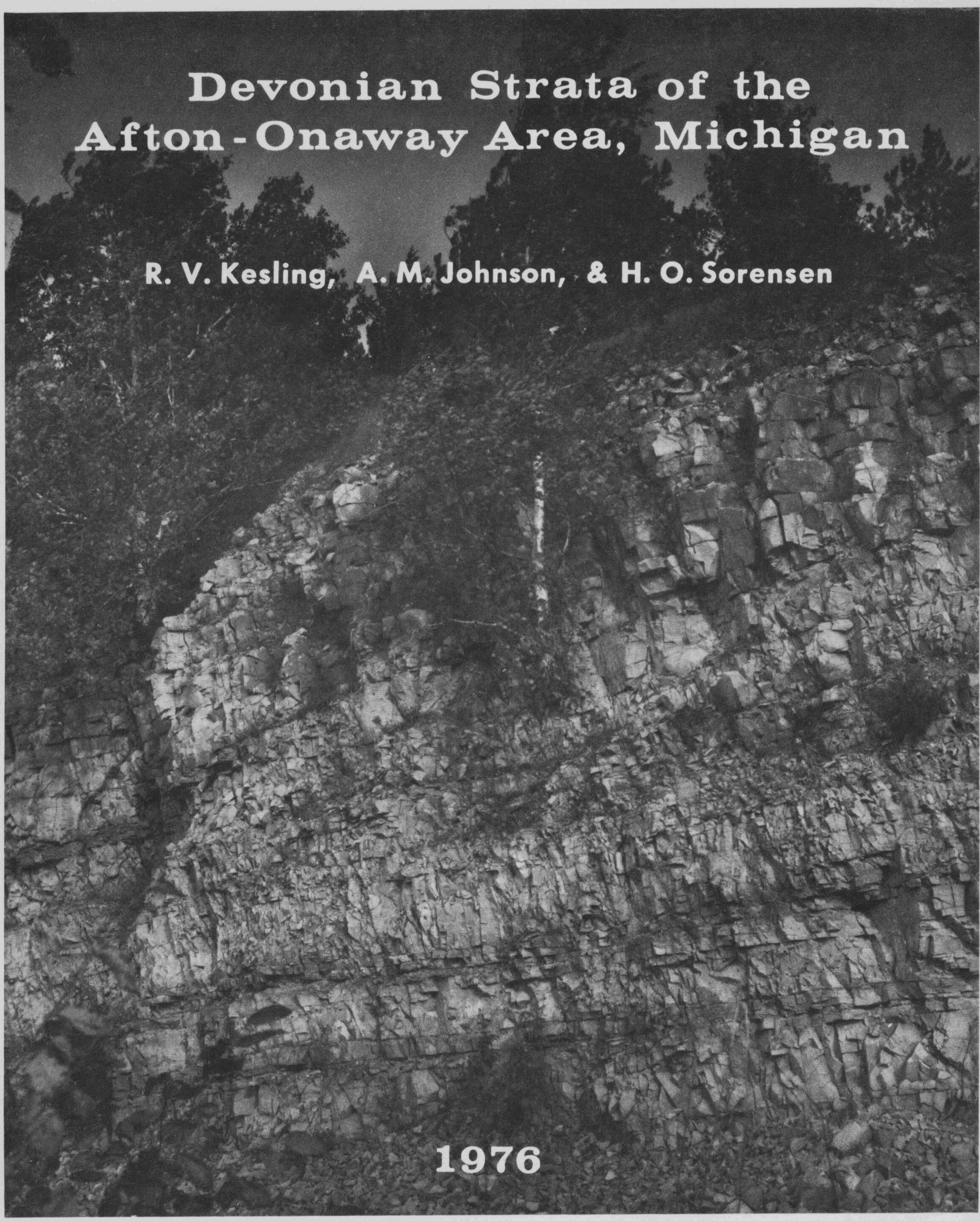
Devonian Strata of the Afton-Onaway Area, Michigan

R. V. Kesling, A. M. Johnson, & H. O. Sorensen



1976

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INTRODUCTION

ALTHOUGH the geology of the Afton-Onaway area has not been known quite as long as that of either the Alpena area to the east or the Charlevoix area to the west, it occupies a crucial position in the Middle Devonian paleogeography and paleoecology of the northern part of the Michigan Basin. At times it was the barrier separating the carbonate deposits of the Alpena area from those of the Charlevoix area. At other times it was cut off from open circulation and accumulated lagoonal beds. And from time to time it was part of the open basin, receiving sediments continuous with those to the east and to the west.

Because of its inland location, the Afton-Onaway area was unknown to the First Geological Survey of Michigan. The adventuresome Douglass Houghton and his assistants did their reconnaissance by sailing vessels and canoes. The frontiers of state geology were extended as thin margins bordering the Great Lakes. Thus, even the copper region of Lake Superior was studied years before the inland areas which lay closer to the centers of government and education in the state.

Nevertheless, some progress was made in expanding the area of geological observations. After the tragic death of Houghton, drowned in Lake Superior during a storm on 14 October 1845 while leading a geological expedition, the Survey continued under Christopher C. Douglass and later under Alexander Winchell. It was a time of great activity on the Michigan frontiers. Amid the frenzy of homesteading and land clearing, pioneer villages were quickly erected and railroads proliferated into a network across the southern part of the state. Field work became feasible in new counties. By 1871 geological observations were lacking only in isolated inland spots -- pockets of wilderness that geologists had passed by. The Afton-Onaway area was one of these.

In 1871 Dr. Carl Ludwig Rominger became State Geologist and methodically and tirelessly began to eliminate the geologically unknown areas and to fill in the state map. In the year 1874, spring came late and it was not until the 20th of May that Rominger was able to sail from Detroit for Alpena. He arrived there late on Friday, the 22d, and immediately set about investigating the geology of nearby islands and coasts, newly opened quarries, and sinkholes reported by settlers. Having completed his observations there on the 10th of June, a Friday, Rominger sailed aboard the Marine City from Alpena for Cheboygan, where he landed early Saturday morning. On Sunday, with an assistant, he headed up the Cheboygan River for Black Lake. According to Rominger's diary:

> ... the river divides a few miles above town into two arms one coming from Mullet lake and navigable the other coming from Black Lake and equally large but not navigable on account of rapids in the river ... We went up black river ... Cheboygan or Black lake is a very beautifull large sheet of water ...

They camped that night beside the lake and continued the next morning towards the mouth of Rainy River. Thus it came about that on Monday, the 13th of June in 1874, a geologist first set eyes upon the Middle Devonian strata of this area. As Rominger wrote in his field notebook:

> ... suddenly the limestones of the Hamilton grp form a vertical escarpement of about 40 feet ...

They went on to explore the bed and banks of Rainy River that day. Not all was excitement and glory, however, for the following night was described by Rominger as:

> restless night from mosquitoes, left camp at 5 ... on our return to Cheboygan we were considerably impeded by timber floated on the river, perfectly obstructing it. we had to remain on mister Thomas farm 8 miles from Cheboygan unto next day, when the river drivers broke the jam ... returned to Cheboygan at noon.

In 1876 Dr. Rominger included his observations on the geology of the area (with corrected spelling and polished wording) in "Geology of the Lower Peninsula," which was published as volume 3 of the Michigan Geological Survey.

More will be said below about the ensuing detailed work in the area. R. A. Smith of the Survey made extensive analyses of the Devonian rocks by 1915 and 1916. His reports engendered dreams of investment for the State -- dreams that were never to reach full realization. In 1923 Smith supervised exploratory drilling and drew up detailed maps for utilizing the limestone at Marvin Quarry and the black shale near Beebe School on a grand scale. Once again, the inland location of the Afton-Onaway area proved a serious handicap, and today the modest production of crushed stone is used only locally; meanwhile, the lakeside quarries at Charlevoix, Petoskey, Rogers City, and Alpena developed, expanded, and continue to flourish because of the ease and low cost of transportation by water.

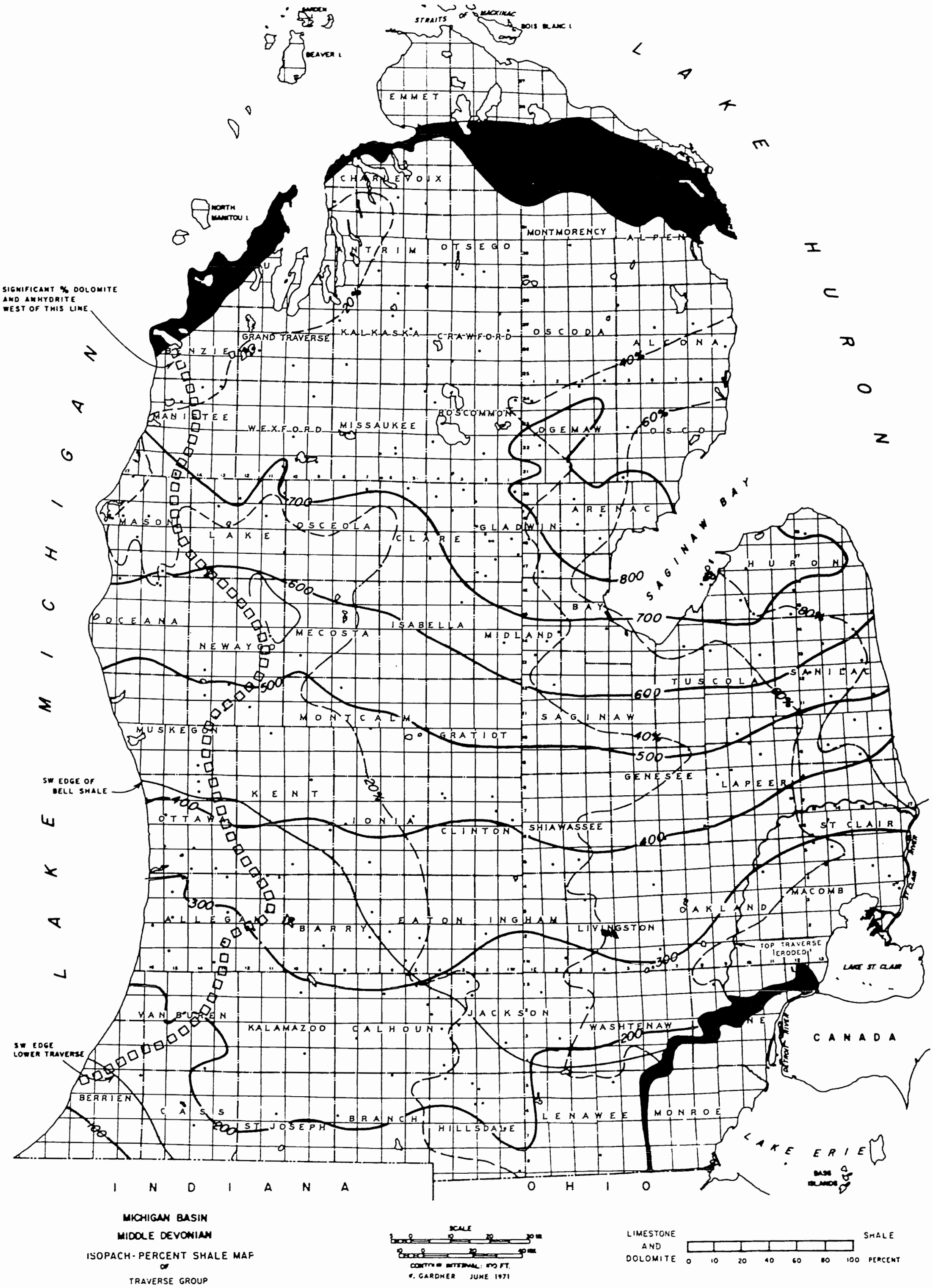
If the surface outcrops of the Afton-Onaway area no longer hold economic interest for geologists, they still contain the keys for understanding Middle Devonian sedimentation in the region. Repeatedly during Middle Devonian time the northern part of the Michigan Basin presented an astonishingly accurate analog of modern carbonate environments; and each time the Afton-Onaway area provided the essential information for our geological interpretation.

Periodically every area needs a review to take account of new exposures and to take advantage of new ideas in our science. Our viewpoint is different from that of the previous publication on the area. Past geologic work had correlation as its ultimate goal. Actualistic models were not even considered, much less slighted. As we look back over the period in which geology was established as a series of measured sections and dotted lines of inference, we are tempted to agree with younger colleagues in calling them the days of "pancake geology" -- a somewhat harsh condemnation but with a grain of justification. There was a general belief that lithology could be strongly equated with contemporaneity. Within the confines of a depositional basin, it was supposed, a particular rock type continued uninterrupted for miles and miles unless it interfingered with a different rock type (and this tended to be regarded as a special case involving ancient deltas). In such a basin, depth changed suddenly (isostatic adjustment) and the whole basin (except for marginal beaches, perhaps) received different sediments and evolved different fauna for another uninterrupted interval of time. Thinning of a unit represented fortuitous "bypassing" or erosion at one time or other; and the absence of a unit in the section could only mean an unconformity, or at least a disconformity. Correlation was a grand and serious game of matching lithologies and faunas.

Geological interpretation has been a long time in reaching the Middle Devonian formations of Michigan. In this respect, they have not been treated so differently from Paleozoic rocks of other states, considering the time at which they were investigated. Geology itself has changed greatly within the last quarter of a century. Even the cult of geosynclines, which were thought to explain the mass and pattern of sediment distribution, is rapidly being disbanded and fading into history. No longer is "facies" a sacred word. "All a young man needed to know about geology" in 1950 is quite inadequate in 1975. Sedimentary petrography and sedimentology have acquired acceptance and elaboration. Sea-floor spreading and continental drift are in vogue. The older geologists among us -- who have witnessed the displacement of one set of "laws" by another, by another, by another -- may be forgiven a tiny bit of reticence about the whole of the New Geology. The recently constructed bandwagon may need a few mechanical adjustments before it becomes the standard-model, smooth-riding, long-mileage vehicle.

Perhaps because geology can borrow from other natural sciences, as well as the physical sciences, many of the revolutionary ideas smack strongly of serendipity -- "the facility or habitual experience of making fortunate and unexpected discoveries by accident." If this be so, other "earth-shaking" concepts may be anticipated at unpredictable times on an irregular schedule.

Whereas the previous work on the Afton-Onaway area did little toward an actualistic model of Middle Devonian sedimentation in the Basin, it did amass a great deal of basic data. The stratigraphic succession was established at numerous localities, the structure of small-scale folds was plotted, and the fauna was at



TEXT-FIG. 1 -- Isopach map of the Traverse Group and equivalents in Michigan, with percent shale added as dashed lines. A line of small squares marks the general boundary of dolomite and anhydrite in the western margin of the state. Recent investigations show that the line for "SW edge of Bell Shale" should extend farther south to include the lower part of the Silica Formation. From Gardner, 1974, fig. 15.

least partly studied in the various units. Without this heritage, the task of reconstructing Middle Devonian history of the area would be much more difficult.

PREVIOUS WORK

Rominger

To appreciate the enormity of the contribution of Carl Ludwig Rominger to Michigan geology, we should begin at the Michigan Historical Collections. There are preserved his fifty field notebooks, original maps, correspondence, and family memorabilia. In his notebooks, Rominger meticulously recorded the events, observations, and interpretations of each day spent in the field as State Geologist, writing partly in English and partly in German (more or less in accord with the rigors of the situation). They constitute a first-hand look at the Michigan frontier, as well as the emerging state geologic map, with here and there his poignant concern for conservation.

During his fourteen years as State Geologist, Rominger probed nearly every county in the state; nevertheless, he was remarkably astute in his analyses. Except for subsequent divisions into smaller stratigraphic units, his sections, descriptions, and maps have been changed surprisingly little in the nearly seventy years since his death.

After his first observations on the exposures at Black Lake and Rainy River, we find no evidence that Rominger ever again returned to the area. He wrote (1876, p. 52, 53):

> ... Rock beds similar to those of Crawford's quarry [now the Calcite Quarry of United States Steel Corporation at Rogers City], or somewhat higher beds, are, all over these high plains, not very deeply covered by drift, and are frequently denuded. The principal denudations of the rock are confined to certain belts striking in a southeast and northwest direction. One of these belts may be indicated by a line drawn from the north end of Long Lake to the mouth of Oqueock River in Hammond's Bay; another limestone belt can be followed from the head branches of Thunder Bay River (north branch) to Rainy River and Sheboygan Lake.
>
> The surface rock most frequently seen on these high plains is light-colored, of crystalline grain, and principally contains the already-mentioned species of Stromatopora; a species of Diphyphyllum is also quite common (Diphyph. rectiseptatum). In some localities, shaly beds, intermediate between the limestones, are very fossiliferous... A continuation of the same range of rock exposures of the lower division of the Hamilton group is seen on Rainy River, 4 miles from its entrance into Black Lake (Sheboygan Lake), and in the rock bluffs facing Black Lake in Town. 35, R. 2, east, Sect. 7. In both localities, from 30 to 40 feet of strata are exposed. Highest are light-colored limestones, with Stromatopora and Cyathophyllum profundum, 20 feet in thickness, and somewhat variable in the structure of the single beds. Below these are about 12 feet of calcareous shales full of well-preserved fossils, viz.: Cyathophyllum profundum, Cyathophyllum Houghtoni, Cyathophyllum resembling C. cornicula, Cystiphyllum Americanum, Favosites digitatus, Favosites Hamiltonensis, Zaphrentis, Syringopora nobilis, Fistulipora, Chaetetes and other Bryozoa, Atrypa reticularis, Spirigera concentrica, Strophodonta demissa, Strophodonta concava, Spirifer zigzag, Spirifer granuliferous, and fragments of Proetus. Lowest are hard, smooth-bedded limestone strata containing few fossils.
>
> Westward from Black Lake, the environs of Mullett Lake and Burt Lake, and all the district north of them, up to the Straits of Mackinac, are deeply covered with drift deposits, with the exception of the foot of the promontory at McGulpin's Point, which, as we have seen before, presents the upper strata of the Helderberg group ...

A. C. Lane

As State Geologist, A. C. Lane did not publish much on the Traverse Group, apart from mentioning it several times in summary. He did, however, come forth with some remarks that seem oddly far ahead of his time, and which seem appropriate to repeat here. He wrote (1895, p. 8):

> ... even as now in different places different kinds of deposits are forming, -- in swamps, peat; at the mouth of the Mississippi, mud; on the coral reefs, limestone; -- so it has always been. Hence the Old Red Sandstone in one place may correspond to a limestone elsewhere. ...
> .. as now, so always, the kinds of animals and

> plants found in a given place or buried in a particular epoch vary, and depend not only upon their environment, -- whether fresh water or salt, warm water or cold, muddly water or clear, shallow water or deep, -- but also on more remote causes...
>
> Thus we can rely blindly neither on the physical character of the rocks nor on fossil-lists. In either case we must also have an eye to what we may call paleogeography, and any classification we make will apply first and foremost only to a certain district.

Evidently, an appreciable amount of unrecorded work was done by the Survey in the Afton-Onaway area around the turn of the century, presumably in the administrations of Lane and his successor, R. C. Allen. By 1915, as we see below, the Black Lake Quarry, the Campbell Stone Quarry at Afton, the Legrand Quarry, and the Marvin Stone Quarry had come into operation.

R. A. Smith

Even before he became State Geologist, R. A. Smith had done notable work for the Geological Survey of Michigan. He visited all the localities known to Alexander Winchell, Carl Rominger, and Amadeus Grabau, as well as the new quarries and known exposures of Paleozoic rocks in Michigan. He measured sections, constructed compass-pace detailed maps of selected localities, studied well records, and conferred with other geologists. Despite his extensive knowledge, however, Smith published few contributions. He shied away from stratigraphic names, but he knew the composition and economic value of every kind of bedrock in the state. R. A. was a walking encyclopedia of geologic information, and unselfishly gave his hard-won knowledge to others.

In 1916, in Michigan Geological & Biological Survey Publication 21 (published as part of the Annual Report of the Board), Smith published his significant "Limestones of Michigan" (1916, p. 101-311), which included descriptions of the geology involved in all limestone production as well as chemical analyses (often bed-by-bed) and measured sections for 24 counties.

For the Afton-Onaway area, Smith presented descriptions, measured sections and chemical analyses for the strata exposed in the Campbell Quarry at Afton, the Black Lake Quarry, the Legrand Quarry, and the Marvin Quarry (the last-named was erroneously called the "Marion" quarry in publication), as well as descriptions and analyses of well cores in nearby areas. Some of these are quoted below in the discussion of formations.

At the Marvin Stone Company Quarry, the average $CaCO_3$ content of the beds was found to be nearly 97% and the glacial cover was very thin over a considerable acreage. Within $2\frac{1}{2}$ miles to the southwest, near Beebe School, the black shale of Upper Devonian age was also found in a ridge with scant glacial cover. Evidently, the State developed interest in a large-scale cement industry because of the proximity and ready accessibility of both limestone and shale. In 1923, Smith, by that time State Geologist, made compass-pace topographic maps of the two areas and analyzed a series of cores from test holes. Old blue-print copies of his maps and section, preserved in the Museum of Paleontology, were photographically "restored" and are presented here as text-figures. Smith calculated a limestone reserve of over 14 million tons. Nothing happened. The Marvin Stone Quarry closed down. Investment shifted to the limestone reserves with port facilities, and today the Portland cement industry thrives at Charlevoix (Medusa Portland Cement Company), Petoskey (Penn-Dixie Cement Corporation), and Alpena (Huron Portland Cement Company). The dream faded quickly. Of the four active quarries mentioned in Smith's 1916 report, all but one ceased operations within a few years -- the Campbell Quarry at Afton; and that quarry was inactive for a long interval. In 1926, Smith wrote to Professor E. C. Case at The University of Michigan (see text-figures), explaining some details of the geologic situation; he did not mention any known plans for developing the limestone resources at that time.

A few months ago (after our first draft), Harry Sorensen came across some documents in the files of the Michigan Geological Survey which explain the motivation of R. A. Smith, State Geologist, in searching out the site and

STATE OF MICHIGAN

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DIRECTOR

R. A. SMITH
STATE GEOLOGIST

L. P. BARRETT
MINING GEOLOGIST

W. I. ROBINSON
GEOLOGIST

H. O. DAVIDSON
MINING ENGINEER

DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION
LANSING

November 8, 1926

Dr. E. C. Case,
Department of Geology
University of Michigan
Ann Arbor Michigan.

My dear Doctor Case:

Your letter of October 28 came when I was up against it for a time in getting out our biennial report.

Now as to the detailed section of the Calcite quarry, I haven't one, for the sample reason that at the time I made my survey in 1914 it was not healthy to make a careful examination of the section. Many of the sections were blasted down; therefore inaccessible, and in the other ones the cracks were so wide and the overhang were so pronounced that I thought I would rather be a live coward than a dead hero in the cause of geology. I had one chance up against the north end of it if I had known it, but by the time I got wise to the situation they were pop-holing in that part of the quarry. The hole analysis is given in Publication 21, a copy of which I think you have.

I am sending you my section of both of the quarries at Afton and the record of the 98 foot drill hole at the abandoned Marvin quarry southeast of Afton. In the publication this is called the Marion quarry. A mistake was made in the rather illiterate writing of this work so it got into the publication wrong.

I haven't got the elevation for M-10 where it crosses the Ocqueoc River but I will see the Highway Department and see if it may be dug up. I may get it in time to inclose. If not it will come along later.

It would be a mighty good thing if Ulrich could see the fossils at Ann Arbor before you send them on to him. It strikes me that he would be able to form a better opinion if he could see all the junk together.

Sincerely yours

R. A. Smith

ras/b

TEXT-FIG. 2 -- Letter from R. A. Smith of the Geological Survey to Professor E. C. Case of the University of Michigan, explaining the error in spelling of "Marvin" Quarry in Smith's 1916 publication.

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DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION
LANSING

November 10, 1926

Dr. E. C. Case,
University of Michigan,
Ann Arbor Michigan.

My dear Case:

I have your letter of Novemoer 9 with accompanying exhibits, including my letter of November 8, the section of the Marvin or Marion stone quarry, and the deep core hole near the latter. You are absolved from all charges of stupidity for the set of exhibits was "bumbled." I neglected to put a slip in for the typist to copy the Campbell or Afton quarry section. I am having this done and it is inclosed herewith.

I am also sending you a sketch map of the surface geology and location of properties for the Afton region; a contour and drill hole map of the property drilled by the State, including both the limestone and shale; also a north-south cross section of the Marvin limestone property on which I have marked the various sections and beds as described by Robinson and later analyzed. These sections, however, were made on the basis of lithological and physical characteristics, and had nothing whatever to do with faunal divisions. The elevations of the north rim of the quarry and of hole No.4 are given; therefore you may observe that the top of hole 4 is 19 feet higher than the top of the quarry. The section ends directly with the quarry; hence this may give you some idea as to how Robinson tied up his beds with the quarry section.

The strong northward dip is purely local and unquestionably the dip is sharply up to the north beyond the section of this property. I think Robinson and I figured that the Campbell quarry section was considerably below that of the Marvin quarry section. To our surprise we found the highest point of the Marvin property higher than the top of the Campbell quarry. Mr. Pardee, who ran the levels, took a sight on the top of Campbell's quarry and found that the instrument swung above the Campbell bluff.

I have even more interesting sections west of Charlevoix which show the rapid undulations of the beds in that region and the two clay and shale beds which formerly were supposed to be one. If you care to have a similar bunch of exhibits for the Charlevoix region I should be glad to send them on.

Here is hoping that I have "unbumbled" the section. If not come back again.

Sincerely yours

R. A. Smith

ras/b

TEXT-FIG. 3 -- Letter from R. A. Smith to E. C. Case, explaining the strike from Marvin Quarry to the Campbell Quarry at Afton. At this time the properties for the proposed state-operated cement industry had been surveyed and reserves estimated.

estimating the reserves for a state-owned cement industry. As it turns out, cement was only one element in a "community of prison industries" planned for the northern part of Michigan.

Smith reported sufficient limestone in the proved deposit at Marvin Quarry for operating a 2-million-barrels-per-year cement plant for 60 years. He also estimated that the waste stone from the Campbell Quarry could be purchased to provide an additional 100 thousand barrels of cement each year. The shale near Beebe School was estimated to have enough reserve for over 100 million barrels of cement, with other potential supplies along the railroad three or four miles south of Indian River. The transportation was already present at the Marvin Quarry site -- the Haakwood-Afton branch connected to the Michigan Central Railroad and leading to the dock at Cheboygan, about 18 miles north of the quarry. An additional spur could be constructed to the shale property, about 2 miles long to avoid excessive grades.

Other industries were evidently contemplated which involved appreciable power. Smith investigated the possibilities of water power on the Pigeon River. A dam only two miles from the limestone quarry, at the so-called "Afton Site" in his report, was proposed, to have a head of 16 feet and an estimated horsepower of 320. About 6 miles northwest of the quarry, at the so-called "Gerow Site" on the same river, a second dam was projected with a head of 87 feet and estimated horsepower of 3000 for a ten-hour day and 1000 for a 24-hour day (the price quoted to Smith for this dam was only $20,000 when the report was submitted on 5 May 1924!).

Smith also recommended that cement produced for various road contracts in the area could be delivered to the site in bulk by trucks provided with air- and moisture-proof demountable boxes, thus saving the expense of bagging and handling the product. (In this, Smith was years ahead of his time in foreseeing standard transportation units.) He further suggested a move to avoid the high freight rates for cement. This could be accomplished by producing clinker at the quarry site, shipping this material as "stone" (at about half the rate for "cement"), and performing the final grinding and bagging at "district plants" situated at points convenient to market areas. The detailed report also included notations on soils and timber in the area, and available acreage of each.

We do not know what voided all these special plans for a "community of prison industries" in the Afton area. Perhaps the proposed "community" did not hold particular appeal for the community already established in southern Cheboygan County. Or politics and economics may have found their happiness elsewhere.

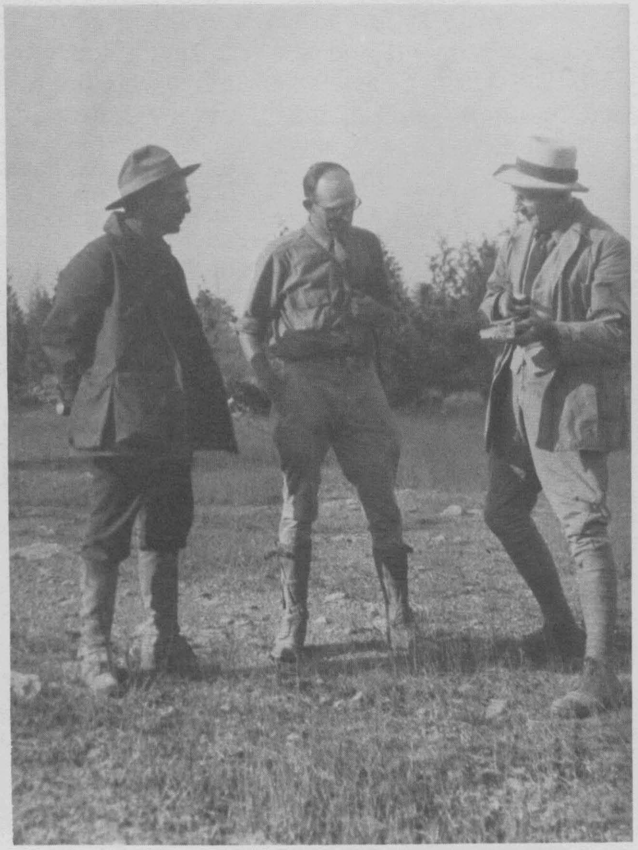
The 1926 Expedition

The Michigan Geological Survey sponsored a major project to study the Devonian strata in the northern part of the Lower Peninsula in 1926. The party included E. O. Ulrich (United States Geological Survey) and E. C. Case, G. M. Ehlers, Charles F. Deiss, and A. Scott Warthin, Jr. (University of Michigan). The vicissitudes of the expedition have been recently recounted (Kesling, Segall, & Sorensen, 1974, p. 5, 6). After an industrious field season of measuring, recording, and collecting at over fifty localities, activity suddenly stopped. The Grand Vision of a monograph on the region succumbed to neglect. Ironically, no one of the field participants ever by himself wrote a major article on the results of the expedition.

In the ensuing years, the information reposing in the field notes and collections was adopted and adapted by others: Pohl (1929) on the Little Traverse Bay region, Warthin & Cooper (1943) on the Thunder Bay region, Kelly & Smith (1947) on the Afton-Onaway area, Ehlers & Kesling (1970) on Alpena and Presque Isle Counties, and Kesling, Segall, & Sorensen (1974) on Emmet and Charlevoix Counties -- not to mention shorter references and articles.

The 1938 Field Trip

On 28 and 29 May 1938, the Geology and Mineralogy Section of the Michigan Academy of Science, Arts & Letters held its 8th Annual Field Excursion to study the northern part of the Lower Peninsula. S. G. Bergquist conducted the part dealing with glacial geology, and G. M. Ehlers the part concerning the Devonian. The itinerary included stops at the Campbell



TEXT-FIGS. 4 and 5 -- The 1926 Expedition into the Michigan Devonian. These photographs were preserved by the late Emeritus Professor George Marion Ehlers; from them we see the team in action. Notebooks of Ehlers and Case reveal the points of difference between Dr. E. O. Ulrich of the U. S. National Museum and Professor Case; Ehlers acted as the secretary for Dr. Ulrich while Case preferred to take his own observations throughout the combined expedition. The stars of the field party were ably assisted by two University of Michigan students -- A. Scott Warthin, Jr. (who taught later for many years at Vassar) and Charles F. Deiss (who is remembered for his later work at Indiana University and the Indiana Geological Survey). The young members collected fossils from all the localities visited and carefully labeled them. Both Case and Ulrich were recognized authorities of their day, and appear to have been anxious to maintain their respective reputations and stations. Despite the grandiose plans to settle the Devonian problems once and for all, no publication was ever a direct result of the field conference, and thirty-six cartons of the fossil material is unpacked and stored in the basement of the Museums Building at The University of Michigan. The notebooks, however, have served as source material for numerous contributions: E. R. Pohl (1929) on the Devonian of the western outcrops, Warthin & Cooper (1943) on the Thunder Bay region, Kelly & Smith (1947) on the Afton-Onaway region, Ehlers & Kesling (1970) on the Alpena and Presque Isle Counties region, Kesling, Segall, & Sorensen (1974) on the Emmet and Charlevoix Counties region, and various guidebooks for the Michigan Basin Geological Society. Above, at the left, is a scene that must have been repeated many times in the summer of 1926: at the right, Dr. Ulrich proclaims his incontrovertible, indisputable, brilliant deductions from the fossils at hand, while Professor Case listens with considerable skepticism and plans to write his interpretation of the true situation in his own notebook, and youthful Professor Ehlers is amazed at the cleverness of his idol. At the right, above, is evidently the end of the excursion and a memorable occasion; Case and Ulrich pose while shaking hands, perhaps declaring a conciliation or at least a temporary truce in their geological and paleontological confrontation.

Quarry and at other exposures near Legrand, Afton, and Beebe School in this area. Measured sections, some directly from the 1926 notes, were offered in the guidebook.

The 1940 Field Trip

On 25 and 26 May 1940, W. A. Kelly of Michigan State College (now Michigan State University) conducted the Tenth Annual Geological Excursion of the Michigan Academy of Science, Arts & Letters to the Afton-Onaway district. For many years he had been measuring sections and mapping formations in the area, and in the guidebook he presented his latest interpretation.

In the eastern part of the area (his map 3, entitled "Rainy River - Ocqueoc Area") he had the "Killians" overlain directly by the "Lower Alpena." In the central part (his map 2, entitled "Black River Area") he had the "Killians" underlain by "Lower Genshaw" and overlain by (1) "Lower Alpena" east of Tower and (2) "Afton" west of Tower. He did not map any Ferron Point Formation between his "Rockport" (Rockport Quarry Limestone) and "Lower Genshaw." In the western part of the area (his map 1, entitled "Afton Area") he showed a succession of "Genshaw," "Killians," "Afton," and "Marvin" below the Antrim. His diagrammatic sections, which are reproduced in our book with new-typed labels, conveyed a clear picture of the quarry exposures at Black Lake, Afton, and Le Grand quarries, in the banks at Ocqueoc Falls, and along the shore of Black Lake east of the quarry. The field trip included 27 stops.

On two cross sections of exposures with elevations, Kelly made the first interpretation of structure in the area. One he termed an "anticline south of Afton" and the other an "anticline southwest of Black Lake." From logs of wells subsequently drilled in the area, we can now give a more detailed structural analysis; but with only outcrops for reference, Kelly did an excellent job.

On the final page of the guidebook, Kelly offered his correlation of the formations in the Afton-Onaway area with those in the Alpena area to the east and the Little Traverse Bay area to the west. He correctly (we think) showed the Charlevoix pinching out eastward and the Four Mile Dam and Norway Point pinching out westward, with none of the three represented in the Afton-Onaway section. He indicated that the upper part of his "Marvin Beds" was equivalent to the Potter Farm Formation to the east and to the Petoskey Formation to the west. Well records now reveal that Kelly seriously underestimated the total thickness of his "Afton Beds" and "Marvin Beds" (which were later, in 1947, divided by Kelly & Smith into the Koehler Limestone, Gravel Point Formation, and Beebe School Formation).

From the exposures available at the time, Kelly divided them into mappable units, worked out the areal distribution, and even noted facies changes in some of the formations.

Kelly & Smith - 1947

In 1947, W. A. Kelly and G. Wendell Smith published their combined efforts in a 23-page article in the Bulletin of the American Association of Petroleum Geologists. Illustrated with map, cross section, structural contour map, and correlation of local sections, the work summarized the field efforts of many summers.

Unfortunately some inconsistencies crept into the Kelly & Smith account. No doubt most of these originated from the long span of time they devoted to the measuring and mapping, with numerous revisions of interpretation. Ten contradictions stand out: (1) the map (1947, p. 448) correctly shows the belt of outcrop for the Beebe School Formation extending both north and south of Beebe School; but the cross section of geologic formations extending north from the school (fig. 5 on p. 459) portrays the Antrim Shale cropping out at the school site. (2) The map (p. 448) shows locality 8 in the W$\frac{1}{2}$ SW$\frac{1}{4}$ sec. 29, T 35 N, R 1 W, a position consistent with the areal geology; but in the list of localities (p. 461), locality 8 is said to be between sections 29 and 30, T 34 N, R 1 W.

(3) The list of localities describes Sorenson's Quarry as located in the SE$\frac{1}{4}$ sec. 2, T 34 N, R 2 W; but figure 5 (p. 459), a cross section, shows the quarry to be about 1$\frac{1}{4}$ miles north of Beebe School, which would locate it in section 11; then on page 454, Kelly & Smith

say the quarry is in sec. 11, T 34 N, R 1 W; actually, the quarry lies in the NE$\frac{1}{4}$ sec. 11, T 34 N, R 2 W. (4) The fourth inconsistency concerns the thicknesses of the formations as shown by the scales in figures 3 and 5 and by the reports in the text:

Formation	Fig. 5	Fig. 3	Text
Beebe School	200	73	(p. 461) 75
Gravel Point	190	60	(p. 460) 60
Koehler	100	50	(p. 454) 30-40
Killians	70	27	

(5) The described section of beds exposed in the Campbell Stone Company Quarry near Afton (p. 457) shows the Welleria zone to occur 10 feet 4 inches below the base of the dark limestones of the Gorbut Member; but figure 4, a cross section south of Le Grand, shows a Welleria zone to be stratigraphically above the Gorbut Member of the Gravel Point Formation; although Kelly & Smith stress the similarity of the exposures in the Le Grand Quarry and in the Campbell Quarry (p. 457), they do not indicate in their paper that there are two separate Welleria zones (nor have we found the zone anywhere except below the Gorbut dark beds).

(6) In their text (p. 460), Kelly & Smith mention outcrops of massive white limestone on the road leading west from Onaway and in a railroad cut in sec. 6, T 34 N, R 1 E; the latter is evidently their locality 27, which they describe as in SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 6, T 34 N, R 2 E; the cut is undoubtedly the one in R 2 E, for there is no railroad passing through sec. 6, T 34 N, R 1 E. (7) These massive limestone beds of the railroad cut and the road leading west from Onaway are reported (p. 460) to "overlie strata assigned to the Koehler formation ... The character of the post-Koehler beds suggests the Alpena limestone of the Lake Huron shore vicinity section, rather than the Gravel Point limestone of the Lake Michigan shore vicinity section"; however, their map (p. 448) has only a blank area in the Onaway district above the Killians Member of the Genshaw Formation; then, on page 468, this outcrop in the railroad cut is called "Gravel Point, or at least post-Koehler limestone."

(8) Ledges of black Killians Member are described at their locality 29 as in the E$\frac{1}{2}$ sec. 13, T 34 N, R 2 E (p. 463), below water level in the upper part of Black River; but Black River does not flow through this section; instead, as indicated on Kelly & Smith's map (p. 448), this locality is in sec. 13, T 34 N, R 1 E. (9) Kelly & Smith (p. 463) describe their locality 32, 1$\frac{1}{2}$ miles north of Onaway, as exposing tan to light-brown crystalline limestone which is "tentatively assigned to the upper Genshaw"; nevertheless, they show no beds of that designation on their map, and instead continue the Killians Member south through the village of Onaway. (10) On page 467, the elevation of the Rockport Quarry - Ferron Point contact at Black Lake Quarry is given as 610 feet; however, the map (p. 448) shows lake level to be 610 feet and the Rockport Quarry Limestone is reported (p. 449) to have a minimum thickness of 50 feet in the quarry; probably, the correct elevation is 654 feet, as given by Kelly & Smith in their figure 6 (p. 464), a structural contour map drawn on the top of the Rockport Quarry Limestone.

There are some other discrepancies in vertical distances and horizontal locations of points north of Beebe School, as stated in the text and shown by scale in figure 5.

On the whole, however, their work was remarkably perceptive for the formations in the area. We must bear in mind that Kelly & Smith did not have access to the information later made available by well cores, and their estimates of thickness for the Beebe School and Gravel Point Formations was based on estimates of the dip in the western margin of the area and on compass-and-pace maps for the most part.

The work by Kelly & Smith is the most accurate that has appeared to date, and their map is very accurate in most particulars. However, their description of the Koehler Limestone had the top at an unconformity and separated from the base of the Gorbut Member of the overlying Gravel Point Formation by a few feet of limestone (including the Welleria zone). In their map (1947, fig. 1) Kelly & Smith show the Gorbut Member as the lowest unit of the Gravel Point Formation throughout its extent. In the old classification of strata, used in the 1940 guidebook, the "Afton Beds" extended up to the

"Marvin Beds," the basal unit of which was the dark coral-bearing limestone which Kelly & Smith made into the Gorbut Member. Hence, the Koehler - Gravel Point contact of Kelly & Smith was several feet higher, at least in the described section at Campbell Quarry, that the Afton - Marvin contact of the old informal rock classification. We suspect that Kelly & Smith prepared their map before the stratigraphic revision, and that their designation of "Koehler" actually applies to the old Afton Beds throughout the map.

The 1949 Field Trip

On 16 and 17 June 1949, Professor W. A. Kelly led the Michigan Geological Society on its Annual Geological Excursion. The subject, of course, was the Traverse Group of the northern part of the Lower Peninsula. The tour covered significant exposures from Alpena County on the east to Charlevoix County on the west. Seven stops were made in the Afton-Onaway area.

Most of the interpretation of geology agreed with the publication of Kelly & Smith two years previously. Map No. 3 in the guidebook was taken directly from Kelly & Smith's figure 1; the only change was the addition of a small exposure considered to be Bell Shale on the Black River in NE$\frac{1}{4}$ sec. 20, T 35 N, R 1 E, about 2$\frac{1}{2}$ miles southwest of Black Lake and a little over 3 miles downstream from Tower Dam. However, Map No. 2 of the guidebook was a revised presentation of the geology from Onaway to Ocqueoc Falls; the legend stated that it was compiled in 1948. On this map, the exposures just north of Onaway were classified as Koehler Limestone; the exposures at the crossroad just west of Rowe School were interpreted as an outlier of Koehler; the exposure of Genshaw Formation at Black Lake Quarry was shown to be a narrow synclinal extension from the main belt of outcrop; a small anticlinal exposure of Ferron Point was mapped on Stoney Creek; a somewhat larger anticlinal exposure of Rockport Quarry Limestone bordered by Ferron Point was shown just below the falls on Rainy River; and the belts of exposure were bent sharply upstream along Ocqueoc River as though influenced by an anticline. For the Beebe School area, the guidebook called attention to the "relatively high dip of the southwest flank of the anticline previously noted at the Campbell Stone Company Quarry."

This was the last publication on the geology of the Afton-Onaway area. With the 1947 AAPG article, it summarized the years of field work accomplished by Bill Kelly.

Later work

After the 1949 guidebook, some staff members of the Museum of Paleontology at The University of Michigan collected fossils from the strata in the area, but never published on the results.

LOCALITIES

In the following list, each locality is identified by four elements: number of the Township (North), number of the Range East or West, number of the section, and letters for the part of the section (as close as possible to the actual site). Localities are from many sources: the list used by A. W. Grabau (unpublished, on file in the Museum of Paleontology, University of Michigan); the list started in 1926 by the expedition of Michigan Geological Survey, University of Michigan, and United States National Museum (identified as "Old MGS Loc."), and with later additions by Dave Swann in the late 1930's; the stops on the Annual Geological Excursions by the Michigan Academy of Science, Arts & Letters and by the Michigan Geological Society; and the list published by Kelly & Smith (1947). In the cases where localities can be identified definitely as those mentioned in these sources, a notation is made to the number.

Only localities within the area of this report are listed. They follow the same format used for localities in Alpena and Presque Isle Counties by Ehlers & Kesling (1970) and in Emmet and Charlevoix Counties by Kesling, Segall, & Sorensen (1974).

The localities are all updated from plat books and highway maps to give present geographic names and reference points. Where possible, revised and new descriptions are given.

T 35 N, R 3 E - Ocqueoc Twp., Presque Isle County

35-3E-20 E: Road cut on North Ocqueoc Road about $\frac{1}{2}$ mile south of Ocqueoc and 0.4 mile north of southeast corner of sec. 20, near King Tower and Assembly of God Church adjacent to land owned in 1970 by Alex King. Old MGS Loc. 61. Ocqueoc Twp., Presque Isle County. Genshaw Formation.

35-3E-22 S: Ocqueoc Falls on Ocqueoc River in Black Lake State Forest, reached from Ocqueoc Falls Highway off M-68. Old MGS Loc. 30. Ocqueoc Twp., Presque Isle Co. Rockport Quarry Limestone.

35-3E-24 S: Road cut on Ocqueoc Falls Highway (part now included in M-68), just east of Little Ocqueoc River and 1 3/4 miles east of Ocqueoc Falls, west of center of south line of sec. 24 adjacent to land owned in 1970 by Albert Roth. Old MGS Loc. 60. Ocqueoc Twp. Presque Isle County. Genshaw Formation.

35-3E-24 W: Outcrops of limestone in isolated sections of channel of Little Ocqueoc River. Underlying beds have caves in many places due to solution, and stream flows below the surface. Area shown on some old maps as Disappearing River. Site about $\frac{1}{2}$ mile north of M-68 and reached by Silver Creek Road; about $1\frac{1}{2}$ miles east-northeast of Ocqueoc Falls. Stop #26 on 10th Ann. Geol. Excursion of Michigan Academy in 1940. Ocqueoc Twp., Presque Isle County. Rockport Quarry Limestone.

35-3E-27 C: Exposures along Ocqueoc River about $\frac{1}{2}$ mile above the falls, not far west of point where M-68 curves south to join Millersburg Road. Ocqueoc Twp., Presque Isle Co. Ferron Point Formation, with Rockport Quarry Limestone downstream and Genshaw Formation upstream.

35-3E-32 E-NE: Roadside material on west side of South Ocqueoc Road and just north of tributary of Ocqueoc River, about $2\frac{1}{2}$ miles south of Ocqueoc. Material may be in place or may be dumped to fill roadside area. Ocqueoc Twp., Presque Isle County. Genshaw Formation (in place?).

35-3E-33 W-NW: Road cut on South Ocqueoc Road, about 2 miles south of Ocqueoc and $\frac{1}{4}$ mile south of northwest corner of sec. 33. Old MGS Loc. 59. Ocqueoc Twp., Presque Isle County. Genshaw Formation.

T 35 N, R 2 E - North Allis Twp., Presque Isle County

35-2E-7 NW: Abandoned Black Lake Quarry, formerly owned and operated by the Onaway Limestone Company, on the shore of Black Lake. Land now owned as small tracts in Cedar Cliff subdivision. Quarry exposures extend into low cliffs facing the lake to the northeast. Locality visited before quarrying by State Geologist Carl L. Rominger. Loc. 97 of A. W. Grabau (unpublished list), who probably visited the site before quarrying began, and listed "Rockport and Ferron Point Limestone" in SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 7. Old MGS Loc 29. Loc. 34 of Kelly & Smith (1947). North Allis Twp., Presque Isle County. Rockport Quarry Limestone and Ferron Point Formation, with Genshaw Formation exposed in slope above the quarry.

35-2E-20 SW: Exposures along Stony (also spelled "Stoney") Creek between Hutchinson Highway on the southeast and M-211 on the northwest. North Allis Twp., Presque Isle County. Ferron Point Formation.

35-2E-21 N-NE: Roadside exposures along North Allis Highway, about 3/4 mile east of North Palmer Road and about $\frac{1}{4}$ mile west of northeast corner of sec. 21; about $5\frac{1}{4}$ miles west of Ocqueoc. Old MGS Loc. 62. North Allis Twp., Presque Isle County. Genshaw Formation.

35-2E-26 S-SW: Exposures along Rainy River about $\frac{1}{4}$ mile below the falls on land owned in 1970 by Walter Boldenow; reached from Gilbert Road (formerly Porter Road) by a $\frac{1}{2}$-mile west section of Twin School Highway (which stops at the river). North Allis Twp., Presque Isle County. Ferron Point and Genshaw Formations.

35-2E-26 SE: Outcrop of limestone and shaly limestone in gully (small tributary to Rainy River) near southeast corner of sec. 26, near intersection of Gilbert Road and Twin School Highway. Massive limestone has Sieberella romingeri and other fossils typical of the lower part of the Genshaw, like those at the

Tower damsite. A well drilled nearby at elevation 787 feet reached Rogers City Limestone at 187 feet. Site is about 3/4 mile east-northeast of Rainy River Falls, and lies on land owned in 1970 by Carl Bush. Stop #24 on 10th Annual Geol. Excursion of Michigan Academy in 1940. North Allis Twp., Presque Isle County. Lower part of Genshaw Formation.

35-2E-29 SW/20 SW-SW: Exposures on southwest bank of Stony Creek (also spelled Stoney) extending northwest from former site of Rowe School (in SE corner of SW$\frac{1}{4}$ sec. 29) nearly to intersection of M-211 and Stony Creek. Intermittent exposures along low escarpments totaling nearly 40 feet of strata. Escarpments nearly connect westward with locality 35-1E-25 SE through section 30. Loc. 31 of Kelly & Smith (1947). North Allis Twp., Presque Isle County. Lower part of Genshaw Formation.

35-2E-31 NE-NE: Exposures along M-211 about 180 feet south of Twin School Road. About 4 feet of black shaly limestone is overlain by 2 feet of fossiliferous tan to light-brown crystalline limestone with a fauna like that of the upper part of the Genshaw. Exposure resembles that of locality 35-2E-32 NW-SW. Although only 1$\frac{1}{2}$ miles north of Onaway, these light strata are very different from the non-fossiliferous thin-bedded limestones being quarried just north of the town. Loc. 32 of Kelly & Smith (1947). North Allis Twp., Presque Isle County. Genshaw Formation, upper part of Killians Member and overlying upper part of Genshaw.

35-2E-32 NW-SW: Outcrop on east side of M-211 about 4$\frac{1}{2}$ miles south of Black Lake and a little over $\frac{1}{2}$ mile south of Twin School Road. Approximately 1$\frac{1}{2}$ feet of black shale overlain by 2 feet of gray limestone. Loc. 30 of Kelly & Smith (1947). North Allis Twp., Presque Isle County. Killians Member of Genshaw Formation, contact with upper Genshaw.

35-2E-35 N-NW: Rainy River Falls on Rainy River, reached by section of Twin School Highway (formerly Vermilya Highway), which extends west from Gilbert Road (formerly Porter Road) and is interrupted (for about $\frac{1}{2}$ mile) at the river. North Allis Twp., Presque Isle County. Genshaw Formation.

T 34 N, R 2 E - Allis Twp.,
Presque Isle County

34-2E-5 N: Outcrops and small quarries operated by the Onaway Stone Company along M-211 about $\frac{1}{2}$ mile north of Onaway, about $\frac{1}{4}$ mile north of Detroit & Mackinac Railroad tracks. Formerly, the quarries were situated east of the highway, but the land was taken by the county for an airport and the quarries (shallow anyhow) were filled and bulldozed smooth. The present property of the stone company lies west of M-211 in N$\frac{1}{2}$ NW$\frac{1}{4}$ sec. 7. The thin beds of irregular thicknesses are selectively quarried and trimmed to brick size for building facings; sparsely fossiliferous, they are undoubtedly lagoonal deposits. Northwest corner of Allis Twp., Presque Isle County. Probably facies of Koehler Limestone.

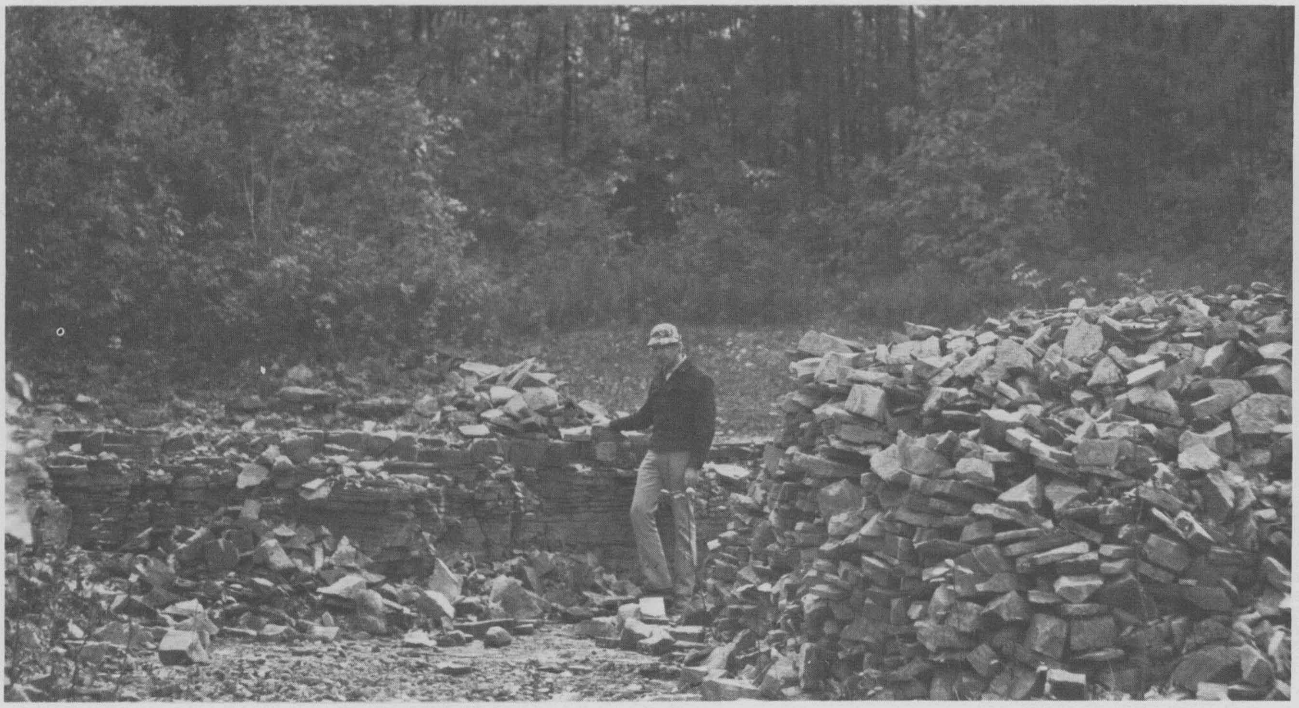
34-2E-6 SW-NW: Massive crystalline white to gray limestone exposed in cut of Detroit & Mackinac Railroad nearly a mile west of Onaway, 300 feet east of grade crossing of county line road. Contains few fossils, but includes Hexagonaria cf. percarinata. Loc. 113 of Dave Swann (added to MGS list). Probably close to Loc. 98 of A. W. Grabau (unpublished list). Loc. 27 of Kelly & Smith (1947). Allis Twp., Presque Isle County. Gravel Point Formation, beds said to be a few feet above the Gorbut Member.

T 35 N, R 1 E - Waverly Twp.,
Cheboygan County

35-1E-21/22 S: Exposures along and near Dangler Road in Black Lake State Forest, about $\frac{1}{4}$ mile north of intersection with Buck Road and about 1$\frac{1}{2}$ miles northeast of Black River Dam. About 13 feet of limestone exposed on north face of an east-west bluff, known locally as "Limestone Hill." Loc. 18 of Kelly & Smith (1947). Waverly Twp., Cheboygan Co. Lower part of Genshaw Formation.

35-1E-22 C: Exposure of semi-lithographic limestone in bed of Fisher Creek. Part of Loc. 18 of Kelly & Smith (1947). Waverly Twp., Cheboygan County. Rockport Quarry Limestone.

35-1E-23 E: Drift exposure along Upper Black River Road about 2 miles south of Black Lake.



TEXT-FIG. 6 -- Carl Safronoff Quarry, Locality 34-1E-6 SE-NW-SE. The quarry, now abandoned, was formerly operated for dressed building stone by the Onaway Stone Company. Al Johnson in the foreground. Photo by Kesling, 1 Oct 1975.

TEXT-FIG. 7 -- Campbell Quarry, about 3/4 mile north of Afton, Locality 35-2W-36 NE. This quarry has been operated intermittently for many years. The floor of the quarry and the lower quarried beds are Koehler Limestone; the upper beds are Gravel Point Formation. Photo by Kesling, 1 Oct 1975.

The gravel in the cut is almost entirely composed of dense lithographic limestone similar to that exposed in Black Lake Quarry, and probably reflects the underlying rock. Waverly Twp., Cheboygan County. Site probably underlain by Rockport Quarry Limestone.

35-1E-23 SW: East-west outcrops for about 600 feet of 8 feet of dark-gray limestone with stromatoporoids and corals. The lower bed forms the cap rock of a perennial spring. Loc. 23 of Kelly & Smith (1947). Waverly Twp., Cheboygan County. Lower part of Genshaw Formation.

35-1E-25/35-2E-30: Intermittent exposures along an escarpment trending east-west, extending from about 1,100 feet south of W$\frac{1}{4}$ corner of sec. 25 (best exposure) to E$\frac{1}{4}$ corner of sec. 30, totaling about 22 feet of limestones. This includes locality 35-1E-25 E-SE. Loc. 33 of Kelly & Smith (1947). Waverly Twp., Cheboygan County. Lower part of Genshaw Formation.

35-1E-25 E-SE: Exposures on north face of 25-foot bluff $\frac{1}{4}$ mile north of southeast corner of sec. 25, near County Line Road and between Purdy Road and Twin School Road, about 3$\frac{1}{4}$ miles south of Black Lake. Elevation at base of bluff 772 feet. Fauna includes Sieberella romingeri and other typical lower Genshaw species. Stop #4 on 10th Ann. Geol. Excursion of Michigan Academy in 1940. Waverly Twp., Cheboygan County. Lower part of Genshaw Formation.

35-1E-26 NE: Excavation showing very fossiliferous shale boulders with Ferron Point fauna, probably locally derived, at an elevation of 772 feet; 800 feet south and 400 feet west of northeast corner of section. This excavation existed in 1940, when it was Stop #3 of the 10th Ann. Geol. Excursion of the Michigan Academy. Loc. 24 of Kelly & Smith. Property owned in 1970 by V. & E. Gray. Waverly Twp., Cheboygan County. Site probably underlain by Ferron Point Formation.

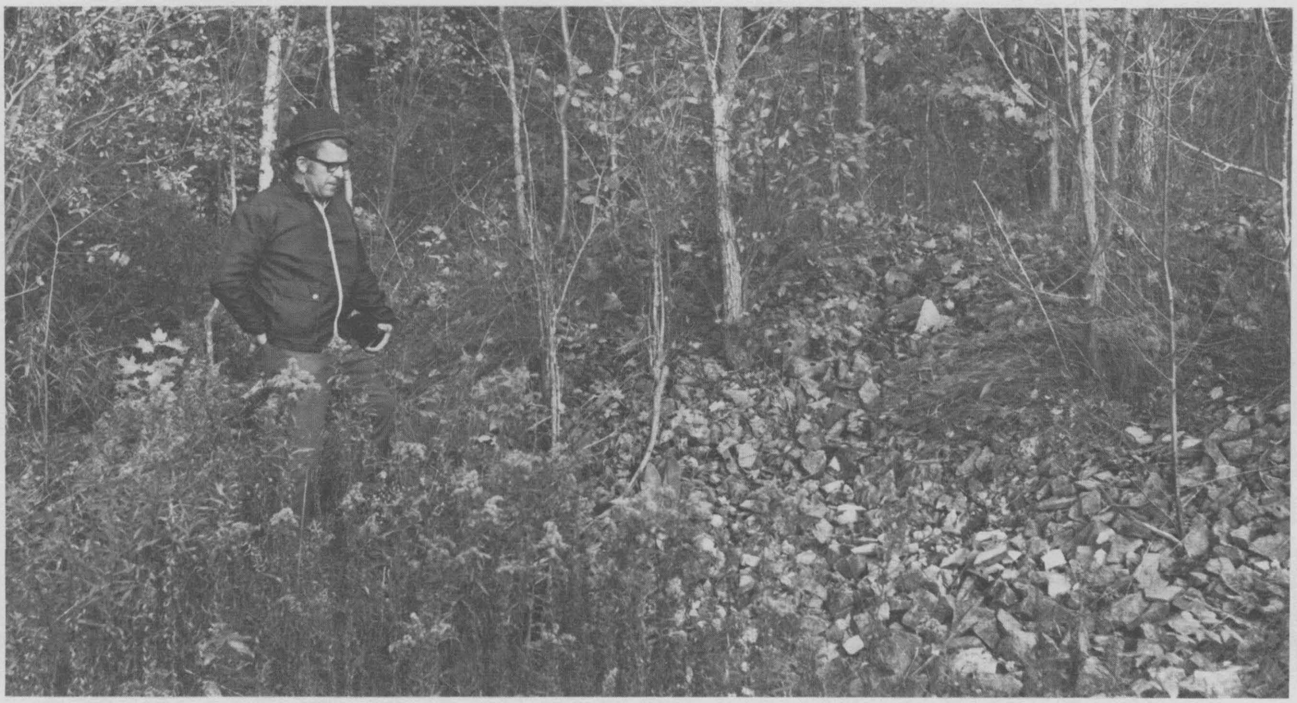
35-1E-28/33 W: Shanty Rapids of Black River. Dense limestone totaling about 15 feet was exposed in the banks and stream bed at intervals for $\frac{1}{2}$ mile. Stop #9 on 10th Ann. Geol. Excursion of Michigan Academy in 1940. Loc. 19 of Kelly & Smith (1947). Site now inundated by Kleeber (also called "Kleber") Pond, formed by the Black River Dam around 1950; present exposures below the dam (see 35-1E-29 E). One plat book shows Kleber Shores Subdivision on "Kleeber Pond" approached by "Klieber Road." Waverly Twp., Cheboygan County. Rockport Quarry Limestone.

35-1E-29 E: Black River Dam forming Kleeber Pond on Black River. Exposures are just below the dam. The pond inundated the site of Shanty Rapids. Plat book shows the dam site accessible by "Klieber" Road which curves around the north end of Kleeber Pond and joins West Twin School Road. Waverly Twp., Cheboygan County. Rockport Quarry Limestone.

35-1E-31 N/30 SE/29 SW/32 NW/29 C: Exposures along Milligan Creek, a tributary of Black River, from center of north half of sec. 31 (where creek changes flow from east to northeast), under Brady Road and Waveland Road, to point where it is crossed by bridge of Detroit & Mackinac Railroad just east of center of sec. 29 (southwest of Black River Dam). Creek passes mostly through Black River State Forest. Stop #10 on 10th Annual Geol. Excursion of Michigan Academy in 1940 was along creek near Waveland Road (lower part of Genshaw Formation). Loc. 17 of Kelly & Smith (1947), who mentioned: "One small exposure occurs in a miniature sinkhole on the north side of the road, 900 feet east of Waverly School." Waverly Twp., Cheboygan County. Rockport Quarry Limestone at railroad bridge; about 85 feet of Ferron Point and Genshaw Formations upstream.

35-1E-34 E-NE: Bluff extending from locality 35-1E-34 C; exposures about $\frac{1}{4}$ mile south of northeast corner of section, where cap rock is massive limestone with conspicuous crinoid columnals in a dark gray matrix. Part of Loc. 22 of Kelly & Smith (1947). Waverly Twp., Cheboygan County. Genshaw Formation, possibly part of Killians Member.

35-1E-34 C: Exposures along North Tower Road about 1$\frac{1}{2}$ miles north of center of village of Tower. Exposures of shale and limestone in an east-west bluff. Presence of large gomphoceroid cephalopod and fish plates suggest Killians, according to Kelly. Stop #8 on 10th Ann. Geol. Excursion of Michigan Acad-



TEXT-FIG. 8 -- Harry O. Sorensen in the abandoned small Sorenson Quarry, on the west side of Munger Road southwest of Afton, Locality 34-2W-11 E. The quarry, scarcely more than a test pit, exposes Koehler Limestone. Photo by Kesling, 2 Oct 1975.

TEXT-FIG. 9 -- Exposure of Upper Devonian black Norwood Shale in abandoned roadside pit about 1/3 mile west of Beebe School, Locality 34-2W-14 NW-SE. The shale, well exposed in the 1920's, is being overgrown and obscured. Photo by Kesling, 2 Oct 1975.

emy in 1940. Loc. 22 of Kelly & Smith (1947), who estimated nearly 100 feet of limestone and shale in the discontinuous exposures. Waverly Twp., Cheboygan County. Genshaw Formation, lower part and Killians Member.

35-1E-36 SE: Exposure of black shale and limestones (massive) beside County Line Road at southeast corner of sec. 36, about $4\frac{1}{2}$ miles south of Black Lake. Stop #5 on 10th Ann. Geol. Excursion of Michigan Academy in 1940. Loc. 26 of Kelly & Smith (1947). Loc. 114 of Dave Swann (addition to MGS list). Waverly Twp., Cheboygan County. Genshaw Formation, Killians Member.

35-1E-36 NE-SW: Low cuestas with steep faces to the north, exposing various limestone units of Genshaw. Land owned in 1970 by Meredith & Howard Nave. Loc. 25 of Kelly & Smith (1947). Waverly Twp., Cheboygan County. Genshaw Formation, lower part of Killians Member and adjacent underlying beds.

T 34 N, R 1 E - Forest Twp., Cheboygan County

34-1E-1 S-SE: Limestone exposed in road cuts along M-33/M-68 about $1\frac{1}{4}$ miles west of Onaway and 2 miles east of Tower Pond. Some of limestone lacks stratification and resembles a reef facies. The stratified limestone is crystalline and crinoidal in contrast to the typical dense lithographic limestone known to overlie the Killians farther west. Stop #6 on 10th Ann. Geol. Excursion of Michigan Academy in 1940. Loc. 28 of Kelly & Smith (1947). Loc. 99 of A. W. Grabau (unpublished list). Forest Twp., Cheboygan County. Lower part of Alpena Limestone or Gravel Point Formation.

34-1E-3 C: Ledges below dam on Black River (Tower Dam), impounding water of Tower Pond; about $\frac{1}{2}$ mile northeast of center of village of Tower. Strongly dipping beds capped by a massive limestone bearing Sieberella romingeri and other fossils typical of the lower Genshaw including spherical stromatoporoids. Old MGS Loc. 28. Stop #7 on 10th Ann. Geol. Excursion of Michigan Academy in 1940 and Loc. 21 of Kelly & Smith (1947). Forest Twp., Cheboygan County. Lower part of the Genshaw Formation.

34-1E-3 E-NE: Roadside exposure along Tower Road 3/4 mile north of M-33, about $\frac{1}{2}$ mile northeast of Tower. Part of Loc. 21 of Kelly & Smith (1947). Forest Twp., Cheboygan Co. Killians Member of Genshaw Formation

34-1E-5 NE-NE: Dense limestone exposed in upper part of bluff on Welch Creek, about $1\frac{1}{2}$ miles west-northwest of center of Tower. Loc. 16 of Kelly & Smith (1947). Forest Twp., Cheboygan County. Koehler Formation.

34-1E-5 NW: Base of north slope of hill in north west corner of section, near intersection of Brady Road and Kisser Road, about $2\frac{1}{2}$ miles west-northwest of village of Tower. Elevation at base of hill is 775 feet. Surface of hill mantled with blocks of dense semi-lithographic limestone similar to the Afton Beds exposed in the lower part of the Campbell Quarry north of Afton. Stop #11 on 10th Ann. Geol. Excursion of Michigan Academy in 1940. Forest Twp., Cheboygan County. Probably underlain by lower part of Alpena Limestone.

34-1E-6 SE-NW-SE: Carl Safronoff Quarry and nearby test pits, now abandoned. Quarry begun and operated by Onaway Stone Company; land owned (1970) by Ralph Covell. About 3 miles west-northwest of Tower. Forest Twp., Cheboygan County. Koehler Limestone.

34-1E-6 SE-SE/8 W-NW: Exposures and float of "sub-lithographic and cavernous limestone extending $\frac{1}{4}$ mile south" from near intersection of M-33 and Brady Road. Part of Loc. 15 of Kelly & Smith (1947). Forest Twp., Cheboygan County. Koehler Limestone.

34-1E-6 S: Road cut on highway about 3 miles west of Tower; this was probably seen before present M-33/M-68 section of highway was built and may be situated along the old road. Forest Twp., Cheboygan County. Old MGS Loc. 63. Genshaw Formation.

34-1E-6 W-SW: Ledges below water level in Milligan Creek where it is crossed by M-33. Exposures of the black limestone continue to the east along highway. Loc. 15 of Kelly & Smith (1947). Forest Twp., Cheboygan Co. Killians Member of Genshaw Formation.

34-1E-8 NE-NE/9 NW-NW: Exposures near intersection of M-33 and Freeman Road. About 6 feet of Killians dark limestone exposed in ditch along Freeman Road in sec. 9, and a small exposure of lighter limestone on south side of M-33 in sec. 8. Loc. 20 of Kelly & Smith (1947), who interpreted the latter as an inlier of "sub-Killians Genshaw." Forest Twp., Cheboygan County. Genshaw Formation, most (if not all) Killians Member.

34-1E-13 E-SE: Ledges of black limestone below water level in Upper Black River, about 3 miles southeast of Tower. This is the most southerly exposure in the area. Loc. 29 of Kelly & Smith (1947), as shown on their map (but described on their p. 463 as in R 2 E). Forest Twp., Cheboygan County. Killians Member of Genshaw Formation.

T 35 N, R 1 W - eastern Koehler Twp. and western Waverly Twp., Cheboygan County

35-1W-19 SW/30 NW: Ledges and roadside exposures of black shale and limestone extending into sections 24 and 25, T 35 N, R 2 W, around junction of Cross Road and Ostrander Road, about 2 miles west of Le Grand and 2 miles north-northeast of Afton. Elevation 710 feet. Stop #15 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Loc. 7 of Kelly & Smith (1947). Koehler Twp., Cheboygan County. Genshaw Formation, Killians Member and higher beds.

35-1W-28 SE: Le Grand Quarry, now abandoned but formerly operated by owners of the Marvin Quarry. Section nearly matches that exposed in the Campbell Quarry north of Afton about 3 miles due west. Quarry is reached from the Finger Board Corner by M-33 1 mile north, Knight Road ½ mile east, and a lane leading to the northeast. Quarry now (1970) on land owned by Fred Coates et al. The town of Le Grand is less than a mile north-northwest of the quarry. Part of Loc. 9 of Kelly & Smith (1947). Koehler Twp., Cheboygan County. Gravel Point Formation, beds formerly referred to as the "Afton Beds" and "Marvin Beds."

35-1W-29 NE/28 W/33 NW: Exposures in escarpment more or less following M-33 from about ¼ mile south of Le Grand to ¼ mile south of Knight Road. Outcrops are discontinuous, extending eastward to Le Grand Quarry and to abandoned railroad cut at 35-1W-33 N. Loc. 9 of Kelly & Smith. Koehler Twp., Cheboygan County. Koehler Limestone and Gravel Point Formation.

35-1W-29 SE-NE: Cut along M-33 about 1 3/4 miles north of The Finger Board Corner and about ½ mile south of Le Grand. Exposures extend from ½ to 3/4 mile north of the site of Gorbut School (destroyed, but shown on all older maps). Stop #14 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Rocks are part of bluff continuous with that in Le Grand Quarry (see 35-1W-28 SE). Part of Loc. 9 of Kelly & Smith (1947). Koehler Twp. Cheboygan County. Gravel Point Formation, lower part in beds formerly referred to as the "Afton Beds."

35-1W-30 N-NW: Road cut along Ostrander Road about 1 3/4 miles west of Le Grand and ¼ mile east of northwest corner of sec. 30, about midway between Cross Road and Morrow Creek. Old MGS Loc. 64. Koehler Twp., Cheboygan County. Genshaw Formation.

35-1W-30 W-NW: Road cut along Cross Road 100 feet south of junction with Ostrander Road, about 2 miles west of Le Grand; part of a low ridge. Old MGS Loc. 65. Koehler Twp., Cheboygan County. Genshaw Formation, Killians Member.

35-1W-30 SW-NW: Open field exposures on land now owned (1970) by August Carter about 3/8 mile south of Ostrander Road and just east of Cross Road, about 1 3/4 miles north-northeast of Afton. Stop #16 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Cross Road rises about 100 feet from the northwest corner to the southwest corner of sec. 30, crossing several formational boundaries. Part of Loc. 7 of Kelly & Smith (1947): "the best exposure of the Killians limestone in the Afton area occurs on a hill in NW¼ sec. 30 ... about 25 feet of Killians and 2 feet of sub-Killians are exposed." Koehler Twp., Cheboygan County. Genshaw Formation, Killians Member.

35-1W-33 N: Exposure of massive crystalline limestone in long-abandoned cut of railroad, about 1/8 mile south of point where Knight Road turns south, about 7/8 mile north-northeast of The Finger Board Corner on land owned (1970) by Fred Coates. Stop #13 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Cut is $\frac{1}{2}$ mile east of the site of Gorbut School and about $1\frac{1}{4}$ miles south-southeast of Le Grand. Part of Loc. 9 of Kelly & Smith (1947). Loc. 115 of Dave Swann (addition to MGS list). Elevation is 825 feet. Beds have been considered higher than any exposed in Le Grand Quarry, about $\frac{1}{2}$ mile to the northeast. Koehler Twp., Cheboygan County. Gravel Point Formation, beds a few feet above the Gorbut Member; strata formerly referred to as the "Marvin Beds."

35-1W-33 W-NW: Road cuts on M-33 about $\frac{1}{4}$ mile south of former site of Gorbut School, which was at the northwest corner of sec. 33; road cuts about $1\frac{1}{4}$ miles south of Le Grand. Loc. 117 of Dave Swann (addition to MGS list). Koehler Twp., Cheboygan County. Gravel Point Formation, Longispina emmetensis zone.

35-1W-33 SE-SE: Exposures along banks of Adair Creek near corner of M-33 and southeast end of Knight Road, on land owned in 1970 by Ernest & Mary Knight. Loc. 10 of Kelly & Smith (1947). Koehler Twp., Cheboygan County. Koehler Formation (dense sublithographic limestone).

T 34 N, R 1 W - Walker Twp., Cheboygan County

34-1W-3 N-NE: Exposures in roadbed of M-33 about 1 2/3 miles east-by-south of The Fingerboard Corner, not far beyond point where road bends southeast. Loc. 11 of Kelly & Smith (1947): "massive fossiliferous limestone." Walker Twp., Cheboygan County. Gravel Point Formation (presumed to lie above the Gorbut Member).

34-1W-6 SE: Exposures on southwest face of bluff north of intersection of Weir Road and Pigeon River Road, a little over $\frac{1}{2}$ mile north of Marvin Quarry. Stop #23 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Walker Twp., Cheboygan County. Gravel Point Formation, in old reports called "Lower (Black) and Upper (Gray) Marvin."

34-1W-7 S-NE: Marvin Stone Quarry (also erroneously referred to as "Marion" Stone Company Quarry in R. A. Smith (1916)), now long abandoned. Accessible from Montgomery Road; about $\frac{1}{2}$ mile south of Weir Road and about $1\frac{1}{2}$ miles southwest of The Finger Board Corner, about $\frac{1}{2}$ mile north of Wilkes Creek, and near west end of Brasseau Road, on land owned (1970) by Campbell Stone Company. Stop #22 on 10th Ann. Geol. Excursion of Mich. Academy in 1940: "at the west end of the quarry beds of the Afton are exposed, but owing to an easterly dip, higher beds of the Lower (Black) and Upper (Gray) Marvin are exposed in the main portion of the quarry." Plans to expand the quarry to the north and east in 1923 never materialized. Loc. 12 of Kelly & Smith (1947). Old MGS Loc. 27. Walker Twp., Cheboygan County. Koehler Limestone and Gravel Point Formation.

34-1W-17 W-SW: Roadside and field exposures along Pigeon River Road about $\frac{1}{4}$ mile north of point where road turns north. About 5 feet of limestones and calcareous shale, including 1-foot bed of dense black shale. Loc. 14 of Kelly & Smith (1947). Walker Twp., Cheboygan County. Gravel Point Formation.

34-1W-17 SW-SW: Outcrop of black limestone in bottom of gully near corner of sec. 17, near point where Montgomery Road joins Pigeon River Road and curves north, now (1970) on land owned by Robert L. Reynolds. Stop #21 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Loc. 13 of Kelly & Smith (1947). Limestone carries the same fauna as that found in the Gorbut at Campbell Stone Quarry and Marvin Quarry. Walker Twp., Cheboygan County. Gravel Point Formation, Gorbut Member.

34-1W-19 N-NE: Exposures along Pigeon River Road not far west of its junction with Montgomery Road. Limestone bearing relatively small Atrypa with coarse radial plications. Stop #20 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Walker Twp., Cheboygan County. Upper part of Gravel Point Formation (called "Upper Marvin" in old reports).

T 35 N, R 2 W - eastern Tuscarora Twp. and western Koehler Twp., Cheboygan County

35-2W-24 W-NW: Two feet of limestone exposed along southern branch of Little Pigeon

River where the stream crosses the west line of sec. 24. Loc. 6 of Kelly & Smith (1947). Koehler Twp., Cheboygan County. Genshaw Formation.

35-2W-36 NE: Campbell Stone Company Quarry now reactivated but abandoned for various intervals in the past. About 3/4 mile north of Afton at Kimberly Creek; quarry may be reached from either Quarry Road (on the west) or Cross Road (on the east). Land owned (1970) by Cal Campbell, Jr., and 2d National Bank of Saginaw. Stop #17 on 10th Ann. Geol. Excursion of Mich. Academy in 1940; referred to as "Afton Quarry" in the guidebook. Loc. 5 of Kelly & Smith (1947). Stop #11 on Ann. Geol. Excursion of Mich. Geol. Society in 1949. In 1940 the strata were divided into the Afton Beds and Marvin Beds, but in 1949 they were divided into the Koehler Limestone and Lower Gravel Point Formation. Old MGS Loc. 25. Koehler Twp., Cheboygan County. Koehler Limestone and Gravel Point Formation (including the Gorbut Member).

35-2W-25 N-NE: Road cut along Ostrander Road about 2.3 miles west of Le Grand; exposures extend along north line of sec. 25 to Cross Road. Approximately Stop #15 of 10th Ann. Geol. Excursion of Mich. Academy in 1940. Old MGS Loc. 66. Koehler Twp., Cheboygan County. Genshaw Formation, Killians Member.

T 34 N, R 2 W - Ellis Twp.,
Cheboygan County

34-2W-2 NE: Outcrops along north bank of Pigeon River, about 1300 feet west and 1200 feet south of northeast corner of sec. 2; higher beds exposed at a spring about 30 feet up the slope and 600 feet west and 500 feet south of the corner. Loc. 4 of Kelly & Smith (1947). Ellis Twp., Cheboygan County. Genshaw Formation.

34-2W-11 E: Abandoned small Sorenson Quarry and roadside exposures, about $\frac{1}{2}$ mile west and $1\frac{1}{2}$ miles south of Afton, on west side of Munger Road. Quarry is little more than a test pit; it is situated on top of the first hill south of the Pigeon River crossing on Munger Road. Old MGS Loc. 22. Elevation about 795 feet. Dense "semi-lithographic" limestone with many solution cavities. Stop #18 on 10th Ann. Geol. Excursion of Mich. Academy in 1940; beds assigned to the "Afton" on basis of elevation. Loc. 2 of Kelly & Smith (1947); beds assigned to the Koehler on the basis of lithology. Ellis Twp. Cheboygan County. Koehler Limestone (probably upper part).

34-2W-12 SE-NW: Exposures on Pigeon River below site of Old Elmer Dam, about $\frac{1}{2}$ mile east of Sorenson Quarry and about midway between Afton and Beebe School. Elevation about 750 feet. Loc. 3 of Kelly & Smith (1947), who said a total of 21 feet were exposed. Ellis Twp., Cheboygan County. Genshaw Formation.

34-2W-13 NW/14 NE: Exposures of limestone on steep and gentle slopes of northwest-trending cuestas. Dip averages $2\frac{1}{2}$ degrees southwest. Stop #19 on 10th Ann. Geol. Excursion of Mich. Academy in 1940. Exposures cross Munger Road about $\frac{1}{4}$ mile north of Beebe School Road and the site of Beebe School. Part of Loc. 1 of Kelly & Smith (1947). Road was partly under construction in 1926 when visited by the expedition of the USGS-Michigan Survey-University of Michigan, and beds were better exposed. Ellis Twp., Cheboygan County. Uppermost Gravel Point Formation, near contact with the Beebe School Formation.

34-2W-14 E: Roadside exposures near Beebe School (now occupied as a residence), extending north, south, and west of intersection of Beebe School Road and Munger Road. About $\frac{1}{2}$ mile west and $2\frac{1}{2}$ miles south of Afton. Exposures of soft shale extending north from intersection and limestone extending south and west. Old MGS Loc. 23. Loc. 1 of Kelly & Smith (1947). Stop #12 of the Ann. Geol. Excursion of Mich. Geol. Society in 1949; the guidebook stated that "the boundary between the Gravel Point and the Beebe School is located at the contact halfway up the first (northern) cuesta, between a dense limestone carrying Hexagonaria and a sparse brachiopod fauna, and a biostrome carrying numerous crinoidal fragments as well as a few branching cylindrical corals." Beds dip steeply to the southwest. Ellis Twp., Cheboygan County.

Beebe School Formation (probably equivalent of Potter Farm Formation to the east).

34-2W-14 E-NE-NE: Roadside exposures on Munger Road, about $\frac{1}{2}$ mile west and 2 1/8 to 2 3/8 miles south of Afton, about $\frac{1}{4}$ mile north of Beebe School Road. Separated by covered interval from exposures at Beebe School. Old MGS Loc. 26; in 1926 much better exposed because of construction of the road. Ellis Twp., Cheboygan County. Gravel Point Formation.

34-2W-14 NW-SE: Abandoned roadside shale pit on south side of Beebe School Road, about 1/3 mile west of Munger Road and about $2\frac{1}{2}$ miles south-southwest of Afton, located partly on county right-of-way and partly on land owned (1970) by C. G. Edmunds. Separated by short covered interval from exposures of Beebe School Formation (see 34-2W-14 E). Plans in 1923 to develop a major quarry to take shale from the hillside for a state-owned cement industry were abandoned; the hill or ridge extending northwest-southeast and intersecting Munger Road about $\frac{1}{4}$ mile south of Beebe School is composed of black shale with very little glacial cover. Part of Stop #12 on Ann. Geol. Excursion of Mich. Geol. Society in 1949. Old MGS Loc. 24. Ellis Twp., Cheboygan Co. Norwood Shale (or Antrim Shale).

THICKNESS OF TRAVERSE GROUP FORMATIONS

Previous publications on the Afton-Onaway area have seriously underestimated the total thickness of the Traverse Group strata. In part, these low figures were the result of unexpected local changes in the amount of dip. Kelly & Smith (1947, p. 461) assumed a dip on the Beebe School Formation to be $2\frac{1}{2}$ degrees; this was in the vicinity of Beebe School, where we have observed dips to be nearly 5 degrees on some bedding planes.

In the 1940 guidebook, W. A. Kelly presented a stratigraphic column in which the total Traverse Group was 500 feet thick.

In 1947, Kelly & Smith gave the following thicknesses, summarized in their figure 3 on page 456:

Beebe School	73	(p. 461)
Gravel Point	60	(p. 460)
Koehler	40	(p. 454)
Genshaw	150	(p. 452)
Ferron Point	9	(p. 451)
Rockport Quarry	50	(p. 449)
Bell Shale	75	(fig. 3)
Traverse Group	457	

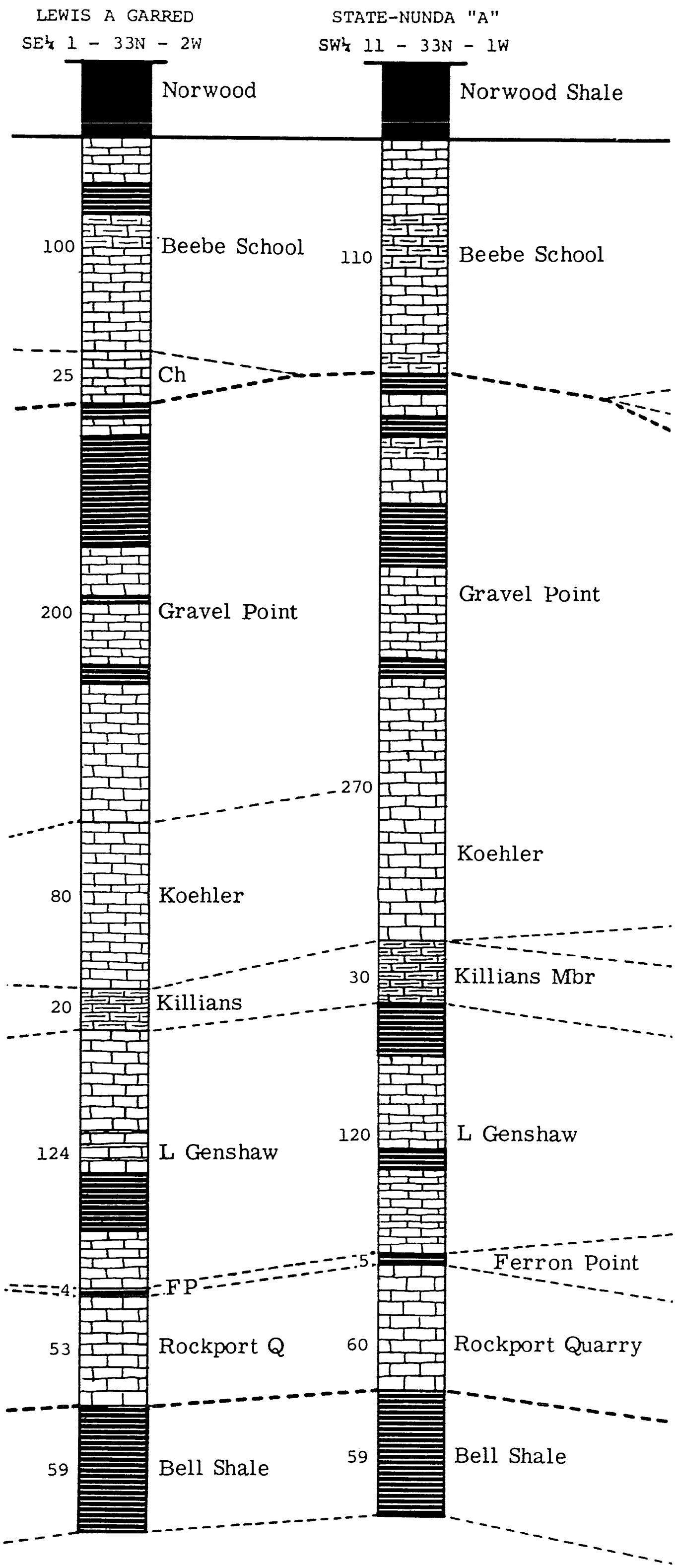
They stated (1947, p. 449), "The estimated total thickness of the Traverse group south of Afton is considerably less than that for either the sections near Lake Huron or Lake Michigan. Because Afton is no farther from the center of the Michigan synclinorial basin than are Alpena and Petoskey, the estimated thickness is less than the expected thickness, and suggests different environmental conditions." Their figure for the Bell Shale was based on two wells in the area.

Two deep wells, drilled just south of the outcrop area, penetrate the whole of the Traverse Group. These are the Lewis A. Garred in SE$\frac{1}{4}$ sec. 1, T 33 N, R 2 W, and the State-Nunda "A" in SW$\frac{1}{4}$ sec. 11, T 33 N, R 1 W. The logs of these wells reveal the following average thicknesses:

Beebe School	118*
Gravel Point	200
Koehler	75
Genshaw	147
Ferron Point	5
Rockport Quarry	56
Bell Shale	59
Traverse Group	660

* Including 25 feet in one well which appears to be Charlevoix Limestone.

In these wells, the base of the Upper Devonian black shale at the top of the Traverse and the base of the soft blue shale of the Bell at the base of the Traverse cannot be mistaken, either by core lithology or by Schlumberger logs. Obviously, past errors in thickness were concerned primarily with the Koehler Limestone, Gravel Point Formation, and Beebe School



TEXT-FIG. 10 -- Stratigraphic sections in two wells in western half of Afton-Onaway area, showing thicknesses and lithology of formations in Middle Devonian Traverse Group.

Formation. None of the three has a complete section exposed in the area, and estimates of the strata included between formational contacts was based on assumption of a gentle dip prevailing throughout the area.

TRAVERSE GROUP FORMATIONS

Type locality and name. -- As pointed out by Kesling, Segall, & Sorensen (1974, p. 53), the name of the group evolved from the use of "Little Traverse Bay limestones" by Christopher C. Douglass in 1841. The rocks of the area were referred to as "Little Traverse" by Alexander Winchell and in 1895 (p. 24) A. C. Lane shortened the name to "Traverse." Lane also established the stratigraphic limits of the Traverse Group which are still accepted today.

Formations. -- The Traverse Group in the Afton-Onaway region can be divided into stratigraphic units using some formational names from the region of Alpena and Presque Isle Counties to the east, one name from the region of Charlevoix and Emmet Counties to the west, and two formational names not used elsewhere. No new formations are introduced here. The sequences are given for the three regions below.

BELL SHALE

Type locality and name. -- In 1901 (p. 191) A. W. Grabau officially named the formation for the bluish shale dug from clay pits north of the village of Bell. The village no longer exists, and some confusion as to its exact location persists because (according to accounts) many years ago the houses were moved to the shore of False Presque Isle Harbor. Whether we accept the location given by Grabau (1902, p. 191,

Charlevoix & Emmet Counties	Afton-Onaway Region	Alpena & Presque Isle Counties
JORDAN RIVER		SQUAW BAY
WHISKEY CREEK PETOSKEY	BEEBE SCHOOL	THUNDER BAY POTTER FARM
CHARLEVOIX		NORWAY POINT FOUR MILE DAM
GRAVEL POINT	GRAVEL POINT	ALPENA
	KOEHLER	NEWTON CREEK UPPER GENSHAW
	KILLIANS MBR	KILLIANS MBR
(Subsurface	LOWER GENSHAW	LOWER GENSHAW
units	FERRON POINT	FERRON POINT
only)	ROCKPORT QY	ROCKPORT QUARRY
	BELL SHALE (no outcrops)	BELL SHALE

pl. 7) as about in the SE$\frac{1}{4}$ sec. 14, or the location given by Warthin & Cooper (1943, p. 578; based on reports by the old collector H. H. Hindshaw) as the village in sec. 13, the post-office in NE$\frac{1}{4}$ sec. 34, and the pits in SE$\frac{1}{4}$ sec. 11 -- the type locality for the formation was somewhere in southeastern Presque Isle County between the south end of Grand Lake and False Presque Isle Harbor.

The shales were known much earlier, studied by Rominger in the NW$\frac{1}{4}$ sec. 6, T 32 N, R 9 E, in northeastern Alpena County near the site where the Kelley's Island Lime & Transport Quarry was later developed. He mentioned (1876, p. 50) "blue shales" at the foot of the limestone bluffs there.

Occurrence. -- No outcrops of the Bell Shale have been found in the Afton-Onaway area although the formation is known to lie on the bottom of Black Lake not far offshore from the southern end.

In the 1949 guidebook to the Afton-Onaway area, Bill Kelly reproduced the map used in the AAPG article by Kelly & Smith (1947) as his Map 3, adding an area of exposure of Bell Shale along Upper Black River in sec. 20, T 35 N, R 1 E, about 3 miles southwest of Black Lake. Samples were collected at what seemed to be this locality by R. V. Kesling around 1950; they consisted of soft bluish shale exposed in the banks of Upper Black River and a small tributary entering from the west. These samples were washed and examined for microfossils; unlike the Bell Shale exposed in Alpena and Presque Isle Counties, this sample was barren of ostracods. The absence of fossils does not conclusively prove that the Upper Black River bluish shale is not Bell Shale. The riverbank samples could be from a different facies. However, it seems likely that the exposure is glacial clay. Additional research could be done on this problem.

The Bell Shale does show up unmistakably in all well cores examined. Its thickness is remarkably constant throughout this part of our state, from the wells near Lake Huron to those near Lake Michigan -- around 60 to 100 feet. It is predominantly a soft bluish shale with a few limestone lenses here and there.

In well records, the base and top of the formation are distinctive and definite, and can be used for structural contour mapping as we have done in the section on "Structure."

ROCKPORT QUARRY LIMESTONE

Type locality and name. -- The type locality was visited by State Geologist Carl Rominger, who described it in 1876 (p. 49, 50) as "nodular, unhomogeneous beds of limestones, interstratified with thin seams of shaly substance of black color" which he observed in the bluffs "directly west of Middle Island, on the side of a small creek flowing southeastward into Lake Huron" -- somewhere in the NW$\frac{1}{4}$ sec. 6, T 32 N, R 9 E. From the list of fossils, we can be certain that Rominger visited the type locality before quarrying operations began.

By 1916 the Great Lakes Stone & Lime Company had opened a quarry at the site, and R. A. Smith (1916, p. 175) named the formation the "Rockport Limestone." Unfortunately, however, three other formations had already been named Rockport Limestone, so Cooper & Warthin (1941, p. 260) emended the name to Rockport Quarry Limestone, designating the type locality as the quarry, which by that time had been operated by the "Kelly Island Rock and

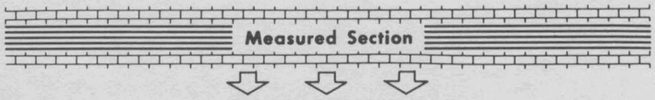
Transport Company at Rockport" as they reported it.

At the type locality, where the entire formation is exposed, the lower 30 feet consist of limestones and a few shale units dominated by stromatoporoids and corals, whereas the upper 12 feet consist of unfossiliferous (except for a few ostracods) gray sublithographic limestone.

Exposures. -- Although the Rockport Quarry Limestone is seen at several other small exposures, three are outstanding. They are Ocqueoc Falls, Black Lake Quarry, and Black River Dam at Kleeber Pond (formerly the site of Shanty Rapids).

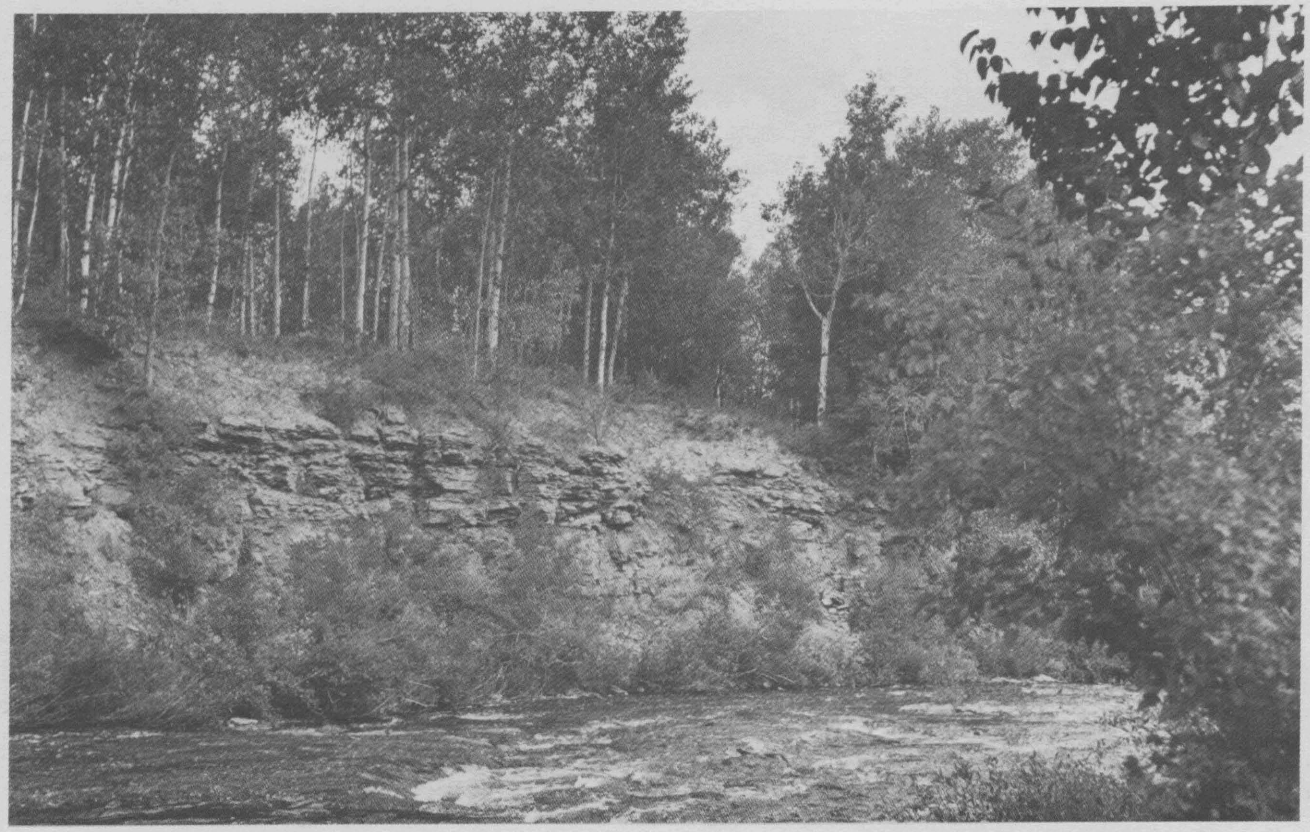
At Ocqueoc Falls on Ocqueoc River, the formation is seen at the falls (text-fig. 12) and in the west bank below the falls (text-figs. 11, 13). The exposures here resemble closely the lower part of the type section, although the stromatoporoids are less numerous.

The 1926 expedition visited Ocqueoc Falls and Ehlers and Ulrich measured the following section:

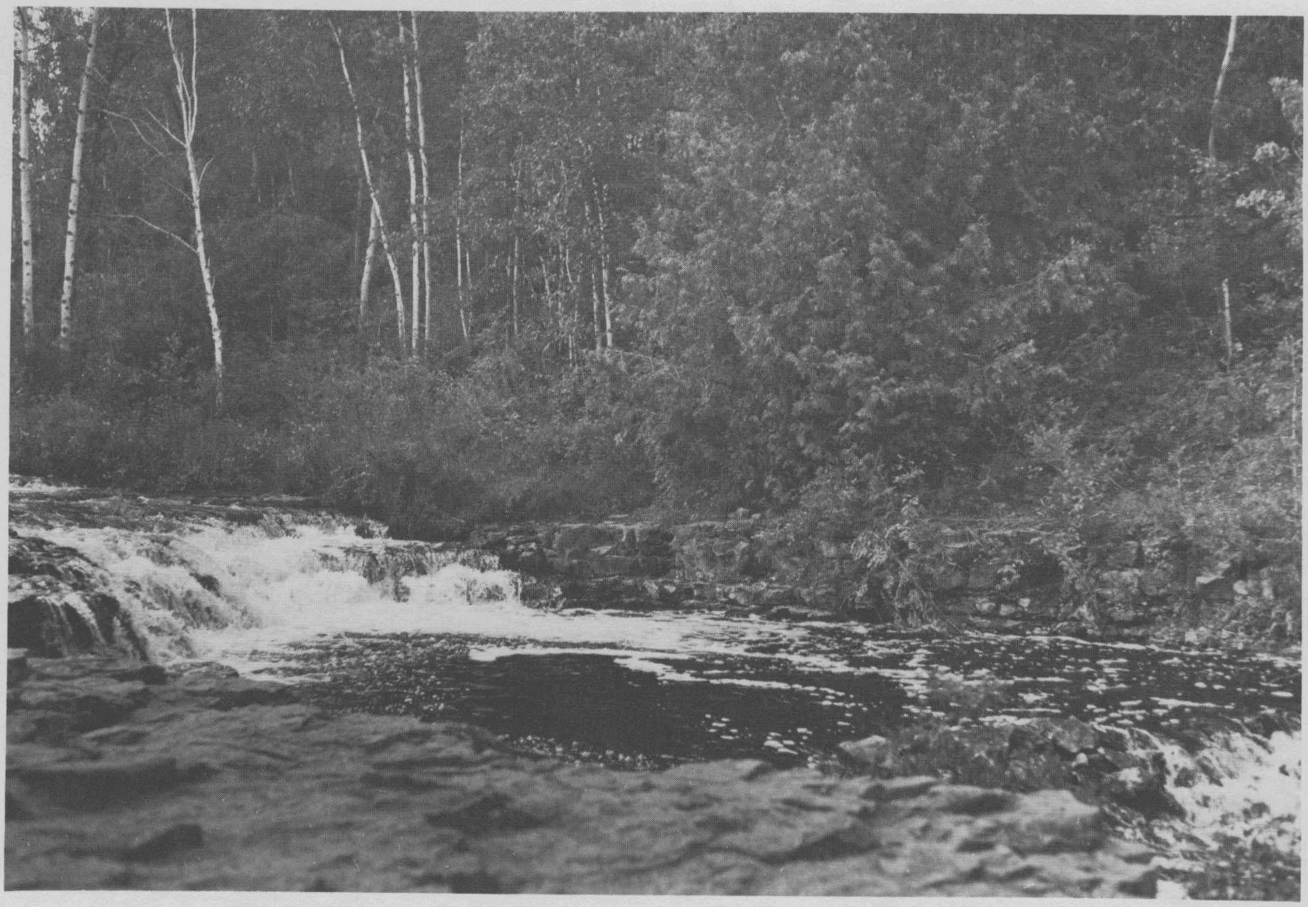


Ocqueoc River and Falls
at intersection with M-10
Loc. 30

About 27 feet of dolomite and limestone. Upper 5' gray subcrystalline limestone with shells and Acervularia, crinoidal. Lower 22' composed almost entirely of dolomite with coral reefs. Rock varies in color from light to dark gray. Lower part black in color. Small athyroid in black part. In coral reef, one reef is notable for great colonies (2 ft. in diameter) of very large Aulopora or Ceratopora and very flat pancake-like stromatoporoids and branching Favosites $\frac{1}{4}$ to $\frac{1}{2}$ inch thick (latter in same layer as Ceratopora). With Ceratopora is Phyllopora and number of specs. taken .... about 27'



TEXT-FIG. 11 -- Rockport Quarry Limestone exposed on west bank of Ocqueoc River just below Ocqueoc Falls. Locality 35-3E-22 S. Photo by Kesling, 1969.



TEXT-FIG. 12 -- Rockport Quarry Limestone exposed at Ocqueoc Falls of Ocqueoc River. Locality 35-3E-22 S. View looking west from park. Photo by Kesling, 1969.

In this section, note that the stromatoporoids tend to be flat "pancakes" rather than the massive structures at the type locality. The upper crinoidal unit is not seen elsewhere. Neither the base nor the top of the formation are seen here.

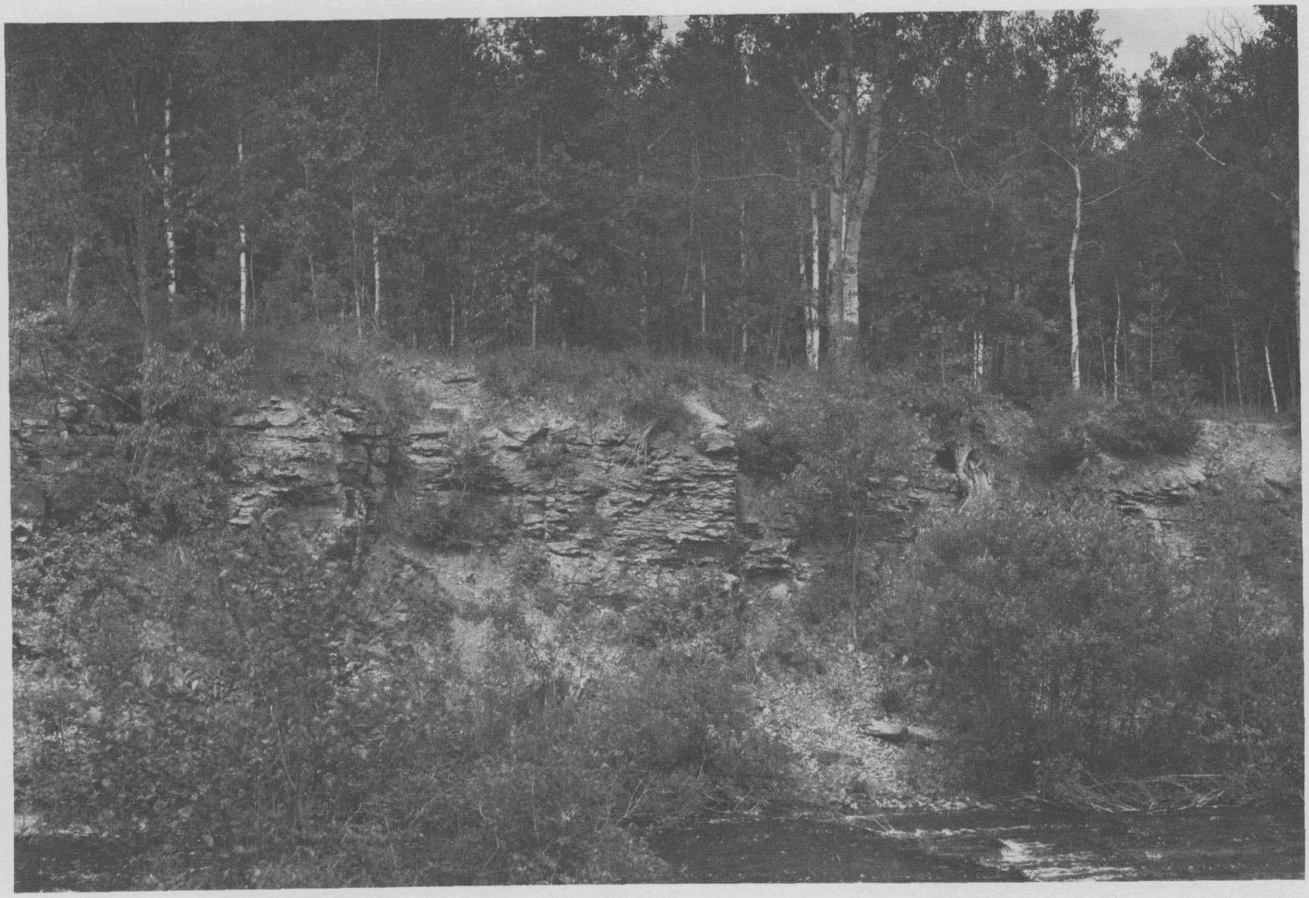
The Ocqueoc Falls exposures were also visited by the field excursion of 1940, led by Bill Kelly. The guidebook for that excursion contained the sketch (here slightly modified) of the section at Ocqueoc Falls (see our text-fig. 17 on page 31).

The second major exposure for the Rockport Quarry Limestone is the now abandoned Black Lake Quarry. This was developed from a natural cliff on the southern shore of Black Lake and was undoubtedly the site viewed by Rominger when he first penetrated into the area, as discussed in the introduction.

In 1916 in his "Limestones of Michigan" R. A. Smith measured the following section at the quarry (note that he numbered the units from the top down):

Section in Black Lake quarry

	Thickness feet
1. Dark bituminous, crystalline, and very fossiliferous beds, containing masses of corals and an abundance of brachiopods. The beds are present only at the east end of the quarry	0-6+
2. Light gray dense grained limestone with small disseminated calcite crystals	8+



TEXT-FIG. 13 -- Rockport Quarry Limestone exposed on west bank of Ocqueoc River short distance below Ocqueoc Falls. Locality 35-3E-22 S. Photo by Kesling, 1969.

3. Dense grained gray limestone with but few crystals of calcite 7
4. Gray dense grained limestone with many small crystals of calcite................ 9
5. Dense grained gray to lithographic limestone with many small crystals of calcite. Lighter than beds Nos. 3 and 4 4
6. Very fine grained, dark bituminous limestone . 1 -
7. Dense grained gray to lithographic limestone similar to No. 5 4
8. Dense grained limestone with bituminous bands .... $1\frac{1}{2}$
9. Dense grained limestone with calcite crystals and dense cavities 1
10. Dark argillaceous bituminous and fossiliferous limestone with druse cavities. Apparently the top of the Long Lake series ...... 1+

The dip is strongly to the southeast and the light gray fine grained beds of the quarry are overlain on the east by gray fossiliferous and more argillaceous beds.

The stone was sold for sugar manufacture but apparently the percentage of magnesium is slightly too high. The low percentage of impurities make the stone suitable for blast furnace flux and for use in the chemical industries.

As his notes indicate, the quarry was already abandoned at the time. Smith did not mention any beds higher than the Rockport Quarry Limestone at this locality.

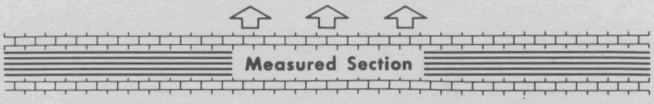
During the 1926 expedition, Ehlers & Ulrich measured a section at Black Lake Quarry, which they designated as Loc. 29:

Abandoned Quarry,
Shore of Black Lake at State Park
Loc. 29

	Ft.	In.
7. Limestone, massive, in two or three ledges, crinoidal; Ceratopora, no different in fauna than shale below	at least 2	
6. Shale with layers of limestone profusely fossiliferous		8
5. Light gray, very finely granular mud limestone, decidedly laminated in upper 3' and breaking platy in upper 4 ft. Two porous beds with calcite streaks in middle one-third with beds of light, dense, gray, abundantly fractured, mud limestone. In lower $6\frac{1}{2}$ feet corals few...		19-20
4. Similar to preceding limestone but darker gray. Bottom conglomerate with pebbles from rock below		$12\frac{1}{2}$
3. Similar limestone to next above in tint and character but often lighter color suggesting emergence. Stringers and specks of calcite. Limestone rests on clay selvage		$6\frac{1}{2}$ to 7
2. Limestone similar to overlying without stringers of calcite, including 1" of shale, which is intermittent		22 to 24"
1. Limestone, 1" to 3" layers of dark shale at top. More or less laminated limestone, mostly dark in color with thin beds of carbonaceous shale. Black shale filling interspaces between corals (branching Favosites) and stromatoporoids. Rock contains structures which are either oolites or Chara spores. Few ostracods present. Ulrichia and Bythocypris noted		$8\frac{1}{2}$ to 9

TEXT-FIG. 14 -- Rockport Quarry Limestone exposed in Black Lake Quarry. Locality 35-2E-7 NW. Photo by Kesling, 1 Oct 1975.

Rock of zone 7 is slumped over rock of zone 6 at east end of quarry. Fauna of zone 6 suggests fauna of shale bed at base of section at Loc. 28.



In this description, the unit 1 seems to be most like the lower beds at the type locality, whereas the overlying units are unfossiliferous except for occasional shale or shaly limestones.

On the same expedition, Case measured this section "north" of the quarry along the lake shore (actually more nearly east):

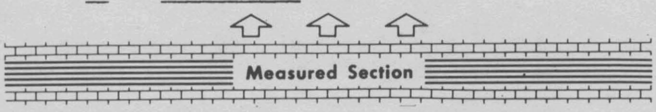
Shore of Black Lake, north of quarry - Loc. 29

7. Crinoidal limestone, slumps over in quarry. . 2+
6. Shale and layers shaley limestone. Profusely fossiliferous .... 8+
5. Light grey very finely granular mud limestone decidedly laminated in upper 4 feet. Patches of coral, Favosites long streaks. Two porous beds, calcite streaks in middle third and dense, fractured, light grey mud limestone in lower third .... 17'
4. Similar to preceding but darker grey. Bottom 2" conglomerate of limestone pebbles from below. Fine grained mudstone ..... $12\frac{1}{2}$'
3. Similar to above in tint and character at top, lighter, suggesting exposure. Some layers filled with calcite specks and stringers. Bottom a clay selvage ..... 5-7'
2. Similar to overlying but without calcite stringers and one 2" shale not continuous .... 22-24"

TEXT-FIG. 15 -- Rockport Quarry Limestone (uppermost beds) exposed along shore east of Black Lake Quarry. Locality 35-2E-7 NW. Photo by Kesling, 1 Oct 1975.

TEXT-FIG. 16 -- Rockport Quarry Limestone just below Black River Dam at Kleeber Pond. Locality 35-1E-29 E. Photo by Kesling, 2 Oct 1975.

1. Top 6" black shale with corals. Then laminar and more or less laminated in thin layers, dark in color and interbedded with at least 1 dark carbonaceous shale (as top), then carbonaceous directly following and including corals. Base formed by black shale with coral. In pit 8" ls., 4" black shale, 1 ft. ls., bottom not seen. The solid limestone of this layer has small white specks either spores or oolites according to Ulrich. Has ostracods Ulrichia and Bythocypris.



The unit 7 was probably Genshaw Formation, and unit 6 contained Ferron Point Formation.

In the 1940 guidebook, Kelly offered the annotated stratigraphic sections shown here as text-figures 18 (p. 32) and 19 (p. 33). He also gave the following description of the Rockport Quarry Limestone, Ferron Point Formation, and basal Genshaw Formation:

Black Lake Quarry - El. 610 ft. Exposure of Rockport limestone, overlain by Ferron Point shale. Because of the relatively strong local dip to the northeast, these two formations dip below lake level within a distance of a few hundred feet, and the bluffs along the lake shore expose the lower Genshaw. The dense limestone of this section is comparable to the upper part of the Rockport limestone in the Rockport Quarry, and may represent a lagunal facies.

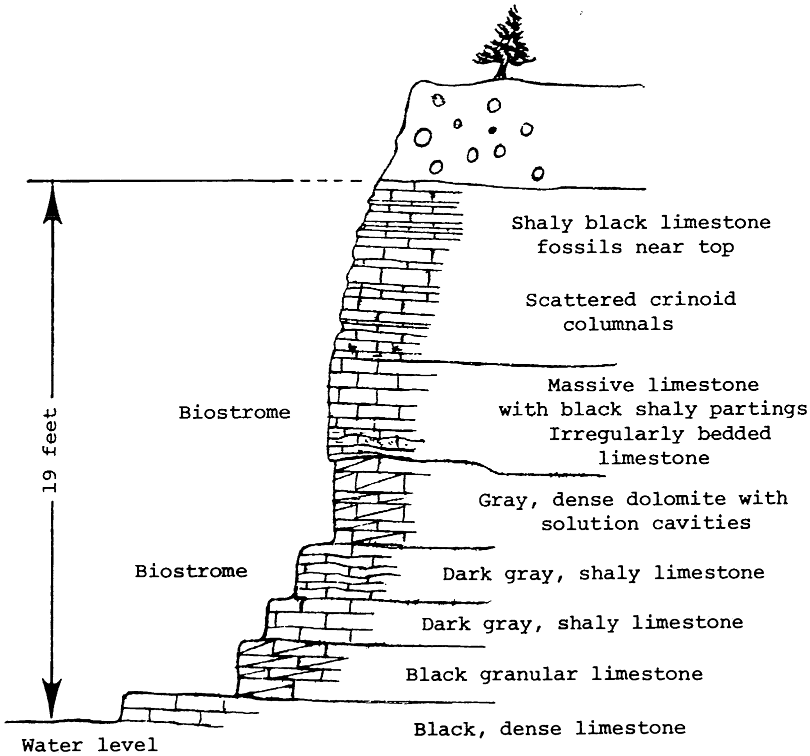
The Ferron Point shale is exposed at the top of the quarry, and also along the lake shore. It carries a rich fauna characterized by corals and brachiopods, including the form Chonetes fragilis, which is diagnostic of the Ferron Point in the Lake Huron section.

The basal Genshaw is a massive, impure limestone with many black shale partings. It contains many overturned specimens of Prismatophyllum. Throughout the limestone there are also many scattered crinoid columnals.

In this description, Kelly suggested for the first time that the strata here represented a different facies from other exposures, and called it the "lagunal" facies.

In the guidebook for the 1949 excursion to the area, Kelly presented the following notes

SECTION AT OCQUEOC FALLS



TEXT-FIG. 17 -- Diagrammatic section of Rockport Quarry Limestone exposed at and near Ocqueoc Falls. From Kelly, 1940 guidebook, with labels relettered.

on the Black Lake exposures and related them to the local structure:

Abandoned quarry of the Onaway Limestone Company on Black Lake.

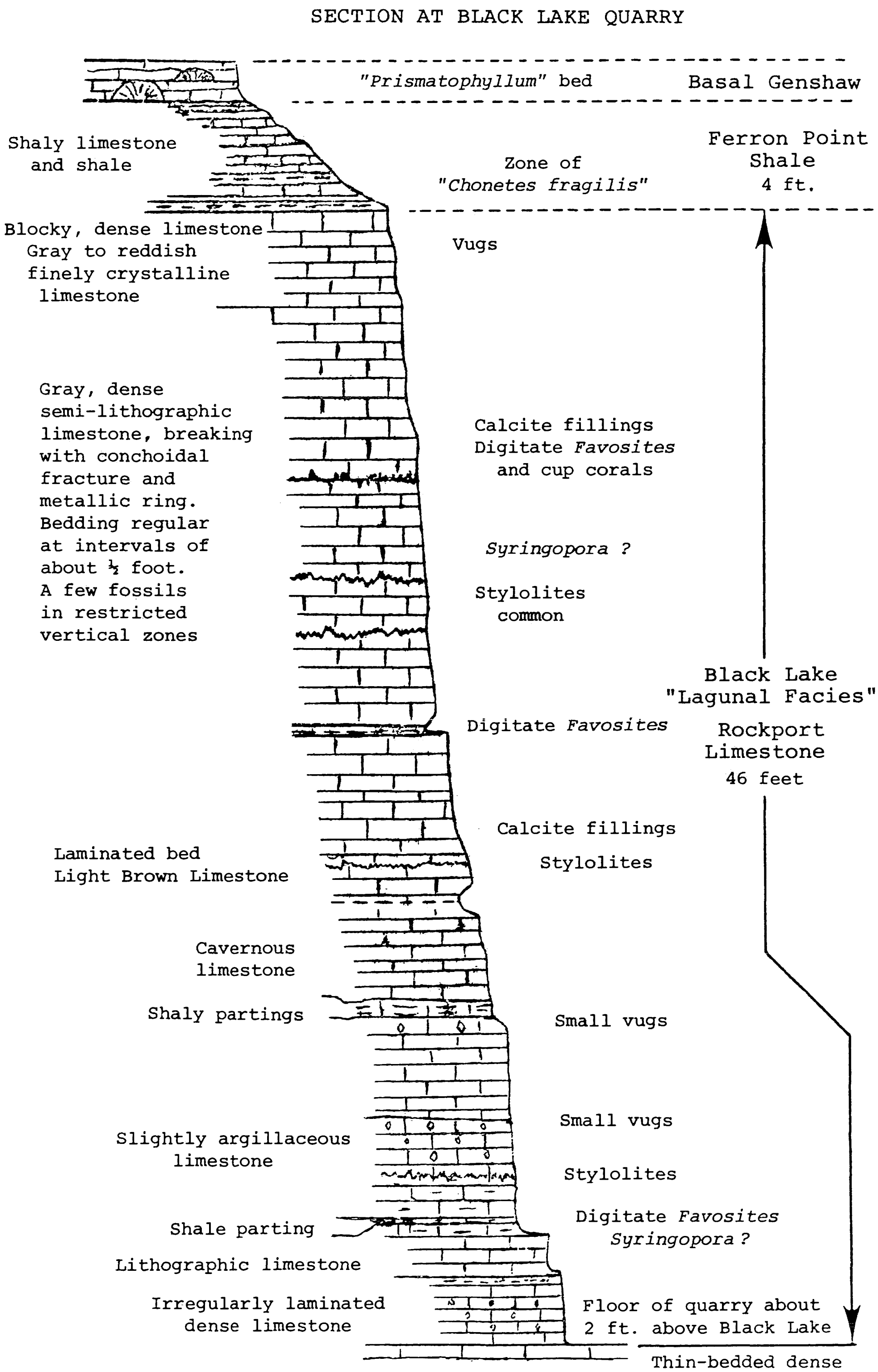
Approximately 50 feet of limestone is exposed in the abrupt face of the quarry. The limestone varies from brown to light gray, and there are several repetitions of this color variation which suggest a cyclic sedimentation. The texture of the limestone is dense and sublithographic, and the rock breaks with a characteristic conchoidal fracture. Stylolites are common in the middle and upper part of the formation. The light colored portions are essentially non-fossiliferous but many of the darker bands contain remains of corals. The corals are long and slender and lie parallel to the bedding. It is suggested that the limestone was deposited in a lagoon, the normally quiet waters of which were sufficiently agitated periodically to snap off the finger-like colonies. Reef-like barriers probably existed to the south.

Lagoonal conditions ended abruptly as indicated by the abrupt contact between the sublithographic limestone and the overlying Ferron Point shale, which is exposed near the north end of the quarry. The relatively steep dip of the beds seen here is continued to the north, and as a result, the Ferron Point and the lower beds of the Genshaw are exposed along the lakeshore (elevation 610 feet). A well $2\frac{1}{2}$ miles southwest (SE/SE/SE sec. 23, T 35 N, R 1 E) records the base of the Rockport at an elevation of 676 feet. Assuming a thickness of at least 50 feet, the dip on the top of the Rockport is 20 feet per mile in a direction opposite to that of the regional dip.

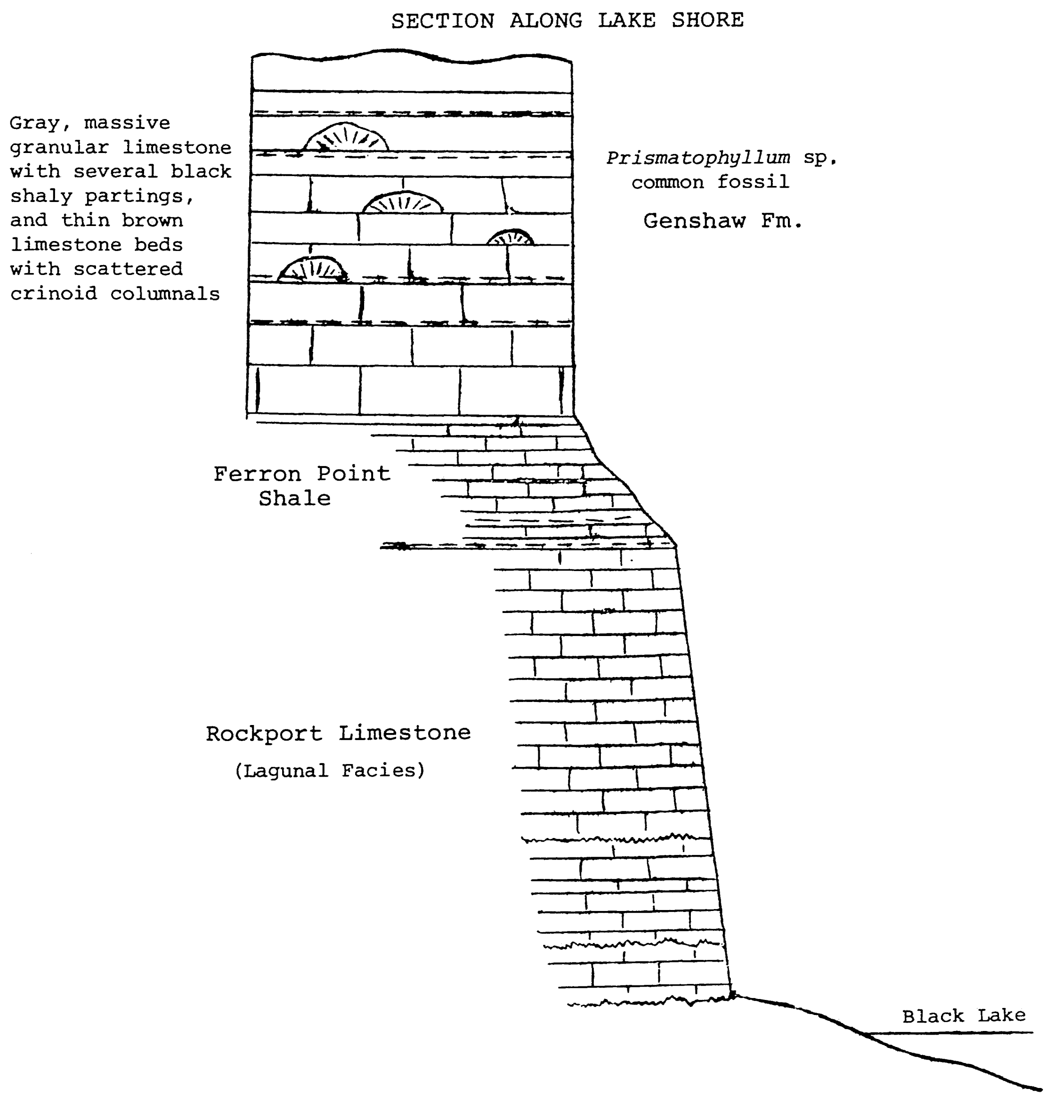
The Genshaw beds at Black Lake differ markedly from the Rockport. They are detrital in character, streaked with shaly layers, and contain large overturned colonies of the coral Hexagonaria. Large flat stromatoporoids are common in a higher zone.

The Bell shale is assumed to underlie most of the lake.

Shanty Rapids of Black River exposed the Rockport Quarry Limestone at intervals for over half a mile. This locality (our Loc. 35-1E-28/33 W) was not recorded by the 1926 Expedition. It was known in the 1930's to members of the Museum of Paleontology at University of Michigan and to members of the Michigan Geological Survey. On the 10th Annual Geological Excursion of the Michigan Academy in 1940, this was Stop # 26. Kelly said little about



TEXT-FIG. 18 -- Diagrammatic section of strata exposed in Black Lake Quarry. From Kelly, 1940 guidebook, with labels relettered.



TEXT-FIG. 19 -- Diagrammatic section of strata exposed along shore of Black Lake east of quarry. From Kelly, 1940 guidebook, with labels relettered.

it in the guidebook, stating only, "Elevation 690 feet. The rapids are formed from ledges of dense limestone of the Rockport... The fauna is poor, and consists of ostracods, cup corals, and digitate Favosites."

In 1947 (p. 451) Kelly & Smith wrote: "The dense facies is the only facies exposed at Shanty Rapids on Black River, and on the lower part of Milligan Creek, southwest of Black Lake." They described this as their Locality 19, as follows: "The upper part of the Rockport Quarry limestone is exposed intermittently in the bed and along the banks of the Black River for a distance of about 1 mile in Secs. 28 and 33, T 35 N, R 1 E, and forms a series of rapids, known locally as Shanty Rapids. The exposures are separated by a quiet portion of the stream from the ledges of the lower Genshaw in Sec. 33. There are a number of small anticlinal and synclinal undulations which make determination of the thickness of the exposures difficult. There is probably a total of 15 feet of beds exposed."

The strata from Shanty Rapids are much

darker than the strata exposed at Black Lake Quarry, and exude a petroliferous odor when crushed (at least in some beds). No corals are preserved in living position, but all are strewn along certain bedding planes as though swept into the site during an unusual storm. The ostracods may well have lived at the place; they are related to the Welleria which is present in the higher beds at Campbell Quarry.

During the early 1950's, a dam was completed on Black River near the lower end of the Shanty Rapids section. The resulting lake, called Kleeber Pond (our Loc. 35-1E-29 E), inundated most of the Rockport Quarry exposures. However, below the dam a few feet of Rockport Quarry Limestone can be seen (text-fig. 16 on p. 30). From the known thickness of the formation in the area, as learned from well records (see Appendix 7; 40 feet of Rockport Quarry Limestone identified in well in sec. 22 of this township), we can only estimate that the strata below Black River Dam here are near the middle of the formation.

Other localities are known in the Afton-Onaway area where parts of the formation can be seen. They include:

(1) 35-3E-24 W, isolated outcrops in the channel of Little Ocqueoc River about $1\frac{1}{2}$ miles east-northeast of Ocqueoc Falls. This is a karst area shown on some old maps as "Disappearing River." The underlying beds have caved in at several places, and stream flow goes underground. This was Stop #26 on the 10th Annual Excursion in 1940.

(2) 35-3E-27 C, exposures along Ocqueoc River above the falls. At this place the Ferron Point Formation is exposed, with Rockport Quarry Limestone a short distance downstream but the contact concealed.

(3) 35-1E-22 C, exposure in the bed of Fisher Creek. Dense limestone much like that at Shanty Rapids can be seen in the stream bed, but the thickness exposed is very little.

(4) 35-1E-23 E, road cut about 2 miles south of Balck Lake. The material in the cut is all gravel but it is composed almost exclusively of dense lithographic limestone like that seen in Black Lake Quarry. It seems highly likely that the place is underlain by Rockport Quarry Limestone at no great depth.

(5) 35-1E-31 N/30 SE/29 SW/32 NW/29 C, exposures along Milligan Creek. Where the creek is crossed by the bridge of the Detroit & Mackinac Railroad just east of the center of section 29, the banks and bed of the creek show Rockport Quarry Limestone. Upstream, the Genshaw is exposed for a long distance in Black Lake State Forest.

Composition. -- We are indebted to R. A. Smith (1916, p. 259, 280) for the analyses of rock in the Rockport Quarry Limestone. He found a drastic difference between the facies at Black Lake Quarry and the facies at Ocqueoc Falls. At the quarry he recorded:

$CaCO_3$	96.84%
$MgCO_3$	2.03%
$Al_2O_3 + Fe_2O_3$	0.52%
SiO_2	0.39%

But at the falls, he found the rock was much higher in Mg:

$MgCO_3$	34.74%

These compositions correspond closely to those found for the upper and lower beds at the type locality.

Fauna. -- Appendix 4 shows *Cystiphyllum americanum bellense* as the only species or subspecies that has been reported in the literature from the Afton-Onaway area. Nevertheless, the same species that have been reported from the Alpena and Presque Isle Counties area to the east are also present in the facies of the Rockport Quarry Limestone exposed at Ocqueoc Falls (Locality 35-3E-22S). This facies is composed of various irregularly bedded dark limestones with some black shaly partings (much lighter shades of gray on weathering), rich in corals and stromatoporoids. The corals are mostly branching types, broken, and evidently transported by high-energy waves and currents (for an unknown distance, possibly not far). The faunal list from the type locality is probably accurate for the Ocqueoc Falls exposures; an asterisk marks the species to subspecies that are unknown in other Traverse Group formations:

Rugose corals
- **Billingsastrea rockportensis* Ehlers & Stumm
- **Cylindrophyllum delicatulum* Ehlers & Stumm
- *Cystiphylloides americanum bellense* Stumm
- **Heterophrentis gregaria* (Rominger)
- **Spongophyllum romingeri* Ehlers & Stumm

Tabulate corals
- *Aulocystis magnispina* Watkins
- *Emmonsia alpenensis* Stumm & Tyler
- **Favosites alpenensis kellyi* Swann
- *Favosites alpenensis peninsulae* Swann
- *Favosites digitatus* Rominger
- **Trachypora rockportensis* Stumm & Hunt

Brachiopods
- *Chonetes mediolatus* Cooper
- **Longispina pelta* Imbrie
- *Pholidostrophia gracilis gracilis* Imbrie
- *Schizophoria ferronensis* Imbrie
- *Schuchertella crassa* Imbrie
- *Spinulicosta mutocosta* Imbrie
- **Strophodonta extenuata rockportensis* Imbrie

The stromatoporoids are not as massive as those at the type locality. They have not been investigated or reported in literature. One bed at Ocqueoc, exposed high in the bank below the falls, contains numerous disarticulated crinoid columnals; to what degree these are transported or reworked has not been determined. The occurrence of fossils in place should be studied here and elsewhere intensively, to discover clues to the energy and mode of deposition.

In the strata of the Rockport Quarry exposed formerly at Shanty Rapids and part of which are still exposed below the Black River Dam at Kleeber Pond, the only fossil that can be found consistently is an ostracod that apparently belongs to *Welleria* sp. The ostracods of this genus are notably tolerant of highly saline waters, thriving in concentrated brine that eliminates their competitors. The *Welleria* bed of the Gravel Point Formation at Campbell Quarry will be discussed later in this paper.

The worn corals strewn along certain planes in the Rockport Quarry Limestone facies at Black Lake Quarry were evidently washed into the area during periodic storms, and were possibly from the vicinity of Ocqueoc Falls. The absence of a living community in the so-called lagoonal facies suggests isolation from the rest of the sea and possibly restricted distribution of oxygen for periods of time.

Sedimentation. -- This formation shows two distinct facies, one fossiliferous and the other essentially unfossiliferous. The fossil-bearing facies is somewhat browner in overall color, with more streaks and partings of carbonaceous shale; the bedding is very irregular but does not show stylolitic seams.

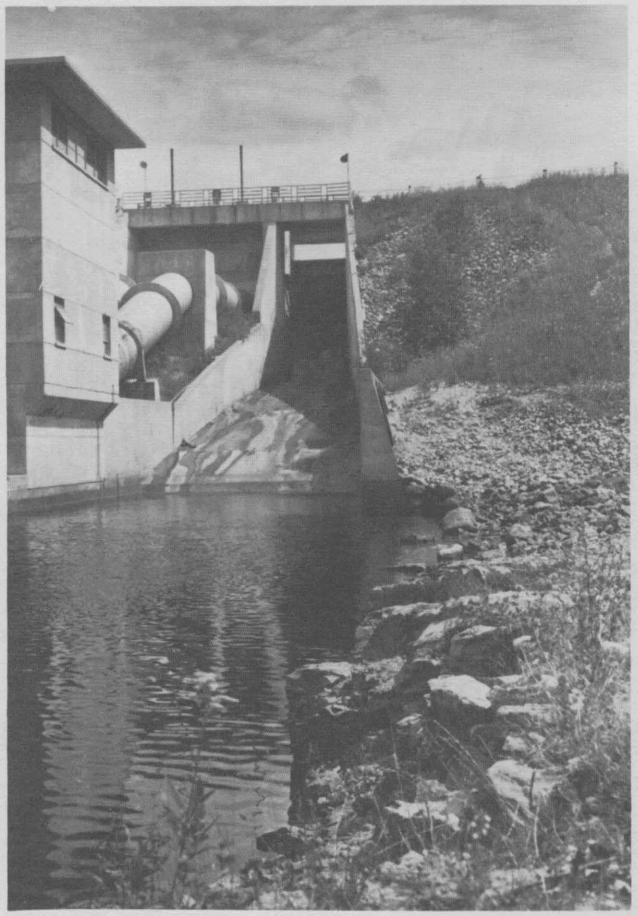
The unfossiliferous facies, referred to as the lagoonal facies, is light-colored, fine-grained to lithographic, and marked by stylolites. These structures suggest purity of the carbonate which permits solution along bedding planes to allow overlying units to settle into dissolved-out spaces between insoluble impurities. The degree to which the whole deposit has been "vertically telescoped" or condensed by the solution that produced the stylolites has not been accurately assessed, but must amount to several feet of the total thickness.

Both facies are shallow-water deposits. The purity and lithographic texture of the lagoonal facies suggest to us that Chemical precipitation, rather than Organic, was dominant in its formation.

FERRON POINT FORMATION

Name and type locality. -- Ferron Point is a small peninsula or point of land projecting into Lake Huron in the southeastern edge of Presque Isle County, in NE$\frac{1}{4}$ sec. 36, T 33 N, R 8 E. It does not have any outcrops of the formation, and the name was selected because it was the only conspicuous named feature in the vicinity for which no formation had yet been named.

By 1902 when Grabau published his observations on the Devonian stratigraphy in the Thunder Bay region of Alpena and Presque Isle Counties, the shale pits of the Alpena Portland Cement Company were already in operation. Here the upper Ferron Point shales are overlain by the lower Genshaw limestones. However Grabau did not distinguish separate formations, but chose to include all the strata in the "Long



TEXT-FIG. 20 -- Rockport Quarry Limestone exposed below Black River Dam at Kleeber Pond (compare with text-fig. 16, p. 30). This was part of the series of exposures along Black River before the dam was constructed, and known as Shanty Rapids. Locality 35-1E-29 E. Photograph by Kesling, 1969.

TEXT-FIG. 21 -- Beebe School Formation at type locality. Locality 34-2W-14 E. View from Munger Road looking west; Karl Kutasi stands on the shale section. The schoolhouse atop the exposure has been modified for a dwelling. Photograph by Kesling, 1969.

lake shales and limestones."

In 1927 (p. 182), Ver Wiebe classified the formation as his "Middle member of the Long Lake series," but did not attempt to set limits on it. By that date, drill holes had penetrated the whole of the formation, but Ver Wiebe did not comment on the thickness or boundaries.

The formation was named and defined by Warthin & Cooper (1935, p. 526), who gave the thickness as about 35 feet and designated the type locality at Rockport Quarry (Locality 32-9-6 NW in Ehlers & Kesling, 1970).

Based on well records and the exposures of the lower beds at Rockport Quarry (the abandoned Kelley's Island Lime & Transport Company Quarry) and the upper beds at the old Alpena Portland Cement Company shale pit, Kesling (in Ehlers & Kesling, 1970, p. 59) put the total thickness at 42½ feet. The section consists of soft shales and a few limestone layers or lenses. The uppermost beds are noted for their abundant Devonochonetes, a number of which bear edrioasteroids. The preservation of the delicate brachiopods and the existence of the edrioasteroids point to very quiet conditions during the accumulation.

Exposures. -- Westward from the type locality, the formation thins drastically, and well cores near the western edge of the Afton-Onaway area show no shale unit between the Rockport Quarry Limestone and the Genshaw Formation.

At the Black Lake Quarry (Loc. 35-2E-7 NW), the Ferron Point can be found as a soft shale above the quarry face. Here the formation is only 9 feet thick, and Kelly & Smith (1947, p. 451) indicate that it is even thinner nearby.

The Rainy River Ridge, a structure extending southeast from Black Lake, arches up the lower Traverse Group formations along Rainy River and Stony Creek. Both streams show exposures of Ferron Point soft gray shale bearing the same fauna as that seen in Alpena County.

Along Rainy River, about $\frac{1}{4}$ mile below the falls, such soft shales can be seen for a short distance along the bank. According to the most recent erosion and slumping, the shales may be conspicuous or difficult to discern. The best site for the Ferron Point here is not far north of the lane which serves as an extension of Twin School Highway (Loc. 35-2E-26 S-SW). The exact thickness cannot be measured, but it is not more than a few feet. The outcrop pattern created by the intersection of the structural ridge and the river valley is a pair of concentric lenses.

Along Stony Creek (also spelled Stoney) at Locality 35-2E-20 SW, the Ferron Point soft shale can be seen intermittently across the southwest quarter of the section between Hutchinson Highway and M-211, never rising more than a few feet above the stream. In many places along Stony Creek, slump has created an admixture of Ferron Point shale, glacial gravels, and pieces of limestone that are probably lowermost Genshaw Formation.

The westernmost exposure or occurrence of the formation is in an excavation about $2\frac{1}{2}$ miles south of Black Lake, in Waverly Twp. This spot is about 400 feet west of Black River Road and about 800 feet south of the eastern end of Buck Road (which at the section corner becomes Hutchinson Highway). This excavation was visited by the 1940 excursion of the Michigan Academy as Stop #3. The land was owned in 1970 by V. and E. Gray. From this excavation, shale boulders were thrown out which were highly fossiliferous with the typical Ferron Point fauna.

Three wells, for which logs are presented in our Appendix 8, show the western thinning of the Ferron Point Formation in this area. In the State-Nunda "A" in SW$\frac{1}{4}$ sec. 11, T 33 N, R 1 W, the formation is 5 feet thick. Less than six miles westward, in the Lewis A. Garred well in SE$\frac{1}{4}$ sec. 1, T 33 N, R 2 W, it is 4 feet thick. And about 6 miles farther west, in the William M. Brown well in NE$\frac{1}{4}$ sec. 12, T 33 N, R 3 W, the formation is absent, having "feathered out" in the interval.

Fauna. -- As shown in Appendix 4, the Ferron Point Formation in the Afton-Onaway area has had a number of species and subspecies recorded in literature. We suspect that the list is far from complete, even for megafossils. The only species that seems confined to this area is indicated by an asterisk. The following is based on the check lists by Stumm (1951, 1961):

Tabulate corals
- *Aulocystis magnispina* Watkins
- *Aulopora serpens* Goldfuss

Brachiopods
- *Devonochonetes* cf. *coronatus* (Conrad)
- *Devonochonetes fragilis* Stewart
- *Devonochonetes mediolatus* Cooper
- *Pentamerella* cf. *dubia*
- *Pentamerella lingua* Imbrie
- *Pentamerella* aff. *pavilionensis* Hall
- *Schizophoria ferronensis* Imbrie
- *Schuchertella crassa* Imbrie
- *Strophodonta extenuata extenuata* Imbrie

Bivalve
- **Cornellites* cf. *flabellites* (Conrad)

In addition, the following genera are listed in Appendix 1 for the formation:

Rugose coral
- *Hexagonaria*

Brachiopods
- *Mucrospirifer*
- *Spinulicosta*

Cricoconarids
- *Tentaculites*

Cephalopod
- *Gomphoceras*

TEXT-FIG. 22 -- Lower part of Genshaw Formation below Tower Dam. Locality 34-1E-3 C. A few feet of impure limestone are visible along the banks of both the power flume and the control outlet (foreground and background). Photograph by Kesling, 1 Oct 1975.

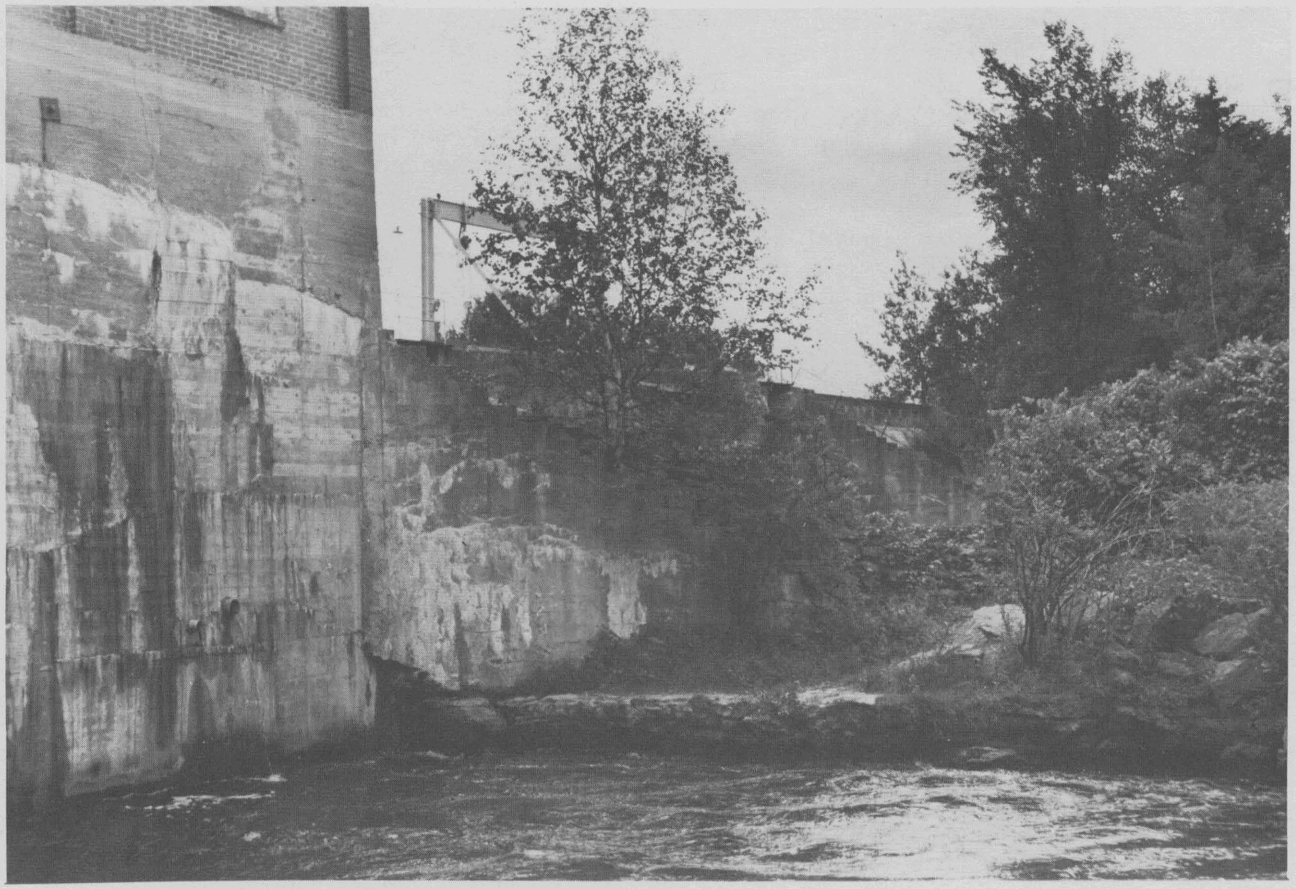
As shown in Appendix 3, the genera of the Ferron Point Formation in this area are most like those of the Gravel Point Formation in Emmet and Charlevoix Counties and like those of the Bell Shale, Ferron Point Formation, and Genshaw Formation in Alpena and Presque Isle Counties. Generically, the fauna is much like that of the Silica Formation in northwestern Ohio and the Arkona Shale in Ontario.

Sedimentation. -- Like other "soft" (low in both lime and silica) shales, the Ferron Point shows many signs of "deep" and quiet deposition. The absence of the high-energy-loving stromatoporoids, the scarcity of rugose corals, the diversity of the fauna, and the presence of delicate spines in the fossils -- all point to long periods of undisturbed bottom conditions during which gentle currents brought in sufficient food for the many kinds of sessile benthonic inhabitants.

The shales of this formation are so poorly exposed in the area that we cannot determine if the pinching out is a depositional or erosional consequence. Both the base and top of the shale seem to be clearly defined from the shallow-water limestones, with neither an interval of transition nor an interfingering of the two lithologies on a local scale.

It would seem that the deepening and the shallowing which initiated and concluded the Ferron Point depositional episode occured rather quickly.

The higher elevations of the sea floor were evidently here and to the west, as indica-



TEXT-FIG. 23 -- Lower part of Genshaw Formation below Tower Dam. Locality 34-1E-3 C. A few feet of limestone are seen here on the opposite bank of the power flume (compare with text-fig. 22 on the opposite page). Photograph by Kesling, 1969.

ted by the prevalence of limestones in the section and the pinching out of shale. The same situation prevails in Presque Isle County in regard to the Norway Point Formation, a shale sequence over 50 feet thick in Alpena County but absent in western Presque Isle County. Insofar as we can learn from subsurface data, the intervening Rockport Quarry Limestone pinches out to the eastward, and the Bell Shale and Ferron Point merge into the Arkona Shale in Ontario. Thus, the Afton-Onaway area would seem to have been near the hinge for periodic deepening of the basin to the east.

It is of interest that the deeper-water fauna followed the shale lithology, so that the Bell and Ferron Point share many species, whereas each has only half as many species in common with the intervening shallow-water fauna of the Rockport Quarry Limestone.

GENSHAW FORMATION

Name and type locality. -- As explained by Kesling (in Ehlers & Kesling, 1970, p. 60), the strata included in the Genshaw Formation as it is presently recognized have undergone several revisions of nomenclature. Grabau (1902, p. 184) placed the lower beds in his "Long lake shales and limestones" and included the black limestone and overlying shales in his version of the "Alpena limestone." Ver Wiebe a quarter of a century later (1927, p. 182) put the lower beds in the "Upper member of the Long Lake series" and evidently left the middle and upper beds in the Alpena. And Pohl (1930) called the lower units the "Long Lake member of the Presque Isle stage." None of these authors designated a type section, and their limits were somewhat vague.

The name Genshaw was created by Warthin & Cooper (1935, p. 526) for strata exposed near Genshaw School (Locality 32-8-13 SE of Kesling). The school house has been gone for many years, but its site on Monaghan Point Road is accurately known. Outcrops revealed in the roadbed and ditches by scrapers are low in the formation and not well exposed. However nearby in the vicinity are exposures that show most of the formation: the contact with the underlying Ferron Point Formation is seen at the abandoned clay pit of the Alpena Portland Cement Company (Loc. 32-9-18 SE), lower strata are exposed along West Long Lake Road between US 23 and Leroy's Resort (Loc. 33-7-36 NW), the Killians Member is seen on French Road south of Long Lake (Loc. 32-8-8 E), and the upper beds are exposed in the Huron Portland Cement Quarry in Alpena (Loc. 31-8-13 W).

Nowhere is there a complete section, and the thickness in the vicinity of the type locality must be learned from well records. About 116½ feet of strata are presently included in the Genshaw Formation in Alpena County.

It is questionable whether any of the upper 35 feet of the formation as known in Alpena County are present in the Afton-Onaway area. These strata, above the dark siliceous Killians Member, consist of gray argillaceous limestone that weathers rather readily.

Exposures. -- Because the Genshaw Formation in most (if not all) of the Afton-Onaway area is capped by the resistant Killians Member, outcrops are numerous. In fact, there are about as many natural outcrops of Genshaw as of all other formations combined.

Unfortunately, the Genshaw has little commercial value; it is too impure for cement or flux and it is no better than any other limestones for crushed rock. As a consequence, no quarries have been developed where an appreciable section of the formation can be measured and studied. The total thickness must be gained from well cores, and the lithology and fauna must be pieced together from isolated occurrences for many of which the stratigraphic position is only approximated.

We list thirty-six localities, some of which are areas that display intermittent exposures of the formation.

(1) Loc. 35-3E-20 E. In a road cut on North Ocqueoc Road about ½ mile south of the village of Ocqueoc and near King Tower and the Assembly of God Church, several feet of impure limestones and interbedded calcareous shales are exposed. The section is fossiliferous and lies in the lower member of the formation.

(2) Loc. 35-3E-24 S. A road cut on Ocqueoc Falls Highway about 1 3/4 miles east of the falls and just east of Little Ocqueoc River exposes the lower part of the Genshaw in the easternmost occurrence of the formation in this area. Between this locality and Swan Creek (southeast of Rogers City at Loc. 34-6-17 NW) the Genshaw Formation is concealed by deep drift filling an old valley.

(3) Loc. 35-3E-27 C. A short distance upstream on Ocqueoc River from the point west of the junction of M-68 and Millersburg Road, Genshaw Formation could be seen at one time. The exposures were not extensive and could not be located in 1975. These beds were very low in the formation, for the Ferron Point is in the streambed nearby downstream.

(4) Loc. 35-3E-32 E-NE. On the west side of South Ocqueoc Road and just north of a tributary of Ocqueoc River, material of the Genshaw Formation is found in an area of over a hundred square yards. Whether this material is in place may be questioned. At least some of it shows evidence of disturbance, but this could be either moved a short distance by bulldozer or a considerable distance by dump truck. The argillaceous limestones and calcareous shales are evidently from the lower part of the formation, as indicated by fossils.

(5) Loc. 35-3E-33 W-NW. A road cut on South Ocqueoc Road, about 2 miles south of the village of Ocqueoc and not far north of the previous locality exposes the lower strata of the formation in what appears to be definitely in-place occurrence.

(6) Loc. 35-2E-7 NW. At the Black Lake Quarry, strata of the Genshaw Formation can

be found on the slopes above the quarry face. As indicated by Kelly (1940) in a diagrammatic section just east of the quarry (see our text-fig. 19 on page 33), the lowermost beds consist of massive gray and thin brown limestones with a few dark shaly partings. They contain, among other fossils, heads of Hexagonaria. These beds contrast strongly with the underlying soft gray shales and shaly limestones of the Ferron Point Formation at this locality.

(7) Loc. 35-2E-21 N-NE. Roadside exposures of the lower Genshaw occur along North Allis Highway about $5\frac{1}{4}$ miles west of the village of Ocqueoc.

(8) Loc. 35-2E-26 S-SW. Along Rainy River about a quarter mile below the falls, the Genshaw crops out in the stream banks near the exposure of Ferron Point Formation shale. Here, various impure limestone units can be seen at intervals, but an accurate section would be difficult to measure.

(9) Loc. 35-2E-26 SE. In a small gully that is tributary to Rainy River near the southeast corner of the section, the lower part of the Genshaw crops out as massive limestone bearing Sieberella romingeri and other fossils typical of the lower member as seen in Alpena County along West Long Lake Road.

This was Stop #24 on the 1940 excursion of the Michigan Academy, at which time Kelly wrote in the guidebook that "One half mile west of the corner are extensive exposures of lower Genshaw limestone and shale along Rainy River. This stream has cut a miniature gorge below a small waterfalls formed by domed ledges of the Genshaw. Small sink-holes present, here, bear a distinct relationship to former stream channels."

This locality is separated from the next by only a short distance, and is probably not far stratigraphically above the strata forming the falls.

(10) Loc. 35-2E-29 SW/20 SW-SW. Intermittent exposures can be seen on the southwest bank of Stony Creek from near the former site of Rowe School nearly to M-211. This was Locality 31 of Kelly & Smith (1947, p. 463), who estimated that a total of 40 feet of strata were involved in the low escarpments here. The lithology of the strata indicates they are below the Killians Member. The outcrop area extends westward through section 30.

(11) Loc. 35-2E-31 NE-NE. Exposures along M-211 just south of Twin School Road may include some strata that represent the upper member of the formation in Alpena County to the east.

This locality was Locality 32 of Kelly & Smith (1947, p. 463), who wrote, "About 4 feet of bituminous black shaly limestone assigned to the Killians is overlain by 2 feet of fossiliferous tan to light brown crystalline limestone 180 feet south of the SE corner of Sec. 30, T 35 N, R 2 E, $1\frac{1}{2}$ miles north of Onaway. Because its fauna resembles that of the Genshaw rather than that of the Newton Creek, this limestone is tentatively assigned to the upper Genshaw."

(12) Loc. 35-2E-32 NW-SW. Similar to the previous locality, this may include strata of the upper Genshaw. This was Locality 30 of Kelly & Smith (1947, p. 463), who stated, "Outcrop on east side of State Highway M-211, in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 32... Exposure of $1\frac{1}{2}$ feet of black shaly limestone and black brittle shale, containing a large Atrypa, Pentamerella, small strongly costate Stropheodonta, and abundant Pholidostrophia of the Killians member overlain by nearly 2 feet of gray granular limestone. The upper bed resembles the section exposed at locality 32." This exposure is a little over $\frac{1}{2}$ mile south of Twin School Road.

(13) Loc. 35-2E-35 N-NW. Rainy River Falls, as shown in our frontispiece, resembles Ocqueoc Falls (see our text-figs. 11-13 on pages 25-27) as a waterfall-rapids over resistant limestone. However, this falls is over the Genshaw Formation instead of the Rockport Quarry Limestone. The falls was visited by the 1949 excursion of the Michigan Geological Society, at which time Kelly wrote in the guidebook:

Rainy River - Exposures of northeasterly inclined limestone may be seen near the road. The limestone belongs to the Clathrodictyon zone of the lower Genshaw. (At) Rainy River .. still lower beds of the Genshaw form the walls of a miniature canyon. Traced downstream the Genshaw is succeeded by outcrops of the Ferron Point.

The presence of these beds at an altitude of about 750 feet indicates a considerable reversal of the regional dip as one can readily infer by comparison with the elevation of the Ferron Point outcrops along the shore of Black Lake.

Downstream to the north, the anticlinal effects of the Rainy River Ridge expose lower formations along the stream banks.

(14) Loc. 34-1E-3 E-NE. Strata exposed along Tower Road about 3/4 mile north of the village of Tower belong to the resistant Killians Member of the formation. This was part of Locality 21 of Kelly & Smith (1947, p. 462), who described their locality as "about 17 feet of Genshaw limestone and shale is exposed below the Tower Dam in sec. 3 ... along the Black River. This section is typical of the Genshaw and easy to reach from Michigan Highway 33. Beds of the Killians are exposed about $\frac{1}{2}$ mile east. The Killians occurs at a higher elevation along the roadside about $\frac{1}{4}$ mile south of the NE corner of Sec. 3."

(15) Loc. 34-1E-3 C. Ledges below the Tower Dam on Black River belong to the lower member of the Genshaw. Strongly dipping beds are here capped by a massive limestone bearing Sieberella romingeri and other fossils typical of the lower part of the formation in Alpena County. This place is shown in our text-figures 22 and 23 on pages 38 and 39.

The Tower Dam locality was visited by the 1926 expedition. At that time Ehlers & Ulrich recorded in their notes the description of 10 feet of strata:

Measured Section

Exposure below Dam on Black River
$\frac{1}{4}$ mile north of Tower
Loc. 28

	Ft.
3. Limestone, rather massive, irregularly bedded, gray, filled with shells, especially very large Atrypa and Gypidula, Acervularia, Cladopora, etc. At top rock weathers shelly. No species seen exactly like those about Afton - probably indicating slight varietal changes. Beds thought to be older than those at Afton. Possible beds are about the same as those in old quarry one mile north of Bay View (Loc. 21)	8
2. Argillaceous limestone. Large Atrypa and other fossils weathered out of shale layer in limestone	1
1. Massive limestone below. Base not seen. Acervularia	1

Measured Section

At the same time and place, Prof. Case noted the same units and thickness:

Measured Section

Tower (Black River Dam) - Loc. 28

3. Massive limestone, shaly at top. Filled with fossils, corals, large Gypidula, Athyris, Stropheodontas (S. erratica). Number corals, same species different varieties from Afton. Bed thought to be older than those in Afton section. Nearest can be suggested is quarry 1 mile north of Bay View	8'
2. Shale. Fossiliferous. Atrypa	1'
1. Massive limestone at bottom. All seen	1'

Measured Section

The locality was visited in 1940 by the 10th Annual Geological Excursion of the Michigan Academy; Kelly reported that many of the brachiopods formed nuclei of spherical stromatoporoids in the uppermost limestone and that the underlying shaly limestone contained many bryozoa.

As mentioned in the previous locality, nearby, Kelly & Smith recorded about 17 feet of strata in the vicinity.

(16) Loc. 34-1E-6 S. The old Michigan Geological Survey Locality 63 was a road cut on the highway about 3 miles west of the village of Tower. This was probably seen before the present M-33/M-68 section of the highway was built and is probably along the section of the old road that had been bypassed. In 1975 we could not find a good exposure of the lower Genshaw at this place, and it may be obscured by fill for the present highway.

(17) Loc. 34-1E-6 W-SW. Ledges of

black limestone at at and below water level in Milligan Creek where it is crossed by M-33. Exposures of the same black limestone continue east along the highway.

Kelly & Smith (1947, p. 462, their Locality 15) said of the strata here, "A concealed interval separated them from the sub-lithographic and cavernous limestone of the Koehler formation in the SE$\frac{1}{4}$ of Sec. 6. Float of the Koehler formation is abundant $\frac{1}{4}$ mile south of the SE corner of Sec. 6."

(18) Loc. 34-1E-8 NE-NE/9 NW-NW. Exposures near the intersection of M-33 and Freeman Road include about 6 feet of dark Killians exposed in a ditch along Freeman Road in sec. 9 and a small exposure of lighter limestone on the south side of M-33 in sec. 8. This was Locality 20 of Kelly & Smith (1947, p. 462), who interpreted the latter exposure as an inlier of "sub-Killians Genshaw."

(19) Loc. 34-1E-13 E-SE. The most southerly exposure of the area is found as ledges of black limestone below water level in Upper Black River about 3 miles southeast of the village of Tower. This is the Killians Member of the formation. The occurrence is not significant for lithology or fauna, but it serves as a control for areal and structural maps of the area.

(20) Loc. 35-1E-21/22 S. Exposures along and near Dangler Road in Black Lake State Forest, about $\frac{1}{4}$ mile north of the intersection with Buck Road, are part of an east-west bluff known locally as "Limestone Hill." Kelly & Smith (1947, p. 462) reported as much as 13 feet of these lower Genshaw limestones on the north face of the bluff. We found the outcrops to be discontinuous and partly obscured by vegetation in the summer of 1975, so that a measurement of thickness would not be reliable.

(21) Loc. 35-1E-23 SW. The lower part of the Genshaw forms an east-west belt of outcrop extending for about 600 feet in this quarter-section. It includes 8 feet of dark gray limestone with stromatoporoids and corals of which the lower bed acts as the cap rock of a perennial spring.

(22) Loc. 35-1E-25/35-2E-30. Intermittent exposures along an escarpment trending east-west total about 22 feet of limestones of the lower member of the Genshaw. This exposure includes the following locality as part. The escarpment extends nearly through the middle of the two sections, with the better exposures along the west line of the SW$\frac{1}{4}$ sec. 25.

(23) Loc. 35-1E-25 E-SE. Typical lower Genshaw strata containing Sieberella romingeri are exposed on the north face of a 25-foot bluff near County Line Road and between Purdy Road and Twin School Road. This lies near the center of the escarpment constituting the previous locality. It is about $\frac{1}{4}$ mile north of the southeast corner of section 25; westward it extends to about 1,100 feet south of the west quarter-corner of the section and eastward it extends to the east quarter-corner of section 30. All strata involved are below the Killians Member.

(24) Loc. 35-1E-31 N/30 SE/29 SW/ 32 NW/29 C. Along Milligan Creek for several miles are intermittent exposures of Genshaw strata, from west of Brady Road nearly to the railroad bridge of the Detroit & Mackinac Railroad. Downstream are exposures of the Ferron Point Formation and Rockport Quarry Limestone. Excellent exposures in the banks and bed of the stream are found near the Brady Road bridge in Black Lake State Forest.

Kelly & Smith (1947, p. 462) reported, "One small exposure occurs in a miniature sink-hole on the north side of the road, 900 feet east of Waverly School No. 4... An estimated thickness of about 85 feet of Ferron Point and Genshaw lies between the lower and upper limits of the section. Some of the beds are highly fossiliferous."

(25) Loc. 35-1E-34 E-NE. About $\frac{1}{4}$ mile south of the northeast corner of the section, a bluff is capped by massive limestone containing conspicuous crinoid columnals in a dark gray matrix. This may be a unit within the Killians Member, or it may be an exceptionally dark bed in the lower part of the Genshaw. To the southwest, the bluff extends to the following locality. Kelly & Smith (1947, p. 462) said, "The total thickness of the beds exposed is difficult to determine because of the relatively

TEXT-FIG. 24 -- Test pits near the Carl Safronoff Quarry. Locality 34-1E-6 SE. Sorensen stands near the center of the exposure. Beds here are much more weathered than in the main quarry. Photograph by Kesling, 2 Oct 1975. Koehler Formation used as building trim.

long distance between outcrops. A probable interpretation, which accords with available structural information, indicates that nearly 100 feet of strata separate the lowest and highest beds. The highest beds are assigned to the lower part of the Killians member."

(26) Loc. 35-1E-34 C. An east-west bluff intersects North Tower Road about $1\frac{1}{2}$ miles north of the village of Tower. The shale and limestone exposed may include lower Genshaw and Killians Member.

In the guidebook for the 10th Annual Geological Excursion of the Michigan Academy, Kelly (1940) wrote, "The presence of specimens of Gomphoceras, a large cephalopod, as well as fish plates, suggests the Killians fauna, and these beds are probably high in the Genshaw."

(27) Loc. 35-1E-36 SE. About $4\frac{1}{2}$ miles south of Black Lake, black shale and limestone are exposed beside County Line Road at the southeast corner of section 36. The lithology and fauna both suggest Killians Member.

Kelly (1940) recorded, "Characteristic fossils include large sub-spherical heads of Favosites like alpenensis, Prismatophyllum sp., Spirifer like mucronatus (thick variety), Spirifer like euryteines (large variety), Gypidula sp., small Stropheodonta, gomphoceroid."

Kelly & Smith (1947, p. 463) reported that along County Line Road about $\frac{1}{4}$ mile south of this exposure "glacial deposits, containing a large proportion of Koehler limestone, are exposed in road-cuts."

(28) Loc. 35-1E-36 NE-SW. A series of low cuestas with north-facing steep slopes ex-

TEXT-FIG. 25 -- Koehler Limestone exposed in the quarries of the Onaway Stone Company near Onaway. The jointing is used to advantage in the hand-quarrying of particular layers, which are then scored with diamond saw and broken into brick-size blocks for building facings and trim. Locality 34-2E-5 N. Photograph by Kesling, 1969.

pose various limestone units of the lower part of the Killians and underlying strata belonging to the lower member. This locality lies east of Upper Black River Road on land owned in 1970 by Meredith and Howard Nave.

(29) Loc. 35-1W-19 SW/30 NW. About 2 miles west of Le Grand and the same distance north-northeast of Afton, around the junction of Cross Road and Ostrander Road, are ledges and roadside exposures of black shale and limestone that are excellent examples of Killians Member. With some interruptions, the ledges extend into sections 24 and 25, T 35 N, R 2 W.

Kelly wrote in the 1940 guidebook, "Note slabs of Genshaw limestone covered almost entirely with valves of Spirifer mucronatus... Other slabs of Genshaw possess a more varied fauna, including brachiopods such as Schizophoria sp., Spirifer like euryteines, Cyrtina sp., Athyris sp., and bryozoa such as Fenestella sp. and Sulcoretepora sp." We would assume that some of the rocks were probably from the lower member as well as the Killians.

Kelly & Smith (1947, p. 461, their Loc. 7) stated, "The best exposure of the Killians limestone in the Afton area occurs on a hill in NW$\frac{1}{4}$ Sec. 30, T 35 N, R 1 W. About 25 feet of Killians and 2 feet of sub-Killians Genshaw are exposed."

(30) Loc. 35-1W-30 SW-NW. Open field exposures about 1 3/4 miles north-northeast of Afton, situated about 3/8 mile south of Ostrander Road and just east of Cross Road on land owned in 1970 by August Carter. The Killians

here is practically continuous with the previous locality, and includes the hill mentioned by Kelly & Smith.

In the 1940 guidebook, Kelly mentioned several genera of brachiopods, a large cephalopod, and fish plates from this locality. He also said, "Following the road south the elevation increases about 100 feet between the northeast and southeast corners of Section 25, so that one crosses several formational boundaries."

(31) Loc. 35-1W-30 W-NW. A low ridge is cut by Cross Road about 100 feet south of its junction with Ostrander Road, exposing black strata of the Killians Member.

(32) Loc. 35-1W-30 N-NW. Genshaw beds are exposed in a road cut along Ostrander Road about midway between Cross Road and Morrow Creek.

(33) Loc. 34-2W-2 NE. About 3/4 mile west-southwest of Afton, Genshaw beds are exposed in the north bank of Pigeon River. The outcrops are located, according to the measurements of Kelly & Smith (1947, p. 461), about 1300 feet west and 1200 feet south of the northeast corner of section 2. These authors also reported, "Higher beds of the Genshaw are exposed at a spring about 30 feet up the valley slope, about 600 feet west and 500 feet south of the same corner. The section is continued 1000 feet north of the corner, where a bed of black limestone of the Killians member is exposed. The outcrop is about 50 feet west of the section line." We have not seen the spring.

(34) Loc. 34-2W-12 SE-NW. Along Pigeon River below the site of Old Elmer Dam, somewhere about midway between Afton and Beebe School and about ½ mile east of Sorenson Quarry, Genshaw Formation is exposed. Kelly & Smith (1947, p. 461) found discontinuous outcrops downstream from the dam for about 1,500 feet, and estimated a total section of 21 feet of limestone and shale.

(35) Loc. 35-2W-24 W-NW. This was Locality 6 of Kelly & Smith (1947, p. 461), who reported 2 feet of Genshaw limestone exposed along the southern branch of Little Pigeon River where the stream crosses the west line of section 24. This locality, which we have not seen, is situated on State land nearly a mile north of Ostrander Road.

(36) Loc. 35-2W-25 N-NE. About 2.3 miles west of Le Grand, a road cut on Ostrander Road exposes the black strata of the Killians Member. This was approximately Stop #15 on the 10th Annual Excursion of the Michigan Academy in 1940, when Kelly stated:

> Elevation 710 feet. Ledges of upper Genshaw in open field north of section 25, and exposures of Killians black shale and limestone along roadside which follows line between sections 24 and 25. [In this guidebook, this is locality 35-2W-25 N-NE.]

In addition to these localities of exposures of Genshaw strata, R. A. Smith reported in 1916 the results of a core drilling in sec. 19, T 35 N, R 1 W. According to our reckoning, this place is underlain by Genshaw Formation. Smith analyzed the core as follows:

Core drilling Sec. 19, T. 35 N., R. 1 W.

	Thickness feet
Surface	2
Light colored limestone	5
Light colored limestone	8½
White coral limestone	1½
Light limestone	4
White coral limestone	2½
Light limestone	2
White coral limestone	½
Light limestone	4½
Dark limestone	2
Light limestone	6½
Dark rock	1
Blue shale	8½
Gray shale	2

Thickness. -- Based on the averages of two wells in the area (see Appendix 9), the Genshaw Formation is about 147 feet thick in the Afton area, of which 122 feet are lower member and 25 feet are Killians Member.

Well records. -- Where the Ferron Point Formation is present, the base of the Genshaw can be readily and precisely identified as the first limestone unit atop the soft gray shale.

The upper limit of the formation in this area is at the top of the dark Killians Member, which in well logs is referred to as:

(1) W. M. Brown # 1, about 9½ miles southwest of Afton:
Killians Member (36')
Limestone, buff and dark-gray, shaly limestone (drills coarse 21
Limestone, dark-gray, shaly, bituminous ... 15

(2) Lewis A. Garred # 1, about 7 miles south of Afton:
Killians Member (20')
Limestone, very dark gray to black, fine-grained to dense, carbonaceous; shale, very dark gray 20

(3) State-Nunda "A" # 1, about 7½ miles south of midpoint between Tower and Afton:
Killians Member (30')
Limestone, grayish-brown to very dark brown, fine- to medium-grained, carbonaceous 30

Where the Ferron Point Formation is absent (near Afton and westward), the top of the underlying Rockport Quarry Limestone can be placed at the top of the units showing conspicuous porosity. Thus, the uppermost Rockport Quarry is described, in part, as:

(1) Clifford & Francis Brown # 1, about 3/4 mile south of Afton:
"limestone ... some leached porosity."
(2) Fred & Anna Brasseur # 1, about ½ mile south of Afton:
"limestone ... somewhat porous."
(3) State-Nunda # 1-3, about 6 miles southeast of Afton:
"limestone ... trace fine vugular porosity."

Where porosity is not mentioned, the boundary is more difficult to place on the basis of the log alone, because of the varied facies exhibited by the Rockport Quarry Limestone. Where the "coralline" facies is present, the Rockport Quarry is dark and gray compared to the light and buff basal Genshaw. On the other hand, where the "lagoonal" facies predominates the Rockport Quarry is usually harder and less crystalline than the lower Genshaw, often with clear-cut crystals of calcite filling tiny vugs in a sublithographic limestone.

Composition. -- Because the Genshaw Formation lacks commercial value, few analyses are available. However, some old assays were run at 5' intervals in a well in Alpena County at section 6, T 31 N, R 9 E, as reported by Kesling (in Ehlers & Kesling, 1970). In the following divisions of the formation there, the extremes of composition are given and the averages are indicated by asterisks:

Member	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	SiO_2	S	Total
Upper Genshaw	94.82	2.46	1.93	1.38	.11	100.70
	91.29*	2.15*	3.08*	2.60*	.13*	99.25
	87.64	2.35	4.83	4.16	.14	99.12
Killians Member	83.83	2.39	5.32	8.34	.21	100.09
	56.68*	4.34*	15.70*	20.89*	.19*	97.80
	26.42	6.44	25.88	35.24	.23	94.21
Lower Genshaw	92.22	3.13	2.78	5.74	.13	104.00
	75.34*	2.85*	5.25*	15.97*	.16*	99.57
	56.92	2.94	9.52	26.44	.19	96.01

Thus it becomes clear that the resistant Killians Member of the Genshaw is low-calcium, high-clay, high-silica, as compared to the bounding members. It is surprising that the lower Genshaw also contains an exceptional amount of silica. The silica in both is disseminated finely, and not due to sand or chert.

Fauna. -- The invertebrates listed from the Genshaw Formation in the Afton-Onaway area do not reflect the diversity of the fauna. Undoubtedly, careful collecting at the numerous localities would bring many more species to light and discriminating study would result in numerous taxonomic revisions. It would not be unreasonable to estimate that less than one-tenth of the invertebrates are recorded. In the Alpena area, the formation has yielded 43 species and 83 genera, as compared to only 11 species and 14 genera in our area. We believe that the same conditions prevailed in both areas, as indicated by lithologies, and that the same invertebrates resided in them.

From the Alpena area, where more intensive investigations have been carried on, the following are recorded in literature; those marked with an asterisk also have been reported in the Afton-Onaway area:

Rugose corals
- *Aulacophyllum scyphus* (Rominger)
- *Billingsastrea pauciseptata* Ehlers & Stumm
- *Billingsastrea romingeri* Ehlers & Stumm
- *Cystiphylloides phacelliforme* Stumm
- *Heterophrentis ferronensis* Stumm
- *Lythophyllum alpenense* Stumm
- *Tabulophyllum traversense* (Winchell)

Tabulate corals
- **Aulocystis alectiformis reptata* Watkins
- *Aulocystis fenestrata problematica* Watkins
- *Aulopora gregaria* Watkins
- *Aulopora microbuccinata* Watkins
- *Emmonsia alpenensis* Stumm & Tyler
- *Favosites alpenensis calveri* Swann
- *Favosites alpenensis hindshawi* Swann
- *Favosites alpenensis killianensis* Swann
- *Favosites digitatus* Rominger
- *Favosites mammillatus* Stumm & Tyler
- *Trachypora (?) reticulata* Stumm & Hunt

Brachiopods
- *Cyrtina umbonata alpenensis* Hall & Clarke
- *Helaspis luma crista* Imbrie
- **Helaspis luma luma* Imbrie
- *Leptalosia radicans* (Winchell)
- **Longispina subclava* Imbrie
- *Mucrospirifer multiplicatus* (Grabau)
- **Pentamerella tumida* Imbrie
- **Pholidostrophia gracilis gracilis* Imbrie
- *Schizophoria striatula delta* Grabau
- **Schizophoria striatula traversensis* Grabau
- *Schuchertella cornucopia* Imbrie
- *Schuchertella lirella* Imbrie
- **Sieberella romingeri* (Hall & Clarke)
- *Strophodonta acris* Imbrie
- *Strophodonta extenuata* Imbrie
- *Strophodonta extenuata genshawensis* Imbrie
- *Strophodonta proetus* Imbrie
- *Strophodonta titan* Imbrie
- *Truncalosia gibbosa* Imbrie

Cephalopod
- *Lyrioceras hindshawi* (Ehlers & Hussey)

Trilobites
- *Basidechenella nodosa* Stumm
- *Dechenella alpenensis* Stumm
- *Phacops rana crassituberculata* Stumm
- *Phacops rana milleri* Stewart

Blastoids
- *Pentremitidea ovalis michiganensis* Reimann
- *Pentremitidea preciosa* Reimann

In addition, the Afton-Onaway area has produced the following three brachiopods:

- *Heteralosia caperata* Imbrie
- *Orthopleura rhipis* Imbrie
- *Pentamerella* cf. *dubia*

Stromatoporoids have received little attention, but undoubtedly several species are present besides *Clathyrodictyon retiforme*.

Lithology. -- The enigma of the Genshaw is the composition of high-silica limestones in an environment that supported an abundant list of invertebrates. One might be tempted to explain the occurrence as quick precipitation of carbonaceous and siliceous fractions brought in by streams, but the lithology is widespread. We would welcome an explanation.

The impure limestones and shales of the lower Genshaw appear to be continuous with those of the Alpena area, marked by Sieberella romingeri and other large brachiopods; the large colonial corals are less numerous, perhaps indicating slightly different depth and less turbulence.

The Killians Member is the same in both areas, with the same resistance to weathering, the same color and bedding, the same fauna, and probably the same composition. The formation does not crop out in the Petoskey-Charlevoix area, but well records show no comparable lithology at this stratigraphic level, and the member appears to be replaced in that direction by limestone. In this, the Killians resembles the shaly sequences of the Dock Street Clay and Norway Point Formation in thinning out westward in the Michigan Basin.

The few localities where lighter-colored limestone is seen above the Killians may represent the upper member of the formation as exposed in Alpena County. If so, it seems to have thinned drastically. On the other hand, the beds seen above the typical black Killians may be intra-member units of the Killians itself. A quarry or cliff exposure of this portion of the sequence would allow better comparison with the Alpena sequence exposed on French Road and West Long Lake Road in that county. We have seen no unit marked by numerous Cyrtina umbonata alpenensis, for example. Well records are insufficient to document the faunal zones in the Afton-Onaway area; the limits of the Killians Member in wells is set by the lithology. At any rate, there is no thick section with Hexagonaria heads like that seen in the Huron Portland Cement Company Quarry in the city of Alpena.

Zones of Kelly & Smith. -- Kelly had studied the stratigraphy of the area for many years, and he and Smith together examined it intensively before their AAPG publication. No other field investigation has attained this level of thoroughness. At this time, we neither confirm nor dispute their zonation; we can only say that from our hurried visits to the various localities, the zones are not "obvious."

Kelly & Smith (1947, p. 452, 453) identified six faunal zones in the Genshaw of the Afton-Onaway area. From the base upward:

(1) Lower 10 feet of the formation, with two brachiopods which also occur in the Ferron Point Formation, Chonetes aff. fragilis (now Devonochonetes) and Pentamerella aff. dubia.

(2) Lower Pentamerella zone, characterized by their "Pentamerella sp. IV," which they say occurs only in the lower 20 feet of the formation.

(3) Clathyrodictyon-Pentamerella zone, from 25 to 70 feet above the base of the Genshaw, containing abundant specimens of their brachiopod Pentamerella ? sp. I (probably, we suspect, Sieberella romingeri), the stromatoporoid Clathyrodictyon cf. retiforme, and "a new species of Hexagonaria," large coralla of which occur through the zone.

(4) Cyrtina zone, from 70 to 100 feet above the base, with the characteristic zone 6 feet thick at the top containing great numbers of Cyrtina of at least three species.

(5) Transitional zone from the gray sub-Killians Genshaw into the black Killians Member, with abundant "Mucrospirifer sp. I" and Devonochonetes aff. fragilis, as well as undetermined fish plates and pygidia of the trilobite Proetus.

(6) Killians Member, marked by the upward continuation of "Mucrospirifer sp. I" but here associated with a breviconic cephalopod that they provisionally assigned to Gomphoceras; the lower part also contains Devonochonetes aff. fragilis.

These authors (1947, p. 453) also state that the Killians Member "is commonly separated by a concealed interval from the light gray to buff, sparsely fossiliferous, sub-lithographic limestones of the overlying Koehler formation." We have not seen a good locality at which the Genshaw and Koehler are both exposed, even with a covered interval.

KOEHLER LIMESTONE

Name and type locality. -- Kelly & Smith (1947, p. 454) introduced the name and defined the Koehler to include "gray, bedded, dense limestones of sub-lithographic texture, which are known to overlie the Killians black limestone, and underlie, unconformably, the Gravel Point crystalline and shaly limestone strata." The type locality was the Campbell Quarry, about a mile north of Afton in Koehler Township of Cheboygan County.

Seven years previously, Kelly had placed these beds in the lower part of his "Afton Beds" at this quarry, which was Stop #17 on the field excursion of that year. As shown in our text-figure, adapted from Kelly's figure, his "Afton Beds" included nearly 14 feet of Gravel Point Formation above the brecciated cherty limestone and associated clay seam that are taken as the top of the Koehler Limestone at the type locality.

In the Alpena area at about this stratigraphic position, is the Newton Creek Limestone. The Koehler resembles the Newton Creek in being a limestone sequence with apparently no native fauna, and both seem to have been "lagoonal" in the sense of being restricted from the open sea and having waters inimical to invertebrate life. The Koehler Limestone differs from the Newton Creek strata in being much lighter in color, more distinctly bedded, and lacking the ubiquitous petroliferous odor that marks the Newton Creek in all occurrences in Alpena County and eastern Presque Isle County. Analyses are not available, but we would suspect that the Koehler has a much higher percentage of calcium carbonate and a much lower percentage of clay, as well as practically no hydrocarbons.

The unconformity at the top, marked by brecciation below the thin clay seam, continues in subsurface and can be recognized in well logs and in well cores by the exceptional porosity and sudden yields of water at the horizon.

Thickness. -- Wells which penetrate the whole of the formation in the area show it to be around 80 feet thick. In outcrops, the lower contact is not exposed, although the beds in the Onaway Stone Company seem to be very low in the formation. The upper contact is seen in the Campbell Quarry north of the village of Afton, where several feet are presently being quarried for crushed stone.

Exposures. -- The Afton-Onaway area has nine localities at which the strata have been classified as Koehler Limestone. They lie in the projected position on the geologic map and are called Koehler because of their lithology and lack of fossils.

(1) Onaway Stone Company Quarries, $\frac{1}{2}$ mile north of the village of Onaway. For some years previously, small pits and quarries were operated on both sides of M-211 in this neighborhood, but now the sites of the quarries east of the highway have been obliterated by fill to produce runways for the local airfield. The present operations are west of M-211 in N$\frac{1}{2}$ NW$\frac{1}{4}$ sec. 7. The thin beds of light limestone are irregular in thickness and splitting character, so that for building and trim stone they must be selectively quarried. Discarded and stockpiled stone is present in such quantity that the actual outcrop is difficult to discern in many parts of the vicinity.

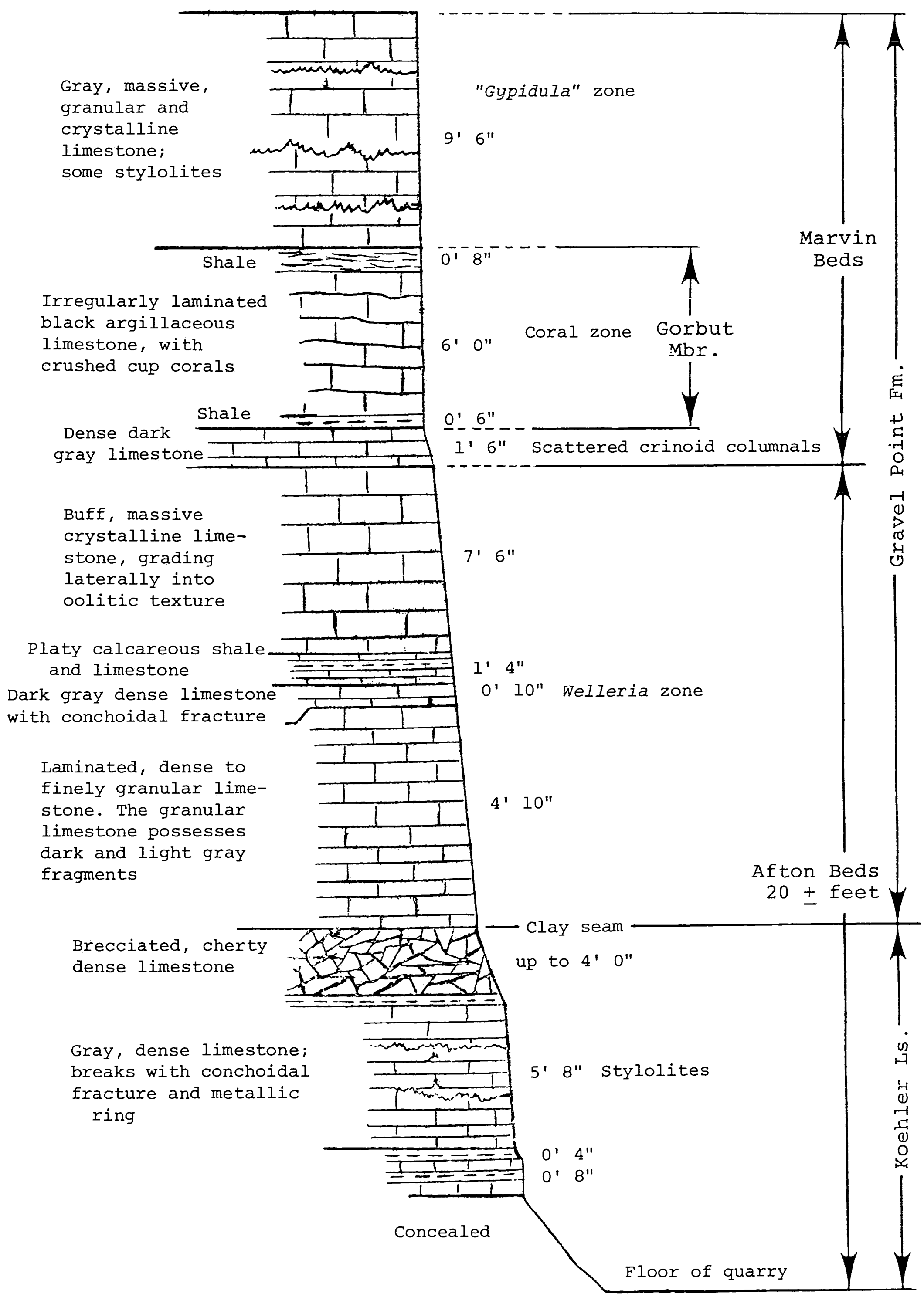
For practical purposes, the beds are unfossiliferous. Whatever invertebrates may be present are so badly worn, broken, and corroded that they cannot possibly be identified. The only identified fossil from the beds was associated belly and side plates of an arthrodire fish which was found by Chad Chapman in August 1962 and placed on display at the quarry office. It came from the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 6. Later, the specimen was donated to the Museum of Paleontology, where it was given number 46647 and became the holotype of Holonema farrowi Stevens. The absence of other animals on which such a large fish could have fed leads us to conclude that it was washed into the lagoon, probably after death and partial decay that resulted in loss of the large head shield.

The map of Kelly & Smith (1947, p. 448) shows this place to be underlain by the Killians Member of the Genshaw. Two years later, in the guidebook for the field excursion, Kelly altered the map of the area on his Map #2 to show Koehler Limestone (but he kept the 1947 version of geology on his Map #3!). Kelly & Smith did not mention the quarries at Onaway in their discussion or list of localities; we assume that the quarrying operations antedated their publication by some years.

In the 1949 guidebook, this locality was not one of the stops; in the description of the strata encountered in the Presque Isle Development Company Well near the railroad station in Onaway, Kelly included the uppermost unit of Middle Devonian rocks, which is evidently 15 feet of Koehler Limestone, under the general heading of "Traverse." Nor did he try to identify formations in his log of the William M. Brown #1 well, for which he presented a log.

The character of the beds at these small quarries is shown in our text-figures 25 (p. 45), 27 (p. 52), and 28 (p. 53). The stone is selectively quarried by hand methods (sledge and pry-bar), scored by diamond saw in the shop,

SECTION AT AFTON QUARRY



TEXT-FIG. 26 -- Diagrammatic section of strata exposed in Campbell Quarry near Afton. After Kelly, 1940 guidebook.

TEXT-FIG. 27 -- Koehler Limestone exposed in Onaway Stone Company Quarry. Locality 34-2E-5 N. The jointing of the limestone here is used to advantage in selective quarrying for building stone. Karl Kutasi, now retired, looks on a temporarily abandoned border of the quarry area. Photograph by Kesling, 1969.

and broken into brick-size pieces for use as facings on buildings, decorative walls, etc. The problem of quarrying for a particular order is the variations in thickness and color. The stone is particularly attractive for fireplace borders.

(2) Locality 34-1E-5 NE-NE. In the upper part of a bluff on Welch Creek, about $1\frac{1}{2}$ miles west-northwest of the village of Tower, dense limestone is exposed. This was Loc. 16 of Kelly & Smith (1947, p. 462).

(3) Loc. 34-1E-5 NW. At the base of a hill in the northwest corner of section 5, on the north slope, near the intersection of Brady Road and Kisser Road, about $2\frac{1}{2}$ miles west-northwest of the village of Tower, is an accumulation of blocks of dense sub-lithographic limestone similar to that exposed in the quarry north of Afton. The exposure, or nearly exposed strata, was described by Kelly in the guidebook for the 1940 excursion as follows:

> Base of north slope of hill in northwest corner of section 5. Elevation 755 feet. The surface of the hill is mantled with blocks of dense semi-lithographic limestone similar to the Afton beds which are exposed in the lower part of the Afton quarry. The character of the rock suggests an origin similar to that for the Black Lake exposures, and this may represent a lagunal facies of the Lower Alpena. This facies is not recorded east of this exposure. [In this guidebook, this is locality 34-1E-5 NW.]

The comparison with the basal beds at the Campbell Quarry near Afton is undoubtedly correct, and the strata belong to the Koehler Limestone.

(4) Carl Safronoff Quarry (Loc. 34-1E-

TEXT-FIG. 28 -- Koehler Limestone exposed in Onaway Stone Company Quarry. Locality 34-2E-5 N. Weathered surface developed along a joint exposes the irregular bedding. Quarrymen avoid the beds of irregular thickness, as well as those which fail to break readily when scored by diamond saw; as a result, the quarry area is congested with discarded pieces of limestone stacked at temporarily convenient areas. Photograph by Kesling, 1969.

6 SE-NW-SE). The main quarry was operated for a time by the Onaway Stone Company as their "No. 2 Quarry" for the same kind of stone as that in their main quarry. Now abandoned (text-fig. 6, p. 15), it has unused stockpiles and exposures of the Koehler irregularly distributed over a small area. The quarry was evidently inconvenient for transport of the stone.

Nearby test pits (text-fig. 24, p. 44) show the same kind of rock, somewhat more weathered. The soil cover in this neighborhood is very thin, and a reserve of the stone is plentiful. We did not ascertain whether the joints at this place are in the same direction as those at Onaway; in all other respects, such as color, bedding, and general hardness, the rock here cannot be distinguished from the product at the "No. 1 Quarry" at Onaway.

(5) Loc. 34-1E-6 SE-SE/8 W-NW. Near the intersection of M-33 and Brady Road, Kelly & Smith (1947, p. 462) discovered an outcrop of "sub-lithographic and cavernous limestone" of the Koehler in the SE$\frac{1}{4}$ section 6. It was not separated by much distance from exposures of the Killians, which crops out as ledges below water level where the stream is crossed by M-33. They included the whole vicinity in their Locality 15.

(6) Loc. 35-1W-29 NE/28 W/33 NW. In an escarpment more or less following M-33 from $\frac{1}{4}$ mile south of Le Grand to $\frac{1}{4}$ mile south of Knight Road, discontinuous exposures include both Koehler Limestone and Gravel Point

Formation. The condition of the exposures changes with the age of ditching operations, and only on fresh excavations can the character of the strata be clearly distinguished.

(7) Loc. 35-1W-33 SE-SE. Near the corner of M-33 and the southeast end of Knight Road (an angled road), on the property owned in 1970 by Ernest & Mary Knight, dense sublithographic limestone of the Koehler crops out in the banks of Adair Creek. When the stream is dry or nearly dry, the rock can be examined in the stream bed.

(8) Campbell Stone Company Quarry (Loc. 35-2W-36 NE). About 3/4 mile north of the village of Afton near Kimberly Creek is the quarry which has been operated intermittently for over 60 years. The easiest access is by Quarry Road on the west. Here the contact of the Koehler and the overlying Gravel Point Formation can be studied in detail.

The quarry was first studied by R. A. Smith (1916), who recorded the following section (numbering his beds from the top down):

Measured Section

Section in Afton quarry

		Feet
Glacial drift		0 to 2+
1. Light gray dense grained to crystalline limestone. $CaCO_3$, 97.32%		5
2. Black bituminous limestone with masses of cup corals. Much of the stone rejected though high in calcium carbonate. $CaCO_3$, 92.6%. Organic matter, 2.61%		6
3. Light gray crystalline limestone. Very pure and burns easily. Used chiefly for paper manufacture by the soda process. $CaCO_3$, 96.97%		4+
4. Disintegrated limestone. Falls to pieces in quarrying		1-
5. Very bituminous, banded, thin bedded limestone with bituminous bands. Parts readily along bituminous bands	$CaCO_3$ 98.04% (5–6)	$2\frac{1}{2}$
6. Similar to No. 5, but less bituminous. More bituminous near top		$5\frac{1}{2}$
7. Badly disintegrated or "vesicular" bed; belongs to bed below. Stone breaks into fine pieces in quarrying		2-
8. Very porous vesicular limestone. Openings due to solution. Stone breaks up badly, resulting in much waste	$CaCO_3$ 95.75% (8–10)	4
9. Light gray to buff fine grained limestone; main quarry beds. Stone used for lime obtained largely from this bed		10
10. Light gray to grayish buff limestone with thin shale parting at top		2
11. Vesicular limestone, the floor in part of the quarry		1+

Measured Section

In this, his units 8-11 includes the strata now assigned to the Koehler Limestone.

Smith also reported on the rocks encountered in a core drilling near the 1916 boundaries of the quarry:

Core Drilling, Afton Quarry

	Thickness feet
Clay, sand and broken rock	4
Light colored rock (This forms the quarry beds. Near the lower south side of the quarry the black limestone (No.2) is not present and the fact that this conspicuous bed was not noted in the record indicates that the hole was near the south edge of the bluff, hence the 38 feet of light colored limestone probably does not include beds No. 1 and No. 2)	38
Brown rock, soft. (This is probably the soft vesicular limestone which forms the bottom of the quarry)	6
Light limestone, hard	6
Dark limestone, soft	1
Dark limestone, hard	1
Blue shale, soft	5
Black limestone, hard	1
Light limestone, soft	2
Black limestone, hard	1
Light limestone, soft	1
Mixed dark and light limestone, hard	13
Light limestone, hard	4
Gray limestone, hard	5
Mixed dark and light limestone, hard	7
Black limestone	5

In the core drilling, perhaps 16 feet of his thick 38-foot unit belong to the Koehler, as well as all the underlying units.

The quarry was also visited by the 1926 expedition, at which time Ehlers, Ulrich, and Case noted the general lithology.

In the 1938 guidebook, Ehlers presented a measured section which he had measured in 1934:

Measured Section

Section of Strata Exposed in the
Campbell Stone Co. Quarry at Afton
By G. M. Ehlers - 1934

	Ft.	In.
8. Limestone, gray, very fine grained. Contains Gypidula, Prismatophyllum sp. with small corallites, columnals of crinoids, Spirifer sp. - S. mucronatus type, Stropheodonta sp. - S. erratica type, and Fenestrellina sp. indet.	8	
7. Limestone, brownish-gray, with irregular black shale partings. Numerous Favosites sp. - F. alpenensis type and cup corals. Carbonaceous shale abundant in lower 2 feet and in a 10 inch band at top	4	10
6. Limestone, gray, numerous fossil fragments in beds, separated above and below by carbonaceous shale partings. Contains Prismatophyllum and Favosites	1	9
5. Limestone, oolitic, light buff gray, thick bedded and massive. Favosites near top ...	8	4
4. Limestone, similar to that below, more thinly bedded and darker; contains numerous specimens of Welleria aftonensis Warthin	2	4
3. Limestone, gray, with some laminae of carbonaceous material, breaking into thick blocks	4	4
2. Limestone, light brown, contains chert and lenses of brown limestone	10 to 16"	
1. Limestone, lithographic, gray, numerous small cavities, base not exposed	6	9
	37'2"	37'8"

Measured Section

His units 1 and 2 are now called Koehler. Comparison with the section measured by Smith (see above), it is obvious that the quarrying operations had changed the base of the quarry, so that Ehlers did not see strata as low as those reported by Smith some 18 years previously.

Kelly & Smith (1947, p. 454) offered a simplified section of the strata at this quarry. They added, "North of the quarry and on the lower slope of the hill, a pit exposes limestone of the Koehler facies. There is a concealed interval of 30 feet between the bottom of the pit and the highest exposed strata of the Killians black limestone member. The evidence suggests that the Koehler formation has a thickness of 30 to 40 feet. This is substantiated by the drill cuttings from the Campbell well No. 1, Sec. 7, T 34 N, R 1 W, south of Afton." We have studied the log of this well and find it so generalized in units and lithology that we would hesitate to put such precise limits on the Koehler Formation. Nevertheless, we find it difficult to accept such a thin total for the formation here, inasmuch as the Koehler is clearly 80 feet thick in the Lewis A. Garred well less than six miles to the south-southwest (Appendix 8).

In 1949, Kelly gave a detailed description of the strata exposed in the Campbell Quarry:

Measured Section

Campbell Stone Company Quarry

Beds 14, 15, and 16 constitute the Gorbut member.

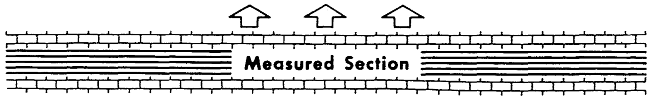
Lower Gravel Point Formation	Ft.	In.
17. Massive, fine grained, gray stylolitic limestone. Coral "Hexagonaria" and "Pentamerella" are most common fossils	9	6
16. Irregularly laminated, lenticular, dark gray to brown argillaceous limestone with many black shale partings	0	8
15. Irregularly laminated black shale and brown to black limestone, differing from bed above in greater proportion of limestone. Numerous crushed specimens of a long solitary coral, provisionally referred to "Heterophrentis," occur in shale layers	6	0
14. Black shale with lenticular black limestone layers	0	6

13. Compact, dense, dark gray limestone with scattered crinoid columnals	1	6
12. Massive, finely oolitic to finely granular buff limestone. Sparingly fossiliferous, but does include isolated gastropods and large heads of "Favosites"	7	6
11. Alternating thin layers of limestone, platy calcareous shale and soft shale. This member is lenticular	1	4
10. Dark gray to black, dense limestone with abundant tests of ostracod "Welleria aftonensis"	0	10
9. Irregularly laminated, dense to finely granular gray limestone	4	10
Total Gravel Point	32	8

There is a prominent break at the clay seam, bed No. 8, in the Campbell Stone Quarry and the overlying beds are assigned to the Gravel Point. The clay seam may be traced almost continuously around the walls of the quarry, but the detailed characters of the beds immediately beneath the clay seam differ from each other. In the section measured along the north side of the quarry, bed 7 underlies the clay seam. At a distance of 800 feet the section on the south side of the quarry shows a 4-ft. bed of gray fragmental limestone intercalated between the clay seam and bed "7". The 4-foot bed contains an agglomeration of small heads of "Hexagonaria" and "Favosites" in addition to fenestellids and crinoid columnals.

Koehler Limestone

8. Clay seam with spherical and ellipsoidal chert concretions. Surfaces of concretions rough and pitted. Fracture surfaces reveal impressions of cubic and tetragonal crystals	1	0
7. Light gray limestone with connected solution cavities near top. Cup corals provisionally assigned to the genus "Heterophrentis" common in lower half. A few specimens of Hexagonaria have also been found in this interval, separated from bed below by thin layer of platy black shale	2	0
6. Light bluish gray, blocky, stylolitic, dense sublithographic limestone with irregular calcite fillings. Rock has conchoidal fracture and metallic ring	5	8
5. Black, platy, hard shale	0	4
4. Dark gray dense limestone with thin intercalation of calcareous shale at base	0	8
3. Light gray, blocky, dense, sublithographic limestone	1	0
2. Concealed	2	0
1. Light gray, thinly bedded, dense limestone forming base of quarry		
Total Koehler	12	8



(9) Sorenson Quarry (Loc. 34-2W-11 E). This small abandoned roadside quarry, now largely overgrown (text-fig. 8, p. 17), has typical unfossiliferous sub-lithographic limestone of the formation exposed not far from the bounding formations. Along Munger Road to the north, near the bridge, are plentiful float pieces of dark limestone that indicate the Killians is not far underground. Along the same road to the south, near Beebe School, are outcrops of the Gravel Point Formation.

This locality was included in the 1926 expedition, and will be discussed later as it refers to the thickness of the Gravel Point.

In the 1940 guidebook, Kelly referred these beds to his "Afton Beds" as they were then known:

> Sorenson quarry. Elevation about 795 feet. Exposure of dense, semi-lithographic limestone with many solution cavities. This bed is assigned to the Afton, partly on its lithology, and partly on its position with respect to an outcrop of the Genshaw limestone (elevation about 750 feet) on the banks of the Pigeon River about ½ mile to the east. South of the Sorenson quarry loose blocks of the ostracod and oolite beds have been found.

In addition to these exposures, the upper part of the Koehler has been reported from the abandoned Marvin Quarry (Loc. 34-1W-7 S-NE). The quarry will be discussed below under the Gravel Point Formation. This site was known to R. A. Smith, who erroneously reported it in his 1916 book on limestones of Michigan as the "Marion" quarry.

In 1940, Kelly included this as his Stop #22 on the field excursion, and wrote, "At the west end of the quarry beds of the Afton are exposed." In 1947 Kelly & Smith reported (p. 454), "Only a few feet of the beds near the upper contact (of the Koehler) are missing in the Marvin and Sorenson quarries." On the following page (p. 455) these authors stated, "In the Marvin Quarry the highest bed of the Koehler is a dense sub-lithographic limestone which contains a relatively large number of gastropod molds." The present state of the quarry did not reveal to us the location of this exceptional occurrence of fossils in the formation, although the stratigraphic position supports the contention of the writers that the strata are indeed Koehler.

Another reported occurrence of the formation is in the Le Grand Quarry (Loc. 35-1W-28 SE). We have not visited this quarry together, and Kesling last saw it around 1949. The section is nearly identical with that of the Campbell Quarry not far to the west. The stratigraphic relationships will be discussed more under the Gravel Point Formation. Kelly & Smith (1947, p. 455) wrote, "No fossiliferous strata were observed in the exposures of the Koehler formation in the Le Grand Quarry... The irregular contact between the Koehler and the lower Gravel Point, suggest that a part of the Koehler was eroded prior to the deposition of the Gravel Point."

It might be pointed out here, to clarify the picture of stratigraphy, that Pohl (1929, pl. 1) correlated the beds now assigned to the Koehler in this area with the Charlevoix Limestone of the Charlevoix area, evidently on lithology and the occurrence of the gastropod molds at Marvin Quarry. However, as pointed out by Kelly & Smith (1947, p. 455), this cannot be supported. They said, "Although both formations are characterized by dense semi-lithographic and stylolitic limestone, and gastropods have been found in each, little weight can be assigned to these criteria. Limestone of lithographic character is comparatively common in Michigan... Preliminary examination of the Koehler gastropods does not indicate that they are conspecific with those from the Charlevoix." They also stated, "The oolite bed of the Charlevoix is stratigraphically much higher than the *Chonetes emmetensis* zone of the Gravel Point, whereas the oolite bed observed in the Afton Quarry is below the Gorbut limestone, which in turn is below the *Chonetes emmetensis* zone."

Sedimentation. -- Whatever the medium of precipitation of these limestone layers, it left no obvious mark. The lack of fauna would indicate that the water was not of normal salinity and that the basin in which the formation was deposited was cut off from the main sea, which in most other Traverse Group formations produced an exceptional array of corals, brachiopods, molluscs, trilobites, stromatoporoids, and bryozoa.

The uneven bedding is notable, evidently the result of interruptions of the limestone-forming process at rather frequent intervals.

Unfortunately, no analyses have been run on the formation. It would be helpful to compare the composition of this formation with that of the bounding formations. The uppermost Genshaw Formation that is seen in most exposures is black Killians Member, exceptionally rich in silica and clay. In the basal part of the Gravel Point Formation, shales are more frequent as interbeds and the strata yield fossils.

The best suggestion for the origin of the limestones of the Koehler is that of Kelly, who first called them (1940) "a lagunal facies." We would interpret this to mean that the area was again like that in which the sub-lithographic facies of the Rockport Quarry Limestone was deposited -- cut off from the main sea and too saline to support most invertebrates.

GRAVEL POINT FORMATION

Name and type locality. -- As pointed out by Kesling, Segall, & Sorensen (1974, p. 58) the first use of the name was by Pohl (1929), who termed it the "Gravel Point stage." He did not specify a type locality, but it must be presumed that he referred to Gravel Point, a small projection of land into Little Traverse Bay just west of Charlevoix. This point has also been called Pine River Point and South Point, the name which appears on some modern maps.

The formation is poorly exposed, particularly at times of high lake level, at the point. The site was visited by the 1976 field excursion of the Michigan Basin Geological Society, but no rock definitely in place could be found; however, excellent exposures near and below lake level were seen about a mile southwest of the point, providing a fine display of *Hexagonaria* heads in the rock. Intermittent exposures extended perhaps half a mile to the north.

TEXT-FIG. 29 -- East wall of Campbell Quarry north of Afton, exposing Koehler Limestone and Gravel Point Formation. Locality 35-2W-36 NE. Karl Kutasi stands on quarry floor. Local unconformities can be seen in both formations. Photographed by Kesling, 1969.

The strata at Gravel Point were well known long before Pohl's publication. They had been described by Alexander Winchell, Carl Rominger, and A. W. Grabau.

The name and implied type locality were not particularly good choices, for in both Charlevoix and Emmet Counties there are much better and more extensive exposures.

Thickness. -- Kelly & Smith (1947, p. 460) based their estimate of the thickness on the occurrence of outcrops along Munger Road. In their figure 5, a cross section along this road, the vertical scale is obviously incorrect; as shown on the USGS topographic map (1:62500), Wolverine Quadrangle, the elevation of Pigeon Creek where it passes under the road is 745' and the highest hill between the creek and Bebee School is 810', or a difference of 65' relief. Kelly & Smith's scale indicates this difference to be about 190' (about 3 times as great) and a figure that cannot possibly be right. They stated, however (1947, p. 460), "If we take an approximate mean of ... dip components, that is about $1\frac{1}{4}°$, and allow for the change in elevation from the northern outcrop to the southern outcrop, an estimated thickness is about 60 feet." As their section shows, the respective outcrops are about 4000 feet apart (horizontally), which at a dip of $1\frac{1}{4}°$ would account for 85 feet of thickness; when their difference in elevation is subtracted (evidently 25'), this gives their estimated 60 feet for the whole of the Gravel Point Formation.

Approximately $5\frac{1}{2}$ miles south of this intermittent outcrop area along Munger Road is the Lewis A. Garred #1 well, in SE$\frac{1}{4}$ sec. 1, T 33 N, R 2 W (see Appendix 8). In this well the top of the Gravel Point Formation appears to be a 7-foot shale unit, which probably cor-

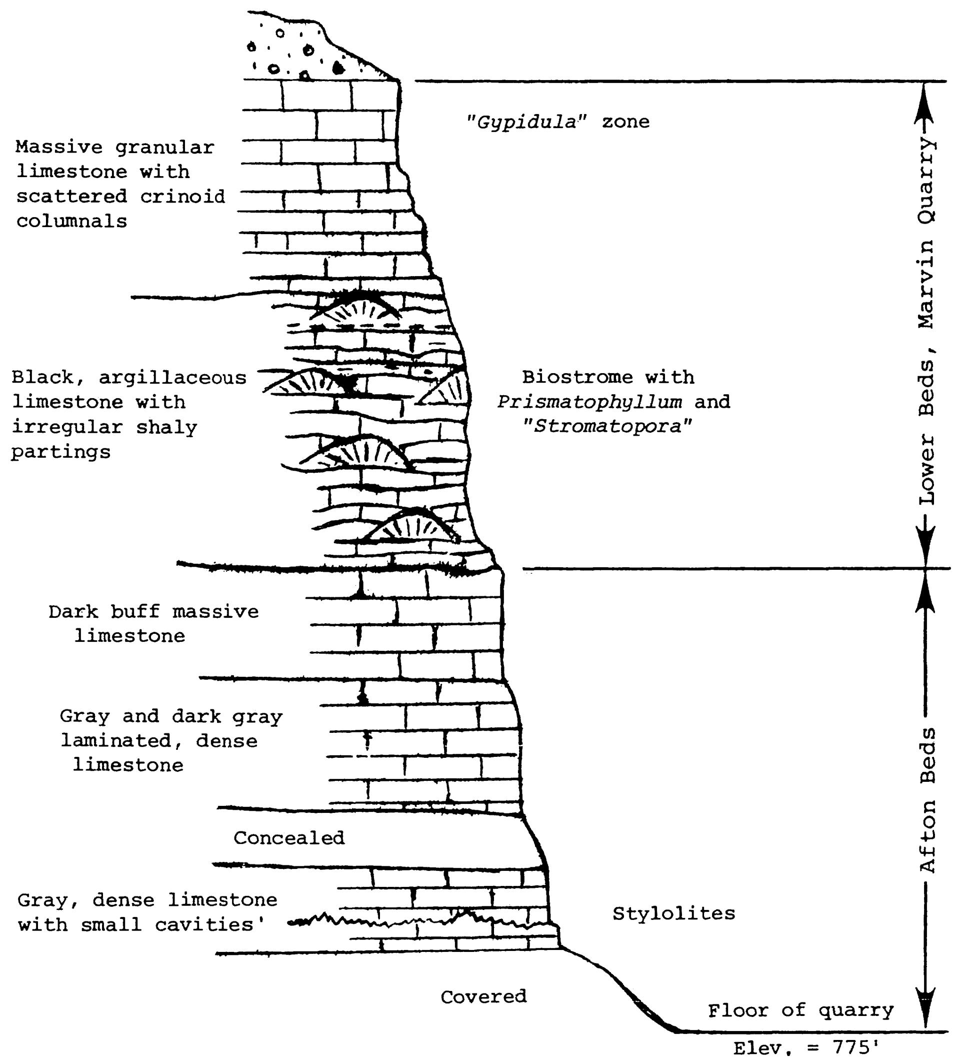
TEXT-FIG. 30 -- East wall of Campbell Quarry showing the best section. At the left side, the following stratigraphic horizons are indicated: GPt/K = Gravel Point/Koehler contact; W = limits of the *Welleria aftonensis* zone; Gb = limits of the Gorbut Member. Photographed by Kesling, 1969.

relates with the "upper blue" shale unit at the top of the formation in Emmet and Charlevoix Counties to the west. The base of the Gravel Point in this well appears to be 80 feet above the 20-foot black limestone unit which we assign to the Killians Member of the Genshaw. Hence, as shown in the full record in the appendix, the Gravel Point Formation appears to be 200 feet thick in this well.

Additional evidence also indicates that the estimate of Kelly & Smith was much too low. The structural contour map on the top of the Bell Shale (presented later in discussion of structure) shows the average southerly component of dip to be about 175'/mile through this part of the township (approximately 2°). Even this figure may be low for this part of the section. Kelly & Smith (p. 460) found the dip in the southern part of the exposures to have a southerly component of about $2\frac{1}{2}$°; they assumed that the strata in the northern part of the exposures were nearly flat, and arrived at their average of $1\frac{1}{4}$°. There are, however, so few exposures in the northern outcrops that a reliable dip cannot be determined. We suspect that the dip of 3°, which we find on the Beebe School Formation just south of these outcrops, continues on through the belt of Gravel Point exposures.

We accept the horizontal distance given by Kelly & Smith (1947, fig. 5) as being correct: about 4000 feet between the upper Koehler Limestone exposed in and near Sorenson Quarry (elevation about 810') and the contact with the Beebe School Formation (elevation about 785'). For a dip of 3° (= 52' vertical/1000' horizontal), a thickness of 208' is indicated; from this we subtract the 25' for topographic difference, and arrive at an estimated thickness of the Gravel Point Formation of 183 feet. If instead, we assume a dip of $2\frac{1}{2}$° (= 44' vertical/1000' horizontal), the thickness for the formation would be 151 feet; but if the dip were as much as $3\frac{1}{2}$° (= 61' vertical/1000' horizontal), the Gravel Point would be 219 feet thick. At any rate, it

SECTION AT LE GRAND QUARRY



TEXT-FIG. 31 -- Diagrammatic section of strata exposed in Le Grand Quarry. From Kelly, 1940 guidebook, with labels relettered.

seems probable to us that the Gravel Point Formation in this area is nearly as thick as it is in the Garred well -- not much less than 200 feet.

The records left by the 1926 expedition are even more puzzling. They examined strata at three localities along what is presently called Munger Road, which they listed as Localities 22 (which Ehlers & Ulrich described as $1\frac{1}{2}$ to 1 3/4 miles south of Afton, and Case called Sorenson Quarry), 23 (in the vicinity of Beebe School; Ehlers & Ulrich described it as 150 feet north to about $\frac{1}{4}$ to 1/3 mile south of the intersection of Munger and Beebe School Roads), and 26 (midway between Locs. 22 and 23. In his notes made in the field, Case wrote, "Probably not much lacking between 22 and 26 (a very few feet at most. Base of loc. 23 continuing north to 22, completing sections 23 and 22." Ehlers & Ulrich were also convinced that they recorded an essentially complete stratigraphic section from Sorenson Quarry on the north to $\frac{1}{4}$ mile past Beebe School on the south; in their revised notes, combined with information supplied by Case, they listed the beds serially from the low-

TEXT-FIG. 32 -- Part of east wall of Campbell Quarry north of Afton. Beds at this place have a slight dip to the north. Locality 35-2W-36 NE. Photographed by Kesling, 1969.

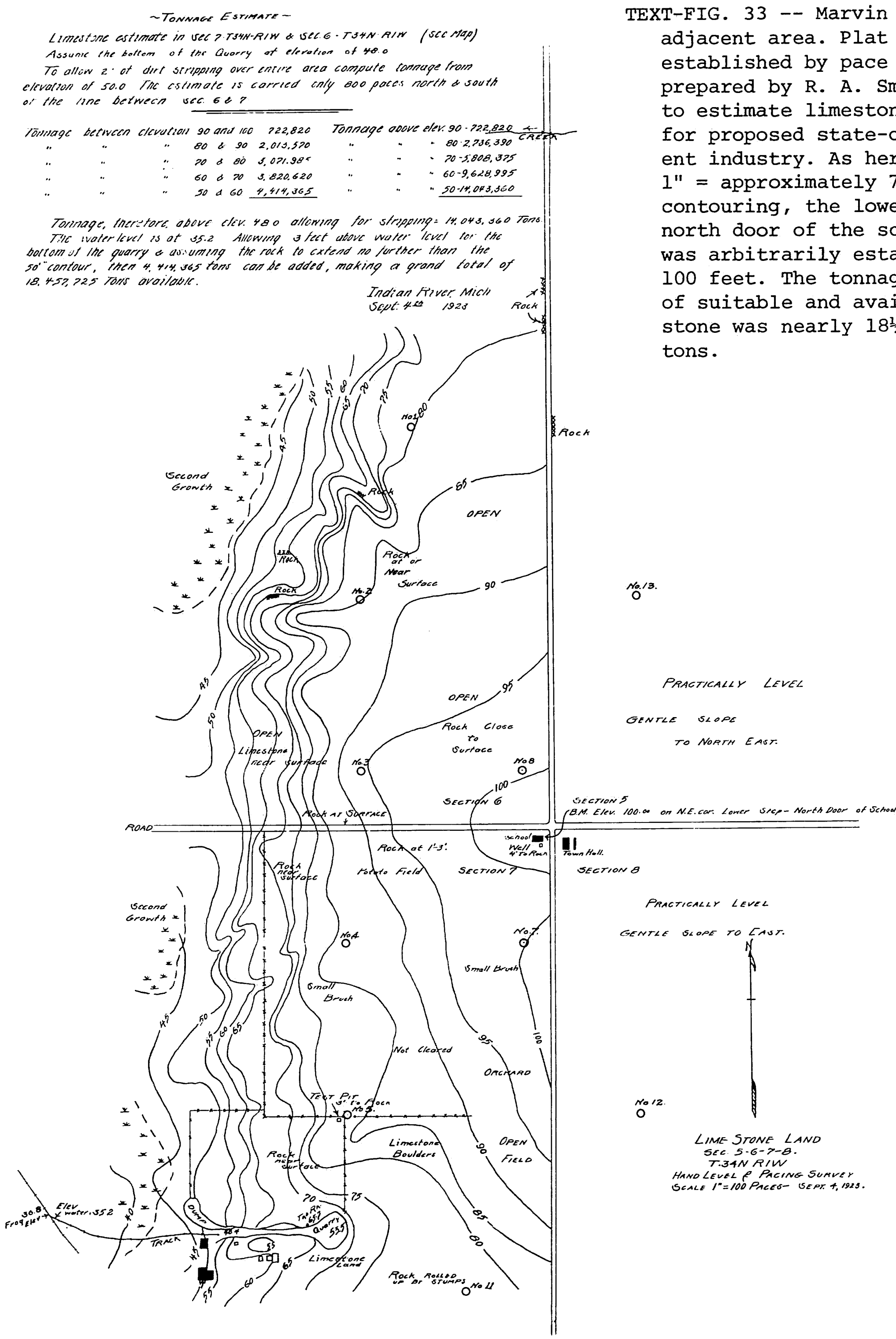
est at Sorenson Quarry to the highest beyond the School. In the 1938 guidebook (Ehlers, in Bergquist & Ehlers, 1938, p. 10-12), this 25-unit combined section was published and credited to "E. O. Ulrich et al. - Michigan Geol. Surv., 1926." The implication was unmistakable, that the section was considered to be essentially entire by all concerned.

However, as shown by Kelly & Smith in their measured section of the Beebe School Formation (1947, p. 460), only the strata exposed in localities 23 and 26 formed a nearly complete section or sequence. We can readily correlate most of the units described in the two accounts:

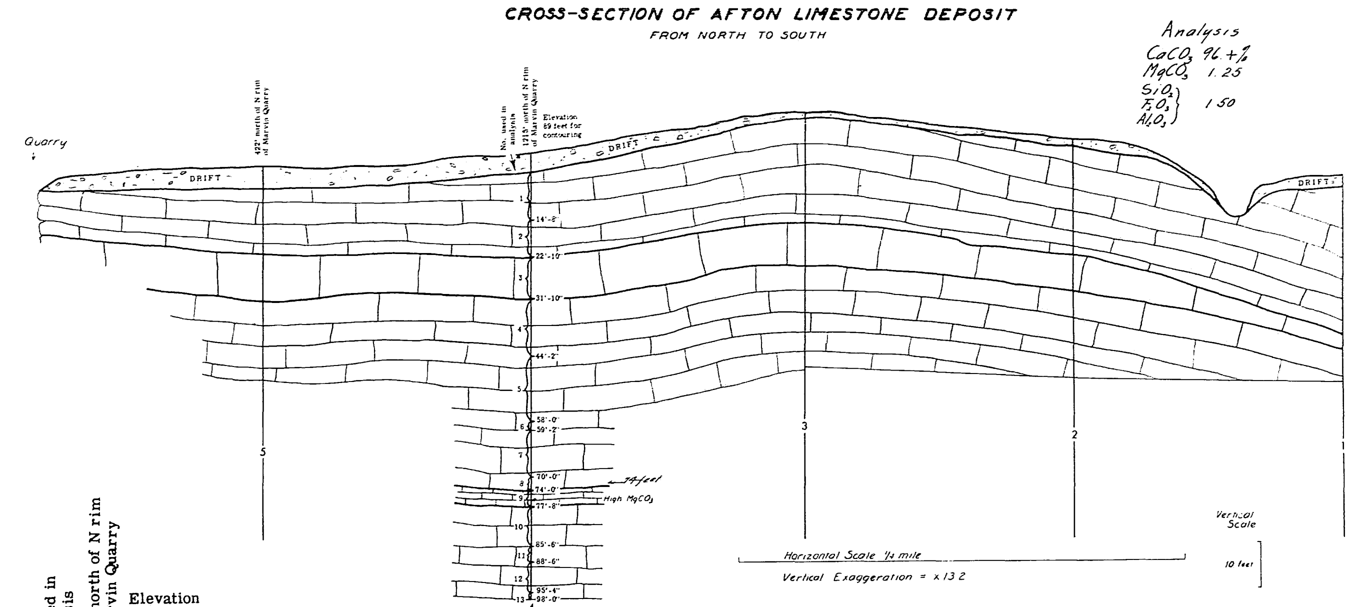
Kelly & Smith	Ehlers & Ulrich
Bed 4 - ls., 20'	Units 16-20 - ls., 21½' max. (= loc. 23, beds 2-6)
Bed 3 - sh., 30'	Units 14-15 - sh., 32' max. (= loc. 23, bed 1, and loc. 26, bed 9)
Bed 2 - ls., 10'	Units 10-13 - ls., 7½' (= loc. 26, beds 5-8)
Bed 1 - reef, 10'	Unit 9 - reef, 3' (= loc. 26, bed 4)

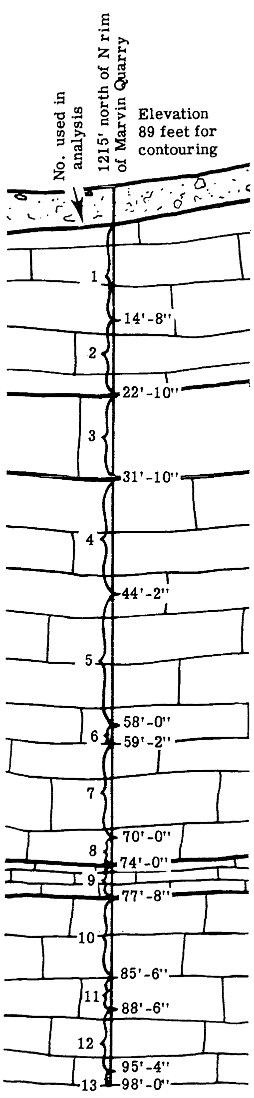
Kelly & Smith described the uppermost bed of the underlying formation as a "massive, fine-grained, gray limestone containing coral Hexagonaria percarinata (Sloss)"; Ehlers (1938 guidebook, p. 11) listed "Prismatophyllum" (old name applied to Hexagonaria) in Unit 8 of the combined section.

As shown by Kelly & Smith (1947, fig. 5), most of the strata at locality 22 (Sorenson Quarry and vicinity), perhaps all, belongs in the up-



TEXT-FIG. 33 -- Marvin Quarry and adjacent area. Plat with contours established by pace and compass, prepared by R. A. Smith in 1923 to estimate limestone reserves for proposed state-operated cement industry. As here reduced, 1" = approximately 775 feet. For contouring, the lower step at the north door of the school house was arbitrarily established as 100 feet. The tonnage estimate of suitable and available limestone was nearly 18½ million tons.





TEXT-FIG. 34 -- Cross section through test holes in Marvin Quarry area, prepared by R. A. Smith in 1923. The locations of the holes is shown in the previous text-figure. At the left is the section through the No.4 hole with units marked for Smith's described section.

permost part of the Koehler Limestone. At this locality Ehlers (1938 guidebook, p. 11, 12; also his original field notes with Ulrich) measured only 9'2" of limestone strata. If, as seems entirely correct, the Sorenson Quarry exposures contain only Koehler, then the 1926 expedition recognized only beds 1-3 of their section at locality 26 (units 6-8 in the 1938 published section) as strata now included in the Gravel Point Formation -- an astonishingly little 4 feet of gray limestones! Yet they assumed that all strata were accounted for in the section. How could they have been misled to believe the sequence was nearly continuous? They examined the exposures while much of the road was under construction, and ditches were fresh. Could there be a fault running through this area? Or could they have missed nearly 200 feet of strata because they connected isolated outcrops by hand-level and failed to take the steep dip into consideration? How did it happen?

The exact thickness of the Gravel Point Formation in the Munger Road vicinity can only be established by a series of drill cores, closely spaced and carefully correlated.

As stated, the Garred well shows 200 feet of Gravel Point; a few miles to the west, the William M. Brown well shows 215 feet (Appendix 8); and far to the west, the East Jordan Lumber Company well shows 195 feet of the formation. This is a consistent formation in subsurface, and we have no cause to doubt that the same general thickness prevails in the outcrop area. Certainly, Kelly & Smith's 60 feet and the 1926 expedition's adjusted 4 feet are not to be accepted.

TEXT-FIG. 35 -- Gravel Point Formation in the Marvin Quarry. Locality 34-1W-7 S-NE. Nearly the same section is exposed here as at the Campbell Quarry, although the Koehler Limestone does not appear in this scene. Photographed by Kesling, 2 Oct 1975.

Exposures. -- In the Afton-Onaway area, the Gravel Point Formation is exposed in both natural outcrops and quarries. It is a series of limestones of varying purity and color interbedded with limy shales. Probably the uppermost unit in this area is a soft shale, only a few feet thick. A few of the units are fairly high calcium stone and constitute a reserve.

(1) Loc. 34-2E-6 SW-NW. This easternmost exposure of Gravel Point is a massive crystalline white limestone, much like the Alpena Limestone in Alpena County, exposed in a railroad cut of the Detroit & Mackinac Railroad about a mile west of Onaway.

A. W. Grabau around the turn of the century constructed a list of localities in Michigan which was never published but a copy was filed in the Museum of Paleontology. From his description, this was at or close to a natural outcrop of limestone which he labeled Locality 98.

Dave Swann in working on his doctoral thesis added to the list of localities compiled by the 1926 expedition, and called this Loc. 113. He regarded the beds as a few feet above the Gorbut Member, based on lithological similarity to the limestones found in the railroad cut near Le Grand Quarry.

Kelly & Smith (1947, p. 463) included the place as their Locality 27. They reported it to be sparsely fossiliferous but containing a coral allied to Hexagonaria percarinata.

(2) Loc. 34-1E-1 S-SE. Limestone is exposed in road cuts along M-33/M-68 about $1\frac{1}{4}$ miles west of Onaway and 2 miles east of Tower Pond. This locality is probably Loc. 99 of A. W. Grabau's unpublished list. It was Stop #6

TEXT-FIG. 36 -- Gravel Point Formation exposed in a long-abandoned railroad cut east of the site of Gorbut School and southwest of Le Grand Quarry. Locality 35-1W-33 N. The limestone here is considered to be above the Gorbut Member. Photographed by Kesling, 2 Oct 1975.

on the 1940 field excursion; Kelly wrote in the guidebook that "Some of the limestone lacks stratification and suggests a reef facies. The exposures of stratified limestone are crystalline and crinoidal, and are in contrast to the dense lithographic limestone, which, in the area to the west, is known to overlie the Killians." He called the rock Lower Alpena limestone.

Kelly & Smith (1947, p. 463) called this their Locality 28, and said, "Few fossils other than flat stromatoporoids, colonial and simple corals, occur. The presence of a variety of Hexagonaria closely allied to form found elsewhere only in the Gorbut member, suggests an age equivalent to the Gravel Point."

In our view, the eastern exposures in the Afton-Onaway area are much more like the Alpena Limestone to the east than the typical beds of Gravel Point in the Campbell, Marvin, and Le Grand quarries. For simplicity in mapping, we call these equivalents in the Afton-Onaway area Gravel Point.

(3) Loc. 34-1W-3 N-NE. In the roadbed of M-33 about 1 2/3 miles east-by-south of The Fingerboard Corner, not far beyond the point where the road bends southeast, exposures of massive limestone could be seen in the past. In 1975, we could not find a good outcrop at the place, probably because of the disturbances caused by grading the shoulders, filling, and blacktopping the road.

Kelly & Smith (1947, p. 462) called this Locality 11, and described it as "massive fossiliferous limestone of the Gravel Point formation, similar to that which overlies the Gorbut member."

(4) Loc. 34-1W-6 SE. A little over half a

mile north of Marvin Quarry, just north of the intersection of Weir Road and Pigeon River Road, exposures of limestones can be seen on the southwest face of a bluff. This was Stop #23 on the 1940 excursion, and Kelly reported the presence of both his "Lower (Black)" and "Upper (Gray) Marvin." Roughly, this corresponds to the dark Gorbut Member and the upper part of the formation.

(5) Marvin Quarry, Loc. 34-1W-7 S-NE. This quarry was studied by R. A. Smith, who reported in 1916 the following section:

Measured Section

Section in Marion Stone Co. quarry

	Thickness feet
Surface	1-3
1. Densely crystalline limestone, fossiliferous in places	4
2. Very fossiliferous limestone with bands of very fine grained limestone, showing "ribbon" structure on weathered surface	$3\frac{1}{2}$
3. Dense grained to crystalline limestone with abundance of corals and brachiopods in places	5
4. Gray crystalline limestone	$1\frac{1}{2}$
5. Light gray densely crystalline and fossiliferous limestone	4
6. Black bituminous limestone with scattered cup corals. Burns hard and larger pieces have a black carbonaceous core	6
7. Vesicular limestone. Cavities due to solution. Lowest bed exposed in quarry	$2\frac{1}{2}$

The vesicular beds when below the water table yield large quantities of water. For this reason quarrying operations must be confined largely to the bluffs where the strata are self draining.

Measured Section

As explained by Smith in his letters to Professor Case (text-figs. 2, 3, on p. 6, 7) the name "Marion" for the quarry was an error.

As discussed in the Introduction and illustrated in text-figures 33 and 34 (p. 60, 61), the area was scrutinized by the state survey in the early 1920's as a possible site for a state-operated cement industry, where prison-labor could be turned to a profit for the state. At that time, analyses were run on the limestone in Marvin Quarry, as recorded in manuscripts deposited in the Survey office. Smith found the following results in the Hole No. 4 (see text-figs. 33, 34):

Analysis of Afton Samples - Hole No. 4

Elevation at top of north rim of Marvin Quarry 65.7 ft. or 19 ft. lower than top of hole No. 4 located 1215 ft. north of north rim of quarry.

Sample No.	Thickness	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	$MgCO_3$
1	10'8"	0.8	0.4	97.2	1.3
2	8'2"	0.6	0.5	98.0	0.8
3	9'0"	0.9	0.7	96.2	1.5
4	12'4"	0.7	0.4	98.0	1.3
5	13'10"	3.4	0.4	92.0	3.6
6	1'2"	2.4	0.6	95.3	1.4
7	10'10"	1.7	0.6	95.8	1.3
8	4'0"	1.9	0.8	94.4	2.3
9	3'8"	3.4	0.9	62.1	33.1
10	7'10"	7.7	1.1	85.6	4.2
11	3'0"	1.3	1.0	69.9	27.0
12	6'10"	1.6	0.8	95.3	1.5
13	2'8"	1.6	0.8	87.6	9.2

The strata of this well were described as:

Afton - Hole No. 4

DESCRIPTION: 528 ft. south and 924 ft. west of SE corner sec. 6, T34 N, R 1 W.
ELEVATION: 84.7 ft. (BM 100 ft. on lower NE school step NE corner sec. 7).
Begun Dec. 20, 1923, day shift. Completed Dec. 22, 1923, night shift. E. J. Longyear Company, drillers; A. Shepsteadt in charge; Wm. Hillman, night shift.

	Ft.	In.
1. Brown, very porous, corals and crinoid fragments	10	8
2. Brown to gray bituminous, crystalline to earthy	8	2
3. Brown to black, very fossiliferous, with bituminous films	9	0
4. Gray to brown earthy, porous, with bituminous laminae	12	4
5. Gray to fine grained	13	10
6. Gray buff, fine grained with calcite crystals	1	2
7. Gray, earthy, calcite seams and cavities	10	10
8. Porous ("honeycombed") gray and brown earthy	4	0
9. Cherty, gray, interlacing bituminous films and crystallization films (last 4 inches a sandstone)	3	8
10. Brown and gray earthy, a few geodes	7	10

11. Brown sandy with bituminous films, dense white zone near top	3	0
12. Gray earthy, honeycombed	6	10
13. Gray and brown dense earthy	2	8
	94	0

The Marvin Quarry was also visited by the 1926 expedition, at which time Ehlers & Ulrich reported in their notebook the following generalized section:

Abandoned Marvin Stone Company Quarry
about $1\frac{1}{2}$ miles east and $1\frac{1}{2}$ miles south of Afton
Loc. 27

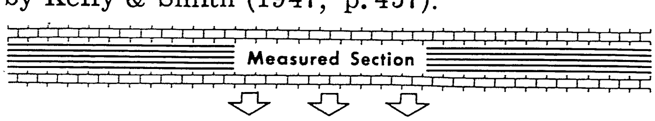
About middle of quarry are beds with Alveolites, large branching Cladopora, thin stromatoporoids, with Astrorhyza and other fossils found in zone 4 of Loc. 26.

Beds above and below this contain Acervularia with raised rim, Cystiphyllum, and Gypidula, and belong in beds in lower 1/3 of section (Locs. 22-26).

Below 18 feet of limestone of quarry are 2 feet of black limestone in railroad approach. Black layer may be upper part of ostracod layer of big quarry 3/4 mile north of Afton. Ostracods found in black layer.

At the present time (text-fig. 35, p. 64) the quarry has been long abandoned and shows it. The walls have slumped in many places, and the floor is largely obscured by rubble. Still, the beds reported here by Smith 60 years ago can still be identified for the most part. The section is much the same as that in the Campbell Quarry. The black bituminous limestone reported by Smith (his unit 6) appears to be the Gorbut Member of the formation, and the vesicular limestone (his unit 7) appears to be the Koehler Limestone immediately below; at the Campbell Quarry, the two are separated by around 16 feet of limestone. If our identifications are right, the strata between the Koehler and the Gorbut Member of the Gravel Point vary in the area. This is probably the result of an irregular topography produced during post-Koehler erosion.

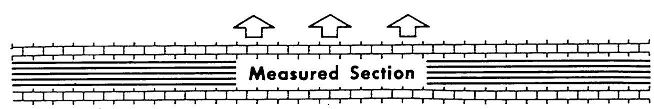
A slightly different section was measured by Kelly & Smith (1947, p. 457):



Overlying formation not exposed

Bed 8 - Massive, fine-grained, gray to buff limestone. Contains Hexagonaria n. sp., Pentamerella sp., Craenena	6'
Bed 7 - Biostrome made up principally of large laminar stromatoporoids	2
Bed 6 - Irregularly bedded massive gray limestone similar to bed 8. Contains stromatoporoids, coral Hexagonaria, and brachiopods	5
Bed 5 - Tan to gray massive limestone. Contains Bryozoa, Brachiopoda, Gastropoda, including Tentaculites	4
Bed 4 - Dark gray dense limestone with Ostracoda	1
Bed 3 - Black shaly limestone with irregular partings of soft flaky black shale	2
Bed 2 - Concealed interval	6
Bed 1 - Underlying formation - dense gray, cavernous, sub-lithographic limestone of Koehler formation.	

Bed 3 is correlated with the Gorbut member.



(6) Loc. 34-1W-17 W-SW. About $\frac{1}{4}$ mile north of the point where Pigeon River Road turns north, about 5 feet of limestones and calcareous shale are exposed along the road and in nearby field, including a 1-foot bed of dense black shale. The strata at this place are thin-bedded, but in fields $\frac{1}{4}$ mile north are outcrops of more massive limestone. The fossils identify this occurrence as Gravel Point Formation.

(7) Loc. 34-1W-17 SW-SW. An outcrop of black limestone occurs in the bottom of a gully near the corner of section 17, near the point where Montgomery Road joins Pigeon River Road and curves north. It carries the same fauna as that found in the Gorbut Member at Campbell Quarry and Marvin Quarry. The gully crosses the line between sections 17 and 18 about 1/8 mile south of the quarter-line. A total of about 7 feet are exposed, including some dark shale. This was noted by Kelly (1940, Stop #21) and by Kelly & Smith (1947, Loc. 13).

(8) Loc. 34-1W-19 N-NE. Exposures of Gravel Point along Pigeon River Road not far west of its junction with Montgomery Road.

The limestone bears a small Atrypa with coarse radial plications. This was considered by Kelly (1940, Stop #20) to be fairly high in the formation, for he called it "Upper Marvin."

(9) Loc. 35-1W-29 SE-NE. A bluff continuous with that in Le Grand Quarry is intersected by cuts along M-33 about 1 3/4 miles north of The Finger Board Corner (whatever existed there is long extinct, but the name persists on maps) and $\frac{1}{2}$ mile south of Le Grand. Exposures extend from $\frac{1}{2}$ to 3/4 mile north of the site of Gorbut School (destroyed, but shown on older maps). The beds are median in the formation, probably all above the Gorbut Member. Kelly & Smith (1947, p. 461) reported finding exposures south of the Gorbut School by some 1200 feet. In their fig. 4, a geologic section along the road south of Le Grand, they show beds from the Koehler Limestone to the "Chonetes" emmetensis zone, including the Gorbut Member and the Welleria zone. The little brachiopod Longispina emmetensis has played a significant role in correlations. More will be said about it below, under Fauna.

(10) Loc. 35-1W-29 NE/28 W/33 NW. Exposures in the escarpment more or less following M-33 from about $\frac{1}{4}$ mile south of the village of Le Grand to $\frac{1}{4}$ mile south of Knight Road, and extending eastward to Le Grand Quarry and to the abandoned railroad cut at Locality 35-1W-33 N. The exposures are discontinuous, but include the Longispina emmetensis zone just mentioned. The sequence of strata can be seen in this and the previous locality, but exact determination of thickness is difficult. Pieces of rock are plowed up in the fields, and the soil cover is very thin in this vicinity. The local strike is nearly east-west, as shown by the same sections seen in Le Grand Quarry and Campbell Quarry. In their figure 4, Kelly & Smith implied that they found Koehler Limestone cropping out along M-33; we have reported it in the SE corner of section 33 (in Adair Creek), whereas their occurrence would be on the west edge of the section.

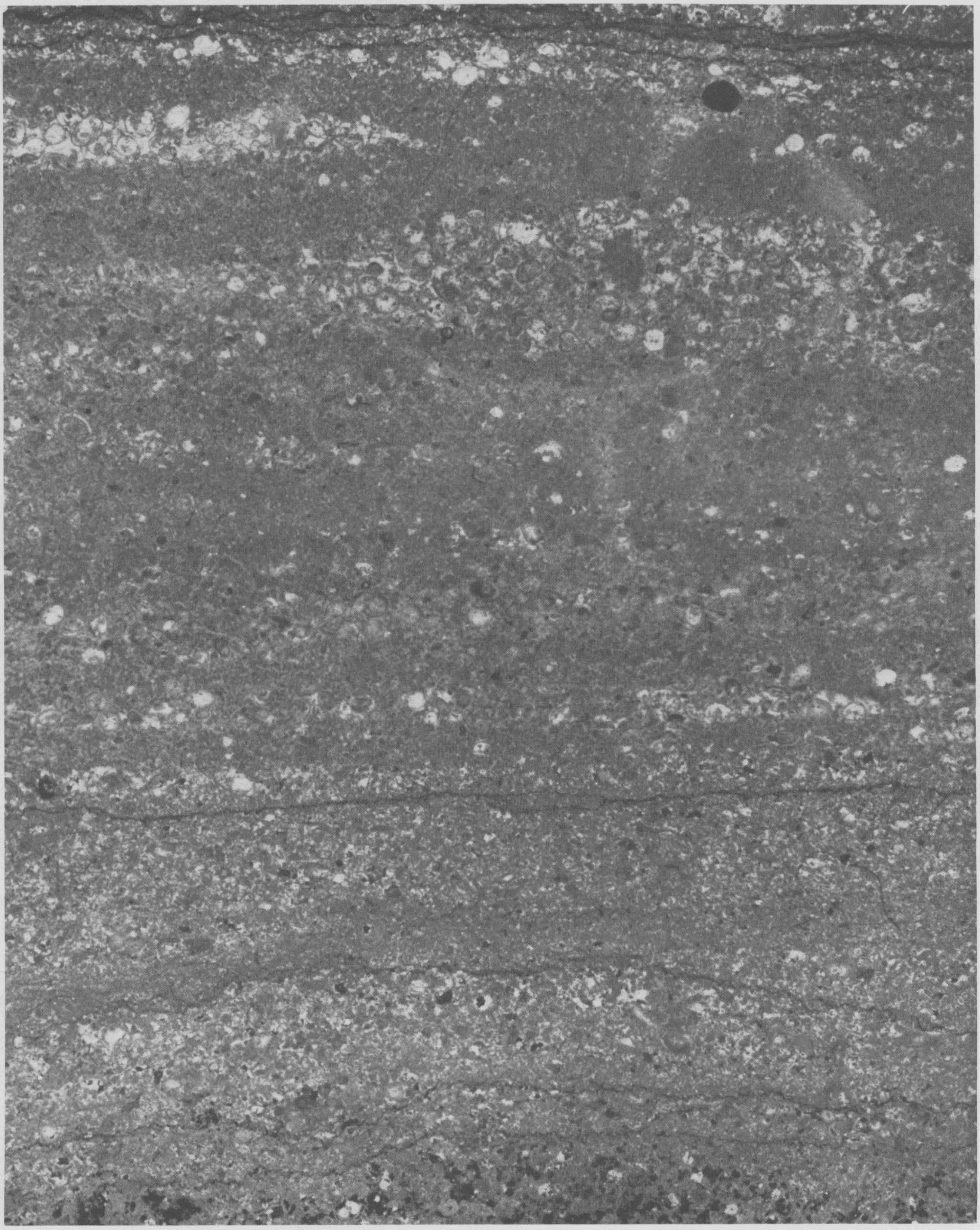
(11) Loc. 35-1W-33 N. In a long-abandoned railroad cut, about 1/8 mile south of the corner where Knight Road turns south and less than a mile north-northeast of The Finger Board Corner, crystalline limestone is exposed (text-fig. 36, p. 65). Here Kelly (1940) reported in the guidebook,

> Elevation about 825 feet. Exposure of massive crystalline limestone in cut of abandoned right-of-way. These beds are higher than any exposed in the Le Grand quarry and belong to the Marvin. The fossils include Gypidula sp. with a smooth umbo; a large Stropheodonta resembling the species from the Gravel Point formation; and a cylindrical coral, Diversophyllum sp., which also suggests the Gravel Point. [In this guidebook, this is locality 35-1W-33 N.]

Inasmuch as the beds here dip to the south, we agree that the strata are higher than those in Le Grand Quarry. Their position with regard to the Longispina emmetensis zone is less certain.

→

TEXT-FIG. 37 -- Vertical section through *Welleria aftonensis* zone in lower part of Gravel Point Formation at Campbell Quarry, as seen by an acetate peel. This and the following four text-figures are printed from negatives of a single acetate peel, prepared by the technique described by Kesling (1957, p. 28-31); other peels prepared in succession by Kesling & Soronen (1957, p. 4, 42) show that this peel is not exceptional for that number of sedimentary features illustrated. These peel sections demonstrate the many and diverse structures which can be clearly discerned by this technique but which are "invisible" in the untreated hand specimen of the unit. Undoubtedly, a more discriminating and lucid interpretation of other beds could result from similarly prepared peels. Here, the concentration of stylolites near the top indicates solution removal of a considerable thickness of the unit. The distribution of light calcite-rich lenses (upper part of figure) and dark hydrocarbon-rich lenses (bottom of figure) in a mottled clay-rich matrix resembles the sorting pattern through a miniature delta. The occurrence of the calcite and concentrated ostracod carapaces coincides, suggesting that the carapaces themselves (1) provided the substance for the calcite, (2) acted as a catalyst for later deposition, or (3) increased the local porosity to enable increased circulation of ground water. The white spots are sections through *Welleria aftonensis* carapaces filled with clear calcite. x 6.



(12) Loc. 35-1W-33 W-NW. Along a cut of M-33 about $\frac{1}{4}$ mile south of the former site of Gorbut School and about $1\frac{1}{4}$ miles south of Le Grand, the Longispina emmetensis zone is exposed. This locality is actually a small part of the escarpment exposures mentioned above (Loc. 35-1W-29 SE-NE and Loc. 35-1W-29 NE/28 W/33 NW).

(13) Campbell Stone Company Quarry (Loc. 35-2W-36 NE), sometimes called the Afton Quarry. The descriptions of the section presented by R. A. Smith (1916), Ehlers (1938), and Kelly (1949) have already been quoted on pages 54-56. The terminology applied to the strata in this quarry can be seen in our text-figure 26 (p. 51); formerly, the Koehler and lower part of the Gravel Point were combined as the "Afton Beds." R. A. Smith (1916) gave these comments on the quality of the stone:

> Bed No. 3, on account of its exceptionally low percentage of impurities, particularly silica and magnesia, is especially adapted for sugar and paper making. It burns very easily and makes a most excellent lime, but owing to the demand by paper and sugar manufacturers for stone from this bed most of the stone used for lime is obtained from beds Nos. 8, 9, and 10, which burn less easily, though making an excellent hot lime.
>
> The quarry beds vary greatly in color, structure and texture but all are very high in calcium and correspondingly low in magnesia. The black limestone owes its color to 2% to 3% of organic matter. As a rule, all but the more fossiliferous and less bituminous portions of this bed are rejected. The vesicular structure is apparently due to solution from water. In portions of some of the beds, the solution channels are so numerous that the stone literally crumbles to pieces under the heel. Blasting reduces this stone to an unsalable mass of small fragments. The percentage of fine material is exceptionally large and ordinarily would be wholly waste. Lime is burned in a rotary kiln ... hence much of the fine material can be directly utilized for lime.

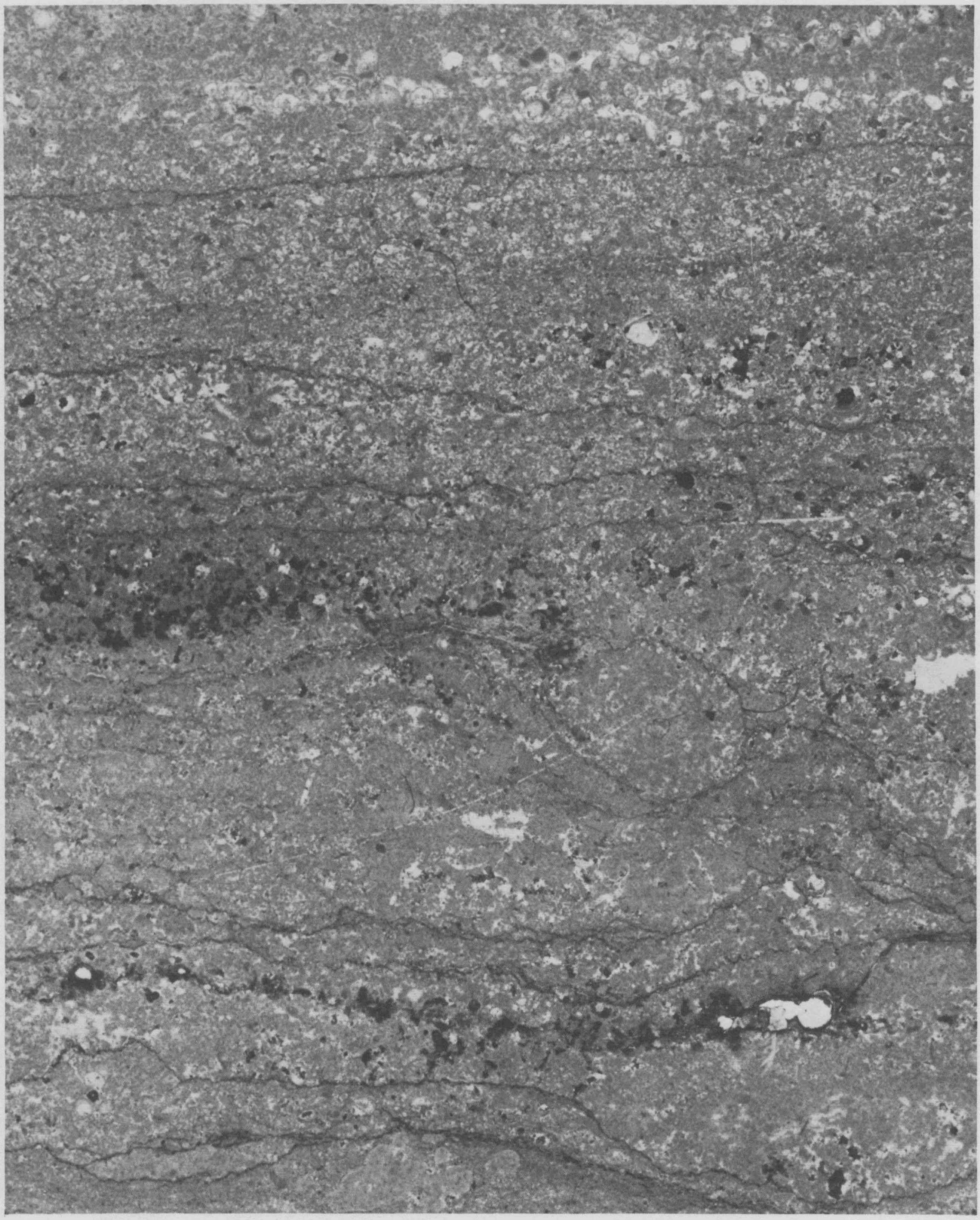
The Campbell Quarry has been abandoned for various intervals, but is now being operated for crushed stone (text-figs. 29, 30, 32). The best exposures are seen on the east wall. The dark band near the middle of the Gravel Point section is the Gorbut Member, named by Kelly & Smith (1947, p. 447, 457), who also mapped the member separately from the rest of the Gravel Point Formation (1947, p. 448). The mapping of the Gorbut as a distinct unit was not particularly wise, for as can be seen in the Campbell Quarry section (text-fig. 26), the Gorbut does not everywhere lie in contact with the Koehler Limestone, as indicated in their map. Probably, the selection was based on the older division into "Afton Beds" and "Marvin Beds."

(14) Loc. 34-2W-13 NW/14 NE. Discontinuous exposures of limestone on steep and gentle faces of northwest-trending cuestas dip rather sharply to the southwest. Dips probably average $2\frac{1}{2}$ degrees. This series of exposures crosses Munger Road about $\frac{1}{4}$ mile north of Beebe School. Together with the strata at the following locality, these exposures figure in the confusion surrounding the thickness of the formation.

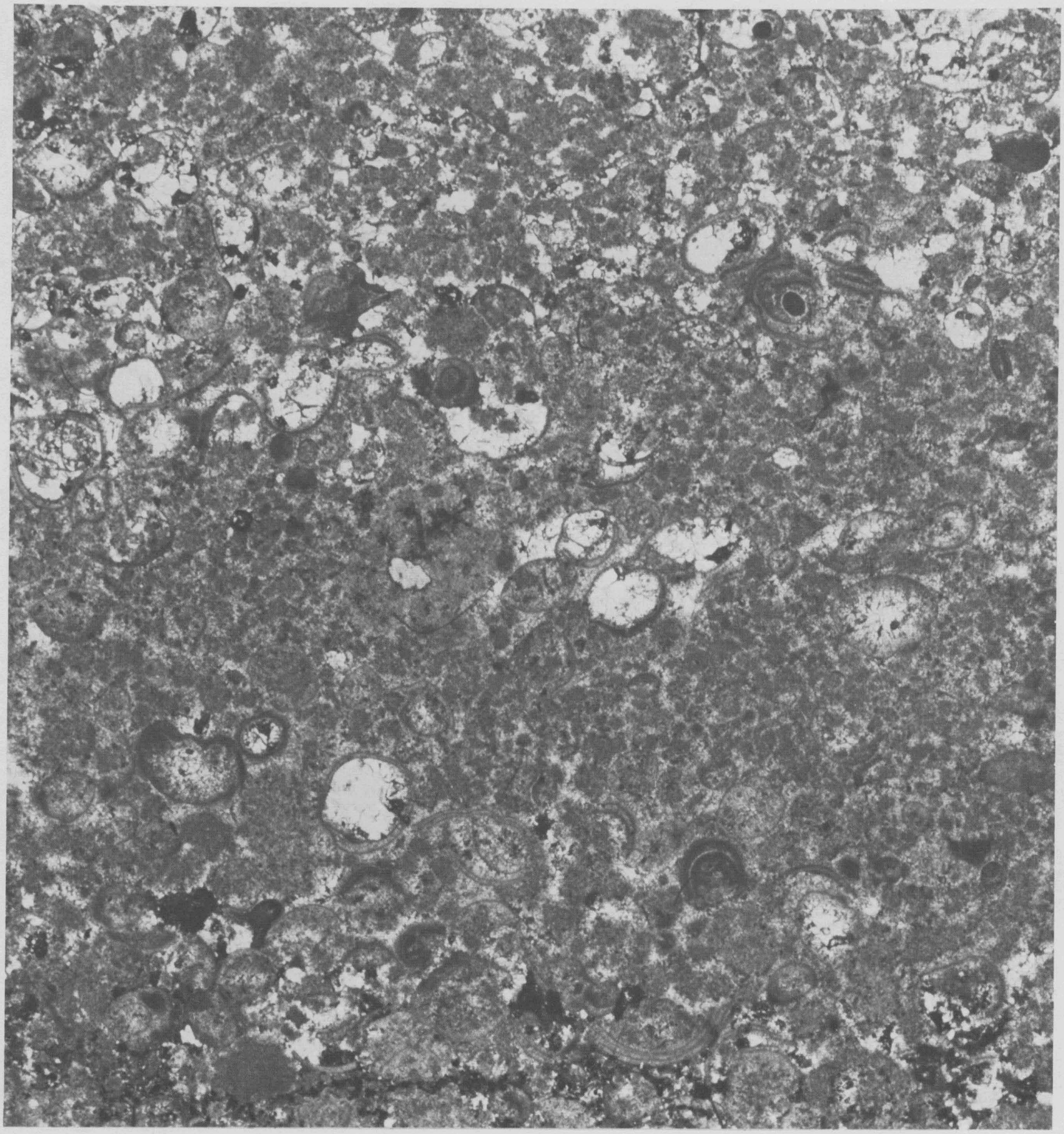
(15) Loc. 34-2W-14 E-NE-NE. Roadside exposures along Munger Road about $\frac{1}{2}$ mile west and 2 1/8 to 2 3/8 miles south of Afton are separated by a covered interval from the exposures near Beebe School.

Some of the confusion on the thickness involved in the Gravel Point Formation and Beebe School Formation has been alluded to in the discussion of thickness. In the roadside exposures along Munger Road from Sorenson Quarry south past Beebe School, the 1926 expedition members made three localities: Loc. 22 at Sorenson Quarry and vicinity, Loc. 23 in the neighborhood of the school, and Loc. 26 between the others. Ehlers & Ulrich entered the following descriptions in their notebook at the time, and Ehlers (1938) published the same in the guidebook for the 8th Annual Field Excursion of the Michigan Academy, except that

TEXT-FIG. 38 -- Vertical section through *Welleria aftonensis* zone as seen by an acetate peel. The hydrocarbons in the dark lenses (left and near bottom of figure) are so rich that the oil seeps out and stains the acetate in the peel; the void near the bottom right marks the spot where hydrocarbons weakened the acetate so much that it broke free during the peeling operation. A large "clay ball" (right center) shows solution surfaces around all its perimeter, and may have originally been larger and more spherical; some of the clay-rich "lenses" (as lower left) may be remnants of original clay balls. x 6. The upper right corner is enlarged in text-figure 41.



TEXT-FIG. 39 -- Vertical section through *Welleria aftonensis* zone as seen by an acetate peel. This section of the peel fits below the section shown in text-figure 38. The stylolite just over the "pelletoid" layer (center) is marked by a clay seam, rather than the usual hydrocarbons. The preserved ostracods in the bed have an oily coating, as can be determined in crushed rock of the unit; one suspects that those without such a protection shortly after deposition were dissolved as the many stylolites were created. x 6.



TEXT-FIG. 40 --Vertical section through *Welleria aftonensis* zone as seen by an acetate peel. Near bottom of this figure is a good example of "nested" ostracod valves, presumed to have attained this relationship as a single valve was gently wafted by currents and settled in the hydraulically firm position inside the concave side of a larger valve. Note the variable orientations of both valves and carapaces, from flat-lying to vertical. Dark blotches in the mottled background may be unslaked fragments derived from thin sun-dried mud chips along the shore; only a few in this figure preserve any angularity. x 40.

in the guidebook all beds were numbered in sequence from 1 to 25.

Measured Section

Composite section
to Beebe School - Locs. 22, 26, and 23 -
presumed to have little if any covered intervals

Ft. In.

Loc. 23 - Exposures in ditch beside north-south road from point about 150 feet north of center of east line of sec. 14, T 34 N, R 2 W (Ellis Twp., Cheboygan County) to point about ¼ mile south of center of this line. In passing southward from road leading westward at north end of locality, beds dip rather rapidly to south and slope of surface conforms more or less closely to this dip to a point ¼ to 1/3 mile south of westward-leading road. [Includes Beebe School yard.]

11. Massive dark dove-colored limestone with irregular stringers of calcite and ramose Favosites .... 16"

10. Darker gray limestone with corals and Idiostroma. Lower half looks in structure like vesicular chert. Corals in upper half .... 20"

9. Gray shale with concretions of darker gray limestone filled with ostracods. Bythocyprids particularly abundant. Ulrichia, Kloedenia, and Primitia noted 2

8. Heavier bedded (than underlying) limestone, with Idiostroma (small hole in center), 2 species of gastropods, a cephalopod, large Ceratopora, large heads of Favosites, and massive stromatoporoids. Limestone is light-gray, fine-grained, and contains thin, irregular layers and lenses of chert, 1½ to 2" thick. Some fossils in limestone are silicified .... max. 4

7. Limestone, magnesian, yellowish, finely crystalline - poorly exposed .... not over 1

6. Limestone, dove-colored, platy, obscurely laminar with dumose Favosites, Aulopora, athyrids (½ to 3/4 inch in diam.) in lower foot .... not over 4

5. Limestone, black, sandy and streaked, all laminar .... 3 to 4

4. Limestone, dove-colored, laminated with cavities - almost vesicular. Top becomes almost black in color ...... 2 to 4

3. Limestone, laminated, yellowish-gray at base becoming pinkish at top 3 6

2. Limestone, yellowish-gray and shaly. Becomes cobbly on weathering. Acervularia at base 6

1. Calcareous gray shale with two fossiliferous zones; the lower is about 6 feet above the base and contains Spirifer mucronatus (wide mucronate type), Stropheodonta, small Atrypa (reticularis type), Spirifer with cardinal area, one valve encrusted with Hederella and bryozoa. The upper fossiliferous zone about 6 feet below the overlying beds (zone 2) and contains Cystidictya, Astraespongia, and other fossils 22

Loc. 26 - Ditch along road midway between Locs. 22 and 23. The beds exposed at this locality are between highest beds at Loc. 22 and lowest beds at Loc. 23. Dip of beds to southward.

9. Shale, part of basal bed of Loc. 23; in the covered interval of 100 feet horizontal, there are 5' or perhaps 10'. The total thickness of the unit, counting covered part, is probably as much as ..... 27 to 32

8. Platey, gray, argillaceous limestone, with many fossils. Productella, Cyrtina with high cardinal area, small mucronate Spirifer, Stropheodonta (variation of the erratica type), large auloporoid, Atrypa reticularis. Productella especially abundant at top. Chert layers 1" thick. Fossils silicified .... 18-20"

7. Chert with fossils similar to above 1

6. Platey gray limestone thickening northward into a coral reef 2½

5. Limestone, laminated, gray, with sedimentary planes through it 2-2½

4. Coral reef; contains 2 species of Conocardium, Cypricardinia, 2 or 3 cephalopods, 3 gastropods - Holopea or Straparollus, Dolatocrinus or Megistocrinus, Goniophora, Acervularia with raised rim, Alveolites, large branched Cladopora, Cystiphyllum, Chonophyllum, stromatoporoids, Phacops, Chaetetes, Favosites of alpenensis type 3

3. Shelly limestone, gray, full of fossils, breaks into spalls. Favosites, Gypidula (large), Stropheodonta demissa, S. erratica, Spirifer mucronatus, terebratuloid, Acervularia, Pholidostrophia 1½

2. Massive limestone, gray, black-speckled; abundant crinoidal fragments and a few shells, Pholidostrophia 2

1. Shaley, crystalline limestone, fossiliferous; fistuliporoids, small-celled Favosites,

Fenestella, Ceratopora (large type), same fossils as above. Bottom not seen .. 6"

Loc. 22 - Road cut on north-south road, 1½ to 1 3/4 miles south and ½ mile west of Afton, Cheboygan County

5. Limestone, fine-grained, dove-colored, with numerous irregular cavities. Contains pelecypods, simple corals, Cladopora, and crinoidal fragments. Crinoidal fragments are at top in peculiarly streaked crystalline calcite specks 3
4. Limestone, more gray than dove-colored, without cavities or with smaller ones than rock above and possibly more magnesian 2
3. Limestone, similar to above with very few cavities and laminated 3
2. Covered interval. Blocks of gray, somewhat crystalline limestone are present at side of ditch. They contain numerous crinoidal fragments, an Acervularia, a large Spirifer, and a small-tubed Favosites. It is possible that these blocks are from the covered interval .... 14"
1. Limestone, dove-colored, very fine grained, with numerous specks of calcite crystals. Bed seems to be very high in $CaCO_3$ ...... 16"

Measured Section

At the same time and place, Professor E. C. Case was also busy measuring and describing the strata:

Measured Section

Beebe School, Ellis Twp. - Loc. 23

11. Massive dark dove limestone. Corals and specks and stringers of calcite .... 16"
10. Black limestone with Favosites, cup corals and Idiostroma in upper half. Lower half like vesicular chert .... 20"
9. Shale bench with ostracods in concretions .. 2'
8. Light grey, fine grained limestone. Gastropods (2 spec.), Favosites, Aulopora, Stromatopora. Chert in lenses and irregular layers. Fossils silicified ....4±
7. Yellowish Mg limestone, finely crystalline, poorly exposed .... 1'
6. Grey, dove limestone, platy, obscurely laminated with corals in lower 1 foot (dumose Favosites).....................4'
5. Black streaked in part, sandy limestone and pure limestone (all laminated) .... 3-4'
4. Grey limestone, fine grained, dove, porous, laminar, at top dense black .... 2' 4"
3. Platy limestone, laminar, pinkish at top .... 3'
2. Limestone, shaly, Acervularia at base. Yellow, mostly unfossiliferous .... 5'
1. At base, 22 feet shale. Two fossil zones. Upper (7 feet below top) with Cystodictyon 1-2" .... 22'

Loc. 26 along road. Probably not much lacking between 22 and 26 (a very few feet at most). Base of loc. 23 continuing north to 22, completing sections 23 and 22.

9. Shaley, unfossiliferous, continuing down from 1 of 26; shows 5, possibly 10 feet of same material. A covered interval between 23 and this part of 26 of 100 feet horizontal .... 5-10'
8. Platy, argillaceous limestone, grey. Very fossiliferous. High beaked Cyrtina, Productella, Atrypa sp. Fossils silicified. Stropheodonta demissa or erratica ..... 18-20"
7. Heavy layer. Silicified fossils and chert bands up to 1 foot. Fossils as above ..... 1'
6. Platy, argillaceous. Thickening to north into 2-2½ feet in a coral reef .... 14-18"
5. Platy argillaceous, laminated, grey, dark red in places .... 2'
4. Another coral bearing layer forming reef, silicified corals .... 3'
3. Shelly limestone full of fossils. Corals, Gypidula, large demissa, erratica, terebratuloids, etc. .... 1½'
2. Massive grey to black, fossil speckled ls. Abundant crinoidal fragments and few shells, erratica type .... 2'
1. Shaley crystalline limestone, fossiliferous. Top only seen. Same fossils as above, Acervularia, small cell Favosites. After interval of 150 to 200 yards, 1 of this locality lies over or upon layer 3 of 26 ....

Sorenson Quarry - Loc. 22 Aug 19, 1926

4. Porous grey limestone, solution cavities. Remains of pelecypods and cup corals (poor).. 3'
3. More solid, dark brown limestone .... 2'
2. Shaley limestone platy zone, dark grey, mass-

ive, crystalline. Shows fine laminae on weathered surface .... 3'

Covered - GME his no. 2

1. Dense, bluish grey limestone with small crystals of calcite, lithographic (?), bottom not seen. "Dove" of Ulrich 1

Measured Section

We can now correlate, with not much question, the units of Ehlers & Ulrich and of Case with the present stratigraphic divisions:

Loc.	Units	Lithology	Thickness E & U	Thickness Case	Present formation
23	10-11	limestone	3'	3'	Beebe School
23	9	shale	2	2	
23	2-8	limestone	26½	23	
23 26	1) 9)	shale	32	32	
26	5-8	limestone	7½	6½	
26	4	reef	3	3	
26	1-3	limestone	4	3½	Gravel Point
22	1-4	limestone	10½	9	Koehler

The area where error seems to have originated lies between their Localities 26 and 22. Case said the covered interval was only "150 to 200 yards." Assuming a dip component as great as 6° and neglecting topographic influence, this would account for only:

$$\tan 6^\circ \times 600' = .105 \times 600' = 63 \text{ feet.}$$

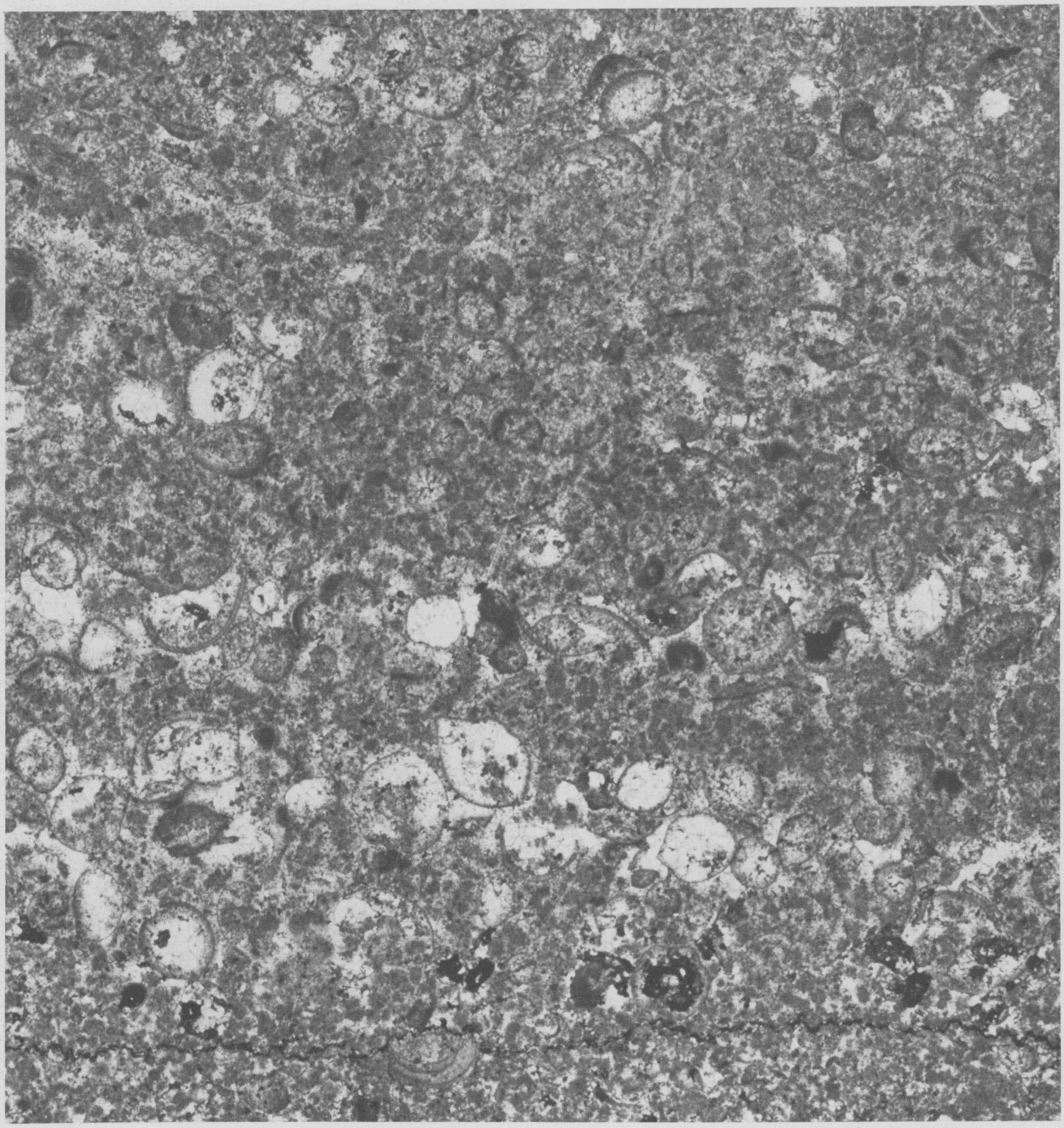
On the other hand, as stated under Thickness, Kelly & Smith (1947) indicated the distance between the Koehler Limestone at Sorenson Quarry and the base of the Beebe School Formation near the schoolhouse to be nearly 4000 feet. Perhaps this figure was high, and 3000 feet would be more accurate. For various dip components this gives the possible thicknesses of the Gravel Point Formation shown at the bottom of the page.

Thus, one could account for a thickness of 185 feet of Gravel Point Formation along the road by (1) a dip component of 3° in a distance of 4000 feet, or (2) a dip component of 4° in a distance of 3000 feet. Dip components of this magnitude are not inconsistent with the observed dips on roadside exposures south of the schoolhouse.

Members of the 1926 expedition appear to have neglected dip in their measurements. It seems likely also that they incorrectly correlated the strata between spotty exposures. Let us take a hypothetical example: suppose they presumed (incorrectly) that a "dove-colored limestone" at one outcrop was the same unit as another "dove-colored limestone" perhaps 50 yards away updip; if the strata were inclined 3° and the outcrops were at the same topographic level, this would omit nearly 8 feet of the section. If such a mistake were repeated several times, the total thickness would be seriously underestimated.

On the other hand, the figures of Kelly & Smith (1947, p. 460) -- 60 feet of Gravel Point Formation along Munger Road -- could be a correct measurement if (1) the formation thins drastically to the north from the Garred well 5½ miles away, or (2) an unseen fault cuts out an appreciable portion of the section. We doubt that either of these possibilities are right.

Dip Component	Tangent	Horizontal distance = 4000': Structural difference	Topographic difference	Thickness	Horizontal distance = 3000': Structural difference	Topographic difference	Thickness
2°	.035	140	-25	115	105	-25	80
3°	.052	208	-25	183	156	-25	131
4°	.070	280	-25	255	210	-25	185
5°	.087	348	-25	323	261	-25	236



TEXT-FIG. 41 -- Vertical section through *Welleria aftonensis* zone as seen by an acetate peel. This section of the peel lies at the upper right in text-figure 38. The stylolite (bottom) appears to truncate ostracod valves. Note that many of the calcite-filled carapaces show that the initial carbonate filling of the interior began as a lining of tiny crystals, forming a miniature geode. The local concentrations of hydrocarbons above the stylolite are unusually large. Obviously, many instars are represented, although the number in the figure is hard to determine because the size of a cross section depends on the position where the carapace is intersected; specimens extracted from the rock by Kesling & Soronen (1957, p. 44-47) included adults and five immature instars. x 40.

Composition. -- R. A. Smith's 1916 analyses of samples from a drill hole near Marvin Quarry have already been presented (p. 66). In the same publication he also gave the chemical composition of other samples in the Afton-Onaway area. In the following excerpts, the samples are of the Gravel Point Formation with the exceptions of 186a and 670, which are Rockport Quarry Limestone in the two facies, and 669, which is Genshaw Formation. Analysis No. 180, from Smith's units 5 and 6 at Campbell Stone Quarry (see his measured section on page 54) which appear to be the Welleria aftonensis zone and beds immediately below it, is an exceptionally high calcium stone.

Anal. No.	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	$MgCO_3$	Organic
177	0.54	0.45	97.32	1.08	---
178	0.63	0.62	92.60	2.56	2.61
179	0.24	1.44	96.97	0.12	---
180	0.28	0.37	98.04	1.07	---
181	1.75	0.64	95.75	1.24	---
184	2.10	0.34	96.52	0.90	0.08
186a	0.39	0.52	96.84	2.03	---
187	0.80	0.55	96.88	1.24	---
669	2.84	1.65	92.97	2.27	---
670	0.33	1.44	63.52	34.74	---

177 - Campbell Stone Co., Afton quarry, Sec. 36, T. 35 N., R. 2 W.; top bed, hand specimen.
178 - Same; Bed No. 2, hand specimen.
179 - Same; Bed No. 3, "Paper stone" bed, hand spec.
180 - Same; Beds Nos. 5 & 6; composite of hand specs.
181 - Same; Beds 8, 9, and 10 - lower 12 ft. of quarry.
184 - Campbell Stone Co., Afton. Drill core 4 to 42 ft. Present quarry section. NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36. Analyses made every 2 feet.
186a - Black Lake quarry, sec. 12, T. 35 N., R. 1 E.; hand specimens.
187 - Marion Stone Co., NE$\frac{1}{4}$ sec. 7, T. 34 N., R. 1 W Quarry beds 1 to 5 and 7; section 21 feet.
669 - Gorge on E. branch Rainy River, SE$\frac{1}{4}$ sec. 26, T. 35 N., R. 2 E. Section about 12 feet.
670 - Falls of Ocqueoc River, SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 22, T. 35 N., R. 3 E.; hand specimens.

Fauna. -- The Gravel Point Formation bears essentially the same fauna as the Alpena Limestone in Alpena County, Michigan.

The formation contains only 11 genera and 5 species reported formally in literature from this area. These are:

Rugose corals
- *Heterophrentis* sp.
- *Hexagonaria percarinata* (Sloss)

Tabulate corals
- *Favosites romingeri romingeri* Swann
- *Trachypora alternans* Stumm & Hunt

Brachiopods
- *Atrypa* sp.
- *Cranaena* sp.
- *Longispina emmetensis* (Winchell)
- *Mucrospirifer* sp.
- *Pentamerella aftonensis* Imbrie
- *Pholidostrophia* sp.

Cricoconarid
- *Tentaculites* sp.

In contrast, in Emmet and Charlevoix Counties, where the Gravel Point Formation has been studied more intensively and where the upper strata are exposed in quarries, 87 species are recorded, including the following additions. Those marked by asterisk also occur in the Alpena Limestone:

Rugose corals
- *Aulacophyllum hemicrassatum* Sloss
- *Aulacophyllum mesodilatum* Sloss
- *Cystiphylloides americanum* (Edwards & Haime)
- *Cystiphylloides tabulatum* Stumm
- *Cystiphylloides varians* (Hall)
- *Diversophyllum traversense* (Winchell)
- *Heliophyllum juvene* (Rominger)
- *Heliophyllum tenuiseptatum traversense* Stumm
- *Hexagonaria cristata* (Rominger)
- *Hexagonaria cristata microcarinata* (Sloss)
- *Hexagonaria pauciseptata* (Sloss)
- *Hexagonaria* cf. *anna* (Whitfield)
- *Naos ovatus* (Sloss)
- **Naos ponderosus* (Rominger)
- *Scoliophyllum* cf. *lamellosum* (Goldfuss)
- **Tabulophyllum traversense* (Winchell)
- *Tortophyllum cysticum* (Winchell).

Tabulate corals
- *Alveolites (Planalveolites) megastoma* Winchell
- *Alveolites (Lunatipora) michiganensis* (Winch.)
- *Alveolites strigillata* Winchell
- *Alveolites* cf. *subramosus* Rominger
- **Aulocystis alectiformis* (Winchell)
- *Aulopora aperta* Winchell
- *Aulopora conferta* Winchell
- *Aulopora cyclopora* Winchell
- *Aulopora michiganensis* Fenton
- *Aulopora "serpens"* Goldfuss
- *Aulopora socialis* Fenton

Drymopora partita (Winchell)
**Favosites alpenensis alpenensis* Winchell
Favosites alpenensis praevigens Swann
Favosites nitellus Winchell
Favosites placentus Rominger
**Favosites romingeri saetigera* Swann
**Pachyphragma concentricum* Watkins
Pachyphragma erectum (Rominger)
Thamnopora magniventra Stumm
Trachypora lineata Stumm & Hunt

Brachiopods
Athyris eborea (Winchell)
Athyris sesquiplicata (Winchell)
Atrypa corrugata Fenton & Fenton
Atrypa dignata Fenton & Fenton
Atrypa petosequa Fenton & Fenton
Atrypa petosequa lata Fenton & Fenton
Cranaena romingeri Hall & Clarke
**Devonalosia radicans* (Winchell)
Douvillina cf. *inaequistriata* (Conrad)
Elytha filicosta (Winchell)
**Megastrophia* cf. *concava* (Conrad)
Mucrospirifer grabaui Stumm
Oligorhachis oligorhachis Imbrie
**Pentamerella alpenensis* Imbrie
Pentamerella intralineata (Winchell)
**Pholidostrophia geniculata* Imbrie
Pholidostrophia cf. *nacrea* Hall
Schuchertella anomala (Winchell)
Spinocyrtia cf. *euryteines* (Owen)
"Spirifer" bidorsalis Winchell
Strophodonta cincta Winchell
**Strophodonta erratica* Winchell
Strophodonta erratica fissicosta Winchell
Strophodonta erratica solidicosta Winchell
Strophodonta imitata Winchell
**Strophodonta nana* Imbrie
Strophodonta titan Imbrie
**Strophodonta titan titan* Imbrie
Stuartella traversensis (Winchell)
**Truncalosia gibbosa* Imbrie

Cricoconarid
Tentaculites subtilis Winchell

Bivalves
Aviculopecten intercostalis Winchell
Conocardium emmetense Winchell
Nuculites oblonga Winchell
Paracyclas hamiltonensis (Winchell)
Sanguinolites (Grammysia ?) sulcifer Winchell

Cephalopods
? *Acleistoceras omicron* (Winchell)
? *Michelinoceras pustulosum* (Winchell)
Tumidoceras lentum Flower
Tumidoceras magnum Flower

Trilobites
Ancyropyge romingeri (Hall & Clarke)
**Dechenella (Basidechenella) pulchra* Stumm
Greenops aequituberculatus Stumm
Greenops traversensis Stumm
**Phacops iowensis alpenensis* Stumm
**Phacops rana rana* (Green)
Proetus (Crassiproetus) traversensis Stumm

Crinoid
Megistocrinus latus Hall

Additional species are present but have not, in literature, been identified except for the genus. We believe that additional collecting in the Afton-Onaway area would add most if not all of these species to the faunal list.

Two species are of special interest in this area. The first is the little brachiopod long known as *Chonetes emmetensis* and now classified as *Longispina emmetensis*. It is in the Alpena Limestone at the type locality and has been reported from the Gravel Point Formation south of Le Grand. It is also present in Emmet County to the west, as the name indicates. Probably, additional field work would establish a *Longispina emmetensis* zone in the formation, which could be traced across the state from Lake Michigan to Lake Huron.

The other species is an ostracod that occurs in prolific numbers in the lower part of the formation in Campbell Quarry. It is called *Welleria aftonensis* and authors have referred to the rather thin unit bearing it as the *Welleria aftonensis* zone of the Gravel Point. More is said about this unusual ostracod below in the discussion of Sedimentation.

Sedimentation.-- Without question, the Koehler Limestone and the Gravel Point Formation are separated by an unconformity. Such an erosional interval is attested by the "brecciated zone" and clay seam at the top of the Koehler as well as by the different beds which meet at the contact within the Campbell Quarry. The difference in the lower section of the Gravel Point Formation at Campbell Quarry, Le Grand Quarry, and Marvin Quarry show that the unconformity was not localized.

From the nature of the upper Koehler at Campbell Quarry, we can deduce that the "lagoonal" deposits of very fine grained carbonate were uplifted and subaerially exposed before consolidation. Drying out of the soft limy top layers produced deep and extensive cracks, leading to the fractured and jumbled chunks seen in the upper part of the formation. The overlying clay, of varying thickness and occurrence, is the ancient "soil" that developed by weathering of this exposed "breccia." The confinement of "brecciation" to the unit just below the clay rules out any appreciable tectonic activity or later movement which could have made a true breccia.

Upon the somewhat irregular topography resulting from this drying, weathering, and erosion, the open sea transgressed to lay down the basal Gravel Point Formation layers of normal marine limestone.

Shortly afterward, isolated salina basins developed from time to time, here and there, with such concentrations of brine that invertebrates died off with the exception of the hardy saliniphilous ostracod Welleria aftonensis. Like the brine-shrimp Artemia now living in Great Salt Lake, this little crustacean of the Middle Devonian thrived in a concentration that would "pickle" its contemporaries.

The intensive study of the occurrence of Welleria aftonensis conducted by Kesling & Soronen led them to report (1957, p. 48):

> The specimens of *Welleria aftonensis* occur as isolated valves and as carapaces. In living ostracods the two valves are opened by the contraction of a ligament which links them together along their dorsal borders, and are closed by the action of internal muscles. When the animal dies the muscles relax and the valves are sprung apart by the ligament; then, in a little while, the ligament decays and the valves are free. From the occurrence of numerous carapaces ... it may be inferred that the living ostracods were entombed in sediment which held their valves in place, or that, before the ligament rotted away in dead ostracods, the force of currents swung the valves nearly together and the weight of accumulating deposits completed the closing. Some carapaces came to rest on their ventral surface, some on their sides, and a few on their ends. Such random orientation must be attributed to soft mud on the sea floor, in which the carapaces were held in position until the deposit became consolidated.
>
> Many of the single valves are found stacked atop one another ... Because the stacks are oriented in various attitudes in the rock, it appears that some were deposited as a single unit and later were moved. We believe that each stack originated when a large valve came to rest on the bottom of the lagoon with its inner (concave) side up and, in sequence, smaller valves being drifted along by gentle currents settled inside it.

Kesling & Soronen also commented upon the lithology of the Welleria beds (1957, p. 49):

> The limestone ... contains numerous thin lenses of calcite. Whether these are primary or secondary is not known, but they indicate a high concentration of calcium carbonate. Certain layers in the limestone are marked by numerous tiny stylolites. Nearly all of the limestone is soluble in hydrochloric acid, and clay and oil remain as insoluble residue ...
>
> The impurities, mostly clay, in the limestone seem to be concentrated in small subangular inclusions which lack sharp boundaries. Most are smaller than 1 mm in diameter, but a few are several millimeters long; some are long, thin, and slightly curved. The inclusions appear as numerous light gray blotches ... We believe the inclusions are remnants of thin layers of mud that were laid down on the shore, dried and cracked by the sun, and later broke into small fragments while being carried by waves and currents. They were laid down before they could be completely disintegrated by abrasion and slaking ... Their presence strongly suggests that the beds with *Welleria aftonensis* were deposited near the shore ... All of the rock is petroliferous and oil seeps from certain laminae when the rock is broken... The fine laminae, cross laminae, and abundance of hydrocarbons all signify a rather quiet shallow water marine environment cut off from the sea.

These authors also investigated the paleoecology of these ostracods; they concluded (1957, p. 49, 50) that:

> There is little room for doubt that *Welleria aftonensis* lived in a large lagoon. The water level of the lagoon shifted slightly from time to time, perhaps regularly, spreading a thin layer of mud along the shore during high levels The mud dried and cracked during low water stage and broke into small chips when the water rose again and waves reworked it. Before the chips were carried far enough to completely slake into clay, they were deposited.
>
> Deposition was slow. Small differences in the kind of sediment available caused the lagoon floor to be covered with successive thin laminae of slightly different content. Gentle currents produced small cross laminae. The

water teemed with ostracods and the soft-bodied organisms, probably protozoa or algae, on which they fed. Through the years, the bodies of the dead animals accumulated on the bottom, and, not being completely consumed by bacteria, changed into oil. Much later, when other beds had been laid down atop the lagoonal deposits and the area was uplifted above sea level, some of the more soluble layers dissolved, leaving stylolites to mark their former positions.

A similar occurrence of a species of Welleria was investigated by Kesling & Takagi (1961), who reported on the concentration of specimens of Welleria meadowlakensis in well cores from western Saskatchewan and eastern Albertà, Canada. There a unit called the "Ostracod limestone" occurs between salt beds of the Meadow Lake beds of the lower Elk Point Formation of Middle Devonian age. As interpreted by Kesling & Takagi (1961, p. 35):

> The "Ostracod limestone" ... consists of carbonates and salt precipitated from the marine water flowing into the highly concentrated solution in the evaporite basin.

Finally, the authors concluded (1961, p. 51),

> Since *Welleria meadowlakensis* is the only kind of animal found in the ... beds, we infer that the environment precluded other organisms, except possibly microorganisms on which the ostracods fed ... Undoubtedly, the first specimens of *Welleria meadowlakensis* came into the channels from the open sea... It now seems reasonable to postulate that the lagoon had higher salinity than the surrounding sea, thus preventing other animals from living there ... Specimens of *Welleria meadowlakensis* are abundant in the "Ostracod limestone," giving certain bedding planes a pebbly texture ... The species was prolific in this environment.
>
> *Welleria meadowlakensis,* like its relative *W. aftonensis,* could live in the open sea but, being saliniphilous, thrived best in brine that eliminated its enemies and competitors.

Another unit of special note is the Gorbut Member. This dark coral-bearing limestone is strongly reminiscent of the dark fossiliferous facies of the Rockport Quarry Limestone at the type locality and at Ocqueoc Falls. In our opinion, the Gorbut was also formed in shallow water, possibly in the intertidal zone.

As for the great thickness of strata above the Gorbut, not all is exposed. As can be seen in well records (Appendix 8), the beds are nearly all limestones of varying color, bedding, clay content, and characteristic fossils. They include the massive limestones of the railroad cut as well as the less resistant and more fossiliferous units exposed below the Beebe School Formation along Munger Road. Lower middle strata, including the Longispina emmetensis zone, are seen in road cuts and fields south of Le Grand. All of these beds appear to be the shallow-water carbonates of normal marine environment.

BEEBE SCHOOL FORMATION

Name and type locality. -- The Beebe School Formation was named by Kelly & Smith (1947, p. 447, 460, 461), who stated, "The name Beebe School is applied to those limestones and shale beds which overlie the Gravel Point, and underlie the Antrim shale, and which are exposed on the front and back slopes of a series of low cuestas which trend in a northwest direction from Beebe School."

These exposures were known long before the publication by Kelly & Smith. The locality was visited by the 1926 expedition, at which time they designated it as their "Locality 23." This number was also used by Warthin & Cooper (1943, p. 577), who described it as: "Exposures along highway, beginning with 22-foot shale bed 200 yards north of Beebe School ... extending thence about $\frac{1}{2}$ mile south. Potter Farm Formation."

Thickness. -- For the thickness of this formation, we can refer to (1) the section given by Kelly & Smith (1947, p. 460), (2) the sections compiled on the 1926 expedition by Ehlers & Ulrich and by Case, and (3) the records of the Lewis A. Garred #1 (SE$\frac{1}{4}$ sec. 1, T 33 N, R 2 W) and State-Nunda "A" (SW$\frac{1}{4}$ sec. 11, T 33 N, R 1 W) wells (see Appendix 8).

In the wells, the top of the formation can be placed at the lower limit of the Norwood Shale, since there is no indication of the Upper Devonian Jordan River Formation. The base of the formation seems to be indicated at the top

TEXT-FIG. 42 -- Beebe School Formation at type locality. Locality 34-2W-14 E. Slumped limestone layers along Munger Road south of the schoolhouse. Photographed by Kesling, 2 Oct 1975.

of a gray calcareous shale, which probably represents the "upper blue shale" unit at the top of the Gravel Point Formation as exposed in Emmet and Charlevoix Counties and identified in all wells in that area. Less than 6 miles west of the Lewis A. Garred #1, the William M. Brown #1 well (NE$\frac{1}{4}$ sec. 12, T 33 N, R 3 W) shows 37 feet of limestone above the "upper blue shale" which can be assigned to the Charlevoix Formation; however, no conclusive evidence of the Charlevoix is to be found in either the Garred #1 or the State-Nunda "A" wells, and the Charlevoix Formation may terminate eastward before reaching the area discussed here. It is possible that the lowest unit in the Garred #1 well which we include in the Beebe School Formation -- 25 feet of brown micritic dense limestone with scattered slight pinpoint porosity -- may actually be Charlevoix; if this were true, then the thickness of the Beebe School Formation at this place would be reduced to 100 feet. In the William M. Brown #1 well, the combined thickness of the strata identified as Petoskey Formation (48') and Whiskey Creek Formation (50') is 98 feet, which corresponds closely to the thickness of the Beebe School Formation in the Lewis A. Garred #1 (125' or 100') and the State-Nunda "A" (110').

The thickness based on outcrops, all in the neighborhood of Beebe School, is appreciably less than that encountered in the wells a few miles to the south, as has been reported in literature. There is strong evidence, however, to show that the thickness computed by Kelly & Smith (1947, p. 461) and described by them (p. 460) is too low.

Kelly & Smith stated (1947, p. 461) "... the north-south component of the dip between the biostrome, bed 1, 650 feet north of, and the out-

TEXT-FIG. 43 -- Beebe School Formation at type locality. Locality 34-2W-14 E. Limestone exposure on west side of Munger Road south of the schoolhouse and near crest of hill. Dips on some strata in vicinity reach 5°. Photographed by Kesling, 2 Oct 1975.

crop of the upper limestone, bed 4, 50 feet south of the school corner, was determined to be $2\frac{1}{2}°$. Since the top of bed 4 is topographically 47 feet higher than the base of bed 1, the computed thickness is 73 feet." Using their figures, we arrive at a somewhat greater thickness: $2\frac{1}{2}°$ = 44' vertical/1000' horizontal (from table of tangents); hence the dip in 700 feet accounts for 31 feet of strata, to which their reported 47 feet difference in elevation is added to make 78 feet of Beebe School Formation at the type locality.

But this figure also seems to be incorrect. As Kelly said later (1949 guidebook), "The boundary between the Gravel Point and the Beebe School is located halfway up the first (northern) cuesta ..."; and the profile and cross section by Kelly & Smith (1947, fig. 5, p. 459) clearly shows such a location for the contact, with the base of the Beebe School Formation (incorrectly labeled) about 1500 feet north of the school corner. Nevertheless, the USGS map shows the location on the "first cuesta" to be 1000 feet from the school corner, and we accept that figure. The topmost exposure of the formation extends well beyond the 50 feet given by Kelly & Smith. In fact, Ehlers & Ulrich in their 1926 field notes reported the most southerly exposure along the road to be $\frac{1}{4}$ to 1/3 mile south of the corner; our own observations would place the last clear exposure of limestone at about 800 feet south of the corner, making a total outcrop belt of the Beebe School Formation along Munger Road about 1800 feet. For these locations, the USGS topographic map (Wolverine Quadrangle) shows the elevation of the base of the Beebe School to be about 785' and the top to be about 810' MSL, making a topographic relief of about 25 feet. Our own measurements of dip with Brunton compass on a few exposures near the top of the formation reach as much as a 4° southerly component. If the average dip is as much as 3° for the formation, then the dip will account for 94 feet of vertical section; with the 25 feet of topographic relief added, this would give a formational thickness of nearly 120 feet. This estimate is much closer to the well records to the south -- 110 and 125 (or 100, if the basal 25 feet is assigned to the Charlevoix Limestone). If the average southerly component is $2\frac{1}{2}°$, then the computed thickness would be 104 feet. To us these seem reasonable figures -- from 104 to 120 feet.

The section described by Kelly & Smith (1947, p. 460) and the section measured by Ehlers & Ulrich in 1926 are appreciably thinner than our estimates. The units of Kelly & Smith total 70 feet; comparison of their section with that of Ehlers & Ulrich shows that the latter gentlemen observed an additional 10 feet of beds, which would make the total section (as pieced together) 80 feet thick. As Kelly & Smith said, however (1947, p. 460), "The thickness of each member of the Beebe School formation is difficult to measure because the bedding planes are imperfectly exposed, or show evidence of slumping, and the structural attitude can only be approximated." The section of Ehlers & Ulrich spanned a covered interval between two localities (their Locs. 26 and 23). Presumably, in covered and poorly exposed intervals, they carried the section topographically and stratigraphically upward by hand level; neglecting the $2\frac{1}{2}°$ to 3° dip could easily explain the difference between our estimates and their reported thickness.

Exposures. -- The only locality where the Beebe School Formation is exposed is the type locality, along Munger Road in the vicinity of the schoolhouse. Here we can see exposures today, but evidently not as clearly as when the 1926 expedition members were there in 1926.

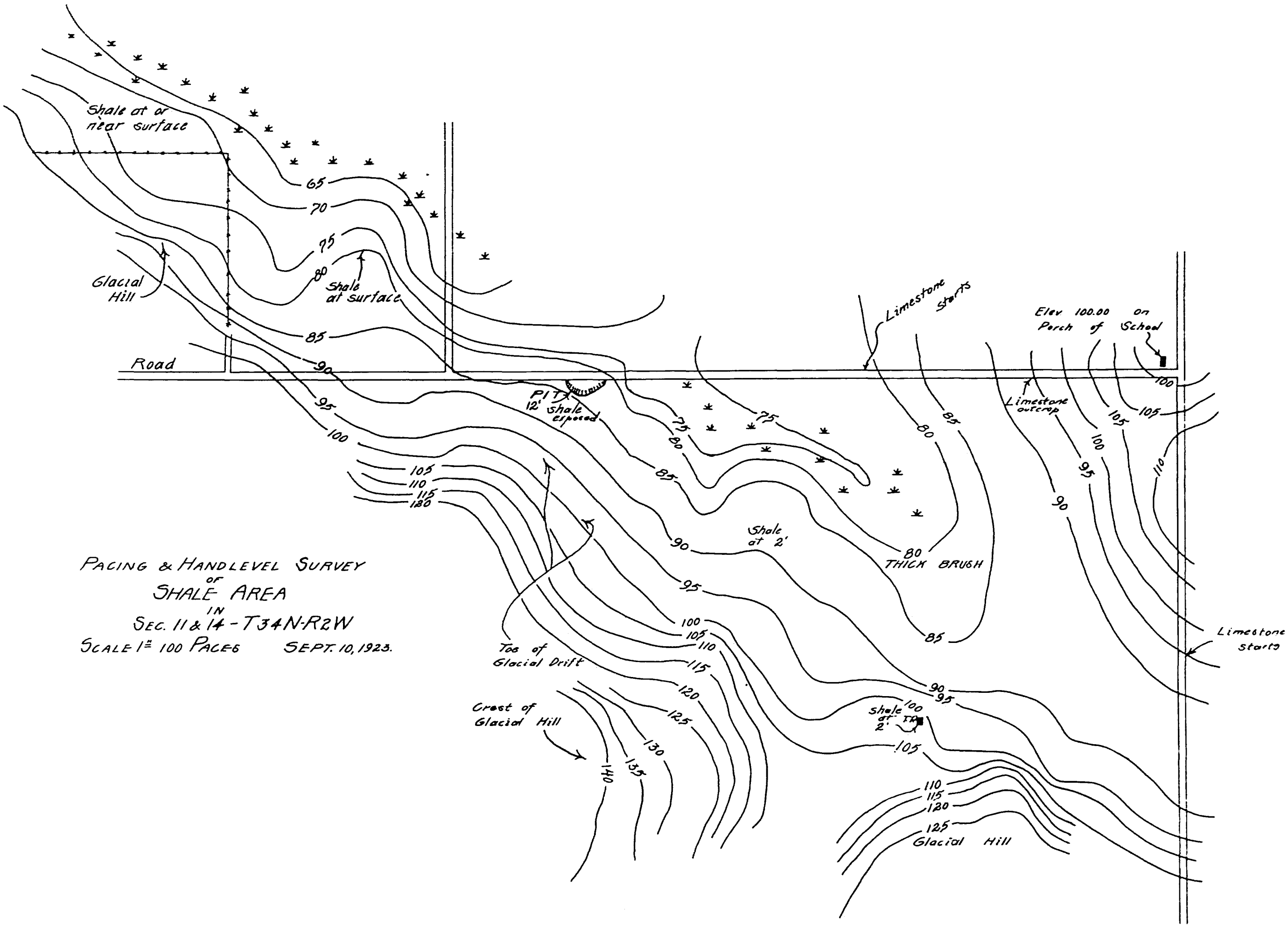
Putting together parts of the sections described by Ehlers & Ulrich with those described by Kelly & Smith, we can arrive at a section that is probably almost complete but underestimated in thickness of units. Here, units 4-13 are adapted from Ehlers & Ulrich's section (see p. 74) and units 1-3 are from Kelly & Smith's section (1947, p. 460):

Measured Section

Overlying formation - Norwood Shale

Covered interval - probably only a few feet.

13. Limestone, massive, dark dove-colored with irregular stringers of calcite and ramose Favosites .... $1\frac{1}{2}$
12. Limestone, darker gray, with corals and Idiostroma. Lower half structurally like vesicular chert. Corals in upper half 2
11. Shale, gray, with concretions of darker gray limestone filled with ostracods. Bythocyprids most abundant 2
10. Limestone, heavier bedded than underlying, with Idiostroma (small hole in center), 2 species of gastropods, a cephalopod, large Ceratopora, large heads of Favosites, and massive stromatoporoids. Limestone light-gray, with thin irregular $1\frac{1}{2}$ to 2-inch thick layers and lenses of chert. Some fossils in limestone silicified 4
9. Limestone, magnesian, yellowish, finely crystalline - poorly exposed ... 1
8. Limestone, dove-colored, platy, obscurely laminar with dumose Favosites, Aulopora, athyrids ($\frac{1}{2}$ to 3/4 inch in diameter) in lower foot 4
7. Limestone, black, sandy and streaked, all laminar 4
6. Limestone, dove-colored, laminated with cavities - almost vesicular. Top becomes almost black 4
5. Limestone, laminated, yellowish-gray at base becoming pinkish at top .... $3\frac{1}{2}$
4. Limestone, yellowish-gray and shaly. Becomes cobbly on weathering. Acervularia at base 6
3. Shale, calcareous, weathering yellow, interbedded with thin, highly fossiliferous limestone layers. Most abundant fossils are short, long-winged Mucrospirifer and small strongly cos-



TEXT-FIG. 44 -- Compass-pace contour map of area near Beebe School, prepared as plat of shale (Norwood Shale) reserves for proposed state-operated cement industry by R. A. Smith in 1923. As reduced, the scale is 1" = about 640 feet. For contouring, the porch of the school house was arbitrarily set as 100 feet. The minimum estimate in this area was 6 million tons of shale, sufficient for 100 million barrels of cement.

tate Strophodonta 30

2. Limestone, thinbedded, light-gray weathering brown, cherty, with some very fossiliferous layers. Most fossils are brachiopods of the genera Cyrtina, Mucrospirifer, Productella, Strophodonta, and Craenena. Some corals, including Cylindrophyllum ... 10

1. Biostrome, massive, porous, and composed of unoriented coralla and fragmentary remains of crinoids, bryozoans, and brachiopods. Matrix coarsely granular. Appears conformable with underlying limestone, but separated by thin concealed interval 10

Underlying formation - Gravel Point. Limestone, massive, fine-grained, gray, containing the coral Hexagonaria percarinata (Sloss).

Measured Section

As given in the original measurements, the units total 82 feet in this composite section. We would suggest that the thickness should be increased by about 20%.

TEXT-FIG. 45 -- Exposure of Norwood Shale west of Beebe School on the south side of Beebe School Road, taken when the shale pit was at its fullest development. Photographed by Ehlers around 1926; compare with recent photograph in text-figure 9 (p. 17). The gentleman in the hat using a hand lens is Dr. E. O. Ulrich; the younger man in the sun visor may be Charles Deiss, graduate student on the 1926 expedition. Locality 34-2W-14 NW-SE.

Well records demonstrate that the shale units in the Beebe School Formation do not occupy precisely the same positions at all places.

A serious question about the base of the formation at the type locality could be raised. In the above composite section, unit 2 (with Cylindrophyllum) can be correlated with the Potter Farm Formation in Alpena County. But unit 1, the biostrome with crinoidal fragments and other invertebrates, seems more like the reworked rubble from a reef in the Alpena Limestone than any of the lower units of the Potter Farm. Careful collecting and identification could decide the affinities of unit 1.

It is also possible that the ecology of the Afton-Onaway area was different from that of the Alpena area, so that the faunal assemblages of one place are not the same as those of the other.

Kelly (1940 guidebook) said of the Beebe School beds:

> Exposures of limestone stratigraphically above the Marvin beds on both the steep and gentle slopes of northwest trending cuestas. The average inclination of these beds is close to $2\frac{1}{2}$ degrees to the southwest. Between the outcrop of limestone (assigned to the Marvin) on the north side of the small creek flowing through sections 13 and 14, and the Antrim exposures west of of Beebe School, there is a calculated thickness of about 125 feet. This relatively small thickness either includes strata equivalent to the thick Alpena and Thunder Bay formations, or indicates non-deposition of, or unconformities within the Upper Traverse of the Afton area. [In this guidebook, this is locality 34-2W-13 NW/14 NE.]

Nine years later, another field excursion was made to the area, and Kelly (1949) specifically placed the boundary of the Gravel Point and Beebe School:

The boundary between the Gravel Point and the Beebe School is located at the contact halfway up the first (northern) cuesta, between a dense limestone carrying Hexagonaria and a sparse brachiopod fauna, and a biostrome carrying numerous crinoidal fragments as well as a few branching cylindrical corals.

Fauna. -- The Beebe School Formation has not been thoroughly or systematically examined at the only locality of exposure. In publication, only 12 genera and 5 species have been formally recorded. This is an insignificant percentage of the total fauna. We suspect that the totals exceed those of the Potter Farm Formation in Alpena County (36 genera, 55 species). The following list is based on the combined Potter Farm fauna of Alpena County and the Petoskey fauna of Emmet and Charlevoix Counties; the species actually reported from the Beebe School Formation are marked with an asterisk:

Rugose corals
- *Aulacophyllum bilaterale* Sloss
- *Aulacophyllum hemicrassatum* Sloss
- *Bethanyphyllum geniculatum* (Rominger)
- *Bethanyphyllum robustum* (Hall)
- *Cylindrophyllum hindshawi* Ehlers & White
- **Cylindrophyllum panicum* (Winchell)
- *Cystiphylloides* cf. *aggregatum* (Billings)
- *Cystiphylloides (?) amalgamatum* Stumm
- *Cystiphylloides americanum* (Edwards & Haime)
- *Cystiphylloides* cf. *conifollis* (Hall)
- *Cystiphylloides petoskeyense* Stumm
- *Cystiphylloides potterense* Stumm
- *Cystiphylloides* cf. *varians* (Hall)
- *Disphyllum compactum* Ehlers & Stumm
- *Hallia vesiculata* Sloss
- *Hallia zonata* Sloss
- *Heliophyllum halli potterense* Stumm & Tyler
- *Heliophyllum rotatorium* Stumm & Tyler
- *Heliophyllum tenuiseptatum tentaculum* S & T
- *Heterophrentis curviseptata* Stumm
- *Hexagonaria profunda* (Hall)
- **Spongophyllum alpenense* Ehlers & Stumm
- *Stereolasma petoskeyense* (Sloss)
- *Synaptophyllum crassiseptatum* Ehlers & Stumm
- *Tabulophyllum traversense* (Winchell)
- *Tortophyllum cysticum* (Winchell)
- *Tortophyllum magnum* Stumm

Tabulate corals
- *Alveolites subramosus* Rominger
- *Aulocystis alpenensis* Watkins
- *Aulocystis cooperi* Watkins
- *Aulocystis parva* Watkins
- *Aulopora gregaria* Watkins
- *Drymopora* cf. *jacksoni* (Grabau)
- *Emmonsia alpenensis* Stumm & Tyler
- *Favosites alpenensis alpenensis* Winchell
- *Favosites alpenensis tenuimuralis* Stumm
- *Favosites* cf. *hamiltoniae* Hall
- *Favosites mammillatus* Stumm & Tyler
- *Favosites placentus* Rominger
- *Favosites romingeri gilvisquamulata* Swann
- *Favosites romingeri patella* Swann
- *Favosites romingeri romingeri* Swann
- *Pachyphragma erectum* (Rominger)
- *Syringopora crassata* Winchell
- *Syringopora ehlersi* Watkins
- *Trachypora alternans* Stumm & Hunt
- *Trachypora perreticulata* Stumm & Hunt
- *Trachypora proboscidialis* (Rominger)
- *Trachypora (?) reticulata* Stumm & Hunt

Brachiopods
- *Athyris lens* (Winchell)
- *Atrypa traversensis* Fenton & Fenton
- *Chonetes ensicosta* Imbrie
- *Chonetes* cf. *coronatus* Hall
- *Cranaena* aff. *amygdaloidea* Cooper & Cloud
- *Elytha filicosta* (Winchell)
- *Mucrospirifer attenuatus* (Grabau)
- *Mucrospirifer grabaui* Stumm
- *Mucrospirifer latus* (Grabau)
- *Mucrospirifer profundus* (Grabau)
- *Oligorhachis littletonensis* (Stainbrook)
- *Pentamerella athyroides* (Winchell)
- *Pentamerella papillata* Imbrie
- **Pentamerella pericosta* Imbrie
- *Pentamerella petoskeyensis* (Imlay)
- **Sphenophragmus nanus* Imbrie
- **Spinulicosta mutocosta* Imbrie
- *"Spirifer" consors* Winchell
- *Strophodonta crassa* Imbrie
- *Strophodonta* cf. *demissa* (Conrad)
- *Strophodonta elongata* Imbrie
- *Strophodonta* cf. *erratica* Winchell
- *Strophodonta potterensis* Imbrie
- *Strophodonta tenuicosta* Imbrie
- *Truncalosia gibbosa* Imbrie

Gastropod
- *Pleurotomaria alpenensis* Ehlers & Hussey

Bivalve
- *Conocardium bifarum* Winchell

Trilobites
- *Crassiproetus alpenensis* Stumm
- *Phacops iowensis iowensis* Delo
- *Phacops* cf. *rana* Green

Blastoid
- *Codaster alatus* Reimann
- *Codaster gracile* (Wachsmuth)
- *Lipsanocystis oblatus* Stumm

Pentremitidea cloudi Reimann

Crinoid
Dolatocrinus grabaui Kirk

Sedimentation. -- Like the correlated Potter Farm Formation and the Petoskey and Whiskey Creek Formations, to the east and to the west of this area, the Beebe School Formation includes both high-calcium and argillaceous limestones, as well as minor units of shale. The less argillaceous limestones bear the coral fauna, and are presumed to have been shallow-water, high-energy deposits. The shales have a diverse fauna and are presumed to have been deep water sediments. All appear to have been laid down in normal marine environment.

UPPER DEVONIAN

NORWOOD SHALE

Name and type locality. -- As explained by Kesling, Segall, & Sorensen (1974, p. 116), the name "Norwood" was proposed somewhat informally by G. M. Ehlers in the 1938 guidebook. He did not accurately define the geographic or stratigraphic limits of the formation, nor did he differentiate it from the Antrim Shale above. The "type locality," to judge by the name, is the black paper shale exposed along the old secondary road leading north from the village of Norwood, nearly a mile north of the pier in NE$\frac{1}{4}$ sec. 27, T 33 N, R 9 W. The outcrop is within sight of Lake Michigan.

Whether the Norwood exposures and the correlated strata across the northern part of the Lower Peninsula are sufficiently different from the Antrim Shale to warrant a formational recognition must remain an open question. The shale appears to be much thinner bedded and to have fewer large concretions. The fauna -- practically all conodonts -- has yet to be studied by currently active paleontologists. Here, we carry over the application of the name Norwood Shale as has been done informally for many years by geologists in Michigan.

Exposure. -- The only place where the black Upper Devonian shales are well exposed in the Afton-Onaway area is in the vicinity of Beebe School. Here, about 1/3 mile west of Munger Road, on the south side of Beebe School Road, is the remains of an old shale pit. Nearby are hillside exposures of the same unit, and the whole ridge has at most a few feet of drift. This is locality 34-2W-14 NW-SE.

The occurrence of black shale was known to R. A. Smith, who investigated the possibility of using the deposit in manufacture of cement by state prison labor. The 1923 plans (see text-fig. 44, p. 85) never materialized and no other firm has become interested in the manufacture of cement at a locality so far from lake transportation. Probably, the pit was developed west of Beebe School at this time.

The shale pit was fully formed by 1926 (see text-fig. 45, p. 86) when the expedition came into the area. Here Ehlers & Ulrich recorded in their notebook the following description:

Measured Section

Roadside Quarry near Center of Section 14,
Ellis Twp., Cheboygan County
Loc. 24

Black laminated shale with lenses of dark limestone, containing fucoid-like structures. A lens in quarry is one foot thick at center. Shale contains many conodonts; of these, 12 were identified with closely related Portage species. Conodonts occur chiefly about 2 feet above base of quarry .... 7'

Measured Section

A similar description was made at the same time and place by E. C. Case:

Measured Section

Shale pit west of Beebe School - Loc. 24

Black shale with large limestone concretions not like Norwood (cut with fucoidal markings) and with conodonts identified by Ulrich as Portage Lake .... 7 feet

Measured Section

In the 1930's, Margaret L. Morse chose to work on the conodont fauna of the black shale

TEXT-FIG. 46 -- Close-up of exposure of Norwood Shale west of Beebe School. Locality 34-2W-14 NW-SE. Photographed by Kesling, 2 Oct 1975.

for her doctoral dissertation. This work was never published, and the taxonomy is undoubtedly outmoded. On pages 13 and 14 of her thesis, Miss Morse described the shale:

Measured Section

Pit on an East-west Road about 1/3 mile west of Beebe School, located ½ mile west and 2½ miles south of Afton (Loc. 24)

Thickness
Feet

Norwood Shale

Shale, black, fissile with buff-gray, lenticular limestone masses very similar to those found at the type locality north of Norwood. The conodont fauna of the shale includes Angulodus walwrathi (Hibbard), Hindeodella gracilis Huddle, Ligonodina falciformis Ulrich & Bassler, Synprioniodina sp. nov., and Palmatolepis punctata (Hinde). The shale contains a pteropod Styliolina fissurella (Hall), which also occurs in the lenticular limestone where it is associated with Barroisella sp., Chonetes sp. cf. C. lepidus Hall, Buchiola retrostriata (v. Buch), Pleurotomaria ? sp., Entomis sp. cf. E. serratostriata Sandberger and Tentaculites sp. .... (approximately) 6

The conodonts noted in the Norwood shale (above) are characteristic of the Rhinestreet shale of New York and the lower New Albany shale of Indiana. The invertebrate fauna of the lenticular limestone is similar to that found in the lenticular limestone masses north of Norwood and is strongly suggestive of the Naples fauna of New York.

Measured Section

Fauna. -- No formal work has been done on the conodonts of the Norwood Shale. The remarks of Margaret Morse quoted above from

TEXT-FIG. 47 -- Exposure of Norwood Shale in Paxton Quarry west of Alpena, Michigan. This quarry supplies shale for the Huron Portland Cement Company in Alpena (formerly the Michigan Alkali Quarry). The young lady is presumed to be Margaret Morse, who did her doctoral thesis on the conodonts of the black shales. Photographed by Ehlers, probably in the 1930's.

her doctoral dissertation include references to most of the species she discovered.

On-the-spot hand-lens identifications of the conodonts had been attempted by E. O. Ulrich on the 1926 expedition. The field notes include the following:

Field identifications by E. O. Ulrich in 1926 at Loc. 24:

Palmatolepis punctata	Prioniodus undosus
Bryantodus crassidens	Ancyrodella nodosa
Bryantodus multidens	Hindeodella alternata
Bryantodus nitidus	Euprioniodina deflecta
Bryantodus obliquus	Styliolina fisherella
Bryantodus sinuatus	Prioniodella aequidens
Lonchodina separata	Prioniodella inaequalis
Palmatolepis punctata	Prioniodella multidens
Ligonodina deflecta	Prioniodella normalis
Ligonodina falciformis	Drepanodus sp.

Sedimentation. -- The change from the fossiliferous marine limestones and shales of the Traverse Group to the near-barren black Upper Devonian shales of the Michigan Basin is sharp and dramatic. Extending far beyond the basin to the south, a foul blanket spread over the sea floor and the arena altered from one of life to one of death.

According to a recent textbook on sedimentary rocks by Blatt, Middleton, & Murray (1972, p. 392-394), the stagnant waters where organic matter accumulates have practically no oxygen content and oxidation potential (Eh) in the area of -0.3 volt. In the absence of circulation by currents, organic matter is deposited with clay-size detritus and persists. The organic compounds which have no nutritive value for bacteria, derived from the breakdown of proteins, polysaccharides, fats, and nucleic acids, are adsorbed in interaction with the clay minerals and immobilized.

Of the general black shale facies, Pettijohn (1957, p. 622) has this to say:

The black shale facies ... has an abnormally high content of carbon (5% or more), is rich in iron sulfide (pyrite), and is noted for its concentration of rare elements (V, U, Cu). The black shale fauna is restricted to a few inarticulate phosphatic brachiopods (*Discina*), conodonts, and resinous spores ... In general black shale sections are not very thick -- several hundred feet is generally the greatest thickness. They may, however, be rather widespread. Their rate of accumulation is perhaps the slowest of all sediments. ... Clearly the black shale association is one characterized by a highly reducing environment. It must be one with a very low oxidation-reduction potential.

The modern example of black shale deposits is the Black Sea, which has been recently studied and reviewed by Degens & Ross (1974) and by others. In his textbook, Pettijohn (1957, p. 622-624) states:

This body of water is over 2000 meters deep in places. Only the upper 50 meters are well enough aerated to support life. All the waters below 100 to 200 meters are toxic by reason of the presence of H_2S. The bottom muds contain 23 to 35 per cent of organic matter, in contrast to the average recent sediment which contains only 2.5 per cent of organic matter. Bottom life, except for anaerobic bacteria, is absent ... The anomalous salinity and temperature variations with depth are explained by the inhibited vertical circulation.

Of the geologic occurrences of black shale, Pettijohn (1957, p. 625, 626), like others who have investigated them, is not certain that the Black Sea is the prototype for all black shale formation. He says:

That the pyritic black shales were deposited under anaerobic conditions is unquestioned. Whether, however, the basin of accumulation was shallow or deep and whether it was landlocked or freely connected with the sea or even only a stagnant area in the open sea has been much debated. It seems most probable that some impediment to convection currents is necessary and that the best hindrance is a density stratification related to salinity differences. Such is readily obtained in a barred basin.

It is our view that restricted circulation was an essential element in the Norwood environment, that such conditions existed over a large geographic area in east central North America, and that they persisted with little change for a long time -- whatever the conditions that led to the restriction.

Norwood Shale as a cement reserve.-- We have already referred to the aborted plans by the State of Michigan to locate a cement industry in this area, depending upon the Gravel Point Formation for the limestone and the Norwood Shale for the shale.

In the process of preparing estimates for the reserves, R. A. Smith of the Geological Survey had analyses made of the stone at several places. One was in the Beebe School area. Here several holes were drilled, of which five were sampled and analyzed. These data are of interest to us because of their revelation of the nature of the Beebe School to Norwood transition; they are of much less interest as economic potential for the strata concerned.

Not all samples are restricted to the Norwood Shale. According to our geologic map and inferred contacts, some of the holes undoubtedly penetrated into the Beebe School Formation.

Nevertheless, it is obvious that the basal part of the Norwood Shale consists of alternating shales and limestones. Not all of the limestone reported in the samples can be attributed to the sporadic occurrences of limestone-rich nodules within the shale. Without question, a series of closely spaced holes would reveal that some of the limestone units are continuous beds.

Our interpretation is that the stagnation producing the initial black shale units was replaced by flushing and vertical stirring from time to time, so that normal oxidation returned to the waters and carbonaceous matter was consumed. We cannot determine from our limited scope of information whether the conditions of unrestricted circulation persisted long enough for the marine invertebrates to re-settle the area. At any rate, we place the base of the Norwood at the first consistent unit of black shale and recognize that the first few feet of the formation is a transition in which stagnation was briefly interrupted several times.

STATE SHALE EXPLORATION

Beebe School Deposit

All wells drilled in 1924 by E. J. Longyear Exploration Company for Geological Survey Division.
All analyses completed in June, 1946, by Aetna Portland Cement Company, Fenton, Michigan.

All locations measured from E$\frac{1}{4}$ corner of sec. 14, T 34 N, R 2 W, Cheboygan County.
All elevations based on B.M. = 100 feet on lower step of Beebe School building.

Hole #1

Location: 3153 feet W and 50 feet N. Elevation: 88.8 feet.

Sample No.	Thick	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss	Total
Drift	14' 6"							
1. Greenish-gray shaly limestone with spots of brown and streaks of light gray	1' 6"	18.8	4.8	5.6	38.2	1.4	33.0	101.8
2. Greenish-brown limey shale with bands, streaks, and spots of light greenish gray	8' 3"	49.2	2.6	14.4	10.0	1.3	20.4	97.9
3. Same	5' 0"	50.0	14.8	6.0	9.6	0.7	20.5	99.6
4. Same but slightly darker color; much higher in lime	5' 9"	32.0	9.6	4.0	17.6	0.7	34.0	97.9
5. Brown crystalline limestone, shaly	4' 6"	6.4	2.0	0.8	47.6	0.6	41.0	98.4
6. Very dark brown, nearly black shale	2' 0"	52.0	11.0	3.6	4.0	0.9	23.6	95.1

Hole #2

Location: 3809 feet W and 726 feet N. Elevation: 75.4 feet.

Sample No.	Thick	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss	Total
Drift	3' 0"							
1. Greenish-gray limestone shale, occasional bands of greenish-brown	14' 0"	26.4	9.6	2.4	29.6	2.2	28.0	98.2
2. Greenish-brown shale with spots and bands of greenish-gray	6' 0"	50.8	14.4	4.8	4.0	2.2	22.4	98.6
3. Same, but twice as limey	4' 0"	42.8	11.6	4.4	8.0	1.7	30.0	98.5
4. Brown shaly limestone	2' 0"	16.4	5.6	2.0	34.4	1.4	37.6	97.4
5. Very dark brown limey shale with pyrite	10' 0"	48.0	8.8	6.8	6.0	1.9	26.6	98.1
6. Light greenish gray limey shale with bands and streaks and lumps of dark-brown shale	5' 6"	52.0	12.4	4.4	9.2	1.7	19.8	99.5
7. Gray limey shale	5' 6"	50.8	12.0	4.0	8.0	1.9	21.8	98.5

Hole #3

Location: 2100 feet W and 60 feet N. Elevation: about 74 feet.

Sample No.	Thick	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss	Total
1. Top of quarry, dark-brown shale	4' 0"	54.4	3.2	8.4	0.8	Tr	31.0	97.8
2. Dark-brown shale	1' 6"	52.0	11.6	7.6	1.6	0.6	27.0	100.4
3. Gray shaley limestone	6' 6"	26.8	4.8	6.4	30.0	0.4	27.4	95.8
4. Dark-brown shale with spots and bands of gray shale	17' 8"	30.0	7.2	4.8	24.4	0.4	30.0	96.8
5. Greenish-gray	7' 4"	13.2	1.6	5.6	40.0	0.3	35.6	96.3
6. Gray and greenish-gray hard limestone	9' 0"	20.8	12.0	2.4	24.0	Tr	40.0	99.2
7. Green shale above, shading to gray below; very limey	4' 0"	38.0	6.8	9.2	14.4	3.3	24.6	96.3

Hole #6

Location: 50 feet W and 1789 feet S. Elevation: 99 feet.

Sample No.	Thick	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss	Total
Drift	4' 0"							
1. Very dark brown	3' 6"	42.8	7.2	8.4	12.8	1.0	24.6	96.8
2. Gray and dark-gray shaly limestone	4' 6"	24.0	8.0	6.0	55.2	0.7	28.0	101.9
3. Dark-gray to light-brown with bands of lighter gray; very limey	13' 8"	40.0	15.2	4.8	20.0	0.9	19.8	100.7
4. Dark-brown	12'10"	48.0	12.0	10.0	5.2	0.6	23.6	99.4
5. Same with considerable pyrite; some gray at end	5' 0"	53.6	8.8	8.4	4.8	Tr	25.6	101.2
6. Hard greenish-gray with bands of dark-brown	5' 0"	54.4	11.6	7.6	13.2	1.4	12.0	100.2
7. Gray hard shale (limestone or limey shale)	1' 6"	35.6	6.8	4.8	24.4	1.2	25.8	98.6

Hole #7

Location: 1109 feet W and 1407 feet S (filed report says "North" but this would place the hole in the Beebe School Formation; evidently an error, for hole appears to be within the black shale deposit). Elevation: 107 feet.

Drift	13' 0"							
1. Very dark brown shale	13' 0"	58.4	14.0	2.0	2.0	1.6	19.4	97.4
2. Same, more iron and alumina	13' 0"	52.8	14.6	3.6	3.2	2.7	21.6	97.5
3. Same	6' 0"	53.3	12.4	3.2	5.8	1.7	21.0	97.4
4. Limestone and gray shale	4' 0"	26.0	7.4	2.0	30.8	1.4	28.2	95.8

INTERPRETING THE RECORD

General Remarks

No matter in what repute Uniformitarianism is currently held, it is still the approach used most to interpret past environments. Once Uniformitarianism was queen of the science, and

"THE PRESENT IS THE KEY TO THE PAST."

but now she is said by some to be a lying old harridan, and

"THINGS ARE NOT WHAT THEY USED TO BE."

The loss of faith (rather than loss of face) seems to have come about because not all factors in the past have been properly evaluated and considered. Indeed, it may not be possible at this time to evaluate some of them. As has been made clear in the past generation of geologists and paleontologists, many conditions were different in the past -- the relative positions of continents, the relative position of the poles, speed of the earth's rotation, presence and location of mountain systems, climate, relative height of sea level, composition of the atmosphere, and many others. Yet there is ample evidence to support our trust that in the long ago, as today, weathering reduced rocks of the highlands, gravity moved the debris downslope, rivers transported it toward the sea, waves and currents sifted and sorted, isolated basins precipitated salt from their brine because of evaporation, each kind of animal fared best in a particular environment, and predation and competition were matters of life and death.

The union of geology and other sciences has produced some vigorous and competent offspring, such as geophysics, geochemistry, and paleoecology. The significant advances in understanding earth history have come with consideration of additional factors -- greater input for greater and better output. We might go so far as to say that even now no observation can be proved irrelevant, no approach can be ruled unproductive, and no mass of data "too much." Modern studies of sedimentation and biology are appropriate and necessary to interpreting the Middle Devonian strata.

As long ago as 1893, Johannes Walther wrote (modern translation by Blatt et al., 1972, p. 187-188):

> The various deposits of the same facies area and, similarly, the sum of the rocks of different facies areas were formed beside each other in space, but in crustal profile we see them lying on top of each other ... it is a basic statement of far-reaching significance that only those facies and facies areas can be superimposed, without a break, that can be observed beside each other at the present time.

In a recent textbook, Blatt, Middleton, & Murray state (1972, p. 185-187):

> There is clearly a close connection between the environment of deposition and the nature of the sediment deposited. For the geologist working with ancient sedimentary rocks, however, the primary data are the rocks and the environment must be interpreted from them ... In ancient deposits the vertical sequence of facies is generally much easier to observe than the lateral sequence, a circumstance that is the exact opposite of the situation in modern sediments.

In 1973 appeared a provocative little volume by Derek V. Ager on The Nature of the Stratigraphical Record. Some of his conclusions are pertinent to our Middle Devonian record in Michigan. On page 13 he wrote:

> AT CERTAIN TIMES IN EARTH HISTORY, PARTICULAR TYPES OF SEDIMENTARY ENVIRONMENTS WERE PREVALENT OVER VAST AREAS OF THE EARTH'S SURFACE. This may be called the *Phenomenon of the Persistence of Facies*.

And on page 34:

> The stratigraphical record is a lot of holes tied together with sediment... THE SEDIMENTARY PILE AT ANY ONE PLACE ON THE EARTH'S SURFACE IS NOTHING MORE THAN A TINY AND FRAGMENTARY RECORD OF VAST PERIODS OF EARTH HISTORY. This may be called the *Phenomenon of the Gap Being More Important than the Record*.

Again, on pages 58 and 59:

> Sedimentation goes on all the time, for ever moving from place to place, for ever cannibalising itself. Subsidence — on the scale we are concerned with here

> — is generally quite a different matter and must be involved with the internal processes of the earth. It is only when sedimentation and subsidence coincide that the conditions will be right for the preservation of the vast thicknesses that constitute the stratigraphical record...MOST SEDIMENTATION IN THE CONTINENTAL AREAS IS LATERAL RATHER THAN VERTICAL AND IS NOT NECESSARILY DIRECTLY CONNECTED WITH SUBSIDENCE. This may be called the *Principle of the Relative Independence of Sedimentation and Subsidence.*

From these excerpts we can derive some "principles" that apply to the Traverse Group of Michigan:

(1) Certain formations are uniform throughout much of the Michigan Basin. The Bell Shale and the Rockport Quarry Limestone are excellent examples of Ager's "Persistence of Facies." Well records across the Basin show that the Bell continues westward from Rogers City, even where exposures are lacking because of glacial cover, with the same overall thickness, color, composition, and consistency. The same observation applies to the Rockport Quarry if we consider the total thickness of the formation, although the situation is somewhat complicated by the different facies and environments represented in its extent.

(2) The rocks of the Traverse Group do not constitute a complete record for the time that elapsed between the depositions of the basal and topmost layers. The incompleteness of the record is suggested by the rather clean-cut changes from one formation to the next. Seldom does the Traverse show a gradational series of beds in the vertical sequence. High-energy limestones with overturned corals and broken stromatoporoids are succeeded directly by low-energy shales with remarkable evenness of bedding and preserved delicate fossils. We have not been able to recognize any good examples of the classical facies diagram -- bands of lithology zigging and zagging upward through the succession. We are led to conclude that the Traverse sedimentation was interrupted many times.

(3) Within the relatively small area of the Michigan Basin, each formation was practically the same age throughout its extent, with the stratigraphic and chronologic units nearly corresponding. Of course, sediments took a little while to spread across the area from Alpena to Charlevoix, and are technically diachronous. For the Middle Devonian in this region, however, the time interval seems to have been insignificant. We are inclined to agree with Ager (1973, p. 53-55), who said in his discussion of C-14 dates of the intertidal algal mats along the Trucial Coast:

> When stratigraphers discovered facies (way back in the days of Gressly), then all differences in lithology tended to become synchronous. Conversely, when they discovered diachronism, all similarities in lithology tended to be taken as evidence of different ages. In other words: "if it looks different it must be of the same age", and "if it looks the same it must be diachronous". Obviously this is an overstatement, but it does not really exaggerate too much the state of mind many of us have reached in stratigraphical discussions.... Diachronism does occur... And yet, is it so impressive? ... We are still dealing with almost negligible figures in geological terms.

And further, on his page 78:

> We also know that each formation is diachronous within itself. But time-wise the gap between them may well be much more important than the time-span within them.

(4) At least some of the Traverse Group deposits appear to have modern counterparts in the genesis of the sediment, the energy of its transport, the relationship to contemporary deposits, and the environment of final deposition. As discussed in the models below, the parallel or identical factors in modern carbonate sedimentation and some of the Traverse units are remarkable, to say the least.

Models

Perhaps "modern counterparts" would be a preferable designation to "models" in this discussion. Comparable depositional situations could be found for many more of the Traverse Group beds than the two elaborated here.

Three difficulties or shortcomings stand out in the applicability of modern processes of sedimentation to past earth history. First, the effects of post-depositional compaction, cementation, and chemical substitutions may be appreciable. Were we permitted to actually see the sediments of the Traverse Group as they were being laid down, we could form more defensible reconstructions of their history. It is wrong, of course, to look upon the Rockport Quarry Limestone as a stack of rock-hard blocks that were Omnipotently sorted for thickness and emplaced during early Traverse time; it is equally wrong to assume that the whole of the formation was at any one instant a soft white-wash slurry like the surficial layer of some of today's carbonate banks. The time involved in diagenesis is important in our understanding Traverse deposits.

A second shortcoming is the uncertainty of correlating strata, even from one part of the Michigan Basin to another. Different formations are present in the Emmet-Charlevoix, Afton-Onaway, and Alpena-Presque Isle areas of our state. From the faunal content, we can draw conclusions on which formations of one area are *approximately* equivalent to those in another; but *approximately* may not be sufficient for reconstructing the depositional history. If we are in error by only, say, fifty thousand years, a lot of changes could have transpired in that time.

The third difficulty lies in the limited view of processes by observing only one depositional basin or province, whereas a much greater area contributes to the nature of the record. Each exposure is evidence of only part of the episode in which it was made. Similarly, each formation cannot be isolated in time and space from formations of slightly different age or location. As Ager stated (1973, p. 79):

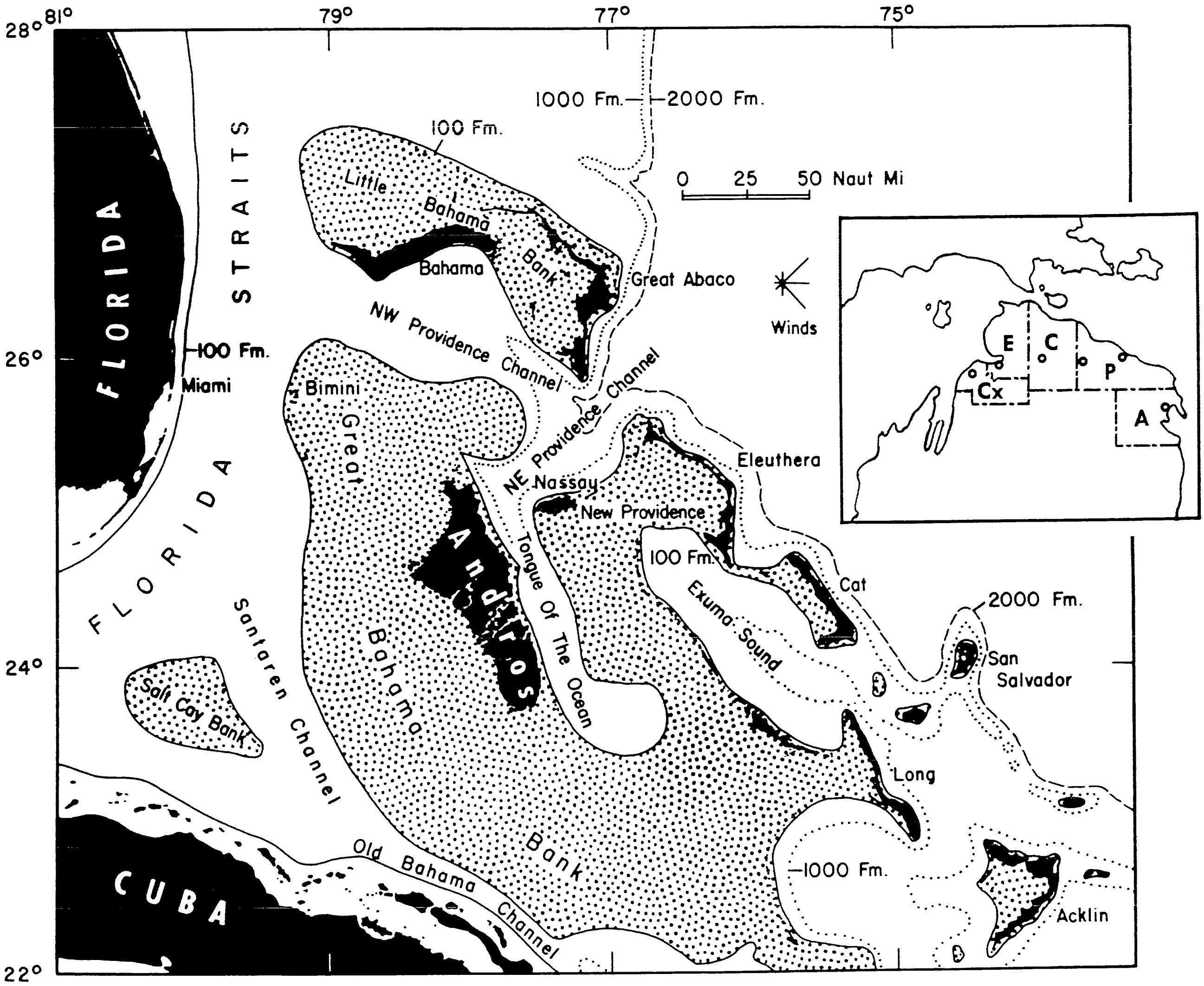
> The 'moving finger' of the dynamic tectonic situation 'writes' the stratigraphical record for us, and only the erosional 'tears' accompanying subsequent uplift can wash out a word of it. This then is the basic tectonic control of the stratigraphical record, in the sense of heaps of sediment being preserved for our study.

MODEL 1 -- The first model of modern sedimentation applicable to Traverse Group strata centers on Andros Island. Situated less than 150 miles east-southeast of the Florida mainland, this island is the major emergent feature of the Great Bahama Bank. The island is at about 24° North Latitude; meteorologically it is in the zone of the "horse latitudes" but because of the dominance of the Bermuda High, the prevailing winds at Andros are easterly (see text-fig. 48).

On the east side of this elongate island, not far offshore, are coral-algal reefs forming an effective windward barrier. Beyond the reefs the bottom slopes off rapidly into Tongue of the Ocean. On the west side of Andros are gently sloping, essentially flat, intertidal and subtidal zones extending for miles before being bounded by the lee-side barrier of oolite shoals. It is in this broad area to the west of Andros Island that carbonates are actively forming. The magnitude of the sedimentation area and the accessibility have made Andros Island rather suddenly the classic example for carbonate studies and the mecca for sedimentology students.

If we examine the cross section profile of Andros Island and adjacent shallow-water, we can readily distinguish six zones between the two barriers; from east to west (in the direction of the prevailing winds), we have (1) back reef, (2) intertidal, (3) high ground, (4) supratidal, (5) intertidal, and (6) subtidal zones.

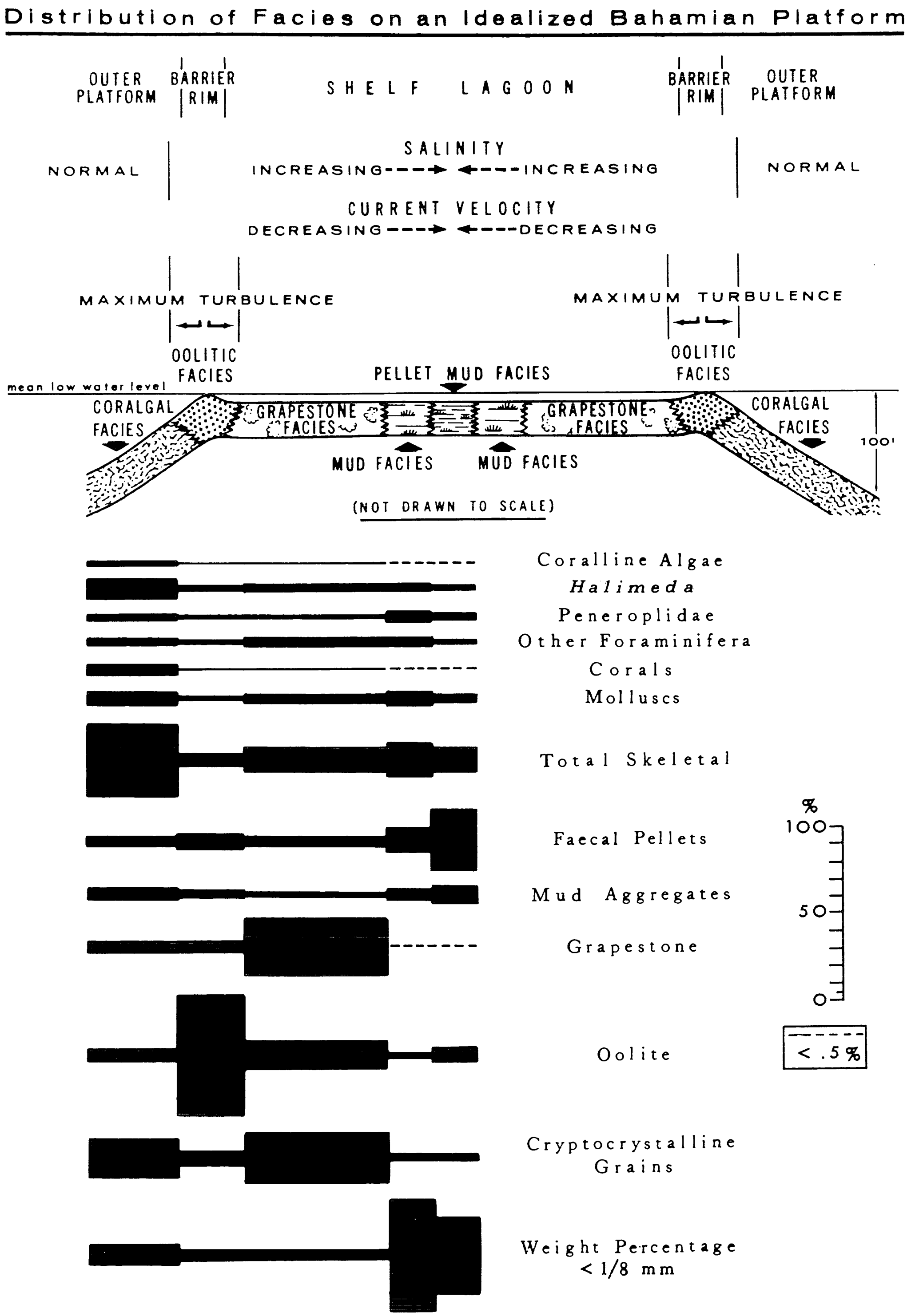
The high ground is a core of older (Pleistocene) carbonate rock that lies above nearly all storm inundations. It is bounded abruptly on the east side by a strip of beach and a narrow intertidal and subtidal skeletal sands. The shallow subtidal back reef area is washed by sheet sands, gradually working downslope and windward with the aid of currents and undertow. Here and there are little patch reefs settling and inhabiting the back reef behind the protective main barrier reef. The barrier itself is composed of corals and coralline algae, so that it is commonly called the coralgal facies. Because the reef is torn and disrupted by tropical storms (hurricanes) which suddenly and violently deepen the zone of turbulence, most reefs show a ter-



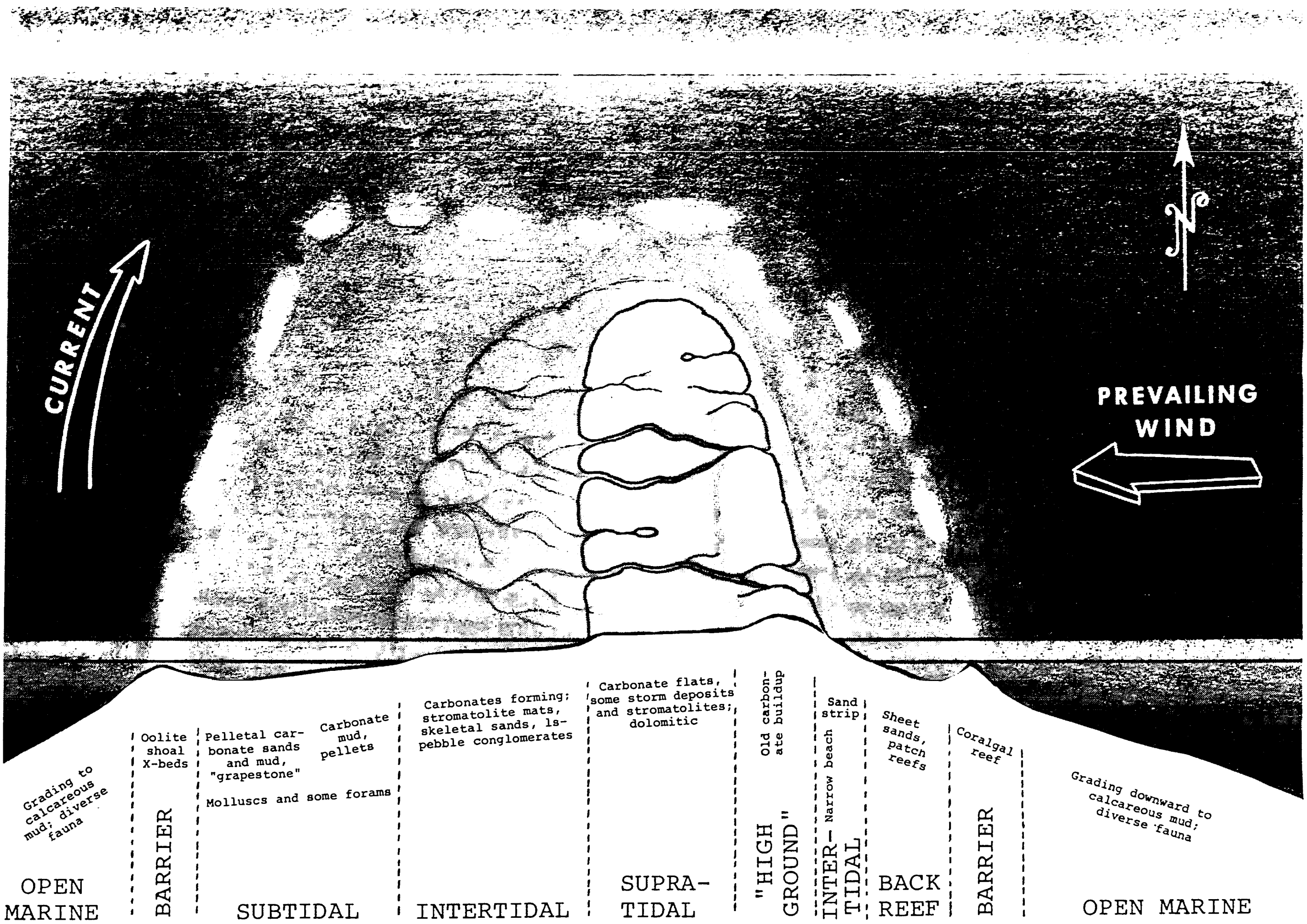
TEXT-FIG. 48 -- Map of the Bahama platform region, with inset map of northern part of Michigan to the same scale. During Middle Devonian time, northern Michigan corresponded remarkably closely to present day Andros Island, from the reef of the Four Mile Dam Formation on the east to the cross-bedded oolitic limestone of the Charlevoix Formation on the west. Modern geologic studies indicate that Michigan was then in the tropical zone of easterly winds, just as Andros Island is today. Letters on the inset map are abbreviations of county names. The map of Bahama region from Purdy & Imbrie, 1964, fig. 1.

raced form to attest to their past crises and recoveries.

To the west, the high ground slopes off into the supratidal flats, a broad band of carbonates with some storm deposits and stromatolite layers. Due to the rapid tropical drying and movement of subsurface water, these onshore deposits are subjected to early diagenetic change and are actively being dolomitized. The intertidal flats tend to build upward to the limit of normal high tides, or even slightly above so that they are exposed to air most of the time. During storms, waves carry carbonate sediment onto these areas, building them above normal tide range; the upward limit is the height of the strongest storm surge. In this manner, the supratidal flats prograde seaward; although somewhat sporadic, sedimentation exceeds er-



TEXT-FIG. 49 -- Characteristic elements and their relative distributions in an idealized modern carbonate platform. In most occurrences, the zones are greatly modified by prevailing winds and the resultant turbulence and currents. From Purdy & Imbrie, 1964, fig. 12 .



Model 1

TEXT-FIG. 50 -- Idealized view and section through Andros Island. Based on various sources.

osion and the result is an extension of the supratidal zone westward from the high ground. In normal evolution of a carbonate platform, the supratidal deposits will cover over intertidal and subtidal deposits.

The intertidal zone, between normal tides, is the area of active carbonate formation. Such calcareous algae as Halimeda, Rhipocephalus, and Penicillus produce aragonite needles within their tissues. All arragonite-secreting algae are found in tropical seas between the 15°C isotherms for the coldest month of the year (Blatt et al., 1972, p. 428). The intertidal zone also supports stromatolite mats, seafloor coverings of blue-green algae which trap and bind carbonate sediment and build upward as accumulations of thin laminae. In recent studies of such algae, they have been classified according to their geometric growth-shapes, as (1) LLH - laterally linked hemispheroids, (2) SH - vertically stacked hemispheroids, and (3) SS - discrete spheroids. The LLH type is most commonly found where wave action is slight, as in protected intertidal mud flats; the SH type is characteristic of stronger wave action, by which the scouring removes thin parts of the mat and leaves the thicker parts to grow upward in isolation; and SS spheroids are found in shallow water near the lower limits of low tides. This last-named algal forms are concentrically built and move during deposition; they are also known as oncolites, and are accretions of carbonate that behave as particles or grains.

Much of the intertidal zone is traversed by dendritic channels that drain off the water at low tide.

In the intertidal and subtidal zones, much of the carbonate mud is ingested by gastropods, polychaete worms, and small crustaceans which produce fecal pellets that act as sediment particles. The pellets are held intact only by organic matter and are readily friable, but they persist and are capable of being preserved. Rounded grains of similarsize and shape are formed by recrystallization of carbonate grains; these pelletoids are contributors to the grapestone facies in the subtidal zone.

The grapestone lumps are formed from partly lithified carbonate sand-size sediment. The cement is fibrous aragonite, and the lumps probably began as eroded and reworked intraclasts of partially consolidated beach rock. Because the subtidal facies includes particles that were (1) probably reworked intraclasts from the edge of the supratidal zone, (2) formed by algal precipitation in the intertidal zone, and (3) resulting from defecation by animals at the site, the sorting of the sediment is poor.

At the western barrier, ooliths form and produce oolite shoals. Individual spherical particles, the ooliths, are generated in sea water that is saturated with carbonate and grow by accretion when periodically lifted, transported, buried, and exhumed. The grains are carried from their origin in the agitated barrier zone and distributed in varying concentrations in the subtidal and intertidal zones as well as seaward and downslope into the shelf area. Within the oolite shoals, crossbedding is prevalent as the pile is reworded by waves and currents.

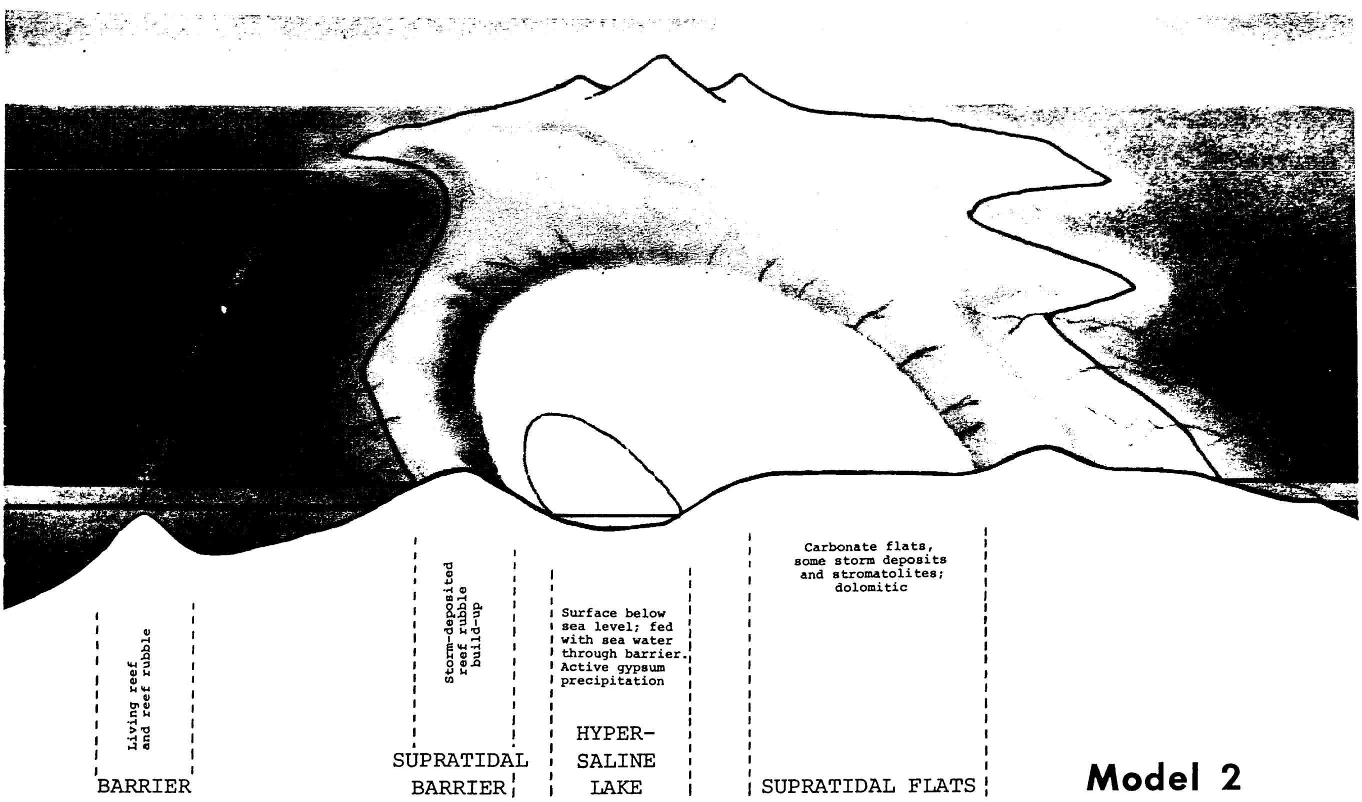
This then is a simplified sedimentational picture of the Andros Island region from east to west: coralgal reef, narrow belt of back reef patch reefs, beach and shallow-water sheet sands, emergent high ground of older rocks, dolomitic supratidal flats, various carbonate muds and sands forming between and below tide levels, and oolite shoals. Around the whole Great Bahama Bank area, the bottom slopes off into the shelf area fairly rapidly beyond the 100-fathom depth.

Middle Traverse sediments. -- One of the best correlations of Middle Devonian strata across the northern part of the Michigan Basin involves the Centerfield equivalents. In the east (Alpena area) the Four Mile Dam Formation forms a reef at the type locality. In the middle of the state (Afton-Onaway area) no record of equivalent rocks has been identified, and the Gravel Point Formation (apparently = Alpena Limestone) is directly overlain by the Beebe School Formation (apparently = Potter Farm Formation). In the west (Charlevoix area) the Charlevoix Limestone is composed in part of cross-bedded oolites with other beds of abundant coral masses and algal laminations.

Several factors favor comparison of this middle Traverse situation with present-time Great Bahama Bank. First, the area across the Devonian outcrop belt is about the same distance as across the Bank (see text-fig. 48, map of Bahama Banks region with inset map of Michigan to the same scale). Second, the location of Michigan during Devonian time has been placed around 7° South Latitude (Seyfert & Sirkin, 1973, p. 263), within what may be assumed to have been the belt of easterly winds. Third, the rocks found in this part of the Traverse Group include stromatoporoid-coral reefs, stromatolitic limestone, various textures of limestones, and oolites -- which appear to be distinctly the Devonian counterparts of living coralgal reefs, stromatolite mats, intertidal and subtidal carbonates, and oolite shoals. The points of agreement seem to us to be more than coincidence. In fact, they are so convincing that they appear "too good to be true."

MODEL 2. -- A second environment which we feel certain provides an analog of conditions that existed during Traverse time in the Afton-Onaway area, although briefly, is found on the island of Bonaire -- a hypersaline lake or gypsum pan which the Dutch named Pekelmeer ("Brine Lake").

Bonaire (or Buen Ayre) is a small island of about 750 square kilometers lying in the Caribbean about 200 km northwest of Caracas. In the southern part of the isle, cut off from the sea by a coral-rubble ridge on the lee side, is



TEXT-FIG. 51 -- Idealized view and section through Pekelmeer on Bonaire Island. Based on various sources.

a flat area of some 30 square kilometers where carbonates are actively forming on the supratidal flats and in shallow hypersaline lakes and accumulating as flat layers and as low dunes. Within this smooth white area, the largest brine lake is Pekelmeer, covering some $2\frac{1}{2}$ square kilometers, its surface kept below sea level by evaporation and continuously receiving sea water which percolates through the reef rubble.

In recent years Pekelmeer has been the focus of many investigations because of its active formation of dolomite and its precipitation of gypsum without halite. Among the sedimentologists who have written about the Bonaire brine lake are Imbrie & Purdy (1962), Deffeyes, Lucia, & Weyl (1965), Lucia (1968), Milliman (1974), and Bathurst (1975). The gypsum and dolomite are intimately related, for the removal of Ca^{++} by precipitation in gypsum raises the Mg/Ca ratio to an exceptional 30/1 and above.

Of the general setting, Bathurst (1975, p. 531) stated:

> Sediments on the lake floor reflect, therefore, a twofold supply of water and carbonates, by storm floods and by seepage. They consist mainly of pelleted lime muds and silts, algal stromatolites and gypsum.

Attention has centered on the manner in which the dolomite is formed -- by reflux of the brine, by uncirculated concentration of Mg ions, or by the capillary draw through unconsolidated sediment by the very active evaporation on the hot tropic flats. As summarized by Bathurst (1975, p. 532, 533):

> In the detailed study of the hydrology Deffeyes *et al.* (1965) investigated the relations between seepage of sea water through the rubble ridge into the lake, rainfall, runoff, evaporation and changes in salinity and of lake levels. Their calculated balance indicates that a counter flow of brine ... should be carrying dense hypersaline lake water seaward through the carbonate sediments underlying the rubble ridge. The driving force for such a *seepage reflux* would be the greater density of the lake water over sea water ...

The seepage reflux hypothesis suffered something of a set-back when Lucia (1968) reported on the lithology of a bore hole through the floor of the Pekelmeer. No dolomite was found and the pore water was normal sea water at a depth where a hypersaline brine would have been expected. It also became known that ... the vertical flow of ground water is restricted to localized permeability channels... The upper ends of the permeability channels manifest themselves as springs around the lake and in the lake floor. Their distribution is apparently related to that of sink holes, in the underlying Pleistocene limestone, which descend well below sea level. Furthermore, the water that flows from the springs is sea water and this path is a more continuous and important one for the delivery of sea water into the lake than the flow through the coral-rubble ridge....

Murray (1969) pointed out that there must be some regular escape of saline water from the lake or the evaporation would have led to the precipitation of the more soluble salts such as halite.

For our model, we are intrigued by the formation of a brine lake where a coral-rubble ridge has cut off open circulation with the sea. Such a situation could easily be produced by a single storm almost anywhere in the tropical carbonate platforms, casting rubble of an offshore reef into shallow water to form a permeable barrier. Seepage inflow of sea water prevents the quick demise of the hypersaline lake by complete desiccation, whereas the continuing evporation keeps the brine concentrated to the point where gypsum precipitates. Brine lakes like Pekelmeer have been reported elsewhere in the tropics, but it has received more attention to date. The surprising thing is not that such brine lakes are formed but that so few have been made known.

Middle Traverse sediments. -- The Pekelmeer model has applications to one and perhaps two sedimentary situations in the Middle Devonian Traverse Group. First, it certainly appears to be the kind of hypersaline basin in which the Welleria aftonensis zone of the lower Gravel Point Formation was deposited. If we are correct, it might explain why the zone is not widespread. As we envisage the deposition, the brine became so concentrated in a cut-off pond or lake that the only animal which could thrive was the little ostracod; it took advantage of the lack of competitors to breed in great swarms. The absence of oxygen led to preservation of many of the hydrocarbon byproducts of the habitat.

A second application is only a possibility. If the water in Pekelmeer could be arrested at the concentration necessary to precipitate gypsum, why could not a Middle Devonian lake be maintained for some time at a somewhat lower concentration sufficient to precipitate incoming calcium carbonate? In this way, some of the lithographic and sublithographic limestones could be formed chemically, or at least in part by such method.

STRUCTURE

Several synclines, anticlines, troughs, and ridges are present in the Afton-Onaway area of Michigan. These folds are open, and there is no confirmation of much closure even though a few feet of closure seems highly probable on two of the structures. Because much of the area is blanketed by glacial deposits and because most of the stratigraphic structures cross the topographic hills and valleys at an angle, folds are better studied from well cores than from outcrop distributions. As in Emmet and Charlevoix Counties, the major Traverse structures show little warps within them, making many local dips unreliable for interpretation of the main features.

Reference surfaces. -- Probably the most accurate stratigraphic marker in the whole Middle Devonian section of the Michigan Basin is the top of the Bell Shale. This marker is recognized in wells both by lithologic change from the soft shale to the hard overlying Rockport Quarry Limestone and by Schlumberger logs. Its only disadvantage is that the Bell Shale does not crop out in the area, being everywhere masked by drift. The structural contour maps shown in text-figures 52 (p. 104), 53 (p. 105), and 55 (p. 107) are based on the top of the Bell.

The next best marker is the top of the Rockport Quarry Limestone. It crops out and can be recognized in most well cores by the abrupt lithologic change from the thick section of hard Rockport Quarry limestone to the thin interval of soft Ferron Point shale. A map of structural contours based on the Rockport Quarry top is shown in text-figure 54 (p. 106).

The structures outlined by these two tops are very similar in configuration, inasmuch as the Rockport Quarry LImestone changes thickness gradually throughout the area.

Dips. -- From the Claude & Bernice Passino #1 well (NE$\frac{1}{4}$ sec. 18, T 34 N, R 1 W, Walker Twp.) to the Lewis A. Garred #1 well (SE$\frac{1}{4}$ sec. 1, T 33 N, R 2 W, Nunda Twp.), the top surface of the Bell Shale dips 674 feet in 4.8 miles, or an average of about 140 feet/mile in the dip component between the two wells. Also in the western part of the area, the same surface from the Frank H. Grim #1 (NW$\frac{1}{4}$ sec. 7, T 34 N, R 2 W, Ellis Twp.) to the William M. Brown # 1 (NE$\frac{1}{4}$ sec. 12, T 33 N, R 3 W, Wilmot Twp.) dips 795 feet in 6.3 miles, or an average of about 126 feet/mile in this component of the dip.

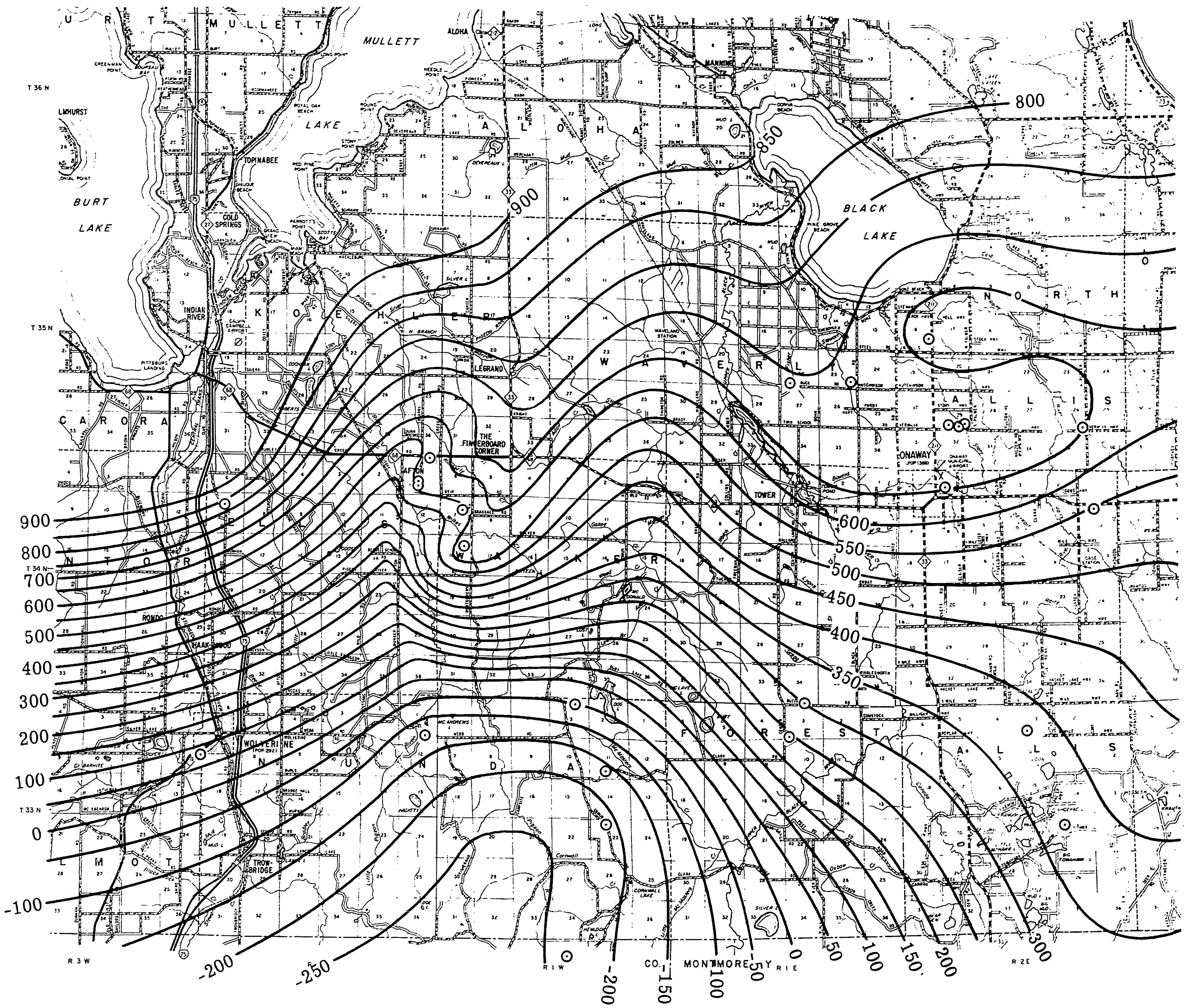
Near Beebe School, some dips on the outcropping Beebe School Formation approach 5° (462 feet/mile) and undoubtedly local dips exceed this amount. Dips are far greater in this vicinity than assumed by Kelly & Smith (1947), accounting for their low estimates of the stratigraphic thicknesses of the Gravel Point and Beebe School Formations, as already pointed out. The component of dip to the south between Beebe School and Sorenson Quarry appears to be slightly greater than 3°.

As stated by Kelly & Smith (1947, p. 463) the average dip in the Middle Devonian in the northern sector of the Michigan Basin is only about 30 feet/mile. Because of the very gentle inclination of the strata into the basin, the rocks of the Traverse Group have a belt of outcrop many miles wide.

Local dips change rather sharply, and some oppose the regional dip. This is quite evident in the area between Black Lake and the village of Onaway. The top of the Bell in the Black Lake State Forest Residence well (SE$\frac{1}{4}$ sec. 18, T 35 N, R 2 E) is 631 feet; 2$\frac{1}{2}$ miles to the south in the Donald E. Drasey Well (SE$\frac{1}{4}$ sec. 29, T 35 N, R 2 E), this top is at an elevation of 684 feet; but 1$\frac{1}{2}$ miles still farther south, in the Presque Isle Development Company well in Onaway (NW$\frac{1}{4}$ sec. 5, T 34 N, R 2 E), the top of the Bell is down to 580 feet. Hence, in this section through the Rainy River Ridge, the dip changes from 21 feet/mile north to 69 feet/mile south (see text-fig. 55, p. 107). Based on 35 wells (see Appendix 7), as well as surface outcrops, our interpretation of structure differs in many details from that of Kelly & Smith (1947, p. 463-468, fig. 6). As a result, we have found it advisable to re-name major features. For example, they proposed a prominent "Onaway syncline" extending south from Black Lake; from our information, Onaway appears to be situated on the southern limb of an east-west structural ridge.

Beebe Syncline. -- In the vicinity of Beebe School, the strata dip sharply to the southwest. Both the westerly and southerly components of the dip can be established by roadside exposures. From Sorenson Quarry to Beebe School, all of the thick Gravel Point Formation and most of the Beebe School Formation dip underground to the south along Munger Road; this shows the southerly component of the local dip. Beebe School is atop a hill; at the base of the hill, about 1/3 mile to the west along Beebe School Road, a pit exposes the black Upper Devonian Norwood Shale, stratigraphically higher and topographically lower than the outcrops at the school house; this shows the westerly component of dip. The strike is indicated by the southeast-northwest ridge of black shale which crosses Munger Road just south of the school and crosses Beebe School Road just west of the shale pit. This was shown by R. A. Smith in his 1923 plat of the shale deposit (text-fig. 44, p. 85). The full dip is about 5° S 45°W.

To account for the higher elevation of the Bell Shale top in the Frank H. Grim well (848 feet in sec. 7, T 34 N, R 2 W) as compared to the elevation in the Clifford & Francis Brown well about 5 miles to the east (522 feet in sec. 1 of the same township), the strata must flex sharply to dip southeast immediately west of the Beebe School vicinity. The same dip and strike are indicated by the Bell Shale tops in the William M. Brown well (53 feet in sec. 12, T 33 N,



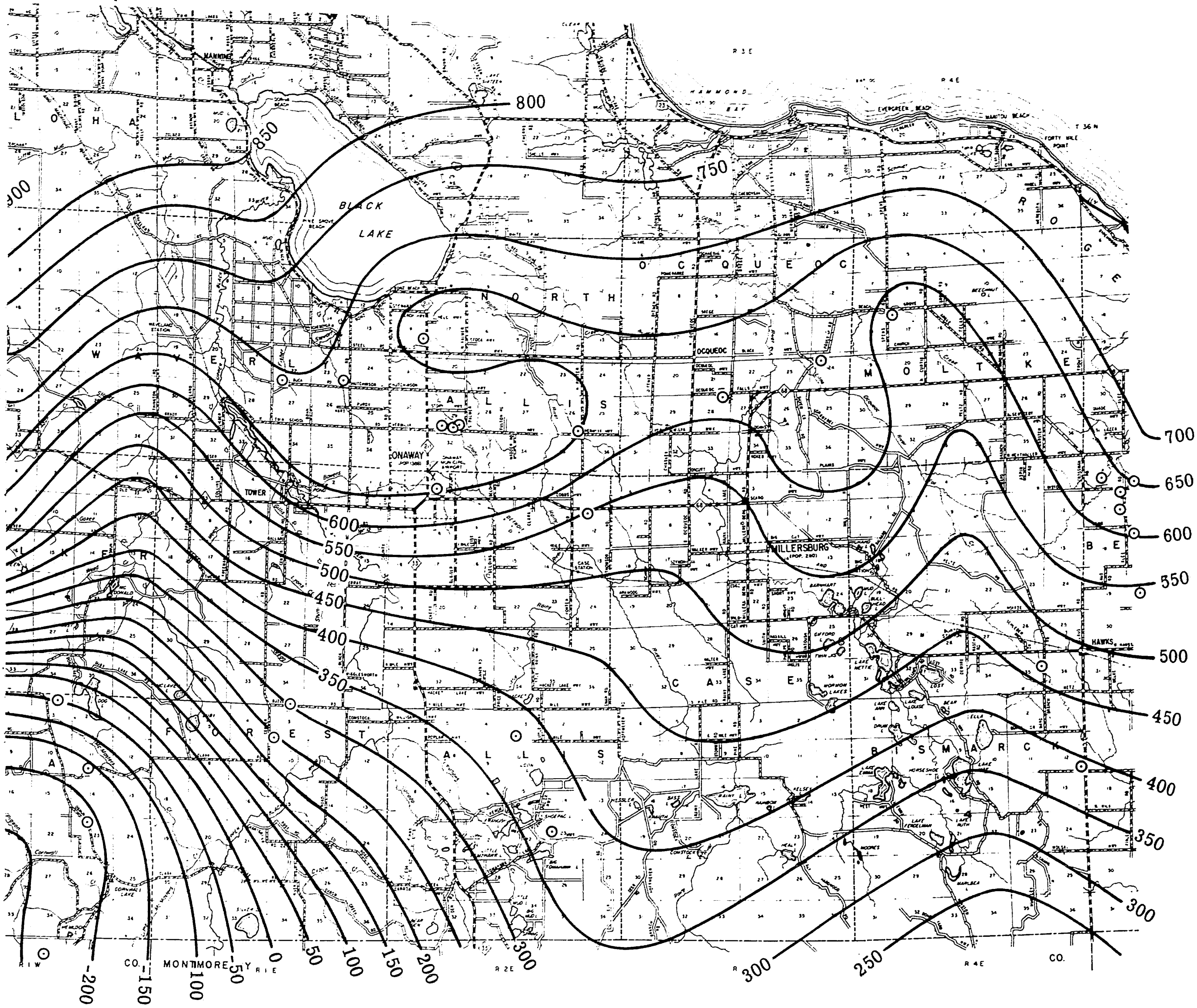
TEXT-FIG. 52 -- Structural contour map of western part of area, based on top of the Bell Shale as shown in well records. For identification of the wells, see Appendix 7.

R 3 W) and less than 6 miles to the east in the Lewis A. Garred well (-113 feet in sec. 1, T 33 N, R 2 W).

The syncline indicated by these surface dips and well records we call the Beebe Syncline (text-fig. 55, p. 107).

Pigeon River Anticline. -- For this structure we retain the name applied by Kelly & Smith (1947, p. 466), although the axis of the anticline on the Bell-Rockport Quarry contact lies east of the Pigeon River and passes through the intersection known as The Fingerboard Corner and through the village of Le Grand.

The same stratigraphic interval is exposed in the Campbell Quarry near Afton (sec. 36, T 35 N, R 2 W) and the Marvin Quarry (sec. 7, T 34 N, R 2 W), about 2 miles to the south-southeast, although both are nearly the same elevation. Hence the general strike is nearly parallel to the line connecting the two quarries.

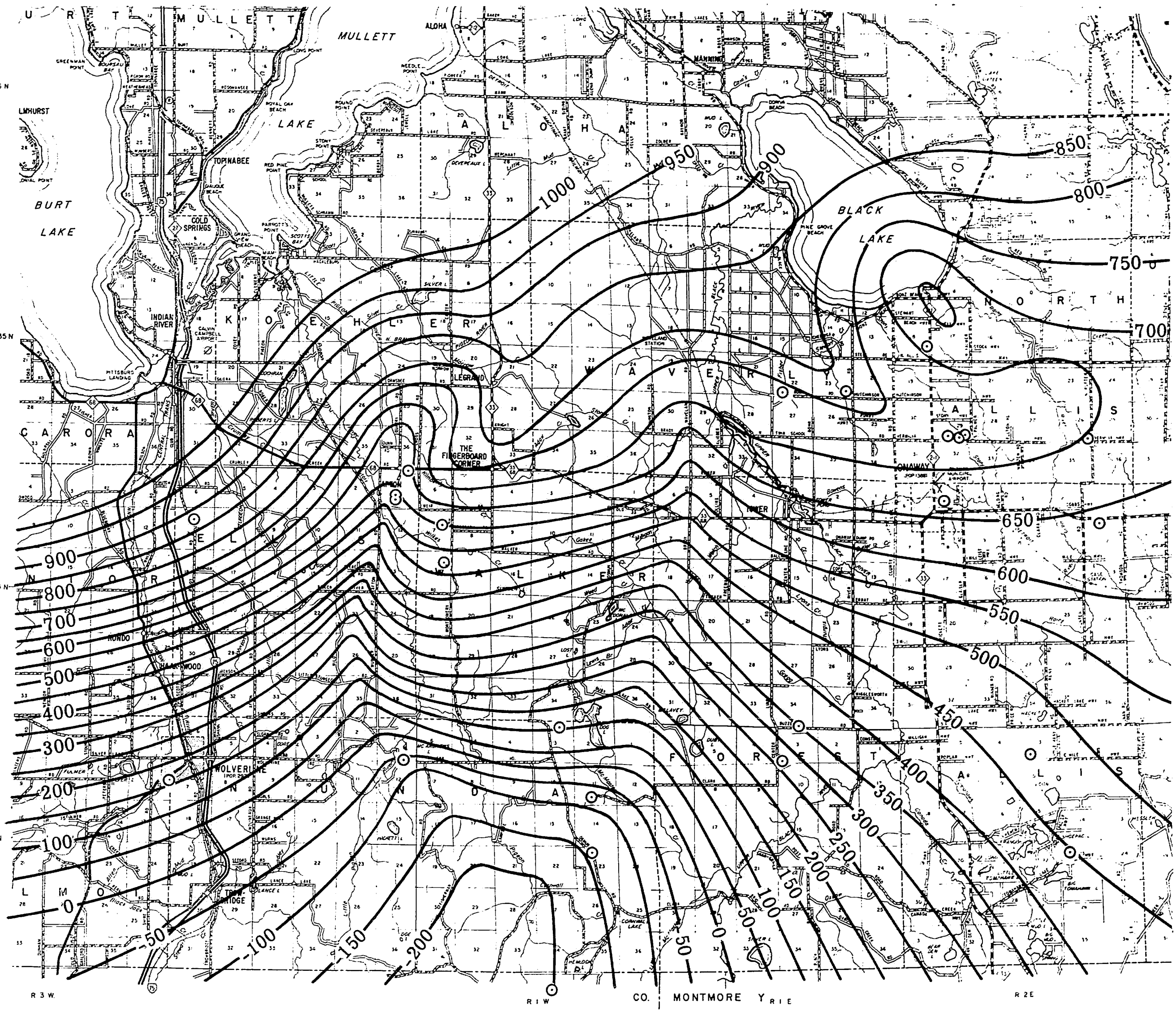


TEXT-FIG. 53 -- Structural contour map of eastern part of area, based on top of the Bell Shale as shown in well records. For identification of the wells, see Appendix 7.

This is confirmed by the elevations of the top of the Bell Shale in five wells in the vicinity (see text-fig. 52; Appendix 7).

The Claude & Bernice Passino well (NE$\frac{1}{4}$ sec. 18, T 34 N, R 1 W, Walker Twp.), in which the top of the Bell is 561 feet, probably lies on the axis of the structure. On the east limb of the anticline, the strike becomes more nearly east or east-northeast.

Black River Syncline. -- Wells are not spaced closely enough to determine the precise extent and orientation of this syncline, but the available records indicate that both the Beebe Syncline and the Black River Syncline are northward-extending branches from the Nunda Syncline. The axis of this fold seems to be nearly north-south and to lie about 2 miles west of Black River. The outcrop expression of the syncline is obscured by the depth of the valleys of Black River and its tributaries. If we compare topographic elevations at the centers of sections in the northernmost row of Township 34 North with the structural elevations on the



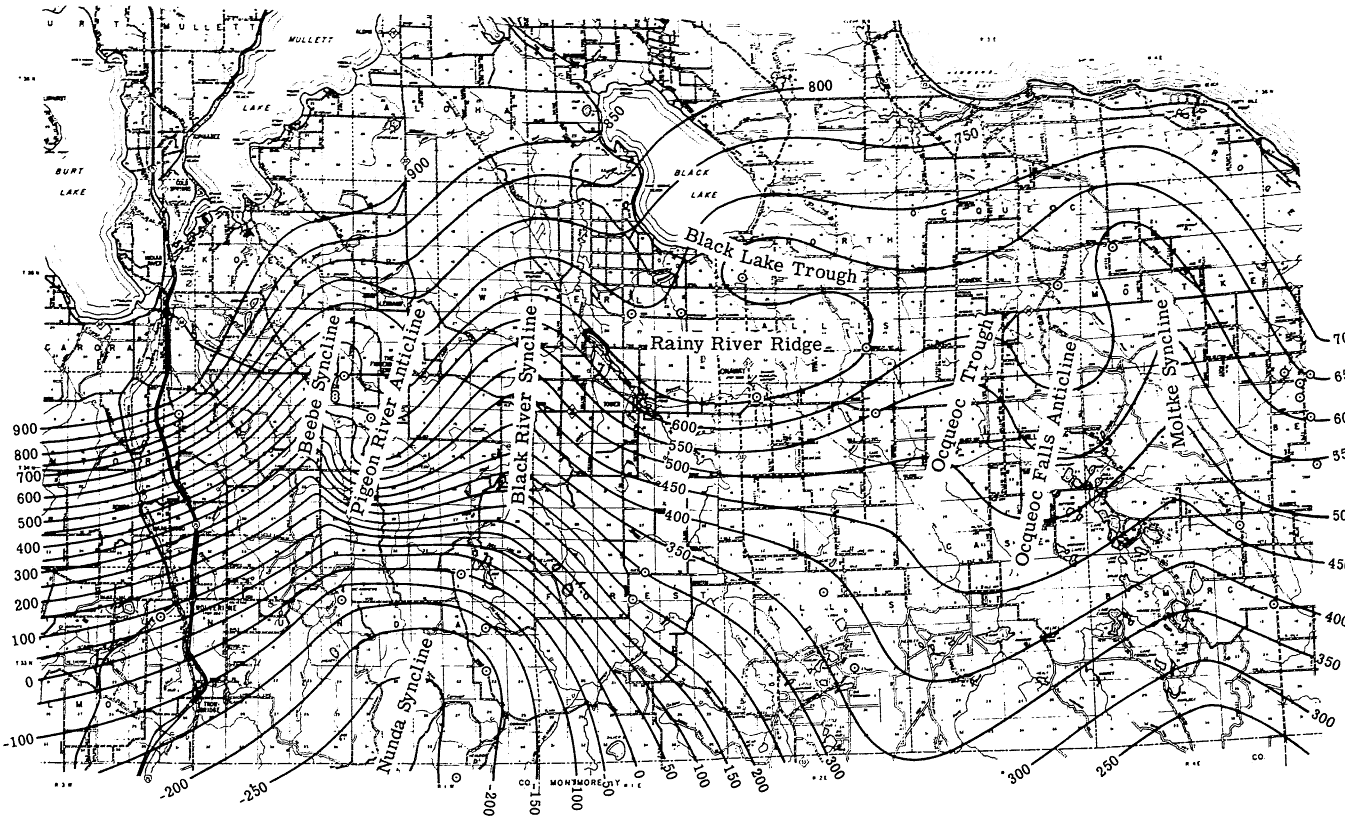
TEXT-FIG. 54 -- Structural contour map of western part of area, based on top of Rockport Quarry Limestone as shown in 24 well records. For identification of the wells, see Appendix 7.

map of the Bell Shale top (text-fig. 55):

Range	1W						1E			
Section	6	5	4	3	2	1	6	5	4	3
Elevation	810	880	940	840	800	760	760	750	720	710
Bell top	600	625	615	550	480	450	480	540	580	625
Bell depth	210	255	325	290	320	310	280	210	140	85

From these figures, we see that from the position of the indicated axis of the syncline, the topography rises to the west and lowers to the east; whereas the top of the Bell is 325 feet deep in sec. 4, T 34 N, R 1 W, it is only 85 feet deep in sec. 3, T 34 N, R 1 E. Particularly on the east limb of the syncline, where the structural surfaces are dipping westward and the topography is dipping eastward, the geologic map fails to convey the inclination of the strata and shows the apparent synclinal axis offset several miles to the west from the true position.

Nunda Syncline. -- The lowest elevation known of the Bell Shale top in Township 33 N is in the eastern part of Nunda Township, Cheboy-



TEXT-FIG. 55 -- Structures in the Afton-Onaway area as indicated by structural contours on top of the Bell Shale. Comparison with the geologic maps (see Maps 2 and 4 at the back of this number) shows that the major features persist even where outcrop pattern is altered by topography.

gan County. In the State-Nunda #1-23 well (NW $\frac{1}{4}$ sec. 23, T 33 N, R 1 W), this surface is at -230 feet. About 12 miles due east, in the State-Allis #1-23 well (NW$\frac{1}{4}$ sec. 23, T 33 N, R 2 E, Allis Twp., Presque Isle County), the Bell surface is encountered at +380 feet. The difference of 610 feet indicates a deep syncline with its axis near the former well. Based on the areal coverage of wells, which is certainly far from ideal, the Nunda Syncline appears to branch northward into the Beebe Syncline on the west and the Black River Syncline on the east.

Rainy River Ridge. -- A gentle structural ridge a few miles west of Black Lake extends south and then east to form an east-west ridge. Areally, this is best expressed by the inliers of Ferron Point Formation shales on Rainy River and on Stony Creek, both in North Allis Township, Presque Isle County (see Map 4). These two exposures, each with Genshaw Formation both upstream and downstream, are nearly aligned east-west. The Rainy River exposures (in sec. 26, downstream from Rainy River Falls), because of the outcrops on the valley slopes and in the stream bed, appear to be a dome. Inasmuch as the Ferron Point is known to be only a few feet thick in the vicinity, it is presumed that the Rainy River Ridge also brings the Rockport Quarry Limestone to the surface in the river valley, but exposures are imperfect. The Stony Creek exposures of the Ferron Point are in SW$\frac{1}{4}$ sec. 20, T 35 N, R 2 E, between Hutchinson Highway on the south and M-211 on the west.

The relief on the Rainy River Ridge, as shown by the uppermost surface of the Rockport Quarry Limestone, is indicated by elevations in three wells; from north to south: 699 feet in the Black Lake State Forest Residence well (SE$\frac{1}{4}$ sec. 18), 729 feet in the Donald E. Drasey #1

(SE$\frac{1}{4}$ sec. 29), and 660 feet in the Presque Isle Development Company well in Onaway. In the same three wells, even greater relief is shown on the uppermost surface of the Bell Shale: 631, 684, and 580 feet, respectively. The thinning of the Rockport Quarry Limestone on the axis of the ridge poses the interesting possibility that the relief of the structure was started post-Bell and pre-Rockport Quarry.

On the structural map of the uppermost Rockport Quarry Limestone (text-fig. 54, p. 106) the Rainy River Ridge is well shown by the 700-foot contour line.

Black Lake Trough. -- This feature is equally clear on the structural contour maps and on the geologic map. Immediately east of Black Lake Quarry, along the southern shore of Black Lake, the Rockport Quarry Limestone, the thin Ferron Point Formation, and the basal beds of the Genshaw Formation have a dip with an appreciable eastward component, as can be readily seen by tracing the beds lower and lower along the shore cliff to the east (text-fig. 15, p. 29). Not far to the north and east, the regional dip to the south prevails. Between the eastward-dipping strata at Black Lake Quarry and the regional southward-dipping strata lies the axis of a trough. The very low elevations on the tops of the Bell Shale (631 feet) and the Rockport Quarry Limestone (699 feet) in the Black Lake State Forest Residence well point to this site in SE$\frac{1}{4}$ sec. 18, T 35 N, R 2 E, as near the axis of the Black Lake Trough.

Perhaps the best location of the axis is shown by the areal distribution of the Genshaw Formation; a narrow strip of the formation extends northwestward through sec. 8, T 35 N, R 2 E, and nearly reaches the shore of the lake. The structural contour map of uppermost Rockport Quarry Limestone (text-fig. 54, p. 106) outlines the Black Lake Trough by the 700-foot contour, and indicates the axis and depth by the 650-foot contour.

Ocqueoc Trough. -- More wells are needed to define this structure more precisely. Nevertheless, as shown on the areal map by Kelly (1949 guidebook, map 2), the Ferron Point and Genshaw Formations have a north-south strike on the west side of the Ocqueoc River and a nearly east-west strike on the east side of the river. To the west, the strike also changes abruptly to become east-west. The axis of a trough passes approximately through the village of Ocqueoc; it is bounded by the Rainy River Ridge on the west and the Ocqueoc Falls Anticline on the east. On the geologic map (see Map 4) the east limb of the trough is accentuated by the valley of Ocqueoc River.

Two wells, nearly aligned in an east-west direction, indicate the west limb of the trough. In the Lobdell-Emery Myers well in the NW$\frac{1}{4}$ sec. 5, T 34 N, R 2 E, the top of the Bell is at 649 feet; in the Alfred Jarvis #1-28 well in the NE$\frac{1}{4}$ sec. 28, T 35 N, R 3 E, about 4 miles away, the top is at 629 feet, an average dip component in this direction of 5 feet/mile. Since this component is in a direction only a few degrees from the strike, the full dip may be as much as 60 feet/mile south-southeast.

Ocqueoc Falls Anticline. -- The area between the Ocqueoc Trough on the west and the Moltke Syncline on the east is structurally poorly known at this time. Between the two axes, a distance of some six to eight miles, the strata form an anticline. Several wells are needed in Case and Bismarck Townships to determine the magnitude of this fold. On the geologic map, the expression of the fold is magnified by the valley of Ocqueoc River.

Moltke Syncline. -- Elevations at the top of the Bell Shale at the eastern edge of the area, in Range 4 East, indicate a major syncline that passes through Moltke Township, Presque Isle County. From the Norman & Dolores Brege #1-17 well (NW$\frac{1}{4}$ sec. 17, T 35 N, R 4 E) to the State-Ocqueoc #1 (NW$\frac{1}{4}$ sec. 24, T 35 N, R 3 E) the uppermost Bell surface rises 38 feet in 2 miles to the southwest; from the same well to the Kreft et al. #1 well (SW$\frac{1}{4}$ sec. 5, T 34 N, R 5 E), the same surface rises 82 feet in 7$\frac{1}{2}$ miles to the southeast; thus, both to the west and to the east of the Brege well, the strata have components of dip opposite to the regional dip. On our structural contour map of the Bell Shale top, the syncline is well indicated by the 600-foot contour line.

Minor folds. -- Although it is obvious and well known, we would like to stress the importance and significance of stratigraphic control data in assessing the structures of this or any other area. If we had, for example, only one control point in each township, we could determine little more than the regional dip. But if we had a control point in each section, we could delineate the major folds with considerable accuracy -- certainly with more accuracy than we were afforded in much of the Afton-Onaway area. Furthermore, if we had data covering all quarter-sections, we might discover smaller-scale warps -- crenulations on the limbs of the major structures.

In our area we have only 35 wells (see Appendix 7), and 8 of these are situated outside the 18 townships included in T 33 to 35 N and R 2 W to 4 E. In Koehler Township (54 square miles) and Case Township (72 square miles) we have no well records; and in Forest Township and Bismarck Townships (72 square miles each) we have only two wells each.

Only in the vicinity of Afton, Onaway, and the eastern edge of the area do we have clusters of wells. In these vicinities, the variations in elevation on the uppermost Bell Shale suggest much greater irregularity of the structural surface than that shown in the rest of our map (text-fig. 55).

Hence, the Devonian strata of the Afton-Onaway area are part of a continuous thick layer of sediments that dips into and passes under the Michigan Basin. The edges now exposed show major folds -- anticlines, synclines, ridges, troughs, domes, and depressions -- with vertical relief of 50 to 200 feet. On the limbs of these major folds are local warps of lesser relief; and on the warps are still smaller scattered and irregular crenulations, some bent just a few degrees from the prevailing dip. Our view of structure changes as we study the Devonian by the state, the county, the section, or by the rare continuous exposure of a few hundred feet along a highway cut or a stream channel.

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Back in December of 1975, as we were bewailing and grousing about the insufficiency of data on drift thickness to reasonably project geologic contacts in the areas having few or no outcrops, we had the good fortune to meet a graduate student at The University of Michigan who just happened to be working on -- the thickness of glacial drift in Cheboygan and Emmet Counties, Michigan. Robert Haag agreed to push forward with his plotting and contouring of Cheboygan County so that the resultant maps could be included in this volume. This is the appropriate place, and it is our pleasure to present his following article and maps on bedrock topography and glacial cover.

Bedrock Topography and Glacial Drift Thickness in Cheboygan County

Robert D. Haag, Jr.

Bedrock topography and approximate glacial drift thickness have been mapped in Cheboygan and Emmet Counties as part of a project undertaken by The University of Michigan Biological Station, in cooperation with the Survey Research Center of the Institute for Social Research. Only Cheboygan County is presented in this discussion.

Map preparation. -- These maps were prepared using water-well logs for the most part, with oil-well logs included where available.

Seventy-five wells actually penetrated bedrock in Cheboygan County, of which fifty-nine were in the southern half and sixteen in the northern half. However, considerable information has been added by wells that did not penetrate bedrock, but define a limit below which the bedrock surface must lie.

On the basis of all of these wells, good contours for the bedrock topography were determined in the southern half of the county, and a very good approximation of the bedrock surface was made in the northern half.

Bedrock and ground surface elevations were plotted for each well with computer assistance, and the bedrock elevations were carefully contoured by hand.

Drift thickness was then determined at every well site in the county by subtracting the bedrock elevation from the surface elevation. The resulting drift thickness values were also contoured by hand.

Bedrock topography. -- A distinct bedrock upland, reaching more than 800 feet above sea level, characterizes the southern half of the county, while three broad lowlands are the prominent bedrock features to the north.

A narrow, steep channel is cut into the southern bedrock upland parallel to the backwaters of Black River behind Kleber Dam.

On its northwest side, the bedrock upland slopes off towards one of the three lowlands. This lowland or channel runs from Little Traverse Bay to the southern end of Burt Lake, at which point it bends northward, roughly paralleling the western shore of Mullett Lake. The deep southern end of Mullett Lake actually lies in this bedrock channel, although its shallower northern end does not.

A second broad bedrock lowland trends east-west in the northern part of Emmet County, and joins the previously described lowland just west of the city of Cheboygan.

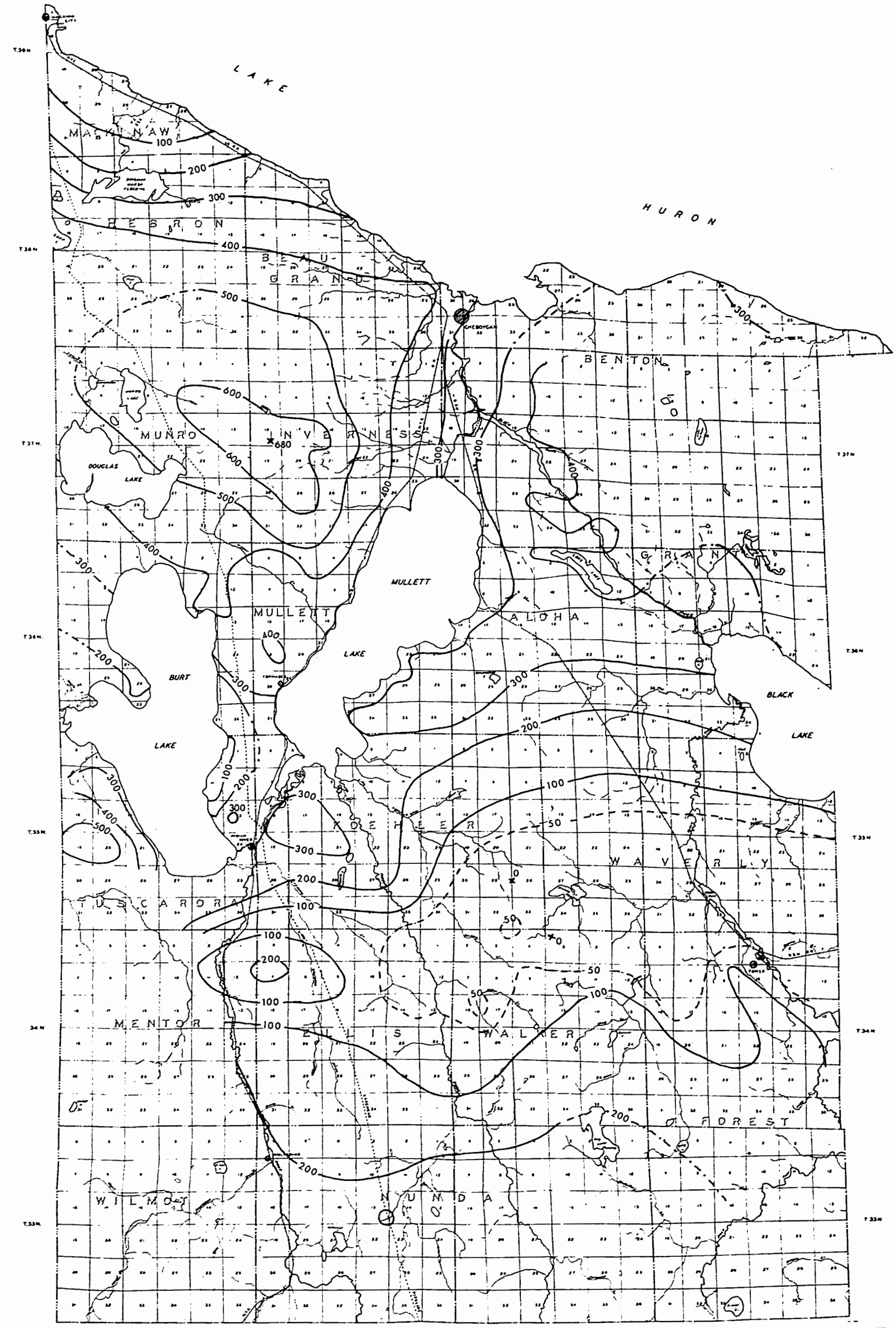
The third broad channel in the northern part of Cheboygan County trends east-west just north of Black Lake, then turns northward at Long Lake, to parallel the first channel described.

Glacial drift thickness. -- The glacial drift cover is thinnest near Mackinac City, and, not surprisingly, over the central part of the southern bedrock upland, where its thickness ranges between 0 and 60 feet.

The drift rapidly thickens in all directions away from this center, and is 300 to 400 feet thick in the vicinity of Burt, Mullett, and Black Lakes, with local spots of thicker cover.

The greatest drift cover occurs where thick glacial deposits overlie the bedrock lowland which is immediately east of Douglas Lake. There, the drift cover reaches nearly 700 feet.

On the maps which follow, the even-hundred contour lines are solid, the intervening 50-foot lines are dashed, and dot-dash lines represent positions of uncertainty.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GRANT
ALOHA
BURT LAKE
BLACK LAKE
KOEHLER
WAVERLY
TUSCARORA
MENTOR
ELLIS
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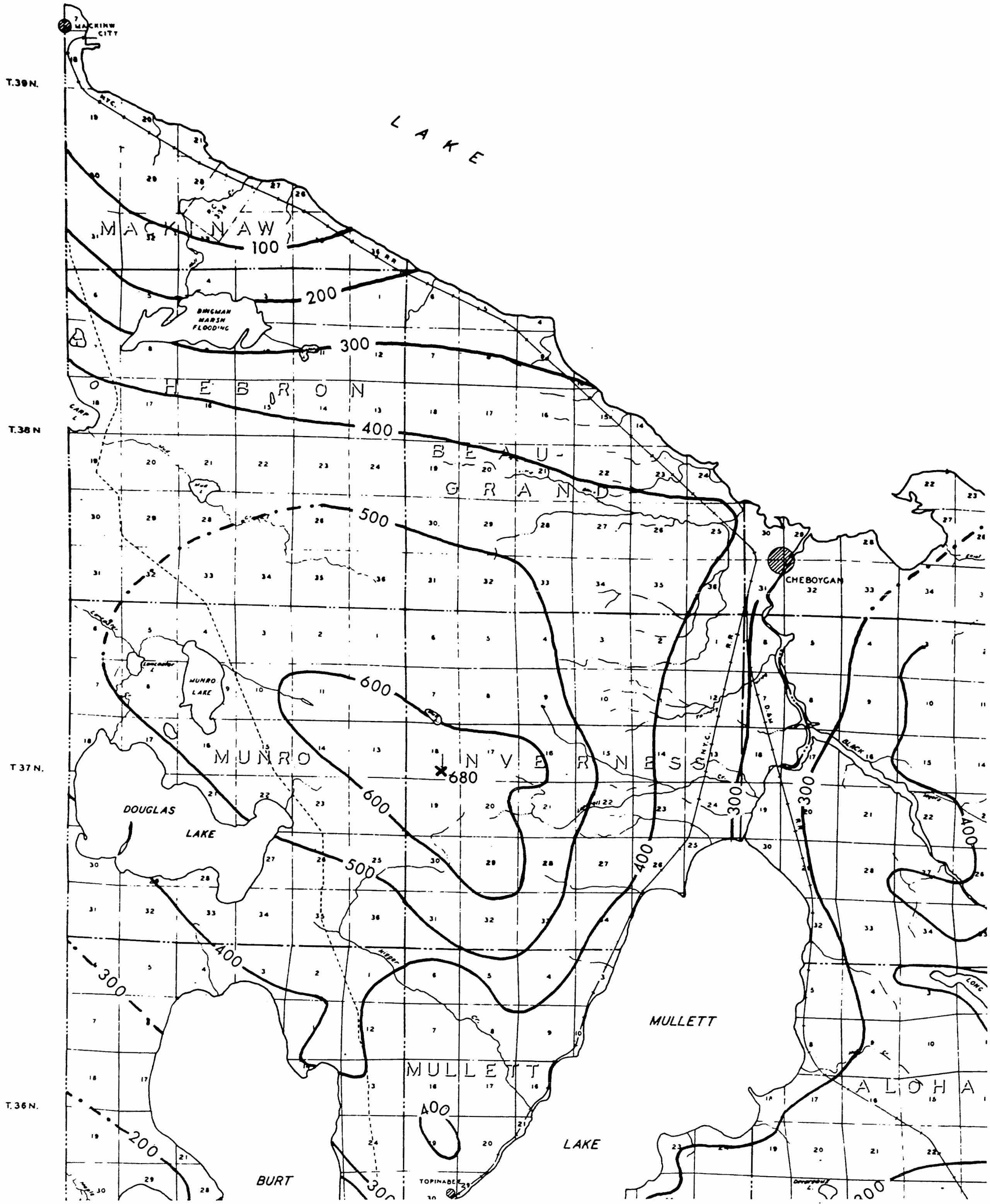
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CHEBOYGAN
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T 37 N.
MUNRO
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TOPINABEE
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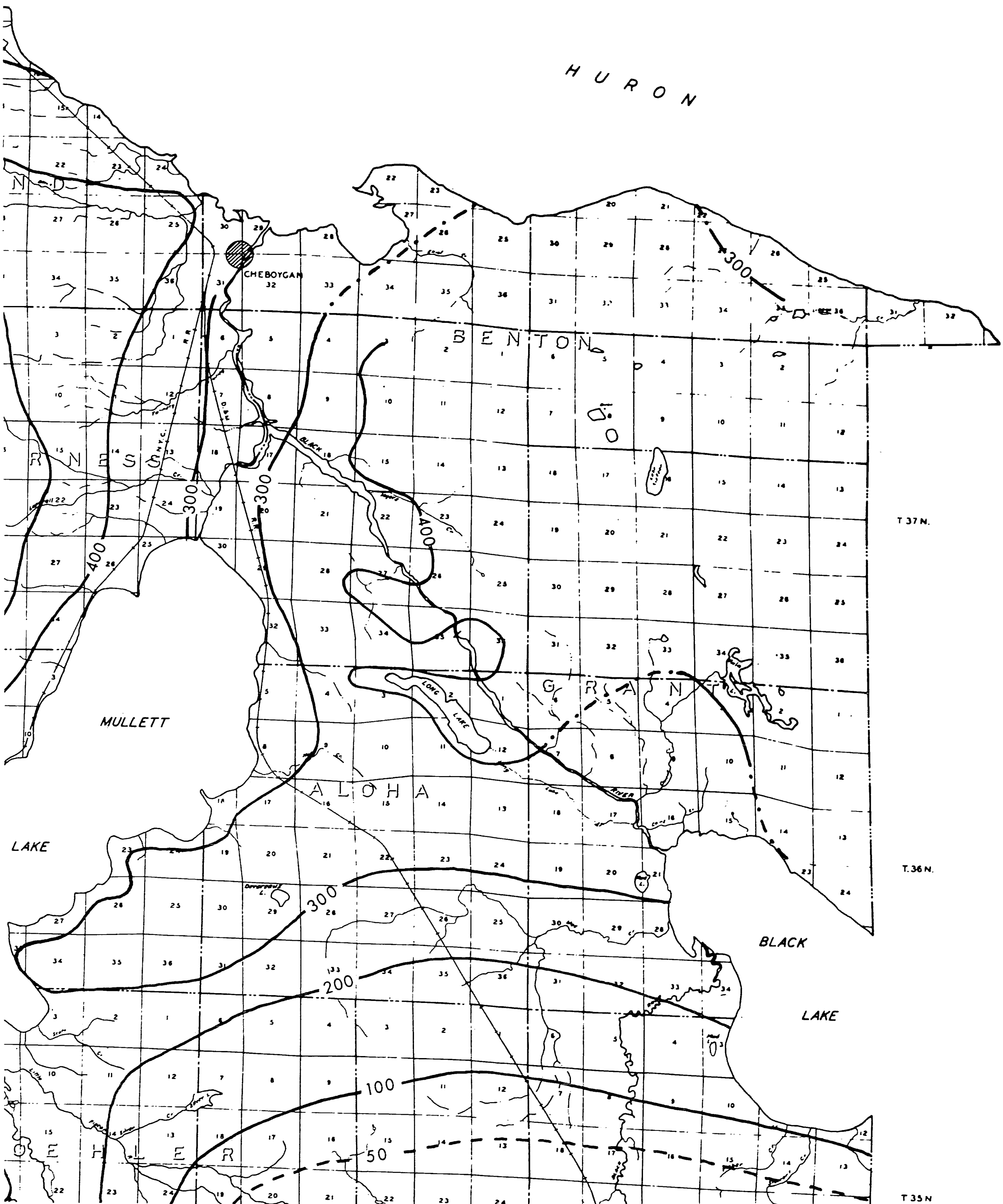
DRIFT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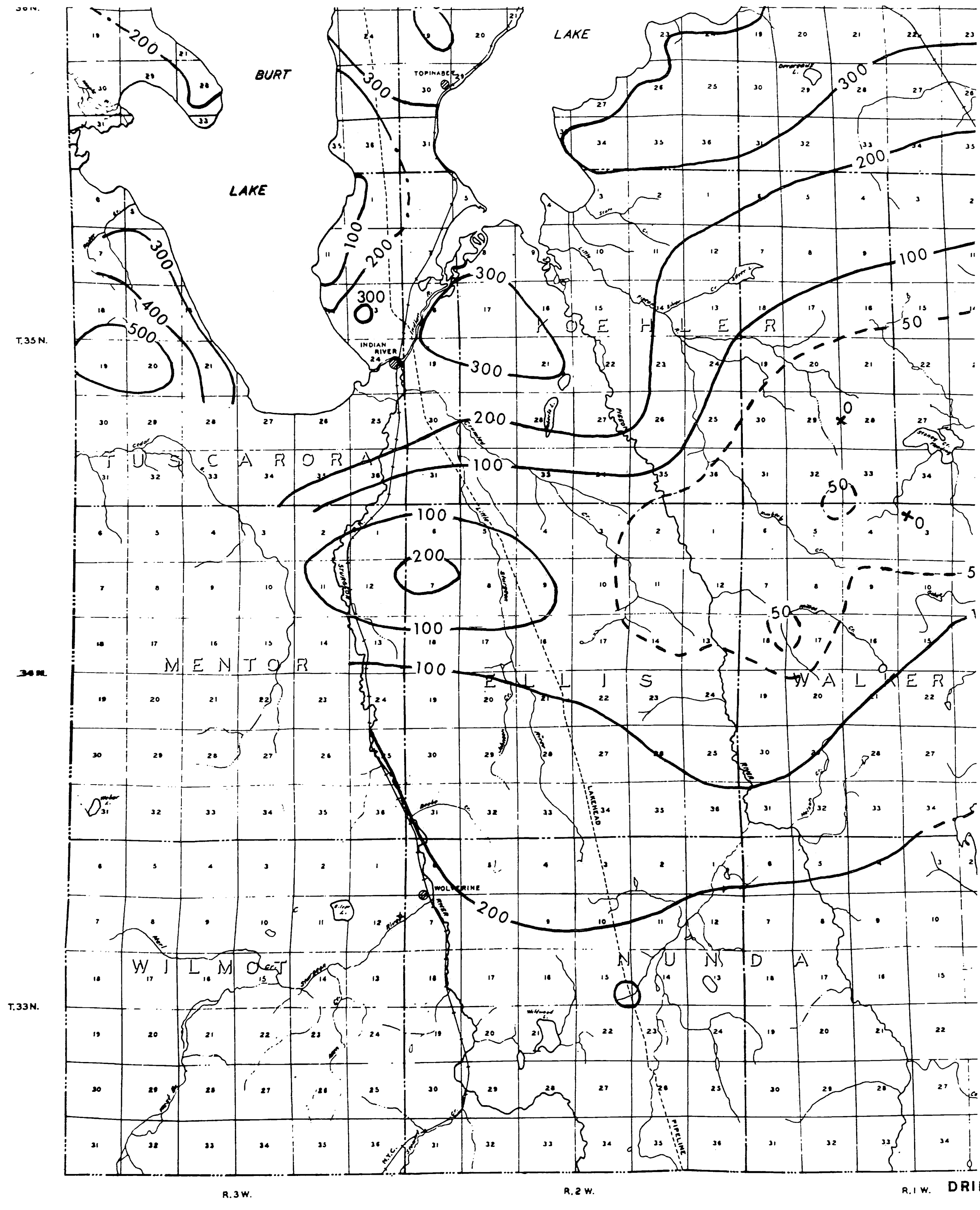
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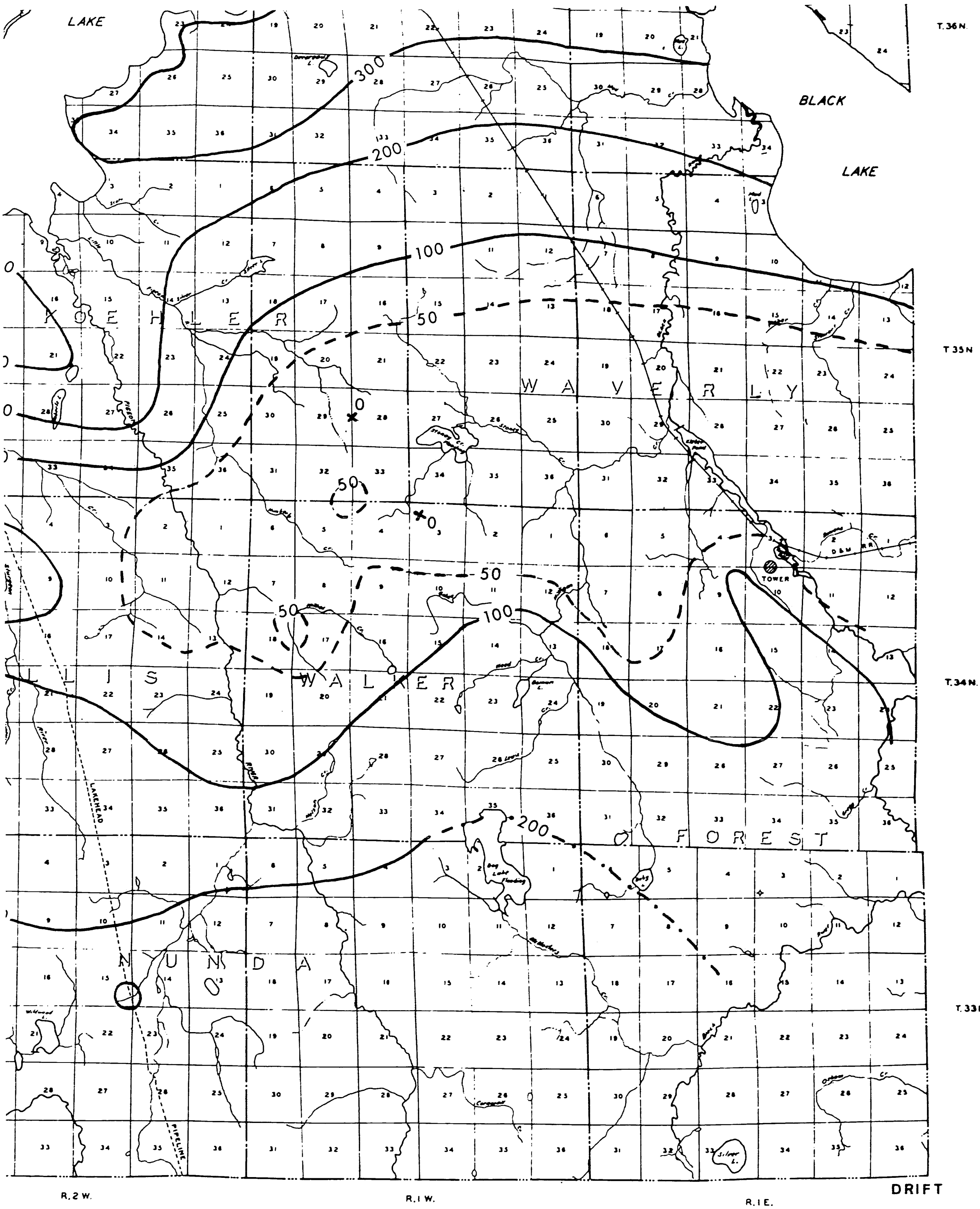
DRIFT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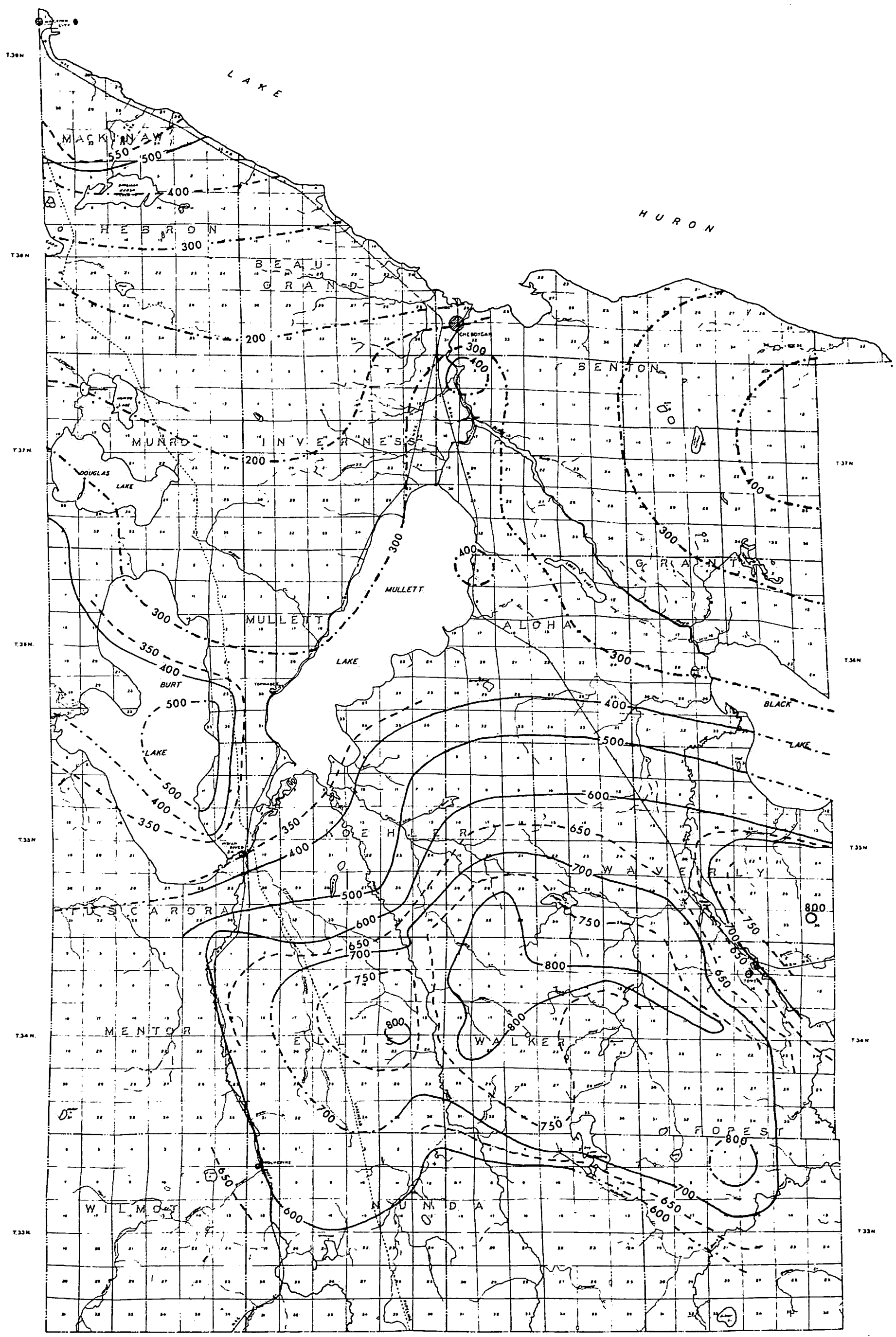
DRIFT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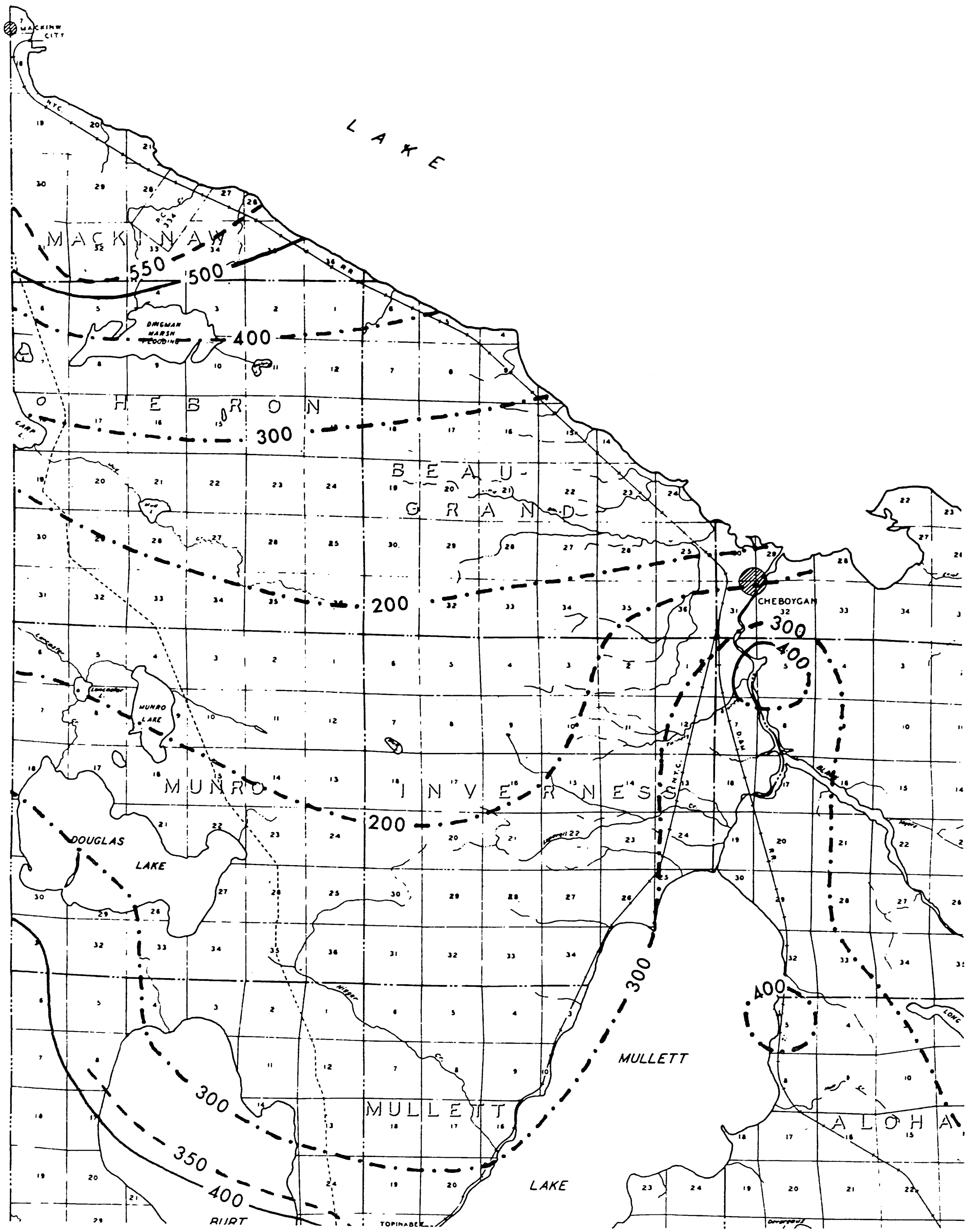
BEDROCK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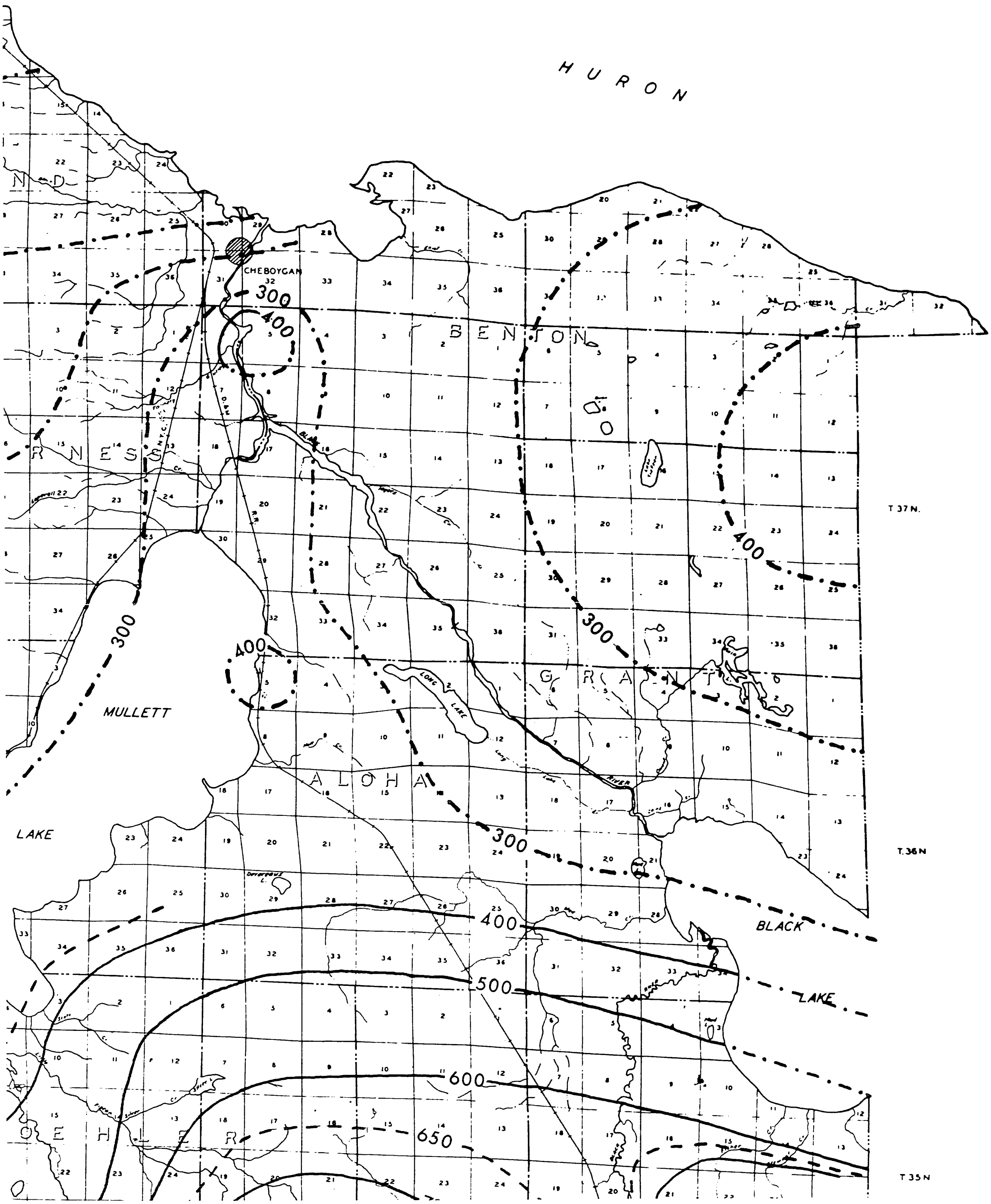
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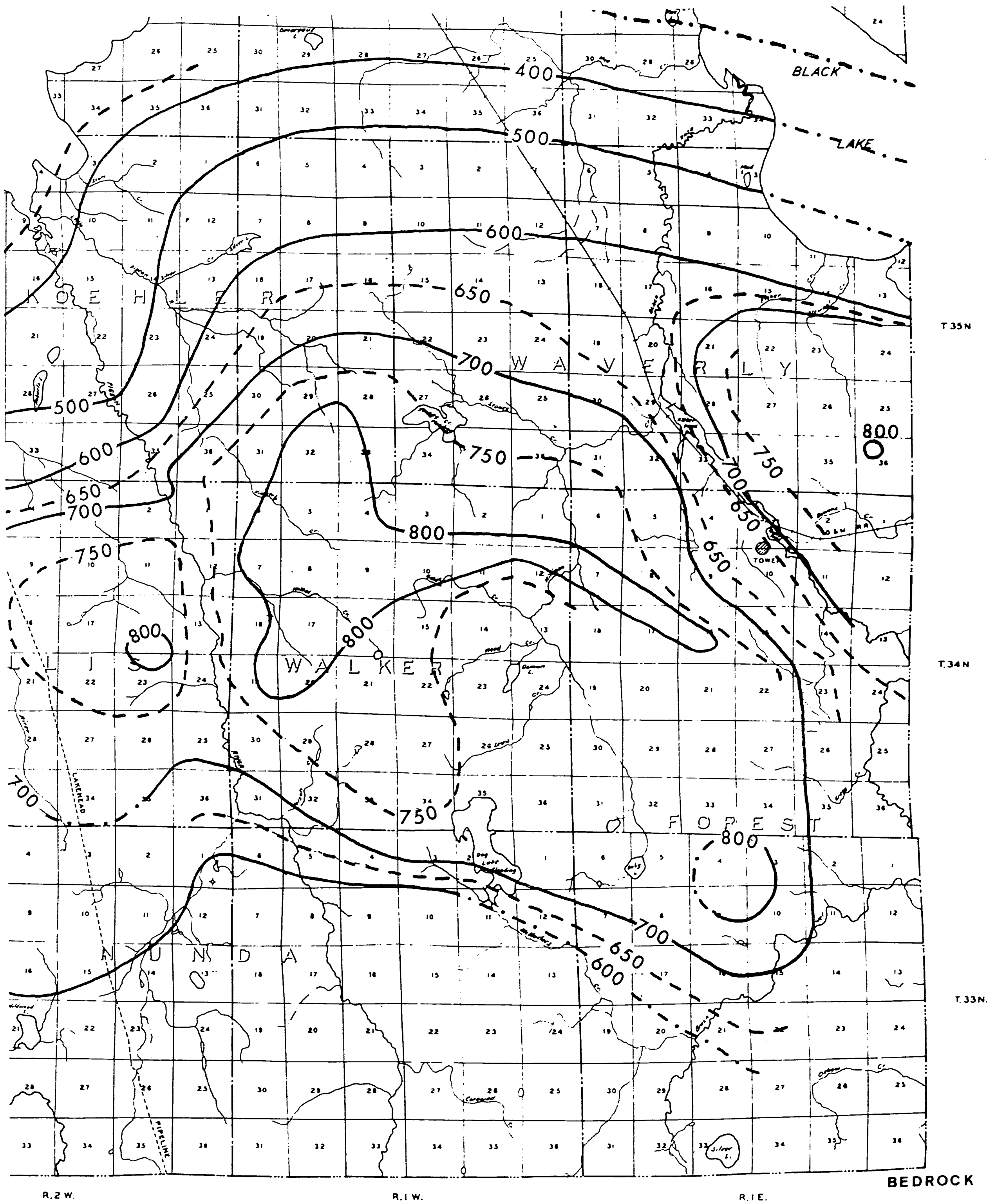
BEDROCK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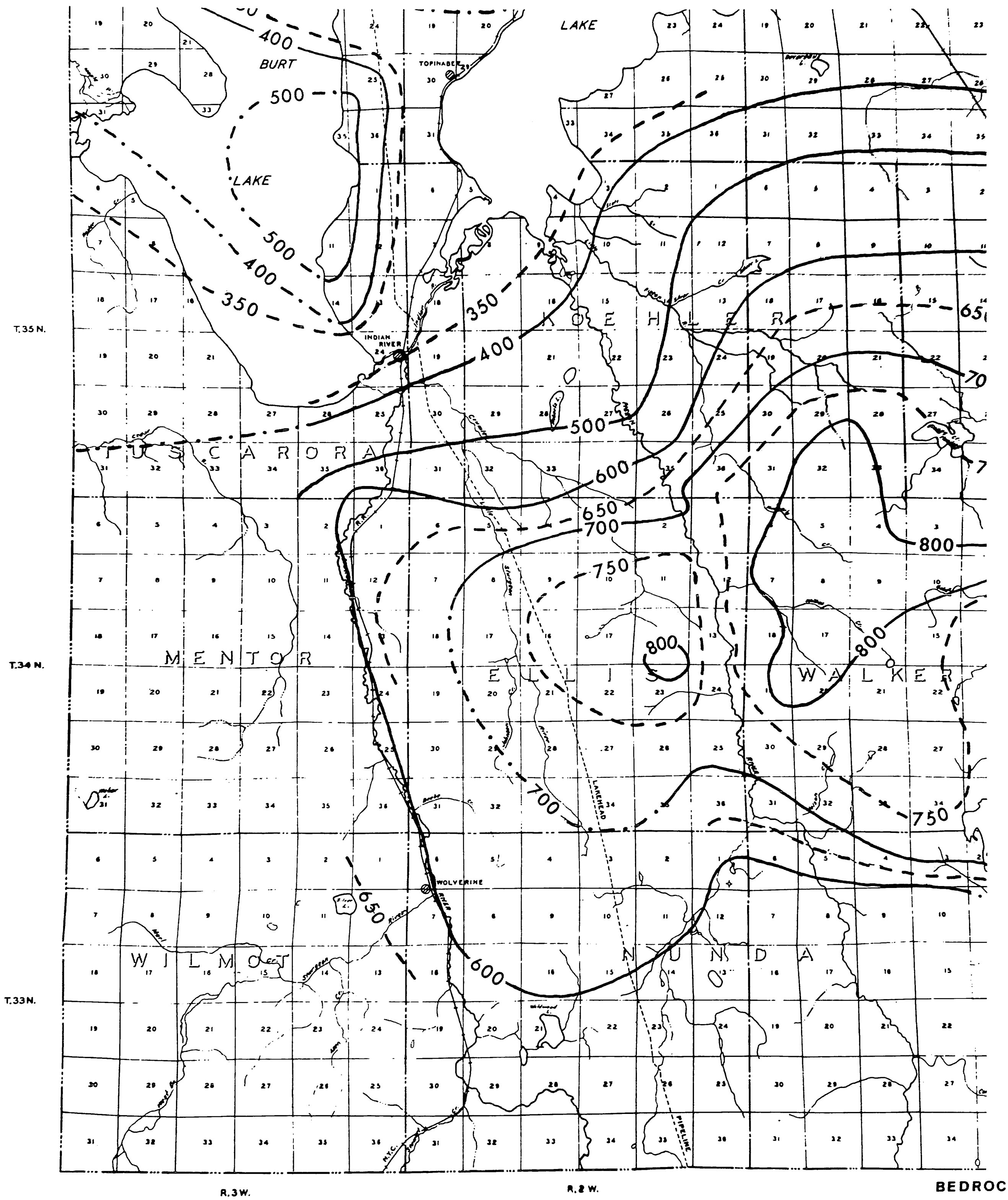
R.1 W.
R.1 E.
BEDROCK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BEDROCK

CORRELATIONS ACROSS THE STATE

The problem of correlation across the Lower Peninsula is compounded by the lack of outcrops. The strata of the Traverse Group exposed in the Afton-Onaway area are separated from those in Alpena and eastern Presque Isle Counties by a belt of glacial drift; they are similarly separated from those exposed in Emmet and Charlevoix Counties by another wide belt of glacial cover. All formations of the group are exposed (with a few covered intervals) in Alpena County; all except the Bell Shale are exposed in the Afton-Onaway area, but much of the Gravel Point Formation is not seen at the surface; and all formations below the middle of the Gravel Point Formation are concealed in Charlevoix County. Hence, much of the correlation must rely upon information from well cores and drillers' records.

Bell Shale. -- The soft bluish-gray shales of the Bell continue across the northern margin of the Michigan Basin without much variation in lithology or thickness. Unfortunately, the formation does not crop out west of Rogers City on Presque Isle County. Nevertheless, the boundaries of the Bell Shale are unmistakably identified in wells by the lithology of the core or by the characteristics of Schlumberger logs. It is clearly set off from the underlying Rogers City Limestone and the overlying Rockport Quarry Limestone.

Three wells in the Afton-Onaway area (text-fig. 56) indicate that the Bell may be consistently a little thinner here than in Alpena County to the east or in Charlevoix and Antrim Counties to the west. However, numerous wells drilled by the Presque Isle Corporation in eastern Presque Isle County displayed almost as great local variations in thickness.

Subsurface data reveals that the Bell Shale thins southward in the basin. However, the presence of Bell species in the lower part of the Silica Formation in northwestern Ohio and southeastern Michigan favors the equivalence of these stratigraphic intervals.

Rockport Quarry Limestone. -- Like the Bell Shale, this formation is consistent across the Lower Peninsula from Lake Huron to Lake Michigan. The dark fossiliferous and the light non-fossiliferous (sublithographic) facies appear to be local features, formed according to the local circulation with the open sea at any particular interval.

The upper limit of the Rockport Quarry Limestone is obvious wherever the Ferron Point Formation is present. But westward from the vicinity of Afton, the shales of the Ferron Point wedge out, and the Rockport Quarry is directly overlain by limestones of the Genshaw Formation. Most well cores give some hint of the facies of the Rockport Quarry, and serve to distinguish it from the overlying Genshaw. The following excerpts from well records will illustrate the differences on which we separate the two formations:

Black Lake State Forest Residence well - SE¼ NE¼ SE¼ sec. 18, T 35 N, R 2 E, North Allis Twp., Presque Isle County:

Genshaw

Limestone, brownish-gray to buff, fragmental, very fossiliferous, trace shale, gray, calcareous, fossiliferous 16

Ferron Point

Shale, gray, calcareous, very fossiliferous; trace limestone, brownish-gray as above 5

Rockport Quarry

Limestone, brown, fine-grained 5

Limestone, buff to brown, fine-grained, with few floating rounded and frosted sand grains 10

Limestone, brown, fine-grained, some tiny fractures with white secondary calcite 25

*****

McClure Oil State Forest #1-34 - SE¼ SW¼ SE¼ sec. 34, T 34 N, R 1 E, Forest Twp., Cheboygan County:

Genshaw

Limestone, gray-brown, argillaceous with stringers of gray limy shale 74

Ferron Point

As above with abundant dark shale partings 8

Rockport Quarry

Limestone, medium-brown, broken and infilled with white lime 36

*****

Leroy Ormsbee #1 - NE¼ NW¼ NE¼ sec. 1, T 34 N, R 2 W, Ellis Twp., Cheboygan County:

Genshaw	
Limestone, crystalline and somewhat coralline; limestone, gray, shaly, fossils, crinoids, bryozoa	35
Rockport Quarry	
Limestone, tan, hard; some limestone with gray shale, few fossils	33
Limestone, tan, hard, slight porosity with some secondary calcite crystals, stylolitic	12

*****

Clifford & Francis Brown #1 - NE¼ SE¼ SW¼ sec. 1, T 34 N, R 2 W, 3/4 mile south of Afton, Ellis Twp., Cheboygan County:

Genshaw	
Limestone, brown to gray, fine-grained to crystalline, fossiliferous; some buff coralline limestone	5
Rockport Quarry	
Limestone, buff, fine-grained in part with some leached porosity	25

*****

State-Nunda #1-3 - C NW¼ NE¼ sec. 3, T 33 N, R 1 W, Nunda Twp., Cheboygan County:

Genshaw	
Limestone, buff gray brown, chalky to dense, slightly fossiliferous, argillaceous with interbedded thin gray-brown shale beds	160
Rockport Quarry	
Limestone, cream-tan, chalky to finely crystalline, coralline, with trace fine vugular porosity	20

*****

East Jordan Lumber Company #1 - S½ NE¼ NW¼ sec. 9, T 31 N, R 7 W, Echo Twp., Antrim County:

Genshaw	
Limestone, gray and white; traces of coralline material	20
Rockport Quarry	
Limestone, darker gray; traces of coralline material	10

*****

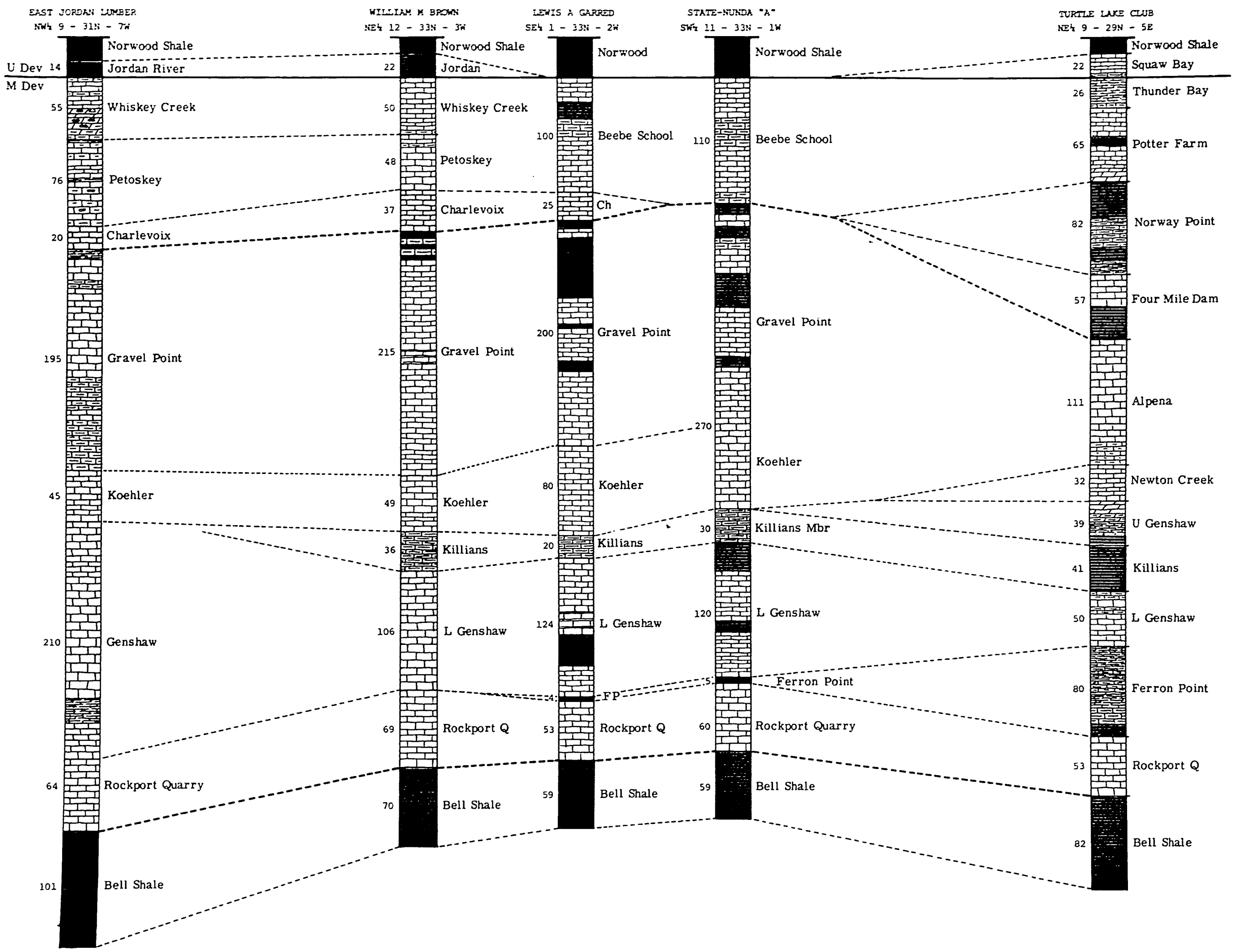
As can be seen, the upper part of the Rockport Quarry lithographic facies is marked by porosity, with secondary filling of voids, whereas the fossiliferous facies is darker than the overlying basal beds of the Genshaw.

Ferron Point Formation. -- From 80 feet thickness in Alpena County, the Ferron Point decreases to only a few feet at Black Lake Quarry. It pinches out between the Lewis A. Garred and the William M. Brown wells (text-fig. 56). We presume that it is the lower part of the formation which extends farthest westward, but exposures are too few to prove this by the contained fauna. No Ferron Point is present in wells in Emmet and Charlevoix Counties.

Genshaw Formation. -- With its presently accepted limits in Alpena County, the Genshaw Formation continues across the basin, becoming thickest in Charlevoix and Emmet Counties, where it is known only in subsurface. The base of the Genshaw can be readily identified east of Afton by the wedge of Ferron Point shale below it; west of Afton, the base is a limestone resting atop the Rockport Quarry Limestone and the identification of the contact is more difficult. In the East Jordan Lumber Company well (see Appendix 7), not far from Lake Michigan, the uppermost Rockport Quarry Limestone is darker gray than the overlying Genshaw. In the Leroy Ormsbee well, cited above, in Ellis Twp., the upper beds of the Rockport Quarry Limestone are tan and hard. with few fossils, porous space filled with secondary calcite crystals, and stylolites, whereas the basal Genshaw is a crystalline limestone with many fossils.

The upper member of the Genshaw in Alpena County is a gray shaly limestone or limy shale that pinches out westward before reaching our area. The middle member in Alpena County is the black siliceous Killians Member, a fairly resistant and distinctive unit, which becomes the uppermost member in the Afton-Onaway area. Westward, in Charlevoix and Antrim Counties, the Killians cannot be identified in the well cores and records and it seems possible that this member also pinches out in that area.

Koehler Limestone. -- The correlation of the Koehler is a problem. Lithologically, it is a light-colored limestone with distinct bedding like that of the Alpena Limestone in Alpena and eastern Presque Isle Counties; but genetically, it is an unfossiliferous "lagoonal" deposit like the Newton Creek Formation. The thin bedding of "brick" thickness and the lack of fauna differ from the Alpena Limestone; and the Koehler lacks the dark color and petroliferous odor of the typical Newton Creek. We suspect that it was not laid down in the same cut-off basin in which the Newton Creek Formation was deposit-



TEXT-FIG. 56 -- Correlation of Traverse Group formations in the Afton-Onaway area with those in the Emmet-Charlevoix area to the west (East Jordan Lumber well) and those in the Alpena area to the east (Turtle Lake Club well). The decrease in shale is apparent, with the argillaceous Ferron Point Formation, Dock Street Clay, and Norway Point Formation pinching out to the west. The Bell Shale at the base of the group is remarkably consistent.

ed. It could have been contemporaneous with either the Newton Creek or the lower part of the Alpena Limestone.

The upper part of the formation shows extensive exposure, with fracturing, local clay capping, and irregular thickness. This exposure was evidently widespread, for as far west as Echo Twp. in Antrim County, a well record describes the intraformational porosity:

East Jordan Lumber Company well - S½ NE¼ NW¼ sec. 9, T 31 N, R 7 W, Echo Twp., Antrim Co.:

Gravel Point

Limestone, gray, shaly 45

Koehler

Limestone, gray and tan; some secondary calcite (300' water 10' above the base) 45

Just west of the outcrop area, near Wolverine, a well attests to the same situation:

William M. Brown #1 - SE¼ SE¼ NE¼ sec. 12, T 33 N, R 3 W, about 9½ miles southwest of Afton, Cheboygan County:

Gravel Point	
Limestone, brownish-buff, coarse	10
Limestone, buff	30
Koehler	
Limestone, very hard (water dropped away 20' in crevice)	10

Even a series of closely spaced wells might not solve the problem of correlating the Koehler Limestone. The closest connections to equivalent sections both east and west would have to detour southward (down dip) because of the thick glacial drift bordering the Afton-Onaway area.

Gravel Point. -- The Alpena and Gravel Point are apparently facies of the same depositional interval. The Alpena Limestone is purer limestone and contains numerous reefs, as compared with the Gravel Point Formation, which contains numerous argillaceous units and has only local build-ups of stromatolites and a few thicker sections with Hexagonaria in the Petoskey-Charlevoix area.

In the Afton-Onaway area, the Gorbut Member, created by Kelly & Smith in 1947, may not be a true member; it may instead be a kind of deposit similar to the dark coralline-stromatoporoid facies of the Rockport Quarry Limestone -- probably accumulated in supratidal flat environments. It is found in the lower part of the formation, but not consistently at the same distance above the base of the formation. In the Marvin Quarry, for example, it appears to be lower in the formation than at the Campbell Quarry. The following excerpts from well logs indicates that it does not occupy a persistent level in the Gravel Point Formation, even allowing for the inaccuracy with which units may be divided in well cores:

	Feet thick	Above base
East Jordan Lumber Co. NW¼ sec 9, 31 N, 7 W	5	50
Wm. M. Brown #1 NE¼ sec 12, 33 N, 3 W	25	40
Lewis A. Garred #1 SE¼ sec. 1, 33 N, 2 W	40	25

It is our opinion that the more argillaceous units of the Gravel Point were deposited in somewhat deeper water than the Alpena Limestone, where the winnowing action of currents was less effective.

An interesting occurrence of a deeper water shale is the uppermost unit of the formation. In outcrops in Emmet and Charlevoix Counties and in wells of Charlevoix and Antrim Counties, the top of the Gravel Point is a soft shale bed known as the "upper blue shale"; it is separated from the "lower blue shale" by a few feet of more calcareous strata. Wells in the Afton-Onaway area (text-fig. 56) also show a shale unit at the top of the Gravel Point. As we turn to the Alpena area, we find that the top of the Alpena Limestone is overlain by a variable shale unit known as the Dock Street Clay and presently included in the Four Mile Dam Formation. When A. W. Grabau named the Alpena Limestone (1902, p. 175), he also named the Dock Street Clay (1902, p. 192). When Warthin & Cooper (1935, p. 526) revised the stratigraphy of the Thunder Bay region, they stated, "The Dock Street clay of Grabau is a local clay facies of the upper Alpena horizon." The Four Mile Dam Limestone was created by Cooper & Warthin in 1941, who did not include the Dock Street Clay in it. Then Warthin & Cooper in 1943 (p. 588) removed the Dock Street Clay from the Alpena Limestone and made it a member of the Four Mile Dam Formation. Here it has remined since 1943.

The occurrence of a soft shale atop a limestone throughout this section of the Traverse Group suggests that they may be parts of the same stratigraphic episode. Two changes could be made, either of which would bring the sequence into stratigraphic harmony: (1) the "upper blue" and associated shales to the west could be made part of the overlying Charlevoix Limestone and the shales at this position in Afton-Onaway could be included in the Beebe School, making the revised Charlevoix and Beebe School formations to contain the same lithologic succession as the Four Mile Dam Formation, or (2) the Dock Street Clay could be removed from the Four Mile Dam Formation and restored to its former position as the uppermost unit of the Alpena Limestone. Of these, we strongly favor the second alternative. The consistency of the shales at this horizon does not rule out a third possibility: making the Dock Street Clay a formation and extending it westward to include the blue shales below the Beebe School Formation and the Charlevoix Limestone.

Cooper et al. (1942, p. 1752) stated, "The 'Upper blue shale' is correlated with the upper Alpena (approximately Dock Street clay) of Alpena County."

The Dock Street Clay is noted for its crinoids, which are conspicuously absent in the fauna of the "lower blue shale" and the "upper blue shale" in former exposures in the Penn-Dixie Quarry near Petoskey and present exposures in the Medusa Quarry near Charlevoix. We must note, however, that the "upper blue shale" near Charlevoix and the Dock Street Clay at Alpena both contain shale layers with gypsum (selenite of the "fish-tail twin" variety) crystals in washed residues.

Is the Dock Street Clay a formation? Is the "upper blue shale" actually equivalent to the Dock Street Clay? Is the rock everywhere below the Beebe School Formation in the Afton area a soft blue shale? Here is a problem for the future geologists. On present information, we incline to regard the Dock Street Clay as the equivalent of the blue shales at the top of the Gravel Point Formation.

Charlevoix Limestone. -- We agree with previous authors in making the Charlevoix Limestone equivalent to the Four Mile Dam Formation at the type locality. The evidence is not overwhelming, for the two represent very different facies and origins; it is our interpretation that the Four Mile Dam was the windward coral-stromatoporoid reef of the temporarily emergent Afton-Onaway area, and the Charlevoix Limestone was the leeward oolite shoal.

The tapering edge of the Charlevoix may extend into the southern part of Cheboygan County in subsurface. The Lewis A. Garred well in sec. 1, T 33 N, R 2 W, records just above the gray shale at the top of the Gravel Point Formation a unit that is described as 25 feet of "limestone, brown, micritic, dense, scattered slight pinpoint porosity," a description that could well fit the Charlevoix Limestone exposed in the old Wolverine Quarry west of Charlevoix.

Beebe School Formation. -- This formation contains many of the same coral species found in the Potter Farm Formation in Alpena County. We agree with Warthin & Cooper that the strata exposed near the schoolhouse can be regarded as a western extension of the Potter Farm. Whether all of the Beebe School is the equivalent of the Potter Farm is undecided.

Just on the basis of thickness and continuity, the Beebe School appears to be equivalent to both the Petoskey Formation and the Whiskey Creek Formation in Charlevoix County. Eastward from the type locality, the Whiskey Creek seems to lose its chert content, as noted in well records.

Squaw Bay Limestone. -- This Upper Devonian limestone thins out to the west from its type locality and is not present in the Afton-Onaway area insofar as we can detect on the outcrops along Beebe School Road. The Beebe School Formation there appears to be directly overlain by black shale.

Jordan River Formation. -- This Upper Devonian thin shaly formation, younger than the Squaw Bay Limestone, is not known except at the type locality. No such formation has been discovered between the Beebe School Formation and the Norwood Shale.

Norwood Shale. -- Whether this is considered a distinct formation or a phase of the Antrim Shale, it continues across the northern margin of the Michigan Basin from Lake Michigan on the west to Lake Huron on the east.

Conclusion. -- The Traverse Group now includes the Upper Devonian Squaw Bay Limestone in Alpena County and the Upper Devonian Jordan River Formation in Charlevoix County. The Middle Devonian section of the group continues across the northern margin of the Michigan Basin without much change in total thickness, but with appreciable changes in the facies represented. Overall, the part above the Bell Shale contains mostly limestone on the west and numerous shales on the east. Such shales as the Ferron Point Formation and the Norway Point Formation pinch out to the west within the confines of the basin. Similarly, the argillaceous upper member of the Genshaw Formation disappears westward before reaching the Afton-Onaway area. To us, the deeper water throughout most of Traverse time lay to the east, and shallow water -- even supratidal conditions -- predominated to the west.

Without question, much remains to be done in collecting significant data on paleogeography, paleoecology, and sedimentary environments.

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APPENDICES

In the following appendices, most of the faunal lists and analyses is based on the check lists of E. C. Stumm (1951, 1961), with additions and revisions from publications since 1961. Only published records are incorporated. In some cases this represents a taxonomic group fairly, but in general little work has been done on the paleontology of this area. We have updated the taxonomy of some species which we recognized at first glance, but we did not conduct an exhaustive revision of genera and species. The appendices give a quick summary of what is published on the fossils of the area.

Throughout we have abbreviated formation names as follows:

West (Charlevoix and Emmet Counties)
- GP = Gravel Point Formation
- CH = Charlevoix Formation
- PK = Petoskey Formation
- WC = Whiskey Creek Formation

Afton-Onaway (southern Cheboygan and western Presque Isle County)
- RQ = Rockport Quarry Limestone
- FP = Ferron Point Formation
- GF = Genshaw Formation
- KO = Koehler Limestone
- GP = Gravel Point Formation
- BB = Beebe School Formation

East (Alpena County and eastern Presque Isle County)
- BS = Bell Shale
- RQ = Rockport Quarry Limestone
- FP = Ferron Point Formation
- GF = Genshaw Formation
- (Newton Creek Formation deleted; no fauna)
- AL = Alpena Limestone
- FM = Four Mile Dam Formation
- NP = Norway Point Formation
- PF = Potter Farm Formation
- TB = Thunder Bay Limestone

Appendix 1

GENERA REPORTED IN LITERATURE FROM AFTON-ONAWAY AREA

and their occurrence elsewhere in the Traverse Group

GENERA	West				Afton-Onaway						East								
	GP	CH	PK	WC	RQ	FP	GF	KO	GP	BB	BS	RQ	FP	GF	AL	FM	NP	PF	TB
RUGOSE CORALS																			
Cylindrophyllum ..			x							x		x				x		x	x
Cystiphylloides	x		x		x						x	x	x	x	x	x		x	x
Heterophrentis	x		x				x	x	x		x	x	x	x	x			x	x
Hexagonaria	x	x				x		x	x		x	x	x	x	x	x			
Spongophyllum										x		x						x	
TABULATE CORALS																			
Aulocystis	x		x	x		x	x				x	x	x	x	x	x	x	x	
Aulopora	x	x	x			x					x		x	x	x	x	x		
Favosites	x	x	x	x				x	x	x	x	x	x	x	x	x		x	x
Trachypora	x		x	x						x	x	x		x	x	x	x	x	x
STROMATOPOROIDS																			
Clathrodictyon							x							x				x	
BRACHIOPODS																			
Atrypa	x		x						x		x		x	x	x	x	x		x
Chonetes	x		x			x	x				x	x	x	x	x		x	x	x
Cranaena	x								x	x			x	x			x	x	x

GENERA	GP	CH	PK	WC	RQ	FP	GF	KO	GP	BB	BS	RQ	FP	GF	AL	FM	NP	PF	TB
Cyrtina	x		x				x			x			x	x	x	x	x		x
Helaspis							x	x			x		x	x					
Heteralosia	x						x							x					
Longispina	x						x		x		x	x	x	x	x	x			
Mucrospirifer	x		x			x	x		x	x	x		x	x	x	x	x	x	x
Orthopleura	x						x												
Pentamerella	x		x	x		x	x		x	x			x	x	x	x	x	x	x
Pholidostrophia	x			x			x		x		x	x	x	x	x		x		
Productella			x							x				x					
Schizophoria				x		x	x				x	x	x	x					
Schuchertella	x					x					x	x	x	x		x	x		
Sieberella							x							x					
Sphenophragmus										x							x		
Spinulicosta						x				x	x	x	x			x		x	x
Strophodonta	x		x	x		x				x	x	x	x	x	x	x	x	x	
BIVALVES																			
Cornellites						x					x								
CRICOCONARIDS																			
Tentaculites	x					x			x										x
CEPHALOPODS																			
Gomphoceras						x								x					
Shared genera	20	3	14	7	1	13	14	4	10	12	18	15	19	24	15	15	13	14	13
Total genera reported	59	9	34	16	1	13	14	5	10	12	45	19	32	49	37	59	33	36	44

Appendix 2 SHARED GENERA

AFTON-ONAWAY AREA FORMATIONS	West				Afton-Onaway						East								
	GP	CH	PK	WC	RQ	FP	GF	KO	GP	BB	BS	RQ	FP	GF	AL	FM	NP	PF	TB
Rockport Quarry	1	0	1	0	-	0	0	0	0	0	1	1	1	1	1	1	0	1	1
Ferron Point	9	2	6	4	0	-	5	1	4	4	10	7	10	10	7	8	7	6	4
Genshaw	10	0	6	4	0	5	-	2	5	3	8	6	10	13	8	5	8	5	5
Koehler	3	2	2	1	0	1	2	-	2	1	4	3	4	4	3	2	0	2	2
Gravel Point	10	2	5	3	0	4	5	2	-	4	7	5	9	9	8	6	5	5	7
Beebe School	7	1	8	4	0	4	3	1	4	-	5	5	7	8	6	8	7	9	8

Appendix 3 FAUNAL INDICES OF GENERA

AFTON-ONAWAY AREA FORMATIONS	West				Afton-Onaway						East								
	GP	CH	PK	WC	RQ	FP	GF	KO	GP	BB	BS	RQ	FP	GF	AL	FM	NP	PF	TB
Rockport Quarry	100	0	100	0	-	0	0	0	0	0	100	100	100	100	100	100	0	100	100
Ferron Point	69	22	46	31	0	-	39	20	40	33	77	54	77	77	54	62	54	46	31
Genshaw	71	0	43	29	0	39	-	40	50	25	57	46	71	93	57	36	57	36	36
Koehler	60	40	40	20	0	20	40	-	40	20	80	60	80	80	60	40	0	40	40
Gravel Point	100	22	50	30	0	40	50	40	-	40	70	50	90	90	80	60	50	50	70
Beebe School	58	11	67	33	0	33	25	20	40	-	42	42	58	67	50	67	58	75	67

Appendix 4

SPECIES AND SUBSPECIES REPORTED IN LITERATURE
and their occurrence elsewhere in the Traverse Group

SPECIES and SUBSPECIES	West				Afton-Onaway						East								
	GP	CH	PK	WC	RQ	FP	GF	KO	GP	BB	BS	RQ	FP	GF	AL	FM	NP	PF	TB
RUGOSE CORALS																			
Cystiphyllum americanum bellense					x						x	x	x						
Cylindrophyllum panicum			x							x								x	
Hexagonaria percarinata	x								x										
Spongophyllum alpenense										x								x	
TABULATE CORALS																			
Aulocystis alectiformis reptata ...							x							x					
Aulocystis magnispina						x						x	x						
Aulopora serpens	x					x										x			
Favosites romingeri romingeri ...			x						x									x	
Trachypora alternans	x		x						x						x	x	x	x	x
STROMATOPOROIDS																			
Clathrodictyon retiforme							x							x					
BRACHIOPODS																			
Chonetes cf. coronatus			x			x					x								
Chonetes fragilis						x					x								
Chonetes mediolatus						x					x	x	x						
Helaspis luma*								x											
Helaspis luma luma							x						x	x					
Heteralosia caperata*							x												
Longispina emmetensis	x								x						x	x			
Longispina subclava							x						x	x					
Orthopleura rhipis*							x												
Pentamerella aftonensis	x								x										
Pentamerella cf. dubia						x	x												
Pentamerella lingua						x							x						
Pentamerella aff. pavilionensis ...						x										x			
Pentamerella pericosta										x							x		
Pentamerella tumida							x							x					
Pholidostrophia gracilis gracilis .							x				x	x	x	x					
Schizophoria ferronensis						x					x	x	x						
Schizophoria traversensis							x							x					
Schuchertella crassa						x					x	x	x						
Sieberella romingeri							x							x					
Sphenophragmus nanus										x							x		
Spinulicosta mutocosta										x	x	x	x			x		x	x
Strophodonta extenuata extenuata .						x							x						
BIVALVES																			
Cornellites cf. flabellites*......						x													
Shared species	5	0	4	0	1	11	9	0	5	5	8	7	11	8	2	5	3	5	2
Total species reported	87	11	41	15	1	12	11	1	5	5	46	18	34	44	60	88	29	55	46

Appendix 5 SHARED SPECIES AND SUBSPECIES

AFTON-ONAWAY AREA FORMATIONS	West				Afton-Onaway						East								
	GP	CH	PK	WC	RQ	FP	GF	KO	GP	BB	BS	RQ	FP	GF	AL	FM	NP	PF	TB
Rockport Quarry	0	0	0	0	-	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Ferron Point	1	0	1	0	0	-	1	0	0	0	5	4	5	0	0	2	0	0	0
Genshaw	0	0	0	0	0	1	-	0	0	0	1	1	3	8	0	0	0	0	0
Koehler	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Gravel Point	4	0	2	0	0	0	0	0	-	0	0	0	0	0	2	2	1	2	1
Beebe School	0	0	1	0	0	0	0	0	0	-	1	1	1	0	0	1	2	3	1

Appendix 6 FAUNAL INDICES OF SPECIES

In these appendices, faunal indices are computed as $FI = C/n$, in which C = number of taxa in common between two formations and n = number of taxa in the formation with the fewest taxa.

AFTON-ONAWAY AREA FORMATIONS	West		East								
	GP	PK	BS	RQ	FP	GF	AL	FM	NP	PF	TB
Ferron Point	20	25	63	57	46	0	0	40	0	0	0
Genshaw	0	0	13	14	33	100	0	0	0	0	0
Gravel Point	80	50	0	0	0	0	100	40	33	40	50
Beebe School	0	25	20	20	20	0	0	20	66	60	50

Appendix 7

SUBSURFACE DATA FROM WELLS IN AFTON-ONAWAY AREA

Elevations of tops are in reference to mean sea level.

Cheboygan County

	SFC ELEV.	BELL SHALE THICK	BELL SHALE TOP	ROCKPORT Q THICK	ROCKPORT Q TOP
T 33 N, R 3 W					
William M. Brown #1 - SE¼ SE¼ NE¼ sec. 12, Wilmot Twp.	778	70	53	69	122
T 34 N, R 2 W					
Leroy Ormsbee #1 - NE¼ NW¼ NE¼ sec. 1, Ellis Twp.	822	72	551	81	632
Fred & Anna Brasseur #1 - NE¼ NE¼ SW¼ sec. 1, Ellis Twp.	775	74	559	47	606
Clifford & Francis Brown #1 - NE¼ SE¼ SW¼ sec. 1, Ellis Twp. ...	772	58	522	60	582
Frank H. Grim #1 - NE¼ SE¼ NW¼ sec. 7, Ellis Twp.	909		848		
T 33 N, R 2 W					
Lewis A Garred #1 - SE¼ SW¼ SE¼ sec. 1, Nunda Twp.	790	59	-113	53	-60
T 34 N, R 1 W					
Campbell #1 - NW¼ SE¼ NE¼ sec. 7, Walker Twp.	847	60	547	50	597
Claude & Bernice Passino #1 - NW¼ SE¼ NE¼ sec. 18, Walker Twp.	842		561		

	SFC	BELL SHALE		ROCKPORT Q	
	ELEV.	THICK	TOP	THICK	TOP
T 33 N, R 1 W					
State-Nunda #1-3 - C NW¼ NE¼ sec. 3, Nunda Twp.	909	60	-51	90	39
State-Nunda "A" #1 - NE¼ SE¼ SW¼ sec. 11, Nunda Twp.	841	59	-155	60	-95
State-Nunda #1-23 - C NE¼ NW¼ sec. 23, Nunda Twp.	898	55	-230	90	-140
Otsego County					
T 32 N, R 1 W					
State-Corwith #1-3 - SE¼ NE¼ SW¼ sec. 3, Corwith Twp.	928	57	-233		
Cheboygan County					
T 35 N, R 1 E					
State-Waverly #1 - SE¼ SW¼ SW¼ sec. 22, Waverly Twp.	789	75	690	40	730
William Commeau #1 - C SE¼ SE¼ sec. 23, Waverly Twp.	766	71	677		
T 34 N, R 1 E					
McClure Oil-State Forest #1-34 - SE¼ SW¼ SE¼ sec. 34, Forest	857	62	304	56	360
T 33 N, R 1 E					
State-Maple Grove #1 - SW¼ SW¼ SW¼ sec. 3, Forest Twp.	881	59	260		
Presque Isle County					
T 35 N, R 2 E					
Black Lake State Forest Residence - SE¼ NE¼ SE¼ sec. 18	720	63	631	68	699
Lobdell-Emery Myers #1 - SE¼ SE¼ sec. 26, North Allis Twp.	787	49	649	48	697
Jacob Middaugh #1 - C SE¼ SE¼ sec. 29, North Allis Twp.	791	64	672		
Donald E. Drasey #1 - SE¼ SW¼ SE¼ sec. 29, North Allis Twp.	809	61	684	45	729
Arnold Vermilya #1 - C SE¼ SW¼ sec. 29, North Allis Twp.	834	64	668		
T 34 N, R 2 E					
Presque Isle Development Company at Onaway - SE¼ NW¼ sec. 5	830	60	580	80	660
L. B. Smith #1 - NW¼ NE¼ NW¼ sec. 12, Allis Twp.	843	60	543	90	633
T 33 N, R 2 E					
Roy N. Skinner et ux. #1 - C SE¼ SW¼ sec. 3, Allis Twp.	867	72	385	70	455
State-Allis #1-23 - NE¼ SW¼ NW¼ sec. 23, Allis Twp.	882	64	380	72	452
T 35 N, R 3 E					
State-Ocqueoc #1 - SE¼ NW¼ NW¼ sec. 24, Ocqueoc Twp.	730	44	620	60	680
Alfred Jarvis #1-28 - NW¼ NE¼ NE¼ sec. 28, Ocqueoc Twp.	760		629		
T 35 N, R 4 E					
Norman & Dolores Brege #1-17 - C NW¼ NW¼ sec. 17, Moltke Twp.	800	43	582		
T 34 N, R 4 E					
Paul E. Trapp #1 - NE¼ SE¼ NE¼ sec. 35, Bismarck Twp.	812	62	482		
T 33 N, R 4 E					
Zwolinski #1-12 - SE¼ SE¼ SE¼ sec. 12, Bismarck Twp.	874	66	388	51	439

T 34 N, R 5 E	SFC ELEV.	BELL THICK	SHALE TOP
Kreft et al. #1 - W½ SE¼ SW¼ sec. 5, Belknap Twp.	785	70	664
Spomer #1 - SE¼ NE¼ SW¼ sec. 6, Belknap Twp.	822	55	617
Herman A. Ristow #1 - NE¼ NE¼ NE¼ sec. 7, Belknap Twp.	823		643
Bruning et al. #1 - NE¼ NE¼ SE¼ sec. 7, Belknap Twp.	838	64	622
Paul Sellke #1 - NE¼ SE¼ SW¼ sec. 20, Belknap Twp.	844	61	534

Appendix 8

ANALYSES OF WELL RECORDS ACROSS THE NORTHERN PART OF THE LOWER PENINSULA

Section encountered in East Jordan Lumber Co. #1
S½ NE¼ NW¼ sec. 9, T 31 N, R 7 W
Echo Twp., Antrim County

	Feet
Drift	240
Mississippian	
Ellsworth Shale	135
Mississippian - Upper Devonian	
Antrim Shale and Norwood Shale	130
Upper Devonian	
Jordan River Formation (14')	
Shale, gray, flaky, very limy	14
Middle Devonian	
Whiskey Creek Formation (55')	
Limestone, gray, shaly, fossils	5
Limestone, gray, dense to crystalline; small amount gray limy shale and fossils	4
Limestone, gray, dense to crystalline; some fossils; small amount secondary calcite	2
Limestone, gray, dense, shaly; some fossils	7
Limestone, grayish-tan, dense, with pyrite	5
Limestone, gray to tan, dense to crystalline, small amount shale, gray; a little chert; a little dolomite (250' fresh water 8' above base)	22
Limestone, tan and gray, dense; some gray and dark-gray shale with spores; oil stain	6
Petoskey Formation (76')	
No samples; driller's log - shale, gray	1
No samples; driller's log - limestone	1
Limestone, gray, shaly; some limy shale; a little chert	19
Limestone, gray, dense to crystalline with numerous fossils; some limy shale and crystals of secondary calcite	8
Shale, gray, limy, and a little limestone	7
Limestone, gray and white; trace of gray shale and chert	40
Charlevoix Formation (20')	
Limestone, tan, gray, and white, dense (shows some porosity in lower 10')	20
Gravel Point Formation (195')	
Limestone, drills up as fine powder; driller's log - gypsum (could be the equivalent of "upper blue shale")	8
Limestone, gray, dense	18
Limestone, gray and tan, shaly, small amount calcite	8
Limestone, gray and tan, dense to broken crystalline	76
Limestone, gray and tan; some fossils, some limy shale, gray	14
Limestone, gray and tan, some shale	16
Limestone, gray and tan, with considerable coralline material and some organic matter (? = Gorbut Member)	5
Limestone, gray and tan	5
Limestone, gray, shaly	45
Koehler Limestone (45')	
Limestone, gray and tan; some secondary calcite (300' water 10' above the base)	45
Genshaw Formation (210')	
No samples; driller's log - traverse limestone	5
Limestone, gray and white	30
Limestone, tan and gray; some anhydrite and gypsum	7
Limestone, gray, and anhydrite	6
Limestone, gray and white, some anhydrite	27
Limestone, gray-brown	15
Limestone, gray	37
Limestone, gray, fossiliferous	28
No samples; driller's log - shale, gray, soft	23
Limestone, gray and white; a few fossils	5
Limestone, gray and white; some coralline material	7
Limestone, gray and white; traces of coralline material	20
Rockport Quarry Limestone (64')	
Limestone, darker gray; traces of coralline material	10

Limestone, tan and white; some gray limestone	5
Limestone, gray; some white limestone	7
No samples; driller's log - traverse limestone	8
Limestone, gray and some white	34
Bell Shale (101')	
No samples; driller's log - bell shale	47
Shale and limestone, gray, fossiliferous	30
No samples; driller's log - shale, dark-gray to black	22
Shale, dark-gray, limy	2
Total Traverse Group	780

Section encountered in W. M. Brown #1
SE$\frac{1}{4}$ SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 12, T 33 N, R 3 W
(about 9$\frac{1}{2}$ miles southwest of Afton; near Wolverine)

	Feet
Drift (muck, gravel, clay)	85
Upper Devonian	
Norwood Shale	
Shale, black and brownish-black, pyrite	8
Jordan River Formation (22')	
Shale, hard, blue	7
Shale, blue	15
Middle Devonian	
Whiskey Creek Formation (50')	
Limestone, gray (Traverse limestone cap rock)	3
Limestone, gray	14
Limestone, gray to pinkish-buff, with pyrite	17
Limestone, gray and coarser	11
Limestone, gray to brown (somewhat bituminous and shaly)	5
Petoskey Formation (48')	
Limestone, vari-shaded gray, fossiliferous	9
Limestone, gray, much coarser with some brown shaly streaks	5
Limestone, brown to grayish-buff that drills very fine	15
Limestone, coarser, brownish-buff	6
Limestone, brownish-buff, fine-grained	5
Limestone, light-gray to buff to dark-gray (bituminous) (4" flow of fresh water from 10" casing)	8
Charlevoix Limestone (37')	
Limestone, fine-grained, buff (slight show gas; more water)	19
Limestone, buff with light-gray specks	8
Limestone, very fine grained, light-buff	5
Limestone, light-gray and buff, crystalline	5
Gravel Point Formation (215')	
"Upper blue shale": limestone, dark-gray shale and shaly, fossiliferous	25
Limestone, light-gray to buff, sandy, drills rather coarse	17
Limestone, coarse, gray, granular, porous and fossiliferous	12
Limestone, varishaded, buff	21
Limestone, dense, gray, drills coarse (fossiliferous and shaly in part)	20
Limestone, buff, hard	10
Limestone, buff, broken with gray shale (pyrite), porous and highly fossiliferous	12
Limestone, gray to buff; coralline and hard	33
Limestone, brownish-buff with some dark-gray (? = Gorbut Member)	25
Limestone, brownish-buff, coarse	10
Limestone, buff	30
Koehler Limestone (49')	
Limestone, very hard (water dropped away 20' in crevice)	10
Limestone, fine-grained, brown	6
Limestone, gray to buff, drills coarse	18
Limestone, buff, finer	6
Limestone, gray to buff	9
Genshaw Formation (142')	
Killians Member (36')	
Limestone, buff and dark-gray, shaly limestone (drills coarse)	21
Limestone, dark-gray, shaly, bituminous	15
Lower Member (106')	
Limestone, gray, dense-grained	20
Limestone, buff, some gray specks; drills fine	25
Limestone, buff	10
Limestone, gray	10
Limestone, light-gray, shaly	15
Limestone, gray to buff	18
Limestone, buff, some slate reported in driller's log (may include Ferron Point Formation)	8
Rockport Quarry Limestone (69')	
Limestone, dark-gray to buff, fossiliferous, drills coarse, hard	29
Limestone, dark-buff (water)	12
Limestone, fine-grained, buff	28
Bell Shale (70')	
Shale, gray, limy, with some buff limestone near top	70
Total Middle Devonian	680
Dundee Limestone	
Limestone, fine-grained, buff	

Section encountered in Lewis A. Garred #1
SE$\frac{1}{4}$ SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 1, T 33 N, R 2 W
(about 7 miles south of Afton)

	Feet
Drift	223
Upper Devonian	
Antrim Shale	
Shale, black, fissile	17

Shale, gray, very calcareous; limestone, gray, very argillaceous	20
Norwood Shale	
Shale, black, pyritic, fissile	40

Middle Devonian

Beebe School Formation (125')	
Limestone, tan to gray, fine to medium, argillaceous	20
Shale, gray, plastic, calcareous	15
Limestone, gray, very fine to fine-grained, argillaceous	15
Limestone, brown, fine-grained	25
Limestone, brown, micritic to fine-grained, dense to crystalline	25
Limestone, brown, micritic, dense, scattered slight pinpoint porosity	25
Gravel Point Formation (200')	
Shale, gray, calcareous	7
Limestone, brown to grayish-brown, very fine to fine-grained, argillaceous	8
Shale, gray, calcareous	52
Limestone, tan to brown, fine- to medium-grained, skeletal, bioclastic	24
Shale, gray, calcareous	4
Limestone, tan to brown, fine- to medium-grained, skeletal	30
Shale, gray, calcareous	10
Limestone, tan to brown to very dark brown, very fine to medium-grained, skeletal in part (includes Gorbut Member)	40
Limestone, buff to grayish-brown, very fine to fine-grained	25
Koehler Limestone (80')	
Limestone, brown to grayish-brown, very fine to medium-grained, skeletal, bioclastic	55
Limestone, brown to black, fine-grained, dense	10
Limestone, brown to grayish-brown, fine- to medium-grained, skeletal, bioclastic	15
Genshaw Formation (141')	
Killians Member (20')	
Limestone, very dark gray to black, fine-grained, to dense, carbonaceous; shale, very dark gray	20
Lower Member (121')	
Limestone, tan to grayish-brown, fine- to coarse-grained, skeletal, bioclastic	19
Limestone, buff, coarse-grained, crystalline, coralline	6
Limestone, black, fine-grained, dense	5
Limestone, buff, fine- to coarse-grained, coralline	10
Limestone, brown to dark-brown, fine- to coarse-grained, skeletal	5
Limestone as above, with shale, gray	20
Shale, gray, calcareous; limestone	28
Limestone, gray to grayish-brown, fine- to coarse-grained, skeletal, bioclastic	28
Ferron Point Formation (4')	
Shale, gray, calcareous	4
Rockport Quarry Limestone (53')	
Limestone, very dark gray to black, fine- to coarse-grained, skeletal with scattered bryozoan fragments, carbonaceous	30
Limestone, tan to brown, fine- to coarse-grained, skeletal, bioclastic	23
Bell Shale (59')	
Shale, gray, plastic, calcareous	59
Total Traverse Group	662
Dundee Limestone	
Limestone, brown, fine- to coarse-grained, skeletal (aggregate of fine- to medium-grained, skeletal fragments with scattered crinoid stems)	

Section encountered in State-Nunda "A" #1
NE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 11, T 33 N, R 1 W
(about 7$\frac{1}{2}$ miles south of midpoint between Tower and Afton)

	Feet
Drift (sand, gravel, boulders)	312

Mississippian (?) and Upper Devonian

Shale, sample badly contaminated with drift; dark-brown to black, fissile	88

Middle Devonian

Beebe School Formation (110')	
Limestone, tan to dark gray brown, fine- to medium-grained, fossiliferous in part	35
Limestone, brown to dark grayish brown, fine- to medium-grained, skeletal, argillaceous in part	25
Limestone, dark-brown, micritic, dense	10
Limestone, dark-brown, micritic to fine-grained, dense	10
Limestone as above, tan to brown	20
Limestone, light-brown, micritic, dense; shale, gray, calcareous 15%	10
Gravel Point and Koehler Formations (270')	
Shale, gray, very calcareous	10
Limestone, dark-gray, argillaceous	10
Shale, gray; limestone, gray, fine-grained	5
Shale, gray, plastic	5
Limestone, gray to dark-gray, fine-grained; shale, gray	10
Limestone, brown to dark-brown, fine- to medium-grained, skeletal to bioclastic grains; trace carbonaceous material	5
Limestone as above, light-brown to brown	10
Limestone, gray to grayish-tan, skeletal, crinoid fragments, argillaceous	5
Shale, gray, calcareous	30
Limestone, tan to brown, fine- to medium-	

grained, skeletal (composed largely of bioclastic fragments, slight intergranular porosity?) 5
As above 40
Shale, gray; limestone, tan to brown, skeletal . 10
Limestone, grayish-tan to dark-brown, fine- to coarse-grained, skeletal, abundant coral fragments 125

Genshaw Formation (150')
Killians Member (30')
Limestone, grayish-brown to very dark brown, fine- to medium-grained, carbonaceous 30
Lower Genshaw (120')
Shale, gray; limestone, gray-brown, fine- to medium-grained 25
Limestone, dark-brown to black, fine- to coarse-grained, skeletal, with crinoid and coral fragments 45
Shale, gray, plastic, calcareous 10
Limestone, dark-brown, fine- to coarse-grained, skeletal, crinoid and coral fragments with trace of shale (10%) 40

Ferron Point Formation (5')
Shale, gray, calcareous 5

Rockport Quarry Limestone (60')
Limestone, brown to dark grayish brown, fine- to coarse-grained, skeletal with abundant crinoid and coral fragments 45
Limestone, tan to dark-brown, fine- to coarse-grained, skeletal with abundant coral and crinoid fragments 15

Bell Shale (59')
Shale, gray; limestone as above (Schlumberger top) 5
Shale, gray, plastic, calcareous 54

Total Traverse Group 654

Dundee Limestone
Limestone, brown, very fine to coarse-grained, skeletal, with coral fragments

Section encountered in
Presque Isle Development Company Well
SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 5, T 34 N, R 2 E
(on Merritt Chandler property, 40 rods west-northwest from Detroit & Mackinac Railroad station at Onaway)

Feet

Drift (clay, pink, calcareous) 10

Middle Devonian

Koehler Limestone
Limestone, gray 15

Genshaw Formation (145')
Limestone, buff and dark-gray and very argillaceous limestone with strong smell of petroleum; dark brown oily scum; includes Killians Member 100
Limestone, gray, granular, bituminous; fossiliferous, crinoids and corals; much white calcite 15
Shale, gray, soft, calcareous 10
Limestone, gray, with much disseminated calcite; fossiliferous, corals 20

Rockport Quarry Limestone and Ferron Point Formation (?) (80')
Limestone, dark; highly calcareous black shale; disseminated calcite 80

Bell Shale (60')
Shale, gray, brown, and black, slightly calcareous 60

Section encountered in Turtle Lake Club #1
SE$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 9, T 29 N, R 5 E
Ossineke Twp., Alpena County

Feet

Drift 320

Mississippian - Upper Devonian

Antrim Shale (possibly also Norwood Shale)
Shale, various dark and black shales 360

Upper Devonian

Squaw Bay Limestone (22')
Limestone, gray, dense; shale, gray 17
Shale and light-brown coarse-crystalline, glassy dolomite, green specks; show of gas near top 5

Middle Devonian

Thunder Bay Limestone (26')
Shale, gray, limy 6
Shale, gray, calcareous 8
Shale, gray, calcareous, with gray crystalline fossiliferous limestone 6
Same, slight increase in limestone 6

Potter Farm Formation (65')
Limestone, gray, fossiliferous, little shale 17
Limestone, gray, fossiliferous and shale 7
Shale, gray, soft 8
Limestone, gray and brown, dolomitic 10
Limestone, dark-gray, fossiliferous with echinoderm stems 10
Limestone, gray, fossiliferous, and brown crystalline dolomite; gas blow at base, blow-down to est. 1000 cu ft after 48 hours open 9
Limestone, brown, dense to finely crystalline, dolomitic; slight trace of shale 4

Norway Point Formation (82')
Shale, gray, calcareous 24
Shale, gray, calcareous, with brown dense limestone 8

Limestone, brown, dense, shaly 10
Limestone, brown, dense, shaly, with gray shale 15
Shale, gray, fossiliferous 12
Limestone, buff, fossiliferous; trace of shale .. 13

Four Mile Dam Formation (57')
Limestone, gray, fossiliferous 27
Dock Street Shale Member: shale, gray, soft .. 30

Alpena Limestone (111')
Limestone, light-brown, crystalline 6
Limestone, light-brown, crystalline, fossiliferous 17
Limestone, white, or dolomite, soft 22
Limestone, light-brown, dolomitic, and dolomite 18
Limestone, light-brown, dolomitic, and dolomite with medium-brown dolomitic limestone 22
Limestone, brown, dolomitic 5
Shale, gray, calcareous, fossiliferous 21

Newton Creek Formation (32')
Limestone, brown, crystalline 9
Limestone, brown, crystalline, a little bituminous material 23

Genshaw Formation (130')
Upper Genshaw Member (39')
Limestone, grayish-brown, dolomitic 10
Dolomite, brown, fossiliferous, shaly 8
Shale, dark-gray, fossiliferous, calcareous ... 12
Shale, gray 9

Killians Member (41')
Shale, black, very limy 11
Shale, black, very limy, with trace of brown fossiliferous limestone 30

Lower Genshaw Member (50')
Corals, brown and white; fossiliferous, slightly shaly limestone 7
Limestone, light-brown to white, dense 8
Limestone, gray, fossiliferous, shaly 3
Limestone, light-gray, fossiliferous (corals), trace of shaly limestone 4
Limestone, gray, fossiliferous 28

Ferron Point Formation (80')
Shale, gray, fossiliferous, calcareous 20
No samples 35
Limestone, brown, shaly 13
Shale, blue-gray 12

Rockport Quarry Limestone (53')
Limestone, brown, dense, fossiliferous 13
Limestone, brown, dense, fossiliferous, with trace of shale 24
Limestone, brown, shaly 6
Limestone, light-brown, with trace of shaly limestone 10

Bell Shale (82')
Shale, blue-gray, and a little limestone 8
Shale, blue-gray, soft 9
Shale, blue-gray, many stems, pyrite 55
Shale, blue-gray; brown, dense limestone, trace of pyrite 10

Total Traverse Group 740

Drilling Project

To extend the accuracy of our maps and to collect information for future stratigraphers, we started a drilling program in this year. We plan to obtain cores reaching around 100 feet each from eleven wells, and to analyze these cores for stratigraphic units as well as for their chemical content.

In October 1975 we met with other members of the Michigan Geological Survey in the field to assess the potential locations for drilling. Many sites were visited and eleven were deemed both suitable and permissible by the Survey. These were:

(1) Black shale on Beebe School Road, NW$\frac{1}{4}$ NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 14, T 34 N, R 2 W, about $\frac{1}{2}$ mile west of intersection of this road with Munger Road (intersection near the schoolhouse), Ellis Twp., Cheboygan Co. Basal beds of Norwood Shale at or very near the surface in the vicinity of the old shale test pit. Elevation about 800 feet.

(2) Sorenson Quarry, SE corner NE$\frac{1}{4}$ sec. 11, T 34 N, R 2 W, along west side of Munger Road, Ellis Twp., Cheboygan Co. Koehler Limestone at surface, probably the upper part. Elevation about 810 feet.

(3) Campbell Quarry, NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36, T 35 N, R 2 W, Koehler Twp., Cheboygan Co. Lower beds of Gravel Point Formation in walls and top of quarry, upper beds of Koehler Limestone in floor of quarry. Elevation about 780 feet.

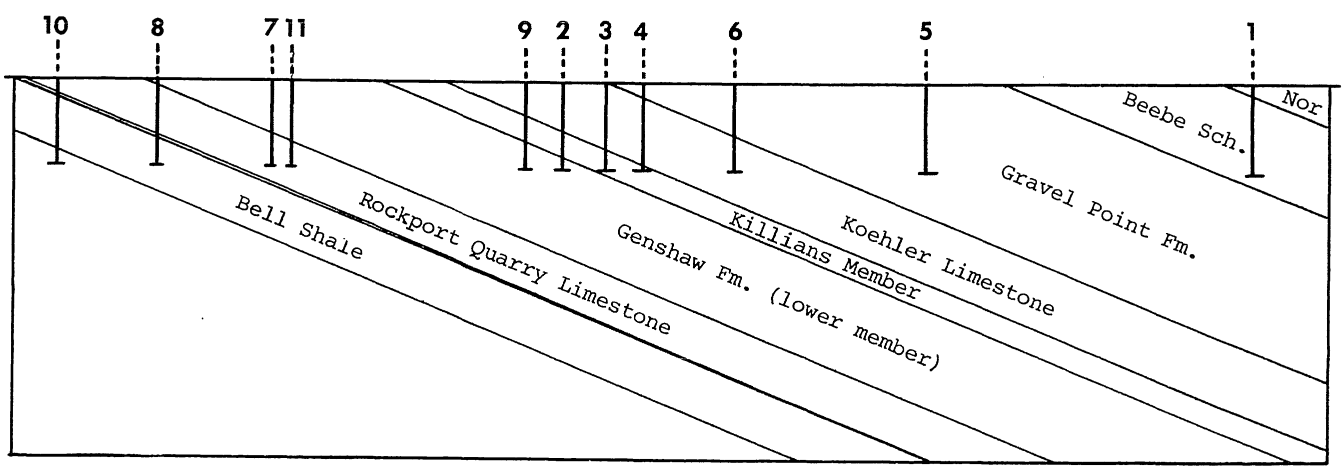
(4) Marvin Quarry, SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 7, T 34 N, R 1 W, Walker Twp., Cheboygan Co. Lower beds of Gravel Point Formation at top of quarry wall. Elevation about 850 feet.

(5) Pigeon River Road, S$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 18, T 34 N, R 1 W, roadside exposure on north side of road, about $1\frac{1}{2}$ miles south of Marvin Quarry, Walker Twp., Cheboygan Co. Gravel Point Formation. Elevation about 850 feet.

(6) Abandoned railroad cut, E$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 33, T 35 N, R 1 W, just west of north-south section of Knight Road, about $\frac{1}{2}$ mile east of site of Gorbut School and about $1\frac{1}{4}$ miles south-southeast of Le Grand. Gravel Point Formation. Elevation about 825 feet.

(7) Milligan Creek, SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T 35 N, R 1 E, exposures on north bank of creek just east of Waveland Road, about 1/10 mile north of intersection with Brady Road, in Black Lake State Forest, Waverly Twp., Cheboygan Co. Genshaw Formation. Elevation about 710 feet.

(8) "Limestone Hill," E$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 21, T 35 N, R 1 E, on west side of Dangler Road about $\frac{1}{4}$ mile north of intersection with



TEXT-FIG. 57 -- Proposed exploratory wells and their anticipated stratigraphic intercepts in the uppermost 100 feet of core.

Buck Road, in Black Lake State Forest. Lower part of Genshaw Formation. Elevation about 760 feet.

(9) Carl Safronoff Quarry, SE$\frac{1}{4}$ sec. 6, T 34 N, R 1 E, west of Brady Road and about 3 miles west of village of Tower; main quarry over $\frac{1}{4}$ mile from road, and test pits between main quarry and road, Forest Twp., Cheboygan Co. Koehler Limestone. Elevation about 820 feet.

(10) Black Lake Quarry, S$\frac{1}{2}$ NW$\frac{1}{4}$ sec. 7, T 35 N, R 2 E, near southern shore of lake, North Allis Twp., Presque Isle Co. Floor of quarry near base of Rockport Quarry Limestone. Elevation about 620 feet.

(11) Ocqueoc, E$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 20, T 35 N, R 3 E, on west side of North Ocqueoc Road between village of Ocqueoc and King Lookout Tower, Ocqueoc Twp., Presque Isle Co. Genshaw Formation. Elevation about 780 feet.

State drilling permits were issued and our first operations were started in May, with additional time in July. A third period of drilling is planned for August.

A 17-horsepower diesel Sprague & Henwood drill was used. This portable rig can be transported by heavy-duty truck and set up by two or three men. Drilling was directed by Al Johnson with a crew consisting of Larry McDonald and Dave Cregger, students at Michigan Tech. Bill Walden of the Michigan Geological Survey joined them in July. Hole elevations were surveyed by Keuffel & Esser level from benchmarks and section-corner elevations by Harry Sorensen and Bob Kesling in mid-July.

Drilling was best in limestone units, with 10-foot core sections common. In shale, the circulation was often shut off by dry plugging at the core bit, and much shorter sections were the rule -- with numerous interruptions to pull the rods and extract the terminal obstruction. Recovery was only fair in the argillaceous strata but excellent in the limestones.

As this report is being written, drilling is still in progress. Cores at Campbell Quarry and Marvin Quarry agreed with the stratigraphy shown by earlier wells. The core at Sorensen Quarry penetrated the black Killians Member of the Genshaw at around 40 feet.

When the project is completed, we hope to have representative cores of the whole Traverse Group. Chemical analyses are planned to discover the quality of the limestone units. Results will be published later.

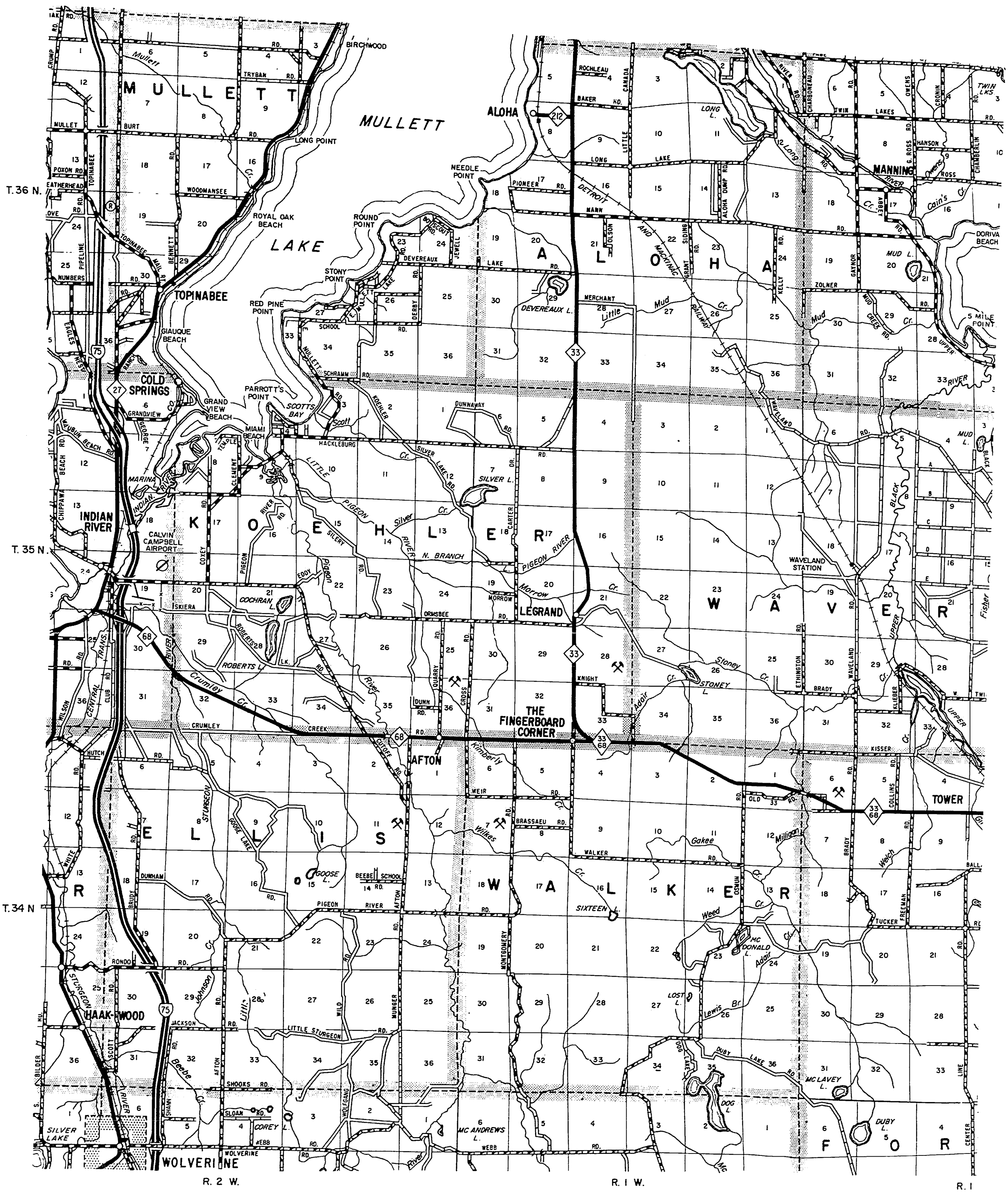
TEXT-FIG. 59 -- Drilling through the Norwood Shale west of Beebe School. Here the core barrel is being hoisted from the hole by McDonald and Cregger.

TEXT-FIG. 60 -- The core has been removed, new sections of stem added, and the drill is put again into operation. Johnson enters the depth in the log.

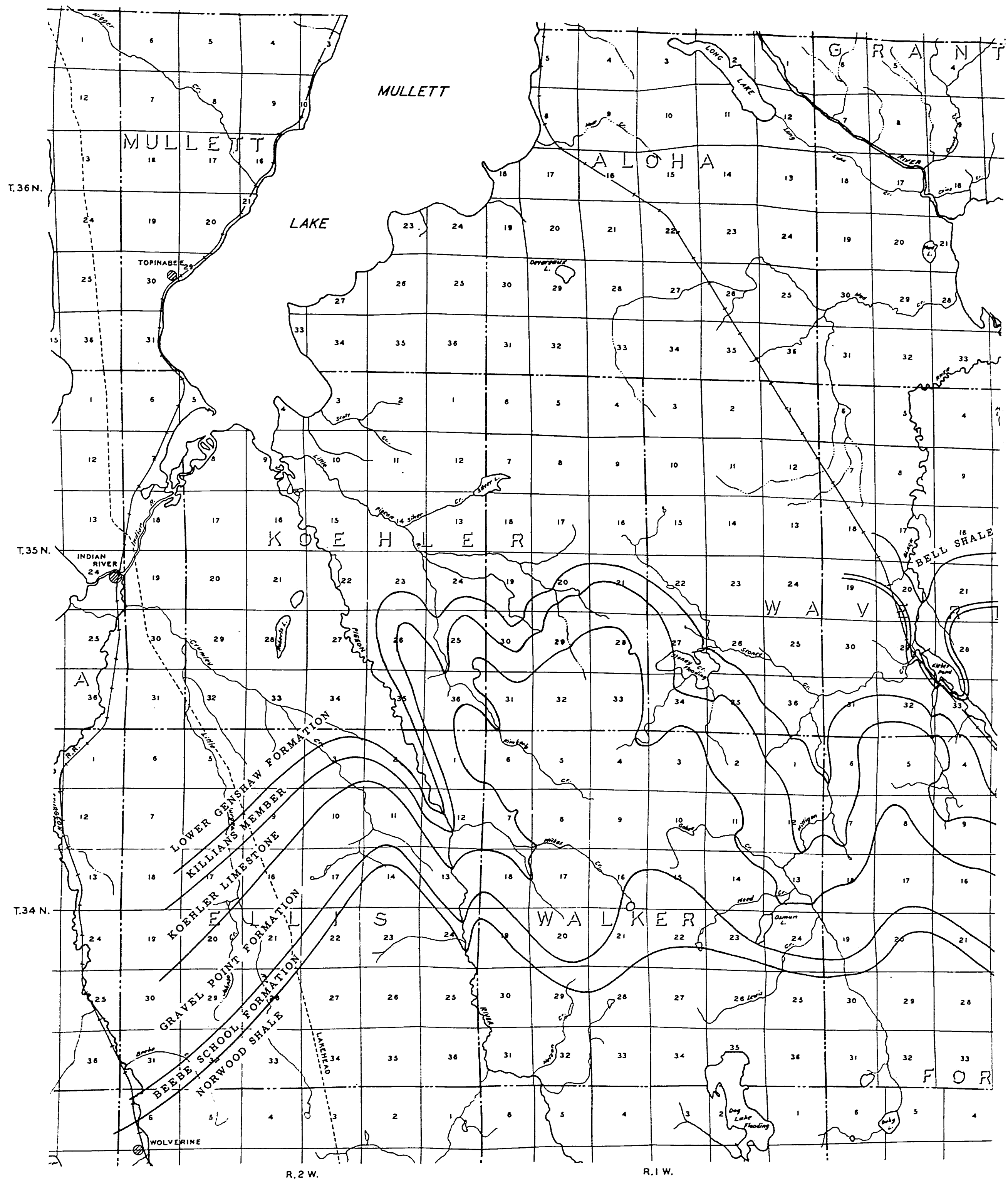
TEXT-FIG. 58 -- The Sprague & Henwood drill in operation. Larry McDonald is at the controls, Dave Cregger is at the casing head, and Harry Sorensen observes the procedure. Photo by Kesling, 14 July 1976.

TEXT-FIG. 62 -- Joint system in the Koehler Limestone at the test pits near Carl Safronoff Quarry. Locality 34-1E-6 SE. Photo by Kesling, 15 July 1976.

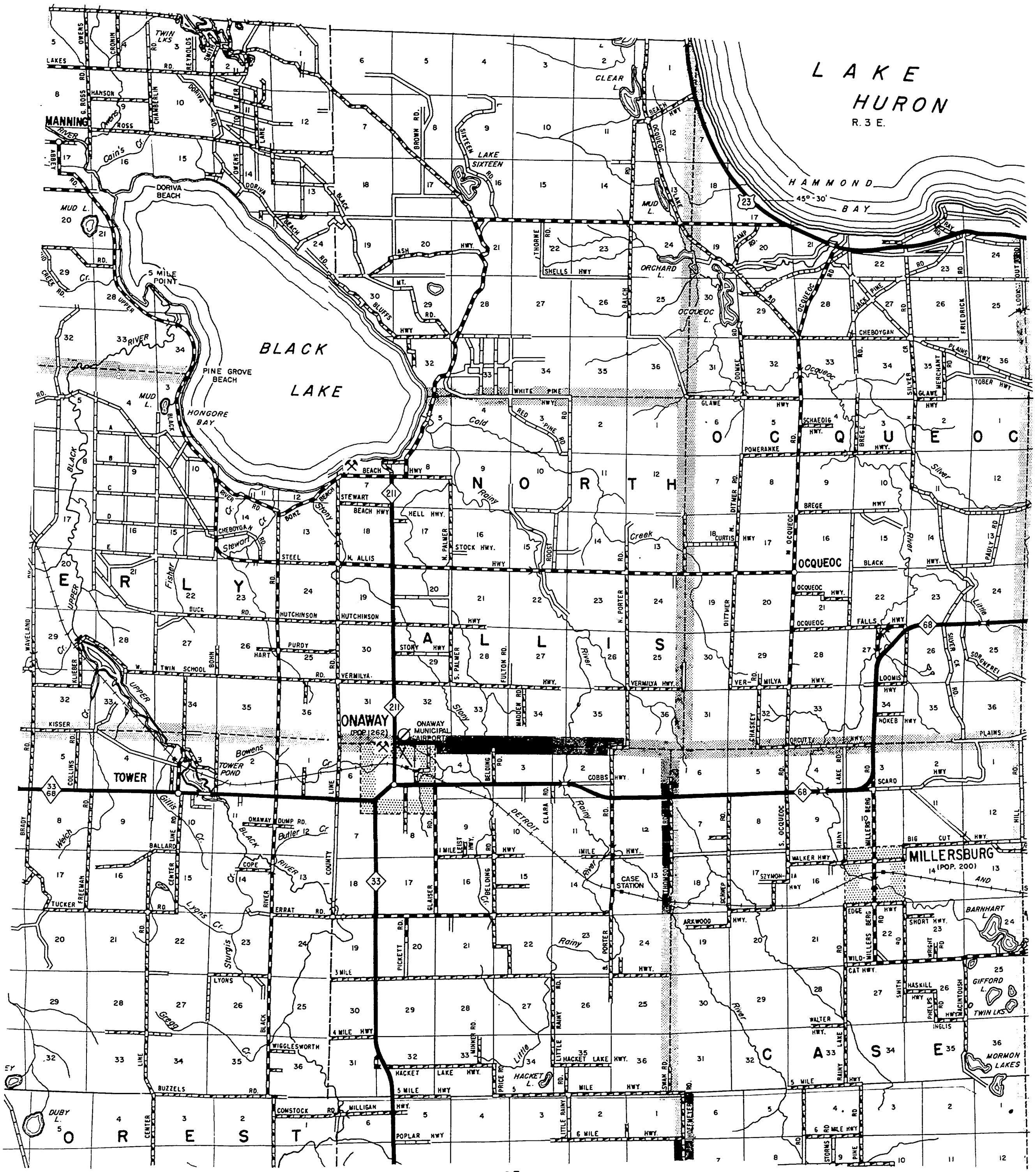
TEXT-FIG. 61 -- All eyes are on the core as it is removed from the core barrel. Here, on 14 July 1976, the contact was reached with the Beebe School Formation.



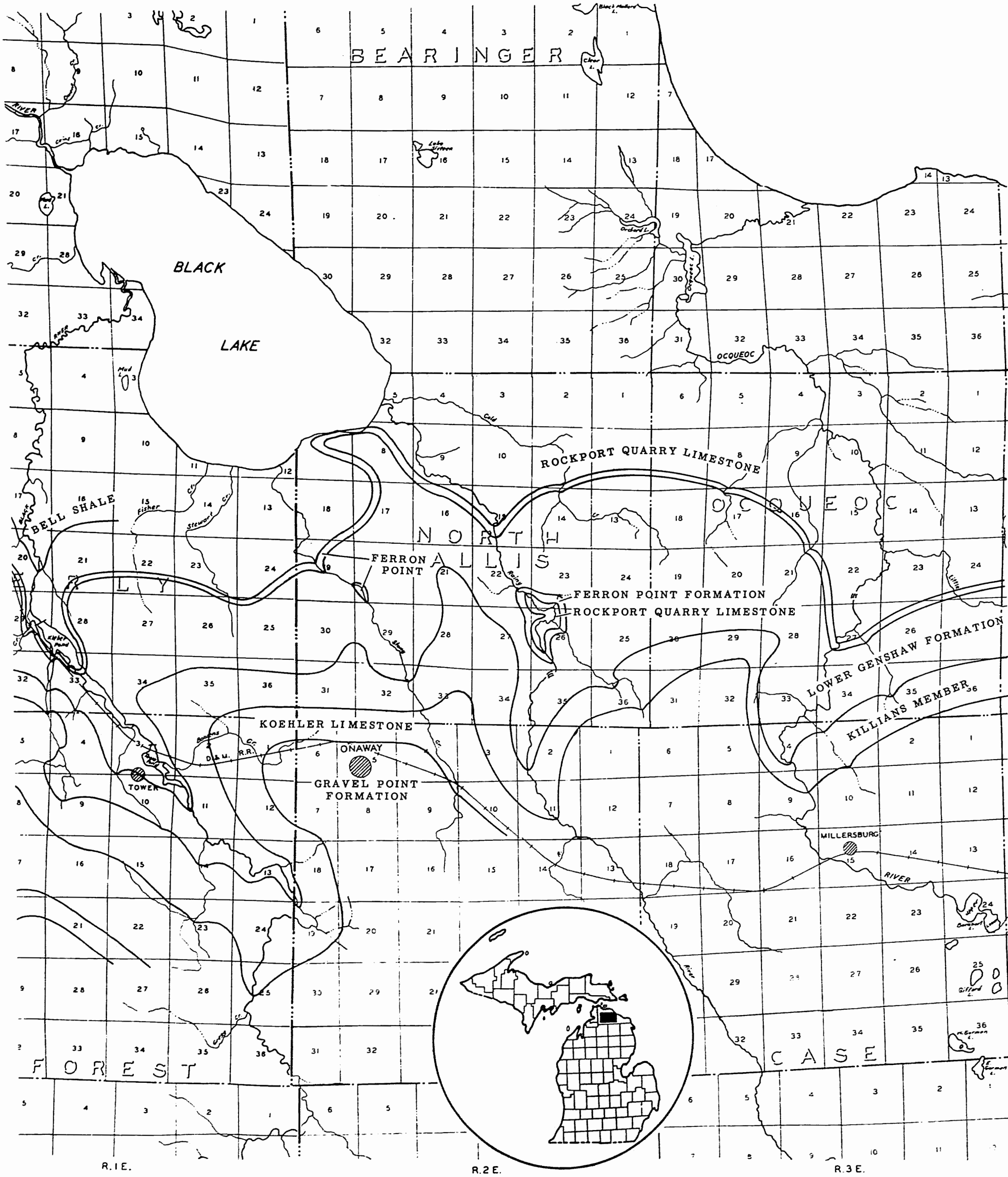
MAP 1 -- Western half of Afton-Onaway area, cultural map.



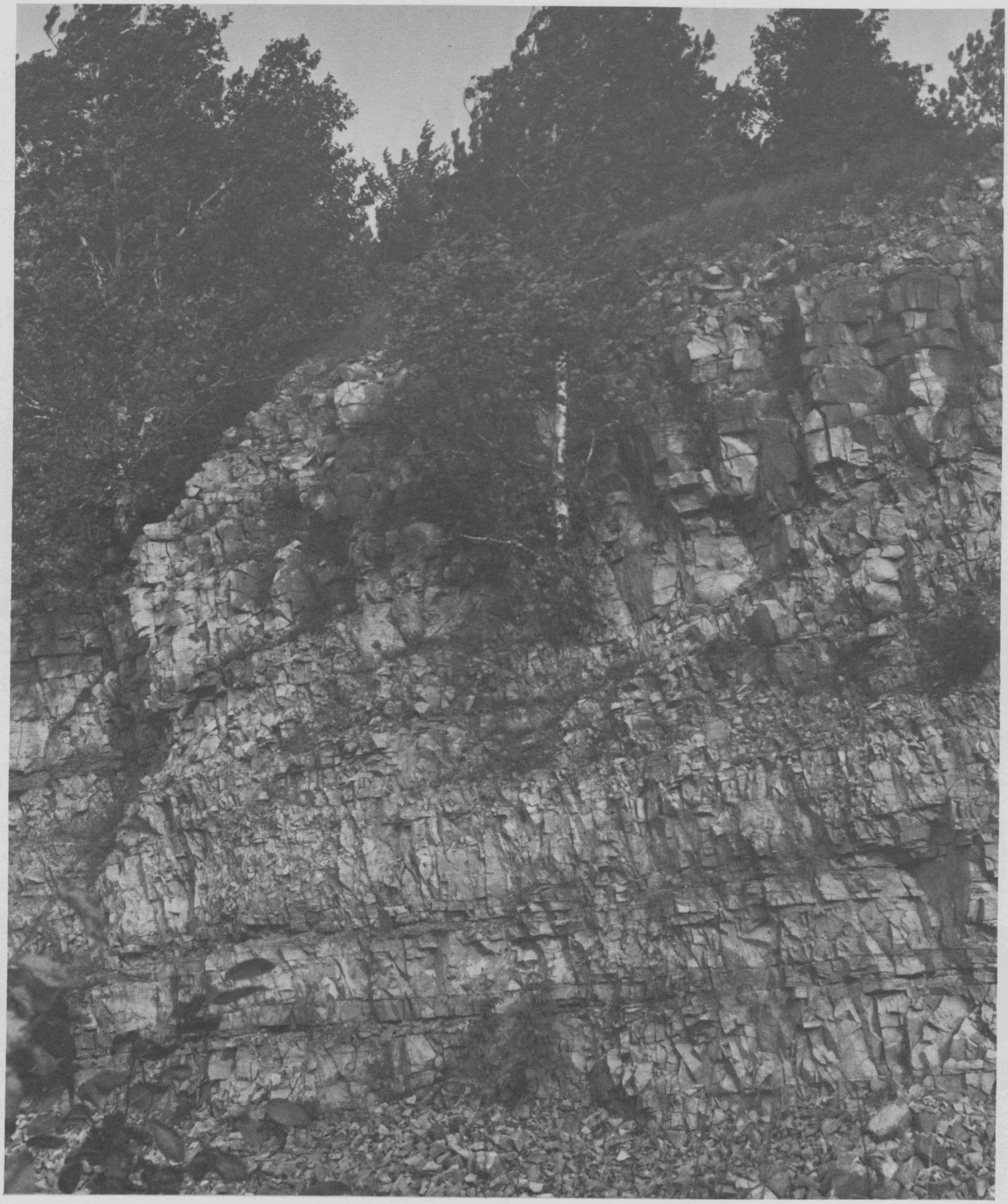
MAP 2 -- Western half of Afton-Onaway area, geologic map.



MAP 3 -- Eastern half of Afton-Onaway area, cultural map.



MAP 4 -- Eastern half of Afton-Onaway area, geologic map.



TEXT-FIG. 63 -- Black Lake Quarry, exposure of Rockport Quarry Limestone in the "lagoonal facies."

ENVOY

The geology of the Traverse Group in northeastern Michigan was summarized in 1970 by Ehlers & Kesling in "Devonian strata of Alpena and Presque Isle Counties, Michigan." Similarly, that in northwestern Michigan was treated in 1974 by Kesling, Segall, & Sorensen in "Devonian strata of Emmet and Charlevoix Counties, Michigan." With this publication, covering north-central Michigan, the review of the group is completed. Much remains to be done on the paleontology, paleoecology, sedimentology, geochemistry, detailed structure, and correlation of the formations. We trust that our efforts herein provide an up-dated review of the progress that has been made on these rocks, and make it easier for future geologists to get on with the solutions to problems of this varied and intriguing section of the Devonian record in the Michigan Basin.

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