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REPRESENTATION OF LAND FORMS IN THE PHYSIOGRAPHY LABORATORY

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LABORATORY WORK IN GENERAL.—Teachers of physiography in the colleges and the secondary schools have been confronted by the problem of the organization and development of adequate laboratory work as a part of the regular instruction in the subject. There is no general plan acceptable to all, and no unanimity of opinion as to what is best. Each teacher has been forced to depend more or less on his own ingenuity, and to work out his own salvation. His particular teaching environment must also be a large factor in whatever plan or scheme he adopts. Doubtless out of it all will ultimately come a general scheme acceptable to the great majority; but at present, in spite of the fact that there are now a number of good laboratory manuals, there is great diversity instead of uniformity of usage.

In the Cornell Department of Physical Geography the problem of the laboratory work has been the most perplexing of all that have confronted the teacher, and numerous experiments have been tried, especially in laboratory work with land forms. One result of these experiments has been to demonstrate the value of field work even with the most elementary class, and in the very first lessons; and for years it has been the custom to devote all the periods in the open season, both in spring and fall, to organized field study. Indoors, however, where it becomes necessary to substitute *representations* of land forms for the real thing, there has been great difficulty with elementary classes. Map work and work with models have been found dull and uninteresting; as such work leads to no tangible end that the average beginning student recognizes as worth while and it assumes a constructive imagination that the average student does not possess.

mountain folding has been successfully undertaken, and plans for other work are under way.¹

At some later time a fuller statement of methods and results will doubtless be published,—after we have had opportunity to develop the matter further. For the present it is proposed to describe the methods and apparatus for only two of the experiments, with a description of some of the results aimed at and attained. This is done in the hope that others may see in such work the benefits which are so clear to us, and try this aid to physiography laboratory instruction. It is also hoped that some may even wish to plan and work out additional experiments; for if there is in this work the value that we believe it to have, it will require the labor of more than one to plan and develop a series of experiments suitable to the needs of a well-rounded laboratory course.

DESCRIPTION OF THE LABORATORY AND ITS EQUIPMENT.—In view of the fact that the work was of an experimental nature, we have not attempted to fit up a laboratory of large size nor with any great degree of elaboration. A small basement room was selected and a cement floor laid, with a gentle slope toward an outlet to which the surplus water drains freely, a screen over the outlet preventing the entrance of coarse sediment. A system of artificial lighting and a supply of water completed the fixed features of the room. The water pipe was tapped at a large zinc-lined sink and at two other points for the attachment of a hose. This is all very simple and quite inexpensive; and such a laboratory, or a better one, might be easily provided in any ordinary school building.

Several pieces of apparatus have been built, but only one need be described for the purpose of this paper. This is a large, square, wooden box, or tank, 8 feet on the side and 16 inches deep. Our tank is made of thick matched boards and is water-tight; but probably a cheaper tank could be made of ordinary boards with a zinc lining; and one could carry on these experiments with a box either larger or smaller than this one. The tank is made for the purpose of holding a body of standing water whose level may be adjusted to suit the requirements. This may be done by any one of several devices: we have used a series of holes with removable plugs.

A second box (5 feet 6 inches on the side and 14 inches deep) was made with a solidly built platform and removable sides. This need not be water-tight, for it is intended solely for the purpose of holding the sand, clay, and

¹ A paper on the work in this laboratory was read by the senior author before the Association of American Geographers at the annual meeting in the Christmas recess of 1907 at Chicago; and by the junior author before the Ithaca meeting of the New York State Science Teachers Association at about the same time. The latter was published under the title "Use of a Wet Laboratory in Physiography Teaching," Education Department Bulletin Number 431, University of the State of New York, pp. 44-49, September 15, 1908.

other materials to be worked upon. The platform, however, should be firmly built to sustain a load. Through each of the four corners of the platform extends a screw used for raising and lowering the platform and for tilting it. On the platform is molded such a land form as is desired; and the outer tank is filled with water to the required height. In erosional and depositional experiments these processes are induced by a spray from one, two or three nozzles; and the land is raised or lowered, or tilted at will, or the level of the water body is varied according to the need.

The materials used in the erosion and deposition experiments were mainly (*a*) common sand; (*b*) moulder's sand; (*c*) ordinary brick clay, ground fine. We tried gravel also but found it too coarse for removal without greatly increasing the volume of water or greatly increasing the slope of the land area. Even common sand is rather coarse for the needs of this work. After several experiments we added a fourth material, that of the recovered mixture of sand, moulder's sand and clay which was deposited during earlier experiments. The use of plaster of paris was also tested, but it was found difficult to avoid making too hard a layer; indeed, the clay itself served well the purpose of a resistant bed. In several of our experiments we succeeded in securing a moderately hard layer by mixing a small amount of plaster of paris with the dry clay, but we would advise extreme caution lest a too large quantity of the plaster be admixed. Slaked lime, powdered, serves the purpose much better. One of the needs which we have as yet been unable to meet satisfactorily in this matter of materials is that of supplying some color to the various layers so that they can be readily differentiated when exposed by erosion. Cheap ochre and other dry colors have been tried but unless very large quantities are used, it has been found that they lose intensity on wetting.

With these materials we built up a land form sometimes with thin, rapidly alternating layers, sometimes with thick layers, or with alternating thick and thin. In some of the experiments the layers were laid horizontally, in others inclined. Some of our land forms were plains, others hilly land, or even miniature mountains; these conditions varying with the result sought.

For the spray we have used the Mistry Jr. nozzles sold for \$1.25 by The Goulds Mfg. Co. of Seneca Falls, N. Y. This spray is a mist caused by an ingenious device, and the nozzle is intended for use in spraying plants. For more rapid work the spray from an adjustable hose nozzle, such as is commonly used with garden hose, was employed. With the finer mist one may carry on an erosion experiment for several successive days, even leav-

ing the spray on all night; but where immediate results are desired it is possible to secure them by means of the ordinary adjustable hose nozzle.

So much for the equipment and material used in the laboratory. It might be worth while to detail further the fitting up of the space we have, but that which has been explained serves the purposes of the two experiments or exercises outlined below, with the description of which we will content ourselves in this paper.

THE TEACHING OF CONTOUR MAPS.—There are certain phases of physical geography teaching which offer difficulties common to all schools. One of these is the proper understanding of hypsometric maps, and in this country more especially of contour maps as furnished by the United States Geological Survey. Moreover, most students not only lack appreciation of the expression of elevation, but also are ignorant as to the philosophy of maps and their making in general, that is of triangulation, traverse and scale.

Now the best way to make this clear to the student is by actually putting him, or the class at work in the field with the plane table, the level and the transit; and have made a map of an actual land surface. But even when these instruments are available this presupposes an undue amount of time given to the work by the instructor, as each individual needs personally to perform all phases of the work in order to get a proper appreciation of the line of procedure. As time is generally the scarcest commodity at the teacher's disposal, and this procedure is therefore practically impossible, the following experiment was devised to meet the need as nearly as possible in the laboratory, and make clear as many phases of it as may be possible under the conditions.

Even the least alert member of a geography class will appreciate that a relief model is a miniature expression of a land surface, actual or hypothetical. He has simply in imagination to enlarge its features to the proper degree if he wishes to realize it in nature. Now the problem is to make him appreciate a diagrammatic expression of the same topography.

With these ideas in mind we modeled on a platform, secured by removing the sides from the inner box described above, a hypothetical land surface with as marked a variation in its topographic features as could be built up without too great difficulty, and yet one that did not possess too great complexity of detail. Thus river valleys, a coastal plain, a volcanic peak and an adjacent high plateau easily came within the scope of these limitations. It may be suggested at this point that if the home region, in whole or in part, is varied enough to admit the reproduction of its broad features in this manner, a distinct advantage could be gained by modeling it

for this experiment, since the familiarity of the pupils with its features would lend an added interest to the work.

In the four corners of the platform on which the model was built up were iron collars, threaded, and into these were screwed the cranks by means of which the platform was supported. The threads on the cranks and in the collars were coarse, some ten or twelve turns to the inch. The ends of the cranks were pivoted in iron sockets, screwed fast to the bottom of the outer tank, so that by turning the cranks simultaneously the whole platform, with its incumbent model, could be rapidly raised and lowered at will.

FIG. 1. MAPPING AND CONTOUR EXERCISE

The land form modeled and all adjustments made for the class to begin work.

The materials used in building up the model were sand and clay, with enough plaster of paris admixed to give the forms sufficient firmness to stand up without slumping, when immersed in water for some time. On account of this tendency to slump, it is also well to make the model a day or so before it is to be used. Just before the beginning of the exercise the outer tank is filled with water, the water level being adjusted by means of the plugs on the one side, and the platform lifted, by means of the crank screws, until the water surface coincides with that of the lowest point on

the land surface (Fig. 1) which should be at the level of the platform top, that is, the edge of a coastal plain, or the mouth of a valley. As rendered on the map about to be constructed, the datum plane or sea level will then be expressed by the square outline of the platform top.

These things adjusted, we furnished the students with detail paper, pencils, magnetic compasses, rulers and yardsticks. They were told that the object of this exercise was the making of a contour map of the miniature land surface before them. Immediately there arose the question of what was to be north; thus bringing out the necessity of determining the meridian when a map is to be made. With our compasses this could only be done approximately, owing to the proximity of iron radiator pipes and electrical currents. This deflection of the needle offered an opening for the explanation of the deviation of the needle from true north in most localities, and also an appreciation of the astronomical methods of getting a north and south line.

There came next the question as to what should be the scale of the map, and on this point students in general have only very hazy ideas. Prompted by leading questions, however, they were soon able to fix upon a suitable measure. As our platform is 5 feet 6 inches square, a scale of one inch to one foot was adopted. Then the class was set to work mapping the model by actual measurement from point to point, using the yardsticks on the model and reducing the measurements so obtained to scale; and then by use of the ruler and free-hand sketching to plot them on their maps. The model was large enough to make it possible for a number of the class to take measurements at the same time. This part of the work could be elaborated by introducing some device for reading angles, and so introducing the methods of triangulation, but we did not attempt this.

After the horizontal projection had been plotted in this way, there remained yet the expression of topography by contours. It was pointed out to the students that their map, as made up to this point, was simply a projection of the intersection of the surface features on a horizontal plane. Then, if a set of lines could be superimposed on this map, showing an actual intersection with a plane cutting through at a level a given amount higher than sea level, these would indicate that in going from sea level to this new set of lines, one must, if traversing a land surface such as this relief model portrayed, climb a proportionate elevation; and, vice versa, that he must descend a like amount in going across country from these lines to the sea level. It was also clear that the sea-level line was shown on the map by the square outline of the platform top, and that such lines

were contour lines. It then became necessary to select a contour interval and for our purposes one inch was chosen. This done, the four cranks were turned simultaneously, by four students, a number of revolutions sufficient to depress the platform and its model one inch; the opening in the side of the tank permitting the outflow of the displaced water. There followed the determination of points where the plane, determined by the level of the water, intersected with the surface features (Fig. 2); and then

FIG. 2. MAPPING AND CONTOUR EXERCISE
Locating a contour line.

came the simple task of sketching in the contour; this part of the work being practically a repetition of what had been done before, presented no new difficulties. Meanwhile a blackboard explanation of the methods of leveling in the field was introduced. Successively higher contours were obtained in like manner until the hilltops were submerged. Then by going over the map with colored crayons the culture, hydrographic and hypsometric features were thrown into relief, and the class had produced in a laboratory period a map whose every feature they clearly comprehended as to significance and manner of obtaining. They saw too, and clearly, that not only elevations but also land forms are accurately shown by a contour map.

There are, of course, a number of other uses to which the same model and apparatus could be put; for example in illustrating a drowned seacoast, in demonstrating in connection with the contours the reasons why roads and railroads follow river valleys, etc.

A LESSON IN EROSION AND DEPOSITION.—In the field, in favorable places, a student may be taken out to study a stream valley; or, failing that, he may study about it in the text, or from photographs, or from maps. In any of these cases he has but the *finished form*, or possibly only the representation of one. In the same way he may study a delta, or a flood plain, or a meander, or a section of sedimentary strata. In the wet laboratory he may see, in miniature to be sure, the process, the development, and the result. With this as a basis he can go to the finished product in nature, or to a representation of it, with a better basis for real understanding and interpretation.

One of our wet laboratory experiments has been devised to supply the need just expressed. A land form, a moderately regular though somewhat undulating plain, with a gentle slope toward the sea, is built in the inner box. The plain may be made by almost any combination of layers, though we obtained the best results and the greatest variety of phenomena by using alternating thin layers of moulder's sand and clay with a small amount of plaster of paris mixed with one or two of the clay layers. It is advisable to sift this material on the surface, layer on layer, when building up the land form, as this gives a more uniform thickness, and, moreover, the strata can be deposited in lenticular overlapping patches as is the case in nature. The greatest depth of the material was made in the upper part of the box in order to secure a slope from back to front. In the very back of the box the deposit was a foot or more thick, in the front only an inch or two. The layers varied in thickness, those of moulder's sand being usually about an inch at the thickest part and thinning down toward the front; the clay only an eighth or a quarter of an inch in the thickest part. The top layer is a sheet of moulder's sand.

When the land form is built up, which may be done before the class assembles, the front side of the box is removed and the tank filled with water to the depth of six inches or thereabouts. Then the platform is lowered until the front edge of the land is submerged; and the back side is raised so as to give a sufficient slope for the water to run off freely. One must be sure that the outlet to the tank is large enough to carry off all the water as rapidly as it is sprayed on, and so maintain a uniform level, else no good delta forms will result. When the class assembles they are told to

examine and make notes upon the land form and the surrounding conditions. They are told what lies beneath the surface and what it has been planned to do. They are asked to classify the land form (a young plain); to describe its relationships (a new land form bordering the sea); and to predict the stages in its dissection when exposed to the denudation which is about to be experienced.

The spray is then turned on (Fig. 3), miniature lakes appear, conse-

FIG. 3. EXERCISE IN EROSION AND DEPOSITION

Flashlight photograph taken while erosion was in progress. Note water in the stream valleys, the development of tributaries, formation of a flood-plain, lateral cutting, etc.

quent streams flow in broad courses over many parts of the surface, and there are consequent rapids and falls. The water along the shore line begins to be clouded with sediment. These features are closely observed and recorded, and predictions are called for as to the results. The consequent lakes and waterfalls soon disappear and one or two major streams develop valleys from which tributaries eat backward by headwater erosion; waterfalls appear and recede when the clay layers retard down-cutting; and a delta surface rises to the water level. As the delta grows outward, dis-tributaries appear upon it and there are frequent shiftings in the stream

courses (Fig. 4). With outward growth the lower courses of the major streams are aggraded and meanders develop. All these features are carefully watched and recorded; and the interest of the class in itself has amply justified the time and work required by the teachers; but, even more important than this, the students have been engaged in observation and deduction

FIG. 4. EXERCISE IN EROSION AND DEPOSITION

A later stage of the preceding and after the water level had been lowered. Note the delta outline, distributaries, and the indications of the clay deposit on the bottom. Erosion performed with Mistry nozzle.

and have been securing a basis for fuller appreciation of the related work with maps, photographs and models.

Draining the water from the tank there is seen a perfect delta, with a broad sheet of clay all over the bottom of the tank. These phenomena are studied by observations; their significance is deduced from the observations; and the form and structure of the delta are observed and explained (Fig. 5).

Following this the tank is again filled to the old height, and by directing the hose with a strong current, material is washed into the water and the front of the plain is notched into a wave-cut cliff. Then the spray is turned on once more and the coastal plain dissected at the new base level.

By hurrying the processes this might perhaps all be done in a single afternoon, but by far the best results are gained by starting the experiment on one afternoon, going far enough with it to allow the class to see the changes well under way, then allowing the spray to work with a gentle mist all night, and studying the phenomena at the next period. The work of forming the coastal plain, and the action of waves and currents may also be performed more slowly, giving to it a full laboratory period.

FIG. 5. EXERCISE IN EROSION AND DEPOSITION

Characteristic delta obtained by rapid erosion with hose nozzle spray. Note sheet of clay in front of delta.

Several objects are sought in this work, as follows: (1) arousing and maintaining interest, upon which alone successful instruction is possible; (2) the training of the eye to close observation of details; (3) the exercise of the mind in deductive reasoning from a basis of observed fact; (4) incidentally, the gaining of some information about land forms; (5) the furnishing of a basis for the exercise of constructive imagination in a study of larger features of similar kind, which can be brought before the student only in field work or in some representation of the real phenomenon, as by a map or a model or a photograph.

RELATION TO MAP WORK.—The latter point is sought by subsequent work. In the spring field work the results of the wet laboratory exercises are applied in study of actual land forms; and before this—and in fact during the progress of the wet laboratory work—there is formal laboratory work with maps. Single and grouped sheets of coastal plains and of deltas are studied, in the regular laboratory, in the light of the observational work in the wet laboratory. The study of the stages in the development of plains from youth to old age is undertaken by map and model study; and here, as elsewhere, wherever possible, by the study of typical photographs or slides. The river valley form and its variations; the meander; the floodplain; river piracy; in fact, numerous topics can be taken up and their study correlated with, and made to yield richer results from the basis of simple studies of artificial reproduction of land forms before the eyes of the students.

Our results in these wet laboratory studies have been so satisfactory, from every standpoint, that we have come to look upon this work as no longer of an experimental nature and of doubtful value. It has now a distinct and significant place in our laboratory course. That there are many more possibilities in it than we have discovered we have no doubt. One could even make a whole laboratory course along these lines, though this does not seem desirable; for a study wholly in miniature would lead to unfortunate results from the standpoint of both training and information. There is a distinct and useful field for some of it, however; certainly as much as is outlined here, and probably more. It has been our hope in preparing this brief outline of the work done in the wet laboratory at Cornell University that it may attract the attention of some teachers who will see something of the possibilities in this work and will be led to undertake it in their own laboratories. There will be some hard work for the teacher; but our experience is that the teacher will find himself amply repaid by the results.¹

The fifth annual meeting of the Association of American Geographers will be held at Baltimore, Md., on January 1 and 2, 1909, in association with the meetings of Convocation Week.

One session will be devoted to a Round Table discussion of Geography for Secondary Schools.

¹ The authors will gladly give further information if desired; and we would willingly permit duplicate copies of our apparatus to be made.