

The Ohio Naturalist,

PUBLISHED BY

The Biological Club of the Ohio State University.

Volume VIII.

NOVEMBER, 1907.

No. 1.

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AGGRADATION AND DEGRADATION OF VALLEYS.

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It is the purpose of this paper to show what a river can do toward filling and degrading its valley, to discuss the conditions favorable to such work, and to briefly describe the resulting land forms. The paper is based on an experiment which was conducted at Ohio State University during the Winter of 1907 as a part of the work in Geology 21—a course in advanced physiography.¹

A watertight box, eighteen feet long, two feet wide and sixteen inches deep, was constructed; and then with weak cement a mature valley was built in the box. The valley walls rose on the sides of the box about five inches, and in the center the construction was about one inch deep. Fig. 1. Spurs alternately entered the valley from opposite sides. Fig. 2. The cement covered the entire bottom of the box except about one and one-half feet of the lower end which was left open for a catchment basin, where delta formation was studied. The upper end of the cement valley was covered with a pile of fire clay upon which played a fine spray.

At the lower end of the box was an elevated plug perforated so as to let out the water above a certain height. This outlet could be adjusted by changing the length of the plug, so that the lake of accumulated water could be given any desired depth.

A jack screw placed under the box about thirteen feet from the mouth of the stream permitted regulating the slope of the valley. Ordinary three-quarter inch rubber hose and a garden nozzle connected with the city water pipes furnished the spray. With varying city pressure frequent adjustment of the nozzle was necessary to keep a fairly uniform stream.

¹ The author desires to thank Dr. Hubbard, under whom the course was taken, for suggestions and criticisms both in the laboratory work and in the preparation of this report.

Aggrading and Degradation.—When the first experiment began, the screw was raised about one inch, which gave a slope of one inch to thirteen feet, or thirty-four feet per mile, equivalent to about one-third of one degree. This is a very steep slope for a stream but the smallness of our stream made it necessary, and even yet the larger particles of clay were only moved a short distance from the heap and that with marked difficulty. Except near the clay pile almost no aggrading at all was done. So the screw was turned up about one-half inch higher which increased the slope to fifty feet per mile. This seems like an enormous grade yet the stream still aggraded its lower valley with difficulty. In fact the stream increased its own slope to more than two inches in thirteen feet by distributing its sediment thicker near the pile of clay. If we could have given the stream more time, of course it would ultimately have aggraded its whole course without either uplift.

The supply of clay was repeatedly replenished that the stream might be constantly taxed to its utmost, and aggradation proceeded. The clay was considerably sorted by the stream. With an uniform slope and a shallow stream, as an aggrading river must be, the larger particles suffered many halts as they were rolled along or dragged on the bottom. While stopped, they served as catchers for other particles which would often accumulate around them. Most of the larger pieces found permanent lodgment before they attained half the journey to the lake and hence the delta built during aggradation consisted largely of very fine material.

The group of particles temporarily or permanently retained in the channel developed into a sandbar dividing or deflecting the water, and causing it constantly to seek new courses. Six observations of the stream were made in less than one hour and during each interval decided changes occurred. Figs. 3-8. It thus appears that a stream engaged primarily in aggrading its valley is shallow, constantly filling its own channel and breaking over its banks.

Aggradation went on until the upper valley was filled even above the rock walls but the lower valley did not fill quite so full. In the hope of more nearly filling the lower valley an increasingly higher perforated plug was repeatedly substituted for the first one, which made the water deeper in the lake. The lower valley then filled satisfactorily.

Upon the completion of the filling process, the heap of clay was no longer replenished but other conditions were left unchanged in order to see whether the stream would cut down into its deposits without further change. Erosion began at once and the sediments were picked up and pushed or rolled along to the lake. Degradation proceeded perceptibly faster in the upper

valley than in the lower. In the latter the stream spread out lazily in a shallow sheet covering nearly the entire width of the valley floor. Here little if any erosion was taking place, because the stream was essentially at base level. Sediments picked up above were transported across this area without modifying the lower valley, and into the lake to extend the delta. As often as the delta was built out to the plug, it was artificially removed. In order to have the lower part of the valley degraded, it was found necessary gradually to lower the plug in the lake, just as, reversing conditions, it was necessary while aggrading the valley to increase its height. This done, terraces were formed by the stream's meandering in the lower course, as well as in the upper.

The rock spurs mentioned at first, jutting out into the valley, resembling in perspective the entering spurs from alternate sides of a valley as seen in mature, dissected plateaus, were built to test the theory of "defended cusps" as set forth in a paper by Davis.² Our results supported his theory perfectly, for while the stream swung back and forth across its meander belt, leaving terraces at the limits of each meander, these terraces were very often destroyed by the next migration until the cutting had reached sufficient depth to discover the rock spurs, when subsequently all terraces, higher on the bluffs than the spur encountered, were preserved. Also in many cases terraces down stream from the spurs were sufficiently defended for preservation.

In Fig. 9, A, B, and C represent terrace tops, t and m, the ledges encountered by the stream, and n, a continuation of the effective spur seen above. While the stream was flowing on terrace C the ledge t protected terraces B and A from being destroyed.

The experiment showed also that the succession of terraces with narrowing strath on each lower level was not due to a decrease in the volume of the stream, for we were careful to maintain a constant stream; and, while there were temporary variations, it is probable that every hour's work was done by about the same quantity of water, and certain that no appreciable decrease in the volume occurred during the degradation process. The terraces were made by the persistent systematic swinging of the stream back and forth across its flood plain. Where the stream encountered the ledges it was restrained in its lateral cutting and each lower level presented a narrower valley than the one above, but where no ledges were met the stream in the end usually undercut the older terraces and destroyed them. The stream in this erosion stage of its work, however, did not change its course nearly so often as it did during the stage of sedimentation suggesting, as has been shown by Griggs,³

² Bull. Mus. Comp. Zool. Harvard. 1902. Geol. Series Vol. V.

³ Bull. Amer. Geog. Soc. 1906. Vol. XXXVIII, pp. 168-177.

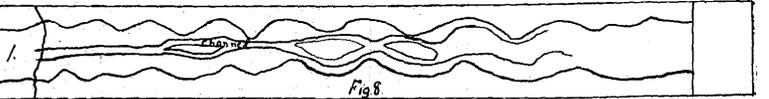
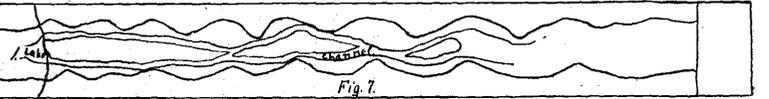
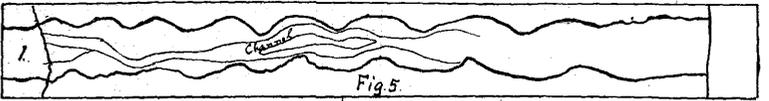
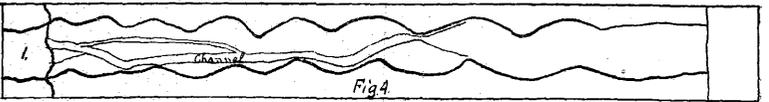
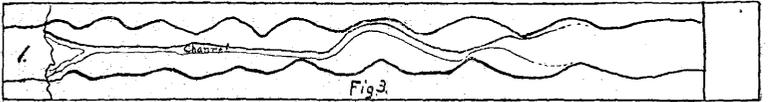
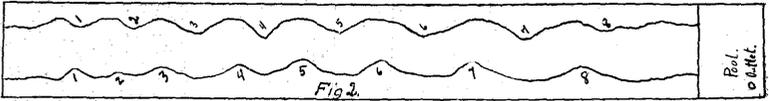
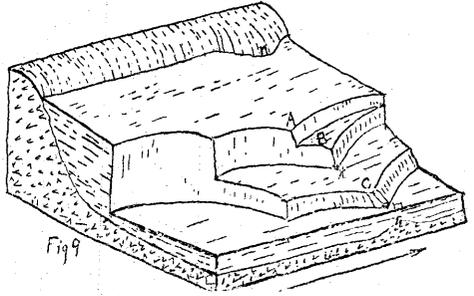
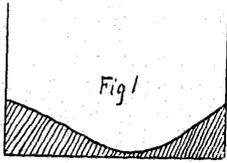


Fig. 1. Cross section of box showing form given to the rock filling put in.
 Fig. 2. Plan to show the series of spurs 1-8 on each side of the valley, also pool and its outlet.
 Figs. 3-8. Successive positions of the channel in the process of aggradation.
 l = pile of clay.
 Fig. 3 shows position of channels at 3:30 P. M., Feb. 21, '07; Fig. 4. at 3:40; Fig. 5. at 3:45; Fig. 6. at 3:55; Fig. 7. at 4:05; Fig. 8. at 4:15.
 Fig. 9. A, B and C are terraces defended at t and m by ledges on the spur n n which has here been encountered by the stream.

that it is largely the deposition of overload in the slackwater sides of streams which engenders meanders and promotes their development. Although the changes in course were so great during deposition, after the supply of sediment was cut off, and erosion began, the stream would go for an hour or more with only slight local changes.

With every swing of the stream from one side of the valley to the other, a thin layer of alluvium was scraped off and a terrace was left. Six distinct terraces were at one time counted on one side of the valley. Terrace fronts were less than half an inch high unless two or more had been combined by cutting out the lower ones. The terraces had a great variety of shapes and directions corresponding to the meanderings of the stream; consequently no two successive fronts were parallel.

Slope, waste, and water supply in relation to eroding power.—

The slope as noted above was about sixty-six feet per mile, and even with this steepness, deposition went on actively as long as the stream's maximum capacity for carrying sediment was taxed, but when the pile of clay was no longer replenished active erosion began. The water supply was kept as nearly the same as possible, and the slope was not increased. Since the amount of sediment in the stream was the only factor changed it follows that any change in the habit of the stream may be intimately related to the load.

Let us look, however, for a moment at the other factors in the problem. The supply of water has a great effect in determining the power of a stream. Several times during the experiment the volume of the stream was doubled for a few minutes and it was easy to see that the power of the stream, whatever it was doing, was more than doubled. With an unlimited supply of waste, the stream simply carried more and on the average, carried it farther with the double volume than with the single volume. It did not degrade at all but rather aggraded faster. With no waste at the source, the increased volume accelerated the stream in its degrading; banks were more quickly undercut, and debris was more abundantly and more rapidly hurried down stream. At a time when the supply of clay was limited but the stream was aggrading, a doubling of the volume of water changed the habit of the stream and it began to degrade. In fact, at this time, a volume of water could be used such that the stream neither aggraded nor degraded perceptibly; but that a very slight increase initiated erosion, and a very slight decrease initiated deposition. The balancing of load and power was very accurate and the adjustment so perfect that very slight changes in stream volume were sufficient to unbalance forces and change the stream's habit.

It was noticed, as above stated, that the doubling of the volume more than doubled the power of the stream. If the volume could have been doubled without increasing the velocity, undoubtedly the power would have been little more than doubled, but this is probably impossible; and since increasing velocity so greatly augments power, the marked increase is thus explained.

To test the influence of changes in slope, the steepness was increased and decreased temporarily under various conditions. The results may be summarized as follows: During the early part of the experiment when the stream was constantly loaded to its maximum capacity, decreasing the steepness checked the velocity and power of the stream from the loading point to its mouth, and hence reduced the rate of deposition because the stream could not start as much waste as formerly, when its power was greater, and manifestly could not drop as much either. Under the same loaded conditions with abundance of waste to be picked up at the source, steepening the slope increased deposition instead of initiating erosion because the stream was able to pick up more waste at the start and hence had more to drop along the valley. These results are really not anomalous, but, when the problem is thought out, quite expectable. No quantitative tests were made but the general results as here stated were so apparent that we believe the facts are exactly as stated above.

When the stream was degrading during the latter part of the experiment, a slight increase in slope increased the rate of degradation and a similar decrease in steepness checked erosion, while more reduction in slope stopped erosion almost completely.

Inasmuch as such changes in slope do not enter into the ordinary field problems of streams we may consider the effects of changes in volume of water and quantity of waste in their general application without considering changes of slope. The experiment was somewhat abnormal to nature in another respect, for in nature waste is not usually fed into a stream, absolutely as fast as the stream will pick it up regardless of variations in the stream's power. In nature, supply of rock waste varies with the volume of water.

Resulting land forms.—The forms resulting from a river's aggrading and subsequently degrading its course are mainly of an ephemeral type. To begin with a constructional plain is formed occupying the valley filled. This plain is composed of loose, more or less systematically stratified materials which, as a rule, do not have time to become much consolidated or cemented before the stream changes its habit and proceeds to send the waste, temporarily rested along the valley, on its journey to the sea. Terraces are thus carved with their level, often crescentic top plains and their steep, serrate, or cusped,

front slopes, and below them new flood plains. Most of the terraces unless defended by rock ledges are subsequently cut out, the flood plain is replaced by a new lower one, and gradually but surely the old valley floor is more or less completely uncovered and the old valley is restored similar to the form which was filled by the accumulating sediments.

The whole cycle of aggradation and degradation constitutes but a little epicycle in the greater round of topographic evolution to which the hard rock lands must submit—a little pleasure trip which the stream takes while it rests from its great work of baseleveling a region. So short-lived are the forms due to these processes that the “eternal hills” do not change much during the entire period of the terrace stage and many epicycles may come and go and leave no record while one turn of the wheel of physiographic development is being made.
