THE MIDDLE DEVONIAN TRAVERSE GROUP OF ROCKS IN MICHIGAN, A SUMMARY OF EXISTING KNOWLEDGE

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INTRODUCTION

It has become more and more obvious with the progress of laboratory and field studies on the faunas and stratigraphy of the Michigan Traverse group of Middle Devonian age that no exact correlation between deposits in the eastern and western parts of the State can be established. This conclusion will serve as the focus of major inferential consideration for the discussion that follows, and while the greater portion of this paper will be devoted to the establishment of the stratigraphic sequence of the Traverse Bay area, the truth of the deduction will appear through comparison of this section with the more completely developed group bordering Lake Huron.

Newly introduced terms must necessarily be provisional, for the study of this problem in its true light is still in its beginning. Such names are here used merely as a means of clarifying a visualization of the stratigraphic conditions contemporaneous with the deposition.

From the standpoint of pure science the most engrossing phase of geological investigation is to the author the derivation of faunas. Marine faunas, so typically encountered in the Traverse, require rational consideration. It appears trite to remark that an association of shallow water invertebrate species, however long extinct, reacted no more peculiarly to their environment than their living representatives. It was an odd individual, not to say species or assemblage, that would walk on dry land or fly through the air from one basin of deposition to another. And yet, were we to allow the gross differences in so-called conspecific forms and associations considered as being present contemporaneously in one and the same depositional basin to be disregarded—as they so flagrantly have been and still are—we must accept some such supernatural attribute on the part of formerly existing organisms. The pathway of encroachment by the Traverse stages into Michigan will be studied by means of species having characteristics limited by physical possibility.

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Location and distribution.—The known areal occurrence of Traverse rocks proper is unequally threefold. By good fortune these three areas of outcrop combine toward a solution of two of the greatest stratigraphic problems—sequence and correlation. No two of these occurrences afford the necessary ties without the third, and they are all therefore of equal importance in any consideration of the Traverse problem.

The area of greatest surface development of these rocks occurs within the boundaries of the five northernmost counties of the Lower Peninsula of Michigan—Charlevoix, Emmet, Cheboygan, Presque Isle, and Alpena—forming thus the outer edge of one of the structural "saucers" centering near Saginaw Bay. That this broad structure is of post-Paleozoic origin will be shown under a later heading. Numerous cement and alkali enterprises have resulted in the excavation along the outcrop of some of the largest lime quarries in the United States, which in conjunction with the shore exposures bordering Lakes Michigan and Huron give the line of sections a southwardly crescentic trend. Northward of this narrow line the surficial distribution is abruptly broken by a thick covering of the ground moraine, and to the southward the limestones of the Traverse disappear beneath the succeeding black shales of Waverlian and possibly Devonian age.

The southernmost outcrop of undoubted Traverse beds is found in the northwestern portion of Lucas County, Ohio. The details of the sections obtained here and their peculiar significance will be discussed with those of the third occurrence of Traverse rocks, a portion of the Thunder Bay series on and near the east shore of Lake Huron in Lambton, Huron, and Middlesex counties, Ontario.

Nomenclature and former conceptions.—It is needless in a paper of this character to recount the historical development of geological knowledge of the Traverse beds of Michigan, especially in view of the fact that the present investigation has shown remarkable incongruities in all phases of the study. These are in most cases entirely excusable, since they are partly due to formerly prevalent misconceptions and misunderstandings of conditions of deposition, partly to the incompleteness of stratigraphic preservation, and partly to a lack of necessary details, especially in the matter of authentic well records.

The solutions of the problems here presented have been accomplished entirely independently under the auspices of the United States National Museum with the assistance of Mr. G. O. Raasch of the Milwaukee Public Museum, and there has been a purposeful disregard of all previous work, published or otherwise, with the exception of the results of the 1926 Michigan Survey field party, in cooperation with the United States Geological Survey, represented

by Dr. E. O. Ulrich, who has very generously allowed full access to all his field notes and collections. Since that time I have been favored with the complete confidence of the officers of the Geological Survey of Michigan, who have made available to me all the information at their disposal.

Since early in the nineteenth century accounts of the Devonian rocks of the Southern Peninsula have commanded a prominent place in geologic literature. The earliest local name reference to these beds was made in 1841 by C. C. Douglass,[1] who referred to them in their Lake Michigan occurrences as the "Little Traverse Bay limestones," while those bordering Lake Huron were called the "Thunder Bay limestones." A. C. Lane[2] indirectly grouped all strata between the Dundee and the black shales under the term Traverse, dropping the, according to his conception, useless prefix "Little," and omitting reference to the Thunder Bay. Actual stratigraphic conditions, however, would have been better served by a retention of the original nomenclature.

An attempt to rectify the nomenclature must take into consideration the fact that the two original names applied by Douglass were adequately described according to our more recently accepted nomenclatorial system. As regards the "Thunder Bay limestone," the term has already been properly restricted to the upper third of the Lake Huron section by Grabau.[3] This will be hereinafter referred to as the Thunder Bay stage (faunal delimitation). Douglass's loosely defined locality of outcrop of his "Little Traverse Bay limestone" is now known to exhibit several distinct stratigraphic units, and since he unquestionably applied this term to all beds occurring on the shores of Little Traverse Bay, as is seen in his indefinite geologic section for the region, it is here suggested that the term be dropped. This disposition will further relieve possible confusion were two terms as closely similar as "Little Traverse" and "Traverse" retained, even though they be of different stratigraphic value.

The first use of the abbreviated title "Traverse" was made by Lane.[4] His usage of the term to include all beds lying between the limestones of Onondaga age and the black shales of Upper Devonian and Waverlian deposition is here retained. It is, however, proposed to extend the rank of the term to the position of a group, for as we shall see the area designated in Douglass's and Lane's descriptions represents the development of several distinct faunal and stratigraphic units.

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[1] Douglass, C. C. Michigan Senate Document No. 16, 1841.
[2] Lane, A. C. Geol. Surv. Mich., vol. 5, pt. 2, p. 24, 1893.
[3] Grabau, A. W. Mich. Geol. Surv. Ann. Rept. for 1901, p. 192, 1902.
[4] Lane, A. C. Geol. Surv. Mich., vol. 5, pt. 2, p. 24, 1893.

The Bell shales, because of their lithological unity, have been separated as the basal Traverse group formation of the Lake Huron section by Grabau.[5] There is no good reason for the assignment of this widespread lithologic member to a distinct formation, for the contained fauna indicates continuous relationship with the succeeding Long Lake beds which are, incidentally, but slightly more calcareous. Grabau[6] has more recently corrected this detail and assigned the Bell shales their proper place as the basal member of the Presque Isle series[7] which further includes the respectively higher Grand Lake and Long Lake members.

A study of the stratigraphic contacts between the Presque Isle, Alpena,[8] and Thunder Bay series has nowhere been given the slightest attention. Faunal distinction is, however, shown to be sharp between the three series, and it is therefore provisionally proposed to refer to them as stages, in conformity with the terminology of similarly unestablished but probable formations.

TRAVERSE BAY SEQUENCE

"Complex" becomes but a mild term when applied to actual stratigraphic, biologic, and structural conditions within the Traverse. For a clear understanding of the subject as a whole it must therefore be separated into its component parts and each discussed individually with evidences for the present interpretation, finally by summary comparison drawing similarities and variances between the separately described portions. Stratigraphically, for present purposes, Traverse rocks in Michigan may be studied independently in their eastern and western occurrences, primarily because of the impossibility of direct lithologic or faunal correlation between the two. Each area will be seen to constitute an entity of sequential events in itself. Of the western section we shall speak first.

The development of geologic understanding of the Traverse group has been until recently much hindered by the comparatively unexploited condition of the country in which it occurs and further through the lack of adequate natural outcroppings. The district bordering Lake Huron has outstripped the Traverse Bay region in industrial development, and as an indirect result of the greater exploitation of natural resources there is a fuller understanding of stratigraphic conditions in the eastern portion of the Traverse belt. In the past decade, however, the Traverse Bay district in Charlevoix and Emmet counties has received greater industrial appreciation and the opening of additional quarries in the vicinity of Petoskey has

[5] Grabau, A. W. Mich. Geol. Surv. Ann. Rept. for 1901, p. 191, 1902.
[6] Grabau, A. W. Unpublished manuscript, p. 290, 1915.
[7] Grabau, A. W. Manuscript, pp. 290–308, 1915.
[8] Grabau, A. W. Mich. Geol. Surv. Ann. Rept. for 1901, p. 175, 1902.

greatly facilitated the unraveling of the heretofore much misunderstood sequence of events and the measurement of stratigraphic thicknesses.

Of former interpretations of the geology of the Traverse Bay district the nearest approach to stratigraphic truth was gained by Rominger.[9] The very paucity of material from which this geologist deduced his results attests his close observation and remarkable acumen of mind. It is totally pardonable that his estimate of the thickness of the exposed section was underrated by nearly 120 feet when we remember that he was first to correct far grosser misinterpretations made by previous workers in the same field.

STRATIGRAPHIC UNITS

Three new terms applying to as many distinct faunal and stratigraphic units are here proposed. The defense for the introduction of each will be treated separately. It has been found necessary to separate the exposed section of the Traverse Bay region into a lower, a middle, and an upper division; and, since there is no way of recognizing these divisions in comparable portions of the section in eastern Michigan, to designate them by new geographical names as nearly typical of their individual development as is possible. In ascending order these divisions are—the Gravel Point stage, the Charlevoix stage,[10] and the Petoskey formation.[11]

Detailed sections.—In the Traverse Bay district field locality numbers have been applied to the many isolated outcrops of Traverse rocks. These have been used in conformity with those employed by the 1926 Michigan Survey field party, although the original number of observed and studied sections has been doubled in the present investigation. The majority of localities investigated are of secondary importance only, since they reveal in duplicate more limited representations of elsewhere more favorably developed sections. A list of the "key localities" follows:

Locations of sections from which the complete sequence of Traverse beds in the Traverse Bay district may be derived.

Locality 7c.—Low bluff on shore of Grand Traverse Bay, 1 to 2 miles northwest of Norwood, about a mile, in secs. 22 and 28, T. 33 N., R. 9 W., Charlevoix County, Mich.

Locality 8.—Ledges and bluffs on shore of Lake Michigan, 1½ miles west of Charlevoix, in secs. 28 and 29, T. 34 N., R. 8 W., Charlevoix County, Mich.

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[9] Rominger, C. Mich. Geol. Surv., vol. 3, pt. 1, pp. 53–63, 1876.

[10] The physical evidence for the separation of the Gravel Point and the Charlevoix beds has not been studied with sufficient intensity to warrant the establishment of the formational rank of these faunally distinct stages at the present time.

[11] This name was first applied by Graban, (Rept. Geol. Surv. Mich., p. 201, 1901), to beds largely equivalent to the formation herein proposed, but without proper delimitation. Since the term is particularly applicable it has been here adapted to the usage proposed.

Locality 8.—Ledges and bluffs on shore of Lake Michigan, 1½ miles west of Charlevoix, in secs. 28 and 29, T. 34 N., R. 8 W., Charlevoix County, Mich.

Locality 8a.—Shore of Lake Michigan from locality 8 to about 1 mile south, Charlevoix County, Mich.

Locality 13.—Main Curtiss quarry, two smaller quarries, and shore bluffs to the west. "Bay Shore quarries." SW. ¼ sec. 6, T. 34 N., R. 6 W., Emmet County, Mich.

Locality 14.—Petoskey Portland Cement Co. quarry, 1¼ miles west of Petoskey city line, SW. ¼ sec. 2, T. 34 N., R. 6 W., Emmet County, Mich.

Locality 14c.—Abandoned quarry one-half mile west of the west end of the Petoskey Portland Cement Co. quarry, (Locality 14*a*), and about one-eighth mile south of Little Traverse Bay. NW. ¼ of the NE. ¼ sec. 9, T. 34 N., R. 6 W., Emmet County, Mich.

Locality 14e.—Abandoned "Bell" quarry, extreme NE. ¼ sec. 8, T. 34 N., R. 6 W., and ledges on shore to west, Emmet County, Mich.

Locality 18.—Northern Lime Co. quarry, bordering Little Traverse Bay near east end of Petoskey, NE. ¼ sec. 32, T. 35 N., R. 5 W., Emmet County, Mich.

Locality 18a.—Bluffs on shore of Little Traverse Bay at P. M. R. R. station, Bay View, extreme NW. ¼ sec. 32, T. 35 N., R. 5 W., Emmet County, Mich.

Locality 21.—To right of Highway No. 11 at intersection of P. M. R. R., just east of East Bay View, NE. ¼ of the NW. ¼ sec. 34, T. 35 N., R. 5 W., Emmet County, Mich.

Regional and local structure play equally important parts in the presence and distribution of Traverse strata; but as a discussion of the deformation is to receive attention under a later heading the direct bearing of these two types of deformation on outcrops only need be mentioned here. To a broad southerly regional dip of indeterminable average intensity is due the appearance on the surface of the concentric Traverse belt. Local deformation of small magnitude but extreme complexity has so confused the general attitude that it is possible to state only the already well known fact, that to the north lower and lower rocks appear on the surface where the cover of drift has been removed, and that to the southward the Middle Devonian disappears from sight under the younger black shales and later beds to reappear again for the first time in northern Ohio.

As has been already mentioned,[12] a good part of the sequence may be learned from a close study of the more or less continuous ledge exposures on the south shore of Little Traverse Bay, where abundant and varying local doming brings to view now one, now another portion of the section. This method is, however, attended by difficulty and uncertainty, especially as regards exact measurement of thicknesses, and since the artificial uncovering through quarry excavation of much of the strata offers a much more ready means of observation, the shore exposures have been used in most cases merely as checks on lateral lithologic and stratigraphic variation.

[12] Pohl, E. R. Smithsonian Explorations Rept., p. 28, 1927.

The establishment of an almost unbroken series of depositional details from the basal exposed Traverse beds to the overlying Waverlian is one of the innovations of the present research, and in view of its initiation here it is desirable to present the details on which the conclusions are founded. For the illustration of the discussion immediately following the reader is referred to Plates 1 and 2, on which evidence and results are graphically represented.

In this presentation the normal method of investigation will be followed and the localities will thus become numerically disarranged when their sections are correlated so as to give a continuous succession from older to younger beds. Field determinations of lithologic "beds" and faunal "zones" are here retained, for they have both usually been found to be consistent over the area under discussion. The fossils particularly, although they may and often do have a greater geological range than is suggested by the places mentioned for them, are there especially abundant and serve as useful handles to characterize individual portions of the section.

The oldest known strata of Middle Devonian age in the western Lower Peninsula are exposed in a series of undulating ledges and low bluffs at water level on and south of Gravel Point, 1½ miles west of Charlevoix. The beds in this vicinity have a slight, generally southeastern dip. This general dip is, however, entirely regional, for the local structure is very complex. The entire region is underlain by more or less elevated domes and local anticlines and synclines which have an entire lack of consistent trend. The base of the section is to be seen in such a dome about one-eighth of a mile south of Gravel Point almost at water level. The sequence is then easily followed northeastward across the beach where the beds dip almost eastward to a low bluff which has been faced by a small quarry. The highest bed is found at Gravel Point in a small syncline or basin. Various zones of the section are excellently exhibited by reappearance at the surface along the shore the entire distance from Gravel Point to about a mile southward. The section exposed here in downward succession is as follows.

Geological section at Gravel Point (localities 8 and 8a)

Gravel Point stage.

Zone 4.—Light brown, cryptocrystalline, extremely massive, pure limestone with a conchoidal fracture, breaking easily in all directions into small fragments with sharp edges. In appearance like lithographic limestone, with no semblance of bedding planes. The fauna is not abundant but is quite varied, comprising a dumose *Favosites*, a small digitate *Favosites*, a distantly mammillated *Stromatopora*, small *Athyris*, large *Craspedophyllum*, costate *Stropheodonta*, and *Prismatophyllum*. A dark gray shale at the top carries abundant small *Stropheodontas* in particular. Thickness exposed----------2 feet 6 inches.

Gravel Point stage—Continued.

Zone 3.—"Emmetensis zone."

Bed 2. This zone is a recurrence of the lithology and fauna of the lower part of zone 1. The rock is a thin-bedded, finely crystalline to semimassive, brown limestone and the fossils are beautifully preserved with the calcareous shells intact. Two and a half feet from the base is a slightly more shaley layer 3 inches thick carrying a solitary coral fauna in addition to the typical association. This bed is characterized by the large number of shells of a nacreous nature (*Pholidostrophia*), preserved with a pinkish color____9 feet 8 inches.

Bed 1. A sharp change in lithology accompanies the abrupt introduction of several new faunal elements, among which *Chonetes emmetensis* Winchell is the most conspicuous. The *Spirifer-Stropheodonta-Cystodictya* association continues in this bed along with the new introduction. The bed consists of a semimassive, flakey, buff-gray, shaley limestone, with a few long, reddish, organic markings, and has no true bedding planes. Frequent shale like layers a few inches in thickness separate the heavy limestones toward the base but the topmost foot and a half is composed of a practically barren, buff-gray, shaley limestone again with worm borings__4 feet 6 inches.

Zone 2.—"Large Atrypa zone."

Lower 12 inches lithologically similar to beds below but introducing a new association of species, consisting of a mucronate *Spirifer*, *concava-like Stropheodonta*, and *Cystodicyta*. Twelve inches above the base are seen many worm borings, and the character of the lithology changes to a brownish gray, very finely crystalline to massive, slightly shaley limestone. The lowest beds are seemingly reworked material filling in the interspaces between the reef heads below. The predominant sediment throughout this zone is of brownish-gray, massive limestone carrying numerous worm borings, but is interrupted at intervals by thin bands of semicrinoidal, crystalline limestone. In general, the entire zone carries a continuous fauna_____8 feet.

Zone 1.—Base of exposed Traverse Group in western Michigan.

Bed 3. Dark brown, massive limestone in four bands nearly 1 foot thick each separated by thin, 2-inch beds of brown to black limey shale. Entire bed bituminous, very fossiliferous below with pelecypods, brachiopods, and individual corals. The top layer contains enormous heads of stromatoporoids, a small digitate *Favosites*, and many *Gypidulas*_____4 feet.

Bed 2. Light brown to buff, shaley limestone introducing a predominating element of *Atrypa* and *Gypidula*, the latter often 2 inches in length. Several bands carry much bituminous matter 2 feet 6 inches.

Bed 1. Exposed in a dome on shore one-eighth mile south of Gravel Point. The basal bed is a dark brown to black, thin-bedded, shale-like limestone with an abundance of crinoidal fragments and crushed *Athyris*_____1 foot 2 inches.

Above this is a lighter brown, fragmental limestone carrying a heavy coral fauna composed of *Prismatophyllum*, small digitate *Favosites*, *Stromatopora* (small mammillate type, mammillae about 2½ mm. apart), *Zaphrentis*, *Conocardium*, and *Athyris*_____2 feet.

Essentially the same succession is encountered in the next mentioned outcrop where in addition the sequence is extended through some 35 feet of younger beds. The effect of structure upon the

distribution of correlative portions of the succession is well appreciated when it is understood that only considerably higher beds than are observed in either outcrop are found between the two sections separated by a distance of fourteen miles. Further, a comparison of the depositional record as seen in the two areas will bear witness to a fairly widely extended continuity of both faunal and physical conditions.

Section at Petoskey Portland Cement Co.'s quarry (locality 14)

Gravel Point stage.

NOTE.—Zones 4 and 5 are exposed to best advantage to the west in the newer parts of the quarry (locality 14*a*).

Zone 5.

Bed 2. Very light gray, granular, fossiliferous limestone, same as exposed at locality 14*c* in similar position. To top of section__2 feet.

Bed 1. "Cherty" chipstone, lower part "mottled." Light to dark gray in color. Fossils scarce with one bed of *Favosites* noted_8 feet.

Zone 4.

Bed 4. Hard, black-brown, bituminous limestone with black shale partings several inches thick. Limestone in beds about 1 foot thick with fossils scarce; *Athyris, Atyrpa.* Corals common in shale at top: *Favosites, Prismatophyllum.* Costate *Stropheodontas* occur abundantly in black shale partings. One brownish black layer 1 foot thick near top contains a spectacular pelecypod fauna of undescribed species of *Ilionia, Leiopteria, Actinopteria, Jancia,* and a small *Leptodesma*-like new genus_____6 feet 6 inches.

Bed 3. "Coral bed." Heavy coral bed with *Prismatophyllum* masses several feet in diameter. Grey-brown cryptocrystalline "chert" or chipstone (lithographic limestone), becoming granular at top with shallow depressions filled with black shale. Fauna: Digitate and turbinate *Favosites, Prismatophyllum, Zaphrentis, Atrypa, Athyris, Cryptonella, Crania,* and a costate *Stropheodonta*__1 foot 10 inches.

Bed 2. Brownish black "chert" (cryptocrystalline chipstone), in beds of moderate thickness with some black shale partings bearing corals and costate *Stropheodontas.* Several more granular, fossiliferous layers. One of these, 30 inches from top, contains *Proctus, Phacops, Asteropyge, Pterinopecten, Actinopteria, Aviculopecten, Stropheodonta concava* and *costata* types, a large, mucronate *Spirifer, Atrypa, Athyris,* and crinoid joints_____7 feet 6 inches.

Bed 1. Dull gray, fossiliferous limestone with shale partings, in beds about 1 foot thick_____13 feet 6 inches.

Zone 3.—"Emmetensis zone."

Gray limestone in regular, rather thick beds splitting in thin slabs on weathering. Nacreous fossils conspicuous, frequently possessing a pinkish color. Corals developed in irregular, reef-like structures along certain beds. Rock adjoining coral reefs granular. Fauna: *Chonetes emmetensis* Winchell, *Pholidostrophia,* mucronate *Spirifer,* solitary and colonial corals_____14 feet 6 inches.

Zone 2.—"Large Atrypa zone."

Bed 3. Barren, light gray, compact limestone with shalelike partings of similar composition. Mottled and with iron-stained worm borings. 3 feet 6 inches.

Bed 2. Brown limestone carrying *Gypidula*_____11 inches.

Gravel Point stage—Continued.

Zone 2.—"Large Atrypa zone"—Continued.

Bed 1. Thick-bedded, gray limestone with shaley bands. Limestone breaks into thin beds on weathering. Fossils conspicuous on bedding planes. Fauna: Large *Atrypa*, *Stropheodonta concava* and *costata* types, mucronate *Spirifer*, *Cyrtina*, globose *Athyris* (almost limited to a single layer near middle) *Spirifer eurytcines* type, *Douvillina* (rare), *Zaphrentis*, digitate *Favosites*_____10 feet.

Zone 1.—Chocolate-brown, hard, fine grained, resistent limestone with numerous fossil fragments and crinoid joints, in thick beds. Fauna consists mainly of *Gypidula*, *Prismatophyllum*, *Pholidostrophia*. Bottom not shown_____8 feet.

The sequence is then further continued in a section exposed in an old, abandoned quarry (locality 14*c*), about an eighth of a mile back from the shore of Little Traverse Bay and a mile west from the last-mentioned outcrop (locality 14). The section begins with the base of bed 2 of zone 5 seen near the top of the exposure at the Petoskey Portland Cement Co's quarry, and extends upward to a position near the base of the "Blue shale."

Section at abandoned quarry (locality 14c)

Drift covering.

Gravel Point stage.

Zone 6.

Bed 2. Equivalent to bed 2 of locality 14*e*. Dirty, bituminous, light brown limestone with bands of fucoidal markings. Fossils, especially *Prismatophyllum*, common. Thickness exposed_____10 feet.

Bed 1. "Lower Blue Shale." Fossils abundant, large numbers of costate *Stropheodontas*, *Atrypa*, digitate *Favosites*, *Prismatophyllum*, mucronate *Spirifer*, large *Spirifer*, *Athyris*, *Cyrtina*, *Fenestella*, and many encrusting, ramose, and flabellate bryozoa_____1 foot.

Zone 5.

Bed 8. Resistant, dark gray, fragmentally fossiliferous limestone with cryptocrystalline matrix weathering into large blocks. Fossils, especially *Favosites*, abundant at contact with lower shale.

2 feet 6 inches.

Bed 7. Fossiliferous black shale. Costate *Stropheodontas* abundant. *Atrypa*, *Fenestella*_____6 inches.

Bed 6. Corraline, fossiliferous, fragmental limestone passing horizontally into chipstone similar to that in bed 5 below. Reef conditions with large masses of corals conspicuous, and fossiliferous black shale partings. Fauna: *Prismatophyllum*, *Stromatopora* (distantly mammillated and nodose forms), dumose and digitate *Favosites*, of many varieties, *Cladopora*, Zaphrentids, and encrusting Trepostomes, *Atrypa*, *Gypidula*, *Cyrtina* (rare), *costate Stropheodontas*, *Proetus*.

12 feet.

Bed 5. Similar to beds 2 and 3 but darker and less slabby. Black shale parting several inches from top of bed. The upper surface of the bed consists of black shale, locally stained red and covered by an abundance of markings similar to worm borings, one-quarter to 1 inch in diameter, several feet long and depressed. Depressions filled with material from succeeding bed (bed 6); Fauna: Digitate *Favosites* and *Athyris*_____ 1 foot 6 inches.

Gravel Point stage—Continued.
Zone 5—Continued.
Bed 4. Granular, fragmental, fossiliferous limestone with *Stromatopora*, costate *Stropheodontas*. Fauna nearly same as in bed 6 above ---------- 6 inches.
Bed 3. Similar to bed 5 above ---------- 3 inches.
See covered interval ---------- 3 feet.
Bed 1. Base of section exposed. Very light gray chipstone (lithographic limestone). *Mottled*, due to leaching. Fossils sparse: *Atrypa* ---------- 5 feet.

About three-quarters of a mile farther west the sequence is again continued through younger beds, and with the inclusion of this last locality the character and thickness of the Gravel Point stage so far as exposed may be realized. Due to the incoherent character of the upper member of the Gravel Point stage and its tendency to break down quickly on exposure, this bed and its contact with those immediately following may seldom be studied.

Section at abandoned "Bell" Quarry (locality 14e)

Charlevoix stage.
Bed 4. "Dumose Favosites bed." Thickness exposed ---------- 4 to 9 inches.
Bed 3. "Laminated bed." Grey, coarsely crystalline, granular, porous limestone with the laminations, probably due to algal growth, decreasing in thickness upward and with the lower 2 inches and upper 6 inches unlaminated ---------- 2 feet 9 inches.
Bed 2. Pure, buff limestone of lithographic texture ---------- 1 foot 9 inches.
Bed 1. Reworked, fragmental clay shale ---------- 6 inches.
Gravel Point stage.
Zone 6.
Bed 3. "Blue Shale." Bluish-grey, incoherent, calcareous shale with numerous more coherent limey lenses. This bed quickly weathers to a sticky, gritless mud, carrying long selenite crystals and allowing the abundance of finely preserved fossils to roll free. The basal foot of this member is more pyritiferous than usual and carries a great number of small crushed *Conocardium emmetensis* Winchell. Fauna of entire bed; *Atrypa*, *Athyris*, costate *Stropheodonta*, *Prismatophyllum*, *Cystodictya* and many other bryozoa, and *Conocardium* are the most abundant ---------- 8 feet.
Bed 2. Same as zone 6, bed 2 of locality 14c ---------- 14 ft.
Bed 1. "Lower Blue Shale" ---------- 1 ft.
Section up to "Lower Blue Shale" is a duplicate of that at locality 14c--25 ft.

A hitherto unnoted section ties in with the upper portion of the two last-mentioned locations and carries the sequence still higher into the Charlevoix stage. This is one of the natural outcrops that preserves one of the most seldom seen Traverse phenomena—the contact between the Gravel Point and the Charlevoix stages. This section, on the shore of Little Traverse Bay at the Bay View Pere Marquette railroad station, was found to be the key to the entire problem of exposed Traverse sequential events, for it presents beds

for a considerable stratigraphic distance on either side of the contact and gives unquestionable evidence for the establishment of a continuity of sections at this previously debated position. The beds here have a rather strong (15°), local, average, easterly dip which gives a comparatively thick section in the limited exposure of the 15-foot bluff.

Geological section at Bay View railroad station (locality 18a)

Drift covering.

Charlevoix stage.

Bed 6. "Pelecypod-Gastropod Bed." Massive, thick, bedded, brown limestone, barren below, thin bedded above with large, discoid, lenslike inclusions. Thickness exposed.....7 feet, 4 inches

Bed 5. "Dumose Favosites Bed." Buff to brown, granular limestone with the leached corrals occurring in abundance in two bands and with the characteristic fauna continuing into the bed shown above as in the Curtiss quarry (locality 13). Top layer finely and unevenly laminated.....9 inches

Bed 4. Similar to bed 2 below.....1 foot 1 inch.

Bed 3. Massive, brown, bituminous limestone, breaking vertically into polygonal blocks.....1 foot 2 inches.

Bed 2. "Laminated Bed." Similar to that at following section (locality 13).....1 foot 3 inches.

Bed 1. Bluish limestone with numerous, rounded sand grains. Material reworked from beds below with a few fragmental and worn fossils.....1 foot, 7 inches

Gravel Point stage.

Zone 6.

Bed 3*b*. "Blue Shale." Same as at locality 14*c*.....9 feet.

Bed 3*a*. "Conocardium Bed." Bluish grey, fragmental limestone, weathering brown. This is not a reef limestone, the corals being usually of solitary type. Preponderance of *Conocardium emmetense* Winchell, *Fenestellas*, *Cladopora*, *Favosites*, *Zaphrentis*, plicate *Gypiduta*.....12 to 14 inches.

Bed 2. Same as at localities 14*c* and 14*e*. Light brown, compact, bituminous limestone of reef composition. Isolated crystals of selenite occur throughout the matrix. Dominant fauna of reef corals and stromatoporoids, very numerous: *Prismatophyllum*, distantly and closely mammillated types of *Stromatopora*, *Conocardium*, costate *Stropheodonta*, *Atrypa*, and *Phacops*. Thickness exposed above water level.....4 feet 9 inches.

That there was at least a local withdrawal of the Traverse sea previous to the deposition of the Petoskey formation can not be doubted after a study of the unconformable relations of the Charlevoix and Petoskey beds to each other, especially in the section to follow. The reader is referred to the insert on Plate 2 for a graphic representation of the actual conditions of contact at this locality. The following section is chosen from the east end of the quarry so as to include the maximum thickness of Charlevoix beds which are elsewhere truncated by pre-Petoskey erosion.

Geological section at the Curtiss quarry (locality 13)

Petoskey formation.

Zone 2.—"Fenestella zone."

Bed 2. Similar to the crinoidal portion of zone 1 below, but carrying numerous broken fragments of Fenestellids. Thickness exposed. 6 feet 6 inches

Bed 1. This bed is made up of numerous layers of rather coarse, yellowish limestone, containing an overwhelming abundance of many Devonian types of bryozoa, but particularly the Fenestellidae, large and small *Spirifers*, and *Gypidulas*. The limestone layers are separated by fine shale partings----------5 feet

Zone 1.—"Cyrtina-Gypidula zone."

The base of this bed, which is dirty throughout, is particularly fragmental. It lies unconformably and by overlap on the various beds of the eroded Charlevoix series. The lateral variation of the lithologic character, being made up at places throughout the thickness of the bed of coarse, crinoidal fragments, and at others of a finer, granular, dolomitic limestone, containing the typical association of the *Cyrtina-Gypidula* zone, indicates a differential sorting probably due to unstable conditions----------0 to 12 feet

Charlevoix stage.

Bed. 9. Gray, fine-grained limestone with numerous cavities; breaking into small, angular fragments. Base stylolitic. Barren. Maximum thickness preserved----------2 feet 6 inches.

Bed 8*b*. Similar to bed 8*a* in lithologic character, but unfossiliferous----------1 feet 6 inches

Bed 8*a*. Coral layer containing same fauna as below but in exceeding abundance. Darker gray, less compact, more resistant, and less brittle than bed 8----------6 to 9 inches.

Bed 8. Grey, lithographic, conchoidally fracturing chip-stone. Lower 6 inches finely and very unevenly and undulatingly laminated, dirty, granular, and porous. Fauna comprises a digitate and dumose *Favosites* and digitate *Stromatoporas*, a large *Stromatopora* and an *intermedia*-like *Ceratopora*----------4 feet 8 inches.

Bed 7. Earthy limestone full of limonitic stains and containing wavy brown laminations. "Brown Bed"----------1 feet 3 inches.

Bed 6. Gray, partially porous and fragmentally grained, fine-grained limestone with numerous, thin, black, bituminous laminations- 1 foot 9 inches.

Bed 5. "Pelecypod-Gastropod Bed." Coarse, buff limestone in lower 3 feet, oölitic, with grains a milimeter or two in size, above. Two pelecypods, *Edmondia mactroides* Winchell and *Edmondia ledoides* Winchell and three gastropods, *Pleurotomaria cavumbilicata* Winchell, *P. emmetensis* Winchell, and *P. parvispira* Winchell are particularly abundant in, and are restricted to this bed----------14 feet 6 inches

Bed 4. "Dumose Favosites Bed." Dolomitic, buff limestone with the typical fossil asspciation of this bed as at Charlevoix Rock Products Co.'s quarry, etc----------3 inches.

Bed 3. Massive, buff, dolomitic limestone, at places bituminous and laminar, with large discoidal lenses of fragmental limestone----------3 feet.

Bed. 2. Heavier, thin-bedded, shallow-water limestone with very uneven laminations and containing fine sand grain inclusions----------1 foot.

Bed 1. Thin bedded, uneven, bluish-gray limestone, frequently coated brown due to weathering of contained pyrite. Thin shale like partings with numerous minute sand grains----------4 to 8 inches.

Gravel Point stage.

Zone 6.

Bed 3. Bottom of section exposed. The "Blue Shale" or uppermost bed of the Gravel Point was dug from a small test pit in the floor of the quarry bringing with it the typical association of fossils—10 feet.

The next section, to be seen near the east end of the town of Petoskey, completes the unbroken sequence in the stratigraphic record of the Traverse. Diligent search, which will be undertaken shortly, will in all probability result in the discovery of whatever beds may be unrepresented in the present succession. It is highly important that a complete succession be established, for such an unbroken record would have immediate usefulness in determining horizons in projected borings. It is highly improbable that any great thickness of beds is absent from the known sequence, for were that the case it would undoubtedly have been recognized in one or another of the numerous fortuitous quarry locations.

Geological section in quarry of Northern Lime Company (locality 18)

Top of section.

Petoskey formation.

Zones undifferentiated.

Bed. 3. Granular, fine-grained, light gray limestone in heavy beds, full of isolated *Stromatoporas*. Partings of black shale between bedding planes. Fauna: Digitate *Favosites*, encrusting *Stromatopora*, *Zaphrentis*, arbusculate *Favosites*, *Cylindrophyllum*, compound *Cystiphyllum*, *Gypidula*_____7 feet.

Bed 2. "Cystiphyllum Bed." Light gray, compact limestone in two beds, breaking into small, angular fragments, Fauna: Digitate *Favosites*, *Zaphrentis*, *Atrypa*, *Athyris*, and *Cystiphyllum*_____5 feet 9 inches

Bed 1. Fine-grained, brown limestone. The major portion of the thickness is composed of isolated, broken, and overturned *Stromatopora* heads, in some places filling the bed from top to bottom in reeflike structure. The interspaces between the reefs are filled with a thick-bedded, often foreset, matrix of fragmental, "coral sand." The thickness of the bed remains constant laterally. Fauna: Arbusculate *Favosites*, small-pitted and digitate *Stromatoporas*, and *Atrypa*_____26 feet.

Zone 1.

Bed 1. Reworked layers between the cessation of erosion of the Charlevoix beds and the beginning of prolonged deposition (?). Generally a light gray, fine-grained limestone carrying small, angular, limey fragments and with many irregular, bituminous partings. Top bed muddy, carrying a lenticular pebble conglomerate. Upper surface of underlying bed irregularly eroded_____1½ to 3 feet.

Charlevoix stage.

Beds 6 and 7. Granular, dirty, brown limestone full of wavy, bituminous laminae. Single bed_____3 feet 6 inches.

Bed 5. "Pelecypod-Gastropod Bed." Gray-brown, very fine-grained limestone. Massive and with conchoidal fracture_____12 feet.

Having thus established an unbroken succession through some 200 feet of beds, any portion of which is easily distinguished from another through all exposed sections in Charlevoix and Emmet Counties, it becomes necessary to find a place for a faunally, lithologically, and geographically isolated 16-foot outcrop near East Bay View. This exposure in a small, abandoned quarry is, so far as known, the easternmost surface indication of Traverse rocks in Emmet County. Much of the contained fauna bears a superficial resemblance to species restricted to portions of the Gravel Point stage; but when compared a wide difference both between species and association becomes quickly apparent. The singular absence of the highly characteristic and ever-present Gravel Point *Prismatophyllum anna* (Whiteaves) argues strongly against a correlation with any portion of these beds. The presence, however, of the coral *Cylindrophyllum panicum* (Winchell), whose only other known occurrence is high in the Petoskey formation, in these beds, indicates a close relationship to the Petoskey formation. From both stratigraphic and faunal standpoints, the section following must be intercalated in the thus partly filled gap within the Petoskey. The Norwood, Charlevoix County, section (to be described later) is the only occurrence at present known where the highest beds of the Petoskey formation are seen to rest in contact with the succeeding Waverlian black shale. Since, then, the complete succession of Traverse beds is known, with the single exception of the break within the Petoskey under discussion, the probably correct position for this debatable outcrop is within that break. The only other possible suggestion, that it is a lower set of beds than is to be seen elsewhere at the surface is strongly denied by the close relationship between its contained fauna and that of the Petoskey formation.

Geological section east of East Bay View (locality 21)

Petoskey formation.

Zones undetermined.

Bed 10. Gray, shalelike limestone. Long, solitary corals. Thickness exposed----------8 inches.

Bed 9. Fissile, black shale with minute, irregular limestone lenses and fossils weathering reddish. Fossils in shale few and crushed. Fauna: *Pharcops* cf. *rana*, large *Spirifer* (*eurytines* type), mucronate *Spirifer*, *Stropheodonta erratica* and *demissa*, *Ceratopora* (large longitudinally striate), ramose bryozoa, *Fenestella*, *Cyrtina* (flat area, curved at beak), *Cylindrophyllum*, *Hederella*, digitate and arbusculate *Favosites*, and *Cranaena*----------2 feet 4 inches.

Bed 8. Dark gray, bituminous, comparatively heavy limestone in eight-inch layers with large fucoids on fossiliferous shalelike partings. Shales composed of fossil fragments, probably deposited under more turbid water conditions. Fauna, especially the corals, abundant. Arbusculate and digitate *Favosites*, mucronate *Spirifer*, *Gypidula*, *Stropheodonta erratica* and *demissa* types, numerous frondose bryo-

Petoskey formation—Continued.

Zones undetermined—Continued.

zoa, crinoid joints, two species of *Cyrtina, Taeniopora*, many types of *Stromatopora, Aulopora, Striatopora, Certopora erecta* type, *Cystiphyllum, Cylindrophyllum panicum* Winchell, and a smaller species, *Fenestella, Atrypa, Athyris, Cranaena* (with fine color bands), *Pholidostrophia* (flexed type), *Conocardium* species, *Phacops, Athyris*, and *Cystodictya*_____3 feet 6 inches.

Bed 7. Soft, fissile, black shale without fossils, containing inch-thick calcareous lenses with *Spirifer* cf. *mucronatus*, and *Fenestellids*, _____6 inches.

Bed 6. Buff, fine-grained, fragmental limestone in single bed becoming shaley at top. Mucronate *Spirifer* (most common), *Favosites* (arbusculate type), *Ceratopora, Heliophrentis, Aulopora*, many Trepostomes, *Stromatopora* (*Idiostroma* type), *Gypidula, Stropheodonta erratica*, digitate *Favosites, Phacops* species and *Striatopora*___3 feet.

Bed 5. Crinoidal, fragmental limestone in thick beds, bluish grey weathering brown. Fauna as below with new elements, i. e., small *Cyrtina, Fenestella*, large, high-areaed *Spirifer*, and numerous species of Trepostomes_____ 5 feet.

Bed 4. "Gypidula Bed." Slightly calcareous shale doming in floor of quarry. Extremely fossiliferous but with few species. Great abundance of *Gypidula*, fine lined *Spirifer*, large, mucronate *Spirifer*, deeply sulcate *Athyris*, broad fronded *Cystodictya*_____Quarry floor.

At the top, as at the base, of this section there is again an hiatus of undetermined extent between it and the next succeeding continuous section. Unfortunately for the study of the stratigraphic succession in this area the thick covering of drift to the south of the narrow belt of hard-rock formations bordering Little Traverse Bay hides the uppermost beds of the Traverse group. These are exposed at but one locality, near the Antrim—Charlevoix County line just north of Norwood. This exposure is, incidentally, at the same time the westernmost and southernmost outcrop of "in situ" Traverse rocks in western Michigan. The location of rocks of this age in Benzie and Leelanau Counties and on the Manitou Islands on the State geological map is purely inferential.

Geological section on shore of Lake Michigan, 1 to 2 miles northwest of Norwood (locality 7c)

Running north along the shore of Lake Michigan for about a mile from a point nearly a mile northwest of Norwood are beds dipping in a southwest direction and forming bluffs at its northern edge of exposure of nearly 15 feet in height above lake level. A point at the northern end of exposure, extending slightly into the lake, exhibits the lowest beds of the section dipping at an angle of about 20° to the south. These beds carry an abundance of small *Atrypas*. Lithologically there is no distinct difference between these layers and the next succeeding, which are, however, characterized by numerous digitate *Favosites*. The basal foot and a half of this latter bed is practically barren and is composed of a light grey, dirty, limey shale, but the upper 6 inches are full of fossils, the upper surface of the bed being covered with

sinuate, usually horizontally compressed fucoids having an average diameter of one-half inch. Passing to the south, some 30 feet of thin bedded, finely crystalline dolomites interbedded with irregular, nodular bands of chert are exposed, due to the southerly dip, in several low bluffs. Near the top of these beds (the "Cherty Beds" of Winchell), are several 1-foot bands of coarse dolomite containing several corals (*Heliophyllum*, *Favosites hamiltoniae* (?), and a questionable *Cladopora*) and a large *Atrypa*. Near the southernmost exposure some large "kettles," radially arranged anthracolite concretions having as a usual nucleus an arthrodiran plate, weathered from the immediately succeeding Waverlian black shale were observed, but no black shale was seen in contact with the underlying Petoskey beds.

The sections as thus combined to give a complete succession for the Traverse Bay district aggregate approximately 250 feet in exposed beds. It is, of course, impossible to even hint at the thickness of the unexposed portion of the Petoskey. It is hoped that further search will bring to light the beds to fill this gap; but for the present it seems probable from attendant circumstances that these will not extend the section very considerably. From a study of the physical relations this volume of deposition is found to be unequally apportioned between three divisions—120 feet in the Gravel Point stage, 28 feet for the Charlevoix stage, and 100 feet for the Petoskey formation, which latter may be increased if the unknown beds are later discovered.

Physical criteria bearing on the restriction of stratigraphic units.—It has been shown that throughout the thickness of beds below the "Blue Shale" there have been common recurrences of a certain number of lithologic characteristics. To sum these up connectedly there has been a singular absence of the coarser clastic materials, especially the silicates, while there is a frequent alternation of fine, gritless shales with the shaley and compact limestones. Fossiliferous black shale partings are particularly abundant toward the middle of the Gravel Point section, while toward the top fine, blue, clayshales become increasingly apparent. A great majority of the sediments are made up of the darker, compact limestones which in many cases are strongly bituminous. Cryptocrystalline limestones with a lithographic texture comprise much of the beds near the middle of the series. Reef structures of limited vertical and lateral extent are one of the commonest features throughout the Gravel Point. While the distinction between lithologic layers is usually sharp there is not the slightest suggestion of broadly unstable conditions within the series. The vertical lithologic variation is to be explained rather on the basis of differential, not too shallow water current sorting and the tendency on the part of the sediments to fill in the depressions between the comparatively rapidly developing *Prismatophyllum* and *Stromatopora* reefs.

At present there are too few occurrences of the "Blue Shale" known to be able to state definitely the amount of variation in its thickness nor to what cause this variation is due. It is now known to range between 6 and 11 feet at different localities. The upper surface wherever seen is slightly undulating; but whether this undulation was caused by sub-aerial or sub-marine erosion it is impossible to determine with the information now at hand.

The sudden introduction in the Charlevoix stage of an entirely new and unprecedented set of physical and lithological conditions is in itself sufficient to make one suspect an erosional break at its base. Throughout the first 2 or 3 feet (in some places greater, see locality 13), of beds in the initial Charlevoix deposition, wherever seen, there is a considerable abundance of fine, rounded quartz grains interspersed more or less evenly through a granular reworked matrix containing numerous worn and broken shell fragments. As a whole the Charlevoix series is characterized by fragmental deposition throughout, frequent occurrences of bituminously laminar beds, the presence of a coarse, calcareous oölite near the middle of the section, and the recurrence of fine grained beds at the top.

The most interesting physical feature of the Charlevoix is, however, the character of its upper surface. For a study of this phenomenon the reader is again referred to the inset on Plate 2 and the geological section taken at locality 13.

At the Curtiss quarry (locality 13), a section through the entire thickness of the Charlevoix stage may be taken and here also may be seen the highest beds belonging to this division visible anywhere in the district. The thickness of this series from the base of bed 1 to the top of bed 9 is slightly short of 28 feet. The preceding beds comprise the Charlevoix series in their greatest preserved development. In the face of the quarry, running in a northwesterly direction, these beds are cut in downward succession by a distinct and pronounced, irregular, angular unconformity. Evidence points to a considerable time interval during which there was much erosion of the Charlevoix series. During the emergence, at various places and in particular the west end of the locality 13 quarry and west along the present lake shore, beds 9, 8*b*, 8*a*, 8, 7, 6, and a few feet of the preceding "Pelecypod-Gastropod Bed," bed 5, were in some places partially, in others completely, removed by erosion. This, like most of the quarries in the region, is situated in the center of a longitudinal dome or anticline, and it is probable that during the post-Charlevoix emergence the beds were domed and then subjected to an irregular peneplaning effect. Accompanying this folding was a slight readjustment by faulting which is well exhibited in the south face of the quarry. This fault has a vertical throw of about 6 inches which does

not continue into beds of the Petoskey formation although it can be easily traced through all the members of the Charlevoix. This can not be explained on the basis of incompetency, for if anything the beds of the Charlevoix are more competent than those of the Petoskey. Nor can it be dismissed by an argument based on "cushioning" for the basal beds of the Petoskey are compact and easily fractured. As if to further substantiate the importance of the unconformity there is a complete change of faunal and lithological characters above the break. In a series of small quarries, bluffs, and ledges near water's edge, forming a continuous exposure of a mile in length to the east of locality 13, the contact between the Charlevoix and the Petoskey series is exhibited at an almost constant height above lake level throughout the length of the exposure. The crinoidal Cyrtina-Gypidula zone of the Petoskey here rests on the irregularly eroded surface of one or another portion of the Pelecypod-Gastropod bed (bed 5) of the Charlevoix. We may thus see that the removal of beds from the top of the Charlevoix stage was not of restricted character, for over considerable distances *there is a known deletion by erosion* of between 12 and 15 feet. It is extremely probable that even greater thicknesses were deposited during Charlevoix time and subsequently denuded, but to what vertical extent can not be ascertained.

The acceptance of the proof presented requires not only the withdrawal of the sea at the end of Charlevoix deposition, but also the emergence of the area for the minimum time necessary for the consolidation of the beds and for the removal of at least 15 feet of mostly tough limestones, before the earliest local encroachment by and deposition in the Petoskey sea.

This contact is again shown to excellent advantage in two other sections and since the importance of this phenomenon can not be underestimated it would be better to include a discussion of their peculiar characteristics here.

In a now abandoned quarry (locality 15), nearly 2 miles west of locality 13 on Nine Mile Point (near center sec. 2, T. 34 N., R. 7 W., Charlevoix County), bed 9 of the Charlevoix stage again exhibits the effects of erosion. This bed is here composed of a massive white limestone with numerous solution cavities, probably due to leaching contemporaneous with the pre-Petoskey denudation. This highest member of the Charlevoix section is deeply gutted and channeled, and the initial deposit of the Petoskey, a course shale about three-quarters of an inch thick, rests on the unevenly eroded surface of the beds beneath. The filling of the irregularities in the underlying series is completed by a fragmental, shaley limestone carrying overturned heads of a small-pitted *Stromatopora* and broken *Gypidula*

shells. The first continuous layer of the Petoskey series is a non-bedded, dirty, fragmental limestone with *Gypidulas* followed by a fossiliferous sand rock. The same upper member of the Charlevoix (bed 9) is again seen in irregular contact with the lowest Petoskey farther west at the junction of State Highway No. 11 and the Walloon Lake Road (south extreme of section line between secs. 1 and 2, T. 34 N., R. 6 W., Emmet County, locality 16), where conditions similar to those just described for locality 15 are to be observed.

At the beginning of Petoskey time conditions were still very unstable, as is evidenced in the lateral variation of single beds, in the overlap by others, and in general by a series of fragmental limestones at the base. There is, moreover, in a certain fragmental, crinoidal coquina excellent indication of shallow water conditions in the foreset, cross-bedded bedding planes near the base of the section. Through the lower 30 or so feet of the Petoskey series are continuing indications of sedimentation within the range of current or wave action. This is especially to be seen in the fragmentary character of the abundant reef-forming *Stromatopora* heads, which more often than not lie disconnectedly and in abnormal position in the fragmental matrix of calcareous sand. These have in most cases been violently broken away from their original connections and distributed at varying distances from them. The middle of the section again shows in its compact and evenly bedded, fine grained limestones and shales a return to normal and steady marine deposition in the area. The introduction in the upper portion of the section of an abundance of colloidal silica in the form of segregated and banded chert argues strongly for a return of the area to a condition which was affected by shore influences and a mingling of land waters carrying silica in suspension with the saline waters of the epeiric sea. This is further emphasized by the occurrence of dolomite in these beds, for it is a known fact that calcium and particularly magnesium are especially effective in the precipitation of colloidal silica. The necessary carbon dioxide was of course produced by the presence of abundant invertebrate life.

At the present time the actual contact between the Traverse and the succeeding black shale has not been seen so that the physical conditions of juxtaposition may not be remarked upon.

FAUNAL INDICES OF THE STRATIGRAPHIC UNITS

The present status of paleontologic knowledge of the Traverse will for some time necessitate the use of rather broad and generalized statements. By far the greater majority of the organic remains preserved in these strata is still undescribed, and those already described and identified have not been sufficiently compared for

correlation purposes with biological relatives found elsewhere. The present section will therefore deal only with the general phases of the subject being limited to a discussion of those distinctive species known to have a restricted occurrence within one or another of the three stratigraphic units of the Little Traverse Bay district. Throughout the sequence fossil remains are legion, but fortunately for stratigraphic discrimination a number of species and several genera have, as usual, a limited range in the succession, and may thus be used as criteria for a ready and undeniable determination of exposed portions of the section.

Indications of the existence of sponges in the Traverse are rare, and yet in several beds numerous, long, monaxon spicules of an unidentifiable Silicisponge are found. The most notable of these occurrences is at the top of the section at locality 21 (middle Petoskey).

No attempt will be made here to give the ranges and restrictions of the numerous species of the Hydrocorallines, algae, and sponges included under the general term "*Stromatopora.*" Several of them have been described but they have never been studied in regard to their stratigraphic position.

From a stratigraphic and biologic standpoint the best understood organic remains of the Traverse series are the corals. This is due to the work of Grabau, and from his unpublished manuscript (1915), is derived the following summary of the positions occupied by a number of closely discriminated species. So far as is now known the species cited for the various units are restricted to them respectively.

Petoskey formation:

Stereolasma cf. *recta* (Hall).
Heterophrentis cf. *prolifica* (Billings).
Pinnatophyllum scyphus (Rominger).
P. scyphus carinatus Grabau (chironym).
Cyathophyllum robustum Hall.
C. subrobustum Grabau (chironym).
Merophyllum kegomigense Grabau (chironym).
Pristiphyllum longiseptum Grabau (chironym).
Cylindrophyllum panicum (Winchell).
C. magnum Grabau (chironym).
Cystiphyllum cf. *vesiculosum* (Goldfuss).
C. conifollis Hall.
C. varians Hall.
C. aggregatum Billings and *aggregatum caespitosum* Schlüter.
Aulopora serpens Goldfuss.
Ceratopora cf. *jacksoni* Grabau.
Syringopora crassata Winchell.
Favosites transitorius Grabau (chironym).
F. alpenensis dumosus Winchell.

Charlevoix stage:

Heterophyllum alpenense Grabau (chironym).
Pachypora limitaris (Rominger).

Gravel Point stage:
Merophyllum cysticum (Winchell).
Prismatophyllum davidsoni michiganense Grabau (chironym).
P. anna (Whitfield).
Chonophyllum ponderosum Rominger.
Aulopora alectiforma (Winchell).
A. aperta Winchell.
A. *conferta* Winchell.
A. cyclopora Winchell.
Ceratopora partita (Winchell).
C. fenestrata Winchell.
Alveolites subramosus Rominger.

Although most of the beds of the Traverse series offer abundant evidence of the existence of a varied crinoid association, identifiable remains are among the rarest occurrences. A few poorly preserved calices of a species of *Megistocrinus* found low in the Petoskey are the only notable exceptions.

Through many of the beds are also found abundant and beautifully preserved fossils of bryozoa. The Cryptostomes are especially numerous, and these are at the present time undergoing revision and discriminating study by C. F. Deiss, formerly of the University of Michigan. Most of the other forms in the Little Traverse Bay area have received little attention. Of the described forms with known limited range only *Cystodictya sulcata* Winchell from the lower part of the Gravel Point may be cited.

Brachiopods are a very common element of the faunal associations. Among them are a number which may be mentioned as characterizing the individual units.

Petoskey formation:
Stropheodonta erratica fissicosta Winchell.
S. demissa forticosta Winchell.
Chonetes cf. *coronatus* (Conrad).
Spirifer filicosta Winchell.
Gravel Point stage:
Stropheodonta erratica solidicosta Winchell.
S. near *concava* Hall.
Douvillina cf. *inaequistriata,* (Conrad).
Chonetes emmetensis Winchell.
Spirifer mucronatus longispina Grabau, (chironym).
S. bidorsalis Winchell.
Athyris eborea (Winchell), var.

Nowhere in the section are the mollusca particularly well represented. Of the pelecypods the only notable representative in the Petoskey beds is a single species of *Conocardium*, *C. bifarium* Winchell. The Charlevoix series is characterized by a profusion of two doubtful species of *Edmondia*, *E. mactrodies* Winchell and *E. ledoides* Winchell. Scattered individuals of a few undescribed species are found in several zones of the Gravel Point. The following forms

are restricted to the lower unit: Several undescribed species of *Actinopteria*, *Janeia* species, *Paracyclas* species, and *Conocardium emmetense* Winchell. Of the gastropods the only remarkable forms are three species of *Pleurotomaria* (?), *P. cavumbilicata* Winchell, *P. emmetensis* Winchell, and *P. parvispira* Winchell, known to be limited to the Charlevoix; and a septate form of *Euomphalus* found low in the Petoskey. Cephalopods are present but not commonly so, and have received little or no attention.

Of the trilobites, species of *Phacops*, *Proëtus*, and *Asteropyge* occur in both the Gravel Point and Petoskey. These have not so far been studied. Ostracods of the *Moorea* and *Beyrichilina* types are found in the Gravel Point and are abundant in some beds of the Charlevoix but again have not been differentiated nor described.

Occasional fish plates of the *Dinichthys* and *Ptyctodus* types are found in isolated occurence, but their rarity precludes any stratigraphical usefulness.

REGIONAL AND LOCAL STRUCTURE

Much has already been said concerning the varied and complex structure of the region bordering Lake Michigan. With the additional evidence now in hand several new features appear to further complicate any intrepretation of these phenomena.

Deformation versus reef origin.—It appears unquestionable that the miniature closed anticlines and synclines which are so abundant at all exposures of the Traverse beds in western Michigan are due to an entirely local and indigenous cause. The positions of numerous, compact *Prismatophyllum* and *Stromatopora* reefs are seen to be geographically and stratigraphically fortuitous, and upon consolidation the strata would naturally conform to the irregularities caused by these more compact masses. Reefs of large dimensions are, however, entirely absent, and for the explanation of the larger domes, anticlines, basins, and synclines we must look to other causes. One undoubted emergence and probable deformation on a slight scale has already been shown to have occurred within the Traverse. The oscillating character of the central basin portion of the Devonian province has just begun to be appreciated. The regional dip has been remarked before as trending irregularly southeastward. Faunal discrepancy between the western and eastern areas of Traverse outcrop is becoming more and more evident as the associations become increasingly understood. It is rather difficult to account for this faunal distinction on any other basis than the hypothecation of at least an intermittent land barrier separating the two regions. This supposition requires a remodification of structural attitudes to account for the present day regional structure.

THICKNESS OF THE TRAVERSE GROUP IN WESTERN MICHIGAN

So far as is known from the combined well records and exposures in the western portion of Michigan there is no great thickness of continuous shale deposition above that at the base of the Traverse. This bed of shale, to which the term "Bell Shale" has been applied in well records in conformity with the occurrence in eastern Michigan of a similar stratum resting on the Dundee, varies according to reports from 40 to 100 feet in thickness. In later and more reliable records this "Bell Shale" is seen to maintain an average thickness of nearly 70 feet, its lower boundary being drawn at the contact, with great lithologic change, with the "Dundee."

Paradoxically enough the most useful of the numerous well records is one of the earliest and least detailed reports, but its location is accurately described and it was begun in beds having a determined position in the stratigraphic sequence. Fortunately this early record gives sufficient information, having penetrated to the Bell Shale, to make possible an estimate of the complete thickness of Traverse rocks deposited in western Michigan. This record has been already published,[13] but for convenience of reference it is again cited.

Location: Sec. 33, T. 35 N., R. 5 W., Bear Creek Township. 120 paces northwest from door of G. R. & I. R. R. station and 40 feet from shore of Bay. "Bay View well."
Elevation: 585 feet above sea level.
Completed July, 1895.

	Thickness, feet	Depth, feet
Pleistocene: Shingle	4	4
Devonian:		
Traverse group—		
Cream limestone	260	264
Medium grey limestone	198	462
Dark limestone	11½	473½
Cellular blue clay (Bell Shale)	25	498½

The mouth of this well is situated at or about the contact between the Gravel Point and the Charlevoix stages. The tools are recorded as encountering the "Bell Shales" at about 470 feet. If to this we add the average 70 feet of the Bell and the minimum known thickness of rocks above the mouth of the well (130 feet), the entire thickness of the Traverse is here shown to have a minimum of approximately 660 feet, proving the existence of more than 400 feet of unexposed Traverse beds underlying the region.

Computations from the records of other wells at various localities in Charlevoix and Emmet Counties substantiate the estimate of the thickness of the western Traverse beds derived from the Bay View

[13] Grabau, A. W. Mich. Geol. Survey Ann. Rept. for 1901, p. 197, 1902.

well. The succession varies in development between 669 and 670 feet of actual and estimated thickness in the two following wells: Boyne City, Northwestern Michigan Development Co., J. M. Stutzman well No. 1, located in the SE. ¼ of NW. ¼ of sec. 16, T. 33 N., R. 6. W., Evangeline Township, Charlevoix County; and the Petoskey municipal well, located near the city waterworks in the bottom of Bear River "gorge" a short distance from Little Traverse Bay, Petoskey, Emmet County.

LAKE HURON SEQUENCE

A restudy of the eastern Michigan Traverse has been undertaken by the geological survey of the State, but further details of this succession must await the completion of field studies. Until recently the sections have remained as they were described by Grabau in 1901,[14] with the exception of a discussion of Grabau's newly proposed Presque Isle series.[15]

Before proceeding to a faunal comparison of the sections exposed in the western and eastern portions of Michigan a brief summary of the existing stratigraphic knowledge of the latter area is appropriate.

The fourfold subdivision previously adopted for the Traverse group in Presque Isle and Alpena Counties has more recently been restricted by Grabau, the Bell Shales now forming the lowest member of the Presque Isle series. The sequence in downward succession as now understood is as follows.[16]

	Feet
Thunder Bay series (stage)	137–190
Alpena series (stage)	118–134
Presque Isle series (stage):	
Long Lake beds (member)	157–169
Grand Lake limestone (member)	39– 39
Bell Shales (member)	60– 80
Total Traverse group	511–612

The contact phenomena of the various stages of the thus subdivided Traverse group in eastern Michigan have not so far undergone close study, but widely different lithic and petrographic characters are found by rock analysis to be constant through each of the divisions. A tabulation of the available analyses will show the percentage range of the major constituents of samples taken from various portions of the succession.

[14] Grabau, A. W. Mich. Geol. Surv. Ann. Rept. for 1901, pp. 175–196, 1902.

[15] Grabau, A. W. Unpublished manuscript, pp. 290–308, 1915.

[16] Grabau, A. W. Unpublished manuscript, pp. 298, 308, 318, 441, 1915. Notes of Mich. Geol. Surv. Expedition, 1926.

A. Analyses of various beds of the Thunder Bay stage show

	Minimum	Maximum	Average
SiO_2	21.54 to	55.86	48.43
Fe_2O_3	4.66 to	5.11	4.89
Al_2O_3	4.58 to	20.93	16.19
$CaCO_3$	3.18 to	60.89	24.90
$MgCO_3$	2.57 to	5.94	3.70

B. Analyses of various beds of the Alpena stage give

	Minimum	Maximum	Average
SiO_2	0.20 to	4.62	1.39
Fe_2O_3	.13 to	.53	.30
Al_2O_3	.13 to	1.79	.75
$CaCO_3$	89.20 to	99.63	96.69
$MgCO_3$	.21 to	8.61	1.71

C. Analyses of various beds of the Presque Isle stage give

	Minimum	Maximum	Average
SiO_2	28.38 to	66.39	52.10
Fe_2O_3	1.59 to	5.87	3.49
Al_2O_3	7.23 to	20.44	13.82
$CaCO_3$	9.12 to	33.00	21.06
$MgCO_3$	.50 to	5.02	2.15

The foregoing tables make no pretense at completeness of statistics, nor are the computed averages of strictly quantitative nature for the entire thickness of any of the stages. They will, however, serve to bring out the strong contrast in the quantative character of the rock constituents in the three series of beds and explain the restriction of the cement industry to beds belonging to the middle division.

Distinctive species of the eastern Traverse.—As with the organic remains of the Traverse Bay section the greater majority of fossils found in the Traverse beds of eastern Michigan have as yet received little or no discriminating attention. A full discussion of the faunal character of associations in the various portions of the section must await the completion of considerable paleontologic study. Ready means for distinguishing between the broader divisions of the succession is, however, afforded through the restriction of a number of abundant and easily recognized species to one or another of the three stages. So far as known the species mentioned below have not been found elsewhere in the sequence than in beds of the stage under which each is respectively cited.

Species characteristic of the Thunder Bay stage

Stereolasma cf. *recta* (Hall).
Zaphrentis (*Homalophyllum*) *exigua* (Billings).
Pristiphyllum longiseptum Grabau (chironym).
Cylindrophyllum cf. *panicum* (Winchell).

Eridophyllum cf. *strictum* Edwards and Haine.
Cystiphyllum arborcum Grabau (chironym).
Ceratopora cf. *partita* (Winchell).
Favosites placentoides Grabau (chironym).
F. nitella Winchell.
Cladopora (*Coenites?*) *fisheri* (Billings).
Trachypora elegantula Billings.
T. (?) *proboscidialis* (Rominger).
Alveolites subramosus Rominger.
Scalaripora separata Ulrich.
S. approximata Ulrich.
Camerotocchia cf. *gaincsi* (Nettleroth).
Cimitaria, new species near *corrugata* (Conrad).
Plethomytilus cf. *oviformis* (Conrad).
Nucleocrinus species cp. *obovatus* (Barris).
New species cp. *meloniformis* Barris.
Heteroschisma gracile Wachsmuth.
Pentremitidea americana Barris.
Gennaeocrinus cassedayi Lyon.
Megistocrinus concavus Wachsmuth.
M. multidecoratus Barris.
Dolatocrinus triadactylus Barris.
Stereocrinus cf. *triangulatus* Barris.

Species characteristic of the Alpena stage

Pinnatophyllum multilamellatum (Nicholson).
Merophyllum (?) *conatum* (Hall).
Prismatophyllum anna (Whitfield).
P. cristatum (Rominger).
Chonophyllum ponderosum Rominger.
Cystiphyllum cf. *aggregatum* Billings.
Microplasma alpenense Grabau (chironym).
Aulopora serpens minuta Grabau (chironym).
Favosites cf. *hamiltoniae* Hall.
F. radiatus Rominger.
F. alpenensis Rominger .
Cladopora robusta Rominger.
C. expiata Rominger.
Alveolites cf. *goldfussi* Billings.
Michelinia insignis Rominger.
Stropheodonta cf. *concava* Hall.
Chonetes cf. *mucronatus* Hall.
Spirifer cf. *pennatus* (Owen).
S. cf. *granulosus* Hall.
Nephriticerina alpenensis Foerste.
Acleistoceras casei Foerste.
A. nummulatum Foerste.
Alpenoceras ulrichi Foerste.
Numerous criniods of the genera *Megistocrinus* and *Dolatocrinus.*

Characteristic species of the Presque Isle stage

Heterophrentis prolifica (Billings).
H. convoluta (Hall).

Zaphrentis (?) *gregaria* Rominger.
Aulacophyllum princeps deflecta Grabau (chironym).
Blothrophyllum rabitcaui Grabau (chironym).
Pinnatophyllum scyphus (Rominger).
Heliophyllum coalitum (Rominger).
Prismatophyllum nanum Grabau (chironym).
Ceratopora near *jacksoni* Grabau.
Favosites placenta Rominger.
F. radiciformis minus Grabau (chironym).
Trachypora near *limbata* (Eaton).
Chonetes fragilis Stewart.
Spirifer prolificum Stewart.
Spirifer near *oweni* Hall.
S. johnsoni Grabau (chironym)
Leiorhynchus lucasi Stewart.
Grammysia cf. *nodocostata* Hall.
Lophonychia, 2 new species.
Pterinea near *flabella* (Conrad) and several varieties.
Phacops milleri Stewart.

DISCREPANCIES IN FAUNAL DISTRIBUTION

There can be no reasonable question as to the general age equivalence of the Traverse group as developed in western and eastern Michigan. Although a heavy drift cover conceals the actual continuity of beds between the two areas, records of wells sunk at various intervals entirely across the region immediately underlain by Middle Devonian rocks establishes the fact that throughout its extent across the northern portion of the Southern Peninsula the Traverse group maintains a thickness close to 700 feet. It is further inconceivable in a region of such comparatively shallow warping that any great thickness of beds deposited in Traverse time was completely removed before the initial invasion and deposition by the early Waverlian sea which soon completely buried the underlying rocks. This explanation might be read into the southward thinning of the Traverse beds and the absence in northern Ohio of later Traverse deposits; but abundant evidence is found in the same paleogeographical basin in Ohio and Indiana farther south of continuing Devonian sedimentation. This fact would deny the necessary time for the removal in great part of a continuous sheet of Traverse limestones to the northward of the latter area. The Upper Traverse is absent in northern Ohio rather through nondeposition and off-lap to the northward. Why then is there no faunal connection between the two areas in which the greatest known succession of Traverse beds was developed? The question can not be answered with the data available at present, and is presented with the hope of stimulating further work on this puzzling problem of faunal distribution.

Study of the whole area of Traverse outcrop has brought to light only normal conditions of sedimentation throughout the group, and

yet there is not a single faunal association common to the eastern and western areas of outcrop. The individual species, too, although belonging in most cases to the same generic and family types, with few exceptions, are distinct in the two regions. To my knowledge not a single highly diagnostic species of any portion of either the eastern or western sections has been found at any place in the other. To be sure, a number of so-called "species" have been identified as occurring alike in the two sections, but for correlation purposes these invariably turn out to be utterly useless on critical examination. Like "*Atrypa reticularis*" they may be "species" with long life histories; or like "*Pholidostrophia iowensis*" they, may have insufficient characters for useful discrimination; or with others like "*Phacops rana*," "*Spirifer mucronatus*," "*Stropheodonta concava*," and dozens more, the name may be merely a jack-pot fed by constantly increasing numbers of indifferently and carelessly identified forms. We are never to arrive at any exact knowledge of true conditions by using *these* "species" for otherwise careful consideration of the problem.

FALLACIES OF CORRELATION AND EVIDENCES FOR PROPER POSITION IN THE GENERAL TIME SCALE

Previous expressions of opinion concerning correlation of the Traverse beds has almost uniformly favored their time equivalence with the "Hamilton" of New York State. That the "Hamilton" of that State comprises several distinct stratigraphic units characterized by distinct faunal associations of different time values has been only recently understood.[17] The combined faunas of beds ranging from the Marcellus to the Tully were grouped and the result was a "typical Hamilton fauna." From this enormous association similarities were drawn with a comparatively few Traverse representatives. Accounting for the absence of diagnostic Hamilton fossils of even the "percentage scale" forms in the Traverse was either disregarded or explained on the basis that westward migration for these species (and in the same way the vast majority) was in some way hindered.

The presence of forms unknown to the Middle Devonian of New York and in a few cases grossly simulating remains from the Wisconsin or Iowa areas were designated "western migrants" commingling with species from the east in a shallow strait opening at the same time to the Atlantic and Pacific. The correlation was thus completed and the "Hamilton" extended to all points of the compass over half a dozen physiographic provinces of North America.

The conception of mid-Devonian paleogeography thus reviewed is, of course, extreme, and individual workers have long known that this

[17] A forthcoming publication by G. A. Cooper, of Yale University, contains the results of a detailed revision of the New York sections.

position was not in accord with actual fact. The past decade has witnessed a careful collection of detailed paleogeographical data, but there has been no attempt to summarize these facts connectively. A brief review of the knowledge of the Middle Devonian of the northern Mississippi Basin has been sketched in a recent paper by the author.[18] It was pointed out that the outcrops of Devonian rocks nearest adjacent the Traverse on the west, those of eastern Wisconsin, were deposited at a considerably later time; and that the Cedar Valley formation, the Devonian of Iowa bearing closest faunal connection with the Milwaukee beds, lies above the "Cuboides zone" in that State, placing it unquestionably in the Upper Devonian.

EVIDENCES FOR PROPER POSITION IN THE GENERAL TIME SCALE

Beds of Traverse age again appear at the surface in northwestern Ohio. These outcrops trend in a general northeast-southwest direction from Lucas to Paulding Counties and have been described in two bulletins of the Geological Survey of Ohio.[19] The Traverse with a slight northwest dip here appears on the surface as the southeastern portion of its broadly concentric outcrop and overlaps to the eastward on the Cincinnati axis. The actual thinning and disappearance of these beds has not been traced, but shortly to the eastward the same stratigraphic position is held by the eastwardly thickening Delaware limestone and its distinctive southern fauna. The greatest thickness of Traverse beds in this region is seen at Ten Mile Creek, a little south of Silica and 10 miles west of Toledo in Lucas County, where the exposed section shows some 47 feet of Traverse delimited below at the contact with the Columbus limestone carrying a true Onondaga fauna. The Traverse apparently thickens westward, but that the complete thickness is in the neighborhood of 50 feet at its westernmost exposure may be seen in the close proximity of the Ohio shale to the west.

The Traverse beds exposed in northwestern Ohio bear a fauna identical with that found in the lower part of the Presque Isle stage farther northward in the vicinity of Alpena in Michigan. Following is a partial list of species common to the Traverse of Ohio and the Bell shale of Michigan.

Heterophrentis prolifica (Billings).
Prismatophyllum cf. *davidsoni* (Edwards and Haime).
Ceratopora near *jacksoni* Grabau.
Cystodictya near *gilberti* (Meek).

[18] Pohl, E. R. Middle Devonian Pelecypods of Wisconsin and Their Bearing on Correlation. Wash. Acad. Sci., vol. 19, No. 3, pp. 53–59, 1929.

[19] Stauffer, C. L. Geol. Surv. Ohio, ser. 4, Bull. 10, pp. 144–156, 1909. Stewart, G. A. Geol. Surv. Ohio, ser. 4, Bull. 32, 1927.

Fistulipora vesciculata (Hall and Simpson).
Botryllopora cf. *socialis* (Nicholson).
Monotrypella ohioensis Stewart.
Reteporina striata (Hall).
Streblotrypa cf. *hamiltonensis* (Nicholson).
Stropheodonta cf. *demissa* (Conrad).
Leptostrophia cf. *perplana* (Conrad).
Pholidostrophia species cf. *iowensis* (Owen).
Chonetes near *coronatus* (Conrad).
Chonetes fragilis Stewart.
Leiorhynchus lucasi Stewart.
Atrypa reticularis (Linnaeus).
Spirifer near *oweni* Hall (*eurytcines* Owen of Stewart).
S. prolificum Stewart.
Grammysia species cf. *rodocostata* Hall.
Pterinea near *flabella* (Conrad) and several varieties.
Phacops milleri Stewart.

The lowest Traverse is thus seen to rest on Onondaga strata and is nowhere known to overlap on younger beds. The basal Traverse is therefore immediately post-Onondaga in age. The basal contact may again be seen in the Alpena region, but since the exact relationships of the Dundee and the overlying "Manitoba beds" are not completely understood direct inferences are best not drawn there.

The Traverse beds thicken to the northward until at their northern edge of outcrop in the northern counties of the Southern Peninsula of Michigan they aggregate between 500 and 700 feet of deposits, mostly highly calcareous. The upper beds of the Thunder Bay stage on the east carry an abundant and very distinctive association of species already cited in part on a preceding page.

Turning now to the Middle Devonian of southwest Ontario a few sections are found exposed on and near the shores of Lake Huron and on the Ausable River and a few of its tributaries in Ontario. These are the famous Canada West localities which have been for a century a paradise of paleontological collectors. Much has been written on the faunas and stratigraphy of the district, and the occurrence has played an important part in former conceptions of Devonian paleogeography, but the full significance of the sections has only recently been learned. Mr. Charles Southworth, of Thedford, an ardent local collector, discovered in 1926 beds representing the lowest exposed portion of the mid-Devonian sequence of the district. These may be seen at times of low-water level in the bed of the Ausable River at Grand Bend on the line between Lambton and Huron Counties. The sequence is carried upward interruptedly to the southward through the "Ipperwash limestone" and the "Olentangy shale," which underlies the "Encrinal limestone" of this section. The exposed succession to the base of the "Encrinal limestone" aggregates close to 60 feet of beds and according to the fossil content is directly correlatable with

the upper portion of the Thunder Bay stage of eastern Michigan. The reference of these beds to the Olentangy shale of Ohio has long been known to be incorrect, and on the grounds here discussed the lower portion of the Ontario section is necessarily considered an eastward extension and integral part of the Thunder Bay stage of the Traverse group. A number of closely differentiated species common to the Thunder Bay stage of Michigan and the lower portion of the Ontario section are cited below.

Cystiphyllum aboreum Grabau (chironym).
Ceratopora cf. *partita* (Winchell).
Cladopora (*Cocnites?*) *fisheri* (Billings).
Trachypora (?) *proboscidialis* (Rominger).
Alveolites subramousus Rominger.
Scalaripora separata Ulrich.
S. approximata Ulrich.
Fistulipora (? *Dichotrypa*) *corrugata* Ulrich.
F. stellifera Ulrich.
Chonetes near *scitula* Hall.
C. near *vicina* (Castelnau).
Pentamerella, new species.
Tentaculites attenuatus Hall (var.)
Spirifer arkonense Shimer and Grabau.
Cyrtina species near *hamiltonensis* Hall.
Cystodictya near *incisurata* (Hall).
Megistocrinus concavus Wachsmuth.

Collections from the lower beds of the Thunder Bay of Ontario are incomplete at present but further additions are certain to bring to light much if not the entire fauna contained in the strata at Partridge Point in Michigan.

Having established the identity of the Thunder Bay strata in Ontario we find them capped by true Hamilton beds overlapping from the New York province. This is the most westward occurrence of beds belonging undeniably to the New York Hamilton, and they fortunately can be placed accurately in the generalized section of that State. The "Encrinal limestone" and the "Coral Bed" of the Widder beds, so classic for their abundant and beautiful fossil remains, are identical with the same beds of the East Bethany section described by Slocum.[20] The occurrence of these strata at the latter locality is found at the long railroad cut a mile and a half west of the station at East Bethany. Slocum, however, in collecting the abundant remains from the talus of this locality mistook the position of the "Coral Bed" to lie below the "Encrinal limestone." Subsequent work at this place has established the fact that the beds under discussion hold the same reference to each other as they do at Arkona and in vicinity of Thedford in Ontario, 200

[20] Slocum, A. W. Field Col. Mus. Publ., vol. 2, pp. 257–265, 1906.

miles farther west. A study of the succession in the region of East Bethany places the age of the two beds named as early Moscow. It is unnecessary here to give a complete faunal list of those species common to the portions of the sequence in Ontario and New York under discussion, for these have been endlessly published elsewhere without results. Suffice it to say that every species found at the one locality may be identified at the other, even to the rarer forms, such as *Pugnax kernahani* Whiteaves and *Eleutherocrinus cassedayi* Shumard and Yandell.

The westward migration by overlap of this portion of Hamilton deposits into Ontario sharply delimits the upper boundary of the Thunder Bay. The conditions of contact indicate a break of considerable duress, and paleogeographical conditions in the upper Mississippi Basin point to a comparatively early cessation of Traverse sedimentation at this location. It is highly probable that Ludlowville and even Skaneateles time are represented here only by the unconformity. This is necessarily so, for it has been shown that the seas of the Traverse were slowly receding to the northward shortly after their first encroachment in Presque Isle time.

The stratigraphic position occupied by the Traverse group is thus clearly delimited, as occurring between the Onondaga and the Hamilton, and the time scale is extended by the interpolation of at least 700 feet of interrupted limestone deposition.

DERIVATION. WHENCE CAME THE TRAVERSE?

Throughout much of Paleozoic time invasion of North America by epicontinental seas with northern connections was active. Axes and basins had long been moulded in semipermanent trend, and their positions were closely related to the derivation and distribution of mid-Devonian strata in the northern Mississippi Basin. The methods by which paleogeographic conditions are reconstructed are essentially paleontologic, for due to subsequent erosion or burial under later deposits a case where it is possible to trace the overlap of beds upon the barriers is exceptional. To reconstruct the geographic conditions during the deposition of the Traverse beds we may fortunately combine the physical and faunal criteria.

Certainly the Traverse faunas have no close relatives in strata having known southern connections. The Traverse stages are furthermore paleontologically isolated from even the Middle Devonian formations which were deposited in the same general region, which in the case of the Hamilton beds overlap the former. Precise information bearing on Middle Devonian remains found in the Arctic and the northern Canadian Provinces is lacking and specific lists

are far from complete. The generic types are, however, sufficiently well known to indicate the connection of the Traverse forms with a northern origin. This is to be expected, for there is not the slightest possibility of their origin in the south or west and an eastern derivation is denied by stratigraphic conditions. It has further been pointed out that the Traverse strata thin to the southward and overlap to the eastward. Thus we come to the conclusion that the Traverse seas successively advanced from the northward across the Laurentian mass into an irregularly and intermittently sinking basin occupying southwestern Ontario, northwestern Ohio, all of the Southern Peninsula, and the eastern part of the Northern Peninsula of Michigan, and opening by way of James Bay and Hudson Bay to the Arctic and the North Atlantic Oceans.

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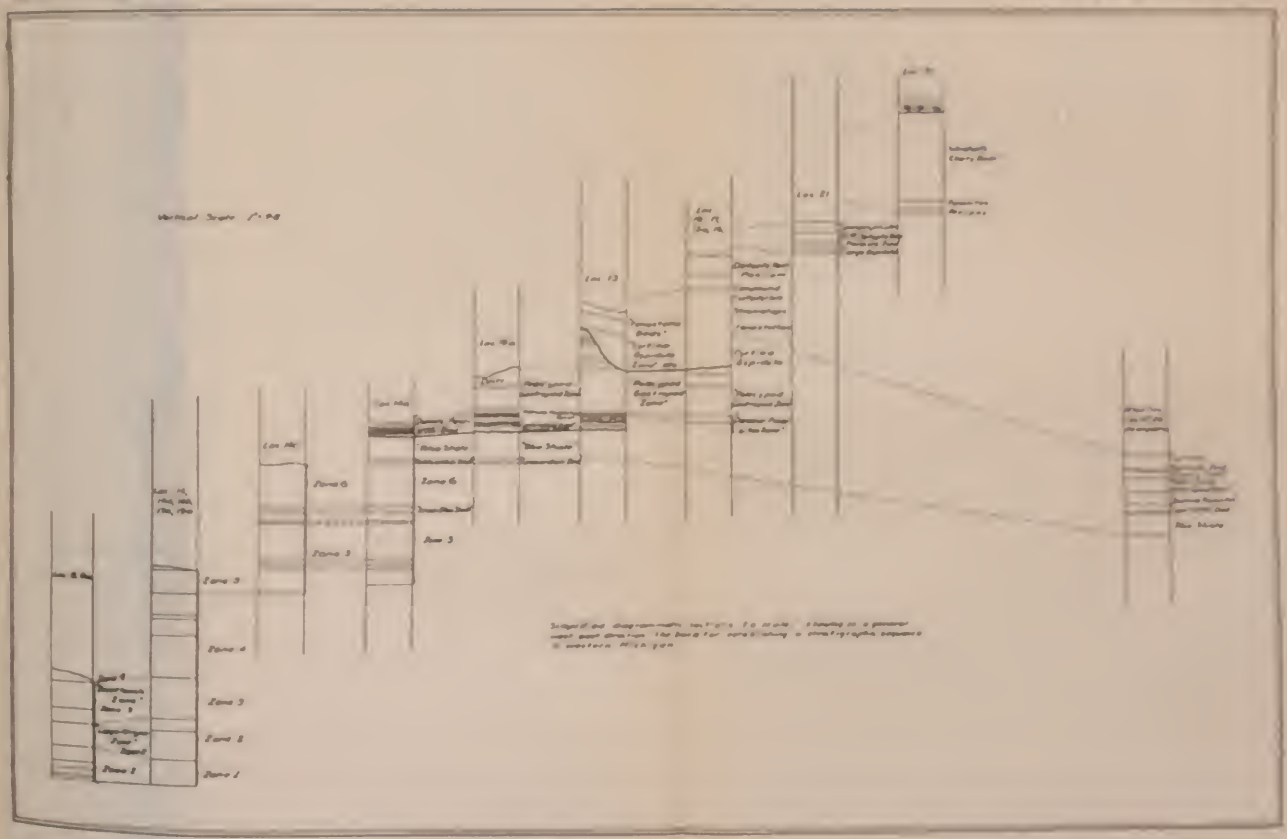
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