FIELD AND LABORATORY EXERCISES
IN
PHYSICAL GEOGRAPHY
FOR USE IN THE SCHOOLS OF ILLINOIS

BY

MARTHA DEETTE ROLFE, B. S., 1900.

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Marcella Helen Wolfe

ENTITLED Field and Laboratory Exercises in Physical Geography

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

of Bachelor of Arts.

C.H. Wolf

HEAD OF DEPARTMENT OF GEOLOGY.
DISINTEGRATION.

Examine a boulder or other loose stone. Break off a piece with a hammer. Compare the fresh surface with the worn one. See if you can explain the difference. Are there places on the exposed surface where particles of the material are soft and fine, and can be rubbed off as a powder with the hand, or picked out with the point of a knife? This fine material is kaolin, or china clay. Do you find anything like it on the fresh surface? Then it must have been formed by weathering, or the decomposition of the rock through the action of the atmosphere. There are places in the earth where immense masses of the rock have decomposed, leaving great beds of white china clay. Look up kaolin in your reference books; learn about its properties and the uses which are made of it. Common clay is formed in the same way as kaolin, but it contains impurities of various kinds. Examine some of it. What is its color? Can you find a boulder which has bits of the impure clay on its surface?

See if you can find boulders which can be broken into sand by hitting them with the foot, or pebbles which can be crushed in the hand. Could they have been in this condition when they were deposited by the glacier? Examine them closely. How do they differ from the boulder first examined? Notice that the hard grains of sand are not firmly cemented, but are very loosely bound together. The substance which formerly cemented them must have been dissolved or worn away. Can you find a bed or bank of sand. Keep in mind the fact that all sand was once a part of large rocks, and that these have been broken down just as was the pebble you examined.

Examine an old brick wall. What has happened to the mortar? If the bricks were soft-burned, what has happened to them? Why?

Examine a number of pebbles and boulders. Are their surfaces rounded, or formed of sharp angles and corners? Why? Which presents more surface to the weather, a sharp-angled stone or a rounded one? What relation exists between the amount of surface exposed and the rapidity with which it is acted upon by the weather?

Go into an old grave-yard. Look at a new monument. The stone has a polish, and the corners are sharp-out. Now find one whose corners have become slightly rounded. Are the corners polished or dull? What has caused the change? Why are the corners affected before the face of the stone? (Remember which presents the greater amount of surface.) Find a stone from which the polish has practically all disappeared. Is the surface still perfectly smooth? What has caused the pitting? Might not this action continue until the stone, or part of it, would fall? Find a fallen
stone and, if possible, note the date on it. See if you can discover a reason for the base giving away first. Are there lichens and mosses growing on, and around the base? What effect do these have on the stone?

If there is a gravel bed near, go to it, and see if you can find pebbles with roots imbedded in their cracks. How might these roots aid in disintegration?

Place germinating beans on a piece of polished marble and keep covered with a damp cloth. After a week or so, remove the beans. Have their roots corroded the marble? Do you consider that plants, when they have access to rocks, are an important cause of disintegration? Notice the roots of trees along steep, rocky banks. How do they make room for themselves?

Examine a deep, vertical bank or a well. Notice the yellow clay near the top, and the blue clay below. Why is there such a difference? Expose a piece of bright iron to the weather for several days. What change in color is there? The iron has become rusted (oxidized). If in the clay there were particles of iron, and these were subject to the action of water, might not they, too, become oxidized? What change in the color of the clay would this produce?

Examine the inside of a teakettle which has been used for some time. What is the coating on the bottom and sides? Where did it come from? Where did the water obtain it? Water possesses a solvent action on rocks. Into a glass of water, put a lump of table salt. (Table salt is the refined form of a rock known as Rock Salt.) What becomes of the salt? Put a piece of limestone, or a chip of polished marble, into another glass of water. Does it seem to dissolve? Add a little acid and set away for a day or so. At the end of that time, examine it. Has there been any change? Water often contains small quantities of acid. Would not a similar action have been produced without adding the additional acid, if a very long time had been allowed? It is in this way that the limestone is dissolved by the well-water, to be later deposited in the teakettle.

If there are stone-quarries near, go to one, and see if you can observe the effects of weathering and solution. Have channels been opened along the joint-planes? How large are they? What produced them? How did the water gain access?

Place a stone in an oven for a day or so. Cool and weigh. Soak in a pail of water for another day; wipe with a dry cloth, and weigh again. What has caused the difference in weight? All rocks exposed to the weather contain more or less water. A rock in a wet place may become saturated; in such case, will there be any exchange of water between the rock and the ground under and around it? How will this hasten disintegration?
What may happen when the water in a rock freezes? What happens when the water in iron pipes freezes? Set a pan of water outdoors in the winter, until it becomes frozen. Do you notice any change in the pan when the ice is emptied out? Is it at all bulged or bent out of shape? Why? Place a bottle of water outdoors in zero weather. What happens before many hours? Why? Apply the same principle to frost in the rock. Why is fall plowing usually better for the land than spring plowing?

The pebbles in Illinois are mostly of three kinds. Crush one; add a little hot acid. If it effervesces, and more than half of it is dissolved it is a limestone pebble. If half or more is left in the form of fine sand, it is probably sandstone, made of quartz grains cemented by lime, or some other material. (If it colors the acid yellow, the cementing material probably contains iron.) If it is not affected by the acid, it is probably a crystalline rock.

Dry a pebble of each kind, and weigh, as before; then soak and weigh. Which absorbs the most water for its size? Then which kind of stone would be most affected by frost? Which the least? Tha air contains a certain amount of carbonic-acid gas, and the water contains other acids. Which kind of stone would be least affected by these? Which would be most affected? Which kind would make the best building stone?

Go into a stone building. Can you find evidences of dampness, especially on the basement walls? See if you can tell of what kind of stone the building is constructed. Can you find a stone building in which this dampness does not exist? What causes the difference? Of what kind of stone is it built?

Do you know of a brick building which is damp? Is it built of soft-burned, or hard-burned brick?

What kind of brick is paving brick? If there are brick-yards near, visit one, and discover what causes the difference between the two kinds of brick. Which is burned at the higher temperature? Note that in the paving-brick, the impurities in the clay melt, and fill the pores with a fluid which becomes like glass when cool. Why is such a brick less affected by the atmosphere and water than a soft, porous one?

The superintendents of some cemeteries are refusing to admit monuments of marble. Can you think of a reason for this action? (Marble is crystallized limestone.)

Why are the rocks and pebbles in stream-beds usually smooth and rounded? How are rock marbles made?

How many forces may act on rocks and aid in their disintegration? Name them. Which ones do you think are most important? Why?
SOILS.

Definition of Soil.

What becomes of the stones and rocks when they are weathered so that they fall to pieces? Grind a pebble to a fine powder. What does it look like?

Put a quantity of soil into a glass jar. Pour on water and shake. Let partially settle, and pour off the water, adding fresh. Continue this washing for some time. What is left in the jar? All the water which is poured off should be saved. Let it settle until clear. Pour off this water and feel of a little of the sediment. Does it contain any sharp, gritty particles? Carefully separate these by washing. (This will require a longer time, as the settling process will be much slower.) What do they look like? How do they differ from the larger particles which were left in the first jar? What proportion of the soil is made up of these finer particles? Can you account for their presence? In studying disintegration, how did you find similar particles were formed? Is there any of the soil that does not feel gritty? Of what do you think it is composed? What have you learned about the way in which clay may be formed?

Crush and grind until very fine, enough pebbles to fill a small pot or box. It would be well to use a mixture of pebbles of different kinds. Plant beans in it. Water occasionally. Do they grow?

To another pot of material prepared in the same way, add one-third its bulk of well rotted manure. Plant beans in it. In which pot do they grow better? Can you account for the difference?

See if you can find leaves which have been piled in a low, wet place for several months. Examine the bottom leaves of the pile. What has happened to them? How do they differ from those near the top of the pile? Leaves which decay while exposed to the air are said to burn up (oxidize); that is, they leave nothing but the mineral matters which they contain. See if you can find the skeleton of a leaf. What does it look like? What part of the leaf must have contained the most mineral matter? Did you ever see a tree which had been through a fire, with the skeletons of part of the leaves still hanging to the branches? Place a dry leaf on top of a stove, where it will burn very slowly. (Its oxidation will be hundreds of times more rapid than in the open air.) What part of the leaf tends to crumble last? What is finally left of it?

Leaves and plants which decay while not exposed to the air, instead of slowing oxidizing, form humus. Humus is a heavy, black substance, containing an acid which, when mixed with the soil, assists in its disintegra-
tion. Consequently it is of very great value to the land. It is never formed except under water, or in a low, wet place or under the ground.

Notice the pile of leaves again. Into what are the lower leaves being converted? What color is the new substance? Put a little of it on a shovel and place in a furnace or stove. Keep at a red heat for about twenty or thirty minutes. Remove from the fire and cool. What change in color do you notice? What is left? Vegetable matter always burns to a light color if heated long enough. What is the color of wood-ashes? Of what are they composed? Why are the upper leaves of the pile not being converted into humus? What will become of them after a sufficiently long time?

Go to some swampy place. Take off a little of the surface material which lies under the water - the coarser this is, the better. Dry and examine. If abundant enough, it would make peat. Peat may become decomposed to form humus.

What kind of land is necessary for the formation of humus? Why do low swampy areas have the best soil? Why is black soil better than light soil? Why, unless the season be too wet, do the low areas yield the best crops? What can be done to the other land to make it more like these areas? Why should corn-stalks be plowed under? Why will they not do as much for the land, if they are left on top? Why is clover plowed under?

In addition to what is indicated above, humus benefits the soil by furnishing, when it decomposes, some plant food; by keeping the soil light and porous, and by acting as a store-house for water and the various plant foods which it takes from the ground-water.

Kinds of Soil.

Residual Soil.

(This section can be used as a field exercise in Jo Daviess County, part of Calhoun County and that part of the state south of the latitude of Carbondale. It is possible that in other parts of the state, small areas of residual soil may be found, but no large ones.) For the rest of the state, the subject should be discussed in class by the teacher.)

Find some place where the rain has cut a trench down to the rock, or where one has been dug to that depth, and examine the vertical bank. Notice the fine clay soil at the top? Take up a handful of it. Does it seem reasonably smooth? Four or five inches lower, take from the bank, with a trowel, another handful of soil. Is it as even-grained, or does it contain more gritty particles? Examine the soil some inches lower. Does the grittiness increase? Can you find a place where the particles are as large as small pebbles? What about the size of those even lower? Those very near the solid rock? Have you found a distinct gradation from the fine clay a-
bove, to the rock below? Make a drawing to show this. Where has the soil come from? Was it ever solid rock? What have been the agencies which have changed it? How may the atmosphere have acted on it? Frost? Water? Why is it finer at the top? Break off a small piece of the rock and test it with hot acid. Is it sandstone or limestone? From what rock was the clay soil formed? Recall the boulder you examined, which was commencing to change to clay.

Find another cut where the soil is sandy. Notice how the grains of sand increase in size and become cemented into groups, as the distance below the surface increases. Notice, also, that these cemented become larger and larger, until they finally merge in the solid rock. Test a little of the rock with hot acid. What is it? Notice how much harder the particles are than those of limestone. Which has been affected in the disintegration, the particles of sand or the cementing material? What has caused the disintegration? (Recall the pebbles you crushed to sand, in a former experiment.) What kind of rock breaks down to form a sandy soil?

See if you can find a third cut with a clay soil at the top, which as it descends, begins to take on a laminated structure; that is, to appear as though in layers, and finally ends in a dark shale. Add hot acid. What is the result? What has caused the shale to disintegrate? Make a drawing of the cut, and compare it with the one you made of the first cut. From what two rocks is a clay soil formed?

Put a little of the sandy soil in one pot and into another, some loose clay soil. Plant beans and watch their growth. Do you notice any difference? Which pot retains moisture longer? Mix a little of the sand with some of the clay soil. (There are impure limestones which contain sand, and sandstones cemented by limestone.) What do you think of this soil?

How far apart were the trenches which you examined? Are clay and sandy soils necessarily far apart? Of two adjoining farms, may one have sandy, and the other, clay soil? See if you can find such an instance. Can you explain it? What determines the nature of residual soil?

Transported Soils.

Glacial Soil.

(This section can be used for field work in all parts of the state north of the latitude of Carbondale, with the exception of Jo Daviess County and a part of Calhoun County.)

Find a deep vertical cut - the deeper, the better. Notice the black soil on top and the clay below. Note the entire absence of structure; the presence of many stones and pebbles, and their irregular size and arrangement. Is there any tendency toward a gradation from the surface down? Can
you account for the irregular stones? In the case of the residual soils, the soil is the result of the gradual disintegration of the underlying rock, and the successive steps in its formation could be seen in the cuts you examined. Glacial soils are transported soils. They were first formed as residual soil, and were then picked up by an immense ice-sheet, carried some distance and deposited again. In this way, the soils from different places became thoroughly mixed. Can you account, now, for the boulders surrounded by fine material? Examine some of the boulders and pebbles. What kind of rock are they? Are they all of the same kind? Can you find a limestone pebble or boulder lying above a sandstone one? How do they happen to be so placed? Can you find pebbles of crystalline rock? There is no place in Illinois where crystalline rock is the surface rock. What does this prove in regard to the place where the pebbles were formed? Give two reasons for saying that glacial soil is transported.

The soil you have been examining in particular, is really the subsoil, for overlying most of it, is a layer of black soil. Burn a little of the black soil in the furnace or stove for fifteen or twenty minutes. What color is it when cool? What has caused the change? What did the soil have before, that it has not, now? (Recall your experiments with the decayed leaves.) What must have been the state of the country while the humus was being formed? Was it under water or not? (Remember the conditions necessary for the formation of humus.) Can you find places where the black soil is deeper than in others? Which were under water longest? How do you know? Can you find places where the black soil is very thin, and perhaps almost disappears? Are these places on the higher land or on the lower? Can you think of a reason for the thinning on the higher parts? Do you notice that the higher parts are often ridges? Might not the rest of the country be covered with water, while the crests of these ridges were exposed? As the country was drained, which parts would be the last to become dry land? How does this account for the heavy black soil on the lower parts?

The part of the land between the ridges and covered with black soil is known as prairie. The ridges (moraines) were originally wooded, but the prairies were covered only with tall grass, etc. The fires which frequently swept through the dry grass kept the prairies open. There was but little grass on the moraines, however, because the trees which had become established there, while the prairies were still under water, cast so dense a shade. The early settlers did not understand this, but thought the prairies were open because the soil was too poor to support trees. Many of them cleared the timber-land for their farms, only to find later that they had chosen the poorest parts of the country. It is interesting to note
that, as late as 1830, a committee of the legislature was appointed to in-
vestigate and report upon some method by which the prairies might be util-
ized for agricultural purposes.

Compare the soil on the prairies with that on the crest of the mo-
raines. What valuable substance does the first have in so much greater a-
bundance than the second? Why is it valuable? How is it formed? Other
things being equal, which land ought to command the higher price? Which
would require more tiling?

Can you find any large swampy areas? What kind of soil is being
formed in the bottom of the swamp? From what does the humus come? If there
were no vegetation in the swamp, would humus form? Can you find evidences
that the swamp was once larger than it is now? That it was once a lake?
When it becomes entirely drained, what name will be given to it? (Recall
the former condition of the prairie.)

Alluvial Soil.

Notice the soil along a river, next to the water's edge. In time
of high water, the river covers this area and deposits over the surface,
a part of the sediment which it carries. What kind of soil is it, then,
residual or transported? Examine some of the soil. Is it clay soil, or
humus soil or sandy? If humus, can you think of a reason why it should
have been washed into the stream instead of clay? Why is sandy soil more
often found on the river's edge than clay? What is the more frequent form
of alluvial soil? Is alluvial soil good for farming purposes? What is
the one objection?

Peaty Soils.

(These are to be found in the Kankakee swamp, the Winnebago swamp, a
region north of Dundee, and many other places. All who have access to
peat swamps should study them carefully.)

What is the character of the swamp? How deep is it? What kinds of
vegetation are growing in it? Is the growth dense or scattering? Collect
a little of the peat and examine it. What is its color? Its form? From
what must it have been formed? Under what conditions? Burn a little of
it, as you did the humus. What is the result? How does it differ from hu-
mus? Will it ever become humus? Could its own weight have caused its par-
tial solidification? What uses are made of peaty soil?)
STREAMS AND STREAM ACTION.

Transporting Power. Relation of Velocity to Sediment.

Notice the streams in your neighborhood. Is the water perfectly clear at all times, or is it sometimes muddy or turbid? Is it more apt to be muddy in high water or in low water?

What difference in load is there between a swollen stream and one in which the water is low? Dip one quart of water from a swollen stream (the largest accessible, even if it be small) into a glass jar, and let it stand. At the same time, let the class be divided into two parties, standing 100 feet* apart on the bank of the stream. Let a chip or stick be dropped in the stream over the natural bed by the upstream party, and the time noted. When it passes the downstream party, let the time be again noted. How long has it taken the chip to go 100 feet? How many miles would it go in an hour? How many miles can you walk in an hour? Repeat ten or twelve times. Each time, let some member of the class follow the chip along the bank to see if its motion is continuous and uniform. If the chip stops, see if you can tell why. How would you find the average velocity of the stream? Would an average of all the trials necessarily be correct, or might some of them have to be thrown out? Why? Label the jar, giving date and velocity.

Watch the stream when it begins to subside, and when it reaches half-stage, dip up another quart jar of water. At the same time repeat the experiment with the chip.

When the stream becomes normal, repeat the entire experiment. Two or three days later, examine the jars, all of which should be properly labeled and note the relative amount of sediment in each. Is there any relation between the velocity of the stream and the amount of sediment? Does one jar contain larger particles than the others? (It may be necessary to wash out the fine material before you can determine this.) What relation exists between the size of the particles and the velocity of the stream? It would be well to try these experiments after several storms to see if the results are always the same. One time watch the settling of the material in the jar. See if you can notice in the other jars, any tendency toward an ar-

* Note. It will be well at this point to learn to measure by pacing. Carefully pace off a length of 50 feet which has been previously measured. Repeat nine or ten times. The average number of steps taken each time, divided into 50 feet will give the length of your step. Pace off the length of a block; multiply the number of steps by the length of your step.
rangement of the particles. Where are the largest ones? Make a drawing to show this.

Erosion of Stream Valley.

Where does the sediment carried by streams come from? If a stream continues to be loaded with sediment for a great many years, what will happen to its immediate banks? Go down to a stream, and walk directly away from it as long as you are going uphill. Then turn and look across it. How does the land on the other side of the stream compare with that of the place where you are standing? How do you account for the depression through which the stream flows? Can you think of a way in which you can calculate how much work this stream has done: that is, how many cubic yards (wagon-loads) of earth it has carried away for each quarter-mile of its length? See if you can find a stream in your neighborhood which does not flow in a depression.

In what different ways is a stream able to erode its banks? Do you consider simple "wash" a large factor in erosion? Which kind of bank will wash more rapidly, rock, sand or clay? Why? See if you can prove your answer by observation or experiment. How may the action of frost aid in erosion? How may solution aid? What evidence have you that in some cases, there may be a grinding action on the river-bed?

How does the fall of the stream determine the rate of erosion? (Remember the relation you discovered the velocity of a stream and the amount of its sediment.)

Lengthening of Streams.

Find the source and the mouth of a very small stream or gully. What is its total length? Can it ever be longer? Would it be possible for its source to be several feet higher, ten years from now? Was the stream ever shorter? Before definitely answering these questions, ask some one who has lived in the neighborhood for a great many years, if any stream now has its source nearer to any known location, as a barn or road, than when he first came to the region.

How does the lengthening occur? Look at the small stream again. During dry weather, drive a two-inch stake into the ground on a level with the source (with the highest water) and about a foot from the water. Immediately after a heavy storm go to the stream. Is it longer? Has the source changed? Why?


Have you ever seen a very large river? Did you notice the large, so-
called hills rising on either side, perhaps close to the river, perhaps some distance away - maybe a mile or two. They are not hills, but bluffs. The word "bluff" is a term applied to the bank of a river, and "bluff-line" to the top or crest of the bluff. If you climb the bluff, will you be above, or below or on the level of the surrounding country? What would you call the depression in which the river flows? Is it a trench or ditch? Do rivers always flow in trenches? What was the level of the river when it was first formed? Do you understand from what you have learned of the small streams of your neighborhood, how the river could have cut so deep-ly? By again studying the small streams, you may be able to discover how it could have such a wide valley, and why there is such a broad strip of nearly level land between it and the bluffs.

Go to any stream. Is it perfectly straight? Can you find one that is? If not, can you account for the fact? Are the banks apt to be per-fectly uniform as to hardness? Would a stream cutting in them encounter equal resistance at all points? Where would it cut more rapidly, through a hard area, or a soft one? If the banks contained bits of harder mate-rial scattered through them, what would be the effect on the stream? Are the slopes near the head of a stream absolutely the same from all direc-tions? May this cause more water to enter from some directions than from others? How may this affect the stream?

Walk along the bank of a stream until you reach a bend or curve. No-tice the current at that point. Where is it swiftest - in the middle, or near the inner or outer bank of the curve? Where is the water deepest? Walk down-stream to the next curve, watching the current closely. Does it change to the other side of the stream? Is it along the inner or outer bank of the new curve? Follow the stream until you can make a definite statement concerning the position of the current with reference to the curves. Which cuts its bank more rapidly, a swift or a slow-moving stream? (Again recall the experiment you performed to determine the relation of the amount of sediment to the velocity of the stream.) Then which bank of each curve - the outer, or the inner - will be cut away more rapidly? At the end of a curve, what happens to the current on that side of the stream? What about the load it is carrying? Throw material into the stream over the strongest current, and watch it when it passes into the new curve. What becomes of it - of part of it, at least? Along which bank does deposi-tion always occur? How high a layer can be built up by such deposition? Can it ever rise above the high-water mark? What kind of a surface will it have? Why? If it slopes at all, will it be toward, or away from the stream? Why? The deposit is known as the flood-plain. Notice the stream in time of flood. How wide is it? Does it cover the flood-plain? How
wide is it when normal? How wide compared to the flood-plain? When the water recedes, is anything left on the surface - fine sand, leaves, straws, etc.? Where did they come from? Why were they left? What name is given to the soil on the flood-plain? After a storm, notice on the walks a thin layer of mud or other fine sediment. Where did it come from? What served as the temporary stream-bed?

Imagine this act of alternate cutting and deposition to continue for many centuries. What would result? Why would the flood-plains be separated by bits of vertical or undercut banks? Why more often vertical than undercut? What would determine the width of the bits of flood-plain? Did you ever see a very large stream whose valley would answer to this description? Why not? The course of a stream is easily altered. What would result if sand-bars were built in the bed of a stream? What effect would they have on the current? Select a small creek. Build an obstruction from one bank out into the middle of the stream. Farther down, build another in a different position with reference to the curve. In another place, build one entirely across the creek. Two or three weeks go again to the creek. In what respects is it different? If similar changes occurred in a large river at intervals of several years, how would the valley be affected? Would it be widened? Would the bluffs be straightened? How? Can you explain, now, how the large river that you saw has reached its present state; that is, tell a little of its history?

Bayous.

If the curves in a stream should increase until they became great loops, almost enclosed, might not the stream cut through the remaining little necks of land in order to shorten its course? The parts cut off would be called bayous. In what part of the United States are bayous most plentiful? Can you think of a reason for this? Go to some sluggish stream which has a broad flood-plain, and see if you can find bayous. What is their shape?

Divides.

Find a little ridge of land between two small streams. Notice the water running from this ridge after a rain. Does it all run in one direction, or does it seem to separate, part to run down on one side and part on the other? Call this line of separation a divide or water-shed. Why are streets and roads made higher in the middle? As the water runs off, it carries soil with it. After twenty years what will have happened to the divide? After two hundred years? After two thousand? Might it not in time become entirely worn down to the present level of the stream? Then we
would call the surface a peneplain and say that the land had been peneplain-
ed.

Can you find a divide whose top is broad and nearly flat? Is it old-
er or younger than the narrow, sharp-pointed divide? Do you find on it, any
small lakes, or depressions which might be filled with water after a rain?
Walk from the top of the divide down to the stream-beds on either side.
Follow them for some distance - first one, and then the other. Are there
any tributaries entering them - small ones, even? Do they reach the crest
of the divide, or do they extend up only a part of the way? Is it possible
for them to lengthen until they do reach the crest? (Recall what you have
learned about the headwaters of streams receding.) What effect would such
lengthening have on the lakes and ponds on the divide? How will the divide
be changed in shape? Now tell which kind of divide is the older. If the
tributaries moved back at the same rate on each side, would the crest be a
straight or a curved line? If they cut back at different rates? Would
they be apt to cut at the same rate? What would be necessary in order to
have them do this?

Which will wear down most rapidly, a ridge covered with grass, or one
that is bare? Notice the water which runs off during and after a hard show-
er. From which kind of ridge is the run-off greater? Which run-off car-
ries the most sediment? Why should cover-crops be used in the winter on
hillside fields? Which kind of ridge will retain moisture longer after a
rain? Why are forests valuable for a country with a thin soil, especially a
country that is hilly?

Gorges and Canyons.

Which cuts more rapidly, a stream with much or little fall? The more
rapidly a stream cuts, the deeper will be its trench in comparison to its
width. A deep and very narrow trench constitutes a gorge or canyon. What
conditions would be necessary for the formation of a gorge in Illinois?
Have you ever seen one in Illinois? Where? How deep is it? How wide is
it? Is it cut in rock or in drift? A gorge is a feature of young topog-
raphy. Which will begin first to change into an open valley, a gorge cut
in rock or one cut in drift? Why?

After a heavy rain, notice a bank of loose clay which is not covered
with grass. Can you see any miniature gorges? How are they being formed?
Are the banks vertical or quite sloping? Why? Make a drawing to repre-
sent a cross-section of one of these little gorges.

Falls.

On a modeling board, form with clay, a hill one foot high and two in
diameter. On one side, instead of a gentle slope, make two or three steps. Pack the clay firmly. Allow a little stream of water to fall on the top of the hill. Notice it particularly on the side with the steps. What is formed? Allow the water to run for several hours. Are the falls as pronounced at the end of that time? Turn off the water and examine the model. Are the edges of the steps as sharp-cut as when you modeled them?

Make another model, putting in flat stones for the top of each step, and sand or clay between the steps. Cover with a mixture of sand and clay, until there is an unbroken surface from the top to the bottom of the hill. Turn on the water, so that a small stream falls on the top. After several hours, examine to see if any change has occurred. Does the side containing the rocks present a smooth, even surface? Are the steps of rock beginning to appear? Why has the erosion not been uniform? Let the water run still longer - perhaps all night. Do the fronts of the steps become perfectly vertical, or is the soft material washed out a little? Why is this?

See if you can find a small waterfall in your neighborhood. Study it carefully. Why does the water fall at this particular point? How does the rock near the crest of the fall differ from that below? What kind of a valley has the stream above the falls? How wide is it? How high and how steep are the banks? What is the character of the valley immediately below the falls? How high are the walls? How steep are they? How wide is the gorge? How long is it? Follow it to its end. Into what do you find it opens? Is there an escarpment? What is its character? Do you think it is probable that that the escarpment was once complete - that it did not have this gorge-like opening? If you can do so, climb to its top. Do you find near the top, any trace of the same layer of the rock as that over which the falls are passing farther upstream? What has removed the long, narrow strip of this rock? Is it probable that the falls are still receding? Give reasons for your answer.

Possibly the fall that you study will be over a precipice that is of the same material from top to bottom. Then it will be like your first model, except that it will not wear down so rapidly because it is all rock. Examine the stream valley above the falls, and that immediately below. How do they differ? What is the width of each? What is the character of the banks - height and slope? Follow the gorge to its end. How long is it? What is the character of the escarpment? Does the stream empty into another at the foot of the escarpment, or does it continue independently? If the latter, what is the character of its valley? What evidence have you that the falls have already receded? How far have they receded? Do you think they are stationary now?
Rapids.

In the first model you made for the study of falls, if you allowed the water to act long enough, the falls became rapids. The stream simply encountered steeper places in its bed, alternating with those which were more nearly level. Are there any rapids near you? If so, study them carefully. Can you learn anything about the slope of the river-bed? How might a fall become converted into a series of rapids?

Alluvial Fans.

Walk along a steep slope. Can you see any small streams or stream-beds? Examine one where it reaches the bottom of the slope. See if you can find a pile of sand or debris, shaped like a half-cone. Where did it come from? Why was it deposited? Call it an alluvial fan or alluvial cone. Make a profile sketch, showing the slope ending abruptly in the level land, and the alluvial fan. If there had been no change of slope, would there have been such a deposit?

Deltas.

During a storm, notice a small stream flowing down a clay bank into a puddle. What color is the water? What causes its color? After the rain is over and the mud-puddle is dried up, examine it closely. Can you find a little pile of mud extending from the mouth of the stream out into the deeper part of the puddle? Why was it deposited? Is its outline smooth and regular, or irregular? Why? Can you see any tiny channels crossing its top? What was their work? Do you understand now, how a river can have several mouths? What is the difference between a delta and an alluvial fan?

Young, Mature and Old Valleys.

Describe a young valley - any of the small, rapidly moving streams of the neighborhood will do for this. What changes will occur in it before it becomes a mature valley? When the river ceases to cut deeper, it becomes an old valley. Can you give the characteristics of that valley? Draw cross-sections of young, mature and old valleys. State the differences between them.

Imperfect Drainage.

Swamps.

Can you find areas which are swampy? Describe one, with reference to its size, soil, character of vegetation, etc. See if you can discover why it is swampy. Walk around it, if not too large. Are there any streams
or evidences of wet-weather streams flowing from it? Notice the stream-beds at the edge of the swamp. Are they lower than, or as low as, the lowest part of the swamp? What must they do before they can completely drain the area? Are there parts of the swamp which are more marshy than others? Why may this be the case?

Notice the farms of your neighborhood. Do any of them have low, swampy, or half-swampy areas? If the year is especially wet, what happens to the crops planted in such areas? How can farmers remedy the difficulty? See if you can learn of farms, especially in the prairie regions, which are good land now, but a few years ago contained great swampy areas. How was the change brought about? If man had been content to wait for Nature, would the work have been accomplished ultimately, without assistance? Would it probably have been finished in your life-time?

Lakes.

Across a small creek, build a strong dam as high or higher than the water. What is the result? Why is the lake so much broader than the former stream? After a week or so, remove the dam. What happens now? See if you can find a lake formed by the natural damming of a stream. What is the character of the dam? Can you think of a way in which it could have been built? Is it a ridge crossing the country, or is it formed of sediment deposited by the stream, itself?

Can you find a small pond which seems distinct in dry weather, but just after a storm is part of a temporary stream? See if you can explain this peculiarity. Notice the height of the pond in dry and in wet weather. What difference is there? Notice the outlet from the pond. Is it low enough to permit the escape of all the water?

Can you find a pond which is marshy along the edge? Why is this? Was the water probably ever higher than it is now? If more of the water were drawn off (if the outlet were lowered) how would the marshy area be affected? Which shows least drainage, ponds or swamps?

If there is a lake in your neighborhood, study it. What is the nature of its shore? Are there many inlets? Is there an outlet? How deep is it? How efficient is it? How deep is the lake?

Where will you find the little lakes known as bayous? Recall the method of their formation.

River Systems.

See if you can find miniature river systems - small streams whose tributaries have branches, and these in turn, other branches. Estimate the length of the main stream and of the whole system. What proportion of the entire system is formed by the main stream? Can you find such a river
system on the divide you studied? Would it cut more rapidly than a single stream? What difference in the effect on the shape of the divide would it cause?

The territory drained by a river system is called a river basin. Trace the outlines of the basin of one of the miniature systems. Does it follow a regular curve, or is it irregular? Why? What relation is there between this outline, and the crest of the water-shed between this system and others?

Detailed Study of Stream.

Make a detailed study of some stream in your neighborhood. First trace from a reliable map, the course of the stream and indicate on it, the part you are to study — a mile or two or three in length. It would be well to select an area where one or more tributaries enters. Draw cross-sections of the valley, in at least three points and mark their location on your map. Each time record the height of the banks, the depth of the water and the character of the bed. Determine also the velocity of the stream. How much of a flood-plain is there? What is the character of the deposit on it? Is it covered with vegetation? Write a full description of the stream and its valley, bringing in all points discovered in your study.
STREAMS (CONTINUED). MAP WORK.

Map Scales.

Draw on the blackboard a map of the block in which your school-house is located, making one inch represent ten feet of actual length. Locate the various buildings and draw their outlines of the proper size. How large an area does your map cover? Make another map of the same block, of such size that it will cover half of this area. How many feet does one inch represent on this map? Draw a map of the area in your note-book. What is the scale used? Look at some house plans. Note the scales. How could you reduce the size of the plans? Why is it necessary, in looking at a map, to know the scale of miles used?

What is a Contour Map?

The following experiment will aid pupils in understanding contour maps. On a flat board model in putty, an irregular island, ten inches in height, with two or three peaks, valleys and stream-beds. Place in the sink, and let the water run until the board is just covered. The bottom of the model which is just exposed, will be the shore-line or zero contour. Draw this shore-line on paper. Notice its irregularities. Turn on the water and let it run until it stands one inch above the board. Observe the new shore-line. Draw it. (It will necessarily be within the former line.) Again add an inch of water so that it will stand two inches above the board, and draw the shore-line. Continue this process until the model is completely submerged. Notice as you proceed that the original island becomes divided into two or more smaller ones, according to the number of peaks. How is this fact noted on your map? What do several closed contour lines within a larger one indicate?

Draw off the water. Mark the position of the streams on your drawing, and note that they occupy the places where the contour lines recede. Do you understand why all contour lines must be closed? (They may travel hundreds of miles before closing, however.)

After the model is dry, it would be well to draw the contour lines on it. Draw the first line around the model, one inch above the board, the second, two inches above, etc. Stand on edge so that the tops of the peaks are directly facing you. Compare with your drawing. Try to imagine your drawing in relief.

From your drawing, make a section through the center of the island. You are now ready to make a study of several contour maps.
Study of Fargo (N.D. and Minne.) Sheet.

Upon a map of the United States, find the location of the area represented by this sheet. About how many miles north of Chicago is it? How many miles west?

Note the scale of miles. How many square miles are contained in this area? Notice the roads. How far apart are they? How far apart are the country roads in your neighborhood? What other features are represented on the map in black? What are printed in blue?

Notice the brown lines (contours). What is the contour interval? What is meant by the term "contour interval"? Notice that every fifth contour is printed heavier, and is marked with its elevation. The elevation of the others is to be obtained by counting from these. Find the 900-foot contour; the 880-foot contour; the 920-foot contour.

Find the highest point in the area. Find the lowest point. Why do you look in a stream-bed for it? What is the difference between the two points? How many miles apart are they? In what general direction does the land slope? In what general direction do the streams flow? Find the elevation of the following places - Walcott, Christine, Wild Rice and Haggart. What is the difference in elevation between Norman and Wild Rice? Between Wolverton and Wild Rice? Commencing in the north-west corner, trace the 900-foot contour. Is the area inside of it - to the north of it, for it is completed in the region farther north - higher or lower than that to the south? Which has the greater elevation, Harwood or Cotters? Find whether a person could go from Wolverton to Glyndon without crossing a contour. Would the route be direct? At the southern end of the map, notice a contour a little west of 96° 42' and another near 96° 38'. Which contour is the lower? What is the rate of slope between them? (Make use of the scale of miles in determining this.) See if you can find other places as level.

How many streams are there in this area? Can you account for the small number? (The region is one of fair rainfall.) Does water easily run off a level surface? What becomes of that which does not run off?

For what part of the distance, does the 900-foot contour form part of the immediate banks of the Red River? Why is the same contour on both sides of the stream? Study the river carefully. What is the difference in its elevation where it crosses the southern limit of this area, and where it crosses the northern? Estimate the length of the stream. (Count the number of miles in a straight line and allow for the windings.) What is its fall per mile? Is there a stream in your neighborhood which has the same fall? Is its velocity high or low? What about the cutting power of a stream with low velocity? How wide is the stream valley? How high are its banks? Can you see any reasons for thinking that the valley is young?
Notice the intermittent streams which are tributary to the Red River. What are they doing to the country? How can you tell? In what part of the year do they probably do most of their work? Why? Notice other contour spurs projecting from the main valley. How have they been formed? Why are streams not represented within them?

In the same way, study Buffalo River and Sheyenne River.

Notice the winding character of all the streams. Can you account for it? Which changes its course more easily, a swift or a slowing-moving stream? Name some things that might act as obstructions to turn the course of these streams. Would they turn a mountain torrent? Can you find evidences of bayous? How were they formed? Can you find places where bayous will be formed before long? Notice the district where the Maple River joins the Sheyenne. What has caused the peculiar appearance? In time of high water, through how many channels do these streams unite? Can you think of a reason why the stream just south of Maple River is an intermittent one? What can you learn of its fall?

Notice the small lake south of Harwood. What can you say about the surface of the area in which it is situated? What does the lake become in time of high water? In which direction does the intermittent stream flow?

Can you explain the diagonal stream crossing from the Red River to its eastern branch west of Kragnes? What effect may this have sometime on the four or five miles of the Red River south of it? See if you can find a place where a similar action has already occurred.

The soil of this area is very rich and it receives an abundance of rainfall. To what occupation is it especially suited? Of what advantage is the level ground and the scarcity of streams? Is the country easily crossed by railroads? Of what advantage is this to the farmer?

Sketch a map of this area about six by nine inches, putting in nothing but the contour lines. Dilute India ink and tint the map so that the highest part will be darkest and each shade will show a difference of twenty feet in elevation. The best results will be obtained if water-color or some other rough-surfaced paper is used.

Draw sections of the surface, using as the horizontal scale, 1 inch = 1 mile, and as the vertical, 1 inch = 200 feet.
(1) Through Walcott from east to west.
(2) Through Averill from east to west.
(3) Through Wild Rice from north to south.

Write a full description of the area, bringing in all points of topography and their causes.
Study of Maumee Bay (Ohio-Michigan) Quadrangle.

Locate the area on a map of the United States. Note the scale of miles and the contour interval. Are they the same as in the Fargo sheet? How many square miles are included in the area? How many in the Fargo area? If this map were drawn to the same scale as the Fargo map, would the contours appear nearer together or farther apart than they do now? Make such a map, drawing only section lines and contours.

In what direction is the general slope of the land? How much difference is there between the highest part of the area and the lowest part? Is the slope reasonably uniform or not? In what striking particulars does this area differ from the Fargo area? Is there any one principal stream? Can you give a reason for this? What is the character of the creeks? How far are their courses influenced by the roadside ditches? Study their fall especially in the parts which are intermittent. How can you find whether it is uniform or not? (Notice how far back the contour lines run each time.) How do these creeks appear in time of drought?

Notice the large, swampy area along the eastern part of the lake shore. What must be the conditions in this area? Do you notice the streams which seem to end in the marsh? See if you can discover a reason for this. There must be less than twenty feet between the 580-foot contour and the shore. How far from the lake shore does this contour cross Cedar Creek? What is the maximum fall per mile over this distance? (It may in reality, be considerably than this. Why?) See if you can learn how much fall is allowed in digging a ditch for a tile-drain. Does this help you to understand why the Ward Canal was put in to carry off the water from Cedar Creek? How does the canal assist in lessening the swamp area?

In Section 10 of Jerusalem Township, notice the tiny tributaries of Cedar Creek. Will two of them ultimately join? How? What will result?

Notice the intermittent streams emptying into the Maumee River. What is the character of their courses?

Make cross-sections of the area, using the same scales as in the Fargo Sheet.
(1) Through Genoa from north to south.
(2) Through Williston from east to west.

Write a full description of the area, emphasizing the uniform slope, and the very young age of the streams.
Study of Olivet (S.D.) Quadrangle.

Locate the area on a map of South Dakota. Note the scale of miles and the contour interval. Are they the same as in the Fargo sheet?

Compare with the Fargo sheet. In each, there is one main river. How do they differ in this respect from the Maumee Bay map? In what direction does the Red River flow? In which does the James flow? In which direction does the surface of the Fargo area flow? In which does this? What is the highest point in the area? The lowest? What is the difference between them?

Study the James River. How wide is its valley? How was this valley made? How high are its banks? Try to find some hills in your neighborhood that have the same height as these banks. How steep are the banks? Can you find hills having the same slope? What is the fall of the riverbed? Is the river older or younger in development than the Red River? Can you account for its meanders? How wide is the flood-plain? How was it formed? Can you see any evidence that it is being widened in places? Can you find places where the bluff is being cut back? Point out places where bayous are apt to form.

Notice the tributaries. What about their fall? How does it correspond to that of the creeks of your neighborhood? Draw length-wise profiles of several small tributaries. How do their valleys differ from that of the James? Draw sections of the James valley through Milltown and Norway, and of Lonetree Creek and Wolf Creek, three miles above the mouth of each. Do you see how the contour lines are being pushed back away from the river?

In the northern part of Emanuel Township, notice two intermittent streams which end before they reach Emanuel Creek. Is there any indication of a change of slope? What may become of the water? What of the load which it carried to that point? In what form will it be deposited? What will be built up at that point?

Draw sections, using the same scales as in the Fargo sheet.

(1) Through Milltown from east to west.
(2) Through Milltown from north to south.
(3) Through Wolf Creek from north to south.
(4) Through Scotland from east to west.

Write a complete description of the area.
Study of Carthage (Mo.) Sheet.

Locate the area on a map of Missouri. Note the scale of miles. How many square miles are contained in the area? What is the contour interval? What is that used on the Fargo sheet? Suppose the 50-foot interval were used on the Fargo sheet. How would it appear? Sketch a map of the Fargo area, using the 50-foot interval. (Start with the 900-foot contour.) How does the map look? Would it be advisable to use so large an interval in mapping such an area? Why not? Suppose the 20-foot interval were used on the Carthage map. How would it change the appearance of the sheet? In studying this, and the following sheets, keep constantly in mind the increased contour interval.

Study in the same way as the Fargo sheet. Note particularly the great number of tributaries. Does this indicate an older or younger stage in topography? Determine the fall per mile of Spring River. How does it compare with that of the Red River in the Fargo area? What would you say as to its velocity? How wide a valley has it cut? How high are the banks? How steep are they? Is their slope uniform? How do they differ from those of the Red River?

Select two or three tributaries and study them carefully. Draw cross-sections of their valleys. Determine their fall and something of their eroding power. Notice how the contours cross the creeks. Why do they do it? Can you find a contour which runs across the country for some distance, then turns abruptly and runs up the creek for some distance before crossing it? Explain the change of course. Why does it run up the creek for some distance before crossing it? Find other examples of the same kind.

Draw the following sections, using the same scales as in the Fargo sheet.

(1) Through Carthage from north to south.
(2) Through Sarcoxie from north to south.
(3) Through Red Oak from east to west.

In the first section, how many divides are shown? What is their character? How will they change as they grow older?

Notice the highland enclosed by the 1000-foot contour in the northwestern part of the area. Explain its peculiar shape. How will the shape change with age?

Judging from the surface alone, would this area be as good for the large farmers as the Fargo area? Give reasons for your answer.

Write a full description of the area.
Study of Nevada (Missouri) Sheet.

This sheet shows the same general features as the last one, and is to be studied in the same way. No general directions are needed, but there are one or two points to be especially noted. Near Bellamy is a 1000-foot contour. About how many square miles does it enclose? What has caused its very irregular shape? Notice the 950-foot contour and the 900-foot one. Is there any tendency to cut the 1000-foot contour until it becomes more or less parallel to them? See if you can find other similar elevated areas. What was probably the original level of the whole southern part of this area? How much below that, have the streams cut?

Draw a section across Speedwell Township from north-east to south-west, and one across Washington Township from north-west to south-east. How do the valleys of Clear Creek and Marmaton River differ?

Write as fully as you can in regard to the geographic history of Doylesport Township.
Study of Sedalia (Missouri) Sheet.

This sheet illustrates an older form of topography. Locate the area on a map of Missouri, note the contour interval and study in the same way as the previous maps.

In what direction does the land slope? What is the elevation of the high points in the southern part of the area? In the northern part? How far below the general level has Lake Creek cut? How wide is its valley? What about Black Water River?

Notice the great difference between the eastern part of the area, and the western. To make it very plain, draw a section from north to south, one mile east of the western boundary, and another one mile west of the eastern boundary of the area. (Use the same scales as for the Fargo area.) What has caused the difference between the two parts? Compare the eastern section with those you made of the Fargo area. Remember that time is all that is required to convert the Fargo area into one like this.

Determine the fall of the Lamine and Black Water Rivers, and of a few of the larger tributaries. Find the steepest bluffs. How high are they? Where are the bluffs low and sloping? Can you find places where flood-plains of any size have been formed? Notice the island in the Lamine River. Can you account for its presence? Observe the open space just north of the island. What does it indicate in regard to a former course of the river? About a mile south-east of the island is a triangular hill, surrounded on two sides by the river, and on most of the third, by a small tributary. What is the river doing at the southern point of the triangle? How will it ultimately cut off the hill entirely? How could an island result?

Trace the divide between the Lamine and the Black Water. Between the Lamine and Flat Creek. Trace the outlines of the basin of Heaths Creek. About how many square miles does this basin contain? If the rainfall is thirty inches, how much water does Heaths Creek carry in the course of a year, on the supposition that the creeks carry two-thirds of the rainfall?

On what topographic feature is the eastern part of Sedalia built? Trace the ridge for its entire length. What is its elevation? Into what main streams does the water that falls on it run? Does it pass through many or few branches? What will result to the crest of the divide from this run-off? Imagine yourself on the ridge. Describe the view of the surface to the north. Write the future history of the ridge.

Study the course of the Missouri Pacific Railroad. Can you see in the form of the surface, a reason for the curve between Dresden and Sedalia? Why does not the road run in a straight line from Sedalia to Gailey? Explain the curve between Dumpville and Mora.

Write a full description of the area.
Study of Elk Point (S.D., Neb. and Ia.) Quadrangle.

What is the contour interval? How does it differ from that of the last three sheets you studied? Make a map of the area south of the river, drawing 50-foot contours. How does it look? Make another map, using a 100-foot interval.

The flood-plain of the Missouri is to be studied on this sheet. How wide is it? How level is its surface? How was it formed? Make a cross-section to show the abrupt rise of the bluffs on either side. Can you explain the fact that the river is not in the middle of the flood-plain? Was it always in this part of the plain? How has it moved? What is the river doing at the points where it is in close contact with the south bluff? Notice the curves and meanders. Were they always in the same parts of the stream? How do you know? Notice the loop at St. Johns. Will the river always continue to follow the loop? What will be formed when it cuts across? Can you tell how McCook Lake came into existence? Notice the sand being deposited in the river. What does it tell about the velocity of the stream? Note the low swampy area near Elk Point. Do you think it was once a part of the river-bed? Give reasons for your answer.

Study the meanders of Big Sioux River. Where are cut-offs most likely to occur? How will they form? Where have some already occurred? Notice the intermittent streams ending abruptly on the plain. What do they show as to the character of the soil? Why does the Big Sioux turn east when it reaches the flood-plain, instead of crossing it to the Missouri? Would it have to cross higher land? Why? What is the fall of the Big Sioux? How does it compare with some stream in your neighborhood?

Notice the contours running east from Vermillion. How high an escarpment or terrace do they indicate? What is the character of the surface to the north of it? At the east edge of this flat surface, notice the abrupt change of slope. How high does the land rise? Is it one bluff of the Missouri? Then the level area north of the terrace was a former flood-plain of the Missouri, and is known as the second bottom. Where is the first bottom? How high would the river have to rise to cover the second bottom? See if you can learn whether it ever rises so high.

What river is cut in the second bottom? How far below the surface of the bottom is its bed? Is it cutting a flood-plain? When it reaches the first bottom, why does it not empty directly into the Vermillion? There are two mounds in the north-west corner of Spink Township. Write their history as completely as possible.

Draw a section extending from Lime Creek to Turkey Creek and another from Joy Creek to Broken Kettle Creek.

Write a description of the Missouri, and of its history to the present.
Study of Charleston (W. Va.) Quadrangle.

Locate the area upon a map of the United States. Of what great plateau is it a part? How is it situated in relation to the Appalachian Mountains?

Note the scale of miles. Is it the same as that of the Elk Point map? What is the contour interval? Compare this map with the one you made of the Elk Point area, using the 100-foot interval. What great difference is noticed? Could the 20-foot interval be used on a map of the Charleston area, if the same scale of miles were used? Why not? How much difference is there between the highest and lowest points in the Elk Point region? What is the highest point in the Charleston area? What is the lowest? Where is it? The difference in elevation is the relief. How many times greater is the relief of this area than that of the Elk Point area? Than that of the Sedalia area? Than that of the Fargo area?

Are the slopes gentle or very steep? Do you find evidences that the surface is a succession of V's and inverted V's? Prove your answer by drawing sections (1) from Wallace to Mink, in the north-eastern part; (2) Comfort to Orange, in the south-eastern part, and (3) Malden to Willie, near the eastern boundary.

What is the altitude of the Kanawha River when it enters the area? What is its altitude when it leaves the area? What is its fall per mile? Is its velocity high, or low? Is it probable that a stream with such velocity is cutting its valley much deeper? How is it changing the valley? How wide is the flood-plain in proportion to the width of the river? Has the river just begun to form the flood-plain? Give reasons for your answer. Notice the curves in the stream. Have they always been exactly as they are now?

Study the bluffs of the river. What can you learn about their height and slope? (Sections made across the river will aid in answering this.) Compare them to the bluffs of some stream in your neighborhood. Are they regular, or they constantly broken into by the tributaries? (Make a section from Malden to Battery Hill along the top of the bluff.) Count the number of tributaries entering in a length of five miles. What is the average altitude at which these enter the river? Find the altitude of the sources of three or four of them. What is their fall per mile? What do you know about the eroding power of streams having such a fall? Notice the branches of some of the tributaries. Do the branches of one, rise very near to those of another? Find the width of the remaining divide, in one or two cases. When the branches lengthen a little, what will happen to the divide? Will that part of the area then become more or less rugged?
Trace the divide between the Kanawha River and the Coal River. Has the area about reached its maximum of ruggedness? Give reasons for your answer. Can you find any very wide divides on the map? Write the future history of Kanawha-Coal divide.

Notice the curves in the Coal River. Were they formed after the river had cut its present valley, or before? Give reasons for your answer.

Why is there no flood-plain? What is the fall per mile of the river? How does it correspond with the rivers of your neighborhood?

What is the fall of the Elk River? Are there evidences that it has begun to form a flood-plain?

Determine the course of Tackett Creek, which enters the Coal River near St. Albans. Why did it turn when it reached the flood-plain of the Kanawha, instead of crossing it directly? Can you find other similar examples? Try to explain them.

Is the area desirable for agricultural purposes? Give reasons for your answer. See if you can learn, by looking in your reference books, what is the chief occupation of the region. Why are the roads so crooked? Why are trails more numerous than roads in the southern part? What great advantage does the flood-plain of the Kanawha afford the railroads? Give reasons for the location of Charleston. What smaller towns are similarly located?

Write a full description of this area, keeping in mind the fact that it is a type of mature topography.
Study of Beloit (Kansas) Sheet.

Locate the area upon a map of the United States. How many square miles does it cover? What is the contour interval? How does it differ from that of the Charleston area? Draw a map of any one township, using 100-foot contours. Is the surface more or less rugged than the Charleston area?

Notice the streams. How many of them have flood-plains? How wide are the flood-plains of each? What does this indicate in regard to the age of the streams? Do young streams develop flood-plains? Will a stream that is cutting deeply, build flood-plains?

What is the character of the bluffs of the Solomon River? How high are they? Are they dissected as much by streams as are those of the Kanawha River? Why are many of the tributaries intermittent? Determine the fall of some of them.

What is the general level of the area? How much above this, do the Blue Hills rise? Are there other elevations, though perhaps not so great? What evidences can you find that the whole area was perhaps once as high as these points are now, and that it has been worn down by stream action? In the south-west corner of Salt Creek Township, there is a 1520-foot contour almost enclosing a bit of high land. Imagine yourself standing on this highland. You will be on the crest of one bank of Salt Creek. Where is the crest of the other bank? How wide is the valley at this point? Draw a section through the valley, from crest to crest. Can you explain the peculiar form of this valley? Starting near this point, trace the 1520 foot contour as far as possible. Try to find reasons for all the crooks and curves.

Try to explain the origin of the Blue Hills. Make a section across them. Find Williams Butte. Describe it and explain its origin.

Compare the shape of the divides of this area with those of the Charleston area. How do you know that this represents an older form of topography?
Study of Portland (Ore. and Wash.) Quadrangle.

This sheet is to be used for the study of the flood-plains. Notice the Columbia River and its tributary, the Willamette.

Study first the flood-plain on the north side of the Columbia. How wide is it? Explain the variations in its width. Was the area now occupied by Vancouver Lake once a part of the river bed? Is the lake probably deep or shallow? Why? What will ultimately become of it? What will become of Shillapoo Lake? Can you see any reason for believing that Shillapoo Lake was once larger than it is now? Explain the presence of Lake River and Blackmire Slough.

Note the exceedingly low, swampy area south of the river. Can you find lakes which have been drained to form swamps? What will further drainage do to them? What is the future of Bybee Lake? What is that of Mud Lake? Why does the marshy area not extend entirely to the water?

Give the history of Hayden Island and of Swan Island. How were they formed?
Study of Niagara Falls Sheet.

Locate the area upon a map of New York. What two bodies of water does the Niagara River connect? In what direction does it flow? What is the distance between the lakes by an air-line? By the river? (Make use of the scale of miles.) Notice that the river divides just north of Buffalo. Where does it reunite? What is the name of the island which divides it? What is the distance from this island to the crest of the fall? What is the average width of the river over this distance? What is the character of its banks?

Where do the rapids begin? At what elevation do the first ones occur? How far are they from the crest of the falls? What is the elevation of the crest? What is the rate of fall or slope from the first rapids to the crest? What island is situated at the crest of the falls? Into what two parts does Goat Island divide the falls? How do they differ in shape? Can you think of a cause for the difference? Over which fall does more water pass? What is the height of the falls?

The gorge extends north from the base of the falls to the location of Queenstown. What is its length? What is its average width? What is the altitude of the river-bed at the foot of the falls? What is it at the end of the gorge? Determine its rate of slope. What is the character of its banks? How deep are they? Notice the whirlpool. Can you explain its form? What is the character of the river in the gorge?

Just before Queenstown is reached, notice the contours turning at almost right angles to the stream. They represent the escarpment. How high is it? How nearly perpendicular? What is the general elevation of the plain above (south) of the escarpment? What is the elevation of that below (north) of it? What does the escarpment mark? Where were the falls originally? How have they cut back from their original location? What have they formed in cutting back? Are the falls still receding and the gorge lengthening? At what rate? (You will have to look this up in some reference book. The Geological Survey has kept records of the observations on the falls for a great many years.)

Compare the river below the escarpment with it in the gorge. What is the distance from the escarpment to Lake Ontario? What is the fall of the river in this distance? How wide is the river? Are there any rapids in this section? How steep are the river banks? How high are they? Can you think of a reason why the river is wider than when in the gorge?

Draw the following sections of Niagara River.

(1) Three miles below the escarpment.
(2) At the Whirlpool.
(3) At Suspension Bridge.
(4) At the east end of Goat Island. Scales same as in Fargo area.

Using the same scales, draw a section on the meridian of 43° 5', from a point a mile south of Goat Island to one a mile north of the foot of the escarpment.

Also, considering Niagara as a perfectly straight river, draw a profile through the center of the same stream, using the same scales.

Write a complete description of Niagara River, bringing in all points shown by the map.

Study of East Delta (Louisiana) Sheet.

By what river has the East Delta been formed? What is the character of the outline of the Delta? Can you explain it? Notice the great number of passes. How were they formed? Of what use are they? Notice the Mud Lumps and explain their presence. Trace the resemblance between the area known as Middle Ground and the Mud Lumps. What kind of surface has the delta? How much difference is there between the elevation of the highest and lowest parts?
Wells - Artesian and Pump.

Inquire the depth of several wells. Is the same depth given for all? Is there much difference? Can you explain the difference? What is the source of the water?

Construct a model from the following sketch.
Shape a mass of clay as X. Let the distance from M to N be two feet, and that from N to B, ten inches. In the upper part, make a deep groove, Y, which does not extend quite to M. Fill with sand and gravel. Cover the whole with another layer of clay Z. At some point, as at A, insert a glass tube into the sand. Turn on the water and arrange so that it will fall on the surface BB. What becomes of it? Why does it rise in the tube? Does it rise above the tube? If not, make the surface BB higher. What have you?

Now cut down the surface BB. Is there any decrease in the flow of water? Cut down still farther, until the water no longer rises above the ground. If this model were large enough, how could the water be obtained? Would it pump more easily than if it rose only a small fraction of the tube? Do you see the relation between an artesian well and a pump well? In which must there be the greater difference between the elevation of the gravel outcrop and that of the place where the well is sunk?

Make another model as before. Insert the tube at A. Turn on the water and observe the flow at A. Insert another tube at C, a little higher than A, and again turn on water. Is there any change in the flow at A? What has caused the change? Why is it that a man living on the side of a hill may, by putting down a well, often injure the flow of a neighbor's well at the foot of the hill?

Cut through the model at D-E in such way that the knife will just pass through the tip of the gravel strip. Remove the part below the knife. Pour on water at BB. What is the result? What have you formed at the new surface? Look at the tubes. Does the water rise in them to the same height as formerly? What has caused the difference? Why does the water leave the strip at O instead of at A? Partially close the outlet at O, by inserting a stopper of clay, in the center of which is a glass tube. Does it produce any change? Repeat, using the smallest tube available. Note the result. Close the hole entirely, using the clay without the tube. What must be the condition in front, in order to produce an artesian well at A?
Springs.

Find a spring in your neighborhood and study it carefully. Is it situated on perfectly level ground, or on a slope or hillside? Is it at the top of the slope? Examine the ground at the spring. Does the water seem to come from the clay or from gravel? What is the nature of the soil directly below the gravel strip? Above it? What effect does this envelope have on the course of the water? So far as you can tell, are the conditions surrounding this natural spring the same as those of the artificial one you made?

If the gravel were made of square pieces of stone with cracks between, the result would be the same. These stones may be very large with large cracks. Would the age of the spring and the kind of rock have anything to do with the size of the cracks? Why? Can you find a spring which seems to come from such stone?

If limestone may be a source of springs, may it not be a source of wells, also - both pump and artesian? Are there wells in your neighborhood which come from the rock? See if you can discover the depths of some of them.

Can you find a "boiling spring"? What does it look like? What is the shape of its basin? At what part of the basin does the water enter? Can you think of anything which might give the water its force? How does it differ from a weak artesian well? (Recall the conditions necessary for the formation of an artesian well.) How has the water been able to make an outlet for itself? How is it constantly changing the form and size of its basin?

Examine the walls of the basin, especially where the water runs over the edge. Are they perfectly smooth, or are they more or less covered with deposits? Do you see anywhere a coating of lime similar to that found inside of tea-kettles? How is the lime obtained? (Recall the experiments you performed to determine the source of the coating in the teakettle. From what kind of rock is it dissolved? What is the character of the water?) In just the same way, the lime is deposited on the basin.

Would the water that forms such a deposit be known as hard water, or soft water? What makes it hard? How does well water differ from cistern water? How do well waters in different places differ as to hardness? Do you know of a city or town which obtains its water supply from a lake or stream? What is done to the water before it reaches the people? Why is it filtered? Why is lime added? See if you can discover how much lime is required for each thousand gallons of water. What does this show as to the solvent power of water?

Is the side of the basin of the boiling spring stained orange-yellow
or reddish? This is caused by a deposit of iron. Recall the experiment you performed to determine the kinds of pebbles. What did the yellow color of the acid indicate? Iron may be present in limestone, itself. Can you tell how the stains on the basin may have been produced? See if you can find ordinary springs with deposits near their outlets.

Are there mineral or medicinal springs in your neighborhood? What is the nature of their water - iron, sulphur, etc.? If a sulphur spring, notice the odor. Does this spring form a deposit? If iron, what about the taste? How does each spring obtain the peculiar substance in its water?

Do you know of artesian wells which yield Magnesia Water, Lithia Water, etc.? How are the mineral substances obtained? Could one well yield water to which several names could be applied? How? Do you know of such a well? Do artesian wells usually contain a large percentage of lime? Is lime healthful? What part of the body does it strengthen?

Do you know of salt wells? If near enough, obtain some of the water. Taste it. Is it used commercially? Through what processes must it pass before it becomes dry salt?

See if you can find springs emptying into streams. How do they affect the streams? Is their presence especially noticeable in time of wet weather? In time of dry weather? Does this explain why some streams do not run dry in the summer?

Why are streams less variable in a country which is forested than in one which is bare? How may the cutting of immense forest tracts cause the streams fed from it to run dry in time of drought?

Contamination.

Are there wells in your neighborhood which have been declared unfit for use? See what you can learn as to the cause of their pollution. If a gravel outcrop is polluted, what will be the result to all wells which draw their supply from that strip? Why, of two wells not more than one hundred feet apart, will one yield pure water and the other contaminated water? In a dug well, how may impurities enter besides through the main gravel strip which supplies the well? See if you can learn of an instance where a well previously pure has become unfit for use very soon after fertilizing the yard with manure. Can you explain the occurrence? Of two wells drawing water from the same strip, which is the more liable to contamination, a dug well or a bored well? Why is contamination more liable to occur after a heavy rain?
Caverns.

Are there any caves or caverns in your neighborhood? If so, go to one and study it. Is it formed in rock or in drift? Examine the rock. What kind is it? How could so large a mass have been removed from it? How is the lime which is deposited in teakettles and on the basins of springs obtained? See if you can find near the cave a vertical or almost vertical out in the rock. Examine it closely. Can you find places where small amounts of the rock have been dissolved away, leaving holes, perhaps large enough to admit your hand? Can you find larger holes? Does solution seem to begin along the joint planes of the stone? As the water sinks into the earth, it follows the paths which offer the least resistance. What will these paths be in case of limestone? What will be the action of the water as it moves along the paths? Do you see how, in course of time, a large room or cavern might be removed? The larger caves all consist of several rooms joined by narrow passage-ways. Can you explain this? Will it ever be possible for them to unite and form one immense tunnel? How will it be done?

Do you notice in the cave, projections from the roof, some of them shaped much as icicles? These are called stalactites, and the similar masses extending up from the floor are known as stalagmites. Examine them closely. Can you discover of what they are composed? In order to form such deposits, the water must be saturated, so that when a little of it evaporates, a small amount of the lime is left behind. Feel some of the stalactites. Are they dry? Where does the dripping water come from? If you can, catch a few drops on a paper, carry it out of the cave, and let it evaporate. What is left? As long as the dripping action continues, the stalactites continue to grow in length and diameter. Can you find any places where they extend as pillars from ceiling to floor? You can make artificial stalactites by causing lime-water to drip through plaster of paris which has been placed in a box with a perforated bottom.

Do you find in a region of caves, what are known as sink-holes? How have they been formed? What was the thickness of the roof which collapsed?
GLACIAL TOPOGRAPHY.

Walk in any direction from your school-house for a mile or two. Notice when you are going uphill and when down. Every time you reach the top of an ascent, turn and look back. See if you can tell what has caused the peculiarities of surface over which you have passed. Make other excursions covering all directions. What have been the agents in forming the surface? You may be able to find old stream valleys which are not now occupied by streams. Why have they been deserted?

Moraines.

(This section is not applicable for field work in the region south of the latitude of Carbondale, nor in Jo Daviess County and part of Calhoun County. The best work can be done in the area north of Mattoon and east of Peoria.)

In your excursions, you may come to an elevation which has no corresponding rise on the other side of the depression. Was it produced by stream action? Would it be possible for a stream to form a single ridge? You may then conclude that the ridge is a moraine.

Go to the top of a high building and look over the country. Can you see the ridge you encountered in your walk? Can you follow its course across the country? Is it an evident feature of the landscape? Is its course straight, curved or winding? What about its surface—is it smooth or billowy? Is the crest regular? Are there depressions in its sides worn by streams? What will happen to the moraine if this action of the streams is continued? Are the streams dry a part of the time, or are they water-courses all the year? Perhaps you can find evidences of both kinds of streams.

Examine the soil on the moraine. Is it residual or transported? Examine the subsoil in the low areas near the moraine. Is it the same? The moraine marks the place where the end of the glacier remained almost stationary for some time. Over the area between the moraines, the glacier was constantly moving backward or forward. Do you find more than one moraine? At each one you may know that the glacier stopped. The material was on top of the ice, beneath it and imbedded in it, and was deposited by the melting of the ice. The longer the glacier remained nearly stationary, the greater was the amount of debris deposited as a moraine.

If the moraine is not too wide, cross it from one side to the other. Which side has the steeper slope? Can you tell why this is the case?

See if you can find pebbles or boulders with scratches on them. What
caused these scratches? Are they parallel? Why? In what condition would you find the underlying rock if all the drift could be removed? What would the direction of the scratches on it indicate?

If there is a gravel bed near, visit it and see if you can explain its formation. In a glacial lake, fed by swift streams, and in which the current was also rather swift, what material would be deposited - the gravel, or the sand and finer materials? Why? What would become of the sand?

See if you can find a place where it was deposited.

Prairies.

The areas lying between the moraines are known as prairies. How were they formed? What was their condition immediately after the glacier withdrew? How were the lakes drained? What vegetation covered them at the various stages? What did this vegetation form when it decayed? If it had fallen on dry ground, would the result have been the same? (Recall the experiments you performed to determine the method of humus formation.) In what ways does humus benefit the land?

Study the surface of the prairie. Is it perfectly flat, or is there a tendency toward a slightly rolling surface? What caused such a surface? How would this tend to make the layer of black soil of uneven depth? Which is better suited for extensive corn-raising, a region with many or few moraines? Why? In northern Illinois, the moraines are much nearer together than in the central part of the state. How does this explain the fact that dairy farms are more numerous in the northern part, and corn farms in the central? Why was Indiana so much more largely wooded than Illinois? (Recall the fact that the prairies were open and the moraines, wooded, with reasons for it.)

Is the prairie that you have studied perfectly drained, or are there low, swampy areas scattered through it? Ask some of the farmers in the prairie about the condition of their farms ten years ago; twenty years ago; thirty or more years ago.

Write a full description of some prairie, describing its topography, drainage, character of soil and method of formation.

Drumlins.

(This section can be used as a field exercise in only the extreme northern part of the state.)

Can you find oval hills interspersed with swampy areas? What is the character of the surface of the hills? Is it smooth and rounded, or rough and uneven? Examine the soil. Is it residual or transported? Give reasons for your answer. Drumlins were deposited, not at the tip of the gla-
cier, as were moraines, but underneath the ice itself. Probably something on the bed of the glacier checked its advance slightly, and the result was a little hill of debris. Notice how a snag in a stream may cause deposition just above it.

Mounds.

(This section can be used for field work over that part of the state north of Carbondale, and south and west of the moraine which runs from Mattoon through or near Shelbyville, Decatur, Peoria and Belvidire. The most characteristic examples will be found south of the latitude of Springfield. Do you find hills or mounds in your neighborhood? Are they usually separate, or in clusters or lines? What is the character of the soil? Is it residual or transported? Give reasons for your opinion. Does the peculiar arrangement of the mounds suggest that they might originally have been parts of ridges or moraines? What has cut down the ridges? What evidences of stream action do you see? How high are some of the mounds? How could the streams have cut so deeply between them? (Recall what you learned about the lengthening of streams and the leveling of ridges and divides.) What sort of a surface will this area have after a longer period of stream action? It may be well to note that this area was covered by but one ice-sheet (the Illinois), and that as long a time elapsed between that and the appearance of the Wisconsin sheet, which covered the state north of Mattoon and east of Peoria, as has elapsed since the disappearance of the Wisconsin. It represents, consequently, a very much older form of topography than that to the north and east. What is the character of the streams? Is the country thoroughly dissected by their branches?

The soil in the southern part has become so fine that it "bakes" very quickly in the hot sun. Does this afford an explanation for the raising of small fruits in that region? (When do these ripen?)
SAND-DUNES.

What do you mean when you say that the roads are dusty? What carries the clouds of dust in the air? If there were no wind, and no driving on the road to create air-currents, would the dust in the air be noticeable? Which carries more dust, a light wind or a strong wind? Why? What becomes of it? Have you ever seen in very dry weather, little piles or mounds of dust beside the fence-posts or under low bushes? Why was it dropped there? Was the wind checked when it reached that point? How? What effect would this have on the load it was carrying? What effect does the slackening of a stream-current have on its load? Would sand be carried more or less readily than dust? Would it require a stronger wind? Would the sand be lifted so high in the air? Give reasons for your answers.

If there is sandy soil in your neighborhood, study it. Can you find mounds of sand? They are called dunes. How large are they? What is their shape? Is their surface perfectly smooth, or is it rippled? Why? Notice the sand as it is dragged by the wind. Does much of it seem to be really lifted? Where is the sand deposited, on the windward, or on the sheltered side of the dune? Why? Why is the air-current checked as it rises to the top of the dune? What effect does this checking have on the deposition of the sand?

Are there many dunes? Is the country open or closed? Why will vegetation often check the formation of dunes? Why is it so hard to establish a sod in such a region? Why is a particular kind of grass needed for the purpose?

Watch individual dunes during several weeks or months, and determine the rate at which they move. Do they move with, or against the wind? Can you describe the process of their movement? How may a small, isolated shrub cause a dune to be built over it? Make sketches of several dunes or groups of dunes.

Dunes can be observed only in certain parts of the state - along the Lake shore; near the Kankakee swamp; west of Kankakee; in Marion County; in Henry County, around the Winnebago swamp, etc. They should be discussed in other parts, however. Much help in understanding their formation can be obtained from studying very dry snow which is drifting.
ADDITIONAL MAP WORK.

Study of Eagle (Wisconsin) Sheet.

Locate the area upon a map of Wisconsin. How many square miles does it include? What is the contour interval?

Make a shaded map of the area by drawing the contours and tinting with dilute India ink, as on the Fargo map. Use this constantly in connection with the sheet.

Note the irregular hills scattered in groups over the surface, and the low, marshy areas between. The hills are parts of a moraine deposited by the glacier. How did the deposition occur? Attempt to trace the outlines of the moraine. Notice of what a dense net-work of smaller ones it is composed. How do these hills differ in form from those on the Charleston sheet? If you were to dig pits in these hills, and in those near Charleston, would you find them made of the same material? Give reasons for your answer. How do these hills differ in appearance from the Blue Hills on the Beloit sheet? How do they differ in method of formation?

Draw cross-sections (1), through Genesee from east to west; (2), through Eagle from east to west, and (3), through Genesee from north to south. What do they show as to the character of the surface? What is the highest point in the area? What is the lowest?

What has caused the great swampy areas? Study the one in which Mukwonago Lake is situated. How large was the lake originally? How has it been converted into a swamp? Where has the water been able to cut an outlet for itself? Can you find another area which is draining into Fox River through a cut in the moraine? Is it so well drained? Why will Booth Lake probably remain a lake longer than Lake Beulah or Mud Lake? Why is not Lake Beulah surrounded by a swamp as is Mukwonago Lake? Why are the rivers sluggish? Can you find any streams that are not bordered by swampy area? Can you explain this condition?

What is the character of the vegetation in the swamps? What substance is being formed from it? When the swamps become completely drained, what name will be applied to them? What will be the character of the soil? How may the draining process be hastened by man? Suppose the moraines were situated many miles apart. What would be the nature of the soil formed in the depressions between them? Do you know of such large tracts of prairie in Illinois?

In its present condition, is this area adapted to agriculture? How could it be greatly improved? In Illinois, most of the roads follow the section lines. Why do they not in this area?
Describe this area as you think it was a great many years ago. How did it differ from its present condition? Explain why. Give its history from that time to the present.

Study of Sun Prairie (Wisconsin) Sheet.

The oval hills represented on this sheet are drumlins. How were they formed? Draw sections, crosswise and lengthwise, of several of them. What would you say as to their surface? In what general direction do their long axes extend? Can you explain this? In what direction was the glacier moving that deposited them? Why are there swampy areas between them? What was the original condition of these areas? What evidences are there that they are being drained? What kind of land will they make when completely drained?
Study of Grouped Sheets -
La Salle, Ottawa, Marseilles and Morris (Illinois).

Arrange the sheets in the order named, and study as one area. Locate upon a map of Illinois. How many square miles are contained in the area? What is the contour interval? How does it compare with that of other maps you have studied?

What is the main river which extends through the entire area? In what direction does it flow? Notice that it appears to be on a flood-plain and yet to have cut a narrow channel below that plain. It was formerly an outlet of Lake Chicago and a much larger stream than now. The plain was deposited at that time. When it ceased to be an outlet of the lake, the dry valley was left. Then a new river formed and has become the Illinois. How far below the old plain has it cut? What is its fall per mile? Name its chief tributary.

Notice the great difference in surface between the different parts of the area. Study the ridge or moraine just east of the Fox River. How do you know that it is a moraine - that it was not formed by river action? How high are the bluffs on the west side of the river? How high is the crest of the moraine? Draw cross-sections of it through Norway and through Danway. What is the shape of the ridge? Is the slope on one side more abrupt than that on the other? How wide is it? Where does it enter the area? Was the course of the moraine determined by that of Fox River, or did the moraine determine the course of the river? Give reasons for your answer.

Trace the moraine to the Illinois River. At what point is its crest? Observe that it is absent from the river valley, but is present south of it. How do you account for this? In what direction does the moraine run then? What effect does this turn have on the area to the north and east? Where does the moraine leave the area? If you could follow it farther, you would discover a bend to the east before long. Other moraines lie north and east of the are, forming with this one, a more or less circular outline. What was the condition of the included area when the glacier retreated? How has it become drained? Where did the Illinois break through the moraine? On the Morris sheet, notice the direction from which the streams enter the river. How does the slope of the basin-like depression account for this?

What is the name given to drained lake areas? What are the characteristics of this prairies? What has given most of the relief to its surface? Select three or four of the smaller streams and determine the width, depth and slope of their valleys. How are some of the streams affecting the eastern side of the moraine? Notice the work of streams on the western side, also. In what way has the shape of the moraine determined the course of the
streams? Notice in Big Grove Township, on the Marseilles sheet, a stream which first flows south, then south-west and finally, north-west. Can you tell how it has come to have such a course?

Study the Fox River valley. Compare it with the Illinois in depth, width and slope.

What is the large, open area north-west of Ottawa? What is its general altitude? How level is the surface? How was it formed? About how large was it, originally? How have the streams affected it?

Notice the moraine which crosses the north-western corner of the Ottawa sheet. Trace it on the La Salle sheet, until it reaches the Illinois. How wide is it? How far does it rise above the general surface? Compare with the Marseilles in regard to size. How did it assist in forming the prairie north of Ottawa? Where have the streams eroded it most? Does the moraine appear south of the river? In what direction does it extend?

Find Covet Creek, which enters the Illinois below Ottawa. Can you trace the low, east-west moraine which starts a little west of the creek, and extends a few miles into the Marseilles area?

Can you find another moraine on the La Salle sheet? What is the character of the surface in the central part of that sheet?

Point out the parts of the complete area which are best suited for agriculture. Why are they better than others? What is the nature of their soil? How was it formed? About what proportion of the area is occupied by moraines? What part of a moraine has the poorest soil? Why?

How have the moraines and the streams influenced the course of the railroads? Why does the C.R.I. & P. follow the Illinois to Morris and then leave it? On the Marseilles sheet, explain the course of the Kankakee and Seneca Railroad. Find Deer Park. What can you learn about it?

A map including the Ottawa, Marseilles and Morris sheets, drawn with a twenty foot contour interval, and tinted with dilute India ink will assist in bringing out the main features of the surface.
Study of Kinsley (Kansas) Sheet.

This sheet is chiefly useful for the study of sand-dunes. Locate the area upon a map of the United States. Note the scale of miles and the contour interval.

What is the character of the surface on which the sand-dunes are situated? Why is a level or very gently sloping surface necessary for the formation of sand-dunes? Why are there none in the extreme south-eastern part of the area? Why do they not extend west of the Arkansas? What would you say about the character of the soil in this region? Is the region adapted to agriculture? Why do the dunes tend to collect in groups? What is the character of the streams? Can you explain it? Why are there so few roads? Explain, as far as you can, their situation.

Study of Garden(Kansas) Sheet.

How far is this area from the Kinsley area? Where are most of the dunes located? Do you notice a great many depression contours? These represent hollows which have been excavated by the shifting sand. Some of the Dakota maps show depressions many miles in length. What are the longest on this sheet?
Make a detailed study of a square area, extending from the school-house a mile on each side. What is the general character of the surface? What are the agents which have produced the topography? Are there streams crossing it? What is the character of their valleys? Have they formed flood-plains or meanders? Do they contain falls or rapids? What is their age? If the main streams do not illustrate all the phases of river action study the gullies. What do they illustrate? Trace the divides between the streams. Does the area contain any ponds or small lakes? What is their origin? Can you find evidences that they were once larger than they are now? By what means have they been partially drained? Can you find ridges or mounds? What are they? How were they formed? To what extent do they show the effects of erosion? Do you find prairie? How was it formed? What is the character of its surface?

Study the soil. How many kinds do you find? Is the soil residual or transported? Of what is it composed? What parts of the area contain the best soil? Why? Can you find striated pebbles or boulders? What do they indicate? If the soil is composed of sand, look for sand-dunes. Are there springs in the area? What is the character of the wells?

Make a map of the area as you proceed in your study. The basis for it may be traced from a large township map, and the special features added as noted. Keep notes of your observations as you proceed, and at the close, write a complete paper, bringing in all points, their causes, so far as possible, and their effect on the topography.
WEATHER.

Clouds.

Watch the steam issuing from the escape-pipe of a steam-engine on a day when there is practically no wind. When steam comes in contact with cooler air, it condenses, and so becomes visible. Why is there a space between the pipe and the steam-cloud? Is there no steam in this space? What form does the visible steam assume? Does it pile up, or does it spread out in all directions? Notice that it is composed of rounded lumps, like a great pile of cotton batting. What causes the lumpy appearance? Notice whether the steam issues in a steady stream or in little spurs. Why is the top more or less conical? Would steam coming from the centre of the pipe, or that coming from the edge remain visible for the longer time? Why? If the apex is exactly over the centre of the pipe, is the surrounding air moving, or is it perfectly quiet? If a little to one side? If the horizontal motion of the air becomes increased, how will the shape of the cone be affected?

What relation can this steam-cloud bear to real clouds? First, see if you can prove that the air near the earth's surface contains moisture. Set a pan of water out into the sunlight. After several days, you may find it empty. What has become of the water? What becomes of the water in clothes when they dry?

There is a solution known as cobalt chloride which possesses a very peculiar characteristic. A cloth dipped into it is pink while wet, but when thoroughly dry is blue. Prepare a piece of cloth - perhaps three inches square - with the solution; dry thoroughly and mount on a card. Notice from day to day. Does the blue color remain constant? What causes the change? Where does the moisture come from?

Select two thermometers that register together. Mount side by side on a board. Around the bulb of one, wrap a piece of wicking, and immerse the free end in a glass of water. The result is a set of dry and wet-bulb thermometers. The wick will draw up water from the glass until it becomes saturated. When the surrounding air is very dry, the water will evaporate from the wick quite rapidly. Evaporation always cools a surface, and the cooling of the thermometer bulb will be shown by a drop in the mercury. If the air contains a great deal of moisture, the amount of evaporation will be less. How will the mercury show this? Will the two thermometers register nearer together when there is much or little moisture in the air? Observe for several days and see if you can prove that the amount of moisture in the air varies. To what conclusions have these experiments led you?
See if you can prove that the air rises from the earth's surface. Place your hand a foot or two above a stove. Does the air feel warm? Where is the heat coming from? Place a thermometer near the ceiling over the stove and another on the floor. What difference is noted? What causes the difference?

Have you ever noticed the heat rising from an asphalt walk on hot summer days. Where did it come from? Why did it rise?

On what principle is the hot-air furnace constructed? Put a few feathers on a register. Do they remain there? What carries them up? Is the air from the register heavier or lighter than that of the room? Why does the cold-air pipe lead from the floor? To what conclusion have these experiments led you?

Suppose a column of air containing moisture moves upward until it comes in contact with the colder air; what will result? What results when the stream of hot, moisture-laden air emerges from the escape-pipe?

Look at the clouds in the sky. See if you can find one which is thick and wooly, and seems to roll up in great masses. Can you see any resemblance between it and the steam-cloud? Is not the chief difference one of size? Call such clouds cumulus.

In what part of the sky do you see cumulus clouds? Why is this? Do you suppose there are none directly overhead? If the cloud had a flat bottom, would you see the thick, wooly character when it was overhead? The air surrounds the earth in layers. The layer which is cold enough to condense part of the moisture will condense all of it. What about the bottom of the cloud - will it be flat or not? Would such clouds form if the air all over the surface of the earth were rising at the same time? Why not?

Look at the clouds again. Do you see any that are in the form of long, feathery or curly wisps, stretching out over a great length of sky? Notice the steam-jet again, - this time when there is a high wind - and see if you can learn anything about the formation of these clouds. What form is the steam taking now? What is the one cause of the change? What must be the state of the atmosphere where the cloud is forming? Is the cold air calm, or moving gently or rapidly? Call all clouds formed with the cold current moving rapidly, cirrus clouds. What is the state of the cold air where Cumulus clouds are formed?

See if you can find clouds which are not conical enough to be called cumulus, and yet not wispy enough to be cirrus. What about the air where they form? For such, the term cirro-cumulus is often used. When clouds become very thick, they are called stratus.

Have you noticed what is called a mackerel sky - a sky filled with
tiny cumulus clouds very near to each other? Suppose that the steam should issue from the steam-jet in tiny but rapid spurts. Would not a multitude of miniature cumulus clouds result? Apply this to the real clouds of the mackerel sky.

Remember that for the formation of any of these clouds, there must be small, but distinct rising currents of air.

Note. The height of a cloud does not determine whether it be cumulus or cirrus. It is the relative velocities of the ascending and horizontal currents which determines this. Notice for several days, and see if you can find both cirrus above cumulus, and cumulus above cirrus.

Lows.

Count the clouds in the sky. Did you ever see just one? For each cloud there must be a column of rising air. What about the number of these columns? Are there sometimes a great many? A very large number of columns of rising air near together, constitute what is known as a Low.

When cirrus clouds are present, observe the barometer. This may be an aneroid, which may be purchased from any dealer in optical goods for about three dollars; or you can make one which will do good service. To do this, secure a piece of 3-16th inch glass tubing about three feet long. Close at one end; fill with mercury and invert in a small bottle of mercury, taking care that no air enters the tube. Bind the whole onto a flat piece of board. Mark a scale beside the tube, showing inches and tenths of inches, or, tack on a yard-stick. The zero mark should be just level with mercury in the bottle. You are now ready to read the barometer; that is, to note the mark on the scale which is exactly on a level with the upper surface of the mercury in the tube. By noticing several times a day, you will be able to determine whether it is rising or falling. A falling barometer signifies that the pressure of the air is becoming less, because the air is rising; a rising barometer, that the pressure is becoming greater because the air is descending. Is the barometer rising or falling when cirrus clouds are present?

Note the direction of the wind at a time when there are cirrus clouds and a falling barometer. Is it blowing from some point in the west, or from some point in the east?

See if you can discover why an east wind accompanies cirrus clouds and a falling barometer. The falling barometer indicates the presence of a Low. What is a Low? When the columns of rising air reach the colder air above, the moisture in each will condense to form a cloud. At the same time, the rising air will tend to spread out on all sides from the center of the group. There is an upper air-current, however, which blows steadily
from the south-west, and causes an increase of the spreading on the eastern side of the group. On the western side, it is just strong enough to counterbalance the tendency of the rising air to spread in that direction, and so produces an area of calm, or quiet air. The clouds which form in this area are of the cumulus type. Why? When the rising columns on the eastern side of the Low reach the cold air, they also encounter the south-west wind and as a result, cirrus clouds form there. Why? As the air in these eastern columns rises from the earth, other air will rush in to take its place. This inrush forms our east wind.

When the cumulus clouds are visible, it is the western edge of the Low which is about us. Are the winds now from the east or west? Why from the west? Where will the air come from to replace that in the western columns? Is the barometer rising when cumulus clouds and a west wind are present?

When cirrus clouds appear after several clear days, notice the barometer and wind. Follow the three closely. When does rain occur? When it begins to clear, what change is there in clouds, barometer and wind? These changes are caused by the passing of the Low. In what direction do Lows move? Suppose you see cirrus clouds appear in a clear sky. Describe the changes which will probably occur before the sky becomes clear again. If rain does not occur, it will probably be because there is not enough moisture in the air. Make use of your wet and dry-bulb thermometers again. If the two columns of mercury stand very near, what will you know about the moisture in the air? If they stand some distance apart?

When the center of the Low is west of you, what wind will you have? When it is east of you? When it is north of you? Could this account for the warm winds when there is a storm north of the Lakes? When the Low is south of you, what will be the wind? Where must the center of the Low be to cause a north-east wind? A rising barometer gives promise of what kind of weather? A falling barometer? A Low always moves in an easterly direction.

Highs.

Since there are ascending columns of air, there must also be descending columns. It sometimes happens that in a group of air-columns, the large majority are descending. Such a group constitutes a High.

Descending air does not produce clouds, while ascending air does. When the latter reaches the cold stratum, it is drawn to a center to form the descending current. This produces an area of calm at the center, which causes the clouds to be cumulus. If the air is descending, will the barometer be high or low? Why? As the air nears the surface of the earth,
it tends to spread out in all directions from the center of the group, forming winds. From what direction will the wind blow at a place east of the High? West of the High? North of it? South of it? Will there be much wind at a place in the center of the High? Describe the weather at such a place.

Weather-Map Exercises.

Procure from the Chief of the Signal Service at Washington, weather-maps - enough so that every one in the class may have one of the same date, if possible.

Notice first the black lines called isobars. These connect points of equal pressure; that is, if a row of barometers were placed across the United States on a line corresponding to one of the isobars and at the same height, they would all show the same reading. (A barometer three hundred feet above sea-level, and one five hundred feet above, would differ a little, and this fact has to be taken into consideration in drawing the isobars.) The figures at the ends of the isobars indicate the pressure. Notice that the isobars are not straight lines, but are curved. In some parts the curve is more pronounced than in others. Can you find isobars which form great loops? Can you find any which are entirely closed to form a circle or closed curve and marked Low? Notice the figures on the isobars. Do the numbers increase or decrease toward the center? What does that indicate with regard to pressure? Imagine yourself in this Low, and tell what you would find as to the weather. Consider first the eastern side. Will the barometer be rising or falling? What will be the nature of the clouds? From what direction will the wind be blowing? Make the same statements in regard to the western side of the Low. Will the barometer be rising or falling? Look near the Low for arrows indicating the direction of the wind. Do they accord with your statements? Would you expect to find rain in the eastern or western half of the Low? Why? If in the morning, the eastern edge of the Low were about you, what changes would probably occur before night? Would you be surrounded by the same part of the Low at noon?

How will the temperature of the country south of this Low be affected by it? The country north? Notice the dotted lines on the map, called isotherms, which connect points of equal temperature. Any place crossed by one of these has the same temperature as all other places crossed by it. How do the isotherms show the effect of the Low? Is there any tendency to a looping toward the front of the Low?

Examine the maps for the day preceding, and two or three following that of the map you are studying. Can you trace the Low in its movement
across the country? What direction has it taken? Can you discover at what point it entered the United States? At what point did it leave? What was its relation to the Great Lakes? Examine other maps until you have traced fifteen or twenty Lows. Make a statement in regard to the paths they follow. What are the three chief routes?

How rapidly does a Low travel? Measure with the scale of miles the distance from the center of the Low one day to the place occupied by the center of the Low the next day. Divide by twenty-four to obtain the rate per hour. How many days does it take to cross the continent? Of what value is this fact? Do all Lows always travel at the same rate?

Return to your original map. Notice the isobars again. Can you find some which are circular where the inner ones of a group bear a higher figure than the outer ones? Trace to the circle or oval at the center. It will be marked "High". Why? Imagine yourself in this area. At the eastern end, what will be the weather conditions with regard to barometer, wind and clouds? At the western end? Verify your statements with regard to the wind by examining the wind arrows. How will the temperature of the country north of the High be affected by it? That south of the High? Where must a High be located to have the same effect on the temperature of a given place as a Low north of that place would have?

Consult the weather-maps each day. When you can calculate the day during which a Low will pass you, keep very close watch of the weather. Notice the barometer, clouds and winds until the storm has passed. Write an account of all that you observe. Does it correspond with your former ideas of the passage of a Low? Make the same observations during the passage of a High. When the pressure is greatest, what is the condition of the sky? What about the winds?

Weather Records.

You are now ready to keep a regular record of weather observations. It will require but a few minutes each day. Once a week, the results should be discussed in class, and then compared with the weather maps for the week. The following observations should be made:

Temperature. For this, a good Standard thermometer is necessary, and readings should be taken three times a day. An average of the three will give a fairly correct average temperature. It is also well to know the maximum and minimum temperatures for each day. For this purpose, schools should be provided with maximum and minimum thermometers. Daily records of their readings should be kept.

Pressure. The barometer should be read whenever the temperature is noted.
Clouds. At the same time observe the clouds, noting the kind and relative part of the sky covered.

Wind. Direction and whether steady or shifting are to be noted three times a day.

Humidity. The relative amount of moisture can be obtained from the wet and dry-bulb thermometers. Do they register near together or far apart?

Precipitation (rain or snow). For this a rain gauge should be fitted up. Have a tin cylinder made, exactly three inches in diameter and two feet in length. Affix to the top a funnel whose larger diameter is six inches, and on the lower end, put a cap. Also procure a good yardstick. Mount the apparatus in some place away from buildings or other objects which would prevent the free fall of rain. Observe once a day whenever rain or snow has fallen. Measure the depth of the water in the tube. This, however, indicates the rainfall over an area as large as the top of the funnel, which is four times that of the tube. Divide by four to obtain the rainfall in inches over the surface. Be sure to empty the tube after each observation. When the precipitation is in the form of snow, it must be melted before measuring.

Weather Predictions.

Make some attempt at predicting the weather for twelve or twenty-four hours. If there is a falling barometer, cirrus clouds, an east wind, and much moisture in the air, what will be your prediction? If the first three conditions prevail, but the air is very dry, how may your prediction differ from that of the first case? Why? If during a storm, the barometer begins to rise and the wind shifts to westerly, what will probably follow?