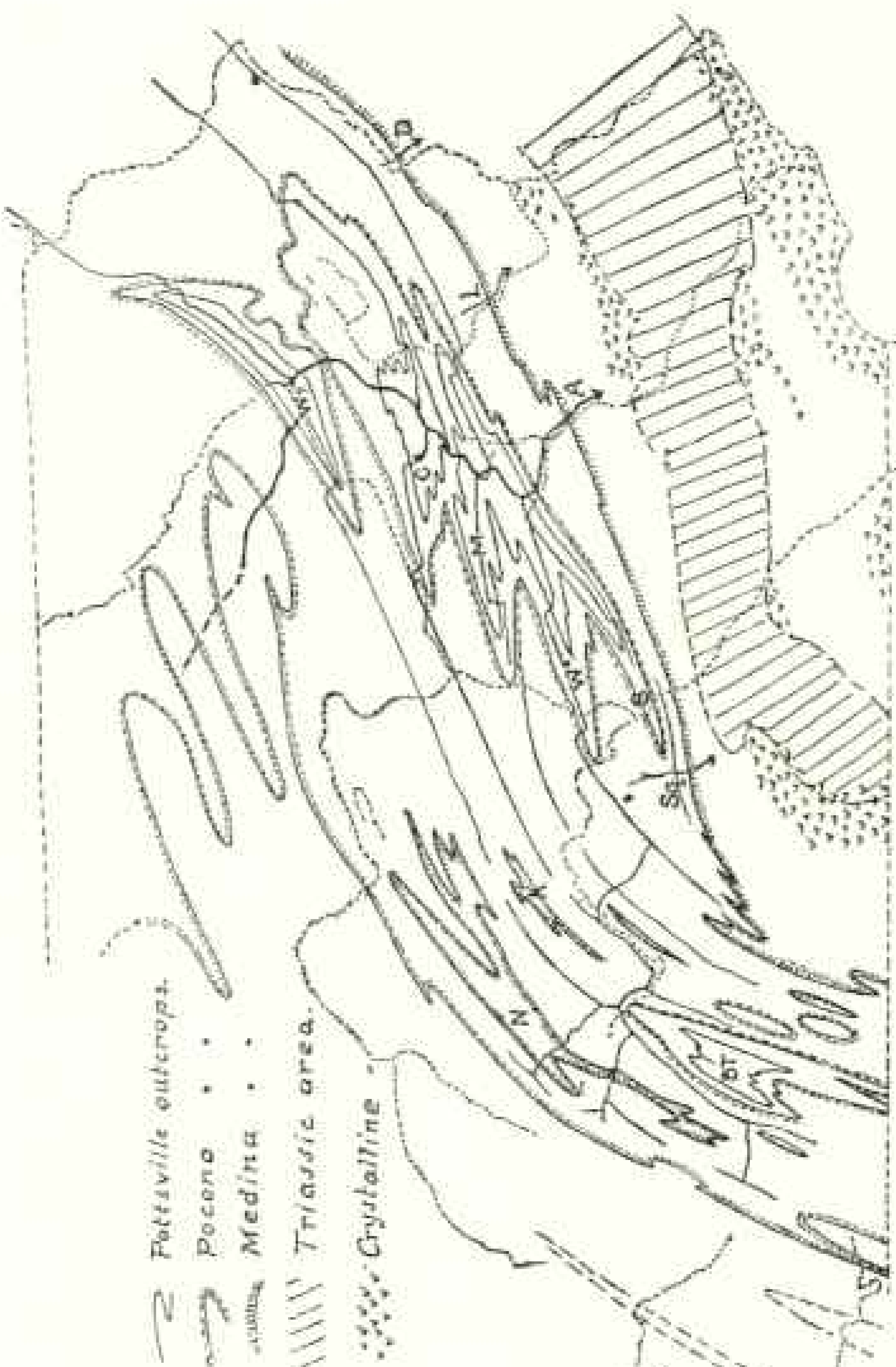


FIG. 25. General distribution of high and low land and drainage in early Jurassic time.

greatest where the dips are least, and hence most apparent at the ends of the plunging anticlines and synclines. Some of the Medina anticlines of Perry and Juniata counties are not indicated because they were not then uncovered. The country between the residual ridges of Jurassic time was chiefly Cambrian limestone and Siluro-Devonian shales and soft sandstones. The moderate ridges developed on the Oriskany and Chemung sandstones are not represented. The drainage of this stage retained the original courses of the streams, except for the adjustments that have been described, but the great Anthracite river is drawn as if it had been controlled by the Newark depression and reversed in the direction of its flow, so that its former upper course on the Cambrian rocks was replaced by a superimposed Newark lower course. Fig. 25 therefore represents the streams for the most part still following near their synclinal axes, although departing from them where they have to enter a synclinal cove-mountain ridge; the headwaters of the Juniata avoid the mass of hard sandstones discovered in the bottom of old Broad Top lake, and flow around them to the north, and then by a cross-country course to the Wiconisco synclinal, as already described in detail. Several streams come from the northeast, entering the Anthracite district after the fashion generalized in fig. 13. Three of the many streams that were developed on the great Kittatinny slope are located, with their direction of flow reversed; these are marked Sq, L and D, and are intended to represent the ancestors of the existing Susquehanna, Lehigh and Delaware. We have now to examine the opportunities offered to these small streams to increase their drainage areas.

The Jurassic elevation, by which the Newark deposition was stopped, restored to activity all the streams that had in the previous cycle sought and found a course close to baselevel. They now all set to work again deepening their channels. But in this restoration of lost activity with reference to a new baselevel, there came the best possible chance for numerous re-arrangements of drainage areas by mutual adjustment into which we must inquire.

I have already illustrated what seems to me to be the type of the conditions involved at this time in figs. 19 and 20. The master stream, A, traversing the synclines, corresponds to the reversed Anthracite river; the lowlands at the top are those that have been opened out on the Siluro-Devonian beds of the present Susquehanna middle course between the Pocono and the Medina ridges. The small stream, B, that is gaining drainage area in these lowlands, corresponds to the embryo of the present Susquehanna, Sq, fig. 25, this having been itself once a branch on the south side of the Swatara synclinal stream, fig. 21, from which it was first turned by the change of slope accompanying the Newark depression; but it is located a little farther west than the actual Susquehanna, so as to avoid the two synclinal cove mountains of Pocono sandstone that the Susquehanna now traverses, for reasons to be stated below (section 35). This stream had to cross only one bed of hard rock, the outer wall of Medina sandstone, between the broad inner lowlands of the relatively weak Siluro-Devonian rocks and the great valley lowlands on the still weaker Cambrian limestones. Step by step it must have pushed its headwater divide northward, and from time to time it would have thus captured a subsequent stream, that crossed the lowlands eastward, and entered a Carboniferous syncline by one of the lateral gaps already described. With every such capture, the power of the growing stream to capture others was increased. Fig. 19 represents a stage after the streams in the Swatara and Wiconisco synclines (the latter then having gained the Juniata) had been turned aside on their way to the Carboniferous basins. On the other hand, the Anthracite river, rising somewhere on the plains north of the Wyoming syncline and pursuing an irregular course from one coal basin to another, found an extremely difficult task in cutting down its channel across the numerous hard beds of the Carboniferous sandstones, so often repeated in the rolling folds of the coal fields. It is also important to remember that an aid to other conditions concerned in the diversion of the upper Anthracite is found in the decrease of slope that its lower course suffered in crossing the coal fields, if that area took any part in the deformation that produced the Newark monocline—whichever theory prove true in regard to the origin of the southeastward flow of the rivers—for loss of slope in the middle course, where the river had to cross many reefs of hard sandstone, would have been very effective in lengthening the time allowed for the diversion of the headwaters.

The question is, therefore, whether the retardation of down-cutting here experienced by the Anthracite was sufficient to allow the capture of its headwaters by the Susquehanna. There can be little doubt as to the correct quality of the process, but whether it was quantitatively sufficient is another matter. In the absence of any means of testing its sufficiency, may the result not be taken as the test? Is not the correspondence between deduction and fact close enough to prove the correctness of the deduction?

33. *Present outward drainage of the Anthracite basins.*—The Lehigh, like the Susquehanna, made an attempt to capture the headwaters of adjacent streams, but failed to acquire much territory from the Anthracite because the Carboniferous sandstones spread out between the two in a broad plateau of hard rocks, across which the divide made little movement. The plateau area that its upper branches drain is, I think, the conquest of a later cycle of growth. The Delaware had little success, except as against certain eastern synclinal branches of the Anthracite, for the same reason. The ancestor of the Swatara of to-day made little progress in extending its headwaters because its point of attack was against the repeated Carboniferous sandstones in the Swatara synclinal. One early stream alone found a favorable opportunity for conquest, and thus grew to be the master river—the Susquehanna of to-day. The head of the Anthracite was carried away by this captor, and its beheaded lower portion remains in our Schuylkill. The Anthracite coal basins, formerly drained by the single master stream, have since been apportioned to the surrounding rivers. As the Siluro-Devonian lowlands were opened around the coal-basins, especially on the north and west, the streams that formerly flowed into the basins were gradually inverted and flowed out of them, as they still do. The extent of the inversion seems to be in a general way proportionate to its opportunity. The most considerable conquests were made in the upper basins, where the Catawissa and Nescopec streams of today drain many square miles of wide valleys opened on the Mauch Chunk red shale between the Pocono and Pottsville sandstone ridges; the ancient middle waters of the Anthracite here being inverted to the Susquehanna tributaries, because the northern coal basins were degraded very slowly after the upper Anthracite had been diverted. The Schuylkill as the modern representative of the Anthracite retains only certain streams south of a medial divide between Nescopec and Blue mountains. The only considerable part of the old Anthracite river that still retains a course along the axis of a synclinal trough seems to be that part which follows the Wyoming basin; none of the many other

coal basins are now occupied by the large stream that originally followed them. The reason for this is manifestly to be found in the great depth of the Wyoming basin, whereby the axial portion of its hard sandstones are even now below baselevel, and hence have never yet acted to throw the river from its axial course. Indeed, during the early cycles of denudation, this basin must have been changed from a deep lake to a lacustrine plain by the accumulation in it of waste from the surrounding highlands, and for a time the streams that entered it may have flowed in meandering courses across the ancient alluvial surface; the lacustrine and alluvial condition may have been temporarily revived at the time of the Jurassic elevation. It is perhaps as an inheritance from a course thus locally superimposed that we may come to regard the deflection of the river at Nanticoke from the axis of the syncline to a narrow shale valley on its northern side, before turning south again and leaving the basin altogether. But like certain other suggestions, this can only be regarded as an open hypothesis, to be tested by some better method of river analysis than we now possess; like several of the other explanations here offered, it is presented more as a possibility to be discussed than as a conclusion to be accepted.

I believe that it was during the earlier part of the great Jura-Cretaceous cycle of denudation that the Susquehanna thus became the master stream of the central district of the state. For the rest of the cycle, it was occupied in carrying off the waste and reducing the surface to a well finished baselevel lowland that characterized the end of Cretaceous time. From an active youth of conquest, the Susquehanna advanced into an old age of established boundaries; and in later times, its area of drainage does not seem to have been greatly altered from that so long ago defined; except perhaps in the districts drained by the West and North Branch headwaters.

34. *Homologies of the Susquehanna and Juniata.*—Looking at the change from the Anthracite to the Susquehanna in a broad way, one may perceive that it is an effect of the same order as the peripheral diversion of the Broad Top drainage, illustrated in figures 22, 23 and 24; another example of a similar change is seen in the lateral diversion of the Juniata above Lewistown and its rectilinear continuation in Aughwick creek, from their original axial location when they formed the initial Broad Top outlet. They have departed from the axis of their syncline to

the softer beds on its southern side; FE of fig. 17 has been diverted to FD of fig. 18.

All of these examples are truly only special cases of the one already described in which the Juniata left its original syncline for others to the south. The general case may be stated in a few words. A stream flowing along a syncline of hard beds (Carboniferous sandstones) developes side streams which breach the adjacent anticlines and open lowlands in the underlying softer beds (Devonian and Silurian). On these lowlands, the headwaters of side streams from other synclines are encountered and a contest ensues as to possession of the drainage territory. The divides are pushed away from those headwaters whose lower course leads them over the fewest hard barriers; this conquest goes on until the upper course of the initial main stream is diverted to a new and easier path than the one it chose in its youth in obedience to the first deformation of the region. Thus the Juniata now avoids the center and once deepest part of the old Broad Top lake, because in the general progress of erosion, lowlands on soft Devonian beds were opened all around the edge of the great mass of sandstones that held the lake; the original drainage across the lake, from its western slopes to its outlet just south of the Jack's mountain anticline, has now taken an easier path along the Devonian beds to the west of the old lake basin, and is seen in the Little Juniata, flowing along the outer side of Terrace mountain and rounding the northern synclinal point where Terrace mountain joins Sideling hill. It then crosses Jack's mountain at a point where the hard Medina sandstones of the mountain were still buried at the time of the choice of this channel. In the same way, the drainage of the subordinate basin, through which the main lake discharged eastward, is now not along the axis of the Juniata-Catawissa syncline, but on the softer beds along one side of it; and along the southern side because the easier escape that was provided for it lay on that side, namely, via the Tuscarora and Wiconisco synclines, as already described. The much broader change from the Anthracite to the Susquehanna was only another form of the same process. Taking a transverse view of the whole system of central folds, it is perceived that their axes descend into the Anthracite district from the east and rise westward therefrom; it is as if the whole region had received a slight transverse folding, and the transverse axis of depression thus formed defined the initial course of the first master stream.

But this master stream deserted its original course on the transverse axis of depression because a lateral course across lowlands on softer beds was opened by its side streams; and in the contest on these lowlands with an external stream, the Susquehanna, the upper portion of the Anthracite was diverted from the hard rocks that had appeared on the transverse axis. The distance of diversion from the axial to the lateral course in this case was great because of the gentle quality of the transverse folding; or, better said, because of the gentle dips of the axes of the longitudinal folds. This appearance of systematic re-arrangement in the several river courses where none was expected is to my mind a strong argument in favor of the originally consequent location of the rivers and their later mutual adjustment. It may perhaps be conceived that antecedent streams might imitate one another roughly in the attitude that they prophetically chose with regard to folds subsequently formed, but no reason has been suggested for the imitation being carried to so remarkable and definite a degree as that here outlined.

35. *Superimposition of the Susquehanna on two synclinal ridges.*—There is however one apparently venturesome postulate that may have been already noted as such by the reader; unless it can be reasonably accounted for and shown to be a natural result of the long sequence of changes here considered, it will seriously militate against the validity of the whole argument. The present course of the middle Susquehanna leads it through the apical curves of two Pocono synclinal ridges, which were disregarded in the statement given above. It was then assumed that the embryonic Susquehanna gained possession of the Siluro-Devonian lowland drainage by gnawing out a course to the west of these synclinal points; for it is not to be thought of that any conquest of the headwaters of the Anthracite river could have been made by the Susquehanna if it had had to gnaw out the existing four traverses of the Pocono sandstones before securing the drainage of the lowlands above them. The backward progress of the Susquehanna could not in that case have been nearly fast enough to reach the Anthracite before the latter had sunk its channel to a safe depth. It is therefore important to justify the assumption as to the more westerly location of the embryonic Susquehanna; and afterwards to explain how it should have since then been transferred to its present course. A short cut through all this round-about method is open to those who adopt

in the beginning the theory that the Susquehanna was an antecedent river; but as I have said at the outset of this inquiry, it seems to me that such a method is not freer from assumption, even though shorter than the one here adopted; and it has the demerit of not considering all the curious details that follow the examination of consequent and adjusted courses.

The sufficient reason for the assumption that the embryonic Susquehanna lay farther west than the present one in the neighborhood of the Pocono synclinals is simply that—in the absence of any antecedent stream—it must have lain there. The whole explanation of the development of the Siluro-Devonian lowlands between the Pocono and Medina ridges depends simply on their being weathered out where the rocks are weak enough to waste faster than the enclosing harder ridges through which the streams escape. In this process, the streams exercise no control whatever over the direction in which their headwaters shall grow; they leave this entirely to the structure of the district that they drain. It thus appears that, under the postulate as to the initial location of the Susquehanna as one of the many streams descending the great slope of the Kittatinny (Cumberland) highland into the Swatara syncline, its course being reversed from northward to southward by the Newark depression, we are required to suppose that its headwater (northward) growth at the time of the Jurassic elevation must have been on the Siluro-Devonian beds, so as to avoid the harder rocks on either side. Many streams competed for the distinction of becoming the master, and that one gained its ambition whose initial location gave it the best subsequent opportunity. It remains then to consider the means by which the course of the conquering Susquehanna may have been subsequently changed from the lowlands on to the two Pocono synclines that it now traverses. Some departure from its early location may have been due to eastward planation in its advanced age, when it had large volume and gentle slope and was therefore swinging and cutting laterally in its lower course. This may have had a share in the result, but there is another process that seems to me more effective.

In the latter part of the Jura-Cretaceous cycle, the whole country hereabout suffered a moderate depression, by which the Atlantic transgressed many miles inland from its former shoreline, across the lowlands of erosion that had been developed on the litoral belt. Such a depression must have had a distinct effect on the lower courses of the larger rivers, which having already cut their channels down close to baselevel and opened their valleys wide on the softer rocks, were then "estuaried," or at least so far checked as to build wide flood-plains over their lower stretches. Indeed, the flood-plains may have been begun at an earlier date, and have been confirmed and extended in the later time of depression. Is it possible that in the latest stage of this process, the almost baselevelled remnants of Blue mountain and the Pocono ridges could have been buried under the flood-plain in the neighborhood of the river?

If this be admitted, it is then natural for the river to depart from the line of its buried channel and cross the buried ridges on which it might settle down as a superimposed river in the next cycle of elevation. It is difficult to decide such general questions as these; and it may be difficult for the reader to gain much confidence in the efficacy of the processes suggested; but there are certain features in the side streams of the Susquehanna that lend some color of probability to the explanation as offered.

Admit, for the moment, that the aged Susquehanna, in the later part of the Jura-Cretaceous cycle, did change its channel somewhat by cutting to one side, or by planation, as it is called. Admit, also, that in the natural progress of its growth it had built a broad flood plain over the Siluro-Devonian lowlands, and that the depth of this deposit was increased by the formation of an estuarine delta upon it when the country sank at the time of the mid-Cretaceous transgression of the sea. It is manifest that one of the consequences of all this might be the peculiar course of the river that is to be explained, namely, its superimposition on the two Pocono synclinal ridges in the next cycle of its history, after the Tertiary elevation had given it opportunity to re-discover them. It remains to inquire what other consequences should follow from the same conditions, and from these to devise tests of the hypothesis.

36. *Evidence of superimposition in the Susquehanna tributaries.*—One of the peculiarities of flood-plained rivers is that the lateral streams shift their points of union with the main stream farther and farther down the valley, as Lombardini has shown in the case of the Po. If the Susquehanna were heavily flood-plained at the close of the Jura-Cretaceous cycle, some of its tributaries should manifest signs of this kind of deflection from their structural courses along the strike of the rocks. Side

streams that once joined the main stream on the line of some of the softer northeast-southwest beds, leaving the stronger beds as faint hills on either side, must have forgotten such control after it was baselevelled and buried; as the flood plain grew, they properly took more and more distinctly downward deflected courses, and these deflections should be maintained in subsequent cycles as superimposed courses independent of structural guidance. Such I believe to be the fact. The downstream deflection is so distinctly a peculiarity of a number of tributaries that join the Susquehanna on the west side (see figure 1) that it cannot be ascribed to accident, but must be referred to some systematic cause. Examples of deflection are found in Penn's creek, Middle creek and North Mahantango creek in Snyder county; West Mahantango between the latter and Juniata county; and in the Juniata and Little Juniata rivers of Perry county. On the other side of the Susquehanna, the examples are not so distinct, but the following may be mentioned: Delaware and Warrior runs, Chillisquaque creek and Little Shamokin creek, all in Northumberland county. It may be remarked that it does not seem impossible that the reason for the more distinct deflection of the western streams may be that the Susquehanna is at present east of its old course, and hence towards the eastern margin of its flood plain, as, indeed its position on the Pocono synclinals implies. A reason for the final location of the superimposed river on the eastern side of the old flood plain may perhaps be found in the eastward tilting that is known to have accompanied the elevation of the Cretaceous lowland.

It follows from the foregoing that the present lower course of the Susquehanna must also be of superimposed origin; for the flood plain of the middle course must have extended down stream to its delta, and there have become confluent with the sheet of Cretaceous sediments that covered all the southeastern lowland, over which the sea had transgressed. McGee has already pointed out indications of superimposed stream courses in the southeastern part of the State;* but I am not sure that he would regard them as of the date here referred to.

The theory of the location of the Susquehanna on the Pocono synclinal ridges therefore stands as follows. The general position of the river indicates that it has been located by some process of slow self-adjusting development and that it is not a persistent

* Amer. Journ. Science, xxxv, 1888, 121, 134.

antecedent river; and yet there is no reason to think that it could have been brought into its present special position by any process of shifting divides. The processes that have been suggested to account for its special location, as departing slightly from a location due to slow adjustments following an ancient consequent origin, call for the occurrence of certain additional peculiarities in the courses of its tributary streams, entirely unforeseen and unnoticed until this point in the inquiry is reached; and on looking at the map to see if they occur, they are found with perfect distinctness. The hypothesis of superimposition may therefore be regarded as having advanced beyond the stage of mere suggestion and as having gained some degree of confirmation from the correlations that it detects and explains. It only remains to ask if these correlations might have originated in any other way, and if the answer to this is in the negative, the case may be looked upon as having a fair measure of evidence in its favor. The remaining consideration may be taken up at once as the first point to be examined in the Tertiary cycle of development.

37. *Events of the Tertiary cycle.*—The elevation given to the region by which Cretaceous baselevelling was terminated, and which I have called the early Tertiary elevation, offered opportunity for the streams to deepen their channels once more. In doing so, certain adjustments of moderate amount occurred, which will be soon examined. As time went on, much denudation was effected, but no wide-spread baselevelling was reached, for the Cretaceous crest lines of the hard sandstone ridges still exist. The Tertiary cycle was an incomplete one. At its close, lowlands had been opened only on the weaker rocks between the hard beds. Is it not possible that the flood-plaining of the Susquehanna and the down-stream deflection of its branches took place in the closing stages of this cycle, instead of at the end of the previous cycle? If so, the deflection might appear on the branches, but the main river would not be transferred to the Pocono ridges. This question may be safely answered in the negative; for the Tertiary lowland is by no means well enough baselevelled to permit such an event. The beds of intermediate resistance, the Oriskany and certain Chemung sandstones, had not been worn down to baselevel at the close of the Tertiary cycle; they had indeed lost much of the height that they possessed at the close of the previous cycle, but they had not been reduced as low as the softer beds on either side. They were only reduced to ridges of

moderate and unequal height over the general plain of the Siluro-Devonian low country, without great strength of relief but quite strong enough to call for obedience from the streams along side of them. And yet near Selin's Grove, for example, in Snyder county, Penn's and Middle creeks depart most distinctly from the strike of the local rocks as they near the Susquehanna, and traverse certain well-marked ridges on their way to the main river. Such aberrant streams cannot be regarded as superimposed at the close of the incomplete Tertiary cycle; they cannot be explained by any process of spontaneous adjustment yet described, nor can they be regarded as vastly ancient streams of antecedent courses; I am therefore much tempted to consider them as of superimposed origin, inheriting their present courses from the flood-plain cover of the Susquehanna in the latest stage of the Jura-Cretaceous cycle. With this tentative conclusion in mind as to the final events of Jura-Cretaceous time, we may take up the more deliberate consideration of the work of the Tertiary cycle.

The chief work of the Tertiary cycle was merely the opening of the valley lowlands; little opportunity for river adjustment occurred except on a small scale. The most evident cases of adjustment have resulted in the change of water-gaps into wind-gaps, of which several examples can be given, the one best known being the Delaware wind-gap between the Lehigh and Delaware water-gaps in Blue mountain. The wind-gap marks the unfinished notch of some stream that once crossed the ridge here and whose headwaters have since then been diverted, probably to the Lehigh. The difficulty in the case is not at all how the stream that once flowed here was diverted, but how a stream that could be diverted in the Tertiary cycle could have escaped diversion at some earlier date. The relative rarity of wind-gaps indicates that nearly all of the initial lateral streams, which may have crossed the ridges at an early epoch in the history of the rivers, have been beheaded in some cycle earlier than the Tertiary and their gaps thereafter obliterated. Why the Delaware wind-gap stream should have endured into a later cycle does not at present appear. Other wind-gaps of apparently similar origin may be found in Blue mountain west of the Schuylkill and east of the Susquehanna. It is noteworthy that if any small streams still persevere in their gaps across a hard ridge, they are not very close to any large river-gap; hence it is only at the very headwaters of Conedogwinet creek, in the northern part of Franklin county, that any water is still drawn from the back of Blue mountain. Again, these small stream gaps do not lie between large river-gaps and wind-gaps, but wind-gaps lie between the gaps of large rivers and those of small streams that are not yet diverted. Excellent illustration of this is found on the "Piedmont sheet" of the contoured maps issued by the United States Geological Survey. The sheet covers part of Maryland and West Virginia, near where the North Branch of the Potomac comes out of the plateau and crosses New Creek mountain. Eleven miles south of the Potomac gap there is a deep wind-gap; but further on, at twenty, twenty-five and twenty-nine miles from the river-gap are three fine water-gaps occupied by small streams. This example merely shows how many important points in the history of our rivers will be made clear when the country is properly portrayed on contoured maps.

A few lines may be given to the general absence of gaps in Blue Mountain in Pennsylvania. When the initial consequent drainage was established, many streams must have been located on the northward slope of the great Cumberland highland, C, C, fig. 21; they must have gullied the slope to great depths and carried away great volumes of the weak Cambrian beds that lay deep within the hard outer casings of the mass. Minor adjustments served to diminish the number of these streams, but the more effective cause of their present rarity lay in the natural selection of certain of them to become large streams; the smaller ones were generally beheaded by these. The only examples of streams that still cross this ridge with their initial Permian direction of flow to the northwest are found in two southern branches of Tuscarora creek at the southern point of Juniata county; and these survive because of their obscure location among the many Medina ridges of that district, where they were not easily accessible to capture by other streams.

38. *Tertiary adjustment of the Juniata on the Medina anticlines.*—The lower course of the Juniata presents several examples of adjustment referable to the last part of the Jura-Cretaceous cycle and to the Tertiary cycle. The explanation offered for the escape of this river from its initial syncline did not show any reason for its peculiar position with respect to the several Medina anticlines that it now borders, because at the time when it was led across country to the Wiconisco syncline, the hard Medina beds of these anticlines were not discovered. It is therefore

hardly to be thought that the location of the Juniata in the Narrows below Lewistown between Blue Ridge and Shade mountain and its avoidance of Tuscarora mountain could have been defined at that early date. But all these Medina anticlines rise more or less above the Cretaceous baselevel, and must have had some effect on the position taken by the river about the middle of that cycle when its channel sank upon them. Blue Ridge and Black Log anticlines rise highest. The first location of the cross-country stream that led the early Juniata away from its initial syncline probably traversed the Blue Ridge and Black Log anticlines while they were yet buried; but its channel-cutting was much retarded on encountering them, and some branch stream working around from the lower side of the obstructions may have diverted the river to an easier path. The only path of the kind is the narrow one between the overlapping anticlines of Blue Ridge and Shade mountains, and there the Juniata now flows. If another elevation should occur in the future, it might happen that the slow deepening of the channel in the hard Medina beds which now floor the Narrows would allow Middle creek of Snyder county to tap the Juniata at Lewistown and lead it by direct course past Middleburgh to the Susquehanna; thus it would return to the path of its youth.

The location of the Juniata at the end of Tuscarora mountain is again so definite that it can hardly be referred to a time when the mountain had not been revealed. The most likely position of the original cross-country stream which brought the Juniata into the Wiconisco syncline was somewhere on the line of the existing mountain, and assuming it to have been there, we must question how it has been displaced. The process seems to have been of the same kind as that just given; the retardation of channel-cutting in the late Cretaceous cycle, when the Medina beds of Tuscarora anticline were discovered, allowed a branch from the lower part of the river to work around the end of the mountain and lead the river out that way. The occurrence of a shallow depression across the summit of the otherwise remarkably even crest of Tuscarora mountain suggests that this diversion was not finally accomplished until shortly after the Tertiary elevation of the country; but at whatever date the adjustment occurred, it is natural that it should pass around the eastern end of the mountain and not around the western end, where the course would have been much longer, and therefore not successfully to be taken by a diverting stream.

While the quality of these processes appears satisfactory, I am not satisfied as to the sufficiency of their quantity. If diversion was successfully practiced at the crossing of the Tuscarora anticline, why not also at the crossing of Jack's mountain anticline, on which the river still perseveres. It is difficult here to decide how much confidence may be placed in the explanation, because of its giving reason for the location of certain streams, and how much doubt must be cast upon it, because it seems impossible and is not of universal application.

39. *Migration of the Atlantic-Ohio divide.*—There are certain shifted courses which cannot be definitely referred to any particular cycle, and which may therefore be mentioned now. Among the greatest are those by which the divide between the Atlantic and the Ohio streams has been changed from its initial position on the great constructional Nittany highland and Bedford range. There was probably no significant change until after Newark depression, for the branches of the Anthracite river could not have begun to push the divide westward till after the eastward flow of the river was determined ; until then, there does not seem to have been any marked advantage possessed by the eastward streams over the westward. But with the eastward escape of the Anthracite, it probably found a shorter course to the sea and one that led it over alternately soft and hard rocks, instead of the longer course followed by the Ohio streams over continuous sandstones. The advantage given by the greater extent of soft beds is indicated by the great breadth of the existing valleys in the central district compared with the less breadth of those in the plateau to the west. Consider the effect of this advantage at the time of the Jurassic elevation. As the streams on the eastern slope of the Nittany divide had the shortest and steepest courses to the sea, they deepened their valleys faster than those on the west and acquired drainage area from them ; hence we find reason for the drainage of the entire Nittany and Bedford district by the Atlantic streams at present. Various branches of what are now the Alleghany and Monongahela originally rose on the western slope of the dividing range. These probably reached much farther east in pre-Permian time, but had their headwaters turned another way by the growth of the great anticlinal divide ; but the smaller anticlines of Laurel ridge and Negro mountain farther west do not seem to have been strong enough to form a divide, for the rivers still traverse them. Now as the headwaters

of the Juniata breached the eastern slope of the Nittany-Bedford range and pushed the divide westward, they at last gained possession of the Siluro-Devonian monocline on its western slope; but beyond this it has not been possible for them yet to go. As the streams cut down deeper and encountered the Medina anticline near the core of the ridge, they sawed a passage through it; the Cambrian beds were discovered below and a valley was opened on them as the Medina cover wore away. The most important point about this is that we find in it an adequate explanation of the opposite location of water-gaps in pairs, such as characterize the branches of the Juniata below Tyrone and again below Bedford. This opposite location has been held to indicate an antecedent origin of the river that passes through the gaps, while gaps formed by self-developed streams are not thought to present such correspondence (Hilber). Yet this special case of paired gaps in the opposite walls of a breached anticline is manifestly a direct sequence of the development of the Juniata headwaters. The settling down of the main Juniata on Jack's mountain anticline below Huntingdon is another case of the same kind, in which the relatively low anticlinal crest is as yet not widely breached; the gaps below Bedford stand apart, as the crest is there higher, and hence wider opened; and the gaps below Tyrone are separated by some ten or twelve miles.

When the headwater streams captured the drainage of the Siluro-Devonian monocline on the western side of the ancient dividing anticline, they developed subsequent rectangular branches growing like a well-trained grape vine. Most of this valley has been acquired by the west branch of the Susquehanna, probably because it traversed the Medina beds less often than the Juniata. For the same reason, it may be, the West Branch has captured a considerable area of plateau drainage that must have once belonged to the Ohio, while the Juniata has none of it; but if so, the capture must have been before the Tertiary cycle, for since that time the ability of the West Branch and of the Juniata as regards such capture appears about alike. On the other hand, Castleman's river, a branch of the Monongahela, still retains the drainage of a small bit of the Siluro-Devonian monocline, at the southern border of the State, where the Juniata headwaters had the least opportunity to capture it; but the change here is probably only retarded, not prevented entirely; the Juniata will some day push the divide even here back to the Alleghany Front, the frontal bluff of the plateau.

40. *Other examples of adjustments.*—Other examples of small adjustments are found around the Wyoming basin, fig. 26.

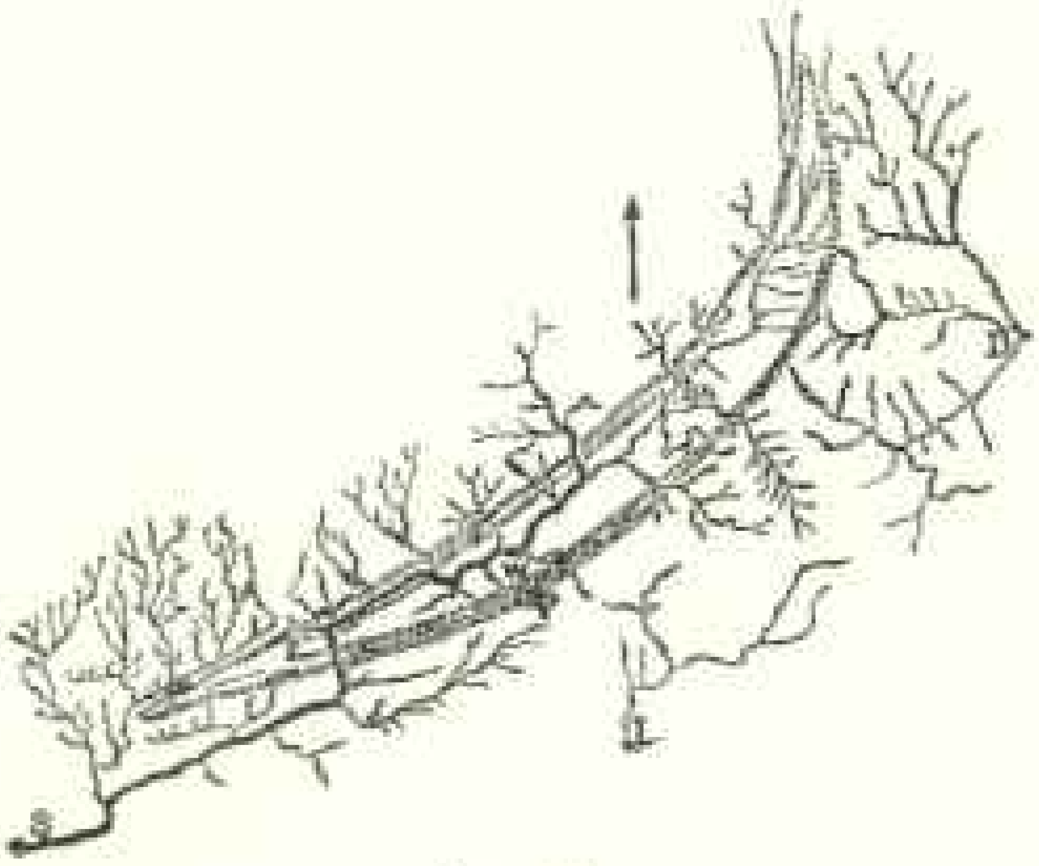


FIG. 26

Originally all these streams ran centripetally down the enclosing slopes, and in such locations they must have cut gullies and breaches in the hard Carboniferous beds and opened low back country on the weaker Devonians. Some of the existing streams still do so, and these are precisely the ones that are not easily reached by divertors. The Susquehanna in its course outside of the basin has sent out branches that have beheaded all the centripetal streams within reach; where the same river enters the basin, the centripetal streams have been shortened if not completely beheaded. A branch of the Delaware has captured the heads of some of the streams near the eastern end of the basin. Elsewhere, the centripetal streams still exist of good length. The contrast between the persistence of some of the centripetal streams here and their peripheral diversion around Broad Top is a consequence of the difference of altitude of the old lake bottoms in the two cases. It is not to be doubted that we shall become acquainted with many examples of this kind as our intimacy with rivers increases.

41. *Events of the Quaternary cycle.*—The brief quaternary cycle does not offer many examples of the kind that we have considered, and all that are found are of small dimensions. The only capturing stream that need be mentioned has lately been described as a "river pirate;"* but its conquest is only a Schles-

* Science, xiii, 1889, 108.

wig-Holstein affair compared to the Goth- and Hun-like depredations of the greater streams in earlier cycles.

The character of the streams and their valleys as they now exist is strikingly dependent in many ways on the relation of the incipient quaternary cycle to the longer cycles of the past. No lakes occur, exception being made only of the relatively small ponds due to drift obstruction within the glaciated area. Waterfalls are found only at the headwaters of small streams in the plateau district, exception again being made only for certain cases of larger streams that have been thrown from their pre-glacial courses by drift barriers, and which are now in a very immature state on their new lines of flow. The small valleys of this cycle are shallow and narrow, always of a size strictly proportional to the volume of the stream and the hardness of the enclosing rocks, exception being made only in the case of post-glacial gorges whose streams have been displaced from their pre-glacial channels. The terraces that are seen, especially on the streams that flow in or from the glaciated district, are merely a temporary and subordinate complication of the general development of the valleys. In the region that has been here considered, the streams have been seldom much displaced from their pre-glacial channels; but in the northwestern part of the State, where the drift in the valleys seems to be heavier, more serious disturbance of pre-glacial courses is reported. The facts here referred to in regard to lakes, falls, gorges, terraces and displaced streams are to be found in the various volumes of the Second Geological Survey of the State;* in regard to the terraces and the estuarine deflections of the Delaware and Susquehanna, reference should be made also to McGee's studies.†

42. *Doubtful cases.*—It is hardly necessary to state that there are many facts for which no satisfactory explanation is found under the theory of adjustments that we have been considering. Some will certainly include the location of the Susquehanna on the points of the Pocono synclines under this category; all must feel that such a location savors of an antecedent origin. The same is true of the examples of the alignment of water-gaps found on certain streams; for example, the four gaps cut in the

* Especially Carll, Reports I_3, I_4; White, Reports G_5, G_6; Lewis, Report Z.

† Amer. Journ. Science, xxxv, 1888, 367, 448; Seventh Annual Rep. U. S. G. S., 1888, 545.

two pairs of Pocono and Pottsville outcrops at the west end of the Wyoming syncline, and the three gaps where the Little Schuylkill crosses the coal basin at Tamaqua ; the opposite gaps in pairs at Tyrone and Bedford have already been sufficiently explained. The location of the upper North Branch of the Susquehanna is also unrelated to processes of adjustment as far as I can see them, and the great area of plateau drainage that is now possessed by the West Branch is certainly difficult to understand as the result of conquest. The two independent gaps in Tussey's mountain, maintained by the Juniata and its Frankstown branch below Tyrone are curious, especially in view of the apparent diversion of the branch to the main stream on the upper side of Warrior's ridge (Oriskany), just east of Tussey's mountain.

43. *Complicated history of our actual rivers.*—If this theory of the history of our rivers is correct, it follows that any one river as it now exists is of so complicated an origin that its development cannot become a matter of general study and must unhappily remain only a subject for special investigation for some time to come. It was my hope on beginning this essay to find some teachable sequence of facts that would serve to relieve the usual routine of statistical and descriptive geography, but this is not the result that has been attained. The history of the Susquehanna, the Juniata, or the Schuylkill, is too involved with complex changes, if not enshrouded in mystery, to become intelligible to any but advanced students ; only the simplest cases of river development can be introduced into the narrow limits of ordinary instruction. The single course of an ancient stream is now broken into several independent parts ; witness the disjointing and diversion of the original Juniata, which, as I have supposed, once extended from Broad Top lake to the Catawissa basin. Now the upper part of the stream, representing the early Broad Top outlet, is reduced to small volume in Aughwick creek ; the continuation of the stream to Lewistown is first set to one side of its original axial location and is then diverted to another syncline ; the beheaded portion now represented by Middle creek is diverted from its course to the Catawissa basin by the Susquehanna ; perhaps the Catawissa of the present day represents the reversed course of the lower Juniata where it joined the Anthracite. This unserviceably complicated statement is not much simplified if instead of beginning with an original stream and searching out its present disjointed parts, we trace the composition of a single

existing stream from its once independent parts. The Juniata of to-day consists of headwaters acquired from Ohio streams; the lake in which the river once gathered its upper branches is now drained and the lake bottom has become a mountain top; the streams flow around the margin of the lake, not across its basin; a short course towards Lewistown nearly coincides with the original location of the stream, but to confound this with a precise agreement is to lose the true significance of river history; the lower course is the product of diversion at least at two epochs and certainly in several places; and where the river now joins the Susquehanna, it is suspected of having a superimposed course unlike any of the rest of the stream. This is too complicated, even if it should ever be demonstrated to be wholly true, to serve as material for ordinary study; but as long as it has a savor of truth, and as long as we are ignorant of the whole history of our rivers, through which alone their present features can be rightfully understood, we must continue to search after the natural processes of their development as carefully and thoroughly as the biologist searches for the links missing from his scheme of classification.

44. *Provisional Conclusion.*—It is in view of these doubts and complications that I feel that the history of our rivers is not yet settled; but yet the numerous accordances of actual and deductive locations appear so definite and in some cases so remarkable that they cannot be neglected, as they must be if we should adhere to the antecedent origin of the river courses.

The method adopted on an early page therefore seems to be justified. The provisional system of ancient consequent drainage, illustrated on fig. 21, does appear to be sufficiently related to the streams of to-day to warrant the belief that most of our rivers took their first courses between the primitive folds of our mountains, and that from that distant time to the present the changes they have suffered are due to their own interaction—to their own mutual adjustment more than to any other cause. The Susquehanna, Schuylkill, Lehigh and Delaware are compound, composite and highly complex rivers, of repeated mature adjustment. The middle Susquehanna and its branches and the upper portions of the Schuylkill and Lehigh are descendants of original Permian rivers consequent on the constructional topography of that time; Newark depression reversed the flow of some of the transverse streams, and the spontaneous changes or adjustments from immature to mature courses in the several cycles of development are so numerous and extensive that, as Löwl truly says, the initial drainage has almost disappeared. The larger westward-flowing streams of the plateau are of earlier, Carboniferous birth, and have suffered little subsequent change beyond a loss of head-waters. The lower courses of the Atlantic rivers are younger, having been much shifted from their Permian or pre-Permian courses by Newark and Cretaceous superimposition, as well as by recent downward deformation of the surface in their existing estuaries. No recognizable remnant of rivers antecedent to the Permian deformation are found in the central part of the State; and with the exception of parts of the upper Schuylkill and of the Susquehanna near Wilkes-Barre, there are no large survivors of Permian consequent streams in the ordinary meaning of the term "consequent." The shifting of courses in the progress of mature adjustment has had more to do with determining the actual location of our rivers and streams than any other process.

Harvard College, June, 1889.

TOPOGRAPHIC MODELS.

By Cosmos Mindeleff.

Of the many methods by which it has been sought to represent the relief of a country or district, only two have been at all widely used. These methods are, in the order of their development, by hachured and by contoured maps. Both have advantages and both have serious disadvantages. Without entering into the controversy that is even yet raging over the relative merits of the two systems, some slight notice of what each claims to accomplish is necessary.

The representation of relief by hachures is a graphic system, and in the best examples we have is an attempt to show, upon a plane surface, the actual appearance of a given area under given conditions of lighting,—as in the Dufour map of the Alps. Of course certain details that would really disappear if the assumed conditions were actual ones, must be shown upon the map,—so that it is, after all, but a conventional representation. The very best examples are, for this and other reasons, unsatisfactory, and far more so is this the case in the vastly larger class of medium grade and poor work.

The contour system represents relief by a series of lines, each of which is, at every point throughout its length, at a certain stated elevation above sea-level, or some other datum-plane; in other words, each contour line represents what would be the water's edge, if the sea were to rise to that elevation. It possesses the advantage of great clearness, but fails to a large degree in the representation of surface detail; moreover, one must have considerable knowledge of topography, in order to read the map correctly.*

To those who must give first place to the quantity of relief rather than the quality, as, for example, the geologist or the engineer, a contoured map is now considered essential. On the other hand, where quality of relief is the prime consideration and the quantity a secondary one, as, for example, for the use of the army, a hachured map is considered the best. The method

* For specimens of representation of the same subject on different scales, in both the hachure and contour systems, see plate from "Enthoffer's Topographical Atlas."

of hachures may be roughly characterized as a graphic system with a conventional element, and the contour method as a conventional system with a graphic element,—for if the contour interval is small enough a sort of shading is produced which helps considerably the idea of relief.

In addition to these two great systems, with which everyone is more or less familiar, there is another method of representing a country or district,—a method that succeeds where others fail, and which although by no means new, has not received the attention it deserves: this is the representation of a country by a model in relief. Certain striking advantages of models over maps of all kinds are, indeed, so apparent that one almost loses sight of such slight disadvantages as can, of course, be urged against them. In the graphic representation of the surface they are far superior to the hachured map, and they have the further advantage of expressing the relative relief, which the hachured map fails to do, except in a very general way. They have also the advantage of showing actual shadows, exactly as they would be seen in a bird's-eye view of the district, instead of more or less conventional ones, and are, consequently, more easily comprehended by the layman, without becoming any less valuable to the skilled topographer. In short, they combine all the graphic features of a hachured map with all the advantages of the best class of contoured maps, and in addition they show more of the surface detail, upon which so much of the character of the country depends and which is very inadequately expressed by hachures and almost completely ignored in a contoured map of large interval. The contours themselves can be made to appear upon the model very easily and without interfering with other features.

The uses of models are many and various. Within the past few years their usefulness has been much extended, and, now that they are becoming better known, will probably receive a still further extension. To the geologist they are often of great value in working out the structure of complicated districts, for the reason that so many important structural relations can be presented to the eye at a single glance. Similarly, for the graphic presentation of results there is no better method, as the topography, the surface geology, and any number of sections can be shown together and seen in their proper relationship. To the engineer an accurate model is often of the greatest assistance in working out his problems, and it is simply invaluable to explain the details of a plan to anyone who has little or no technical training; for, as has been stated, a model is easily comprehended by anyone, while more or less technical knowledge is required for the proper understanding of even the best maps.

I might go on cataloguing in detail the many uses to which models may be put, but shall now mention only one more—perhaps the most important of all—their use in the education of the young. No method has yet been devised that is capable of giving so clear and accurate a conception of the principles of physical geography as a series of well selected models; models have, indeed, already been used for this purpose, but unfortunately their great cost has prevented their general use in schools. Since, however, the study of geography has been placed upon a new basis and a new life has been infused into it, many men have given their attention to the subject of models, and have experimented with a view to cheapen the cost of reproduction, which has hitherto prevented their wide distribution; and probably this objection will soon be remedied. The ability to read a map correctly,—to obtain from a study of the map a clear conception of the country represented,—is more uncommon than is usually supposed. Some of the recent methods of teaching geography are intended to cultivate this very faculty, but it is doubtful whether there is any better method than that which consists in the study of a series of good models in conjunction with a series of maps, all on the same scale and of the same areas. The value of a series of good models in teaching geology is so apparent that it need only be mentioned. It is often, for reasons stated above, far more valuable even, than field instruction.

For the construction of a good relief map the first requisite is a good contoured map. To this should be added, when possible, a good hachured map, upon which the elevations of the principal points are stated,—if the interval in the contoured map is a large one,—and as much material in the way of photographs and sketches as it is possible to procure. The modeler should, moreover, have some personal acquaintance with the region to be represented, or, failing that, a general knowledge of topographic forms, and at least a clear conception of the general character of the country which he seeks to represent. This is very important, for it is here that many modelers fail: the mechanical portion of the work any ordinarily intelligent person can do. A model may be as accurate as the map from which it is made, every contour may be placed exactly where it belongs, and yet the resulting model may be,—indeed, often is—"flat," expressionless, and unsatisfactory. Every topographer in drawing his map is compelled to generalize more or less, and it is fortunate for the map if this be done in the field instead of in the draughtsman's office. But topographers differ among themselves: there may be, and often is, considerable difference in two maps of the same region made by different men; in other words, the "personal equation" is a larger element in a map than is usually supposed. This being the case, there is something more required in a modeler than the mere transferring of the matter in the map,—giving it three dimensions instead of two: he must supply through his special knowledge of the region (or, failing that through his general knowledge) certain characteristics that do not appear upon the map, and undo, so far as it is necessary, certain generalizations of the topographer and draughtsman. This artistic or technical skill required correctly to represent the *individuality* of a given district is especially important in the modeler; it is more important, perhaps, in small-scale maps of large districts than in large-scale maps of small ones,—for in the latter the generalizing process has not been carried so far, and the smaller interval of the contour lines preserves much of the detail.

The methods by which relief maps are made have always received more attention than would, at first sight, appear to be their proper proportion. It may be due, however, to the difficulty of applying any test to determine the accuracy of the finished model, and perhaps also to the general impression that any one can make a relief map,—and so he can, though of course there will be a wide difference in the value of the results. Some, indeed, have devoted their attention to methods exclusively, letting the result take care of itself,—and the models show it. There is no more reason why a modeler should tie himself down to one method of work, than that a water-colorist, or a chemist, or anyone engaged in technical work, should do so; though in some cases he might be required, as the chemist is, to show his methods as well as his results.

One of the earliest methods, with any pretension to what we may term mechanical control, is that described by the Messrs. Harden in a paper on "The construction of maps in relief," read before the American Institute of Mining Engineers in 1887. The method was published in 1838. Upon a contoured map as a basis cross-section lines are drawn at small and regular intervals, and, if the topography be intricate, corresponding lines at right angles. The sections thus secured are transferred to thin strips of some suitable material, such as cardboard or metal, and cut down to the surface line,—the strips themselves thus forming the cross-sections. These cross-sections are mounted upon a suitable base-board, and the cavities or boxes are then filled up with some easily carved material, such as plaster or wax. The top is then carved down to the form of the country or district,—the necessary guidance being obtained by the upper edges of the strips that form the cross-sections. It will be readily seen that this method is a very crude and laborious one. It necessitates in the first place a good contoured map upon which to draw the sections, but sacrifices much of the advantage thus gained because only a number of points on each contour line are used, instead of the entire line. It is no better, although actually more laborious, than the later method of driving contour pins (whose height above a base-board may be accurately measured,) along the contour lines, and then filling in. A slight modification of the latter method can be used to advantage when no contoured map is available, and when the points whose elevation is known are not numerous enough to permit the construction of one. In this case the only control that can be secured is by means of a number of pins driven into the base-board at those points whose elevation is known. The remainder of the map is then sketched in. This method is perhaps as satisfactory as any, when the material upon the map is scanty. Another method, however, growing out of the same scantiness of material, is in some cases to be preferred, especially for large models. The map is enlarged to the required size, and a tracing of it is mounted upon a frame. Another deep frame, just large enough to contain the mounted tracing, is made, and laid upon a suitable base-board upon which a copy of the map has been mounted. Upon this base-board the model is then commenced, in clay or wax. The low areas are modeled first,—horizontal control being obtained by pricking through the mounted tracing of the map with a needle point, and vertical control by measuring down from a straight edge sliding on the top of the deep frame. This system is rather crude, and only useful where the material upon the map is very scanty, but it gives excellent control.

A method used by Mr. F. H. King in the preparation of his large map of the United States is described by him in a letter to Messrs. Harden, and published by them in the place mentioned. A solid block of plaster is used,—the contoured map being transferred to it—and the plaster is carved down to produce a series of steps like those made by building up the contours. The shoulders are then carved down to produce a continuous surface. This method is one of the best of those that require carving instead of modeling.

Many other methods of producing relief maps might be mentioned, but, as most of them have been used only to make special models, they need not be described. The method that has been more used than any other still remains to be described. It is that which the writer has used almost exclusively, and consists in building up the model and modeling the detail, instead of carving it. It is a maxim of the modeler that the subject should be built up as far as possible, should be produced by adding bits of clay or wax, or other material, and not by carving away what is already on,—by addition and not by subtraction. This may be illustrated by a reference to the methods of the sculptor. The bust, or figure, or whatever the subject may be, is first modeled in clay or wax; from this model a plaster mould is made, and from this mould a plaster cast is taken. This cast is called the original, and the finished production, whether in marble, bronze, or any other hard substance, is simply a copy of this original. No one ever attempts to produce the finished bust or figure directly from the object itself. Even where the artist has for a guide a death mask, the procedure does not change. The bust is first made in clay, and this clay model, as a rule, contains all the detail which subsequently appears in the finished bust. It seems strange, therefore, that the relief map maker should use a method which the sculptor, with infinitely more skill and judgment, is afraid to use; and this on subjects that do not differ as much as might be imagined.

The contour interval to be used depends on the use to which the model is to be put. It is not always necessary to carry into the model all the contour lines upon the map: I may go further and say that it is not always desirable to do so. The number to be used depends to some extent on the skill of the modeler. As already stated, the contours are only a means of control, and one modeler requires more than another. To build into a model every contour in a contoured map of ten foot interval is a very laborious proceeding, and not worth the time it takes, as in nine out of ten maps of such interval only the fifty-foot or the one hundred-foot curves are definitely fixed, the intermediate lines being merely filled in. This filling in can be done as well, or better, by the modeler.

The question as to the proper amount of exaggeration to be given the vertical scale, as compared with the horizontal, is the question about which has raged most of the controversy connected with relief map making. This controversy has been rather bitter; some of the opponents of vertical exaggeration going to the length of saying that no exaggeration is necessary, and that "he that will distort or exaggerate the scale of anything will lie." On the other hand the great majority of those who have made relief maps insist upon the necessity of more or less exaggeration of the vertical scale—generally more than seems to me necessary, however.

An increase of angle of slope accompanies all vertical exaggeration, and this is apparent even in models in which the vertical element is only very slightly exaggerated. It produces a false effect by diminishing the proportionate width of the valleys, and by making the country seem much more rugged and mountainous than it really is. A secondary effect is to make the region represented look very small—all idea of the extent of the country being lost. This can be illustrated better than described. The King model of the United States is an example of one extreme; it is worthy of note that no examples of the other extreme—too little exaggeration—are known.

In small-scale models of large districts some exaggeration of the vertical scale is necessary in order to make the relief apparent, but the amount of this exaggeration is often increased much beyond what is essential. The proportion of scales must depend to a large extent on the character of the country represented, and on the purposes for which the model is made. It has been suggested by a writer, quoted by the Messrs. Harden, that the following exaggeration would afford a pleasing relief: "For a map, scale 6 inches to 1 mile: if mountainous, 1:3; if only hilly, 1:2; if gently undulating, 2:3. For smaller scales, except for very rugged tracts, the exaggeration should be correspondingly increased. For a tract consisting wholly of mountains no exaggeration is necessary." I know of no country of such a character that its relief, in all its detail, cannot be shown upon a scale of 6 inches to 1 mile without any exaggeration at all.

It seems to me that the absolute and not the relative amount of relief is the desideratum, and I have always used this as my guiding principle. For small scale models I have found half an inch of relief ample. It may be worth while to state that in a model of the United States made for the Messrs. Butler, of Philadelphia, the horizontal scale was 77 miles to 1 inch, the vertical scale 40,000 feet to 1 inch, and the proportion of scales as 1 to 10. This proportion could have been brought down as low as 1:6 with advantage. One-fortieth of an inch to a thousand feet seems a very small vertical scale, but it sufficed to show all the important features of the relief. It should be stated, moreover, that the model in question was very hurriedly made—in fact, was hardly more than a sketch-model—and that more care and more minute work would have brought out many details that do not now appear. This amount of care was not considered necessary in this instance, as the model was made to be photographed and published as a photo-engraving, and was to suffer an enormous reduction—coming down to five by seven inches.*

It has been frequently urged by the advocates of large exaggeration that the details of a country cannot be shown unless the vertical scale is exaggerated; that hills 200, 300, or even 500 feet high—depending of course upon the scale—flatten out or disappear entirely. This seems plausible, but the advantanges of great exaggeration are more apparent than real. Its effect upon the model has already been mentioned; it should be added that, with the proper amount of care in finishing the model, exceedingly small relief can be so brought out as to be readily seen. With ordinary care, one-fortieth of an inch can be easily shown, and with great care and skill certainly one-eightieth and probably one-hundredth of an inch. Another plausible argument that has been advanced in favor of vertical exaggeration as a principle, is well stated by Mr. A. E. Lehman, of the Pennsylvania Geological Survey, in a paper on "Topographical Models," read before the American Institute of Mining Engineers in 1885. "A perfectly natural expression is of course desired; and to cause this the features of the topography should be distorted and exaggerated in vertical scale just enough to produce the same effect on the beholder or student of the district of country exhibited

* See plate from "Butler's Complete Geography."

as his idea of it would be if he were on the real ground itself. Care should be taken, however, not to make the scales so disproportionate as to do violence to mental impressions. Often, indeed, prominent or important features, when they will bear it, may be still more effectively shown by additional exaggeration in the vertical scale." The fallacy of this argument is obvious. It assumes that the object of a model is to show the country as it appears to one passing through it, and not as it really is—and there is often a very wide difference between the two. The impression derived from passing through a country is, if I may use the term, a very large-scale impression, as any one who has tried it can certify; it is certainly a mistake to attempt to reproduce this impression in a small-scale model, with the help of vertical exaggeration. Even if the principle were a good one, its application would be very limited. It could only be used in large-scale models; to apply it to a model of a large area—the United States, for example—is obviously absurd.

The method referred to as being now generally in use may be briefly described as follows: requisites, a good contoured map; a hachured map in addition, if possible; a clear conception on the part of the modeler of the country to be represented; and a fair amount of skill. Materials: a base-board of wood or other suitable material; card-board or wood of the thickness required by the contour interval and the scale; and modeling wax or clay. Procedure: reproduce the contours in the wood or other material; mount these upon the base-board in their proper relationship; then fill in the intervening spaces, and the space above the topmost contour, with the modeling material.

In a series of models of the Grand Divisions of the earth, made about a year and a half ago, the contours of card-board were made as follows: the map was photographed up to the required scale, and as many prints were made as there were contour intervals to be represented—in a model of the United States of 1,000 feet contour interval there were fourteen prints. Thirteen of these were mounted upon card-board of the exact thickness required by the vertical scale, and one upon the base-board. All large paper companies use a micrometer gauge, and card-board can easily be obtained of the exact thickness required—even to less than the thousandth part of an inch. The lowest contour was then sawed out upon a scroll saw, and placed upon the corresponding line of the map mounted upon the base-board. This process was repeated with each of the succeeding contours until all were placed and glued into their proper positions. At this stage the model presents the relief in a series of steps, each step representing a rise corresponding to the contour interval. The disadvantages of the method lie in the fact that unless the greatest care is exercised in making the photographic prints there will be considerable distortion, owing to the stretching of the paper in different directions, and consequently much trouble in fitting the contours. If care be exercised in having the grain of the paper run in the same direction in all the prints, trouble in fitting the contours will be much reduced, but the distortion in one direction will remain. In our experience this distortion amounts to about two per cent.; in other words, a model that should be fifty inches long will in reality be fifty-one inches ; but, as this error is distributed over the whole fifty inches, it is not too great for an ordinary model. If greater accuracy be required, it can be secured by transferring the contours to the card-board by means of tracing or transfer paper. The great advantage of the photographic method lies in the fact that when the model has been built up, with all the contours in position, it presents a copy of the map itself, with all the details, drainage, etc., in position, instead of blank intervals between the contours. Such details and drainage are a great help in the subsequent modeling.

The next step in the process is to fill in with clay or wax the intervals between the contours. I have always found wax more convenient than clay for this purpose as, unless the surface coating is a thick one, the clay is difficult to keep moist. To obviate this difficulty, some modelers have used clay mixed with glycerine instead of water ; this, of course, does not become dry, but the material is, at its best, unsatisfactory. The filling-in process is the most important one in relief map making, for it is here that the modeler must show his knowledge of, and feeling for, topographic forms. Some models seem to have been constructed with the idea that when the contours have been accurately placed the work of the modeller is practically done. This is a great mistake. The card-board contours are only a means of control, occupying somewhat the same relation to the relief map that a core or base of bricks, or a frame of wood, does to other constructions as, for example, an architectural ornament or a bust. It is sometimes necessary to cut away the contour card ; for, as has been already explained, a map is more or less generalized, and a contour is frequently carried across a ravine, instead of following it up, as it would do if the map were on a larger scale. Such generalizing is of course perfectly proper in a map, but, with the same scale, we expect more detail in a model. The modeler must have judgment enough and skill enough to read between the lines, and to undo the generalizing of the topographer and draughtsman, thus supplying the material omitted from the map. This can be done without materially affecting the accuracy of the model, considered even as a copy of the contoured map.

The contours of card board or other material are, let me repeat, only a means of control. The perfect modeler—a variety, by the way, yet to be evolved—would be able to make an accurate relief map without them, in the same way that other subjects are made; as, for example, a flower panel, an architectural ornament, or any other subject in low relief, where the object sought is artistic effect and great accuracy is not a desideratum. It is the converse of this idea that has produced the numerous models that one sees; accurate enough, perhaps, but wholly expressionless and absolutely without feeling. This is the great fault of nearly all models made by building up the contours in wood and then carving down the shoulders. It is then necessary to sand-paper them, and what little character they might otherwise have had is completely obliterated by the sand-paper. Such models almost invariably *look* wooden. Let the modeler, then, have a clear conception of his subject and not depend wholly on the contours, and let him work out that conception in his model, "controlled" and helped by the contours, but not bound by them; the resulting model will thus be far more satisfactory and a far better representation of his subject, in other words, it will be more life-like—more nearly true to nature.

The model, provided it be not of clay, is sometimes used in the state in which it is left when finished. It is much more common, however, to make a plaster mould, and from this a plaster cast. For this purpose a moulder is usually called in; but moulders as a rule are ignorant men, accustomed to one line of work only, and the result is not always satisfactory. It is much better for the modeler himself to do this work, though to obtain good results from plaster it is necessary to know the material thoroughly, and this knowledge comes only from experience. The mould is generally made quite heavy, in order to stand the subsequent hard treatment that it may receive, and should be retouched and thoroughly dried before being prepared for the cast. The method used by some modelers of placing a frame about the model and pouring in the plaster, filling the frame to the top, is a crude and very wasteful one and not at all to be recommended. In a model of large size—say seven or eight feet square—it would require a derrick to move the mould. It is wholly unnecessary, as, with a small amount of care, a good mould can be made not more than an inch thick, or, at most, an inch and a half. The drying of the mould before use can sometimes be dispensed with, but is always desirable.

Nearly all American moulders (as distinguished from French and Italian ones) varnish the mould, and thus lose some of the finest detail and sharpness. This is unnecessary. The mould can be easily prepared with a solution of soap so as to leave nothing on the surface but a very thin coating of oil, which is taken up and replaced by the plaster of the cast. Of course, if the model has been sand-papered, no fine work in moulding or casting is necessary, as there is nothing to save. If the subject is a very intricate one, with "undercuts" (as they are called), it is customary to make a waste mould; as this is very seldom necessary in relief map work, however, the process need not be described.

To make the cast it is only necessary to repeat the processes used in making the mould. With great care and some skill a cast can be produced but little inferior in point of sharpness and detail to the original model. It is customary to make the cast very thick, and, consequently, very heavy; this is unnecessary. In our work we seldom make a cast thicker than one inch, and yet are never troubled with changes in the model after it is finished. Even in a very large cast (now in the National Museum), weighing nearly 1,500 pounds and presenting a surface of over 160 square feet, the average thickness is less than one inch, although it required over five barrels of plaster to make it. The cast, after being thoroughly dried, should be finished—all its imperfections being carefully repaired. The surface, however, should be touched as little as possible, as the slight roughness of surface that comes from the original model, through the mould, is removed by any tooling. This roughness adds much to the effect of the model; in fact, where the scale is large enough, it is sometimes desirable to emphasize it.

The proper way to paint a model is a matter that must rest principally upon the judgment of the modeler, depending to some extent, also, on the use to which the model is to be put. The plain cast is sometimes used, drainage, lettering, etc., being put directly upon it. This has the advantage of preserving all the detail that comes from the mould, but it has also the disadvantage of a surface easily soiled and impossible to clean. If the model is to be photographed, the surface should be nearly white—in our practice we use a small amount of yellow with the white. This yellow is hardly appreciable by the eye, but its effect upon the photographic negative is quite marked. Yellow becomes grey in a photograph, and, in a photograph of a model colored as described, a grey tint is given to the whole surface. The high lights are not pure white, and there is no harsh contrast between light and shade. There is another point of great importance in photographing models: the surface should have a dead finish—that is, should have no gloss, or, at most, should have only what is known among painters as an egg-shell gloss. It is almost impossible satisfactorily to photograph a model that has a shiny surface. Any portion of a model that it is desired to separate from the rest should be painted a different color—the water, for example, should be painted a light blue; not a blue composed of indigo, however, or any of the grey blues, as these produce in the photograph a dead grey, and are not pleasant to the eye. The most satisfactory color that we have used is a mixture of cobalt—the purest of the blues—with Antwerp blue—which is quite green—and white. This gives a color that is pleasant to the eye, has the retreating quality to perfection, and photographs well.

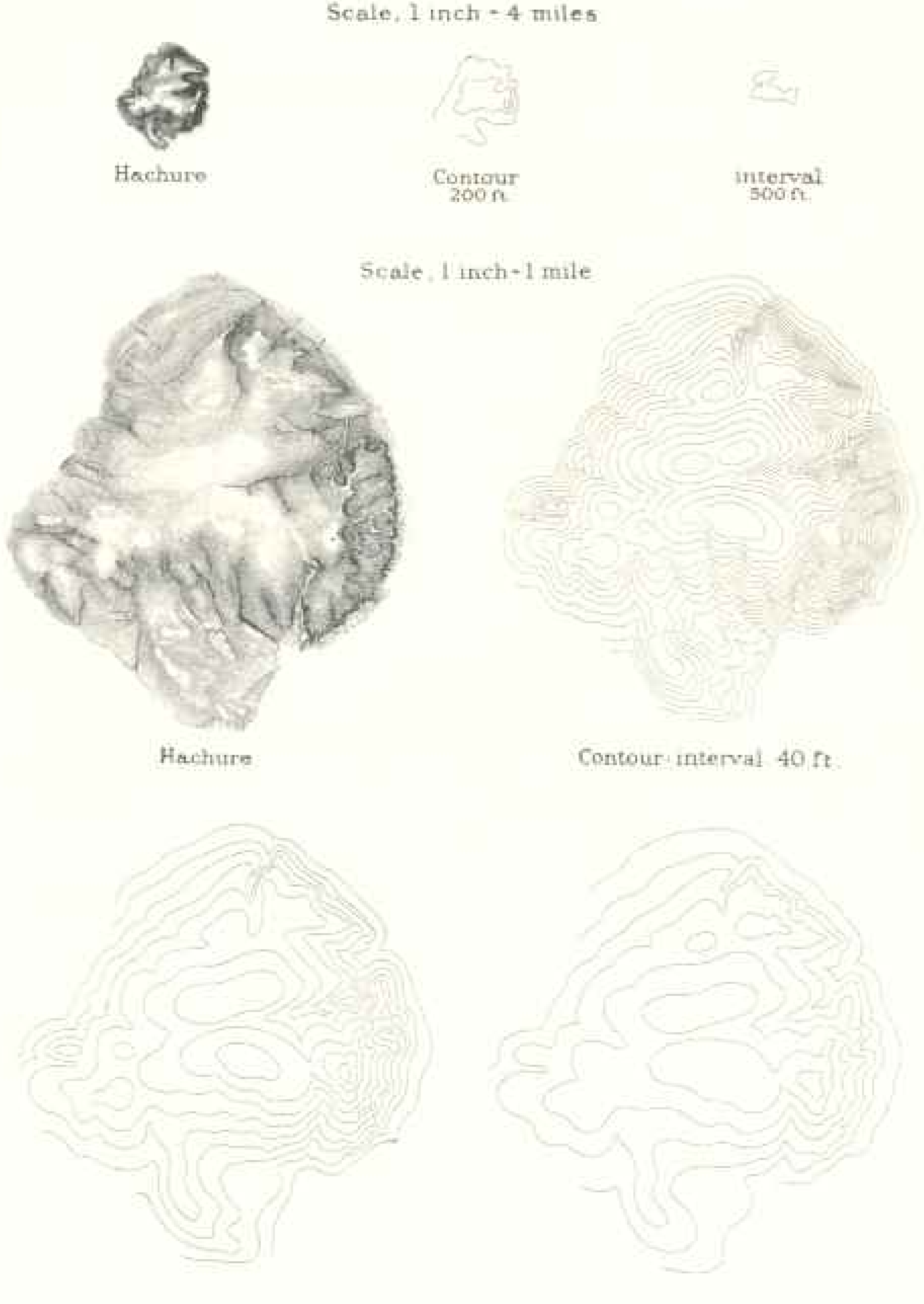
Models intended for exhibition as such should be painted realistically. There is room here for an immense improvement in the usual practice, which is to paint the model either in some conventional scheme of light and shade, or else to put a single flat tint upon it. If the model is to be colored conventionally it is, in my opinion, much better to use a flat tint, light in tone, and with a dead surface. The use of a variety of colors upon the face of a model interferes materially with the relief, especially if the relief is finely modeled. For this reason models colored to indicate geologic formations should always be accompanied by duplicates representing topography only, colored realistically, if possible, and without lettering. Well-defined lines other than those pertaining to the model itself, such, for example, as those used to define the boundaries of geologic formations, should not be allowed upon a model when it is desired to bring out all the relief. The lettering on such models should be kept down as small as possible, or wholly dispensed with. The latter is much the better method.

The cheap reproduction of models is the most important problem connected with the art, and the one that is attracting most attention among those engaged in it; as, until models can be reproduced cheaply, they will never have any wide distribution and there will be far less incentive to the modeler. Various materials have been suggested and experimented on, but nine-tenths of the models that are made to-day are made of plaster of Paris. Although this material was the first to be used for this purpose, it has not yet been superseded. A plaster cast is heavy, expensive and easily injured; but plaster gives an accurate copy of the original, retains permanently the form given it, and is easily finished and repaired. The weight is an obstacle that can be easily overcome. By the incorporation in the plaster of fine tow, or of bagging or netting of various kinds, the cast can be made very light and at the same time strong, but the expense is increased rather than diminished by this method. Models made in this way, however, have the advantage that when broken the pieces do not fall out, they are, however, fully as liable to surface injury as the other kind. The large cast in the National Museum, before referred to, was made in this way. It weighed nearly 2,000 pounds when boxed—not an easy thing to handle—but it stood shipment to New Orleans and back without suffering any material injury. This would hardly have been possible had the cast been made from plaster alone.

Paper seems, at first sight, to be the material best adapted for the reproduction of models; but no one has succeeded well enough with it to bring it into use. Like nearly all those who have given this subject attention, I have experimented with paper, but the only positive result has been a loss of a large part of the confidence that I once had in the suitability of the material. Paper has been used extensively for large scale models of pueblos, ruins, etc., but I have never obtained a satisfactory result with subjects in low relief and fine detail. A paper cast may look well when first made, but it absorbs moisture from the atmosphere, and contracts and expands with the weather. The contraction is apt to flatten out the model and the expansion to make it buckle up.

Casts of models have been made in iron; but this, while suitable perhaps for models of mounds and subjects of like character, would hardly be applicable to small scale models with fine detail; such casts require too much surface finishing. The material known as Lincrusta-Walton seems to me to be the ideal material for this purpose. It is tougher than rubber, will take the finest detail, and its surface can be treated in any way desired. Unfortunately the manufacture of models in this material would require expensive machinery, and is outside the scope of a modeling room. Should it ever become commercially advantageous, however, casts of a model of ordinary size, in every way equal to the original, can be turned out in this material at a very small cost.

It remains to speak of the reproduction of models by process-engravings—a method that will probably receive much more attention in the future than it has in the past. It is perhaps along this line that the cheap reproduction of models will develop; but the subject is too large a one to be adequately treated here, and must be postponed until some future occasion.



HACHURED AND CONTOURED MAPS

REPRESENTATION OF A HILL ACCORDING TO THE TWO SYSTEMS AND ON DIFFERENT SCALES

From Supplement to Enthoffer's Topographical Atlas
by permission of Mr Enthoffer

NATIONAL GEOGRAPHIC SOCIETY.

ABSTRACT OF MINUTES.

October 5, 1888, *Ninth Meeting.*

A paper was read entitled, "Topographic Models," by Mr. Cosmos Mindeleff. Published in the "National Geographic Magazine," Vol. I, No. 3.

October 19, 1888, *Tenth Meeting.*

The attendance being very small, no paper was read.

November 2, 1888, *Eleventh Meeting.*

The paper of the evening was entitled, "Surveys, their Kinds and Purposes," by Mr. Marcus Baker. The paper was discussed by Messrs. Ogden, Goodfellow, Gannett and Baker. Published in "Science," Vol. XII, No. 304.

November 16, 1888, *Twelfth Meeting.*

A paper was read by Mr. Henry Gannett, giving certain "Physical Statistics Relating to Massachusetts," derived from the map of that State recently prepared by the United States Geological Survey. A discussion followed which was participated in by Messrs. Baker, Kenaston, Fernow, Weed, and the author. A second paper entitled, "Something about Tornadoes," was read by Lieut. J. P. Finley, U. S. Signal Corps.

November 30, 1888, *Thirteenth Meeting.*

The annual reports of vice-Presidents Herbert G. Ogden and Gen. A. W. Greely were delivered. Published in the "National Geographic Magazine," Vol. I, No. 2.

December 20, 1888, *Fourteenth Meeting.*

Held in the Law Lecture Room of the Columbian University. The President delivered his Annual Address, entitled, "Africa." Published in the "National Geographic Magazine," Vol. I, No. 2.

December 28, 1888, *Fifteenth Meeting.*

The Society met in the Society Hall of the Cosmos Club, President Hubbard in the chair. Owing to the absence from the city of the Secretaries, Mr. O. H. Tittmann was requested to act as Secretary of the meeting. The minutes of the first and fourteenth meetings were read and approved. The report of the Secretaries was read, in their absence, by the temporary Secretary, and was approved. The Treasurer's report, showing a balance on hand of $626.70, was read and approved, as was also that of the auditing committee.

The President announced that vacancies caused by the resignation of two of the managers, Messrs. W. D. Johnson and Henry Mitchell, had been filled by the Board on the 15th of November, by the election of Messrs. O. H. Tittmann and C. A. Kenaston; and that a vacancy caused by the resignation of Vice-President John R. Bartlett, had been filled by the election of Lieut. George L. Dyer, on November 30th.

The Society then proceeded to the election of officers, with following result:

President—Gardiner G. Hubbard.

Vice-Presidents—Herbert G. Ogden, [land]; George L. Dyer, [sea]; A. W. Greely, [air]; C. Hart Merriam, [life]; A. H. Thompson, [art];

Treasurer—Charles J. Bell.

Recording Secretary—Henry Gannett.

Corresponding Secretary—George Kennan.

Managers—Cleveland Abbe, Marcus Baker, Rogers Birnie, Jr., G. Browne Goode, W. B. Powell, J. C Welling, C. A. Kenaston, O. H. Tittmann.

January 11, 1889, *Sixteenth Meeting.*

The paper of the evening was entitled, "The Great Plains of Canada," and was presented by Professor C. A. Kenaston, of Howard University.

January 25, 1889, *Seventeenth Meeting.*

The paper of the evening was entitled, "Irrigation in California," by Mr. William Hammond Hall, State Engineer of California. To be published in the "National Geographic Magazine," Vol. I, No. 4.

FROM BUTLER'S COMPLETE GEOGRAPHY.

February 8, 1889, *Eighteenth Meeting.*

The following papers were read by Prof. W. M. Davis, of Harvard University: "Topographic Models," and "Certain Peculiarities of the Rivers of Pennsylvania." Published in the "National Geographic Magazine," Vol. I, No. 3.

February 22, 1889, *Nineteenth Meeting.*

The paper of the evening was entitled, "Round about Asheville, N. C.," by Mr. Bailey Willis. The paper was illustrated by charcoal sketches and lantern slides. Discussion followed, which was participated in by Messrs. Baker, Merriam and McGee. To be published in the "National Geographic Magazine," Vol. I No. 4.

March 8, 1889, *Twentieth Meeting.*

The following amendments to the By-Laws were adopted.

[For Article VI substitute the following]:

ARTICLE VI.

MEETINGS.

"Regular meetings of the Society shall be held on alternate Fridays, from November until May, and excepting the annual meeting, they shall be devoted to communications. The Board of Managers shall, however, have power to postpone or omit meetings, when deemed desirable. Special meetings may be called by the President.

"The annual meeting for the election of officers shall be the last regular meeting in December.

"The meeting preceding the annual meeting shall be devoted to the President's annual address.

"The reports of the retiring Vice-Presidents shall be presented at the meetings in January.

"A quorum for the transaction of business shall consist of twenty-five active members."

In Article V, the following paragraph was introduced immediately after the first paragraph of the article:

"The dues of members elected in November and December shall be credited to the succeeding year."

The following papers were then presented: "A Trip to Panama and Darien," by Mr. R. U. Goode, and "Survey of Mason and Dixon's Line," by Mr. Mark B. Kerr.

A Trip to Panama and Darien, to be published in the "National Geographic Magazine," Vol. I, No. 4.

March 22, 1889, *Twenty-first Meeting.*

The paper of the evening was entitled, "Recent Events in the U. S. of Columbia," by Mr. W. E. Curtis. The discussion which followed was participated in by Messrs. Baker, Gannett, and others.

April 5, 1889, *Twenty-second Meeting.*

The paper of the evening was entitled, "House Life in Mexico," by Mr. A. B. Johnson.

April 19, 1889, *Twenty-third Meeting.*

This meeting was devoted to papers upon the Samoan Islands. The following programme was presented :

"Samoa ; the General Geography and Hydrography of the Islands and Adjacent Seas," by Mr. Everett Hayden.

"Climate," by Prof. Cleveland Abbe.

"Narrative of a Cruise Among the Islands," by Capt. R. W. Meade, U. S. N.

"The Home Life of the Samoans and the Botany of the Islands," by Mr. W. E. Safford, U. S. N.

May 3, 1889, *Twenty-fourth Meeting.*

The paper of the evening was entitled, "Across Nicaragua with Transit and Machéte," by Mr. R. E. Peary, U. S. N. To be published in the "National Geographic Magazine," Vol. I, No. 4.

May 17, 1889, *Twenty-fifth Meeting.*

The paper of the evening was entitled, "The Krakatoa Eruption," by Dr. A. Graham Bell. The paper was discussed by Captain C. E. Dutton.

(Translated by Mr. R. L. Lerch.)

INTERNATIONAL LITERARY CONTEST

To be held at Madrid, Spain, under the auspices of the Commission in charge of the celebration of the Fourth Centennial Anniversary of the Discovery of America.

Program.

The work for which a prize is offered is to be a prose essay, a true historic picture giving a just estimate of the grandeur of the occasion to be celebrated.

So much has been written on this subject since the opening of the XVIth century that it would seem difficult to say anything new and good. Perhaps the details, perhaps the circumstances in the life and acts of Columbus are worthy of no little research; but already the Royal Academy of History is engaged in the erudite and diligent task of bringing together and publishing the un-edited or little known papers bearing on this question.

The book required by this contest must be of a different nature: it must be comprehensive and synoptic, and must be sufficiently concise without being either obscure or dry.

Although there is an abundance of histories of America, of voyages and discoveries, of geographic science, and of the establishment of Europeans in remote regions of the earth, there is no book that sets forth as it can be done the combined efforts of the nations of the Iberian peninsula, who, since the commencement of the XVth century, have, with a fixity of purpose and marvelous tenacity, in almost a single century of silent efforts brought about the exploration of vast continents and islands, traversed seas never before cut by Christian prows, and in emulous strife obtained almost a complete knowledge of the planet on which we live.

There is a growing interest and manifest unity in all those more important events; not to mention the circumstantial evidence borne by the charts of 1375 and the semi-fabulous voyages, such as that of Doria y Vivaldi and others less apocryphal though isolated and barren of results, like that of Ferrer, begun in 1434, when Gil Eannes doubled Cape Bojador, discovered Guinea, and dispelled the terror inspired by the unknown ocean, and ended in 1522 with Elcano's arrival at Sanlucar after circumnavigating the globe.

In all this activity very little occurs by chance. The progressive series of geographic discoveries, due to persistent premeditation and not to accident, was inaugurated at Sagres by the Infante D. Enrique and his illustrious pilot Jaime de Mallorca.

Well might Pedro Nuñes exclaim that from that time forth until the form and size of the terraqueous globe were thoroughly known, the most to be obtained would not be firmly established, "unless our mariners sailed away better instructed and provided with better instruments and rules of Astronomy and Geography than the things with which cosmographers supplied them."

The culmination in the progress of that beautiful history falls on the 12th of October, 1492, when Columbus was the first European to set foot upon the intertropical shores of the New World. But this act, considered apart from its intrinsic value, as purely the individual inspiration of a mariner and the generous enthusiasm of a patron Queen, derives a higher value when regarded as part of a summation of efforts, a grand development of an idea, a purpose to explore and know the whole globe, to spread the name and the law of Christ together with the civilization of Europe, and to reap a harvest of gold, spices, and all the riches of which costly samples and exaggerated reports were furnished by the traffic of the Venetians, Genoese and Catalonians, who in turn got them from Mussulmans.

Doubtless the moving cause, whose gorgeous banner so many men of our peninsula followed, was clothed in great sentiments, good or bad; their hearts were filled with religious fervor, thirst for glory, ambition, Christian love, cupidity, curiosity, and violent dissatisfaction (even during the Renaissance), to seek and undergo real adventures that should surpass the vain, fruitless, and fanciful adventures of chivalry; and to make voyages and conquests eclipsing those of the Greeks and Romans, many of which, recorded in classic histories and fables, were now disinterred by the learned.

What must be described is the complete picture in all its sumptuousness so that its magnificent meaning may stand out distinctly, without which the conviction would be lacking that the studies, voyages, and happy audacity of Bartolomé Diaz, Gama, Alburquerque, Cabral, Balboa, Magallanes, Cortes, Pizarro, Orellana, and a host of others, do not dim the glory of the hero whose centennary is to be celebrated, even though it heighten and add greater luster to the work of civilization begun by Portugal. . . .

The book here vaguely outlined must also contain a compendious introduction, notices of voyages, ideas, and geographic progress up to the date of D. Enrique's establishment at Sagres, and an epilogue or conclusion of greater extent, in which are examined and weighed the changes and progress that our subject has made, collectively, in the civilization of the world—in the commerce, economics and politics of the peoples, in regard to the broad field opened to the intelligent activity of Europe, over which it could spread and dominate; the abundance of data, sunken hopes, and more secure basis lent to the studious and wise for the extension of our knowledge of Nature, the unraveling of her laws, and penetration of her mysteries.

The vast, elevated argument of the book requires it be a finished work of art, not in fullness and richness of diction, but in plan and order, in sobriety and unity of style, whose nobility and beauty must lie in simplicity of phrase, correctness of judgment and richness of thought.

There may enter into this contest any unpublished work written to this end in Spanish, Portuguese, English, German, French or Italian.

The tribunal that is to award the prize will be composed of two members of the R. Acad. of History, and one member from each of the Spanish R. Academies of Moral Sciences and Politics, and Exact and Natural Sciences—all to be chosen by the Academies themselves.

Furthermore, there will be included in the tribunal the diplomatic representative of every power whose subject or subjects wish to enter the contest, which is to be done through said representative or some person duly appointed to act in his place.

The tribunal will elect its presiding officer and will decide on the best works by an absolute majority of all the jurors who take part in the vote.

Each work submitted in this contest must be neatly copied, in legible writing, on good paper, without the author's name but with a quotation to identify him afterwards.

Each author will inclose a separate folded sheet on whose exterior is written the quotation he has chosen and the opening sentence of his work ; within, he will write his name and residence.

The folded sheets corresponding to the works that did not get a prize will be burnt publicly without being opened.

Though it is difficult to set a limit as to size, the works should not have more reading matter than is contained in two volumes of the shape and size of the complete works of Cervantes issued by Rivadeneyra in 1863–4.

If the plan or purpose of any of the works require it, there may be added another volume of documents, maps, or other illustrations.

As it will take time to examine and judge the works, they should be sent to the Secretary of the R. Acad. of Hist. prior to January 1, 1892.

There will be first prize of 30,000 pesetas ($5,790) and a second of 15,000 pesetas ($2,895).

Besides this, each of the two successful authors will receive 500 copies of the printed edition of his work.

It rests with the Centennial Commission to determine the number of copies in the edition of each of the two prize works, and what disposition is to be made of the copies that are not given to the authors.

These (the authors) keep the right to re-print and to sell their works, and to translate them into other tongues.

The Commission, however, will have the right, if either or both prize works are in a foreign tongue, to have them translated and published in Castilian.

The Commission affix their seal to the preceding directions for the information of the public and government of those persons who desire to participate in the contest.

Madrid, June 19, 1889.

The Vice President, Duke of Veragua.
Secretaries, Juan Valera, Juan F. Riaño.