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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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MATERIALS OF THE INDIAN LAPIDARY IN THE SAGINAW DISTRICT, MICHIGAN

FRED DUSTIN

IN THE *Report of the Smithsonian Institution for 1877*, Dr. Charles Rau has a paper on "The Stock-in-Trade of an Aboriginal Lapidary," in which he says: "There is little doubt that there were persons who devoted their time chiefly to the manufacture of stone arrow-heads and other stone artifacts, and that certain individuals who were either by natural inclination or practice particularly qualified for a distinct kind of manual labor, devoted themselves principally or entirely to that labor."

Early explorers, missionaries and traders have noted that certain Indians followed particular occupations, so that there were arrow-makers, wampum-makers, canoe-builders and other specialists.

The writer of this paper has personally collected over seven thousand Indian "relics" in Saginaw County, and has seen thousands of others in the possession of a score of other collectors. Even a casual observer cannot see many of these articles without being struck by the beauty of material and cleverness of workmanship. Red, yellow, brown and blue jasper, jetty-black lydian-stone or basanite, gray, red, brown and white agate, white

quartzite, beautiful opaline chalcedony sometimes with drusy surfaces of crystal-clear quartz, bluish chalcedony from Flint Ridge, Ohio, translucent smoky chalcedony somewhat like English flint, but far more beautiful, clear vein quartz, and occasionally a black obsidian arrow-point from the far West: all these beautiful materials along with others are represented in our chipped artifacts.

We find pipes made from the red pipe-stone of Minnesota, animal figures fabricated from beautiful banded slate, and an occasional celt or axe pecked from a boulder filled with hornblende crystals or from granite of the finest texture.

The great mass of chipped implements and weapons are made of the common gray chert, or, as commonly called, flint. Pipes are worked out of limestone, sandstone, argillaceous rock, or rarely from some harder stone. Animal figures, "bird-stones," gorgets, and the like, are fashioned from black, red or brown slate. Axes, adzes, chisels, hammers and mauls are worked from common granite, gneiss, trap-rock, syenite and a half-dozen other common materials.

From whence came this supply? A glance at the map of our State, shows us five rivers converging in Saginaw County to form that estuary of Lake Huron known as Saginaw River, which, given a few hours of hard north wind, flows upstream some twenty miles or more. This is the largest river drainage basin in the State. The geological map of the State indicates that the southwest corner of the county is about the center of the Carboniferous formation, and that beneath this is a series of other formations lying in a shallow bowl or plate form and outcropping at various distances from the center according to the character of the formation. At Saginaw the Carboniferous formation is about two hundred feet below the surface, but thirty or forty miles south it outcrops nearly at the surface, as it also does in the southwest and north, while westward and to the northwest the rocks are buried deep under the drift and morainal deposits. Just across the east boundary of the county at Tuscola, there was formerly to be seen a ledge cutting the Cass River belonging to the Carboniferous, but the outcrop was small and is now said to be buried under alluvial or silty deposits. We see these rock formations taking a roughly circular form, and below the coal measures we will find sandstone, limestone of several descriptions, and shales or slaty rocks.

The Cass River, a few miles southwest of Cass City, runs over a succession of ledges dipping gently downstream. At this point we find a stratum of sandstone which forms the bed of the river for eight or ten miles toward its source. Above the sandstone here, there outcrops a bluish clayey limestone of fine texture, which, when first removed, is quite soft, but on drying hardens somewhat. This was material used for making pipes, a number of which are in the writer's collection, some of nice workmanship and good design. In this limestone are numerous concretions of zincblende or sphalerite, and occasionally, a nodule of chert with sphalerite, making a quite pretty clouded agate plainly showing its metallic content. There are also druse cavities lined with blende crystals or dolomite spar or brownspar. Above this clayey limestone lie beds of shale and sand-rock along with a layer of hard limestone containing numerous chert concretions, thus furnishing a limited amount of material for the arrow-maker. This limestone formation again outcrops at Bay Port and was a source of unlimited supply, for the denuded rock was broken down and dissolved, leaving the hard nodules intact; also at Stony Island and Big Charity Island. In fact, the supply was sufficient for a far more numerous population than ever occupied our State in its primitive condition. These nodules are of much interest both to the mineralogist and archaeologist, and vary from the size of a marble to a diameter of some eight inches. At the Bay Port quarry they may be seen in place as well as at the locality on the Cass, but at the quarry, exposure is artificial, and as blasting goes on continuously, specimens are easily obtained and numerous vugs in the limestone may be explored for other minerals, while in some of the layers fossils are plentiful.

On July 13, 1924, the writer visited the quarry, and examined a few hundred feet of the north face of the workings, which at this point is ten or twelve feet high. The rock first exposed is a dirty-looking sandstone, about three feet thick, underneath which comes one and sometimes two layers of limestone each about two inches thick, and filled with simple coral fossils, mostly lying parallel to the bedding. The replacement material of which they are composed appears to be impure calcite, which stands out in marked contrast to the yellow-gray limestone matrix. Immediately below this comes the cherty limestone which outcrops on the bay shore, and contains thousands of nodules of chert, so many, in fact, that in many portions of the quarry the stone is valueless for lime, while for road metal they are most useful owing to their hardness. Small masses of brown calcite crystals are numerous, their color probably coming from iron which often stains the limestone and sometimes forms small masses of lean iron ore.

At the bottom of the limestone, and resting on the gritty shale below it, is a layer of compressed limestone, very fine grained and of even texture, which when first exposed is of a warm gray color, almost a pale brown showing a decided umber tinge. It breaks with a subconchoidal fracture, and as it weathers, grows lighter and lighter in color as well as harder, until it has the appearance of chert even under the pocket lens. Unfortunately, this layer is only ten or twelve inches thick, for it is a valuable building stone, which was used in the construction of the Hoyt Library and the S. T. & H. Railroad Building in Saginaw. It is not saved at the quarry unless there is a special order for it. No seams or veins of flint (chert) were to be seen; nearly all concretions were of globular form.

During my first years of collecting, I often wondered at my failure to find large or long spear-points and other implements from the familiar chert, and in fact never

have seen one over six inches long in any collection. The reason is simple, for the largest nodules are not often over six inches in diameter, and a quarryman who was employed there eight years told me that he had never seen one over eight inches through. My own collection, gathered from Indian village- and camp-sites, numbers perhaps a hundred specimens, from the perfect unbroken nodule to fragments showing unusual coloring, vugs, chalcedony cores, drusy cavities or agatized formation.

One almost perfect hemisphere is eight and a half inches across; another is in form, size and color a nearly perfect imitation of a baseball, or rather of a large tennis ball. The first one I ever picked up was of a perfect heart-shape, very much resembling a fair-sized pig's heart, even to the severed arteries at the top, and the woman in whose field I found it suggested that it was a petrified heart.

Vugs at the center of nodules are not infrequent, while solid chalcedony cores are quite common as well as vugs lined with beautiful botryoidal masses of that substance. I have others displaying masses of water-clear quartz crystals, the largest individual crystal not over a quarter of an inch in diameter. Rarely one finds an exquisitely banded gray and white agate, one or two specimens in my collection being unique in their delicate contrasting layers. Occasionally a small specimen of clouded gray agate has been found, and one of these had been worked into a lozenge shape by the red lapidary. These Bay Port nodules show little coloring in general, and I am inclined to believe that the occasional yellow and brown arrow-points and such things are largely from the Cass River locality, although further investigation may show that colored chert is produced from other outcrops.

On Section 5, Township of James, there is a space covering about two acres on each side of the north and south quarter-line, and north of the east and west quarter-line which is strewn with flakes and spalls of a yellow-brown chert approaching a jasper, and in some specimens well-deserving that designation. An occasional arrow-point or other object of the same material is sometimes picked up there, and I have two or three pieces showing brown or yellow chalcedony cores. It would seem that a canoe-load of these characteristic nodules had been worked up on this two acres, and I have found fine arrow-points of this material on village sites a mile or more away. It is sub-translucent, and the unpolished fragments have a waxy luster.

On this same section I found, several years ago, a cache of leaf-shaped blades, numbering nearly sixty. They were of the common chert, but showed ochery-yellow stains running through the mass of stone. In March of the present year (1927) I found half a mile to the west on a low sand knoll, where the wind had blown away the sand, a little pile of flakes of the same material and very easily identified by the unusual yellow stains, being the waste from the cache. Near at hand was a common hammer-stone, I doubt not the one used in striking off the flakes from the nodules.

Very rarely an arrow-point or other article chipped from the sphalerite-impregnated chert will be found, and I have in my collection a very thin beautiful blade of peculiar form with tiny notches at one end, thus giving it the outline of a fish. Years ago, a cache of similarly shaped blades were figured by Harlan I. Smith as having been found at the Fraser Mound two and a half miles west of where I collected the one described. As these were too delicate and fragile for use as knives or spear-points, I presume they were intended to be keepsakes or were perhaps of totemic significance. The nodules from which these were formed were large, possibly elongated.

Many of the Bay Port nodules are of imitative forms, being pear-shaped, squash-shaped or egg-shaped, and one or two are of phallic appearance. Many contain fossils, particularly of insects, one slab in the collection being filled with organic remains. Most of these nodules appear to have been formed by the gradual filling up of cavities in the limestone by a process of growth by which the cavity was lined with siliceous material, gradually becoming more and more pure toward the center where the filling was completed with a chalcedony core. Others, however, would seem to have formed around an organic nucleus, which in some specimens has dissolved out, leaving a cast. One egg-shaped nodule has a hole running through its entire length, and appears as though it had grown around a twig, a root, or possibly even some member of an animal, such as a bone.

A large percentage of flint artifacts show the concretionary growth-rings, and tell the tale of *why* we do not find the huge blades that Flint Ridge produced, or the large hoes and spade-like forms from the vein-flint of Illinois.

In short, the Bay Port chert is characteristic for the Saginaw region, and we find arrow-points of it from the Straits to Jackson and from Manistee to Port Huron, the arrow-maker gathering his canoe-load of nodules from the Cass, from the shores of the Bay, from the islands; transporting them to the converging streams of Saginaw; burying them in wet places to keep them workable; from time to time drawing on his stock and working it up into leaf-shaped blades, again cached, and withdrawn as needed to be notched and stemmed into the finished arrow-point: working the odd chips into scrapers for skin-dressing; occasionally chipping out some fantastic form or exercising his skill in the most delicate, dainty chipping in notches so fine and even that they seem almost machine-made, and running in some specimens to thirty or forty to the inch, and sometimes of almost needle-like sharpness of point, all with the crude tools of the Stone Age.

Turning now to the rarer materials, we find two sources of supply; one, the occasional pebble from river-bed, or bank, and the other, traffic with other regions or expeditions to them.

From the river-bed comes the infrequent arrow-point of red or blue or green jasper, the occasional spear or arrow of trachyte or scraper of quartzite with even a possibility of an occasional blade of lydian-stone, although it is probable that lydian-stone nearly always came from the south through trade. Sometimes a mass of chalcedony of beautiful tint and texture may be picked up, and we find chippings and fragments as well as the finished article, thus showing the manufacture of these gem-artifacts on the spot. Once in a while the collector's heart will be gladdened by an agate drill, perforator or arrow-point, and these too are sometimes found in the Saginaw country.

In Saginaw County itself, the Cass River from Cook's Grove at the edge of Bridgeport Township to the county line east, has at least four rapids or rifts where the river-bed is covered with boulders, while the Flint has a notable spot near the south county line, so notable, in fact, that the Indians themselves called it *Peonigoing*, "the place of stones." The Shiawassee, too, above Chesaning, formerly furnished its share of material, but these old rifts are now flooded by the two dams. On the Tittabawassee, there is a boulder bed a mile below Freeland.

Through trade or expeditions our Indian lapidary came into possession of the familiar Flint Ridge chalcedony, as well as the fine pink chert, or more properly, jasper, for it has all the attributes of jasper. This fine material occurred in nearly every quality, and I have seen collected here in this county a pink jasper blade ten and one-half inches long and about two inches wide, as well as arrow-points so small and of so fine quality as to be readily classed with the "gem" points from Oregon and other western localities. Our Michigan chert is characterized by its concentric rings, sometimes very distinct, while the Flint Ridge material is massive, lying in beds or layers. Rarely do we find any flint of lower Michigan origin that is not nodular, although occasionally a specimen is picked up that would seem to have originated in a vein or seam, but usually a close examination will reveal its nodular character.

I have one very good specimen of this character, which has been polished on one face, bringing out the clouded agate formation. From the Satchell Indian village site in Frankenmuth Township, I collected a fair-sized agate of poor quality which is in contrast to the specimen last mentioned, as its concretionary form is very plainly manifest.

Occasionally I have picked up jasper pebbles, mostly from disintegrated "pudding-stone," but sometimes they are found in the gravel or among the boulders in the river-beds of larger size and on these it seems that occasionally some Indian artificer tried his skill and fashioned a beautiful point or drill, almost always small or of medium size.

This gem material is frequently of such beauty that stones suitable for ring and pin settings can be cut from it, and I have had some twenty or thirty such prepared, including jasper, agate, chalcedony, milky quartz and lydian-stone. Some of these were seen by a prominent local jeweler and his wife, and they were so struck by the unique beauty of two lydian-stone gems, one cut cabochon, the other oval table, that they begged a piece of the raw material and had it cut into a pair of similar stones, and the wife now wears one of them in a fine setting in preference to more expensive jewels. A gray agate of unusual markings in this lot is of interest as showing the vast difference between the rough and the polished stone. People seeing them often exclaim, "Is it possible that such a pretty stone can be cut from a piece of common rock?" They do not know that it is not common, but is carefully selected from a thousand pieces of stone which is common, and therefore it has a value because it is scarce.

A carefully selected collection of Indian "relics" will usually contain a number of pipes both of pottery and stone, but the "collector" will usually be looking for "calumets," as he calls them, and usually we will find that he has specimens of very recent manufacture, and ornamented in a way that no primitive Indian ever thought of. Sometimes we see them with mosaic bands and figures of metallic lead of a slightly more remote date, but still showing plainly white influence and white metallurgy. The pipes that interest the archaeologist are those of primitive culture, and occasionally a red or mottled pipe from those noted quarries in Minnesota is picked up in the Saginaw district, and rarely a piece of the raw material. I have one such piece in my own collection, bearing the marks of the primitive tool upon it; also a tiny figure of a beaver two and one-half inches long, one-half inch wide and one-quarter inch thick, with a hole drilled its whole length, a rare little specimen. This stone and this little figurine were very likely secured on an expedition, although perhaps this esteemed material was occasionally obtained through trade.

I have mentioned the fine-grained, clayey limestone from the Cass River used for pipes, and this stream also furnished a sandstone of two or three grades which was used for the same purpose, my collection containing several specimens, one of them a sort of pebbly or conglomerate sand-stone with scattered small pebbles. The Indian pipe-maker well understood his materials, and used only those that would not flake off or crack under the unequal heat or expansion to which they were subjected.

We come now to an interesting section of Indian stone-work, that of tablets, gorgets, bird and animal figures and so-called ceremonials. Here we find as raw material the favorite green banded slate, red and purple slate, black slate and even finegrained sandstone as well as rarely harder and coarser stones. I have in my collection articles of this class running from the roughed-out oval tablet or gorget formed by the chipping process as well as the hard slate shaped by pecking, to the completed, neatly polished and perforated figure of an otter, conventionalized it is true, but indicating an exceedingly skilled workman who knew his trade. Most of this

material was gathered from the rivers; it is a contribution from the Ice Age dropped near the present surface, and uncovered by the wearing waters of the several streams, or possibly in the case of the black slate, occasionally found in place near the few outcrops of the Carboniferous formations. I have collected specimens of almost every variety mentioned on the rifts of the Cass River or other streams, and one specimen in my collection, a boulder weighing several pounds, almost approaches jasper in hardness, being, I should judge without a perfect test, about 6 on Moh's scale. It is beautifully banded in two shades of green together with a red brown. It is also of interest as showing the effects of the great heat by which it has reached its present nature and appearance.

Occasionally harder stone was used for animal figures, and one in my possession is that of a goose, worked from some fine-grained stone of hard texture, perhaps a granite or gneiss. Another is a large roughed-out bird or animal figure of similar hard stone.

We find sandstone in various degrees of coarseness for rough-grinding and sharpening axes and celts, as well as polishing and finishing pieces of slate, almost invariably black, for sharpening and polishing bone needles and awls, and sandstone rubbers for smoothing arrow-shafts and other articles of wood. This sandstone outcropped in several places as has been already noted, and, when frozen into the ice, on the Cass River, was not infrequently brought down in the spring by flood-waters, which often transport stones for miles in this manner. I have picked up small slabs of the sandstone that forms the bed of that stream near Cass City perhaps thirty miles below.

The materials for axes, mauls, chisels, adzes and other weapons and tools worked by pecking was plentifully supplied from the boulder-beds already mentioned, and syenite, granite, gneiss or, rarely, other metamorphic rock such as trachyte. Some beautiful specimens fashioned from fine-grained stone of uniform texture, and others showing hornblende crystals, and still others discovering crystals of feldspar, are to be found, and rarely do we see an implement of this kind that does not exhibit the qualities most needed, such as hardness, toughness or tenacity. A tool for which a sharp edge was required called for qualities different from those of one that was used merely for battering.

Small ornaments, such as beads of aboriginal manufacture, are seldom found in this district, but rarely a hematite bead or one of slate may turn up. The hematite was of course largely from trade or brought south by expeditions to our Upper Peninsula, but some years ago the writer found what to him was a rarity, a small bit of iron ore which was strongly attracted to the magnet. This was collected on a sand knoll, an ancient village site where I have secured many pieces. The sand is filled with flint flakes and other remains of the ancient dweller, but aside from what has been brought by the hand of man is utterly barren of stones, so I was well satisfied that this was a former possession of some Red Man, and treasured for the same reason that I treasured it. A few years later I found a boulder-bed about a half-mile long, three or four miles farther upstream, and to my surprise, discovered that there were numerous pieces of similar ore, some of them weighing many pounds, scattered among the other boulders. Here was likely the source of my bit of iron. This is the boulder-bed mentioned as being on the Tittabawassee River below Freeland. Another thing that seemed curious to me was the fact that large boulders lying in place in the clay were deeply striated, all in the same direction. Perhaps some geologist may explain. Striations are common enough, but to see loose boulders thus striated seems odd. They appeared to follow about the same contour line under the high bank.

I have frequently collected masses of fossil coral, both from village sites and from river beds, and have perhaps twenty or twenty-five varieties, but I have never observed a single ornament made from this material. The most beautiful specimen I have ever seen, I owe to some Indian long dead. The high waters of spring washed out an old wigwam site, and along with other articles I secured this coral. The Indians were as much interested in the curiosities that fell under their observation as we are, and I have a fossil shark's tooth, a piece of rose quartz, a siliceous stalactite, queer concretions, arid other articles taken from graves or village sites that were undoubtedly held with as much interest as I now hold them. A race of men given to contemplation and thought to such an extent as our Indians were could not but observe the wonders and beauties of Nature, and in her works, they saw and marvelled at the strange and wonderful, and admired and delighted in the beautiful.

Could we, in the present generation, get a little away from the material, occasionally, it would well be worth our while. Here we have a man who loves the wild flowers and studies them and revels in gardens of Nature's own planting; here is another whose recreation is found in those winged flowers, the moths and butterflies; still another tells us of those flitting and fleeting creatures that come to us in the spring and depart from us in the autumn, the birds; still another studies the rocks and "the Everlasting Hills," and "follows Nature to her most retired apartments"; another studies with the deepest satisfaction those wonderful, yes, marvellous crystallized and aggregated forms called precious stones, while some poor souls like myself content themselves with those odds and ends that a more or less mysterious people have left behind, and find a pleasure and an occasional "thrill" in being called either archaeologists, professional or amateur, by a small part of the community, but more often referred to as crack-brained bone-hunters by the hard-hearted general public.

It is not well to live in the clouds all the time; neither is it well to live in the dust. There may be a happy medium, but I at least have not found it, for in the necessities of the case, we must feed, house and clothe ourselves and

families, and unless we are professional men following certain lines, we must go to the dust once in a while, for where does one find corn or beans growing in the clouds? It is well thus, and no man, though ever so poor, need lack in sky overhead, or give up his dreams and his joy in living.

SAGINAW, MICHIGAN

A METHOD OF CERAMIC DESCRIPTION

CARL E. GUTHE

CERAMIC specimens form an important group of material, not only in the detailed study of the archaeology of a small restricted area, but also in the larger problems brought out by the study of diffusion of extinct culture traits. Yet little attention has been given to the special problems incident to the proper, accurate description of ceramic specimens. In order that published material on regional ceramics may prove of the greatest value, a form of description must be adopted which treats of all, and not merely of some of the characters of pottery, and which is, within the limits of the problem, comprehensible to investigators in related fields.

Since pottery making is a culture complex, it is, therefore, incapable of description by hard and fast rules, similar to those used by systematists in biology. It is possible, however, to formulate definite principles of treatment, based upon the major characters of pottery, which are common to all things made of clay. Such a study is essentially an objective one, in which all the factors considered exist within the specimen itself, isolated from its cultural and environmental surroundings. The problem before us, then, is that of presenting a broad, practical outline of the way in which a given specimen or group of specimens should be described in order that the description may serve, with or without an accompanying photograph, adequately to reproduce in the mind of the specialist reading it a clear and definite mental image. This problem has four distinct aspects, based upon the four primary characters of ceramic material, which are paste, surface finish, decoration and form.

THE PASTE

There are four attributes of the paste or body which must be taken into consideration in rendering an adequate description. The most obvious of these is its composition, the clay proper and the tempering material or grog. In some instances chemical analyses are advisable. In those classes of pottery in which the temper can be differentiated from the clay itself, special attention should be given the tempering material used, its degree of coarseness, and its relative quantity in proportion to the clay.

The second attribute of paste is its texture. The cross-section of a specimen discloses at once the degree of thoroughness with which the potter treated the paste before construction. In crude pottery the paste usually has an irregular texture, with varying degrees of fineness not only within a single cross-section, but also in different parts of the same piece. In the technically more advanced pieces, levigation causes a uniform, fine texture.

The third attribute of the paste is its hardness, which depends primarily upon the degree of heat to which the specimen has been exposed. It is, however, impossible to arrange a definite table of hardness based upon definite degrees of firing, for different pastes react differently to the process. Hardness is sometimes described by the ease with which the paste can be scratched with a knife. Mr. Kershaw describes a method based upon the ability of the paste to absorb a drop of water.

The fourth and most variable attribute is color. The composition of the paste determines the color in a general way, though the firing also has a strong effect upon it. Variation of distribution or quantity of the fire may cause the color to vary over areas of the piece, or in proportion to its position in the cross-section. Again, in coated vessels, exposure to the naked flame may completely change the paste color.

THE SURFACE FINISH

The term "surface finish" refers to that dominant feature of a ceramic specimen which is the result of a uniform treatment of the major part of its surface. It is the character upon which the first rough classification of material is usually made. Because of the interpretation frequently given the words "decoration" and "ornamentation" to include all embellishments of the paste itself, the real value of the surface finish has not been appreciated.

This second character is not the result of a step in construction but rather that of a complex technique. The first stages of the treatment of the surface may occur before the specimen loses its plasticity, while the last stage may be the ultimate one in construction.

There are two major forms of surface finish. The first is the result of manipulation only of the surface of the paste, by processes known as smoothing, scraping and polishing. The second is due to the coating of the paste with a variety of substances. If a wash of clay is used it is called slipping. Or again a non-mineral substance, such as various tree-gums, wax, oil, and the like, may be used. In certain great areas types of glass are used, which have been designated alkaline, salt, lead, or felspathic glazes, depending upon the character of their principal constituents.

Except in the most simple wares, the surface finish is the result of a combination of treatments. Most surfaces which have been coated have first been smoothed or

scraped. Likewise the coating of the surface may be composed of several layers, not only of different colors, but also of different materials. In describing the surface finish of a specimen which has been coated, four attributes must be taken into account. The first of these is the substance used, the second the color, the third the texture, and the last the thickness of the coat.

The surface finish is also affected by a series of factors entirely distinct from those of construction. These are the result of the treatment after completion, in which use, time or weather may cause the addition of material, discoloration, change in texture, flaking, or complete decomposition and disintegration.

In view of the fact that the problems inherent in the study of the surface finish are multiple and quite distinct from decoration, it is advisable to treat it as a ceramic character distinct from paste, as well as from decoration and form.

THE DECORATION

The third of the ceramic characters is the decoration, the problems of which are of two kinds, those which deal with decorative design, and those which deal with decorative technique. An adequate study of design must be based upon an interpretative consideration of the elements and motifs, which are so varied that they constitute the special problem of investigators working in the restricted ceramic areas.

Because of the limitations of the medium involved, the processes or technique by which those designs may be associated with ceramic material may be classified under a small number of general methods of application, which also fall naturally into two groups. The first of these is that in which minor alterations occur in the surface which is to be decorated, by use of a series of processes which result in incised, engraved and pressed patterns. The second is that in which the design is formed by addition of material to the surface. There are four general processes in this group. The first, and most widely spread, is the application of paint. The second is the application of enamel, which is largely confined to glazed surfaces. The third is by the addition of paste in small quantities in such a manner as to form a raised or applied pattern. The fourth is that of encrusting the surface with fragments of shell, wood, various metals and similar materials. All these processes may be further subdivided by recognition of refinements of technique.

The decoration of a specimen is usually the result of a combination of two or more of the processes mentioned. Similarly, it may be associated with the surface finish in a variety of ways. The design may occur over or under the various coatings, and the decoration may be done at almost any stage in the construction.

The description of the design alone, while properly occupying the major part of a report on a special ceramic group, does not constitute an adequate discussion of the decoration. The various techniques used, their relationships to one another and to the surface finish, must also be adequately described.

THE FORM

The fourth and final ceramic character is the form, in which the shapes encountered are myriad. They may be roughly and inadequately grouped as containers, effigies, and objects of primarily utilitarian or aesthetic nature not included in the first two groups. In spite of the great variety of forms it is possible to indicate certain aspects of this character which must be treated in an adequate description. The first consideration is that of the methods by which forms are achieved. These are three: the use of the wheel, the use of moulds, and the dexterity of the potter's hand alone.

In the discussion which follows containers only are considered, because they form the bulk of comparative material, and because an attempt to include all forms would merely confuse the issue. Emphasis must be placed on the importance of grouping material by criteria of shape alone. An attempt to use related and highly suggestive criteria, such as use, size and functional additions, will do more harm than good.

The most rational method of studying form is by means of cross-sections. But a single vertical cross-section through the center of the vessel is not always sufficient. The possibilities of parallel sections made along two planes at right angles to each other must be taken into account.

By use of the cross-section method it becomes possible to break up the form into its four component parts, which are body shape, basal shape, oral shape and the shape of the secondary features. By body shape is meant the form of that part of the vessel upon which its fundamental shape depends, which in cross-section consists of a uniform curve or group of curves tending to form a simple geometric figure. The basal and the oral shapes are those which result from the specialized treatment of the lower part and the mouth of the vessel, respectively. Secondary features are those which result from the application of large amounts of paste or other materials sufficient essentially to alter or hide the body shape in restricted areas of the surface. The differentiations just made are based upon the lack of harmony existing between the major curves of the four parts, when viewed in cross-section. The actual meeting point of two of these parts is not likely to be a line. It is usually a junction zone, which may be defined as that area of the surface in which the major curves of two adjacent form parts have been altered to permit the gradual merging of the surface of one into that of the other.

If, therefore, the study of this fourth ceramic character is undertaken with an appreciation of the essential individuality and the possible combinations of these four component parts of form, it is believed that the difficulties of classification by this character will be diminished.

Finally, the dimensions of a specimen should be included in a complete description. Measurements should be taken not only of the general size, but also of the cross-section of the body wall. The figures given should be the average of a series of measurements. In addition to greatest height and width of the vessel, it is often advisable to give the dimensions of each of the component parts of the form.

WARES AND STYLES

The discussion of the principles of ceramic description which has just been completed would be largely valueless without a consideration of the connotation of such terms as "wares," "styles," and "types," which unfortunately have a vagueness of definition, resulting from the lax and indiscriminate manner in which they have been used. These terms, if they are to have real value, must refer to groups which combine several of the attributes just discussed. The word "ware" refers to fundamental similarity, the word "style" to superficial similarity, and the word "type" to a large generic group. On this basis the following definitions are suggested.

A ware is a ceramic group in which all attributes of the paste and the surface finish remain constant. A style of decoration is a ceramic group in which decorative design and technique both remain constant. A style of form is a ceramic group in which the form as a whole remains essentially constant, and is distinguished by some outstanding feature. A type is a ceramic group wherein the similarity is a generic one of all four characters caused by the entire pottery complex of the designated culture group. The scope of these definitions may be controlled by the use of delimiting adjectives. It is to be noted that the first three take no account of time or space, and are mutually exclusive, thereby permitting a study of distribution both geographically and stratigraphically without a confusion of terms.

CONCLUSION

The fundamental purpose of this paper is an attempt to evolve a general scheme of ceramic description and classification which might serve to unify ceramic method and improve published descriptions. While the method advanced is neither detailed nor perfect, it is presented in the hope that it may stimulate discussion and research in this rather neglected field of general ceramic method and terminology, and thereby serve to increase the value of ceramics in the study of culture development.

UNIVERSITY OF MICHIGAN

AN ECONOMIC SURVEY OF CHIPPEWA COUNTY, MICHIGAN

WADE E. DEVRIES

IN A geographic study the first item to be considered is the natural environment. In studying the natural environment of Chippewa County, Michigan, the various natural features such as soil, drainage, topography, location and forest growth are considered in relation to one another as forming natural districts. Because of the interrelationship of these features, it follows that a certain soil is associated with a certain class of topography and a certain type of forest cover. Likewise, a certain forest type naturally associates itself with a certain soil type and a certain degree of drainage. In Chippewa County, the natural districts as defined on this basis are very definite and distinct units with easily apparent boundaries. Each district possesses a unity of character and contrasts strongly with every other district. There are no commonly accepted local names for any of the natural districts in this county, except perhaps the "plains" or "pine plains." In the absence of such names, these districts have been named, for the purpose of this article, from their most significant natural features. The map (Fig. 16) shows the location, extent and names of the natural districts of Chippewa County. Natural conditions are not absolutely uniform throughout each district. Small areas here and there offer contrasts. Nevertheless, each district is sufficiently uniform in natural features to be easily recognized as a unity.

The Clay District is an area of prevailingly heavy clay loam soils, locally known as "red clay," which are its most distinguishing natural feature. The surface soil is acid but the subsoil is alkaline. There are some areas of swamp over clay, the largest being in southern Bruce Township and northeastern Pickford Township. Any other swamps are of small extent and unimportant. This district is high in natural fertility. The topography is nearly level, the elevation varying from 650 to 700 feet over a wide area. The drainage is fair to slow. The forest growth is made up of hardwoods principally with softwoods such as poplar on the burned over areas. Swamp conifers are found on the more poorly drained parts. This district corresponds very closely geologically to the clay deposit in Lake Algonquin.

The Shore Border District consists of a strip of land extending along the shore of St. Mary's River, Whitefish Bay and Lake Superior. This land all lies on the first low bench above the present lake level. In most places, there is a very prominent old lake bluff that marks the boundary between this district and those adjacent. The soil consists of sands and sandy loams underlain by heavy clay. Areas of clay soil occasionally occur. The clay is often at a depth sufficiently shallow to hold the moisture up in the sandy loam of the surface. This surface has an acid reaction but the subsoil is alkaline. The natural fertility ranges from high to low. The small patches of alluvial soils are exceedingly fertile, but in localities where the clay is deeply buried by sand, the fertility is very low. The soil in general lacks the uniformity that is found over large areas in the Clay District. The topography is level to undulating. The natural drainage is adequate to poor. The forest growth consists of poplar, white birch and other softwoods on the cut over and burned areas, and conifers in the swampy parts. Hardwoods are found on the better drained parts. This district corresponds geologically to

the Post-Nipissing sand and clay. Its location on the shore border is its most important and most significant natural feature.

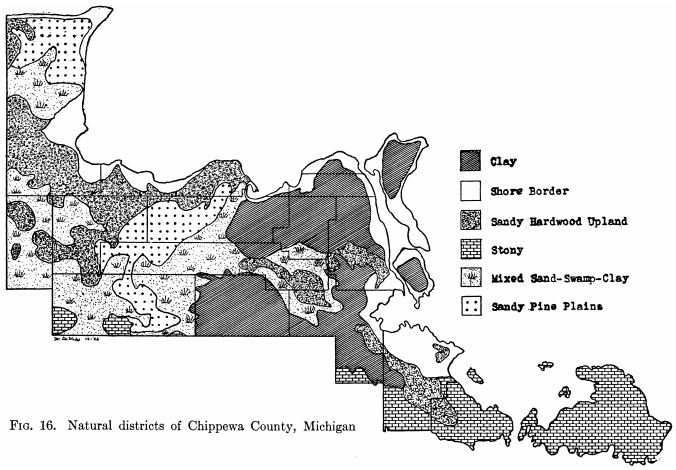

FIG. 16. Natural districts of Chippewa County, Michigan

The Sandy Hardwood Upland District is made up of all the areas of sandy hardwood soils. The largest block of this type of country is in the western and more unsettled part of the county, although there are several patches of this type in the eastern part. The soil is a light sandy loam and prevailingly acid in reaction. In the southeastern part of the county where the Hardwood District extends into the Stony District, as shown on the map (Fig. 16), the soil is somewhat alkaline. The natural fertility of this district is moderate to low. The topography is undulating to rolling. The natural drainage may be described as free. The forest growth consists principally of hardwood, maple and beech. Softwoods such as poplar make up a large part of the stand on the cut over and burned over areas. Most of this district corresponds geologically to marginal moraines.

The Stony District consists of the areas of shallow limestone soils in the southern and southeastern part of the county. The soil is prevailingly a very stony loam. The entire district is underlain at shallow depth by limestone bed rock which frequently outcrops over areas as large as forty acres. The soils are prevailingly high in lime and not acid. They are very fertile, but so exceedingly stony that their agricultural use is very limited. The topography is as a rule gently rolling to level, but with a few outstanding rocky hills, which are the most outstanding relief feature in the county. In the southwestern part of the county, they reach an elevation of 1,000 feet above sea-level, or from 250 to 300 feet above the surrounding country. The subsurface drainage in the Stony District is imperfect, being interrupted by bed rock at or near the surface. There are many small lakes, and swamps are common. Softwoods, swamp conifers and hardwoods constitute the forest cover. The outstanding natural feature which accounts for the soil, topography, drainage and timber is the limestone rock at or near the surface. Geologically, this district is partly till plain and partly sand deposit in Lake Algonquin.

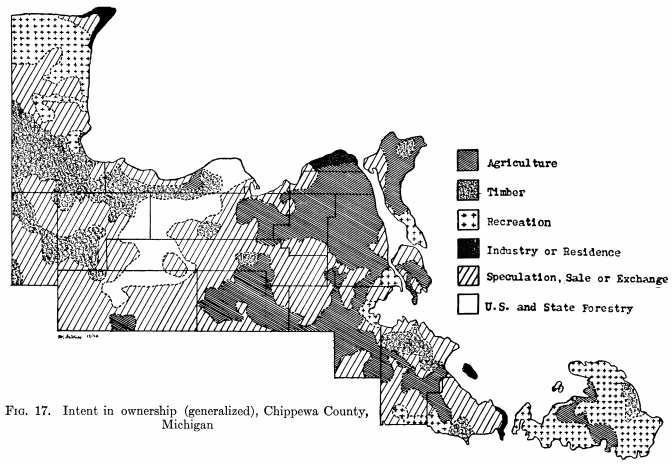

FIG. 17. Intent in ownership (generalized), Chippewa County, Michigan

The Mixed Sand-Swamp-Clay District occupies that transition zone between the Clay District and the Sandy Pine Plains, and between the Clay District and the Sandy Hardwood Upland District. It also includes that area in the southwestern part of the county between the Stony and the Hardwood Upland Districts and also most of the large swamp areas of the county. Most of the swamp and wet sandy lands outside the Shore Border District are included in the Mixed Sand-Swamp-Clay or Transitional District. Near the border of the Clay District, the sand is underlain at a shallow depth by clay, the clay holding up the moisture and keeping the sand wet, while near the border of the Plains or Hardwood the sand becomes nearly dry. The distinguishing characteristic of this district is the lack of uniformity in soil over any considerable area. This characteristic is expressed in the name. The soil is prevailingly acid with the exception of that part bordering the Stony District, where it is somewhat alkaline. The natural fertility is moderate to low. The topography is level to undulating. The drainage is as a rule poor. The forest cover consists principally of swamp conifers with softwoods and hardwoods on the sand ridges. The surface geology is described as sand deposit in Lake Algonquin.

The Sandy Pine Plains District extends in a belt from northeast to southwest across the west central part of the county. It also occupies an area near Whitefish Point. The soil is prevailingly a coarse sand which is very acid and low in fertility. The topography is nearly level. The drainage is excessive, making the soil very droughty. There are practically no streams and no run-off, rainfall draining downward through the sand. The forest cover consists principally of jack pine with scattering areas of Norway pine. Large areas were originally devoid of merchantable timber. The district is now locally known as "jack pine plains" or "the plains." Geologically, it consists of outwash plain and sand deposit in Lake Algonquin.

All the facts presented thus far are true for all time, regardless of the stage of development. It will be noticed that no one feature, such as soil or topography, is sufficient in itself to form the basis of this classification, but each district has a distinctive combination of natural features. (See plates at end of text.)

LAND OWNERSHIP

Inquiry was made regarding the intention of the owner of each parcel of land in the county by the following method. Township plats showing the name of each owner of acreage property were placed before the local assessing officer, as he is the officer most familiar with the plans and policies of the landowners in his district. The local assessor was asked to give his opinion regarding the intent in ownership of each parcel of land in his district. By his answers it was found to be possible to group the intent in ownership into several classes.

The distribution of six principal classes of intent in ownership is shown in Figure 17.

This map is generalized in that the greater part of the area indicated as "agriculture" has by far the greater part of its area in this type of ownership, although there are forty or eighty acres here and there that are in other classes of ownership. The area shown as "timber" has the greater bulk of its area in this type of ownership, although other classes of ownership are scattered here and there in the area. The same is true for the other areas shown on the map.

A comparison of Figures 16 and 17 indicates the close relationship between the Clay District and the Agricultural District. In those sections where the boundaries of the Clay District (Fig. 16) extend out beyond the Agricultural District (Fig. 17), the earliest expansion of agriculture may be expected. A close relationship is seen to exist between the Sandy Hardwood Upland (Fig. 16) and the Timber District (Fig. 17), also between the Mixed Sand-Swamp-Clay (Fig. 16) and the land held for speculation, sale or exchange (Fig. 17) and between Sandy Pine Plains (Fig. 16) and U. S. and State Forestry (Fig. 17).

Figure 18 shows the exact correlation between the natural districts and intent in land ownership in Chippewa County.

Intensive recreational land, such as lake shore cottage sites, is of importance in the Shore Border District. Extensive recreational development in the nature of private hunting lands is of importance in the Stony and in the Pine Plains Districts.

ECONOMIC CORRELATION

The following table of selected data of an economic nature will indicate the correlation between economic and natural features:

CORRELATION BETWEEN ECONOMIC AND NATURAL FEATURES

	Clay	Shore Border	Sandy Hard-wood Upland	Stony	Mixed Sand-Swamp-Clay Transi-tional	Sandy Pine Plains
Valuation, per acre, of undeveloped land (not timbered)	$10.50	$ 8.60	$ 6.70	$ 3.20	$ 5.50	$ 3.30
Valuation, per acre, of owner-operated farms	26.50	14.50	8.50	3.40	10.10	—
Valuation, per acre, of rented farms	29.10	29.10	11.50	8.40	10.30	7.50*
Valuation, per acre, of abandoned farms	11.40	3.60	4.30	2.40	8.50	3.80
Percentage of all farms owner-operated	80½	87	79	75	79	—
Rented	17½	7	7½	2	10	22*
Abandoned	2	6	13½	23	11	88
Population, per square mile	20½	8½	6	3½	2	1

* Only 1 farm (80 acres)

The valuation indicated above is the equalized valuation put upon land and buildings for the purpose of taxation. The valuation of one parcel of land is to the valuation of another parcel of land as the local appreciation of the qualities of parcels of land are to one another. This valuation is not productive value or selling value, but it is recognized as representing true proportional valuation.

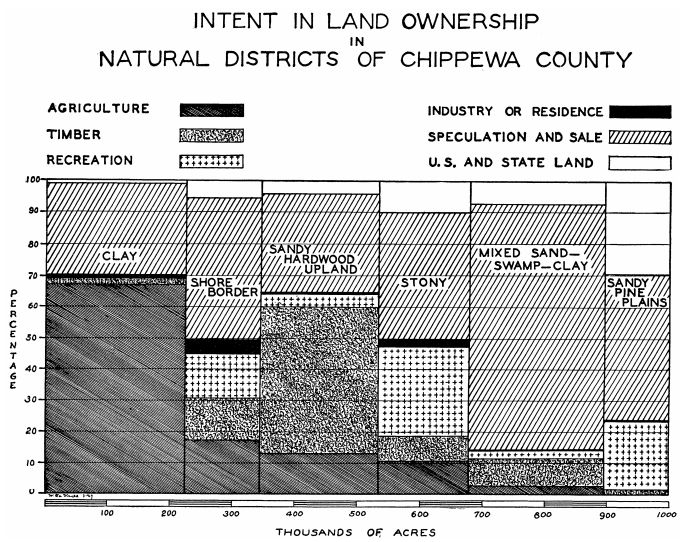

FIGURE 18

The relative valuation of land held for speculation, sale, or exchange (undeveloped land) in each natural district shows the relative soil values, eliminating from consideration timber cover and improvement due to land clearing.

According to the valuation, the owner-operated farms on the Clay District are worth nearly twice as much as those in any of the other districts. The rented farms in both the

Clay and the Shore Border Districts are worth over twice as much per acre as those in any of the other districts. The value of the average farm is lowest per acre in the Stony District. This is as true of the rented farms as of the owner-operated farms. From these figures, it would seem that the Clay District is best suited for farming development and the Stony District and the Sandy Pine Plains least suited to farm development. These three districts have all been opened to farm development for about forty years. In all the natural districts of the county, the rented farms have a higher valuation, per acre, than the owner-operated farms. It is profitable to rent only the best farms. A farm on poor soil or a farm that is only partially developed will not support a tenant and pay rent.

In every district the abandoned farms have a much lower valuation than the occupied farms. They have the highest valuation in the Clay District, where abandonment does not occur on the clay lands proper, but on the patches of poorly drained or high but stony land. Such soil does not lack in fertility but the physical difficulties in cultivation are too great to be overcome, hence, the abandonment. The abandonment in the Mixed Sand-Swamp-Clay District has taken place on the margin of the clay lands where the land was too wet for cultivation without drainage. The valuation of the abandoned land here is nearly as high as such land in the Clay District. In the Shore Border, Sandy Hardwood Upland and Sandy Pine Plains Districts, the abandonment is the result of isolation or lack of fertility in the soil on which farming was attempted. In these districts the valuation is extremely low. The valuation of abandoned farm land in the Stony District is as low as for any class of land in the county and the farms that are occupied have a valuation that is not much higher. There are two reasons for this: first, the labor cost of preparing this stony land for cultivation and second, the difficulty of marketing produce in this district, most of which is over fifty miles from a railroad station.

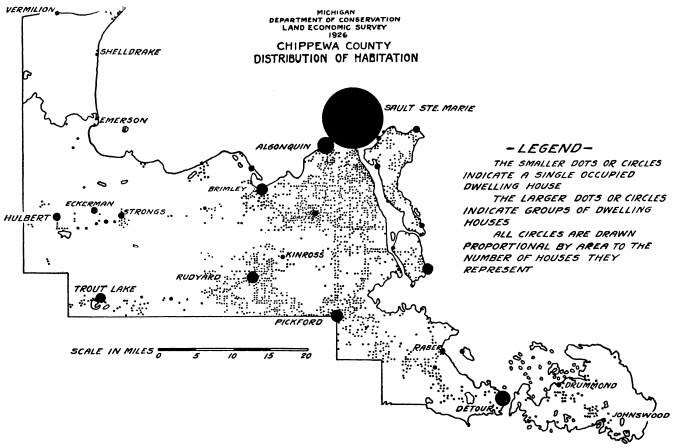

FIGURE 19

Figures showing the percentage of all farm land owner-operated, rented and abandoned establish the fact that rented farms are associated mainly with the Clay District and are of relatively less importance in the Stony District and in the sandy districts. Farm abandonment is distinctly not associated with the districts where rented land is common.

DISTRIBUTION OF POPULATION

A summation of the productivity of land resources, as at present developed, is indicated by the density of permanent population supported in each district (see table). Figure 19 shows where the population of the county is located. An occupied house generally indicates the location of a natural resource that gives employment to people. The greater the concentration of habitations, the greater the concentration of developed natural resources. A comparison of the number of occupied dwelling houses in any area with the population as reported by the last U. S. census shows a population of between four and five persons per dwelling house. Most of the dwellings shown in the west-central part of the county, with the exception of those at Hulbert, are temporary tar paper structures built to serve during the period of the lumbering operation. Since they are not intended for permanent homes, no pride is taken in the matter of their appearance. The farm dwellings in the eastern part of the county offer a sharp contrast to this condition.

CONCLUSION

The work of the Michigan Land Economic Survey is concerned with an inventory of the resources of northern Michigan. The principal natural resources are soil, forest growth or cover and water. The economic inventory considers the present status of utilization of these resources. The data which have been presented in this paper show that there is a decided relationship between natural and economic conditions.

In Chippewa County there is room for farm, forest and recreational expansion, but this expansion should recognize and be guided by this relationship between natural and economic conditions. An over-expansion of farming upon soils which are unsuited to it has resulted and will result in abandonment and consequent loss of wealth. An over-expansion of forest development to the detriment of the farming interests is unnecessary and undesirable. It is hardly possible for forest expansion to be anything but advantageous to recreational expansion. Farm, forest -and recreational expansion is necessary to the complete utilization of this county's resources.

DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

PLATE XX

FIG. 1. Typical forest cover in the Clay District. This is the type of land which is most promising for future agricultural expansion.

FIG. 2. The greater part of the Clay land is now in farms. Note the good road, large barns and prosperous appearance typical of the Clay District.

PLATE XXI

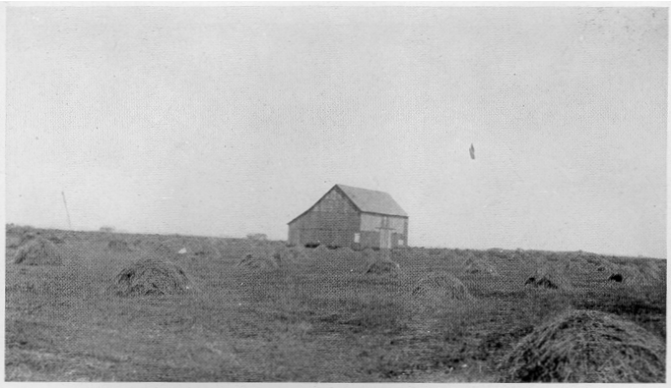

FIG. 1. Hay fields and large barns. No woods or woodlot is visible on the horizon. Woods are much less frequent than in southern Michigan.

FIG. 2. Hay and dairy products, the principal sources of income in the Clay District.

PLATE XXII

FIG. 1. Virgin hardwood forest on the Sandy Hardwood Uplands. Logs and chemical wood are the principal products of this District.

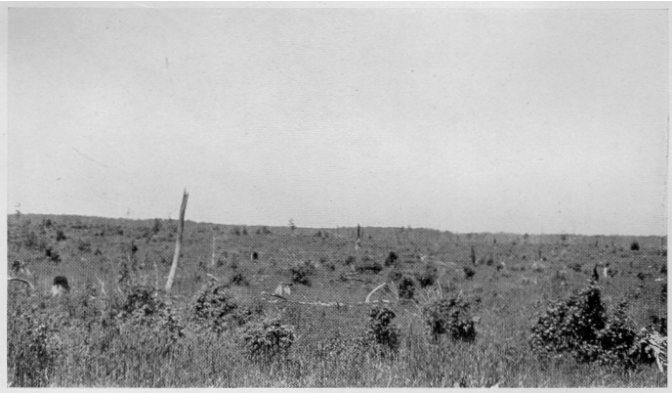

FIG. 2. After the lumberman and fire have gone over the land.

PLATE XXIII

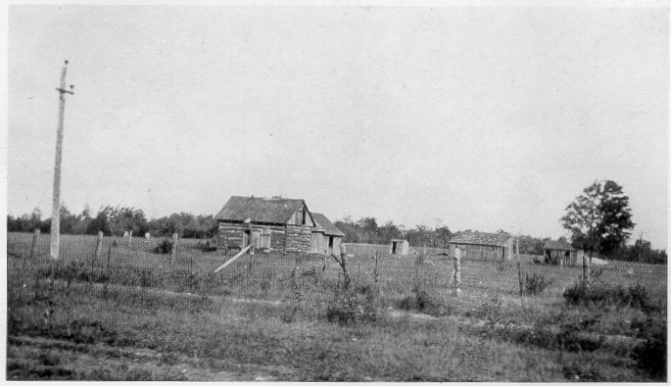

FIG. 1. A farm failure on the Sandy Hardwood Uplands resulting in a loss of wealth. Hardwood reproduction in the background.

FIG. 2. The Upper Falls of the Taquamenon, site of a proposed state park; scenic beauty in the virgin hardwoods.

PLATE XXIV

FIG. 1. Another scenic spot in the Sandy Hardwood Uplands. View from Mission Hill, Spectacle Lake, in foreground. Head of St. Mary's River in background.

FIG. 2. A view in the Stony District. Note the nature of the soil, and the beauty of the islands in Lake Huron. This is a potential resort site.

PLATE XXV

FIG. 1. Typical forest cover in the Stony District. Here, as well as in the Transitional District, practically the only exports are such forest products as pulp wood, posts, poles, ties, bolts and piling.

FIG. 2. Farm development in the Stony District. The difficulty of cultivation here is apparent. The county would be much more wealthy if this land was covered with the forest shown in the background.

PLATE XXVI

FIG. 1. The U. S. Post-office at Maxton, Michigan. The postmaster comes twice a week. This post-office is 65 miles from the nearest railroad and all mail passes over four stage-routes to get there. This is an example of the isolation of the greater part of the Stony District.

FIG. 2. A view on the Sandy Pine Plains. A thick stand of jack pine in the background. Jack pine reproduction after a fire in the foreground. Blueberries are extremely plentiful on such land the second year after fire. The blueberry crop brings an income of $125,000 yearly to the pickers or about one third of the value of all dairy products sold in the county.

FIG. 3. Sandy Pine Plains that have been burned and reburned until there is no forest reproduction. This is an example of the land that has reverted to the state for non-payment of taxes, or land that is being planted to pine by the Federal Government.

THE DRY PRAIRIES OF MICHIGAN

JETHRO OTTO VEATCH

THE pioneers and early settlers in Michigan applied the term *prairie* to treeless bodies of land, but did not everywhere make a distinction between relatively dry grassland on the one hand and marsh on the other. The dry prairies constitute the subject of this paper. These natural features possess considerable local historic, physiographic, geographic, pedologic and ecologic interest. This article is presented from the point of view of the pedologist, or soil scientist, as a contribution to the geography of the state.

Location and size. — The prairies are restricted to the southwestern part of the state (see sketch maps, Figs. 20-21). They occur as small, separate bodies, varying in size from about 80 acres to a maximum of about 25 square miles. A total of 39 have been located.

Physiography. — In topography all the land is level or has only a slight slope or very gentle roll. Some of the larger bodies include shallow depressions or basins which either may be dry or may contain lakes and peat deposits. Since the drainage is largely subterranean, there has been practically no stream-cutting. In one place, namely, Grand Prairie west of Kalamazoo, there has been a small amount of gullying on the edge of the prairie adjacent to the river valley escarpment, and also on the Big Prairie in Newaygo County wind-erosion has disturbed the original surface.

All the prairies occur on glacial outwash or on the coarse valley filling in old glacial drainageways. The geologic deposits underlying appear to be the same or very similar in origin, and in mechanical composition and structure, in that they are glacial outwash or valley filling, are relatively coarse sand or gravel or both, unconsolidated and pervious. The deposits vary slightly locally in lithologic composition, for example, in the relative proportion of some one kind of rock as shale or limestone, but in general the deposits are heterogeneous, since they contain a variety of both crystalline and sedimentary rocks. In geologic age, the deposits belong presumably to the Wisconsin stage of the Pleistocene.

There appears to be no consistent difference in elevation with reference to contiguous forest land on the plains. But where a prairie borders a moraine or a swamp, as in a few places, the forest may be higher or lower. The general elevation of the plains above sea-level is approximately 800 to 900 feet.

In brief, there appears to be no marked difference in topography and geology from the adjacent forest land on the outwash plains, although some slight differences in the lithologic composition of the underlying deposits may exist.

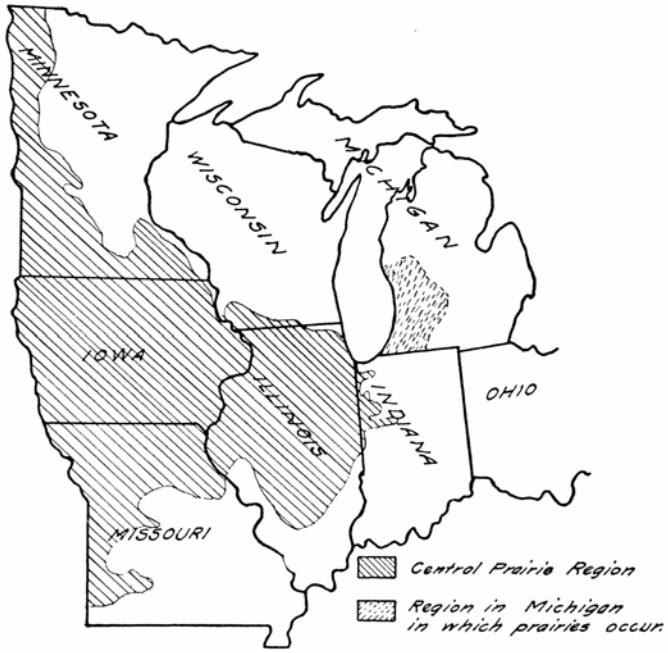

FIG. 20. Location of the prairies of Michigan with reference to the central prairie region of the United States

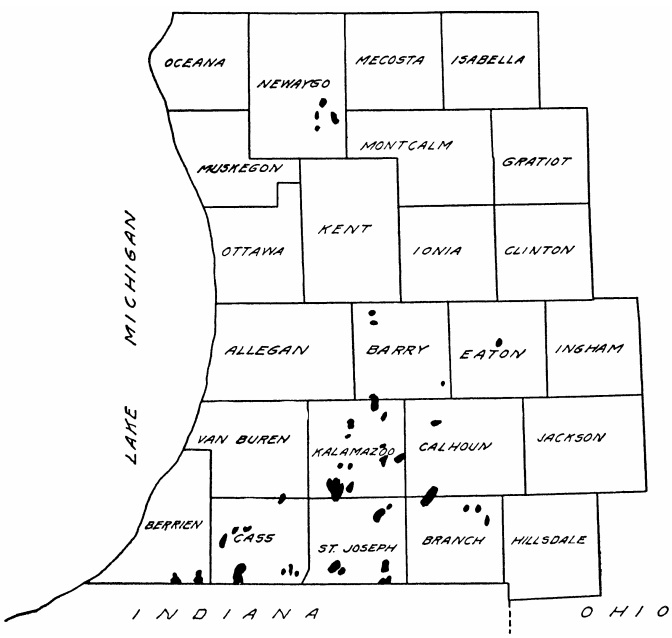

FIG. 21. Map showing distribution of prairies in Michigan

Vegetation. — There were a few burr oak (Quercus macrocarpa, Pl. XXVII) on nearly all the prairies and some hazel brush, particularly on the forest border. No complete list of the species occurring in the original herbaceous cover can be given. The land was broken up for farming at an early period and it is fairly certain that no virgin prairie land exists at present. We can safely assume, from the accounts of early settlers, that the grass formed a sod and was tall. Probably the chief genus was Andropogon.

The following list of species on the prairies was given by Dr. Beal:[1]

Amorpha canescens Pursh.
Asclepias verticillata L.
Atheropogon curtipendulus (Michx.) Fourn.
Bouteloua curtipendula (Michx.) Torr.
Baptisia leucantha Torr. and Gray.
Coreopsis palmata Nutt.
Echinacea purpurea Moench.
Helianthus rigidus Desf.
Phlox bifida Beck.
Silphium spp.

Climate. — The prairies occur in a region of 32 to 36 inches annual precipitation and 46 to 49 degrees Fahrenheit, mean temperature. The precipitation is fairly evenly distributed, but is slightly greater in May, June and July.

Soils. — The soil of all the prairies has a darker color than the surface horizon of the well-drained mineral soils of the forest, a higher content of humus and coloring from humus to greater depths. The soils of all the prairies, with one exception, have the same profile and belong to one series or group in the technical classification. A number of separate phases, however, can be recognized, based upon slight textural variations and variations in thickness of separate horizons. The generalized soil profile is as follows:

1. Surface horizon, dark brown; organic matter in very fine state of division and humified; granular-loamy in consistency; thickness, 6 to 20 inches.

2. Gradational horizon, lighter shade of brown than No. 1; granular, friable; thickness, 3 to 10 inches.

3. Yellowish-brown to reddish-brown, very compact clayey horizon; thickness, 4 to 20 inches.

4. Sand and gravel, unconsolidated; pervious and relatively dry or low in moisture.

Horizons 1 and 2 range in texture from sandy loam to silt loam; the content of organic matter in Horizon 1 is generally about 3 to 4 per cent. Horizon 3 probably nowhere contains more than 20 to 25 per cent of clay and includes considerable coarse matter, which may be in places of gravel size, but becomes very compact under certain conditions, so much so that it is referred to locally as "hard pan." The colloidal or clay matter present is strongly cohesive or adhesive and possesses very high tensile strength upon drying. Horizon 4 consists of unaltered or but slightly altered parent material and is composed of stratified or water-assorted sand and gravel, with cobbles in places. The depth of appreciable alteration by weathering or soil-forming agencies is 30 to 40 inches. The soil holds only relatively small amounts of water, but slightly higher than the associated forested sands. The upper part of the substratum is dry or very low in moisture and the water-table lies generally at depths greater than 8 or 10 feet. The whole profile is penetrable and roots of trees and

shrubs, alfalfa, or sweet clover penetrate to and into the sand and gravel of Horizon 4, while the roots of blue grass penetrate well into Horizon 3.

Chemical analyses reveal no unusual or abnormal peculiarities in composition. The organic matter and nitrogen are somewhat higher for the same thickness as compared with forested soils; the amounts of lime, magnesium, phosphorus, potash, sodium, iron and aluminum are not different from those of originally forested soils of similar texture throughout southern Michigan. An analysis of a representative soil from Portage Prairie, Berrien County, follows:

ANALYSIS * OF PRAIRIE SOIL, BERRIEN COUNTY, MICHIGAN

	Horizon 1	Horizon 2	Horizon 3	Horizon 4
H_2O	1.98	1.30	1.82	0.38
Ignition loss	10.33	5.16	5.70	1.89
SiO_2	74.60	77.40	76.85	87.01
CaO	1.73	1.85	1.78	1.85
MgO	1.95	2.03	2.10	1.43
K_2O	1.82	2.00	1.94	1.54
Na_2O	1.30	1.22	1.12	1.14
Fe_2O_3	2.10	2.80	3.65	2.50
Al_2O_3	1.85	5.18	4.48	2.08
TiO_2	0.28	0.48	0.53	0.45
P_2O_5	0.22	0.12	0.09	0.05
MnO	0.15	0.12	0.31	0.08
SO_3	0.62	0.08	0.05	0.09
Total	98.93	99.74	100.42	100.49
CO_2	1.87		0.07	0.15
N	0.21	0.08	0.05	0.02

* The analysis is quoted from a paper by M. M. McCool, J. O. Veatch and C. H. Spurway, "Soil Profile Studies in Michigan," *Soil Science*, 16: 100.

The surface horizon is strongly to very strongly acid in reaction according to hydrogen electrode measurements and field-tests with Soiltex; Horizon 2 is strongly acid; Horizon 3, strongly acid in the clay part, but some of the coarse matter is basic; the substratum, or Horizon 4, is calcareous, or aklaline, owing to coarse particles of limestone and incrustations calcium carbonate as a secondary deposition.

The profile of a forested soil associated with the prairie is given for comparison (see sketch, Fig. 22):

1. Surface horizon, leaf litter and mold;
2. Light brown, humous soil, thickness 2 to 4 inches;
3. Gray to yellow leached horizon, 6 to 15 inches;
4. Compact clayey horizon, yellowish to reddish-brown, in places red when moist, thickness 6 to 15 inches;
5. Sand and gravel, unconsolidated, pervious, dry.

The most marked difference in the profiles is in the organic matter in the surface horizons; otherwise they seem to be similar chemically and physically and in profile arrangement. It appears from observation that there may be slightly more compaction in the B or clay horizon of the prairie soil, although convincing quantitative proof of this is lacking.

The prairie soils, according to the scheme of classification adopted by the United States Bureau of Soils, are classified as Waukesha (Warsaw) types and the analogous forest soils as Fox types.

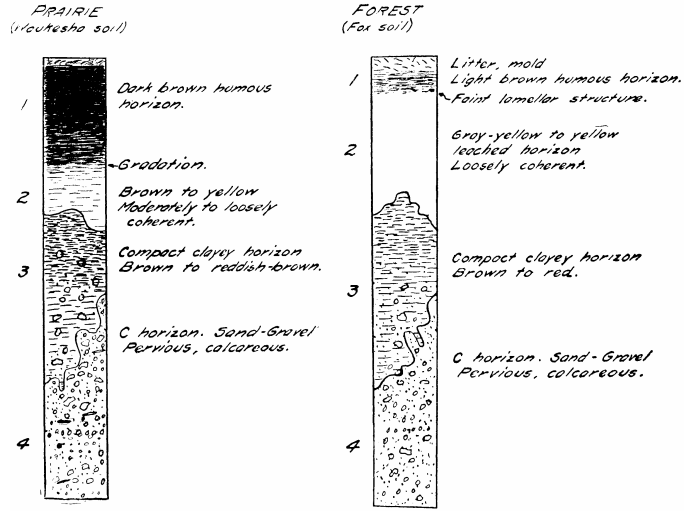

FIG. 22. Comparison of profiles of prairie and forest soils, Michigan

The soils of the Michigan prairies, compared with those of the subhumid prairie regions of Illinois, Iowa and Missouri, have in common a dark brown or blackish color, and high humus and nitrogen content to relatively great depths. There are also small bodies of the same type of soil, but most of the types in the prairie region to the west show marked differences, such as a high lime or non-acid condition at the surface, much heavier texture throughout the profile, and higher fertility.

The soils of the Big Prairie of Newaygo County constitute a single exception to the description of the Michigan soils just given. Here the dark color is present at the surface, but the texture is sand throughout the profile.

Geographic influence. — The prairies comprise a total of about 80,000 acres and this is distributed in separate small bodies. They have, therefore, not exerted any great influence on the trend of settlement or upon the character of the people and industries in the state. The prairies attracted the pioneers, who began making permanent homes in southwestern Michigan about 1825-30, because the land could be plowed immediately and did not require so laborious effort for reclamation as did the forest land. The land had an advantage in being level, and was therefore prized, so that it was all occupied at an early date. It was well adapted for wheat and this crop was grown continuously year after year in many places, as was true on the prairies farther west. The level topography and easy tilth favored rather large fields and farms and these have remained to the present time. In fertility and productiveness the prairie soil is considered to be intermediate, being somewhat higher than the forested sands and rolling sandy loams, and less than the forested more level clay soils of this region. Lack of sufficient moisture at critical periods in crop growth is probably the chief limiting factor in the production of very high yields. Relatively, the land probably had a higher agricultural value fifty to seventy-five years ago than at the present time.

There are no large cities and the towns and villages located on the prairies, such as Schoolcraft, Climax, Girard and Richland, are probably no larger or more important than forty or fifty years ago. The city of Charlotte in Eaton County is supposed to occupy a prairie, but there is no evidence of any prairie soil outside the city limits, and the land otherwise is so completely occupied that it is not possible to make satisfactory comparisons with other bodies.

Practically all the prairie land is in use at the present time for agricultural purposes, except the Big Prairie in Newaygo County, which was originally productive but at the present time is largely abandoned because of wind-erosion.

Origin. — Observations on the soil support a theory that the prairies were naturally treeless and not treeless primarily because of fires. The humus of the surface horizon of the soil appears to be derived entirely from the organic matter of herbaceous plants, while the thickness of the humus horizon indicates age. In pedologic terminology the soil is mature. In a great number of detailed profile descriptions, I find no evidence of a degraded forest soil, no suggestion of the grayish or pale yellowish highly leached horizon characteristic of forested acid mineral soils of this region.

The profile indicates further that the soil developed under conditions of intermediate or relatively low moisture — moderate average, but variable soil moisture in the surface, relatively low though more uniform in the B horizon, and very low in the C, beginning at depths of 2 to 3 feet. There is no evidence remaining of the peculiarities common to excessive moisture or waterlogging if these conditions ever existed.

The prairies are assumed to be relicts of grassland which was a part of the great subhumid prairie region of the Mississippi Valley. It is conceivable that the whole region of southern Michigan was treeless immediately after the retreat of the ice-sheet. The soil or geologic formations differed and on some sites conditions were more favorable for an early occupation by forest than on others. The climate could hardly have been different on present forested and unforested sites. There is no evidence to support a contention that some chemical condition in the prairie soil inhibits tree growth. On the contrary, trees grow when planted, and there is abundant evidence that the forest has been rapidly encroaching under natural conditions. Incidentally the soil profile affords a means of estimating the time since contiguous lands have been forested, inasmuch as the thickness and color of the A 2 horizon may be taken as a criterion.

In this region loam and silt loam types underlain by clay in the B and C horizons, such as the Miami and Brookston, possess sufficient moisture and fertility to support both grass and tree growth. At the other extreme, on the driest and least fertile soils, such as the Plainfield, subject to shifting by wind action, the physical conditions were unfavorable for a complete cover or sod of herbaceous vegetation, and therefore trees could obtain a foothold. An intermediate condition, particularly in relation to moisture and a loam or silt loam texture, would appear to have been most favorable for grass. Such a condition is found on hilly or rolling types of soil, but these have been forested for a great period of time. Slopes, however, favor wind- and water-erosion, and stones on the surface present conditions favorable for trees and shrubs in competition with grasses. A moderately dry soil, therefore, level in topography, loamy or silty in the surface, would be most favorable for grass under the condition of climate prevailing.

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[1] Beal, W. J., *Michigan Flora*, Prepared for the thirtieth annual report of the State Board of Agriculture, 1904, p. 19.

PLATE XXVII

PRAIRIE NEAR ATHENS, MICHIGAN. BURR OAK WERE PRESENT ON THE VIRGIN LAND

SOME ASPECTS OF MARL DEPOSITS IN OCEANA COUNTY

STANARD G. BERGQUIST

OCEANA COUNTY is typically an area of sandy soil, made up largely of out wash and till plains. Approximately eighty per cent of the surface area is light and sandy in character and the remaining twenty per cent about equally divided between lowland swampy areas, including lakes, clayey till and gravelly loam.

The marl is quite widely distributed through the county although in some of the townships, especially those in which the soils are uniformly and persistently light in texture, no trace of marl is to be found.

The deposits of marl in the county are of two distinctively different types and for the sake of convenience I have tentatively classified them into two groups, based upon their relationship to the water table, namely, lowland and upland deposits.

LOWLAND MARLS

(See Plate XXVIII)

The lowland types are by far the more common and make up the greater proportion of the deposits in Oceana County. They occur in beds of variable thickness in swamps and marshes, in river beds and as marginal deposits in lakes.

The marl in these areas is generally found below the normal water table and in such positions as to be constantly saturated with water. The thickness of the beds ranges from a few inches to twenty and more feet, depending to a large extent upon the size of the depression in which the material was allowed to accumulate.

The lowland marl beds are usually mantled with a layer of muck and peat which in many of the swamps and decadent lakes has accumulated to rather extensive depths, indicating that quite a long period has lapsed since the cessation of marl-forming activities. In some areas, however, marl is still in the process of formation and is accumulating more rapidly than is the encroaching vegetation, which in time will undoubtedly form a layer of organic matter to seal up completely the deposit and prevent further deposition of marl.

The marls of this type are extremely variable in color and in quality. The purer forms are as a rule grayish but, where intercalated with vegetal remains in the form of muck and peat, they generally assume a darker shade. The color of marl is not always an index of its quality, although it is unquestionably true that those of lighter colors contain less organic matter of vegetable origin, and hence would be likely to have a higher percentage of calcium carbonate than those that run darker. In some of the darker marls, however, those which apparently were contaminated with muck and peat, the final analysis showed a relatively high content of lime.

The waterlogged marls are heavy and difficult to handle. When freshly dug they contain water to approximately half of their weight and are frequently pasty or mushy in character. If intermixed with clayey material, they are plastic and sticky. When they dry, a large amount of water is released and the color becomes considerably lighter, oftentimes pure white. A cubic foot of marl taken from the borders of McLaren's Lake was weighed immediately after its removal from the water and found to weigh 104.8 pounds. A cubic yard of this material, completely saturated with water, would accordingly weigh 2829.6 pounds.

In the deeper layers of the saturated deposits and particularly where the marl is of a colloidal nature, the presence of hydrogen sulfide seems to be quite apparent, both in the lake and marsh deposits. This substance is readily detected by its odor when present in large quantities and will frequently produce a purplish tarnish on a brass rod even if in only limited association with the marl.

Marl which has formed and developed completely under water is generally not fit to be applied directly to the soil immediately upon being dug. It should be piled up in small heaps and allowed to weather thoroughly. The process of drying tends to remove a large proportion of the water and allows the included toxins to escape. At the same time the marl is rendered more friable and made easier to apply and also more useful as a soil-builder. If piled up in large deposits on the surface, the material weathers very slowly, and ordinarily only in the outer portions. On the inside it remains quite unchanged as to moisture content and textural properties.

UPLAND MARLS

(See Plate XXIX, Figures 1 and 2)

The upland areas of marl are somewhat more limited in their distribution, but nevertheless constitute beds of great importance in the county. They are found in the terraces of lakes, where the water level has subsided, and in the upper flats, terraces and old meander channels of streams and rivers.

The marl in these deposits is largely concentrated in beds that lie above the present normal water-table. They are for the most part fairly dry as compared with the lowland types. In seasons of excessive rainfall, however, the water-table rises, very frequently to levels above the surface of the deposits. In general the beds are relatively shallow, seldom, if ever, attaining a thickness exceeding six or seven feet; they would probably average three to four feet thick for the county.

The surface cover ordinarily is so thin as to be practically negligible. It consists merely of a few inches of muck, more often up to six or eight inches of wind-drifted sand. Occasionally, thin lenses of sand are found scattered

through the marl beds, but not in quantity sufficient to be of serious consequence in the economic handling of the deposits.

The upland marls are predominantly grayish to whitish. In deposits where clay forms the substratum and prevents proper drainage, they are frequently mottled with brown. As a general rule the marl of this type is fairly pure and runs high in calcium carbonate content. Very little muck or peat is interassociated with it.

Inasmuch as the deposits lie above the normal level of the ground waters, the marl is comparatively light in weight. A cubic foot of the material was dug from the dry bed on Carlton Creek and found to weigh 56.8 pounds, that is, 1533.6 pounds per cubic yard. Another sample, taken from the flood-plain terrace of Cushman Creek, weighed 85.1 pounds per cubic foot or the equivalent of 2297.7 pounds to the cubic yard.

The upland marl is characteristically friable in texture and breaks readily into a crumb structure upon weathering. Because of its relatively porous nature and exposure to weathering activities, it is quite commonly completely aerated and requires little or no preliminary curing to be used on the soil. In several areas, especially where the marl was colloidal and the base of the deposit rested in the upper ground waters, the odor of hydrogen sulfide was very apparent.

ECOLOGICAL CONSIDERATIONS

There seems to be a rather definite relationship between marl deposits and plant associations. In the southern part of the state, a variety of Potentilla grows luxuriantly in areas where marl is present. In fact, the presence of this plant may be reliably used as a positive indicator of marl. In Oceana County not a single trace of the plant was found, although in the adjoining county of Newaygo it was present in merely one isolated area of the six townships surveyed.

If we are to differentiate between bog and marsh in reference to character of soil and type of vegetation present, it will be quite necessary to make some changes in the nomenclature of marl deposits. If we define a marsh as an area of low-lying, swampy land with soil of an alkaline character and supporting vegetation with alkaline requirements, and then contrast the bog as having an acidic soil and favoring a growth of vegetation with acidic tendencies, it is no longer correct to classify marls in the category of bog limes, as has been done in the past. Marls do not form under bog conditions although it would be possible for a bog to become the site for marl deposition through a change in drainage conditions. If the ground waters, flowing through the soil containing nodules and concretions of limestone, were diverted from their courses so as to carry lime carbonates into a bog, conditions might then be made favorable to marl-forming processes. With the neutralization of the heretofore acid waters of the bog, lime-secreting plants and animals would undoubtedly come in and assist further in marl accumulation.

Of the bog types of plants found in Oceana County, two are especially outstanding in their complete aversion to marl. Wherever Cassandra (see Pl. XXIX, Fig. 3) and Andromeda grow, marl will not be found even with depth. Bogs with these plant types are numerous in the sandy plains of the county and occasionally also in the areas where the heavier types of soil have developed under conditions of improper drainage. Soiltex tests made in these bogs and also in the soils of the higher surrounding areas always revealed an acid character of soil.

It is natural, of course, to expect that acid bogs should be developed in regions where the ground waters flowing into them have their origin in glacial deposits containing soil of an acid nature. It seems probable that the environmental conditions are the factors which would determine whether lowland areas will develop into marshes or bogs. The type of vegetation which would come into the depression would be influenced largely by the conditions existing in the watershed area of the basin.

Sphagnum moss occurs in lowland habitats and almost always in acidic associations. Occasionally, thin beds of marl are present in the sphagnum-floored depressions, but generally below a thick mantle of muck and peat.

Tamaracks and cedars grow under variable conditions and their presence in the swamps is never a positive index to the occurrence of marl.

Along the lake borders, the growth of Chara and Potomogeton always seems to indicate areas in which marl is in process of accumulation. On the other hand, in regions where lily pads and cat-tails form the bulk of the vegetation, muck and peat with scarcely any marl characterize the deposit.

From observations made in a large number of deposits during the summer of 1926 I am somewhat inclined to discount the importance of Chara as a factor in the formation of thick deposits of marl. It is obvious that Chara is a lime-secreting plant and functions to a certain degree in the accumulation of marl, but many other plants are of equal importance in this respect. Much of the marl, especially the extensive deposits, has formed through the accumulation of animal remains and also through the process of precipitation of calcium carbonate carried into the depressions by surface and ground waters.

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PLATE XXVIII

FIG. 1

FIG. 2

FIGS. 1-2. Lowland areas of marl deposits. The marl in these beds has a thickness exceeding twenty feet and is covered with a mantle of twelve to sixteen inches of muck and peat. The water-table is above the surface of the marl

PLATE XXIX

FIG. 1

FIG. 2

FIGS. 1-2. Upland areas of marl deposits. Terraces of marl a quarter of a mile back from the present stream. The beds contain marl to a depth of six feet and are covered with a few inches of wind-drifted sand

FIG. 3

FIG. 3. A Cassandra bog

THE PROGRESS OF REPLACEMENT AND THE FORMATION OF CONCRETIONS

CHARLES W. COOK

THE problem of the replacement of fragments of rock by the action of mineral-bearing solutions and of its effect upon the shape of the replaced fragment has received considerable attention in recent years. Spurr[1] has emphasized the significance of angular fragments in supporting his theory of ore magmas, while Bateman[2] has shown that angular fragments may be formed by replacement.

Another closely related problem, which has also been the subject of debate among geologists, is the formation of nodules or concretions in shales and sandstones. The preponderance of opinion apparently has favored the theory of a segregation around an original nucleus.

A third problem has to do with the role of diffusion in causing the migration and segregation of minerals.

A specimen which the writer found near Silver Camp, Lewis and Clark County, Montana, appears to offer possibilities of shedding some light on all three of these problems.

DESCRIPTION OF THE SPECIMEN

The specimen to be described (see Plate XXX, Fig. 1) is a cleavage fragment of arenaceous slate or quartzitic schist of pre-Cambrian age. Its general color is yellowish to buff, upon which background is superimposed the red color of the "rings" which it is the purpose of this paper to discuss.

The fragment possesses a pseudo-hexagonal outline and measures from five and a half to six inches between opposite angles and approximately three eighths of an inch in thickness. The pseudo-hexagonal outline of the fragment is suggestive of hexagonal jointing resulting from contraction. I do not believe, however, that the hexagonal outline is more than a coincidence, as it does not seem possible that original mud cracks could have persisted during the metamorphism to which the rock has been subjected. Furthermore, the joint planes make different angles with the plane of schistosity. For example, the angle between the joint plane a (Fig. 23) and the plane of schistosity is 90 degrees, whereas the angle between *b* and the plane of schistosity is 70 degrees. There are apparently three sets of joints, indicated in Figure 23 by *a*, *b*, and *c*, sets *a* and *b* making an angle of approximately 45 degrees with each other; and *b* and *c*, 35 degrees, thus accounting for the pseudo-hexagonal outline.

The "rings" which are due to segregations of hematite are the feature of most striking interest in the specimen. These may be seen in Plate XXX, Fig. 1, which is a photograph of the specimen or perhaps better in Figure 23 which is a rather accurate drawing of the specimen, in which the shaded portions represent the red color of the hematite, the heavier shading representing the more intense color. The features of the "rings" to which I wish to direct attention are: (1) the tendency to follow the joint form in the outer "rings"; (2) the tendency to assume an elliptical form in the central portion; (3) the fact that the inner margin of the outer broad band conforms to the angularity of the fragment more closely than does the outer margin of the band; and (4) the banded or zonal distribution of the hematite, giving the appearance of Liesgang rings. It should also be pointed out that these "rings" are not a surface feature, as they are observable on both sides of the fragment. Plate XXX, Fig. 2, is a photograph of the reverse side of the fragment, the surface of which has been produced by grinding in order to prove definitely that the "rings" are not a surface feature.

ORIGIN OF THE "RINGS"

In attempting a satisfactory solution of the problem of the origin of the "rings," the normal method would be to determine first the source of the iron. Was the iron originally present in the rock and subsequently segregated into the "rings," or has it been introduced from the outside by circulating waters? If the iron was originally present, have the "rings" been formed by the segregation of disseminated iron compounds or by rearrangement of preexisting concentrations?

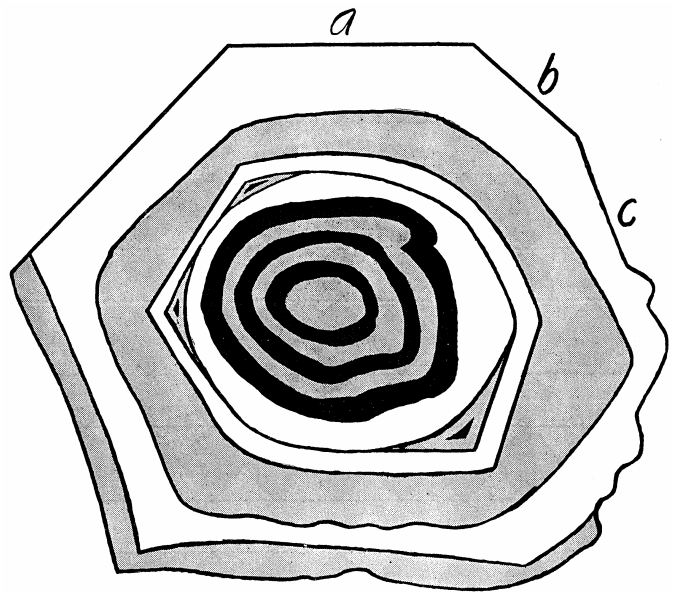

FIG. 23. A line-drawing of the fragment shown in Plate XXX, Fig. 1. The degree of shading indicates the intensity of the iron coloration of the "rings."

The slates of the area are for the most part gray to blue to black, becoming yellowish to buff on weathering and therefore indicating the possible presence of iron compounds, but scarcely in sufficient amounts to account for the amount of hematite which has been concentrated in the specimen. The possibility that this

represents a rearrangement of an original concentration, such as a pyrite nodule or ironstone concretion, in the premetamorphic rock, does not receive much support from field evidence. No such concretions were found in the rocks from which the specimen was obtained. Although this does not disprove the former presence of iron concretions, it does cast doubt upon it. Further the writer is unable to account for the fact that the inner margin of the outer band conforms more closely to the shape of the fragment than does the outer margin, on the basis of an original iron concretion, the iron of which has been subjected to disseminating action by solutions. Moreover such action is contrary to the general tendency of solutions, which is toward concentration rather than dissemination.

As to the possibility of the iron having been introduced from an outside source, its segregation along the joints in the slate is suggestive, although this segregation may have occurred during weathering. The slates of the area have been intruded by both basic and acid igneous rocks and numerous veins and veinlets carrying metallic sulphides have been formed, those showing only pyrite predominating. This suggests a possible source for the iron-bearing solutions. It is to be concluded, therefore, that the evidence, although not definitely positive, favors an outside source.

If we assume that the iron has been introduced from an outside source by solutions circulating along the joint planes, what is the mechanics of its introduction into the fragment which will account for the phenomena shown by the "rings"? Since the iron is not concentrated along fractures in the slate fragment, it must have been introduced through capillary openings. And since the concentration has been toward a single point, concentration by circulating solutions could not have occurred. Therefore, the iron must have been introduced by diffusion from the solutions circulating along the joint planes.

If the iron were present in the joint solutions in the form of the ferrous salt, such as the ferrous bicarbonate, oxidation, either before or after deposition, would be necessary in order to give the hematite "rings." Since there is no evidence of an oxidizing agent which might have caused the iron to be deposited in the ferric form originally, the oxidation of the iron, if it occurred, would most likely have been subsequent to the original deposition. There is no evidence that such subsequent oxidation has occurred.

As already mentioned, there is evidence in the district of the deposition of pyrite from solutions probably of magmatic origin. Becker,[3] Doelter[4] and others have stated that pyrite may be transported in the form of the sulphide in solutions of alkali carbonates and sulphides containing an excess of carbon dioxide. According to Stokes,[5] the following reversible reaction is possible:

$8FeS_2 + Na_2CO_3 = 4Fe_2O_3 + 14Na_2S + Na_2S_2O_3 + 15CO_2$.

Since this is a reversible reaction, the direction in which it will proceed is dependent upon the addition or abstraction of compounds from the system and possibly upon temperature changes.

As already indicated the evidence points to the fact that the iron could have been introduced only by diffusion. Therefore the other substances in solution with the iron would likewise diffuse from the joint openings into the fragment. Since the rate of diffusion differs with both the substance and the concentration of the substance, at a given distance from the point of diffusion the ratio of the dissolved substances would be changed. This might result in supersaturation with respect to certain compounds, a reversal of the reaction, and the precipitation of hematite.

The precipitation of hematite would be accompanied by the formation of sodium sulphide, which would pass into solution, and the liberation of carbon dioxide which would tend to dissolve the silica, thus permitting its replacement by iron. The points at which the precipitation would occur should tend to form a line parallel to the joint planes. From this line the sodium sulphide liberated would diffuse both toward the joint planes and toward the center of the fragment. That portion of the sodium sulphide diffusing toward the joint planes would tend, first, to decrease the diffusion of the sodium sulphide from the solution in the joint plane, and secondly, to stop the precipitation of the hematite or even to dissolve some of the hematite already precipitated. That portion of the sodium sulphide which would diffuse toward the center of the fragment while the hematite was being precipitated would be establishing conditions unfavorable to the deposition of hematite, so that the iron would pass through a certain zone before supersaturation would again develop and a second deposition of hematite occur. This process would be repeated periodically with a narrowing of the zones of deposition and non-deposition until the center of the fragment was reached, the zones tending to become elliptical because of the elongation of the fragment and the increasing distance from the influence of the joint-form. Since certain cleavage planes would function as circulation channels in the plane approximately at right angles to the joint planes and since the spacing of these would tend to be greater or less than the spacing of the joint planes, the resulting depositional form would be either elongated or flattened in this dimension.

The phenomenon of rhythmic banding, known as Liesgang[6] rings, which the "rings" in this fragment suggest, has been shown experimentally to occur when an electrolyte penetrates a gel and precipitation takes place. Ostwald[7] suggested that this is due to recurrent periods of supersaturation. More recently Bradford[8] has advocated the theory that the rings are adsorption phenomena and has opposed the supersaturation theory. All the experiments in connection with this rhythmic banding have been carried on in the presence of colloids and the implication is that the phenomena are

related to colloids. In the case under discussion there is no evidence of the presence of colloids. For that reason the phenomena have been explained on the basis of reactions resulting from differential diffusion of substances in the same solution which give rise to recurrent periods of supersaturation. In the experimental work the reacting substances have been introduced in different solutions, which have been brought into contact by diffusion through a colloid gel. May it not be the case that the action is not a phenomenon specifically related to colloids, but that they supply conditions which make possible the use of stronger solutions and shorter periods of time than is necessary in the case of geological phenomena?

In his monograph on the Ray and Miami, Arizona districts, Ransome[9] shows an excellent example of the "rings" in a quartzite. As to the origin, he believes that they have been formed during weathering and says:[10] "The coloring matter of the concentric rings is iron oxide, and the pattern was apparently produced by rhythmic alternations of solution and precipitation of the iron along joints in the quartzite." No reasons for these assumptions are given.

CONCLUSIONS

From a consideration of the facts and interpretations presented, it may be concluded that:

1. In the replacement of fragments by circulating solutions, the action may begin at some point within the fragment rather than at the margins, if the primary chemical reactions involved take place between compounds all of which are in solution, instead of occurring at the contact between the solutions and the wall rock.

2. When the replacement is of this type, the reaction begins at the point at which the distance from the source of the diffusing substances is sufficient to permit diffusion so to change the composition of the solution that precipitation will occur.

3. The extent to which the original form influences the shape of the replaced fragment is a function of the distance from the margin at which the reaction takes place and the angles between the faces of the fragment. That is to say, if precipitation occurs before the lines of diffusing ions from different faces meet, the deposit will tend to take the form of the fragment. Beyond that point the tendency is to produce a spherical form. The resulting form, however, will generally be that of an oblate ellipsoid, since the fragment will rarely be a perfect cube.

4. Concretions do not necessarily represent segregations of minerals around an original nucleus, but may result from the rhythmic deposition of minerals, the constituents of which have diffused from solutions in joints and bedding planes, the shape of the concretions being determined by the spacing of these planes.

5. An apparent nucleus may represent merely an unreplaced portion of the original rock.

6. In a specimen in which segregation around a nucleus has occurred, the nucleus itself may have been formed first by segregations due to differential diffusion of reacting substances in the same solution.

UNIVERSITY OF MICHIGAN

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PLATE XXX

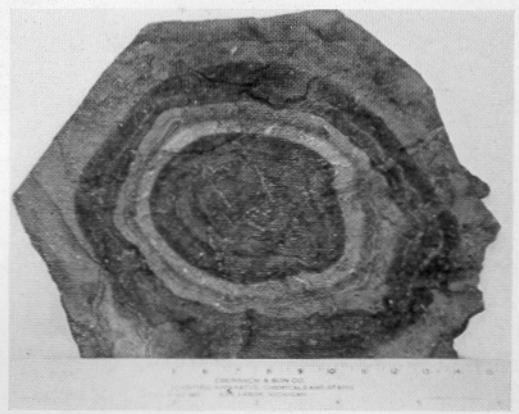

FIG. 1

FIG. 2

THE CARBONIFEROUS FAUNA OF GRAND LEDGE

WILLIAM A. KELLY

IN THE spring of 1926 Professor S. G. Bergquist and I discovered a few marine fossils in an outcrop on the right bank of the Grand River just below the railroad bridge. The small collection made at that time was augmented by later collections from what appears to be the identical horizon exposed in the Briggs quarry, a short distance downstream from the place of original discovery. To date no systematic search has been made for fossils, but the results of several collecting trips in the past promise a comparatively large marine fauna. Although the outcrops at Grand Ledge are mentioned in some of the reports issued by the Michigan Geological Survey, I have not seen any references to a fauna consisting of more than a few forms. The preliminary study I have been able to give to the fauna has produced very few results, other than to show that a marine invertebrate fauna, consisting of at least a dozen species, is present. In the hope, however, that helpful suggestions for further study may be received, and also because of the interest that a new occurrence of Carboniferous fossils in Michigan may have, I am presenting what information I have been able to obtain.

There are two fossiliferous horizons containing marine faunas represented in the vicinity of Grand Ledge. The lower horizon, a dark, compact shale, is found on the south side of the Grand, in the bottom of a quarry worked by the Grand Ledge Clay Products Co. The only fossil I have found there is a species of *Lingula*, which appears to satisfy the written description of *L. umbonata* Cox given in the Thirteenth Annual Report for Indiana, Part II, p. 120, although it does not agree very closely with the plate figure of that species given in the same report.

The higher, and more interesting horizon, occurs on the north side of the river in the localities mentioned previously. The fossils are in a bed of black, compact, calcareous shale, interbedded with fissile shales. The fauna is made up principally of brachiopods, which are generally rather poorly preserved, the preservation in some instances being by pyritic replacement.

Thus far I have been able to identify the following forms:

A small cup coral
Crinoid stems
A ramose bryozoan
Echinoconchus (*Productus*) cf. *biseriatus* (H.)
Echinoconchus sp., undet.
Marginifera (*Productus*) cf. *muricata* (N. & P.)
Orthothetes cf. *crassus* M. & H.
Productus cora d'Orbigny
Productus cf. *costatus* (Sowerby)
Productus sp., undet.
Pustula (*Productus*) *nebraskensis* (Owen)
Schizophoria sp., undet.
Spirifer aff. cameratus Morton
Griffithides scitulus (M. & W.)

This list has an undoubtedly Pennsylvanian aspect. It is possible that a closer study of the fauna of Grand Ledge will enable one to make a much closer correlation, and to restrict the zone to a definite horizon. This will involve a more intensive study of the literature of this and adjoining states than I have been able to devote to it.

Thus far I have laid stress upon the species of the most common genus, namely *Productus*, and its subgenera *Echinoconchus*, *Marginifera* and *Pustula*. Of the fauna, *Productus prattenanus*, which Schuchert gives as a synonym for *P. cora*, is reported from the Lower Verne near Mercer by Lane.[1] *Marginifera muricata* is also reported from this horizon. I have been unable to secure a good description or plate figure of this form, and therefore cannot be sure of my identification.

In the vicinity of Owosso, a small fauna, including species of *Productus*, *Spirifer*, crinoid stems and *Zaphrentis*, as well as others not found at Grand Ledge, is reported by Rominger.[2] The fossils there occur partly in calcified, partly in pyritous, condition, and are found in a black shaly lime rock. The description given of the Owosso occurrence might almost hold true for the Grand Ledge occurrence, and is suggestive of correlation, when the genera common to both localities are taken into account.

It will be noticed from the list of fossils that I have given that many of the species are compared with known species or are represented as undetermined. The resemblances in many specimens are very strong, and I do not expect that any new species will be described from the Grand Ledge fauna. In the identification of *Orthothetes crassus* there is a large element of doubt, since the form I have compared to it is represented only by outer molds, and the comparison has been based principally upon external ornamentation. *Productus cora* and *Marginifera muricata* are the two most common species. As stated before, I am uncertain of the identification of the second species. *Productus costatus* may not be present in the fauna. If it is, it is a form with finer costae than are usually associated with that species. The specimen of *Schizophoria* is represented by a fragment of a brachial valve and a few imprints of entire valves. The brachial valve is strongly ventricose and possesses a short hinge-line. The surface is covered by fine striations, crossed by a few concentric growth-lines near the lateral border. Distinct punctae can be seen on the striations. Only one specimen of a spire-bearer has been collected. It is imperfectly preserved, but suggests the fasciculate character of the plications characteristic of *S. cameratus*. The subclass, trilobita, is represented by a single pygidium. The nature of preservation is such, however, as to make identification fairly certain.

I have no doubt that the fauna of the upper marine horizon, which is represented today by fourteen species,

will be increased when careful collecting is done. I think, too, that a comparison of this fauna with material available from other Carboniferous horizons, such as the one at Owosso, will reveal many forms in common and be a step toward the elucidation of the stratigraphy of the Pennsylvanian of Michigan.

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GEOLOGIC STRUCTURE OF A SMALL AREA IN WAYNE, PULASKI AND RUSSELL COUNTIES, KENTUCKY*

DONALD C. MAcLACHLAN

INTRODUCTION

Location and Size of Area

THE area discussed in this paper is in the south-central part of Kentucky and is that part of the northeast quarter of the Monticello Quadrangle situated north of an east-west line extending through Mill Springs on the Cumberland River. The area is reached most easily from Burnside, Kentucky, which is twelve miles northeast of Mill Springs and is the nearest railroad station. A motor bus line connecting Burnside with Monticello runs through Mill Springs and serves as a convenient means of reaching the area.

Purpose and Methods of Study

The purpose of the study was to determine the nature of minor geological structures in the area. To this end the top of the Chattanooga shale was selected as a key horizon. This selection was made because the Chattanooga shale is the one formation in the region that may be immediately and positively identified by its lithological characteristics, since contacts between it and the formations above and below it are very sharply defined, and since the outcrops are always at or near the bottoms of the creek beds where they are accessible for accurate instrument readings.

Detailed observations were made on all exposures of the Chattanooga formation. In places where the Chattanooga was not exposed, but where there were marked changes in the direction or degree of the dip of the accessible beds, strike and dip data were secured and the results used to supplement the determinations made on the Chattanooga. Numerous strike and dip readings and elevations were made on the Beaver Creek "sand," a readily identified bed of siliceous limestone in the New Providence shale. This "sand" served as an excellent substitute key bed, owing to the fact that its base is 40 to 45 feet above the top of the Chattanooga throughout the area.

SURFICIAL GEOLOGY

The Cumberland River, flowing through the area from east to west in a series of meanders, has cut a steep-walled valley through which the stream runs normally at about 590 feet above sea-level, while the general level of the upland is between 850 and 1000 feet above sea-level. The relief of the land in the north and the northwest part of the area is strikingly different from that to the southeast. In the north and northwest the relief is the result of the close dissection by streams which have carved steep-sided valleys and ravines leading back from the incised Cumberland. By contrast, in the southeast part of the area and in the region immediately beyond, the upland is generally flat, modified only by shallow sinks and a few hills that rise to a height of about 400 feet above its surface. This general character of the topography suggests former base-leveling and rejuvenation, so that now the Cumberland River is flowing some 300 feet below its old valley flat. In the southeastern part of the area the rocks of the upland are largely pure limestone; consequently, the water which falls there readily seeps below the surface, with the result that a system of underground drainage has been developed leaving the surface of the upland but slightly modified by erosion. On the other hand, in the north and northwest, the rocks are much more argillaceous and the water runs along the surface and down the short slopes toward the Cumberland, thus effecting the close dissection of the land.

STRATIGRAPHY

General Statement

The rocks of the area have a general dip to the southeast, owing to the fact that they are on the southeastern limb of the Cincinnati geanticline, the crest-line of which is several miles to the northwest of the area. As a result of the southeastward dip one encounters successively younger formations at the same level in going from the northwest to the southeast part of the area.

Most of the rocks of the area are of Mississippian age, but at some places along the Cumberland River and in a few of its tributary valleys older strata, Ordovician and Silurian, are exposed. To the south of the area Pennsylvanian strata are present at the surface. On the top of Big Hannah Hill, immediately south of the limits of the area and about two miles west of Mill Springs, the youngest Mississippian formations of the region are overlain by a thin covering of Pennsylvanian rocks.

Southeastward from Big Hannah Hill the Pennsylvanian section thickens and progressively younger beds appear at the surface.

Description of Formations

Richmond limestone. — The oldest rocks of the area belong to the Richmond formation, which is included in the Ordovician system by some geologists and in the Silurian by others.

One of the best exposures of the Richmond is on the face of Shinbone Cliff a short distance below the mouth of Cub Creek. The lower part of the formation at this place consists of thin, even-bedded, greenish-gray limestones containing ripple marks and mud cracks. The upper half or more of the formation consists of uneven-bedded, greenish to brownish-gray, argillaceous limestones with a few thin intercalated layers of shale. The nodular appearance of the weathered surfaces of these beds readily distinguishes them from the even, ripple-marked beds below. A few of the argillaceous limestones contain fossils which are diagnostic of the Richmond.

According to Doctor Aug. F. Foerste,[1] the Richmond at the mouth of Little Cub Creek, which is probably the same locality as that mentioned above, has a thickness of 19 feet. Measurements made by the writer indicate, however, that the thickness is about 46 feet. Excellent exposures of Richmond also occur along Forbush Creek, beginning at a point about one mile above its mouth and continuing for a distance of two miles upstream. The beds here are similar lithologically to those exposed on the face of Shinbone Cliff. At some places along the creek the upper 4 to 5 feet of the Richmond consists of even-bedded, greenish-gray limestones similar to those of the lower part of the formation.

Brassfield limestone. — The Richmond is overlain disconformably by the Brassfield limestone of lower Silurian age. This limestone is magnesian, somewhat arenaceous, thick-bedded and light brownish to reddish-gray. It is well exposed on the face of Shinbone Cliff about 300 feet south of Cub Creek. On the northeast limb of a small anticline at this place the greatest thickness shown is 9 feet 4 inches. Although the top of the limestone is not shown it is doubtful whether the total thickness is much greater.

Excellent exposures of the formation occur also along Forbush Creek and its tributaries. About half a mile above the mouth of Forbush Creek and just below the mouth of the first tributary entering the creek from the north, 15 feet of the limestone is shown, the basal part of the formation not being visible. The total thickness at this place is probably not greater than 17 feet.

Crab Orchard shale and limestone. — Overlying the Brassfield is a greenish-blue shale with intercalated thin layers of limestone which Dr. Aug. F. Foerste at first[2] assigned to the Osgood formation and later[3] placed in the Crab Orchard division of the Niagaran. The Crab Orchard, according to Dr. Foerste's classification,[4] includes the Indian Fields formation below and the Alger formation above. The Indian Fields formation contains two members, the Plum Creek clay below and the Oldham limestone above, and the Alger formation three members, the Lulbegrud clay at the base, the Waco limestone above and the Estill clay at the top.

Certain limestones in eastern Kentucky, which lie below the typical Plum Creek clay but still may be considered as a part of the Plum Creek clay member of the Indian Fields formation, contain *Whitfieldella subquadrata* Foerste. Frequently associated with this brachiopod are water-worn crinoid or cystid columnals and other fossils which, as stated by Dr. Foerste,[5] were originally included in the Brassfield limestone and subsequently incorporated in the basal beds of the Plum Creek clay.

According to Dr. Foerste,[6] 17 feet of Crab Orchard shale and limestone with remains of *Whitfieldella subquadrata* at the base rest upon 15½ feet of Brassfield near the mouth of Little Cub Creek. In the valley of Forbush Creek near the house of William Richardson, which apparently is the house now occupied by Mr. W. L. Scott, this writer[7] reports a thickness of 1½ feet of Crab Orchard.

The present writer did not observe as great a thickness of the Crab Orchard as did Dr. Foerste, owing to the fact that these exposures were either covered with talus or were not found by him.

The only exposures noted by the writer were located in the bed of Cub Creek about 200 feet north of the Russell-Wayne county line and in the bed of White Oak Creek about mid-way between the mouths of Laurel Fork and Lick Branch. At each locality only 18 inches of interbedded green shale and greenish-gray to buff limestone is exposed.

Chattanooga shale. — Unconformably overlying the Ordovician or Silurian formations is the Chattanooga shale of Mississippian age. This shale, the most easily recognized formation in the area, is thin-bedded and exceptionally well jointed (see Pl. XXXI). It is bituminous and contains scattered crystals of pyrite. Certain layers contain numerous remains of *Lingula* closely related to or identical with *Lingula melie* Hall. The formation is from 30 to 40 feet thick in most places where its entire thickness is exposed. The greatest thickness observed was 42 feet on the face of Shinbone Cliff.

A brown sandy formation quite commonly occurs at the base of the Chattanooga. In most places this sandy layer is only 1 or 2 inches thick, but in one locality, in a tributary that enters Forbush Creek about one-half mile above its mouth, the formation has a thickness of 3 feet.

New Providence shale. — The New Providence formation lies disconformably upon the Chattanooga shale and has a uniform thickness of from 80 to 100 feet

throughout the area. It is characterized by having three distinct parts. The lower part consists of thin, uneven-bedded, greenish-gray shale about 40 feet in thickness. Above this is a massive, uneven-bedded and very hard siliceous limestone. It is pinkish-gray and contains irregular masses of chert (see Pl. XXXII, Fig. 1). This bed, the so-called Beaver Creek "sand," is about 5 to 10 feet thick and is important physiographically because of its tendency to form water-falls (see Pl. XXXII, Fig. 2). It has been given the name "sand" because it is an important oil-bearing formation in central and southern Wayne County. The upper part of the New Providence ranges in thickness from about 35 feet to 50 feet and is quite similar to the bottom part in its lithological characteristics.

Near the base of the New Providence phosphate nodules are common. Most of these nodules are about the size of hickory nuts but some, usually elongated, have a length of from 3 to 4 inches.

Fort Payne formation. — The Fort Payne formation seems to lie conformably on the New Providence. The measured thickness ranges from 100 feet to 124 feet. The lesser thickness was measured in the northwestern part of the area in a tributary to Cub Creek and the greater thickness on the bluff of White Oak Creek about one quarter of a mile below the mouth of Lick Branch. On Shinbone Cliff and along the road north of the mouth of Forbush Creek the thickness of the Fort Payne is 115 feet.

The beds of the Fort Payne are primarily limestones which vary greatly in their lithological characters. Interbedded with the limestone beds are numerous thin, irregular layers of chert with occasional beds of shale. Thin, uneven-bedded, greenish-gray argillaceous limestones containing numerous quartz geodes are particularly characteristic of the formation.

Warsaw formation. — The Warsaw lies disconformably upon the Fort Payne. Its thickness ranges from about 40 feet, in the northeastern part of the area, to about 140 feet near the Bench Mark west of Shinbone Cliff. In the western part of the area, north of the Cumberland River and between Forbush and Cub creeks, there is a uniform thickness of between 100 and 110 feet, with a small amount of thickening southward. East of Forbush Creek there is a pronounced thinning toward the head of Lick Branch from all directions.

The Warsaw formation consists of limestones and shales of varied lithological character, some of the limestones grading horizontally into shale. Quartz geodes are common in some of the limestone beds. In many localities in the southwestern part of the area thick beds of bluish-gray shale make up a large part of the formation.

St. Louis limestone. — A disconformity separates the Warsaw from the St. Louis above. The St. Louis forms the surface of the upland south and east of White Oak Creek, increasing in thickness from a few feet along White Oak Creek to over 100 feet in the southeastern part of the area. North and east of White Oak Creek it occurs only near the tops of the highest elevations.

Massive beds of pure limestone are predominant in the St. Louis formation. Limestone sinks and red soils with numerous nodules and irregular masses of chert derived from the weathering of the limestone characterize the upland where the St. Louis is at the surface.

St. Genevieve limestone. — The St. Genovieve limestone overlies the St. Louis formation on the tops of Rankin Knob and the high elevation between Dry Branch and Cub Creek. The formation is composed of beds of oolitic limestone and is the youngest formation in the area. The St. Genevieve is 30 feet thick between Dry Branch and Cub Creek and about 100 feet thick on the top of Rankin Knob.

Formations south of the area. — South of the area studied younger beds of Mississippian age intervene between the St. Genevieve formation and the Pennsylvanian strata. These younger Mississippian rocks are the Gasper, Glen Dean and Pennington formations.

STRUCTURE

General Statement

In general the strata of the region dip gently southeastward away from the axis of the Cincinnati geanticline. This average condition is markedly modified by a number of minor structures the general characteristics of which are defined by the undulations of the top of the Chattanooga shale (see structure map, Fig. 24).

In the northeastern part of the area there is a pronounced nose or dome, the summit of which is near the head of Lick Branch. Between this dome-like structure and Cub Creek, north of the Cumberland River and the lower course of Forbush Creek, the top of the Chattanooga shale presents the appearance of an unbroken plain sloping gently southward. There is an elongated dome south of the mouth of Forbush Creek, a second small dome west of Shinbone Cliff and a fault immediately to the west of the mouth of Cub Creek.

Local Features

The most prominent structural feature in the area is the dome in the northeastern part. The surface of this dome is modified by terraces and noses. The average dip of the top of the Chattanooga shale, measured down the southeastern slope of the dome from near the head of Lick Branch to White Oak Creek, is 150 feet to the mile (about 1° 38'). Locally, in several places, the dip of the strata is more than 6 degrees in the direction of the general slope of the structure and in Lick Branch the Chattanooga shale has such a dip of about 20 degrees.

Immediately above slopes of this nature the beds are virtually horizontal and in some places seem to have a slight dip in the opposite direction. These local accentuations of the slopes of the structure disclose the terraces and noses that vary its surface.

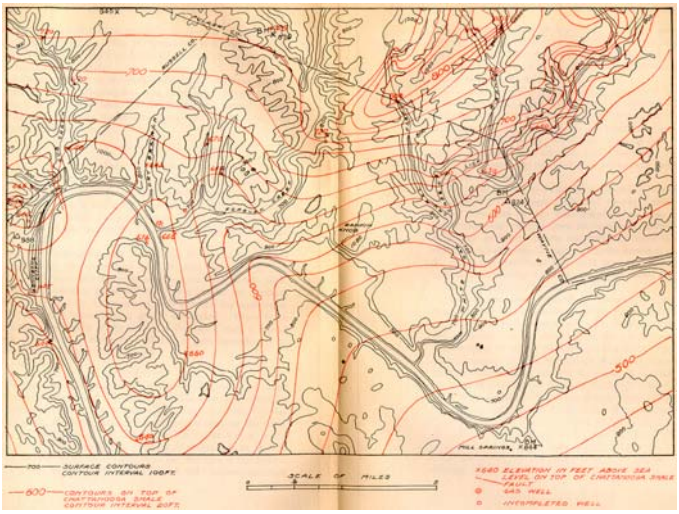

FIG. 24. STRUCTURAL MAP OF PARTS OF WAYNE, PULASKI AND RUSSELL COUNTIES, KENTUCKY, SHOWING, IN RED, CONTOURS ON THE TOP OF THE CHATTANOOGA SHALE

The most conspicuous nose on the structure is in the northeastern part of the area at the juncture of the two forks of White Oak Creek. On the front or east slope of the nose there is a dip of 15 degrees. This dip was observed along the road on the west side of the creek. About one quarter of a mile west of the creek and at an elevation of 120 feet above the creek the strata are nearly horizontal. On the north side of the nose there is a dip of 7 degrees northwest.

The west slope of the dome is suggested by the elevations of outcrops of Chattanooga shale and Beaver Creek "sand" in Laurel Fork and by dip determinations on beds of the Fort Payne along the tributary from the northeast, which joins Laurel Fork near its head. Along this tributary there is an average westward dip of nearly 2 degrees. At the mouth of the tributary the dip of the Fort Payne beds is 11 degrees west and about 300 feet upstream the dip is 7 degrees east, indicating the presence of a nose on this slope of the dome.

Another prominent structure of the area is a low, elongated dome, the top of which is south of the Cumberland River opposite the mouth of Forbush Creek. The outlines of this dome are well established by the elevations of the top of the Chattanooga shale exposed at several places on the structure. The highest observed exposure of the Chattanooga shale is on the south side of the Cumberland valley opposite the mouth of Forbush Creek, the elevation of the top of the shale at this point being 676 feet.

A third dome is present immediately west of Shinbone Cliff. The highest point noted on the structure was observed in the more southern of the two ravines entering the valley back of the north end of Shinbone Cliff from the west. The elevation of the top of the Chattanooga shale in this ravine is 685 feet.

A normal fault occurs across the nose of Shinbone Cliff a short distance below the mouth of Cub Creek. The strata displaced belong to the Richmond, Brassfield and Chattanooga formations. The strike of the fault plane is north 22 degrees west and the dip is 89 degrees northeast. The vertical displacement of the bottom of the Brassfield is 15 feet 6 inches. On the northeast or downthrow side of the fault the bottom of the Brassfield is about 28 feet above the low water level of the river. The strike of the Brassfield on this side of the fault is north 60 degrees west and the dip is 22 degrees northeast. Northeastward from the fault the angle of dip lessens perceptibly and near the mouth of Cub Creek, where the Brassfield is at the level of the river, it is only 9 degrees, indicating that the displacement along the fault plane was accompanied by considerable drag on the downthrow side. On the southwest side of the fault the bottom of Brassfield is about 43 feet above the river. At this place the thickness of the Brassfield is 8 feet 10 inches, with a covered interval of 10 feet between the top of the formation and the Chattanooga shale.

On the south facing slope of the valley back of Shinbone Cliff there is an exposure of the Chattanooga in which the beds have a steep dip to the northeast as they have on the face of Shinbone Cliff northeast of the fault. Apparently the fault does not extend more than a short distance beyond this point, because the beds of the Chattanooga shale, where exposed along the creeks a short distance farther north and northwest, are nearly flat and show no indication of faulting. South of the Cumberland River no evidence of the fault could be found.

Rocks younger than the Chattanooga shale are not exposed at any place where the fault was observed; hence, the time of the faulting cannot be determined.

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DETROIT, MICHIGAN

* The field equipment consisted of a government topographic map, a Brimton compass, a hand level and an aneroid barometer.

[1] Foerste, Aug. F., "The Cincinnati Anticline in Southern Kentucky," *The American Geologist*, 30: 365. 1902.

[2] *Op. cit.*, pp. 361-362.

[3] Foerste, Aug. F., "The Silurian, Devonian and Irvine Formations of East-Central Kentucky," *Kentucky Geol. Surv.*, Bull. 7, pp. 114-115. 1906.

[4] *Op. cit.*, p. 18.

[5] *Op. cit.*, pp. 36-38 and 44-45.

[6] Foerste, Aug. F., "The Cincinnati Anticline in Southern Kentucky," *The American Geologist*, 30:362, 1902, and "The Silurian, Devonian and Irvine Formations of East-Central Kentucky," *Kentucky Geol. Surv.*, Bull. 7, pp. 114-115, 1906.

[7] As quoted in the first reference of note 6.

PLATE XXXI

FIG. 1. Typical exposure of Chattanooga shale, showing laminated character of the formation. View taken along tributary stream of Forbush Creek

FIG. 2. Jointing in Chattanooga shale. View taken along tributary of Coldweather Creek near juncture of Cold weather and Fishing creeks about seven miles northwest of Somerset, Kentucky

PLATE XXXII

FIG. 1. Weathered surface of Beaver Creek "sand" member of New Providence shale, showing characteristic irregular masses of chert of this member. View taken on slope above house of Mr. W. L. Scott near mouth of Forbush Creek

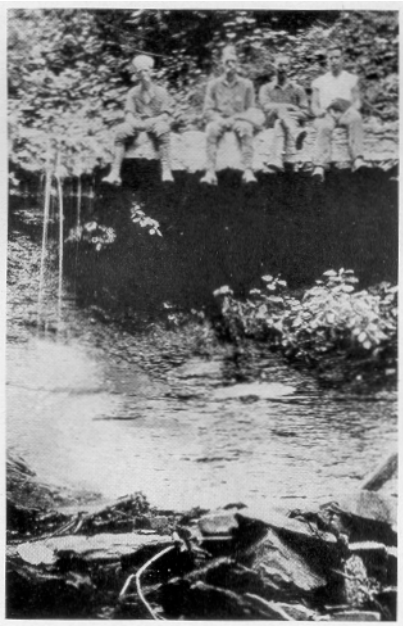

FIG. 2. Lower part of New Providence shale and capping bed of Beaver Creek "sand." View taken in tributary of Laurel Fork about one and one-quarter miles north of White Oak Creek

STRATIGRAPHY OF CHIPPEWA COUNTY, MICHIGAN

WALTER A. VER WIEBE

THE data presented in the following pages are based upon material collected and work done during the summer of 1926. The field-work was conducted as part of an inventory of the natural resources of Chippewa County made by the Land Economic Survey of Michigan.

LAKE SUPERIOR SANDSTONE

The oldest Paleozoic formation exposed in Chippewa County is a sandstone of variable thickness and character. At one time it was the subject of a great controversy in which European as well as American geologists were involved. Even now the age of this formation is not satisfactorily defined. Fossils from the Lake Superior sandstone were reported by a number of geologists, but none of these were found *in situ*. The writer feels, therefore, that he was particularly fortunate in 1926 when he came upon some fossils in the Lake Superior sandstone at Sault Point. They were sent to Dr. Ulrich for identification. He states that they belong to the genus *Ophileta* and that probably three species are represented. In his opinion the rocks are of Canadian or Ozarkian age. In this connection see Rominger[1] regarding *Ophileta levata* in conglomeratic limestone blocks.

Outcrops in Chippewa County. — In Chippewa County outcrops of the Lake Superior sandstone are not numerous. The most extensive outcrops appear in the Taquamenon River, about fourteen miles above its mouth. The rock is a nearly pure, siliceous sandstone in thin beds, and with considerable cross-bedding. About fifty feet of rock is exposed in the rapids. In the upper falls of the Taquamenon another sixty or seventy feet of sandstone appears. This section is more variable than in the lower falls, showing some soft sandstone, some coarse layers, some shaly layers, and some deep red shale layers.

Another outcrop of considerable extent is the one in the rap ids of the St. Mary's River at Sault Ste. Marie. The most interesting outcrop in the county, however, appears along the shore-line of Lake Superior at Sault Point. The outcrop begins near the northeast corner of Section 30, T. 47 N., R. 4 W., and extends almost to the north line of Section 19. There is a total thickness of about fifteen feet exposed in this distance. At the base the sandstone is soft, greenish, shaly and thin-bedded. One foot above the base *Ophileta* occur in considerable numbers in a soft, friable, sandy matrix. Above this level the sandstone is harder, but irregularly bedded. The best way to reach this locality is to set out from the Dollar Settlement. A passable sand road leads along the shore to Pendell's Creek. From there a trail runs north to the lake, whence easy travelling will take one to the outcrop.

The thickness of the sandstone varies greatly, because it fills the depressions in a late Algonkian land surface, which appears to have been quite rugged. In the well drilled by A. W. Palmer for the American Alkali Co. near Sailors' Encampment Island, T. 45 N., R. 2 E. (Section 36 ?), the sandstone is 194 feet thick. The upper 161 feet is white and the lower 33 feet red. In the Pickford well the thickness is uncertain; it may be 800 feet, but is probably less.

ORDOVICIAN ROCKS

The rocks which can be assigned to the Ordovician system were found and described at an early date. In Jackson's report of 1847[2] Locke describes the outcrops in the St. Mary's River at the lower Neebish rapids. Robert Bell states on page 111 of his report for 1869[3] that "the Trenton strikes and enters Michigan at Neebish Island"; and, on page 113, that "on the north side of Drummond Island the upper beds of the system are exposed which as usual are of a massive calcareous nature and form a strip about seven miles long and two broad." Rominger in his report of 1873[4] describes the outcrops quite completely on pages 54-79.

Black River (?) of Chippewa County. — The author of this paper is inclined to believe that the formations of the lower part of the Ordovician will be found to differ somewhat from west to east across the Upper Peninsula. He has studied the formations in Menominee County as well as in Chippewa County and believes that the typical part of the Calciferous of Rominger, called Hermansville in Menominee County, is missing farther east. Few fossils are to be found in the Hermansville, but its lithologic character is very distinctive. It is a coarse, sugary, friable, porous dolomite, with greenish cavity filling at many places. Such a rock is not to be found in Chippewa County. Not only are there no outcrops of such a rock, but also no trace of such a rock is to be found in the rather numerous drift boulders.

Instead of the Hermansville, a different kind of rock appears below the Trenton. It is a fairly hard dolomite, of dark grey color, which breaks into large rectangular pieces and which can readily be distinguished from the typical Trenton. E. O. Ulrich and G. M. Ehlers have examined this rock and its contained fauna at the upper end of the Neebish channel cut and consider it to be the probable equivalent of the Black River.

Waiska River outcrop. — The most remarkable outcrop of Black River is in the Waiska River southwest of the village of Brimley in the northwest quarter of Section 29, T 46 N., R. 2 W. The river runs over rapids which begin close to the section-line between sections 29 and 30 and extend toward the east for about half a mile. Toward the eastern end of the rapids the solid ledges of limestone may be seen, but farther west they are obscured by alluvial material and fallen blocks. The two or three feet exposed may be described as very massive and hard limestone. It resembles the lower part of Rominger's

Trenton, as revealed in the Menominee River, more closely than any rock seen in the Upper Peninsula. Some fossils are present. The river has cut down through the Algonquin lake clay nearly 50 feet along the rapids. At one point the river has bared an ancient wave-cut cliff. In this cliff additional layers of the Black River may be seen, but in a peculiarly jumbled condition. The cliff looks as though it had been undercut by waves and large blocks of the overhanging portion had tumbled down. In the upper part of the cliff the typical Trenton limestone crops out.

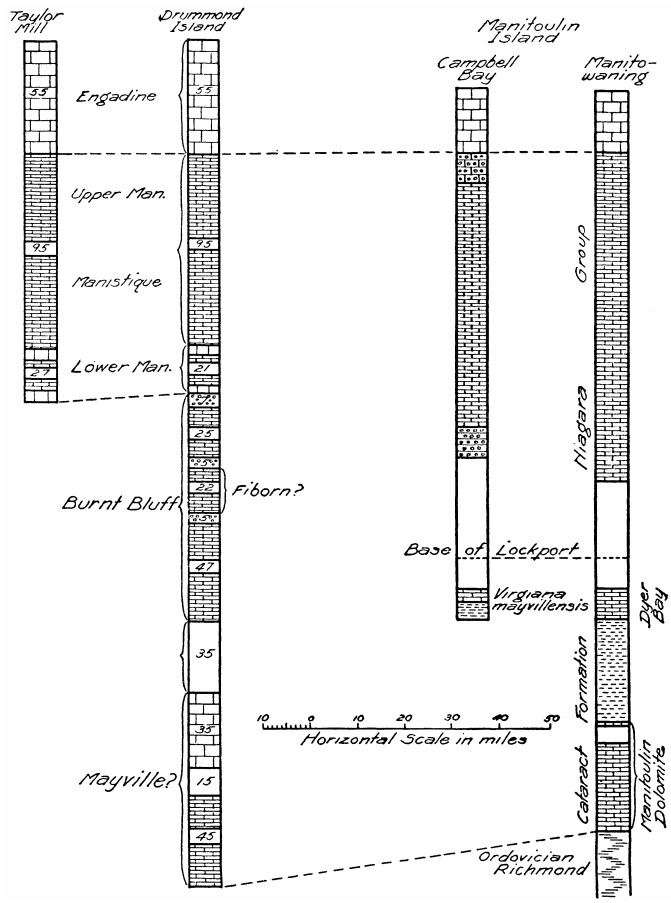

FIG. 25. Stratigraphic sections to illustrate Silurian rocks in Chippewa County and to show correspondence with the Silurian of Ontario

Neebish Island outcrops. — The same kind of rock crops out on both sides of Neebish Island. Along the western side a harrow channel has been blasted out for the ships that pass down the St. Mary's River. Great piles of rock 30 to 40 feet high line both sides of the channel for a distance of over one quarter of a mile in Sections 20, 28 and 29 of T. 45 N., R. 2 E. This is hard, dark, massive and coarsely crystalline limestone. Walls have been built in the channel with blocks of the same limestone, which break up into large rectangular blocks ideal for such a structure. In the rock of the wall the most common fossil is a large *Orthoceras*, five to six inches in diameter and four feet long; other fossils are not at all numerous. In certain places of the wall some black, shaly limestone blocks are common. These are usually well filled with a large variety of invertebrates. On the other side of Neebish Island, there is another outcrop of the same rock. It forms the floor of a small stream channel which separated Neebish Island from Sailors' Encampment Island in times of higher water. The outcrops are in Sections 36, T. 45 N., R. 2 E., and 31, T. 45 N., R. 3 E. Only the flat surface of a hard, buff crystalline limestone is to be seen at present. Farther east there are some low cliffs which probably are rock cliffs with a very thin cover of glacial material. Numerous blocks of Trenton lying about indicate that this is not far from the stratigraphic boundary between the Black River and the Trenton. A well drilled near this outcrop is recorded by Lane in the state geologist's report for 1901. The record of this well is also given by Smith,[5] but in his report the details are quite different from those given by Lane. Smith gives the Trenton a thickness of 190 feet with 161 feet of St. Peter sandstone. More than likely what is here called the St. Peter is the upper or white portion of the Lake Superior sandstone.

Pickford well — In 1906-7 a deep well was drilled at Pickford for oil. Dr. Lane compiled the record from a partial set of samples and this record is published by Smith.[6] Lane shows 132 feet of surface deposits down to the Niagara (Lockport) limestone. To this he gives a thickness of 128 feet, then to the Lorraine 215 feet, and to the Utica 50 feet, down to the Trenton. These correlations are subject to revision in the light of the author's studies in Chippewa County. The author found the *Pentamerus oblongus* zone (base of Manistique) at an elevation of 730 feet above sea-level in the hilly region four miles south of Pickford (see Taylor Mill section in Fig. 25). The elevation at Pickford is 605 feet above sea-level. Allowing 132 feet in depth for the distance down to solid rock gives 473 feet for the top of the so-called Niagara. Assuming a dip to the south of 40 feet to the mile, or 160 feet, would give the Pentamerus layer a height of 890 feet above Pickford. Now, according to a carefully measured section which the author made for Drummond Island (see Fig. 26) the interval between the lower Pentamerus layer and the top of the Ordivician is equal to not less than 240 feet and probably not more than 290 feet. Subtracting 290 feet from 890 feet would place the top of the Richmond at 600 feet, or about at the surface of the ground at Pickford. At a depth of 132 feet, therefore, we should be well within the Richmond after allowing liberally for a thickening of the formation from Drummond toward the west. The 128 feet given as the thickness for the Niagara must, therefore, belong to the Richmond or at least to the Cincinnatian. The revised section would then read as follows:

	Thickness in feet	Depth in feet
Clay	119	119
Sand	13	132
Richmond	128	260
Lorraine (?)	215	475
Utica (incl. Collingwood)	50	525
Trenton and Black River	275	800

Glacial boulders. — A careful examination of the boulders on the marginal moraines of Chippewa County adds considerable to our knowledge of the areal distribution of the Black River. Localities where such boulders were seen are indicated on the map, Figure 27.

Trenton limestone. — The Trenton limestone is exposed at only one locality in Chippewa County. This is the outcrop described in the foregoing pages as occurring in the Waiska River, southwest of Brimley. At this locality the upper part of the ancient sea cliff uncovered by the Waiska River shows some layers of a very white limestone, which has lumps of clay scattered through it that produce greenish spots. It is a very even and thin-bedded limestone and contains many fossils. This limestone is exactly like the Trenton so well shown one-half mile north of the town of Bark River in Delta County (Galena Limestone of Wisconsin?). G. M. Ehlers reports finding Trenton fossils in rock from the southern end of Neebish channel cut.

Glacial boulders. — In Chippewa County boulders of this (Trenton) rock are found at widely scattered points in the glacial drift. The pieces are so distinctive that they may be recognized without difficulty. Those which are weathered are still very white and show a strong tendency to split into thin sheets because of the greater solution along parting planes. The pieces are tabular with jagged edges. The muddy spots are prominent and fossils are common. Localities where these were seen are shown on the map, Figure 27.

When paleontological studies have been completed on the faunas contained in these Ordovician strata, it will probably be found that they represent the Lowville, Black River and Trenton of the New York section. The most recent discussion of Ordovician rocks in neighboring areas is to be found in Guide Book No. 5 (*Excursion in the Western Peninsula of Ontario and Manitoulin Island*[7]), where August Foerste describes the Mohawkian (middle Ordovician) on Manitoulin Island and the small islands between it and the mainland. He differentiates the following members:

Trenton limestone	
Black River	80 feet +: dark limestone
Lowville (Leray)	soft white limestone with 11 feet of fine-grained hard limestone at top
Lowville (lower)	70 feet +: red shales

Cincinnatian. — The uppermost portion of the Ordovician is the Richmond formation. In other areas, notably in New York and Canada, the Richmond is separated from the Trenton by the black Utica shale and the blue Lorraine shale. These may be present also in Chippewa County. A piece of black shale was found on Drummond Island in Section 6, T. 42 N., R. 7 E. It is difficult to see how this bituminous shale should appear in this strip unless the black shale is present farther north. Some pieces were also seen in a gravel pit in the southeast quarter of Section 10, T. 44 N., R. 1 W. Bell mentions finding fragments of Utica shale on St. Joseph's Island. On Manitoulin Island, east of Chippewa County some sixty miles, he reports an outcrop at Maple Point. In the Pickford well 50 feet of black shale is reported and 215 feet of Lorraine shale.

In Chippewa County the Richmond crops out only along the north shore of Drummond Island, where it appears at frequent intervals over a stretch of seven miles. In this stretch there are cliffs 20 or more feet high and the outcrops continue below water level for an equal thickness. These outcrops were described by Bell[8] under the name of Hudson River. Later, Rominger[9] described them more fully and listed the fossils. The rocks exposed along the north shore of Drummond Island may be described as shaly limestones or argillaceous limestones. The color is dark grey and they are not very hard. Fossils are rather plentiful.

In the Pickford well, discussed in the preceding pages, the Richmond (?) appears to be at least 128 feet thick. The blue shale (Lorraine ?) below it is 215 feet thick and the Utica black shale is given a thickness of 50 feet.

Correlation of the Cincinnatian. — The Utica can be traced from New York into Ontario chiefly by its characteristic lithology. Black shales are to be found in a strip running north through Ontario to Bruce Peninsula and thence to Manitoulin Island. These may be the equivalent of the Utica or of only a portion of it. Raymond applied the name Collingwood to these and Foerste used the same name in describing the outcrops on Manitoulin Island. In Michigan Ruedemann and Ehlers[10] have found the Collingwood fauna in drift specimens a short distance west of Chippewa County. It appears probable, therefore, that a portion or the whole of the 50 feet of black shale in the Pickford well is to be considered as Collingwood in age.

The Lorraine can be traced from New York to Manitoulin Island, though it is likely that the name Lorraine will be supplanted by local names or perhaps by names taken from the Cincinnati area. Foerste says, after discussing the Lorraine of Ontario and Quebec:[11] "From the preceding observations it becomes evident that the richly fossiliferous Waynesville horizons . . . are underlain by horizons lithologically resembling the Pulaski part of the Lorraine, and containing in the upper parts at least the lamellibranch *Pholadomorpha pholadiformis*. . . . It is doubtful whether the use of the term Lorraine ... can be of great value. . . . The use of the terms Maysville and Eden for the strata exposed in Ontario may eventually prove much more appropriate." The Eden on Manitoulin Island consists of clays, greenish and soft above and more fissile below, with a thickness of 107 feet near Little Current. The Maysville in the same region consists of clay shale with occasional limestones having a thickness of 114 feet at McLean Hill south of Little Current.[12]

The Richmond formation is also present on Manitoulin Island. In a section northwest of Kagawong, Foerste measured 127 feet of this formation most of which is solid limestone, the rest being argillaceous limestone.[13]

If we total the thicknesses found by Foerste[14] on Manitoulin Island we can construct the following table:

Richmond	127	
Maysville	114 to 170	
Eden	107	(excluding Collingwood)
Collingwood	22?	
Total	365 to 421	

In the Pickford well a total of 393 feet of Cincinnatian rocks was encountered. As stated on page 314, however, the top of the Richmond is probably missing for about 130 feet. It is very likely, therefore, that the Cincinnatian has thickened toward the west in the 60 miles from Manitoulin Island, so as to have a thickness of roughly 520 feet.

SILURIAN ROCKS

The Silurian rocks of Chippewa County are very interesting, partly because they are better developed on the outcrop and partly because they have been more extensively described than the other rocks. The oldest strata which appear to belong to this system were found on Drummond Island in the Potagannissing area. The upper 20 feet or so of these strata is a massive bryozoan or coral reef. The best place to study it is in the center of Section 9, T. 42 N., R. 6 E., where the waters of the bay have washed it clean and brought it into prominence. It may be described as a very hard limestone which is porous and extremely massive. Some of it is blue and some buff. Scattered through the mass are small siliceous pipes or stems of bryozoan or coral fragments. The only complete specimen seen by the writer is a species of *Favosites*. This ancient reef can be traced over a considerable area as it produces low, rocky mounds devoid of vegetation. One such mound may be seen in the exact center of Section 10, where the road passes over it. Another may be found on the farm of Mr. Stevenson near by. Fossils collected from this stratum by G. M. Ehlers indicate that it is probably equivalent to the lower part of the Mayville.

Below this reef rock there appears to be a thin-covered interval of possibly 15 feet. In the succeeding part of the section dolomites appear which resemble those of certain portions of the Niagara. They are probably 40 to 45 feet thick, but only the upper and lower strata are exposed. The lowest strata were seen by the writer on the south side of a marsh located in the north part of Section 3, T. 42 N., R. 6 E. Here 12 feet of dolomite 5 crops out in a bluff which extends some distance east and west of the end of the road or trail from the south. The rock is greyish-blue on a fresh exposure, but weathers very quickly to a dull yellow. It is medium-grained in texture and breaks into fairly regular pieces roughly 8 inches thick and rectangular. It is marred by small nodules of chert which also seem to decay rapidly on exposure to weathering. The upper layers of the 40-foot interval crop out at lake level on Walter Stevenson's farm in the southwest quarter of Section 3, T. 42 N., R. 6 E. This is a very hard dolomite which weathers deeply, however, with a brown concentric shell. Some fossil fragments were observed here.

In the absence of paleontologic evidence, these strata are difficult to place. They may be of Mayville age or possibly even of Richmond age though the writer believes this is unlikely. The writer searched for a rock of similar stratigraphic position and lithology. The Manitoulin dolomite described by M. Y. Williams appears to come as close as anything he was able to find. This dolomite has a thickness of 50 feet near Manitowaning (on Manitoulin Island) and also has local coral and bryozoan reefs in the upper 20 feet.[15]

Niagaran rocks. — Above the dolomites just described there is a covered interval which includes possibly 35 feet of strata. This is succeeded by dolomites of Niagaran age with an aggregate thickness of approximately 285 feet. In describing these strata in detail the writer will use the nomenclature suggested by Ehlers,[16] since he feels that the paleontological evidence brought together by Ehlers and now in manuscript form nearly ready for the press will establish the validity of the classification.

Mayville formation. — Ehlers defines the Mayville as the "northeast ward continuation of the Mayville of Wisconsin. The base of the formation in Michigan has not been seen; the top is provisionally placed at the top of a yellowish grey dolomite containing numerous remains of the brachiopod named *Virgiana mayvillensis* by Savage."

In Chippewa County there are no outcrops of the Mayville to be seen on the mainland, but on the islands, notably Lime Island and Drummond Island, the beds are known to occur. The writer has not been on Lime Island, but the top layer of the formation containing the Virgiana has been found there by Ehlers. On Drummond Island Ehlers reports finding the same fossil as far north as Section 15, T. 42. N., R. 7 E., along the eastern side of the island in wave-drifted boulders.

Burnt Bluff formation. — The Burnt Bluff formation is described by Ehlers as the "northeastward extension of the Byron, Transition and lower part of the Lower Coral Beds of Wisconsin." This formation crops out at a number of places on the mainland of Chippewa County, but is particularly well displayed on Drummond Island. One of the best places to study it is in the L. Seamon quarry at the western edge of the village of Drummond. In this quarry the top layer is very distinctive because it weathers out with a peculiar nodular or gnarled surface on account of differential weathering. It is coarse-grained and deeply iron stained to buff, cream, or brown. Inasmuch as this layer proved to be an excellent key horizon, the writer named it the lower nodular layer and it will be so referred to in the following pages where it is necessary to clarify the stratigraphic position of layers in a section. It was called the *lower nodular layer* because two others were found in the Burnt Bluff, just like it in every respect, which were named the *upper* and *middle*

nodular layers. Below the lower nodular layer in the Seaman quarry there is a somewhat monotonous succession of strata which may be described in general as very hard, even-bedded, light grey to pale buff, fine-grained dolomite. A striking characteristic is the presence of thin, dark to black, carbonaceous bands, parallel to the bedding which give the rock the appearance of "ribbon structure" when freshly fractured. Another striking feature is the fact that the jointing is so well developed in two sets of joints at right angles producing rectangular blocks.

Lime kiln quarry. — These same characters distinguish the rock in the lime kiln quarry which is located in Section 18, T. 42 N., R. 6 E., near the shore-line of Potagannissing Bay, where the following section was measured.

SECTION IN LIME KILN QUARRY, DRUMMOND ISLAND

(Elevation at top, 653 feet above sea-level)

	Thickness in feet	Total in feet
1. Middle nodular layer, coarse, cream-colored, porous, weathers with nodular surface	1	1
2. Interval mostly covered, but typical, broad-banded limestone of Fiborn (?) may be seen	22	23
3. Lower nodular layer, like No. 1	2	25
4. Covered	4	29
Top of quarry		
5. Dolomite, thin-bedded, even-bedded, grey, fine-grained	3	31
6. Dolomite, brownish, medium-grained	4	35
7. Dolomite, yellow, medium-grained	5	40
8. Dolomite, light cream color, saccharoidal	2	42
9. Dolomite, brownish, moderately coarse, friable	5	47
10. Dolomite, thin and even-bedded, rectangular jointing, thin bituminous partings, partly covered to lake	25	72

Other outcrops. — On the point one-half mile west of Drummond village, the Burnt Bluff forms the shore-line for some distance and fossils are present. Again, on the point one and one-half miles east of the village (Sections 17 and 18, T. 42 N., R. 6 E.), the lower part of the formation may be studied. In the narrow strip shown on the areal geology map it crops out at many places, the most convenient one being along the road to Maxton especially in the northeast corner of Section 21, T. 42 N., R. 6E.

Fiborn. — On Drummond Island the Niagara may be studied in its entirety, from the top of the Engadine down to near the base of the Burnt Bluff (see Fig. 26). In the thickness of 285 feet there are no beds which exactly resemble the Fiborn limestone. The beds which most nearly approach the Fiborn as described by Smith are a zone of 22 feet, lying 37 feet below the top of the Burnt Bluff formation. The best place to see it is in the old quarry one mile west of Drummond village. Here the following section was made by the writer. The uppermost five feet are most typical, and layer No. 11 stands out because of its striking white color, and because it weathers out in broad ribbon bands one to three inches wide. The writer did not see any other layer just like this one in the whole 285 feet of the Niagara exposed on Drummond Island.

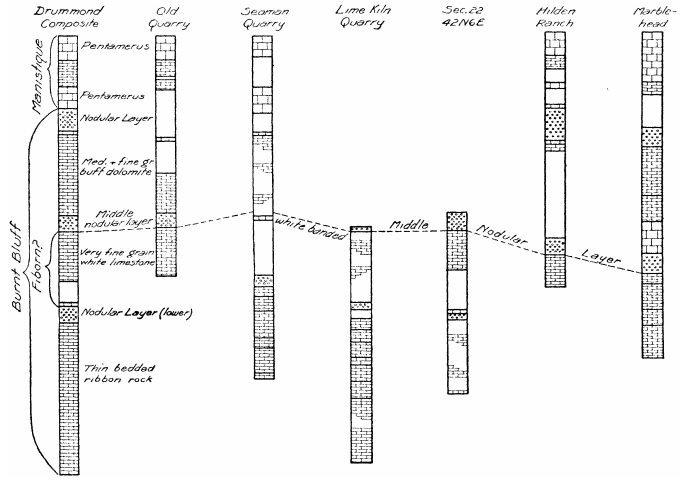

FIG. 26. Stratigraphic sections across Drummond Island to illustrate character of middle Silurian and persistence of Fiborn

SECTION IN OLD QUARRY ONE MILE WEST OF DRUMMOND VILLAGE

(Elevation at base of quarry, 615 feet above sea-level)

	Thickness in feet	Total in feet
Manistique formation		
1. Upper Pentamerus layer, massive dolomite, cream-colored, coarsely crystalline, filled with casts of *Pentamerus oblongus*, weathers dark brown	7	7
2. Dolomite, thin-bedded, weathers into white sheets	5	12
3. Dolomite, one layer, very hard, medium-grained, buff	$\frac{3}{4}$	$12\frac{3}{4}$
4. Dolomite, thin-bedded, pale grey, very fine grained	3	$15\frac{3}{4}$
5. Covered	15	$30\frac{3}{4}$
Burnt Bluff		
6. Dolomite, one layer, saccharoidal, brownish	1	$31\frac{3}{4}$
7. Covered	10	$41\frac{3}{4}$
8. Dolomite, thin-bedded and even-bedded, buff and grey, medium-grained and lithographic	11	$52\frac{3}{4}$
Top of quarry		
9. Middle nodular layer, coarse, cream-colored dolomite	$4\frac{1}{2}$	$57\frac{1}{4}$
Top of Fiborn (?) member		
10. Limestone, fine-grained, buff	$2\frac{3}{4}$	60
11. Limestone, lithographic, weathers white, broad bands	3	63
12. Dolomite, medium-grained, buff	$2\frac{1}{4}$	$65\frac{1}{4}$
13. Limestone, lithographic, grey	$\frac{1}{2}$	$65\frac{3}{4}$
14. Dolomite, like No. 12	$\frac{1}{2}$	$66\frac{1}{4}$
15. Limestone, like No. 13	$2\frac{1}{4}$	$68\frac{1}{2}$
16. Limestone, pale yellow	$1\frac{1}{4}$	$69\frac{3}{4}$
17. Limestone, like No. 13	$\frac{3}{4}$	$70\frac{1}{2}$
18. Dolomite, medium-grained, buff, hard	$1\frac{3}{4}$	$72\frac{1}{2}$

The white broad-banded rock (No. 11) can be traced from this quarry to the L. Seaman quarry one mile east. It appears again in a high cliff in the northern part of Section 22, T. 42 N., R. 6 E. From this point it can be followed for a distance of over a mile into Section 23. In this stretch the middle nodular layer is the cliff-forming rock and has protected the Fiborn (?) from erosion. Behind it, to the south, other rock terraces appear held up by higher members of the section. By means of these related rocks the Fiborn (?) can be traced to Marblehead in Section 31, T. 42 N., R. 8 E., at the eastern extremity of the island.

Marblehead. — The stratigraphic sequence at Marblehead was carefully measured by Rominger, whose section is reproduced by Smith.[17] Smith suggests that layer No. 10 is the probable equivalent of the Fiborn and cites a chemical analysis (No. 237 of the same publication) to corroborate this conclusion. This analysis shows 95 per cent of calcium carbonate. On this basis it does not seem unreasonable to include Nos. 11 and 12 of Rominger's section, inasmuch as No. 12 shows 94 per cent of calcium carbonate. These three beds together total a thickness of 16 feet. Bed No. 9 in Rominger's section is probably the middle nodular layer, so characteristically present above the Fiborn (?) farther west.

Ehlers has found in several places west of Chippewa County evidence that seems to indicate that the Fiborn and some lower beds grade laterally into dolomite. Further he is inclined to believe that the beds which are the equivalent of the Fiborn on Drummond Island are dolomites and occur higher up in the Burnt Bluff formation than these selected by the present writer.

Manistique. — The second division of the Niagara, Ehlers calls the Manistique, using the name first suggested by Smith *but in a more restricted sense*. He defines the Manistique as the "northeastward extension of the Upper Coral Beds and the upper part of the Lower Coral Beds of Wisconsin." The writer has arbitrarily subdivided this formation into an upper and a lower division which will be called in this paper simply *upper Manistique* and *lower Manistique*. This distinction is desirable on account of the lithologic differences which set off the divisions. The upper division consists of 95 feet of thin-bedded cherty, fossiliferous dolomites. The lower division consists of two beds of massive brownish coarse dolomite with numerous casts of *Pentamerus oblongus* with some interbedded thin dolomites. It was found convenient in the field to distinguish the two *Pentamerus* layers as the upper and the lower *P. oblongus*. They are so used in this paper without implying that they are regarded as formation names or member names.

The most convenient place to study the lower Manistique is on the Victor Hilden ranch, in the northwest quarter of Section 26, T. 42 N., R. 6 E., the details of which are given below.

SECTION ON VICTOR HILDEN RANCH

(Elevation at top of section, 695 feet above sea-level)

	Thickness in feet	Total in feet
Lower Manistique		
1. Upper Pentamerus layer, massive, light cream colored, coarsely crystalline, casts of *P. oblongus*, weathers dark chocolate-brown	7	7
2. Dolomite, weathers into thin white sheets	4	11
3. Covered	4	15
4. Lower Pentamerus layer, like No. 1	2	17
5. Covered	5	22
Burnt Bluff		
6. Dolomite, one layer, saccharoidal, brownish, weathers rounded edges	1	23
7. Upper nodular layer, coarse, sugary dolomite, weathers dark	10	33
8. Same as No. 6	1	34
9. Dolomite, thin, hard, buff, medium- to fine-grained	2	36
10. Covered. Section continues one eighth of a mile to north	27	63
11. Middle nodular layer, coarse, cream-colored, porous	5	68
Fiborn (?) member		
12. Thin and even-bedded limestone, some buff and hard, others grey. The typical white, broad-banded rock is prominent	10	78

In this section the upper Pentamerus layer shows up in its full thickness. Only 4 feet of the thin-bedded white dolomite between the two Pentamerus layers is revealed here. These layers are seldom seen in their entirety. The only place where they crop out in full thickness is above the old quarry in Section 23, T. 42 N., R. 5 E. The lower Pentamerus layer is also visible only in part. The best place to study this layer is in the hillside behind the L. Seaman quarry.

SECTION IN L. SEAMAN QUARRY AT DRUMMOND VILLAGE

	Thickness in feet	Total in feet
Lower Manistique		
1. Upper Pentamerus layer	6	6
2. Covered	11	17
3. Lower Pentamerus layer, coarse, porous, brown dolomite crowded with casts of *P. oblongus*, like No. 1	8	25
Burnt Bluff		
4. Covered	6	31
5. Dolomite, one layer, saccharoidal, brownish, weathers with rounded edges	1	32
6. Dolomite, thin and even beds, buff and grey, largely covered	25	57
Fiborn (?) member		
7. Limestone, lithographic, weathers white, broad bands	1	58
8. Covered	17	75
Top of Quarry		
9. Middle nodular layer, coarse, porous, weathers with lumpy surface	3½	78½
10. This layer and lower layers are described by Smith (on p. 208 of the publication mentioned in note 5, to which the reader is referred)		

The two Pentamerus layers are very important stratigraphic key horizons. They are very persistent both in character as well as in thickness. On account of their massiveness and resistance to erosion they are likely to form escarpments and terraces similar to those made by the Engadine. Coming, as they do, almost in the middle of the Niagaran, they are valuable in giving the geologist a clue to the position of the otherwise confusing strata above and below. They can be traced across Drummond Island from Marblehead almost mile after mile. A splendid exposure may be studied in the

northwest quarter of Section 3, T. 41 N., R. 7 E., three miles west of Marblehead. The upper Pantamerus layer is 6 feet thick and lies at an elevation of 630 feet above sea-level. Higher on the hill about 15 feet of the cherty, fossiliferous upper Manistique crops out.

Stalwart. — On the mainland outcrops are rare. At Stalwart in the northwest quarter of Section 30, T. 43 N., R. 2 E., outcrops appear which represent scattered portions of the Burnt Bluff from the upper nodular layer down for about 20 feet. It appears that the Pentamerus layers are responsible for the hill at Stalwart, for they protected it until very recently.

Both layers of *P. oblongus* crop out at Taylor's Mill in Section 20, T. 43 N., R. 1 E., the upper one at an elevation of 735 and the lower one at 715 feet. Both are about 7 feet thick, but the interval between them has thickened to about 13 feet. It is the same characteristic thin-bedded, white weathering, limestone found farther east. In Sections 11 and 12 of T. 43 N., R. 2 W., large blocks of Pentamerus layers were seen. One of the layers was in place on the section-line at an elevation of 790 feet above sea-level. In Sections 8 and 9 of T. 43 N., R. 3 W., both layers are present and crop out on both sides of the road. The elevation is approximately 770 feet above sea-level.

Scott quarry. — At Scott quarry in Section 29, T. 44 N., R. 4 W., the Pentamerus layer may be found in the sides of the hill just east of the crusher at an altitude of 835 feet, 95 feet below the top of the quarry. Only one layer was seen by the writer, but the white thin-bedded layers below it indicate that it is the upper one.

Upper Manistique. — The best place to study the upper Manistique is at Taylor's Mill in Section 20, T. 43 N., R. 1 E. Here it is 95 feet thick and practically the whole of it crops out. Fossils are abundant throughout. At Scott quarry the whole interval is also present, but the Engadine is missing. In the face of the quarry, 60 feet deep, a good opportunity is offered to study the character of the component layers and to search for faunules. On Drummond Island 20 feet of the topmost portion may be studied along the west side of the island below the ferry. In the southwest quarter of Section 26, T. 42 N., R. 5 E., a good cliff may be seen in which fossils are numerous and a great variety of species may be collected. Farther east scattered outcrops are numerous to Marblehead.

Upper Manistique in Ontario — In order to compare the strata in Chippewa County with those in Ontario, two sections were chosen from those pictured by Williams (Fig. 25). They are the Campbell Bay section and the Manitowaning section. Unfortunately the Pentamerus layers do not appear in either section, although the assumed horizon is shown by the dashed line which is Williams' position for the base of the Lockport. The writer believes this line, if it represents the Pentamerus layers, should be placed considerably higher. The upper 30 feet of the Manitowaning section is the Engadine and serves to tie up the sections.

Racine. — The uppermost formation of the Niagara was named the Racine by Ehlers. It is equivalent to the Engadine described by Smith as "an extremely massive, hard, and very crystalline dolomite, distinctly bluish or mottled and streaked with blue." In Chippewa County this formation crops out better than any other and can be traced along almost mile after mile by following it occasionally into Mackinac County. It is responsible for the "Niagara Escarpment" in this part of Michigan. The line of outcrop is shown on the map (Fig. 27) and it will be seen that the westernmost outcrop is the one three miles east of Trout Lake. Here the full (?) thickness of about 55 feet is exposed with the base at 970 and the top at 1020 under the fire tower. At Maple Hill in Section 3, T. 43 N., R. 4 W., nearly the full thickness is again shown with the base at 955. Near Rockview four miles south of Pickford the full thickness of 55 feet may also be seen. For other outcrops the reader is referred to the map where the elevation at the base is also given for purposes of calculating the dip and strike.

Before we leave the Engadine one outcrop should be mentioned which is very exceptional. It is on the section-line road between Sections 10 and 11 of T. 42 N., R. 1 E. The dip of the formation, which is usally 40 to 50 feet per mile to the south, is reversed and very much steepened, for the rocks dip 30 degrees to the northwest. This may be due to a coral reef, but if this is so, it is the only one seen by the writer. More probably it is due to faulting, for the elevations of the Engadine masses farther east seem to be too high.

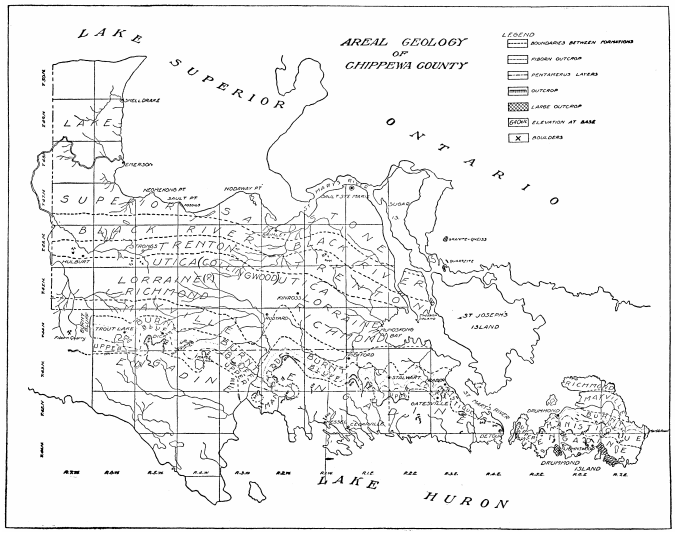

FIG. 27. AREAL GEOLOGY OF CHIPPEWA COUNTY, MICHIGAN

On Drummond Island the Engadine crops out over large areas on the southern fourth of the island. At Huron Bay and in the vicinity of Johnswood the largest outcrops are to be seen. The most accessible one lies south of the ferry along the west end of the island, where the whole thickness is present and the contact with the Manistique

may be traced for several miles until it enters the lake just north of Crab Island.

The following composite section for Drummond Island was made after all the localities had been visited.

COMPOSITE STRATIGRAPHIC SECTION FOR DRUMMOND ISLAND

	Thickness in feet
SILURIAN SYSTEM	
Engadine Formation	
1. Bluish grey mottled dolomite, extremely massive, hard, coarsely crystalline. Fossils not common, but in certain horizons *P. oblongus*, *Halysites*, *Favosites*, etc.	55
Manistique Formation (Upper Division)	
2. Grey and brownish-grey thin-bedded dolomite, weathers white, much chert so that disintegrated outcrop often resembles heaps of ashes, fine-grained to medium-grained texture, very fossiliferous	95
Manistique Formation (Lower Division)	
3. Upper Pentamerus layer, one massive layer of buff dolomite, weathers easily to yellow-brown and dark brown, coarsely crystalline, on outcrop dark-colored and irregular, filled with casts of *P. oblongus*	7
4. Pale, brownish-grey dolomite, weathers white, fine-grained, resembles Fiborn in texture, hard, thin-bedded	8
5. Lower Pentamerus layer, same as No. 3	7
Burnt Bluff Formation	
6. Upper nodular layer, cream-colored dolomite, weathers brownish, nodular and dark, coarse texture, porous, upper one foot is saccharoidal	7
7. Buff dolomite, fine-grained to medium-grained, thin-bedded and even-bedded	25
8. Middle nodular layer, dolomite like No. 6	5
Fiborn (?) member	
9. Grey and buff limestone, some lithographic texture, some medium-grained, all thin-bedded and even-bedded. Layers in upper part weather out white and with broad ribbon bands	15
	Thickness in feet
10. Covered interval	7
11. Lower nodular layer, dolomite like Nos. 6 and 8, except upper 18 inches, which is similar but saccharoidal	5
12. Grey to buff dolomite with thin dark, carbonaceous streaks (ribbon rock), hard, even-bedded, fairly massive, breaks into rectangular blocks	15
13. Brown dolomite, saccharoidal, massive	7
14. Ribbon rock, like No. 12, partly covered	25
Base of Burnt Bluff (?)	
15. Covered interval	35±
16. Grey and blue limestone, extremely massive, without apparent bedding planes, weathers into dome-like masses, very hard porous, silicified fossils (coral reef)	35±
17. Covered interval	15
18. Yellow dolomite, some chert in nodules, even-bedded, weathers deeply, *Favosites*, partly covered	45±
ORDIVICIAN SYSTEM	
Richmond Formation	
19. Blue and grey limestone, calcareous mudstone, quite fossiliferous at many horizons	100±

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