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PART II: ZOÖLOGY

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ANTHROPOLOGY, GEOLOGY
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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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VOLUME XXIV (1938)
IN FOUR PARTS

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
—SENECA, *Naturales Quaestiones*

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CULTURAL RELATIONSHIPS OF ARCHAEOLOGICAL SITES IN THE UPPER GREAT LAKES REGION

EMERSON F. GREENMAN

THE region of the Upper Great Lakes has threefold interest for the student of its prehistory and ethnology: (1) It was one of the first regions in the interior of the North American continent to be visited by Europeans, who made reliable records of native life as far back as 1634; (2) It contains as obstacles to the spread of culture three great expanses of water, Lakes Michigan, Superior, and Huron; (3) It has within it two different physiographical zones, which would seem to have imposed unequal strains upon the cultures introduced into it or originating in it. These zones are the fertile hardwood region of the southern part and the sandy plains and coniferous trees of the north. With this varied background of physical environment in mind the investigator interprets what he knows of aboriginal life from historical record and excavation.

In this area is represented quite a diversity of cultures, which fall under two main heads, Woodland and Mississippi. The Woodland and the Upper phase of the Mississippi are present both in pure forms and in a form strongly suggesting the mergence of the two. "Woodland" is a term which includes the Hopewell, Adena, Algonkian, and gravel kame cultures and the Intrusive culture; the Mississippi culture has three subdivisions: "Upper," "Middle," and "Lower," which have reference to types of artifacts and structures rather than to relative position. The Upper Mississippi includes the Fort Ancient and the Iroquois; the latter designation is also a linguistic term and is acceptable on that basis because some of the sites represented are known to have been occupied in historic times by Iroquois-speaking groups.

The so-called "Esquimoan," of New York, a designation from the older terminology, was left to stand by itself since it is a culture unrelated to any of the others. The same situation applies to another series, the Archaic, which split off from the Algonkian of New York (33).

The Woodland pattern has two major subdivisions called phases, the Lake Michigan and the Northeastern, both of which are represented in the region under discussion. The Lake Michigan phase, which is a western manifestation, centers in Wisconsin, Minnesota, northern Illinois, and the western part of the Lower Peninsula of Michigan. In Wisconsin it includes effigy and noneffigy mounds, some of which contain burials and some of which do not (26, p. 469). So far as is known, in Illinois and Michigan the burials are in mounds not of the effigy type, and throughout the entire area of the Lake Michigan phase determinant traits are found in open village or camp sites and, in Michigan at least, in earthen enclosures. The term "Northeastern" has been suggested to include the various aspects of the Woodland pattern in New York and to the east. It is used provisionally, pending demonstration that there is sufficient divergence from the Lake Michigan to necessitate the use of more than one phase for the northern Woodland.

The Northeastern phase is represented at the Younge site (11, p. 96) and the Rivière au Vase site (14), both in southeastern Michigan. Another division of the Woodland in the region of the Upper Lakes is the Hopewellian, the position of which in the classification is at present in dispute. Some call it a phase of the Woodland pattern, and it is so tabulated at the end of this paper; others give it the status of a pattern.

The Iroquois aspect of the Upper Mississippi is present in what may be called a pure form only in the northern part of the area, on Isle Royale in Lake Superior, at Lake Nipigon (21, p. 197), near Sault Ste Marie in the Upper Peninsula of Michigan, and near the tip of the Lower Peninsula. It may also occur along the Canadian shores of Lake Huron and Georgian Bay.

The Middle Mississippi is represented only as a narrow arm extending from Illinois to within sixty miles of the northern border of Wisconsin (22, p. 1).

The establishment of the distribution of archaeological complexes is a preliminary step to the determination of their chronological relationships, and their identification, so far as is possible, with historically known groups. In the Upper Lake region chronology is determined for the most part by vertical sequence in the ground or by intrusion.

The oldest remains in the Upper Lakes region and in the entire eastern part of the United States appear to be those of Brown Valley, Minnesota, where a skeleton accompanied by Folsom-like points was found (23). No later remains were unearthed on the site, and the relationship of Brown Valley man to the other cultures of the region is unknown. The earliest complex lying beneath remains of later cultures is the Archaic pattern of New York. This Archaic is a nonceramic, nonagricultural horizon, and is characterized by certain stone and bone implements and by a long-headed, high-vaulted, narrow-nosed physical type (32, pp. 408-409). Formerly regarded as representing the first occupation of New York by the Algonkian, the Archaic now stands in a class by itself, with a distribution limited to New York and Ontario.

Under "Woodland" the Vine Valley aspect (formerly called Second Algonkian in New York) comes next in time. It lies in the upper levels of Archaic sites in New York, and is differentiated by the introduction of pottery, agriculture, and new artifact forms, and by a new physical type characterized by round-headedness and a broad nose. In New York this aspect is influenced by mound cultures (33, p. 106), and in Michigan is represented by a group of burial mounds in Montmorency County excavated by Dr. W. B. Hinsdale (17).

Throughout the region of the Upper Lakes the Woodland is found in the bottom layers of all sites where Woodland and Mississippi occur. The region appears to have been first occupied by the various groups of people represented in the Woodland, then by the Mississippi groups.

In western Ontario, northern Ohio, and southeastern Michigan there seems to have been a fusion of Woodland and Mississippi. It is apparent to some extent in the pottery and other features at the Younge site, in Lapeer County, Michigan, and is markedly so at the Rivière au Vase site in Macomb County. These two sites are tentatively placed in the Owasco aspect of the Northeastern phase of the Woodland pattern. This assignment is based upon similarity of pottery decoration and the forms of pipestems to those from sites of the Owasco aspect in New York, where Upper Mississippi influence, specifically that of the Iroquois aspect, is strong. Mixture of the two complexes at the Rivière an Vase site appears to represent a fusion between an unknown aspect of the Lake Michigan phase of the Woodland with the Iroquois aspect of the Upper Mississippi of New York. A chronological position independent of stratigraphy is indicated in this fusion, which, in the region of the Upper Lakes, must have taken place after the beginning of the Lake Michigan; in the Owasco aspect of New York, after the beginning of the Woodland forms.

The occurrence of a mixed Upper Mississippi and Woodland complex in New York, southeastern Michigan, and western Ontario raises interesting questions, since in New York this underlying mixture is followed in time by the introduction of Upper Mississippi in an unmixed form, i.e. the fully developed "pure" Iroquois. This would imply the existence of the Iroquois in pure form somewhere near, while the fusion represented in the Owasco aspect was going on. To put it another way, the pure Iroquois must somewhere have been contemporaneous with the Owasco and close enough to assist in its formation by direct contact.

The question arises whether the Owasco aspect of southeastern Michigan was formed by influence from that of New York or directly from the Iroquois of New York. Complications arise from the fact that there is another mixture of Iroquois and Woodland along the south shore of Lake Erie (12), where it is predominantly Iroquoian; the Owasco as represented at the Younge and Rivière au Vase sites is predominantly Woodland. The pure Iroquois forms that are found in the region of the Upper Lakes may be the result of brief visits of small Iroquois groups from New York in fairly late times.

In the study of the aboriginal history of any locality it is necessary to make an attempt to bring historical documentation as near as possible to the latest archaeological levels. Only rarely can one do so, and even when an archaeological site has native material in association with European-made objects and the occupants of the site are known to history, it is still usually impossible, in the region of the Upper Lakes at any rate, to come closer than 100 or 150 years to the actual date represented by the European materials. Historic objects on a site in the Upper Lakes region might, therefore, mean 1680 or 1780, unless, as is the case with certain objects made of silver, the date of their manufacture or distribution is known, by which a lower limit is set for native objects found in association (30).

The early historic records of the region give some idea of the distribution of aboriginal groups at the particular moment that each group was observed. Three different linguistic groups were in occupation of the region: the Algonquian, the Sioux, and the Iroquois. The Algonquian (Chippewa, Ottawa, Miami, Sauk, Fox, Menomini, Cree, etc.) were the most numerous and most widely distributed; the Sioux were represented by the Winnebago in Wisconsin and the Dakota Sioux in Minnesota, and the Iroquois by the Huron, Neutral, and Erie. In correlating archaeological remains with historically known groups the principle has been accepted that historical material on a site is attributable to the earliest Indian group shown to have occupied that site in historic times, and that, if there is native material in association, such material is also ascribable to that historic group, on that site and wherever else similar material is found. The probability that identification on this basis is correct is much increased if the same historic and native complexes are found recurrently on different sites. By this method sites in New York and Ontario are ascribed to the Iroquois linguistic stock with a fair degree of probability.

In the region under discussion objects made by white men and traded or given to Indians have been found on the actual sites of several Indian villages or camps where there occurred native materials such as potsherds and flint points, notably at Lake Mille Lacs, Wisconsin (4, pl. XXI; 22, p. 8), at the Fisher site near Joliet, Illinois (7, p. 94; 24, p. 156x), at Cross Village,[1] Harsen's Island[1] (at the mouth of the St. Clair River), near Mount Clemens, Michigan (15), and on various sites in Canada (36, p. 121). At Lake Mule Lacs the historic materials were on sites bearing Woodland pottery, and since the Dakota Sioux were said by Hennepin to have occupied the locality in very early historic times, this material is attributed to them (22, p. 8). By the same process of reasoning the historic objects at the Fisher site would be attributed to the Potawatomi; those at Cross Village, to the Ottawa. There would be some doubt about the identity of the Indians who left such objects at Harsen's Island and at the Furton site on Lake St. Clair, since a variety of tribes were in that locality in early historic times. In none of these places were objects made by white men in direct association with native materials in graves or refuse pits, and they provide, therefore, no trustworthy indication of the tribal affiliations of the makers of the native materials.

Two matters of great importance to the solution of the archaeological problems of the region are (1) systematic description and classification of materials excavated and (2) a critical examination of all available historic records which deal with the distributions of the various Indian groups when they were first encountered by Europeans.

Appended to this paper is a tabulation of the larger sites in the region of the Upper Lakes with respect to the position of each site in the system of classification now used. The name of each site (or component) is followed by a number referring to the published record or to a footnote if other information is necessary. Under the terms "pattern," "phase," "aspect," "focus," and "component" the sites are successively regrouped according to the traits exhibited by them. For example, in the Hopewellian phase of the Woodland there are fifteen mound groups in the component column. It is found upon examination of the material from these groups that ten resemble one another more closely than do any of the remaining five; they are all in northern Indiana and southwestern Michigan, and thus they possess unity of geographical position as well as unity in trait content, considerations setting them apart as a single community, to which the term "Goodall focus" is applied. The remaining five groups separate into three subgroups or foci: the Trempeleau in Wisconsin, the Cedar River in another part of the same state, and the Esch focus, comprising the Esch mounds near Huron, Ohio.

When compared with other manifestations of the Hopewellian these four foci are found to exhibit a few traits which necessitate their inclusion in a larger group, the Elemental aspect. If our tabulation included all the manifestations of the Hopewellian it would show, in addition to the Elemental, the Ohio aspect, which is the term given to the traditional *Hopewell* of southern Ohio, and the Southern aspect, of the Gulf States, and each of these aspects would be subdivided into its own foci, all three comprising the Hopewellian phase of the Woodland pattern.

The "pattern" is a grouping of a large number of sites on the basis of a small number of traits, and the number and particularity of traits increase through phase, aspect, and focus down to the components. Correct placement of a site in this classification is dependent upon a precise comparison of the traits of one site with those of another. Since this has not yet been made for all sites, the classification as here set forth is subject to change in the foci and aspect groupings. Despite the limitations of the quantitative analysis of data as variable (and sometimes as incomplete) as are those of archaeology, this classification has been adopted (22) as the best means of systematic description yet devised.

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[1] This material is in the Division of the Great Lakes of the Museum of Anthropology, University of Michigan, Ann Arbor, Michigan. Some of it has been described by Quimby (30).

CLASSIFICATION OF CULTURES IN THE UPPER GREAT LAKES REGION

The Trempeleau and the Cedar River foci are in the Mississippi River drainage basin, but are included here to show the northward extension of the Hopewellian to within one hundred miles of Lake Superior.

The six components of the Younge focus may later be grouped into more than one focus. The Gibraltar site is in Wayne County, Michigan; the Sandwich, in Sandwich, Ontario. There is no published report for either site.

Pattern	*Phase*	*Aspect*	*Focus*	*Component*
Mississippi	Upper	?	?	Fisher site (7; 24; 30, p. 71) Blue Island site (29)
		Iroquois	?	Isle Royale. No publication Alpena (34, p. 74) Lake Nipigon (21, p. 197)
			Whittlesey	Reeve (10) Tuttle Hill (12) South Park (12) Wolf? (15) Uren? (35)
		Oneota	Lake Winnebago	Karow–McCauley, Wis. No publication Neenah site, Wis. No publication
			?	Watasa Lake (3)
			?	Moccasin Bluff, Berrien Co., Mich. No publication
	Middle	?	Rock River	Aztalan (1)

Pattern	*Phase*	*Aspect*	*Focus*	*Component*
Woodland	Hopewellian	Elemental	Goodall	Goodall (8, pp. 143–144) McNeal (31) Spoonerville (31) Brooks (18, pp. 130–135; 31) Sumnerville (31) Marantete (31) Scott (31) Converse (31) Norton (31) Grattan (31)
			Esch	Esch (13)
			Trempeleau	Shrake (27) Nicholls (27) Schwert (27)
			Cedar River	Cyrus Thomas group (6)
	Lake Michigan	Wolf River	Keshena	Big Eddy (3) La Belle Lake (3) Makimitas (3) Watasa Lake (3)
		?	Shawano	Kakwatch (3) La Belle Lake (3) Big Eddy (3) Makimitas (3) Watasa Lake (3) Beaver Dam (3) Pewisit Lake (3) Nakuti (3) Five Islands (3)
		Effigy Mound	Sheboygan	Kleitzen (26)
			Buffalo Lake	Neale and McClaughry (25)
			Horicon	Nitschke (26)
		Mille Lacs	Kathio	Kathio (4)
		?	Furton	Furton (15)
		?	Missaukee	Missaukee (9; 16) Rifle River (16)
	Northeastern	Owasco	Younge	Younge site (11) Rivière au Vase (14) Flat Rock (20) Farmington (20) Gibraltar Sandwich
		Vine Valley	Montmorency	West Twin Lakes (17)

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FURTHER TECHNOLOGICAL NOTES ON THE POTTERY OF THE YOUNGE SITE, LAPEER COUNTY, MICHIGAN

FREDERICK R. MATSON, JR.

I. INTRODUCTION

IN THE published technological study of the pottery found by Dr. E. F. Greenman during the excavation of the Younge site in Lapeer County, Michigan, there was only a brief discussion of the experiments in firing shrinkage (6, pp. 109-115). Sherds were refired at gradually increasing temperatures, the amount of linear shrinkage was measured, and the percentage of linear firing shrink- age (6, p. 111) was plotted against the temperature (6, Fig. 9, p. 112). A study of the average shrinkage curves and of the color changes in the clay at different temperatures indicated that the original firing temperature of the pottery might have been approximately 600° C. (6, p. 115).[1] Recently it was possible to restudy the firing data and to make a few further experiments, with the result that the conclusions concerning the firing temperature were somewhat altered. It seemed advisable, therefore, to prepare a brief report on the supplementary material.

The possibilities of error in the determination of the firing temperature by the shrinkage method have already been pointed out (6, pp. 109-110). The small size of the test pieces (2.5 X 1.5 X 1 cm.), which was necessitated by the type of dental porcelain kiln used, was perhaps an additional source of error, but the accuracy of the measurements may have largely compensated for the reduced size of the specimens. It is usually better to measure the volume firing shrinkage and then to calculate the linear shrinkage, but when one is using small thin test pieces, accurate linear measurements are sufficient.

The shrinkage curves (Fig. 1) are plotted on the same scale as those previously published (6, Fig. 9, p. 112), but the present graph shows a different average shrinkage curve for the sherds and an improved plotting of the levigated clay curve (B). The sherd curve represents the average of fourteen pieces, all of which were fired to 950° C. Twelve other sherds, eight of which were used in the average curve IV of the earlier report, are not included. These twelve were fired only to 550° or 600° and were then discarded because of mechanical failures which made them unsuitable for further accurate measurements. Owing to marked individual shrinkage and expansion variations among them, they were not used for comparative studies with the briquettes. The number of briquettes averaged in each of the four groups is as follows: Six made of the natural clay (curve A) were fired to 1100°C.; four made of 75 per cent natural clay and 25 per cent crushed granite (curve C) were fired to 1000° three of levigated clay (curve B) were fired to 980°; three of 75 per cent levigated clay and 25 per cent crushed granite (curve D) were fired to 1145°.

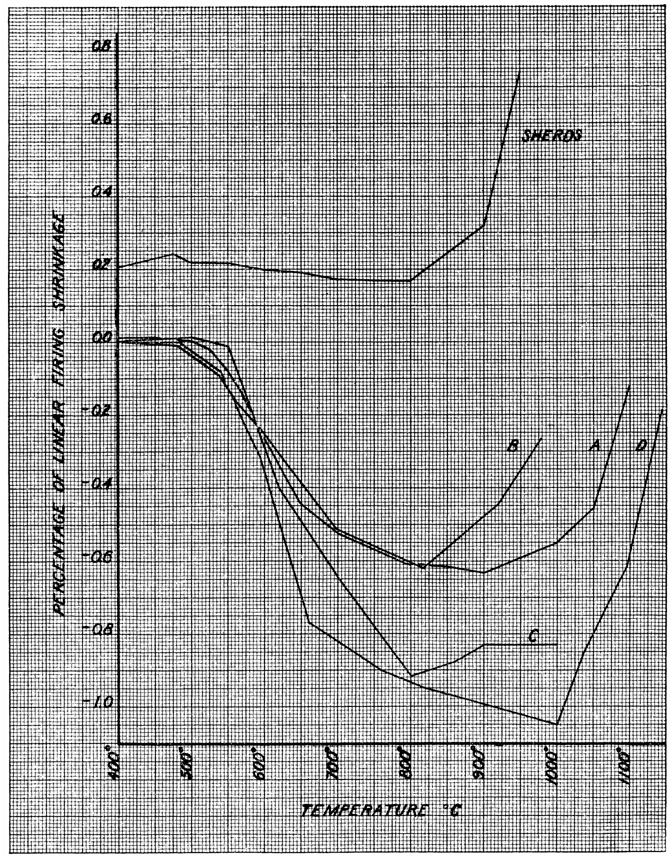

FIG. 1. Percentage of linear firing shrinkage of sherds and clay from the Younge site, Lapeer County, Michigan

Materials represented by curves *A-D*: *A*, natural clay; *B*, levigated clay; *C*, 75 per cent natural clay, 25 per cent crushed granite; *D*, 75 per cent levigated clay, 25 per cent crushed granite

An examination of the curves shows that each falls into three phases: low-temperature shrinkage, expansion, and, finally, rapid shrinkage.

II. CHANGES DUE TO FIRING IN THE SIZE OF THE SHERDS AND THE CLAY BRIQUETTES

Shrinkage below 500° C.

The sherds began to shrink soon after the refiring had started and continued to do so until, on an average, 475° was reached; above this temperature expansion began (see Fig. 1). In this period there was a total shrinkage of 0.24 per cent, 0.03 per cent of which occurred between 400° and 475°. Only five of the fourteen sherds showed shrinkage above 400°.

Two of the six briquettes composed of natural clay shrank 0.01 per cent below 450°, and two of the four pieces compounded of 75 per cent natural clay and 25 per cent crushed granite (group C) maintained a slight shrinkage until 500°. The test pieces, both plain and tempered, made of levigated clay showed no initial firing shrinkage. It is possible that if the briquettes in this temperature range had been fired more slowly, they might have had a greater shrinkage.

Three of the thirteen clays tested by Knote (4, p. 228) and three of the ten clays studied by Brown and Montgomery (2, p. 14) showed firing shrinkage below 450°. This was inferred from the increased true specific gravity reported for these six clays up to 4500; it indicated a diminution of volume because the mass remained constant. (In the C. G. S. system the specific gravity is the ratio of the mass to the volume.) Several of the British fire clays reported by Firth, Hodkin, and Turner also showed a slight shrinkage below 500° (3, p. 197),

It seems likely that the shrinkage is due to the dehydration of the clay, a process that is practically completed at 500°. Brown and Montgomery found that, when clays were heated to equilibrium conditions at increasing temperatures, the rate of loss of water was greatest between 400° and 500° (2, p. 22). Morgan concluded that under equilibrium conditions the true maximum rate of evolution of chemically combined water occurs in the range from 440° to 510°, but that the apparent temperature at which maximum evolution occurs may be raised as high as 650° by increased heating rates and greater size of specimens (7, p. 35). The small size of the test pieces probably neutralized to a large extent the effect of the rapid heating upon the dehydration temperature.

The shrinkage of the sherds may perhaps be attributed to the rehydration of the fired clay resulting from long burial in moist earth, as was suggested in an earlier report (6, p. 114). The rehydration of lightly fired clays is a slow and usually incomplete process, and may perhaps be accompanied by a slight increase in volume. The difference in the amount of shrinkage between the sherds and the briquettes (0.23 per cent) may be partly due to the fact that the briquettes were dried at a temperature of 150° before they were re fired (some shrinkage may have occurred between 110° and 150°), whereas the sherds, unfortunately, were only air-dried.

Expansion between 450° and 900° C.

The refired sherds began to expand after 475° and continued to do so until about 800°, with a maximum average expansion of only 0.07 per cent and a maximum individual expansion of 0.26 per cent. All the briquettes began to expand between 450° and 500°, with the exception of those of group C, whose expansion started after 500°. The test pieces made of natural clay attained their maximum expansion at 900° and began gradually to shrink when fired above that temperature. The levigated clay reached its maximum expansion at 815°, after which it started to shrink quite rapidly. The greatest average expansion of the levigated pieces was 0.62 per cent, about the same as that for the natural clay. Curves C and D, representing the briquettes to which 25 per cent crushed granite had been added, agreed quite closely with A and B until they approached 600°. Above that, the tempered pieces began to expand more rapidly than did the briquettes of groups A and B, attaining a maximum expansion of 0.3 per cent and 0.45 per cent more than the untempered pieces.

The increased expansion of the tempered pieces is probably due to the effect upon the body of the alpha-beta quartz inversion which occurs at 573° C. At this temperature quartz experiences a sudden increase in volume. The reaction is completely reversible and there is no residual effect in the quartz itself after it has returned to the low temperature alpha state. As the speed of the inversion is high, the volume expansion, which amounts to 0.86 per cent according to Sosman (10, p. 364) (about 0.29 per cent linear expansion), causes stresses that leave their impression upon the clay matrix in the form of small cracks. Although the quartz returns to its original volume when cooled below 573°, the cracks in the clay do not disappear, but cause a permanent increase in the bulk volume of the briquettes. With each successive refiring the cracks are enlarged and there is an additional volume increase. This process continues until the clay has been fired to a temperature at which the body just begins to melt. The incipient vitrification makes the clay start to shrink toward its minimum volume, i.e. its maximum density. The higher the temperature within the vitrification range, the greater the rate of shrinkage.

The tempered briquettes made of levigated clay (group D) expanded more than did those in which the natural clay was used (group C). The fine sand occurring naturally in the clay probably offered resistance to the formation of cracks and prevented their rapid development and a corresponding increase in volume. The smaller amount of sand in the levigated pieces made it possible for the cracks to grow with less opposition and resulted in a greater maximum expansion than appeared in the natural clay. After the tempered briquettes had been fired to 900° cracks were very noticeable in those made of levigated clay but not in the ones compounded of the natural sandy clay. If volume expansion instead of linear expansion had been measured the apparent difference between the tempered and untempered groups might not have been so great, for the bulk volume effect of the cracks would have been eliminated. If the briquettes had been refired several times at temperatures between 700° and 8000 further expansion would probably have occurred.

The difference in the expansion behavior of the sherds and of the briquettes can be attributed to the fact that the sherds had already been fired to a moderate temperature, probably many of them above 573°. It is likely that cracks were present in the sherds which absorbed the initial stress of the quartz inversion so that upon refiring further cracking was slight. Part of the friability of many rock-tempered sherds may be attributed to the formation of these expansion cracks.

In the discussion above only the effect of the quartz inversion has been mentioned. Since most granites such as the one used for the tempering material contain from 25 per cent to 30 per cent quartz a sufficient amount would be present to exert considerable expansive force upon the body. Several published studies show that a slight expansion of the clay when fired below the temperature of incipient vitrification is not unusual. All ten of the clays tested by Brown and Montgomery showed some expansion below 500°, as is indicated by the decrease in the specific gravity (2, p. 14). Between 500° and 550° a slight shrinkage occurred. Several of the British fire clays studied by Firth, Hodkin, and Turner began to expand by 200°. Their total expansion below 1000° varied from 0.04 per cent to 0.28 per cent (3, p. 197). These data show that transient expansion is due in part to the physical properties of the clay minerals themselves, for it often occurs below the quartz inversion temperature of 573°.

For a study of the effect of body thickness upon shrinkage, a series of briquettes that in the plastic state had thicknesses of 5, 8, 10, and 12 millimeters were prepared from the natural clay. These pieces were fired by stages to 1000°. There were no observable differences in their firing behavior which might be attributed to variations in thickness. Below 900° the maximum difference between these curves was about 0.10 per cent.

The expansion of some clays during a stage of their firing is an interesting phenomenon that has not been adequately studied as yet. Most investigations of uncalcined clays employ true specific gravity and loss of weight determinations. Shrinkage and expansion changes can be inferred from the specific gravity reports, but insufficient data are given to allow their calculation. A study of the clay expansion under better-controlled conditions than those possible in examining the Younge site material might provide a useful technological tool both in identifying clays with those used in the sherds and in determining the original firing temperatures.

Shrinkage above 800° C.

Most of the sherds and levigated clay briquettes began to shrink rapidly when fired above 800°; three sherds did not start shrinking until after 900°. The shrinkage of the natural clay began at 900°, proceeded gradually until 1050°, and then progressed more rapidly. The initial slowness was probably due to the fine sandy structure of the body, which may have been stiff enough partly to resist the early stages of the clay shrinkage. The rock-tempered natural clay shrank slightly between 800° and 900°, but then remained constant in size until 1000°. None of the samples of group C were fired above this temperature, but they doubtless would soon have begun to shrink rapidly. The rock-tempered levigated clay did not shrink until it was fired above 1000°, although the untempered levigated clay started at 815°. The reason for this discrepancy is not apparent, especially as the untempered levigated clay begins to shrink, as would be expected, before the natural clay does. It may be that the measurement of a larger number of samples would have given different results. The rate of shrinkage of the sherds and the briquettes is approximately the same, and they both begin to contract at about the same temperature; this indicates that the sherds had not been previously fired above 800° and that the clay used in the synthetic study is essentially the same as that employed by the Indians.

The shrinkage occurring above 800° or 900° indicates incipient vitrification and begins in the temperature range normal for most clays containing fluxing impurities; these cause the clays to start forming a glassy solution at moderately low temperatures. Ries and Kümmel found that all but one of the eight clays they tested showed a marked shrinkage between 900° and 1000° (8, p. 94). several of the British fire clays tested by Firth, Hodkin, and Turner had their initial shrinkage between 750° and 900° C. (3, p. 197). Morgan has shown that the rate of heating has a very definite effect upon the temperature at which changes in the physical properties of clays may appear. He found that when a clay was heated to equilibrium a given loss might occur at a temperature as much as 180° lower than that at which the same loss was evident when the furnace temperature was increased at the rate of 260° per hour. Because of the very rapid rate at which the briquettes and the sherds were heated (to 500° in five minutes and to finishing temperature in fifteen minutes, the finishing temperature being maintained for fifteen minutes), it may be that the temperatures at which changes occurred were higher than they would have been if the clays had been fired more slowly, although the small size of the specimens partly counterbalanced the speed of the temperature rise. The rate of heating employed was similar to that of the San Ildefonso and Santa Clara II firings reported by Miss Shepard (9, pp. 455 and 457). With the exception of the Zia polychrome ware none of the modern southwestern pottery whose firing schedules have been published was kept at the maximum temperature for more than five minutes. Therefore it would seem that the maintenance of the maximum temperature for fifteen minutes in the present experiments was ample.

III MAXIMUM FIRING TEMPERATURE

The purpose of this study of the refiring shrinkage of sherds and clays was to determine if possible the temperature at which the sherds had originally been fired. In the earlier report it was suggested that this temperature might have been about 600° C. (6, p. 115). A reexamination of the data indicates that some of the sherds may have been fired at a higher temperature. Bleininger and Brown say: "It must be realized that in burning clay products conditions of equilibrium are never reached. The contraction resulting at a certain finishing temperature is by no means constant, and upon reheating the product to the same temperature an additional shrinkage will be noted. The higher the temperature, however, the less will be the contraction upon reburning" (1, p. 42). The same statement would of course apply also to expansion during the lower stages of firing. The sherds, on an average, began to expand after 475°, that is, within the 450°-500° range in which the briquettes started. The expansion continued at a very moderate rate until 800°, after which rapid shrinkage began. Even though the sherds were originally fired to a temperature higher than 475°, they might have expanded further at that temperature, for the pottery was fired so rapidly that the shrinkage and expansion adjustments were difficult to complete in the body. This low-temperature expansion of the sherds seems to indicate that time rather than temperature may be the controlling factor. It is possible that the rehydration of the sherds is the cause of the expansion that occurs below the original firing temperature.

If it is assumed that the rate of heating in the kiln was equivalent to that used by the Indians, an estimate of the temperature to which the pottery was fired may be obtained by subtracting the percentage of maximum expansion of the averaged sherds from that of each of the four groups of briquettes and noting the temperature at the point on each curve that represents the resulting expansion figures for the briquettes. When this is done, the following values are obtained:

Natural clay....................	(A)	730°
Levigated clay..................	(B)	735°
Tempered natural clay..........	(C)	775°
Tempered levigated clay........	(D)	875°

This could indicate that the sherds had a maximum firing temperature of about 750° C. Most of them were certainly fired below 800° because all except three began to shrink at that temperature and had shown a slight expansion below that point. There are so many conditioning factors affecting shrinkage and expansion that the subtraction method of temperature determination is of questionable validity.

IV. MINIMUM FIRING TEMPERATURE

In order to determine the minimum temperature to which the Younge site clay would have to be fired to lose its plasticity and its ability to slake down in water, some of the briquettes that had been used in the study of the depth of color penetration as related to time and temperature (6, pp. 118-119) were ground fine enough to pass through a 30-mesh screen, tempered with water, and reshaped. An unfired briquette was given the same treatment in order to serve as a standard for comparison.

The raw clay, after it had been pulverized in a mortar and pestle, felt like fine flour and absorbed water rather slowly. It formed a good plastic mass which, when dry, did not have a powdery surface and was not easily crushed.

The clay that had been fired between 400° and 500° for ten minutes was black, for the organic materials in the paste had been carbonized; it ground down to a fine powder that absorbed water more rapidly than did the raw clay. The amount of water that the carbonized clay could hold and still remain a plastic mass was much less than that taken up by the raw clay, and the body was of a short, mealy consistency. After the clay had dried it was quite weak and could easily be crumbled between one's fingers. Such behavior might be expected from a body that was only semiplastic.

The clay fired for fifteen minutes at 500° behaved very much like that just described.

After having been fired at 550° for fifteen minutes the clay showed a marked change in behavior. When powdered it was granular and absorbed water rapidly without attaining a plastic state. The water bound the grains together sufficiently so that a pellet could be formed. When dry the clay was very friable. The change in properties between 500° and 550° is doubtless due to the fact that the dehydration was completed in this range and the clay lost the remnants of its plastic qualities.

The clay fired for fifteen minutes at 600° was very sandy in texture when pulverized, soaked up water rapidly, and was quite difficult to shape into a pellet. When dry the surface of the briquette powdered at the slightest touch. The behavior of this piece was very similar to that of sand.

These results agree with those of Brown and Montgomery. In studying the residual plasticity of clays after they had been heated at increasingly higher temperatures they found that nine of the ten clays investigated showed a more or less pronounced loss of plasticity between 350° and 400°. "Beyond this point, the water required to produce a mass which can be moulded increases decidedly and may be equal to or greater than the weight contained in the natural plastic clay" (2, p. 20).

Other briquettes were soaked in water for several days to see how they would be affected by moisture. A pellet of unfired clay that contained 40 per cent crushed granite slaked down completely within two and one-half minutes. A raw, untempered piece rapidly developed cracks when placed in water and disintegrated in less than half an hour, but the cracked external shell remained standing through- out the four days' duration of the test. Three other specimens fired at (*a*) 500° for ten minutes, (*b*) 550° for ten minutes, and (*c*) 550° for fifteen minutes showed no signs of disintegration after having soaked in water for four days. The surfaces were possibly not quite so hard as those of the dry briquettes.

These experiments indicate that the Indians at the Younge site need not have fired their pottery at a temperature higher than 550° in order to make the clay lose its plastic properties and become resistant to the action of water. Even when burned to only 500° the body was not seriously affected by water. It is likely that little of the Indian pottery made in the eastern United States had to be fired, for structural reasons, at a temperature higher than 500°. Increased temperatures within the range attainable in an open fire would only result in the better development of the surface and body colors.

As has been previously stated (6, p. 115), colors found on the sherds could be matched by those obtained on pellets that were fired as high as 740° under oxidizing conditions. There was very little color difference noted between 600° and 740°. Pellets fired only to 500° could also be matched in color by sherds. Thus, in terms of color, there is a possible temperature range for the firing of the pottery from 500° to 740°.[2]

V. CONCLUSION

Because the degree of heat obtained in an open fire would have been far from uniform and because in successive firings the same temperature would not necessarily have been reached, it seems better to think of the firing temperature of the pottery in terms of a range rather than as any one fixed point. On the basis of the shrinkage, color, and plasticity studies, the range suggested for the Younge site pottery is 500° to 750° C.

The cultural significance of the determination of the firing temperature of pottery lies in the fact that such a determination gives archaeologists additional information about the technological abilities of the Indians of the region. Although the degree of heat attainable is conditioned by the type of fuel used, it also depends on the manner of firing. This may be expected to have varied with different types of pottery. Miss Shepard found that the firing temperature range of the southwestern potters whom she had studied was from 625° to 940° C. (9, p. 456). The determination of firing temperatures is a difficult and complex problem, but it is well worth investigating. It would be of interest in the study of American Indian cultures to know whether or not there has been any significant change in the firing techniques of the Southwest, for instance, from the earliest known pottery horizons to the present and whether or not the suggested 500°-750° temperature range at the Younge site can be considered representative of the technological cultures of the eastern United States. Knowledge of firing temperatures is also of interest in connection with metalworking. A metallographic study of copper implements showed that a Wisconsin spearhead was heated to about 800°, and that a Wisconsin arrow point and an Ohio axe were worked at about 500° (11, pp. 111-112). After further metallographic and ceramic studies have been made it may be possible to demonstrate regional technological differences that will be of cultural value.

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[1] In 1907 the refiring shrinkage of sherds was used as an indicator of the temperature to which the ware was originally fired by H. Le Chatelier (5, p. 837) in the study of Greek pottery. Other investigators have also used this method, but the detailed results of their work have seldom been published.

[2] The smoky open fires of the Indians would at times have had a partly reducing atmosphere, and the clear colors obtained under oxidizing conditions might not have had a chance to develop because of the incomplete oxidation of the chief coloring agent, the iron, and because of the presence of carbon. In such cases the resulting colors would tend toward the grays. Since many sherds were found that had a good buff to salmon surface color and since there is no evidence that any special attempt was made to procure a reducing atmosphere, it is permissible to base conclusions concerning the relationship of the firing temperature of the sherds and the colors that appear on them on a series of test pieces fired under oxidizing conditions.

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EUROPEAN TRADE ARTICLES AS CHRONOLOGICAL INDICATORS FOR THE ARCHAEOLOGY OF THE HISTORIC PERIOD IN MICHIGAN

GEORGE I. QUIMBY, JR.

ONE of the current aims of archaeological research is to bridge the gap between the historic and the prehistoric: to reveal the relationships between known ethnic groups and prehistoric cultures which have been discovered through excavation. It is toward that end that this paper is directed.

European trade articles may be used as chronological indicators for the archaeology of the historic period, and, by comparison of the dates of occupancy thus obtained with documentary data, the identity of the culture bearers may become known.

The historic era in Michigan may be divided roughly into a late and an early period, each characterized by various types of European trade objects. The early period is from about 1700 to 1760, and the late period from about 1760 to 1825.

The European trade objects dealt with in this paper are the re suits of excavations or surface collections from fourteen historical sites, thirteen belonging to the late period, and one to the early period. The latter is the Fort St. Joseph site near the city of Niles in Cass County, Michigan. Briefly outlined, the history of Fort St. Joseph is as follows:[1] Sometime after 1700 the French established the site as a fort. The British captured it in 1760-61. During Pontiac's uprising in 1763 it was recaptured and burned. It was never rebuilt to its former strength, although it was evidently still maintained as a fort. In 1777-78 it was twice taken from the British by Frenchmen and Illinois Indians, and in 1781 the Spanish captured it. This final capture seems to have ended the career of Fort St. Joseph.

In the vicinity were two Indian villages, a Potawatomi village upon one side of the St. Joseph River and a Miami village upon the other side. Both of these tribes appear to have been relatively late arrivals in the region, although the Miami antedated the establishment of the fort and the Potawatomi settled there about 1720.

The fort itself was in all likelihood little more than a trading post. It was probably located upon the lowest terrace of the river valley, which is now inundated because of the impounding of the waters by a power dam at Niles.[2] It would seem that many evidences of occupation must be preserved beneath the water. If this is so, they offer an excellent opportunity for the discovery of the material culture of the Potawatomi and Miami Indians, which should give a complete picture of technological acculturation in stratified sequences.

During the past sixty years a number of European trade objects have been collected or excavated in the general neighborhood of the site by amateur investigators.[3] The trade articles which are characteristic of the early historic period, 1700-60, are as follows (see Pls. I and II):

Jesuit rings. — The Jesuit finger rings are made of brass or, per- haps, of bronze. The faces are oval, octagonal, heart-shaped, or round, and bear such inscriptions as "N.," " I.N.," " IXXI" (this is probably one "M" inverted and superimposed over another), "I.H.S." with a cross, three fleur-de-lis, "L" and a heart, figures of saints, the Maltese cross, "V.I. "F.I.," and others now indistinct. Probably seventy-five or more of these rings have been found.

Brass rings set with glass. — A number of brass rings with small round or oval faces set with plain or colored glass have been collected.

Iron caltrops. — Iron caltrops are four-pronged, barbed weapons which resemble grappling hooks. They were designed so that no matter how they were dropped one barbed prong always faced upward. When left on trails or in other places where they might be stepped upon caltrops were an effective means of injuring an enemy.

Jesuit medals. — The Jesuit medals are made of bronze and are oval or octagonal in outline. Means for suspension are provided at the top. The medals are stamped with figures of saints, Latin and French inscriptions, religious symbols, and letters which are abbreviations of prayers. There are medals of St. Anna, St. Matthia, St. Rosa, St. Magdale, St. Ignatius, St. Francis, and St. Benedict. Some of the inscriptions are *Soc Iesu* and *Par votre mort et votre sépulture déliverez nous Jésus.*

Jesuit crosses and crucifixes. — The crosses and crucifixes have figures of saints and religious symbols stamped upon them. Since means for suspension are provided at the top of both crosses and crucifixes, they were probably worn or used on rosaries.

Iron knives. — There is an abundance of iron knife blades from the general site. These are probably blades of clasp knives which were manufactured in France. They are stamped with such names as IEAN B. TIVET, IEAN PERRIOT, PIERRE, I. ROVET, CLAUDI, IEAN ARCONE, HUGUE PALLE, I. C. DORON, ANTOINE, and BARTELEMY PERRIN. Other names have been obscured by deterioration and encrustation.

Lead seals. — The lead seals are oval or round, and consist of two parts joined together by a narrow strip. The parts were folded over each other and the fabric or blanketing was held between them. The seals are stamped with fleur-de-lis and other decorative or symbolic figures, most of which are indistinct. Some of the inscriptions are ORAINE DE LILLE, RIOVE DE CARCA, ZIT [?] DE MAZAMET, ONTROLL DE MAZAMET, M. AUDUIT LONDON, and BUCK AND HERSHAW HALIFAX. Observable dates on the French seals are 1734 and 1746. It is probable that the French seals bear the maker's name and the town in which the fabric was manufactured. Mazamet was a French town well known for the manufacture of textiles and especially famed for one fabric which was called Mazamet.4 Other

French towns represented upon the seals are Lille and Carcassonne. Two seals, from London and Halifax, are British, and may not be characteristic of the early period, although similar ones have not been found in Michigan at any of the sites of the late period. Crudely scratched on the backs of these seals are many numbers and fractions.

Polished stone Micmac pipes made with iron tools. — Fragments and whole pipes of this type, apparently made with iron tools, occur in rather large quantities. Some of them are of catlinite or slate, but the majority are of some soft sedimentary stone. A few specimens have a circle made with a compass upon the basal part of the pipe.

Copper and brass projectile points. — Several varieties of metal projectile points are represented at the Fort St. Joseph site. There are triangular points, which may be perforated or unperforated, stemmed triangular ones, and hollow ones of rolled sheet metal.

Glass beads. — Great quantities of glass beads have been re covered from the general site. Some of them are polychrome and spheroid or elongated-spheroid. There are a few raspberry-shaped beads of opaque colored glass and some large spheroid beads of opaque uncolored glass, as well as a good many white, blue, or red spheroid or tubular seed beads. The seed beads are characteristic of the late period also.

Blown-glass bottles. — Thick pieces of rather large bottles have been found. These are color-patinated and have a tendency to flake. On the neck fragments there is an external strip, or collar, around the upper part, just beneath the lip.

Shell runtees. — Two fragmentary specimens of shell runtees are in the collections from the Fort St. Joseph site. One of these has the common circle motif made with a compass.

Stone mold. — A rather unusual specimen from this site is a stone mold for making lead crosses. The crosses are of the small single-barred type with crenulated edges.

Brass bracelets. — A large number of bracelets of heavy brass wire occur. Although such bracelets are also found in the late period, they are less common, owing to the introduction of silver bracelets.

There are prehistoric artifacts represented in the collections from Fort St. Joseph, but the exact nature of their association with the European trade articles is not known. The trade articles, however, may be considered as part of the material culture of the Potawatomi and Miami Indians between the years *c*. 1700 and 1760. There are a number of trade objects which seem to be characteristic of the entire historic era in Michigan, but enumeration of these will be withheld for subsequent discussion.

European trade articles characteristic of the late period, that is, from about 1760 to 1825, have been found at a number of sites in Michigan. Materials from eleven of these sites have been reported and illustrated in a previous paper,[5] and hence will not be illustrated here. However, trade objects representative of this late period are as follows:

Silver ornaments. — A variety of trade silver ornaments occur at late-period sites. These include various types of brooches, effigy or spoon lockets, single- and double-barred crosses, arm bands, wrist bands, bracelets, and crowns. The great majority of these silver ornaments, identified by means of their touch marks, were made by Montreal silversmiths between 1770 and 1825, and many of them have been discussed in a previous paper.[6] That they belong to the late period is manifested not only by identification of the makers but by documentary evidence and by the absence of silver ornaments from early-period sites in other areas as well as in Michigan. Skinner reports no silver ornaments from late seventeenth- and early eighteenth-century historic Cayuga sites in New York,[7] although he did find Jesuit rings, medals and crucifixes, polychrome beads, iron implements, brass triangular projectile points, and other trade articles representative of the early period. Cadzow reports no silver from the sites in Pennsylvania which he believes to be seventeenth-century Susquehannock.[8] He did, however, find other trade objects representative of the early period, as well as trade articles which occur throughout the entire historic era and which at the present time seem to be diagnostic only of white contact in general. Trade silver ornaments seem to be the best single criterion for the late period in Michigan.

Glass bottles. — Glass bottles are not numerous in late-period sites. Only two have been reported in Michigan. One of these is an enameled Stiegal glass bottle, and the other a long-bodied, long-necked plain bottle. It is different from the bottles of the early period in Michigan in that it does not have the external strip around the neck just beneath the lip. Both bottles have pontil marks.

Glass beads. — These are of the seed type, small tubular glass beads, generally white or blue.

China. — The china is of the Staffordshire type. Various designs are lithographed in mottled blue, mulberry, pink, and other colors.

There are a number of trade articles which occur in both early- and late-period sites. These are: flintlock rifles and pistols, gun- flints, glass mirrors, brass and copper kettles, tomahawk pipes, iron hoes and axes, iron knives, iron fishhooks, pewter vessels, brass hawk or morris bells, white clay pipes, scissors, vermilion paint, and jew's harps.[9] (The trade articles are presented by periods in Table I.)

TABLE I

Chronology of Trade Objects in Michigan

Trade objects	Periods 1700–60	Periods 1760–1825
Silver ornaments		×
Stiegal glass		×
Staffordshire pottery		×
Glass seed beads	×	×
Vermilion paint	×	×
Scissors	×	×
Flintlock guns	×	×
Jew's harps	×	×
Mirrors	×	×
Copper and brass kettles	×	×
Pewter vessels	×	×
Brass morris bells	×	×
White clay pipes	×	×
Tomahawks	×	×
Iron implements	×	×
Brass bracelets	×	×
Large blown-glass bottles	×	
Jesuit rings	×	
Jesuit medals	×	
Iron knives stamped with French names	×	
Glass polychrome beads	×	
Micmac pipes, iron-tooled	×	
Lead fabric seals	×	
Iron caltrops	×	
Copper and brass projectile points	×	
Shell runtees	×	

Probably the technological change in the aboriginal culture caused by European contact was very rapid. The late-period sites which are Ottawa, Potawatomi, and Chippewa offer nothing of value in the way of traits representative of the prehistoric culture. Therefore, the best possibility of correctly applying direct historical methods in Michigan lies in the investigation of contact sites of the early period.

University of Michigan

[1] The historical data were obtained from Mr. W. Vernon Kinietz, ethno-historian, Museum of Anthropology, University of Michigan.

[2] Some slight investigation of the probable location of Fort St. Joseph as well as a study of the objects said to have come from the general site was undertaken as part of an archaeological survey of the St. Joseph River Valley. This survey was made by the writer in the summer of 1937 under the auspices of the Museum of Anthropology, University of Michigan, and in coöperation with Mr. Glenn A. Black, of the Indiana Historical Society.

[3] Many of these trade objects are in the Museum of the Fort St. Joseph Historical Society at Niles, Michigan. The writer is very much indebted to Mr. and Mrs. Ralph Ballard, the curators of that museum, for their valuable assistance and interest. Other trade objects from this site are in the Museum of the Northern Indiana Historical Society at South Bend, Indiana, and in the Kalamazoo Public Museum, Kalamazoo, Michigan.

[4] This information was obtained through correspondence with E.-Z. Massicotte, archivist, Old Courthouse, Montreal.

[5] Quimby, George I., Jr., "Dated Indian Burials in Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters,* 23 (1937): 63-72. 1938.

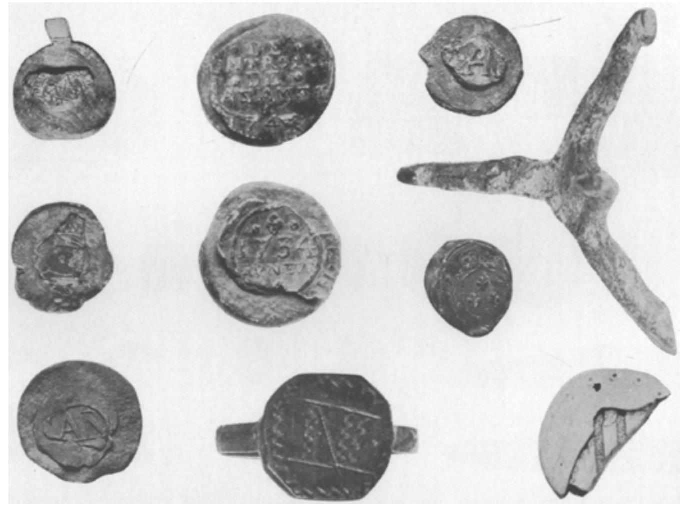
[6] *Idem*, "Notes on Indian Trade Silver Ornaments in Michigan," *ibid*., 22 (1936): 15-24. 1937.

[7] Skinner, Alanson, "Notes on Iroquois Archaeology," *Indian Notes and Monographs*, Museum of the American Indian, Heye Foundation, 1921.

[8] Cadzow, Donald A., *Archaeological Studies of the Susquehannock Indians of Pennsylvania*. Safe Harbor Report No. 2, Publ. of Pennsylvania Historical Commission, Vol. III. Harrisburg, 1936.

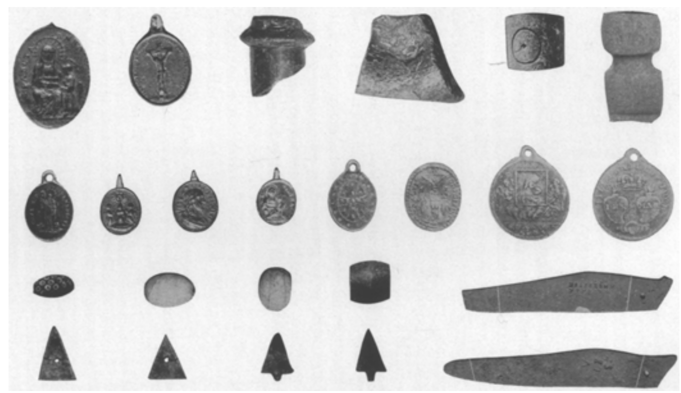
[9] Although jew's harps have been found on no late-period sites in Michigan, they are reported from early sites in other areas and are frequently found upon trade inventories as late as 1815.

QUIMBY PLATE I



Row 1: Lead seals for fabric and an iron caltrop; Row 2: Lead seals for fabrics; Row 3: Lead seal for fabric, Jesuit brass ring, and fragmentary shell runtee. Scale variable

QUIMBY PLATE II



Row 1: Jesuit medals, glass bottle fragments, and Micmac pipe fragments; Row 2: Jesuit medals; Row 3: Polychrome glass beads and iron knife blade; Row 4: Sheet brass or copper projectile points and iron knife blade. Scale variable

RELATIONS BETWEEN GRANITE AND SLATE IN THE EUREKA MINE, RAMSAY, MICHIGAN

ROBERT M. DICKEY* AND DAN S. YOUNG†

INTRODUCTION

THE Eureka Mine, at Ramsay, Michigan, occupies parts of Sections 12 and 13, T. 47 N., R. 46 W., toward the eastern end of the productive portion of the Gogebic iron range. It is adjoined on the west by the Palms-Anvil-Keweenaw Mine, and on the east by the inactive Asteroid and Mikado mines, the former of which was at one time worked as part of the Eureka operation.

The geologic structures of the Eureka Mine are among the most complex to be found in the Lake Superior region, not because of intensive deformation by folding, but by reason of an intricate pattern of faulting. The Eureka, Asteroid, and Mikado properties are west of a northeast-trending oblique dislocation known as the Mikado fault. This fault forms the west boundary of a block of Huronian rocks which has been displaced downward and to the south of the general trend of the iron-bearing rocks of the Gogebic range; this block is margined on the east by the northwest-striking Sunday Lake fault, and on the north by the east-west Wakefield fault.

The area of the Eureka Mine comprises, therefore, a part of the Gogebic range which has been the site of major, though relatively localized, faulting — a fact which led the writers to suspect the presence of igneous intrusion in the immediate vicinity. As a result, the relationships between the sedimentary rocks and the granite beneath these sediments in the Eureka Mine were studied in the various cross-cuts leading north from the No. 4 shaft, and some interesting features were observed which are believed to be worthy of note.

Since this paper is primarily concerned with only a single phase of the geologic relationships observable in the Eureka Mine, no attempt will be made to consider in detail the geology of the entire property. It has been ably discussed by Hotchkiss[1] and, except for the pronounced structural dislocations, is similar to that of most of the eastern portion of the productive part of the Gogebic range.

DESCRIPTION OF THE GRANITE-SLATE CONTACT

The contact studied was that between the Palms quartz slate, which on the Gogebic range makes up the basal portion of the pre-Cambrian sequence known as the Middle Huronian, and the granite beneath the Palms formation and to the south of it. The Huronian rocks in the Eureka Mine generally strike about east-west and dip north at angles usually ranging from 65° to 70°; the surface of contact between granite and slate ordinarily conforms with relatively minor variations to the strike and dip of the bedded Huronian rocks.

The granite-slate contact was observable in the No. 4 shaft cross-cuts on the twenty-second, twenty-fourth, twenty-fifth, twenty-sixth, and twenty-seventh levels, at elevations below mean sea level of 498, 895, 1,094, 1,292, and 1,490 feet, respectively. Projected vertically to the surface, the intersections of the contact with these levels are in the E. ½ of the NE. ¼ of the NW. ¼ of Section 13, T. 47 N., R. 46 W. Because of the heavily gunited condition of the crosscuts, the geologic relationships could not be seen to the best advantage, but they were exposed sufficiently to provide a basis for what are believed to be correct conclusions.

Character of the Palms quartz slate. — The Palms quartz slate is a fine-grained, thin- to medium-bedded, greenish gray, indurated, elastic sedimentary rock. For the most part it possesses no secondary cleavage, and in this respect is not a typical slate. It is, however, much more dense and compact than shale, and perhaps the term "slate" is the most suitable of the common rock appellations which might be applied to it. Microscopic study shows its dominant constituents to be quartz grains and numerous parallel wisps or shreds of sericite, chlorite, and muscovite, with some biotite occurring locally. Rounded to subrounded to angular grains of pinkish to yellowish high—birefringence zircons are relatively abundant. Near its base are scattered grains of detrital orthoclase and plagioclase.

Character of the granite. — The granite is one of medium grain, and ranges in color from gray to pink to reddish. In places the ferromagnesian constituents have a rude parallelism trending normal to the contact with the slate; elsewhere this parallelism is not apparent. Microscopic inspection shows the granite to be made up of quartz, orthoclase, acid plagioclase, secondary chlorite, sericite, apatite, pinkish to yellowish high-birefringence zircon, and pyrite.

Exposures of the granite-slate contact. — On the twenty-second level the contact between granite and slate, though broadly regular, is irregular in detail. The slate projects into the granite in jagged extensions one inch or less in width, and about six inches in maximum length. A few small rounded to angular fragments of granite and occasionally of chert occur at the base of the slate immediately adjacent to the granite. The granite just below the slate is noticeably kaolinized, Narrow stringers of white vein quartz cut the granite, but are sharply terminated at the contact. The slate bedding is not entirely concordant with the surface of the granite, inasmuch as thin basal slate beds narrow and pinch out ultimately against it. The granite shows no evidence of contact chilling. A prominent feature of the slate is marked silicification in a basal zone about two feet thick, which has resulted in thorough induration and the imparting of a well-developed conchoidal fracture. Microscopic examination of this altered slate reveals that the metamorphism has been confined to silicification, without apparent development of new minerals.

The granite-slate contact in the twenty-fourth level crosscut is much more regular than that on the twenty-second level. The slate bedding appears to be entirely concordant with the granite surface, and there has been no silicification of the slate, with the observed exception of a single narrow extension of silicified elastic material into the granite. No conglomeratic horizon was seen at the base of the Palms.

On the twenty-fifth level the slate bedding is concordant with the surface of contact with the granite. A basal zone of the slate on the east side of the crosscut shows prominent silicification, but this is absent on the west side of the same crosscut. As on the level above, no conglomeratic material was found at the base of the slate.

The base of the Palms on the twenty-sixth level is marked by the presence of a thin conglomerate consisting of rounded to sub-angular fragments of chert, which range from dense and cream colored to granular and reddish. Some of these fragments are true jasper. The matrix of the conglomerate is feldspathic to chloritic, and in some places is cut by narrow stringers of pyrite. The conglomerate truncates what appears to be a rounded xenolith of chloritic, feldspathic amphibolite included in the granite. Neither the conglomerate nor the overlying slate shows silicification.

On the twenty-seventh level the basal portions of the slate are markedly silicified, and, as on the twenty-second level, thin basal beds of the Palms pinch out against the granite. Narrow, irregular extensions of slate into the granite are numerous. The granite just below the contact has been intruded by relatively abundant white vein quartz, with considerable amounts of pyrite and, to a minor extent, chalcopyrite; the pyrite contains traces of gold. No conglomerate characterizes the lower part of the Palms.

INTERPRETATION OF THE EXPOSURES

The nature of the granite-slate contact leads to the conclusion that the relationships are fundamentally those of unconformity. This is evidenced by the discordant relationships between the granite-slate contact and the trend of the oriented ferromagnesian constituents of the granite, by the broad regularity of the contact, by the inclusion locally of detrital fragments of the underlying granite in the basal portions of the slate, by the truncation by the slate of a xenolith in the granite, by a general concordance of the slate bedding and the granite surface, and by a lack of contact chilling in the granite adjacent to the slate. This view is supported by the presence of pinkish to yellowish high-birefringence zircons in the granite. In the igneous rocks of Upper Michigan this type of zircon occurs only in Laurentian granite, according to S. A. Tyler and R. W. Marsden,[2] who have conducted an extensive investigation into the heavy accessory minerals of the pre-Cambrian granites and sediments of Michigan and Wisconsin. The uniform character of the granite ex posed in the mine is believed to preclude the possibility of the presence of both pre-Palms and post-Palms granites.

The narrow jagged extensions of slate into the granite are interpreted as having resulted from deposition of elastic material in crevices on the erosional surface of the granite during the early Palms sedimentation.

The silicification of basal parts of the quartz slate and the obvious introduction of metallic sulphides and some gold adjacent to the granite-slate contact are thought to have been brought about by the agency of hydrothermal solutions of post-Palms age. The silicification and sulphide mineralization are irregularly distributed, as has been previously indicated in the descriptions of the granite-slate contact on the various levels. However, where observed, they are localized in the immediate vicinity of this contact, L. M. Scofield[3] has noted a closely parallel case in the Palms basal conglomerate un conformably overlying granite in the Newport Mine some distance to the west of the Eureka Mine; this conglomerate contains the following metallic sulphides in order of relative abundance: galena, pyrite, chalcopyrite, bornite, pyrrhotite, molybdenite, and sphalerite.

It seems that in the Eureka Mine the unconformable surface of contact between granite and quartz slate has provided a favored avenue of upward migration of hydrothermal solutions from a source which probably underlies the property at some depth and which is post-Middle Huronian in age.

SIMILAR CONDITIONS IN OTHER PARTS OF UPPER MICHIGAN

The close association of pronounced alterations, of a type usually attributed to igneous intrusion, with erosional contacts between sediments and granites, is perhaps more widespread in the pre-Cambrian rocks of the Upper Peninsula than has been recognized in the past.

Dickey[4] has recently described an occurrence of quartzite conglomerate and quartzite in unconformable contact with granite-porphyry which intrudes an earlier quartzite series, a short distance southeast of Floodwood, Michigan. The conglomerate adjacent to the granite is thermally metamorphosed to a pronounced degree, its matrix consisting largely of secondary biotite, chlorite, sericite, abundant quartz grains, and, locally, idiomorphic crystals of bluish hornblende. The quartzite overlying the conglomerate grades from a type showing abundant sericitization upward through graywacke and ultimately to decomposed ferruginous quartzite; in one place the quartzite near its base contains grunerite-magnetite rock. Evidences of igneous activity subsequent to the deposition of the conglomerate and quartzite in erosional contact with the granite are restricted to thermal metamorphism of this series and, to a minor degree, its in by a few quartz veins.

Another exposure, which is perhaps more debatable than are the occurrences at Floodwood and in the

Eureka Mine, is found southeast of Republic, Michigan. This exposure has been described by several writers;[5] according to Dickey's interpretation, granitized quartzite and granite-porphyry are unconformably overlain, by a conglomerate containing boulders of the underlying material in a quartz-biotite-chlorite matrix, which is locally feldspathic. The conglomerate is intruded in some places by pegmatitic material and quartz veins, and the sedimentary material overlying the conglomerate contains andalusite locally. Others disagree with this interpretation and prefer to regard the conglomerate as intruded by the granite-porphyry, basing their opinion on the thermal metamorphism of the sedimentary material and its local indisputable invasion by pegmatites and quartz veins.

CONCLUSIONS

The contact between granite and Palms quartz slate in the Eureka Mine is dominantly that of erosion, modified by the activity of hydrothermal solutions rising along this contact for the most part and resulting in local silicification of the slate and the introduction of pyrite, chalcopyrite, and traces of gold, associated with vein quartz.

In a number of places in Tipper Michigan thermal metamorphism of sedimentary rocks has been attributed to the nearest exposed igneous rock, especially if that igneous rock is granitic, regardless of whether the igneous material can be definitely proved to intrude the metamorphosed sediments. In fact, if the sedimentary sequence shows thermal metamorphism, this alteration is frequently offered as evidence of intrusive relationships. However, the examples cited in the foregoing discussion suggest that this criterion is one to be used with the utmost caution; thermal alteration in a sedimentary rock adjacent to the contact with a granite has not invariably been developed through intrusion by the granite. To cite two places where the relationships may be regarded as established, in the Eureka Mine and at Floodwood erosional contacts between granites and overlying sedimentary sequences have served as the principal ob served avenues of upward movement of hydrothermal solutions emanating from a buried source. These solutions have brought about pronounced thermal alteration of the sedimentary rocks in the vicinity of the erosional contacts. The contacts are observed to be those of unconformity, but where they are not fully exposed their marked spatial association with thermal metamorphism might easily lead to the erroneous conclusion that the relations are those of intrusion.

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† Chief engineer, Castile Mining Co., Ramsay, Michigan.

[1] Hotchkiss, W. O., "Geology of the Gogebic Range and Its Relation to Recent Mining Developments," *Eng. Min. Journ*., 108: 443-452, 501-507, 537-541, 577-582. 1919.

[2] Personal communication.

[3] Personal communication.

[4] Dickey, R. M., "The Ford River Granite of the Southern Complex of Tipper Michigan," *Journ. Geol*., 46: 321-335, 1938.

[5] Smyth, H. L., "A Contact between the Lower Huronian and the Underlying Granite in the Republic Trough, near Republic, Michigan," *Journ. Geol*., 1 : 16-29. 1893; Lamey, C. A., "Republic Granite or Basement Complex?" *Journ. Geol*,, 45 : 487-510. 1937; Dickey, R. M., *op. cit.;* and *idem*, "The Granitic Sequence in the Southern Complex of Upper Michigan," *Journ. Geol*., 44 : 317-340. 1936.

NATURAL BRIDGES IN THE MANSFIELD FORMATION OF INDIANA

KENNETH W. DOW

IN THE Mansfield sandstone formation of Indiana there are two natural bridges, the Portland and the Mansfield. The Portland Arch natural bridge is situated in Fountain County, in the region of the great bend of the Wabash. It is located just south of the town of Fountain, formerly called Portland. Orahood[1] mentioned it briefly in 1915, and in 1910 Cleland[2] had given the following descriptions of it:

Bridge at Attica, Indiana — A natural bridge over which a roadway passes, said to be about 30 feet in height from the stream bed to the top of the bridge, spans Bear Creek near Attica, Indiana. From the very imperfect description of the bridge, which it has been possible to secure by correspondence, it appears that this bridge was formed, as in the case of the Campton [Ky.] bridge, by the stream tunneling through the isthmus of the incised meander.

Catalog of North American Natural Bridges — Indiana — A sandstone (?) bridge near Attica.

This explanation of origin and location is incorrect and, as Cleland has stated, was derived through correspondence rather than from actual observation.

Bear Creek, which together with its main tributary, Rattlesnake Creek, covers a rather extensive area in west central Indiana, flows through a deep gorge of Mansfield sandstone at Fountain, and thence into the Wabash River. The Portland Arch occurs in this canyon about one-half mile inland from the Wabash, near the juncture of a minor spring-fed tributary with Bear Creek (see Fig. 1). At this point, running in an east-west direction between the main stream and the tributary, is a narrow sandstone divide about 300 feet in length and approximately 42 feet in width except where it tapers at the western end. This divide has been cut through and a bridge formed, so that the tributary has been diverted from its course and now enters Bear Creek 93 feet farther upstream than before ; and the section from the bridge to the former mouth of the stream has been abandoned (Pl.. I, Fig. 1). The tributary has continued to cut down, with the result that the abandoned or pirated part remains as a distinct terrace 5½ feet above it. There is also the possibility that Bear Creek was at a somewhat lower elevation, and when the cutoff became established the increased gradient of the diverted part of the tributary may have caused it to entrench itself slightly in the bed of its old course. Dake[3] describes a situation somewhat analogous to this in Missouri.

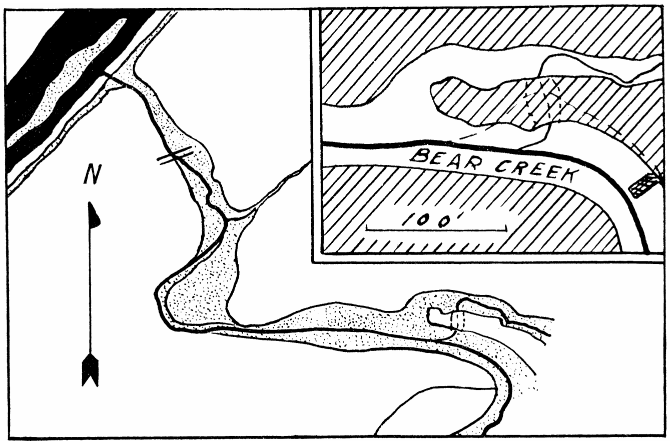

FIG. 1. The approximate course of Bear Creek from the vicinity of the Portland Arch to the Wabash River. Stippled areas represent low ground along the stream. The inset enlargement shows the divide pierced by the opening, the present course of the tributary, and the course of Bear Creek before its diversion, caused by the building of the dam, away from the wall of the canyon

The divide in which the bridge occurs reaches a height of 33 feet above the creek at the western end and a height of 38½ feet at the arch. The opening of the bridge ranges from 10 feet high on the northern side to 15 feet high at a point 20 feet south from the center. This variation is mainly due to the unusually wide overhang on the south or Bear Creek side of the bridge. Similarly, the width of the actual opening is 19 feet, but on the tributary side the span of the arch is 36 feet, and on the south it is 69 feet (see Pl. I, Fig. 2). The floor of the bridge is only 16 inches above Bear Creek.

As to the origin of the bridge, Cleland's explanation can be eliminated immediately, because the divide is not the isthmus of an incised meander. However, the widely overhanging and undercut walls on the southern side do indicate lateral planation by Bear Creek, which has progressed to such an extent that it may actually have cut through the divide. It should be noted that although the stream no longer flows close to this north wall of the canyon, it apparently did so prior to the building of the concrete dam on the meander bend a short distance upstream. The wall of the bluff on the tributary side is somewhat overhanging but not greatly undercut. The overhang seems to be due to weathering of the face of the cliff and to the dropping off from time to time of loose blocks, rather than to undercutting by the tributary. The base of the arch is only 2 feet thick east of the opening, and 15 feet thick to the west. The fact that the abutments of the bridge are close to the tributary side of the divide would also indicate that the greater part of the cutting had been done by the larger stream. It would seem, therefore, that lateral planation was most important in the formation of the bridge. The conditions and causes of diversion of the tributary stream appear to be similar, though on a much smaller scale, to those existing at the Edwin natural bridge in San Juan County, Utah, as described by Cleland.[4]

The possibility that minor factors contributed to the opening of the Portland Arch should not be neglected. Bear Creek canyon has been cut through the alternately flat-lying and cross-bedded strata of the Mansfield sandstone formation, which forms the basal member of the coal measures of Indiana. These strata, of Pennsylvanian age, rest unconformably on the Mississippian formations. The Mansfield sandstone or "millstone grit," as it is sometimes called, extends from Benton County on the north in a direction a little east of south to the Ohio River. The upper layers in this formation have disintegrated less rapidly than the underlying strata. Streams have cut narrow gorges through the rock, and the steep walls often present a castellated appearance, with undercut and honeycombed cliffs. The sandstone is soft, medium- to coarse-grained, and very porous. Much of it is stained with ferruginous bands of various colors and is somewhat micaceous (Pl. II Fig. 1). Cross-bedding and deeply weathered joints are also characteristic. For further descriptions of the Mansfield formation see Cumings[5] and the descriptive booklet on Turkey Run State Park.[6]

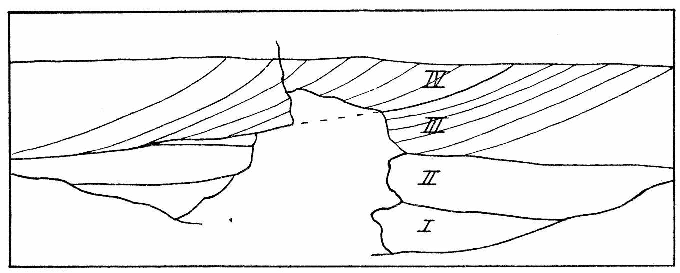

FIG. 2. Sketch showing how strata outcrop on the northern side of the Portland Arch

The sandstone exposed in the walls of Bear Creek canyon is typical of the Mansfield. In the western part of the divide it is apparent that at least five separate strata of various widths have been pierced in the development of the bridge (see Pl. II Fig. 2). The two lower strata are horizontally bedded, whereas those above display marked cross-bedding. In connection with the outcropping of these strata there are four features which may be noted in text figure 2: (1) The top of the second stratum, where it outcrops on the tributary side of the divide, is even with the top of the terrace marking the former level of the tributary. (2) Just opposite the opening of the bridge stratum number III pinches out and disappears, so that a few feet to the east stratum number IV rests on number II. (3) At the apex of the opening a rather large fracture cuts at right angles through stratum number IV, and has resulted in the dropping off of an irregular block, and the consequent heightening of the bridge. Whether or not this fracture continued through the lower strata cannot, of course, be determined. (4) The first two strata are tilted very slightly and those above more markedly, so that the outcropping of the series on the northern side is somewhat higher than that on the southern side. All four of these factors may have aided in the formation of the bridge just at this point in the divide.

Tests with hydrochloric acid indicate iron compounds to be the main cement of the sand grains, with lime present in negligible amounts. Though the cement is not especially subject to solution, seepage from the tributary stream along and through the plane of bedding at the top of stratum II could easily have occurred.

At present all the bedding planes are deeply weathered and, in some places, as for example between strata I and II, narrow cavities extend back as much as four feet along the bedding plane. As has been stated, the Mansfield is an extremely porous and friable formation, much given to crumbling. This is especially true of the lighter- colored parts of the rock, where there is less iron in the cementing material. The sandstone is characteristically riddled with incipient fractures and small parallel cavities, which may be related to some irregularly distributed weakness (see Pl. II, Fig. 1). Thus water might easily find passage through the inherently weak rock of the divide, especially at such favorable places as along one of the major planes of bedding. Bryan[7] has given an account of this type of weathering, due, as he claims, primarily to differential sapping as water moves through the porous sandstone.

The fact that stratum number III pinches out just at this point, and results in two major bedding planes in close proximity, would further weaken the rock, even if it were not cut here at right angles by the fracture passing vertically through the stratum immediately above.

Because of the slight tilting of the strata gravity would aid in the flow of water from the tributary side along the bedding planes and through the divide.

The combination of all these factors might have materially weakened the rock at this location, and aided in the initiation of the opening.

In addition, the effect of frost on the moist rock should not be overlooked as an agent of weathering and an element in the enlarging of the aperture. The opening, although lateral planation by Bear Creek has ceased because of the presence of the dam, is still being enlarged, chiefly by corrasion. During normal times this is accomplished by the tributary's wearing away the abutments of the arch. In flood, however, Bear Creek has been known to rise 13.7 feet, to the top of the old dam. The water then completely covers the opening of the bridge and surges through to the tributary side and out over the abandoned channel. At such times corrasion of the entire opening must result. This reversal in drainage is similar to the conditions existing at the Creelsboro natural bridge in Kentucky when the Cumberland River is in flood.[8]

A small natural bridge about two miles northeast of the town of Mansfield in Parke County, Indiana, also occurs in the Mansfield formation but owes its origin to a somewhat different set of conditions. This and the Portland Arch are, to the author's knowledge, the only true bridges found in the Mansfield formation. Cleland applies the term "bridge" rather than "arch" to those forms spanning valleys caused by stream erosion. It is proposed that the term "Mansfield natural bridge" be applied to this span.

The Mansfield natural bridge was briefly described in 1912 by Dryer.[9] It is located on a small tributary of Raccoon Creek (Pl. III, Fig. 1). The height of the bridge is 9 feet and the height of the opening ranges from 5 feet on the side toward the road to 6 feet on the opposite side. The inside length of the span is about 54 feet. Its width is approximately 22 feet. The stream must originally have flowed over the sandstone ledge, at a level with the present top of the bridge, in a small waterfall. Several such falls may be observed near by. The majority are slowly cutting narrow channels through the sandstone. In the case of the Mansfield bridge a fracture or joint, cutting the stream channel at right angles a short distance back from the brink of the fall, must have permitted some of the water to seep down through the harder sandstone layer into the more pervious strata below. As enlargement of this opening progressed through removal of these softer layers, the stream abandoned its course over the resistant ledge, which remains to span the present channel (Pl. III, Fig. 2). A small spring issuing from the strata at one side, near the base of the bridge, may also have aided in the development of the opening.

CONCLUSIONS

The Portland Arch, occurring in a narrow sandstone divide between Bear Creek and a tributary stream, is the result primarily of lateral planation by the larger stream. Weakness in the sandstone at this point offered peculiarly favorable conditions for the formation of the opening. The aperture is being enlarged by sapping and by corrasion of both the tributary and Bear Creek.

The Mansfield natural bridge is due to seepage along a joint or fracture, with resultant diversion of the stream to a lower but parallel course.

UNIVERSITY OF MICHIGAN

[1] Orahood, C. H., *Fountain County Soil Report*, Ind. Dept. Geol. and Nat. Res., 40th Ann, Rep., p. 201. 1915.

[2] Cleland, Herdman F., "North American Natural Bridges, with a Description of Their Origin," *Bull. Geol. Soc. Am*., 21 : 317, 337. 1910.

[3] Dake, C. L., "Stream Piracy and Natural Bridges in the Loess of Southeast Missouri," *Journ. Geol*., 22 : 498-499. 1914.

[4] *Op. cit*., p. 319.

[5] Cumings, E. R., "The Geological Conditions of Municipal Water Supply in the Driftless Area of Southern Indiana, Part IV," *Proc. Ind. Acad. Sci*., pp. 140-141. 1911.

[6] *Turkey Run State Park, a History and Description*, Ind. Dept. of Cons., Division of Lands and Waters, Indiana. 1930.

[7] Bryan, Kirk, "Niches and Other Cavities in Sandstone at Chaco Canyon, New Mexico," *Zeitschr. Geomorphologie*, III Band, pp. 134-135, 139-140. 1927-28.

[8] Scott, Irving D., and Belknap, Ralph L., "The Creelsboro Natural Bridge," *Pap. Mich. Acad. Sci., Arts, and Letters*, 7 : 133. 1926.

[9] Dryer, Charles R., "Wabash Studies, Part III," *Proc. Ind. Acad. Sci*., pp. 212-213. 1912.

DOW PLATE I

FIG. 1. Western end of divide, with abandoned course of tributary to left

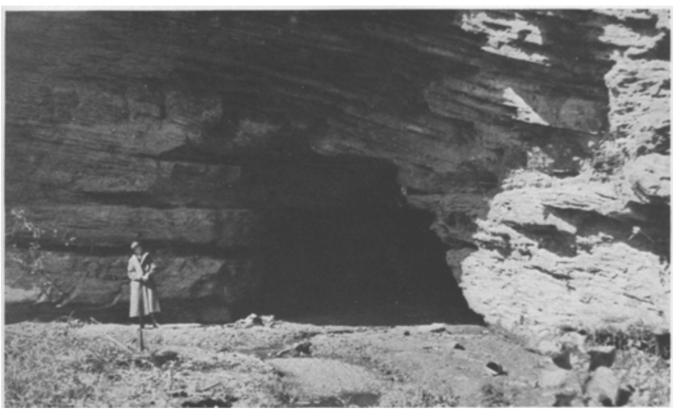

FIG. 2. Close-up of the Portland Arch, on the Bear Creek side

DOW PLATE II

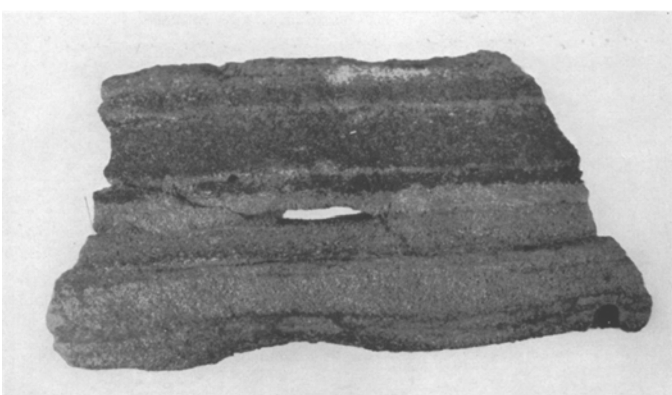

FIG. 1. Typical fragment of Mansfield sandstone from vicinity of the Portland Arch, showing small cavity with incipient fractures, and ferruginous banding

FIG. 2. The Portland Arch from the south, with outcropping of strata indicated

DOW PLATE III

FIG. 1. The Mansfield natural bridge; view up the tributary

FIG. 2. The Mansfield natural bridge from upstream side, looking toward Raccoon Creek

A GREAT ALLUVIAL FAN IN THE TRIASSIC OF PENNSYLVANIA

DEAN B. MCLAUGHLIN

SURVEY OF THE PROBLEM

THE best-exposed section in the New York-Virginia area of the Triassic is that along the Delaware River, which was studied some years ago by the Geological Survey of New Jersey.[1] The series there consists of three formations: the Stockton sandstone, Lockatong black shale, and Brunswick red shale. This sequence came to be regarded almost as a type section for the whole area.

More recent work farther west, notably in the vicinity of Gettysburg,[2] has shown that the three formations are not everywhere present. In that area and in Maryland only two principal formations are recognized: the New Oxford sandstone and the Gettysburg shale, lithologically equivalent to the Stockton and the Brunswick, respectively. The Lockatong pinches out in Chester County, Pennsylvania, and does not reappear farther west. In Virginia[3] the Manassas sandstone and the Bull Run shale are probable equivalents of the New Oxford and Gettysburg.

The preceding paragraph is not, however, a complete picture of the stratigraphy of the New York-Virginia area. The three formations exposed in the Delaware River section do not pass directly into the two-formation series of the Gettysburg district merely by disappearance of the Lockatong. Between the two regions there is a large area which is unique in the New York-Virginia belt.

Apparently the Second Geological Survey of Pennsylvania gave little attention to the Triassic of southern Berks County and adjoining parts of Lancaster and Chester counties. Detailed descriptions of outcrops close to the northern border were published by d'Invilliers,[4] but no description of the region south of the Schuylkill River was given by him. One finds in other county reports little specific information on the rocks of that age.[5]

In 1926 the writer found south of Reading a thick succession of conglomerates and coarse sandstones with almost no shale, directly on the strike of the Lockatong and the Brunswick formations, which are widely exposed east of there. At that time no available map showed the character of the rock, and no publisthed sdatement referred to it as conspicuously different from that of other parts of the belt.[6] The dip and width of outcrop indicate a thickness of approximately 15,000 feet. So large a succession of sediments deserves a name, and the writer proposes "Robeson conglomerate" as appropriate, from Robeson Township, Berks County. The relations of this conglomerate to the formations east and west of it and to the crystalline highlands constitute an interesting problem of stratigraphy and structure.

Without any detailed information other than the rough areal distribution just described, we recognize four possible hypotheses as to the nature of the Robeson conglomerate. It may be: (1) a group of fault blocks of the Stockton formation in its conglomeratic facies, separated by normal faults from the Lockatong and the Brunswick formations on the east; (2) a wide outcrop of the Stockton continuous with that to the east, extending far north of the main belt owing to warping of the basin, the Lockatong and the Brunswick being flexed to the north around it; (3) a later formation unconformable on the Lockatong and Brunswick; (4) a deposit contemporaneous with the Lockatong and the Brunswick and grading into them along the strike.

It is not essential to review here all the merits and the shortcomings of the four hypotheses; it will be evident, from the description which follows, that the first three are untenable and that the fourth is correct. The great body of conglomerate is the stratigraphic equivalent of the Lockatong and the Brunswick formations.

LATERAL GRADATION OF THE DELAWARE RIVER SECTION

In order to present an adequate picture of the stratigraphy it is necessary to begin with au area far from that with which we are chiefly concerned. In the description below extensive use will be made of unpublished data accumulated by the writer during several years' study of the Triassic of New Jersey and Pennsylvania.

A map of the entire region to be discussed is given in Figure 1. We first focus attention on its eastern part. Near the Delaware River the Stockton and the Lockatong formations reach their greatest development. The Stockton, consisting of red, gray, and brown sandstones, with quartz conglomerate beds of variable thickness in its lower part, is approximately 4,500 feet thick. It grades upward into the Lockatong black argillite, which has about the same thickness. In the upper Lockatong there are several hard red argillite members, and passage to the overlying Brunswick formation occurs gradually through an increase of the red beds and a decrease of the black. The lower Brunswick is a rather hard red argillite, with several interbedded black members.[7] Upward in the section the number and the thickness of the black beds decrease, both black and red become softer, and the formation becomes the typical Brunswick red shale, in which individual strata are not recognizable. We need not be concerned here with the sediments above the diabase sill of Haycock Mountain. The series is repeated by faulting, but the southern outcrop at the Delaware River is outside the limits of the map. Its westward extension appears in the southeast corner of Figure 1. The northern outcrop of the Stockton and the Lockatong is terminated by the Chalfont fault, which dies out westward just before reaching Perkiomen Creek.

The southern belt of the Stockton formation is several miles wide in Bucks County. To the west, without any considerable change of dip, the width of outcrop diminishes steadily. At Norristown it is about four miles, at Valley Forge three, just west of Phoenixville only two, and at Coventryville (five miles south of Pottstown) it is hardly a mile wide, which indicates a thickness of about 1,000 feet. From east to west the upper beds overlap the lower ones. A small section of this overlap is very well exposed in a quarry at Port Kennedy, south of the Schuylkill and four miles west of Norristown. There the lower beds of sandstone abut westward against the under- lying Cambrian limestone. The same structure on a larger scale is inferred for the whole district. Evidently the floor on which deposition occurred was irregular, and the Honeybrook Upland remained above the level of sedimentation through most of Stockton time.

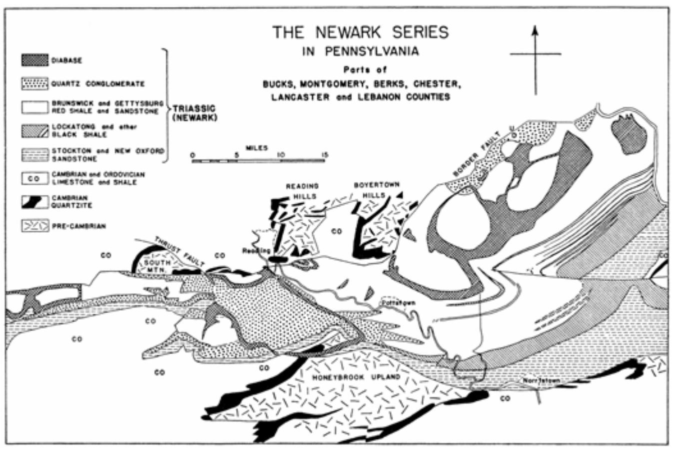

FIG. 1. Areal geology of the Triassic from the Delaware River westward nearly to the Susquehanna River. Pre-Triassic geology from the Geologic Map of Pennsylvania (1931); boundaries of the diabase from the same map, with local revision by the author. Triassic geology; east of the east end of South Mountain, by the author; west of that locality, from the Pennsylvania map. Faults in the western part of the area are omitted

The Lockatong formation also becomes thinner westward, but in a different manner, which is best illustrated by the northern belt. Southwestward from the Delaware River the red argillites become steadily thicker, and the black beds thin out and finally disappear. Thus successive black beds are lost from the top of the Lockatong as we follow it westward to the Chalfont fault. They are replaced by red argillites and softer red shales of a type identical with those of the Brunswick formation. Close to the Chalfont fault — notably in the railroad cuts at Souderton (five miles north-northwest of Lansdale) — some strata can properly be called fine sandstones, as distinct from the argillites or true mudstones farther east.

In the southern outcrop of the Lockatong there is similar gradation westward. The formation decreases in thickness from about 3,000 feet near Gwynedd, south of Lansdale, to 1,500 feet at Phoenixville. At Bucktown, five miles due south of Pottstown, it has diminished to about 100 feet, and only traces of it are found farther west. Although no claim is made that the base of the Lockatong is a fixed horizon throughout that distance, it is certainly not subject to important change. The top, however, descends in the series as the higher black beds pinch out.

South of the Chalfont fault, in both the Lockatong and the Brunswick, some sandstones occur as far east as Lansdale. At first the arenaceous beds are few and thin, with thick successions of shale between them, but west of there the proportion of sandstone increases and some coarser sand appears. The transition is so gradual that it is easily overlooked until comparison of sections some miles apart makes it conspicuous. Once detected, however, the change can be traced step by step from the vicinity of Lansdale to the Schuylkill River. A map of this region is given on a larger scale and in greater detail in Figure 2.[8]

At the Schuylkill River the lower Brunswick is chiefly fine red sandstone, with some interbedded red shale. Several coarser red, brown, and gray sandstone beds are present, and at a few places thin beds of quartz conglomerate with sparsely scattered small pebbles occur. The arenaceous beds extend down to the remnant of the Lockatong formation and are surely contemporaneous with the black argillites of the middle Lockatong of Bucks County.

West of the Schuylkill the changes are more rapid. Within a few miles the lower Brunswick grades into pinkish and grayish medium-grained arkosic sandstone, with some conglomerate and some fine-grained sandstone. The amount of conglomerate increases until, west of State Highway 100 south of Pottstown, the rock is chiefly conglomeratic, with much coarse and medium sandstone and practically no true shale. In the higher portions of the Brunswick, more than five miles north of Phoenixville, red shale persists for a few miles farther west. Exposures of it occur west of the Schuylkill along State Highway 83 from Pottstown four miles southeastward toward Phoenixville, and some occurs near Brethren Church one mile south of Pottstown. But just west of there the rock becomes dominantly sandstone and finally conglomerate.

THE ROBESON CONGLOMERATE AREA

The region just described, from the Chalfont fault southwestward past the Schuylkill River, is a rolling lowland with elevations mostly below 300 feet, except for the Lockatong ridge, which rises above 400 feet. West of State Highway 100, however, the country consists of irregular and prominent hills, rising within a few miles to elevations of 800 and 900 feet. They are heavily wooded and only sparsely inhabited. The rock is chiefly coarse dull reddish or brown conglomerate containing well-rounded pebbles of the Cambrian Chickies quartzite, and is interbedded with coarse arkosic sandstone. Exposures are not numerous; the conglomerate is deeply weathered, and the hills are covered with large loose blocks. Over wide areas the angle of dip is, therefore, rather uncertain.

The conglomerate hills extend entirely across the Honeybrook quadrangle and into the southwest corner of the Reading quadrangle. About Joanna and Geigertown there is a large amount of softer sandstone, and thick shale and soft sandstone members occupy the valleys of Allegheny and Muddy creeks in the northwest corner of the Honeybrook quadrangle, eight to ten miles south of Reading. These areas are shown on the map, Figure 2.

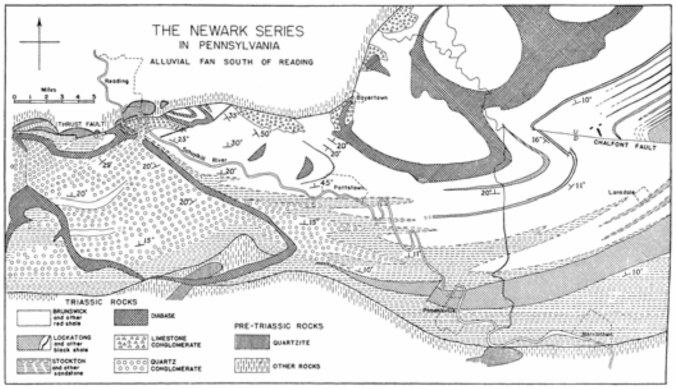

FIG. 2. Areal geology of the Triassic south of Reading, Pennsylvania, and eastward to Bucks County. Gradational boundaries between conglomerate and sandstone and between sandstone and shale are only approximate

The northern edge of the conglomerate hills is determined by a bold ridge south of the Schuylkill River and nearly parallel to it for several miles. This marks the outcrop of a great disabase dike which extends from Harmonyville (five miles southwest of Pottstown) northwestward nearly to the bend of the Schuylkill south of Reading. Then, after an interruption of only one-half mile, its continuation passes westward to Fritztown, just south of the east end of South Mountain. The contact of the diabase with the sediments is ex posed at several places and is roughly perpendicular to the bedding. For a few hundred feet on either side of the dike the conglomerate and sandstone are altered to resistant gray quartzite.

Another part of the same intrusive body extends westward from Harmonyville along the southern edge of a "bay" of Cambrian and pre-Cambrian rocks which enters the Triassic area. At Morgantown it turns northwestward and cuts across the strike of the beds until it reaches a large area of diabase about ten miles southwest of Reading. The "bay" of pre-Triassic rocks appears to indicate a fault along the northern edge of the dike, which causes repetition of the base of the Triassic at Knauertown and Hopewell.

West of the area shown in Figure 2 the writer's field work has been limited to reconnaissance. The belt of Triassic rocks becomes narrower (see Fig. 1), chiefly owing to increased dip, associated with extensive block faulting in the New Holland quadrangle.[9] The Robeson conglomerate occupies a prominent ridge through the center of the belt, known as Furnace Ridge in the Lancaster quadrangle. It is cut off by a fault shown near the western edge of Figure 1,[10] and from that point to the Susquehanna River there are no bodies of coarse conglomerate comparable with that south of Reading. In its extreme western part Furnace Ridge contains more coarse sandstone than conglomerate. The pebbly sandstone on Governor Dick Hill, just north of the west end of Furnace Ridge, may be the same horizon repeated by the fault which cut off the latter. In the Middletown quadrangle,[11] bordering on the Susquehanna River, conglomerates have been mapped in the upper part of the Gettysburg formation, but they are not comparable in thickness or coarseness with those farther east. All these facts indicate lateral gradation to finer material westward from about the longitude of Reading.

STRUCTURE OF THE ROBESON CONGLOMERATE AREA

Some typical dips and strikes are plotted in Figure 2. From the Schuylkill River westward to the great dike the strike is nearly east-west, and the dip north 15°. North of the river and west of Pottstown there is a pitching syncline with dips as high as 50°. For several miles along its northern flank the strata dip southwestward. On its southern flank near Pottstown the dips are northward, representing merely a steepening of the inclination of the beds south of the river and east of the dike. Near Reading, however, the dips are *northeast, directly away from the diabase*. The rocks composing the syncline show no evidence of unconformity with respect to those south of the Schuylkill and east of the dike. They are chiefly red shale and sandstone, with interbedded limestone conglomerate near the north border, and are evidently upper Brunswick. Confirmation of this stratigraphic position is found in the presence of a lava flow which forms the inner one of the two semielliptical ridges mapped as diabase southeast of Reading. Extrusives in the Triassic of Pennsylvania and New Jersey occur only in the uppermost beds of the series.[12]

South of the diabase ridge the conglomerate dips *northwest* 20°, almost perpendicular to the course of the dike. As nearly as can be determined from the scarce exposures, the change of direction of dip occurs at the dike. Near Harmonyville the intrusive obviously passes through the conglomerate, but for several miles it seems to lie at the boundary between the coarse conglomerate to the south and the red shale and sandstone to the north. Close examination shows, however, that there is a narrow fringe of conglomerate north of the dike. Where it is not the dominant rock there are at least thin beds of it in the sandstone. Moreover, these sandstones are mostly coarser than those north of the river, hut dip conformably with them as far west as Birdsboro (eight miles west of Pottstown). Thus the change of strike occurs at the diabase, but the change from conglomerate to fine sandstone and shale does not. The evidence indicates rapid gradation along the strike, accompanied by a change of strike at the diabase dike. This may be more than a coincidence; it appears possible that the region of gradation was a zone of weakness which offered less resistance to the magma and that the intrusion produced the deformation of the strata.

West of Birdsboro the strike of the beds north of the river is practically parallel to the dike, whereas the conglomerate to the south strikes almost at right angles to it. Here there seems to be no satisfactory explanation save faulting. On the geologic map of Pennsylvania such a fault is shown passing between the diabase and the sediments north of it at a locality just east of the large bend of the Schuylkill River south of Reading. At that place there is an excellent exposure of the contact of the diabase with the sediments. The intensely metamorphosed shale dips *northeast* 30°, conformably with the limestone conglomerate and shale a short distance north of there. The igneous contact is obviously an undisturbed intrusive one, for the diabase shows a fine-grained zone of contact chilling several yards wide. A fault at that locality is thus out of the question, unless faulting was contemporaneous with the intrusion. A fault about one-quarter mile north of there appears possible, however.

Two other observations indicate such a fault. The close juxtaposition of quartz and limestone conglomerate just north of the igneous contact is conveniently explained by it. The other locality is at the north end of the Gibraltar bridge over the Schuylkill, two miles southeast of the previous exposure. There the red shale beds are very much crumpled, but without brecciation.

Toward the center of the large area of conglomerate the dip swings around to the north, conformably with the curvature of the southern border, where the basal beds lie upon the Cambrian limestone. Even where exposures are scarce the topography expresses the strike of the beds. No indications of markedly discordant dip occur within the main area of conglomerate. In the sandstone near the base of the series at Geiger's Mills there are small faults and discordances of dip probably due to faulting. In the main, the conglomerate within the elliptical area enclosed by the large diabase dikes appears to be a conformable series without important alteration of apparent thickness by faults. The continuity of the valleys eroded on softer rocks by Allegheny and Muddy creeks is favorable to this view.

COLUMNAR SECTIONS

In regions farther east the lack of extensive repetition of strata by unknown faults has been demonstrated by the continuity of thin beds for many miles along the strike.[13] In the pitching syncline north of the Schuylkill River there is no possibility of important repetition. In the Robeson conglomerate area the evidence is less conclusive, but it appears sufficient, as noted above. Assuming no duplication, we obtain the following sections:

SECTION 1. MORGANTOWN (BASE) TO GOUGLERSVILLE

	Feet
Coarse quartz conglomerate	6,000
Red shale and soft red sandstone	1,400
Quartz conglomerate and coarse sandstone	2,500
Red shale and soft red sandstone	900
Quartz conglomerate and coarse sandstone	4,500
Red and brown arkosic sandstone	1,800
Cambrian limestone	...
Total	17,100

SECTION 2. COMPOSITE SECTION: COVENTRYVILLE (BASE) TO STOWE; BIRDSBORO TO JACKSONWALD[14]

	Feet
Red sandstone	500?
Basalt flow	300 –
Red shale and sandstone	1,000
Diabase sill	700
Red shale and fine red sandstone	9,600
Stowe–Birdsboro Horizon	
Red shale and fine red sandstone	1,300
Quartz conglomerate and coarse sandstone	7,200
Black and green shale (Lockatong)	100
Red and brown arkosic sandstone (Stockton)	1,000
Pre-Cambrian gneiss	...
Total *sediments*	20,700

SECTION 3. KIMBERTON TO LOWER POTTSGROVE TOWNSHIP

	Feet
Diabase sill	...
Red shale (upper 600 feet metamorphosed)	2,300
Red shale with red and gray sandstone, and a few beds of black shale	3,200
Arkosic red sandstone with some red shale, and a few thin beds of conglomerate	3,500
Black shale (Lockatong)	1,200
Arkosic sandstone (Stockton)	1,800
Pre-Cambrian gneiss	...
Total	12,000

For comparison two sections are given below for the areas to the east, in which individual beds have been traced.

SECTION 4. NORRISTOWN TO SCHWENKVILLE

	Feet
Diabase sill	...
Red shale (upper 600 feet metamorphosed)	1,800
Black shale	200
Red shale	1,700
Interbedded red and black shale (Graters)	200
Red shale with numerous beds of fine sandstone (Brunswick and upper Lockatong)	3,900
Black shale (Lockatong)	2,400
Arkosic red and brown sandstone (Stockton)	3,500
Cambrian limestone	...
Total	13,700

SECTION 5. STOCKTON TO HAYCOCK MOUNTAIN

	Feet
Diabase sill	...
Red shale with a few thin blue and gray beds (upper 800 feet metamorphosed)	2,500
Black and red shale (Graters)	120
Red shale with several thick black shale beds	1,300
Black shale with several thick red shale beds (upper Lockatong)	1,700
Black hard argillite (Lockatong)	2,800
Red and gray sandstone, with conglomerate beds in lower 1,500 feet (Stockton)	4,500
Cambrian limestone	...
Total	12,920

From the measures of strike it is concluded that the Stowe-Birdsboro horizon is identical with the one at the base of the sill in sections 3 and 4. The thickness from the base of the Lockatong to that horizon is 8,600 feet in section 2, and 10,200 feet in both 3 and 4. Considering the scarcity of exposures suitable for measurements of dip in the lower part of section 2, the agreement is regarded as satisfactory.

THE SOURCE OF THE SEDIMENTS

Throughout Lockatong and Brunswick time a copious and persistent supply of coarse detritus was evidently poured into the basin of deposition at about the longitude of Reading, and prevented the existence there of the quiet swamp conditions which gave rise to the Lockatong formation farther east. Sheets of gravel spread out as far as twenty miles from the source, and sand was carried to much greater distances. The lateral gradation from black to red shale between the Delaware River and the Chalfont fault probably indicates the influence of the source near Reading, from which the finest muds spread out fifty miles or more. In later Brunswick time the conglomerate was deposited in a less extensive area still centered near Reading. The localization of the source of material and its wide spread from that center indicate a great alluvial fan formed by a single stream and its distributaries. It is certainly no exaggeration to call this single alluvial fan the principal source of Triassic sediments between the Delaware and the Susquehanna rivers.

Such a volume of sediment demands a large source of supply. The pebbles are of Cambrian quartzite, which is abundantly exposed north and south of the Triassic belt. The fan occurs between the Reading Hills and South Mountain on the north and the Honeybrook Upland on the south (Fig. 1).

There are several reasons for doubting a southern source:

(1) The coarsest conglomerates are not at the base at the southern border, but several miles north of there and closer to the northern border.

(2) The southern area is the basement on which the Triassic rocks rest. The probable extent of deposition far south of the present border is a difficulty in the hypothesis of a southern source.

(3) The increasing coarseness of sediments upward in the series would require a steepening of gradient if the material came from the south. This supposition would be very difficult to justify. For a northern source repeated faulting at the border is an adequate cause.

(4) At many places along the northern border smaller fans were active in later Triassic time. In Figure 3 a map of the New York-Virginia area is given, indicating the distribution of conglomerates.[15] The great extent of the conglomerate associated with the alluvial fan south of Reading is evident. Other large bodies of similar character are located west of the Susquehanna River, in and north of the Conewago Hills. A source at the northern border is suggested for these also. Several miles northeast of Frenchtown, New Jersey, a fan of moderate size existed at the north border through most of Lockatong and Brunswick time and spread gravel five miles or more from the border.

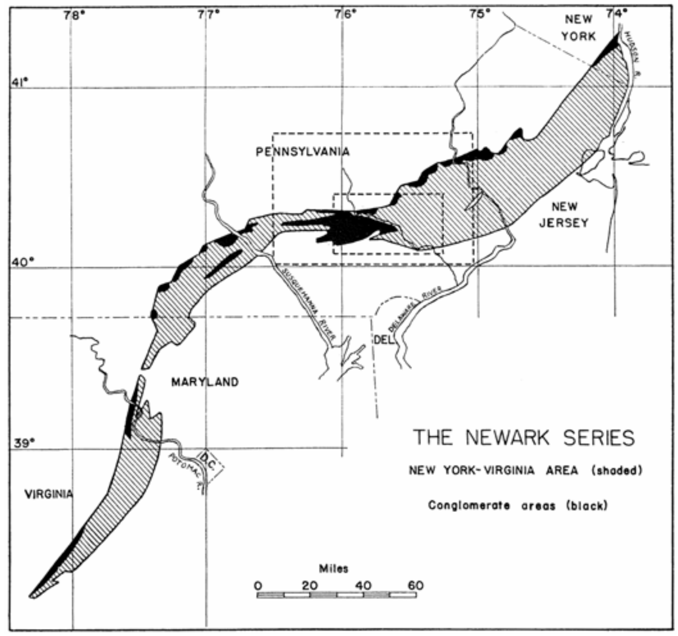

FIG. 3. The New York area of the Triassic, showing the distribution of the larger bodies of conglomerate. Basal conglomerates along the southeastern border are omitted. The large and the small dashed rectangles indicate the outlines of Figures 1 and 2, respectively

(5) A principal source to the north, even at the beginning of deposition, is suggested by the Stockton formation in the Delaware River section. In its southern outcrop the Stockton contains only thin strata of conglomerate; in its northern area at the type locality the conglomerate beds are strongly developed.

The present extent of the Reading Hills and South Mountain does not appear adequate to furnish so much sediment. During Triassic time the Reading Hills especially were probably covered by limestone which furnished the pebbles of the limestone conglomerate south of Reading. The region between these two northern Cambrian and pre-Cambrian areas is now covered by Cambrian and Ordovician limestone (Fig. 1). However, a thrust fault occurs in the Paleozoic rocks just north of the Triassic belt. South Mountain, the hills east of it, and Neversink Mountain, east of the Schuylkill south of Reading, are parts of the overthrust block. Before erosion had cut so deeply as at present quartzite must have covered a much larger area north of the Triassic near Reading. The overthrust block, now chiefly removed by erosion, seems to be the logical source of the great volume of quartzite incorporated in the Robeson conglomerate.

It is inferred, therefore, that in Triassic time there existed, near the present location of the city of Reading and the limestone valley west of it, a lofty range of mountains or a plateau, formed by a great block of Cambrian and pre-Cambrian rocks which was overthrust during the Appalachian Revolution. The region south of it subsided by faulting along the present north border of the Triassic area. From a gorge in the elevated area there issued a torrential stream carrying a heavy burden of sediments which were spread widely over the lower land to the south. Under the load of deposits the basin continued to subside by repeated faulting at the border, and deposition continued until a total thickness of about 20,000 feet had accumulated. To the east, out of range of the coarser sediments, black mud was deposited in a large quiet swampy area, but more turbulent conditions, expressed by the red mud washed in from the Reading district, interrupted the Lockatong deposition several times. With partial exhaustion of the supply, the spread of alluvium from Reading decreased, but other streams became active at numerous points along the northern border and washed in sufficient mud to inhibit the swamp conditions which had given rise to the Lockatong formation. Only a few short-lived recurrences of black shale deposition are recorded in the Brunswick formation. The intrusion of great masses of diabase and the outpouring of lava over the surface occurred near the end of the period of sedimentation. The entire series was subsequently faulted, tilted, and broadly folded (probably by local subsidence), which produced the structures observed today.

The entire New York-Virginia area of the Triassic is a unit and must be studied as a unit in order to appreciate the manner of accumulation of the deposits. Some results of an attempt in that direction are recorded above. The writer acknowledges here his appreciation of the suggestion, made to him a few years ago by Dr. G. H. Ashley, state geologist of Pennsylvania, that he undertake that ambitious program.

UNIVERSITY OF MICHIGAN

[1] Kümmel, H. B., "The Newark System," *Geol. Surv. of N. J., Ann. Rep. of State Geologist*, 1896 : 27.

[2] Stose, G. W., and Bascom, F., "Description of the Fairfield and Gettysburg Quadrangles," *U. S. Geol. Surv*. Folio 225. 1929.

[3] Roberts, J. K., "The Geology of the Virginia Triassic," *Bull. Va. Geol. Surv*., 29. 1928.

[4] D'Invilliers, E. V., "The Geology of the South Mountain Belt of Berks County," *Second Geol. Surv. of Penna*., D3, 2 : 197. 1883.

[5] Bucks and Montgomery counties constitute an exception to this statement. There B. S. Lyman determined the general structure and subdivided the series, recognizing essentially the sequence of formations known today ("Report on the New Red of Bucks and Montgomery Counties," *Second Geol. Surv. of Penna., Final Report*, 3, Part 2 : 2589. 1895).

[6] On the new geologic map of Pennsylvania (1931) the area is mapped as quartz conglomerate.

[7] McLaughlin, D. B., "A Note on the Stratigraphy of the Brunswick Formation (Newark) in Pennsylvania," *Pap. Mich. Acad. Sci., Arts, and Letters*, 18 (1932) : 421. 1933.

[8] In the nature of the case, when one is dealing with gradation along the strike a boundary between shale and sandstone or between sandstone and conglomerate is somewhat arbitrary. In Figure 2 an attempt has been made to indicate the predominant rock in an area without presenting small details which would interfere with legibility.

[9] Stose, G. W., and Jonas, A. I., "Geology and Mineral Resources of the New Holland Quadrangle, Pennsylvania," *Penna. Geol. Surv*., Fourth Series, Top. and Geol. Atlas, 178. 1926. To avoid confusing the small-scale map these faults are omitted in Figure 1.

[10] *Eidem*, "Geology and Mineral Resources of the Lancaster Quadrangle, Pennsylvania," *ibid*., 168. 1930.

[11] *Eidem*, "Geology and Mineral Resources of the Middletown Quadrangle, Pennsylvania," *U. S. Geol, Surv. Bull*., 840. 1933.

[12] The flows at Bendersville near Gettysburg, at Sand Brook and New Germantown in New Jersey, and the great sheets forming the Watchung Mountains all occur in deep synclinal basins which have preserved the upper Brunswick from erosion.

[13] McLaughlin, D. B., "Note on the Thickness and Structure of the Triassic Series in Pennsylvania" (Abstract), *Bull. Geol. Soc. Am*., 44 : 178. 1933.

[14] The equivalence of the beds at Stowe and Birdsboro is based on the strike of the beds.

[15] Basal conglomerates along the southeastern border are not shown; indeed, they are not sufficiently extensive to be indicated clearly on a map of such small scale.

THE BEARING OF THE DETROIT RIVER SERIES ON DEVONIAN CORRELATIONS

ALDRED S. WARTHIN, JR.

THOSE rocks of the Michigan basin province which comprise the Detroit River series present a problem in correlation which has long puzzled stratigraphers. In 1910 Grabau,[1] in a paper on the Monroe beds, presented two correlations for the Detroit River series, one indicating an upper Silurian and the other a lower Devonian age. Stratigraphic relations, as Grabau understood them, seemed to negate the latter view. Williams[2] and Carman[3] have since demonstrated by evidence of various types that the series must be Devonian. Thus far, however, no exact correlation has been made with the Devonian rocks of New York state, which are usually accepted as the standard for this continent. New evidence bearing on this problem is now available.

The boundary relations of the Detroit River series help to delimit its age. In the type region the basal bed, the Sylvania sandstone, lies upon beds of upper Silurian age. In 1930 Pohl[4] indicated that the Sylvania was not a homotaxial unit, but one which rose in position as it was followed outward from the Michigan basin. This is admirably demonstrated in Ohio and Indiana, where the Hillsboro sandstone (middle or upper Devonian) and the Pendleton sandstone (middle Devonian) are both lithologically like the Sylvania. These two formations are both younger than the type Sylvania and, as would be expected in an expanding unconformity, lie upon distinctly older beds (Niagaran) than does the type Sylvania. If we look toward the east, sandstone outcrops above the Silurian are found near Decewville, Ontario. This sandstone is of Oriskany and basal Onondaga age, and in part resembles the Sylvania in lithology. Being older than the Hillsboro or Pendleton formations, this sand should rest upon younger rocks than they do.[5] The subjacent bed is of upper Silurian age. It is not certain whether this Sylvania-type sand lies upon the pre-Oriskany or the post-Oriskany unconformity.

In the type region the beds superjacent to the Detroit River series are of Hamilton age. Although usually identified as Onondaga limestone, the capping bed in Ontario is also of Hamilton age as far east as Woodstock, east of which point the Detroit River series itself has not been identified. From Woodstock north to Lake Huron several inliers of the Detroit River are capped by Onondaga limestone, but always by the lower part (*Amphigenia elongata* zone) of that formation, the upper Onondaga being absent. As the lower Onondaga here is quite thin it is remarkable that it persists over such a distance. This would seem to hint that the uppermost Detroit River beds are separated by no important break from the Onondaga. Such an inference is reinforced by the observation that the uppermost Detroit River bed is also persistent along the same belt.

On the basis of stratigraphic considerations alone the base of the Detroit River series varies in age by overlap, and the top seems to be closely related in time to the lower Onondaga. Fossils must confirm or deny this hypothesis.

Most of the Detroit River faunas have a middle Devonian aspect, but identities with New York species have not been established. It would be more than remarkable, however, if the Detroit River series is to be correlated with either the Helderbergian or the Oriskanian of New York. Despite facies differences some elements of those faunas should have penetrated to Michigan. In New York the Oriskany is overlain by the Esopus, a formation still unnamed, and the Schoharie, a pre-Onondaga series of fine, somewhat calcareous elastics about five hundred feet thick. The fauna of this group has been little studied since the comparatively brief treatment given it by James Hall. The Detroit River faunas do not appear in the Schoharie, but there is some similarity in the evolutionary stage of many fossils, chiefly brachiopods and corals. Lines of evolution within genera must be carefully studied in order to evaluate these similarities. A case in point is that of the medially plicated *Spiriferi*. These commence in North America with *Spirifer arenosus* and an unnamed form in the Oriskany. This unnamed species is probably the ancestor of *Spirifer divaricatus* in the Onondaga and of *Spirifer venustus* in the Hamilton. In Ontario *Spirifer divaricatus* occurs above the *Amherstburg dolomite*, which contains at Formosa and in the Amherstburg type region another unnamed medially plicate *Spirifer*. This last species is neither *divaricatus* nor the unnamed Oriskany form, but is extremely close to both and indicates a time relation somewhere between the two. Similar close discriminations in other genera will probably strengthen this tentative correlation of the exposed part of the Detroit River series with the lower Ulsterian of New York.

If the correlation mentioned above proves to be correct the pre Sylvania unconformity loses its importance as a milestone at which to begin the Devonian system. Where, then, should we draw this boundary in North America? In eastern New York there is no great unconformity at the base of the Coeymans limestone, nor is there any great change in fauna at that level. Many genera and some species continue across the Siluro-Devonian boundary, whether it is placed at the base of the Coeymans or at the base of the Keyser formation.

In this connection it is worth remembering that the original Devonian was described in England, and that the English Devonian rocks, together with the neighboring German deposits, are the standard for correlation. If the lower Devonian of Europe (Gedinnian and Coblenzian) is searched for species similar to American Devonian forms they may be found in considerable numbers. In the Coblenzian, particularly, is a group of genera which are represented again as a group in this country, but in the Hamilton beds.

Since the Helderberg faunas are made up largely of Silurian holdovers and descendants, and since there is no important break in sedimentation at the base of the Helderberg, it is possible that there is something wrong with our present intercontinental correlation. If the German lower Devonian resembles our middle Devonian beds in its fauna it seems that efforts should be made to correlate them. That would necessitate raising the base of the American Devonian to a level where there is a widespread hiatus, where Silurian types show a marked decrease, and where American faunas first begin to resemble the lower Devonian faunas of Europe. There is only one horizon in America which seems to fulfill these requirements, and that is the base of the Oriskanian series. As our knowledge of the Siluro-Devonian geology of this country is increased we must give serious consideration to a redefinition of the lower limit of the Devonian sys tem in this continent.

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[1] See Grabau, A. W., and Sherzer, W. H., "The Monroe Formation of Southern Michigan and Adjoining Regions," *Mich. Geol. and Biol. Surv*., Publ. 2, Geol. Ser. 1, pp. 225-234 (1909). 1910.

[2] Williams, M. Y., "The Silurian Geology and Faunas of Ontario Peninsula," *Geol. Surv. Canada*, Mem. 111 : 18-22. 1919.

[3] Carman, J. E., "Sylvania Sandstone of Northwestern Ohio," *Bull. Geol. Soc. Am*., 47 : 253-265. 1936.

[4] Pohl, E. R., "Devonian Formations of the Mississippi Basin," *Journ Tenn. Acad. Sci*., 5 : 56. 1930.

[5] The principle applied here was first enunciated by A. W. Grabau in "Types of Sedimentary Overlap," *Bull. Geol. Soc. Am*., 17 : 616. 1906.