# THE GASPORT DOLOMITE

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# IN THE

# VICINITY OF HAMILTON, ONTARIO

by

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SCOPE AND CONTENTS:

The Silurian Gasport dolomite member was studied in the Hamilton area. In spite of the masking effect of dolomitization, the stratigraphic relations and results of petrographic and sedimentalogical examination suggest that the depositional locus was that of a shelf or bank.

A thin layer of jarosite was observed; further study may show this layer to have important stratigraphic time value.

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# INTRODUCTION

## General Statement

Silurian rocks of Southern Ontario and the adjacent State of New York have been extensively studied in the past by Canadian and American geologists. Besides forming the basis of this research, these rocks will doubtless continue to be of interest to geologists in the future.

Although other Silurian units have received considerable attention, relatively little has been written about the Gasport dolomite. A study of the literature reveals considerable disagreement among geologists with regard to its rank and position.

It is hoped that this study of the Gasport dolomite will aid in the general interpretation of Silurian sedimentation. Stratigraphical, petrographical and paleontological studies form the basis for the interpretation of the Gasport dolomite and its paleogeographic relationships.

## Previous Work

The classic writings of Grabau (1901 - 1910), Hall in 1874, Schuchert in 1914, and Williams (1919) have contributed much to our present knowledge of Silurian sediments in the Niagara Escarpment. In more recent years Dr. J. F. Caley (1940) carried out extensive geologic mapping in the area, revising much of the earlier work.

The most recent survey in the area was undertaken by T. E. Bolton, who in 1950 and 1951, carried out geological mapping for the Geological Survey of Canada. His findings were published in a paper (1953a) containing extensive references to previous investigations undertaken in this region.

## Acknowledgments

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# GENERAL SETTING

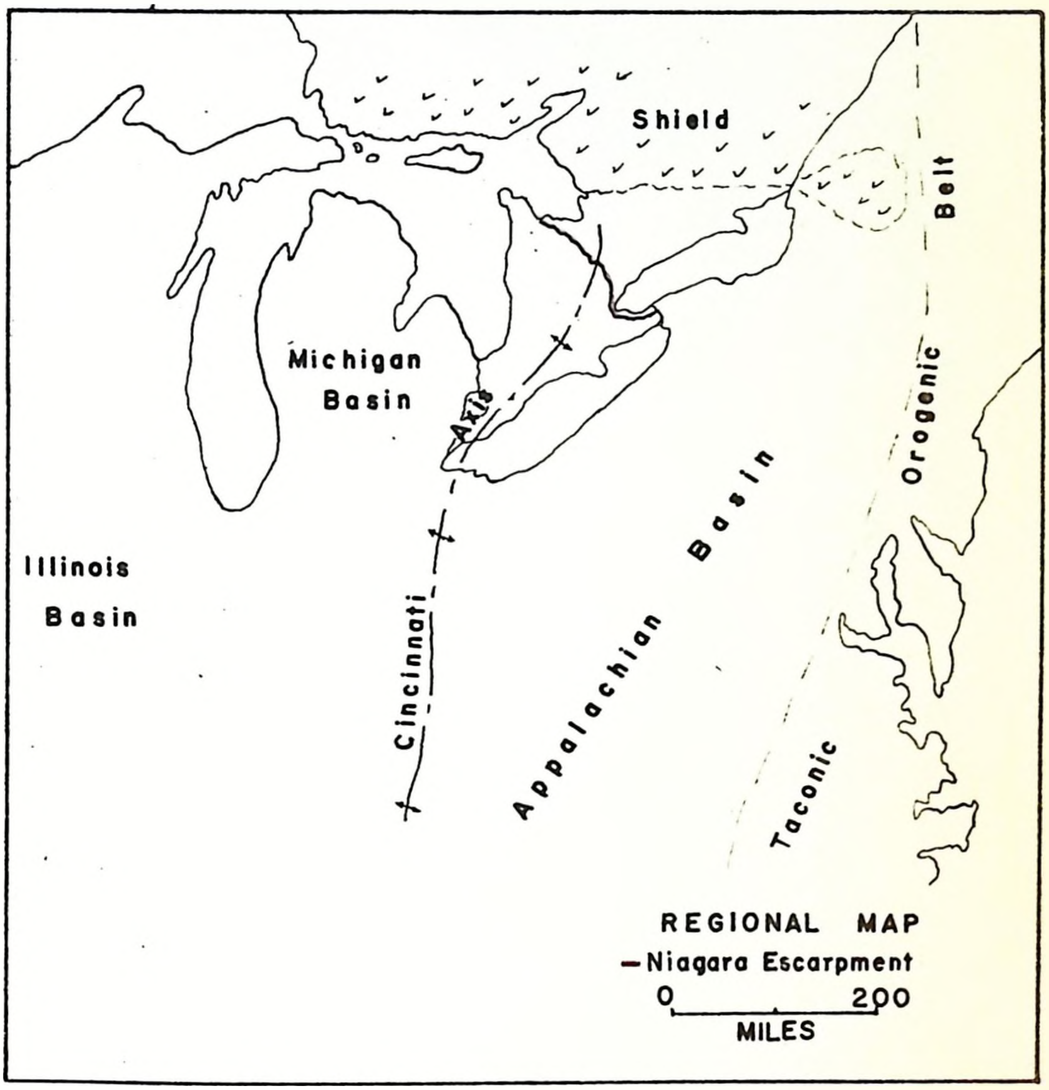
## General Geology

"Undisturbed Ordovician, Silurian, and Devonian strata underlie the whole of the Ontario-Michigan basin, but are mainly exposed in the Niagara Escarpment, which partly encircles this basin. These sediments lie upon the irregular surface of Precambrian igneous and metamorphic rocks, which outcrop a hundred miles to the north as the Canadian Shield" (Fig. 1).

The escarpment trends from the Niagara River north-westerly to the tip of Bruce Peninsula, and is composed almost entirely of Silurian dolomites forming north-easterly facing, vertical cliffs, while the lower slopes are developed in softer red shales of Late Ordovician age. In Southern Ontario the sediments, in general, dip gently to the south-west away from the Canadian Shield at about 20 feet per mile.

During Pleistocene time the region was glaciated by the south-westward advance of the Labrador Ice Sheet. The Niagara Escarpment, lying in the path of its advance, had much boulder clay of two or three ages piled against it (Coleman, 1941). The escarpment itself is the result of differential erosion of practically flat-lying sediments. Away from the escarpment the variable thickness of glacial drift covering the bedrock controls the topography - the present surface in no way reflecting the structure of the underlying rocks. It is estimated that the ice of the last glacial period left the Ontario region 8,000 to 9,000 years ago. (Flint and Deevey, 1951).

Fig. I


Shield
Belt
Orogenic
Michigan
Basin
Axis
Cincinnati
Appalachian
Basin
Illinois
Basin
Taconic
REGIONAL MAP
—Niagara Escarpment
0
200
MILES

## Middle Silurian Nomenclature

Extensive lithological and paleontological studies have placed our theories of Silurian sedimentation on a firm foundation. On the basis of these studies the Silurian system has been subdivided into three series: lower, middle and upper. But, in the Niagara Escarpment, assignment of the various formations and members in each subdivision is a matter of considerable disagreement.

A recent study by Bolton (1953b) contains an excellent summary of the history of Silurian nomenclature in the Niagara Escarpment. In the escarpment, Middle Silurian formations consist dominantly of carbonates with minor argillaceous components. The following table (1) illustrates some of the different opinions with regard to Middle Silurian terminology. As can be seen there is little agreement on either rank or position of the Gasport dolomite.

In this paper the Gasport is considered the basal unit of the Lockport formation of Niagaran age, and is therefore a member.

## Location

The Gasport dolomite was studied in the vicinity of Hamilton, Ontario. The region is bounded on east and west by longitudes 79° 00' and 80° 00' respectively, and extends from latitude 43° 20' south to latitude 43° 10' (index map). Although the boundaries enclose approximately 180 square miles, outcrops represent less than one per cent of the total area, being mainly confined to the face of the escarpment.

## Physiography

The Niagara Escarpment rises in New York State near Rochester, parallels Lake Ontario westward to Hamilton, then passes north to the tip

| 4 | | | | 3 | | 2 | | 1 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| T.E.Bolton 1953 | | | | G.S.A. 1942 | | J.F.Caley 1940 | | M.Y.Williams 1919 | | |
| NIAGARA SERIES | ENGADINE GROUP | | Guelph Fm. | LOCKPORT GROUP | Guelph Fm. | | Guelph Fm. | | | Guelph Fm. |
| | | Lockport Fm. | Eramosa Mbr. | | Eramosa Fm. | LOCKPORT FM. | Eramosa Mbr. | NIAGARA GROUP | Lockport Fm. | Eramosa Mbr. |
| | | | Goat Is. Mbr. | | Suspension Bridge Fm. | | Undivided | | | Undivided |
| | | | Gasport Mbr. | | Gasport Fm. | | Gasport Mbr. | | | Gasport Mbr. |
| | CLINTON GROUP | Upper | De Cew Fm. | CLINTON GROUP | De Cew Fm. | | De Cew Mbr. | | | De Cew Mbr. |
| | | | Rochester Fm. | | Rochester Fm. | | Rochester Fm. | | | Rochester Fm. |
| | | | Irondequoit Fm. | | Irondequoit Fm. | CLINTON GROUP | Irondequoit Mbr. | CLINTON GROUP | | Irondequoit Mbr. |
| | | Middle | | | | | | | | |
| | | | | | Williamson Fm. | | | | | Williamson Mbr. |
| | | | | | | | | | | |
| | | | | | Walcott Fm. | | | | | |
| | | | | | Sodus Fm. | | | | | |
| | | Lower | Reynales | | Reynales Fm. | | Reynales Mbr. | | | Reynales Mbr. |
| | | | | | Maplewood Fm. | | Furnaceville Mbr. | | | Furnaceville Mbr. |
| | | | Neahga | | | | | | | |
| | | | Thorold | | | | | | | |

of Bruce Peninsula. Within the map area the escarpment is divided into two components by the pre-glacial Dundas Valley. From the eastern limit of the area westward to Ancaster, the base follows the 350-foot contour while the top of the cliff reaches the 625-foot level.

Northward from the Dundas Valley the base of the escarpment follows the 350-foot contour, while the brow reaches the 750-foot level. The topography rises northward attaining its maximum elevation of 1400 feet at Credit Forks, some fifty miles to the north of the map area.

## Location of Measured Sections

During the autumn of 1954 the author measured and systematically sampled seven sections along the face of the Niagara Escarpment, five of which lie east of the Dundas Valley. These sections were chosen on the basis of their areal distribution, accessibility, degree of exposure, and lithological characteristics. The sections are listed with their corresponding letters on the index map and Fig. 4:

A - Stoney Creek Falls
B - Highway 20
C - Albion Falls
D - Jolley Cut
E - Ancaster
F - Sydenham Street
G - Clappison Cut

In addition the following numbered locations are significant:

1 - Webster Falls
2 - Fruitland Road Cut
3 - Beamsville

## Regional Structural Setting

Lower Silurian (Medinan) sedimentation was initiated on a relatively flat continental platform. During much of Medinan time clastics were being supplied by the Taconic Mountain range. A broad, ill-defined arch, the Cincinnati axis, (Fig. 1), crosses southwestern Ontario from the southwestern tip of the province northeastward to Lake Simcoe. The Cincinnati axis acted as a structural barrier (Cummings, 1939), resulting in lithologic and faunal differences to the east and west of the axis. The Medinan sedimentation represents a closing phase of deltaic deposition which had been initiated in Richmond time (Fisher, 1954).

Middle Silurian sedimentation was marked by a return to transgressing conditions. The Niagaran sea advanced, probably from the southwest, inundating a much larger area than earlier Medinan seas. The Clinton sediments reflect a much lower Taconic Mountain range. There is no evidence that positive areas lying to the north and northwest were supplying sediments to Middle Silurian seaways.

The lack of clastics in carbonate deposits of the Lockport formation seems to indicate a complete absence of adjoining tectonically active source lands.

In the past it has been contended that during Niagaran time the Cincinnati axis still controlled sedimentation. Bolton (1953a) has indicated that an axis proper did not exist in Niagaran time, at least in the escarpment region. In his opinion, sedimentation in Niagaran times was strongly influenced by a broad shelf which extended from Hamilton to Owen Sound, and divided the area into two sites of deposition - one in the Niagara Peninsula area, the other in the region embracing the Bruce Peninsula, - Manitoulin Island, and northern Michigan.

During the course of the present research, considerable evidence has been found that substantiates the presence, in Niagaran time, of a broad shelf in the vicinity of Hamilton. On the basis of the evidence available locally it is not possible to say whether this shelf is discontinuous with the Cincinnati axis, or is merely an extended bifurcation of the axis proper, or represents a submarine deltaic deposit.

## RESEARCH

### The Gasport Dolomite

The Gasport unit was named by Kindle (1913) from exposures at Gasport and Lockport, New York. Here it is represented by a nine-foot bed of coarse, pure, semicrystalline, crinoidal limestone. According to him (p.7 ):

> Westward from Lockport the limestone becomes gradually more magnesian. The section on the Canadian side at Niagara Falls shows seven feet of hard grey subcrystalline crinoidal limestone, sharply differentiated from the saccharoidal dolomite above, and clearly the equivalent of the Gasport member at Lockport, although it is dolomite throughout.

Within the map area the Gasport is represented by beds of fine grained, crinoidal, crystalline dolomite which outcrops along the face of the escarpment. Farther north, according to M. Y. Williams (1919, p.59 ) "the term Gasport does not seem applicable as crinoid columnals occur throughout the 70 feet of dolomite at Kelso, and elsewhere crinoidal zones occur at different horizons in the Lockport." The southern extremity of the Gasport dolomite has not been ascertained but no Gasport was identified in drill core from Simcoe, Ontario, located thirty miles south of Hamilton (Fig. 3).

### Thickness

The thickness of the Gasport varies considerably throughout the region, but as M. Y. Williams (1919, p. 59) states:

> A member which is differentiated only by the presence of crinoidal characters will vary much in thickness from place to place.

TABLE 2 THICKNESS MEASUREMENTS

| | *Sy | Webster | | | | Ancaster | | | | Clapp | | | | Jolley Cut | | | | Albion | | | | Hwy.20 | | | | St.Ck. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | W | B | A | S | W | B | A | S | W | B | A | S | W | B | A | S | W | B | A | S | W | B | A | S | W | B | A | S |
| Gasport | 16 | | | 15 | 13 | 15 | 13 | xJ | 14 | | 10 | 11 | 11 | 6 | 8 | 9 | 8 | | 7 | | 6 | | 4 | 5 | 5 | 6 | 7 | 7 | 6 |
| DeCew | | | | 4 | 4 | | 6 | | | | | 2 | 2 | 3 | D | 9 | 9 | | 6 | D | 12 | Dx | 4 | 16 J | 16 | 3 | 8 | D 8 | 13 |
| Rochester | | | | 7 | 8 | 15 | 9 | | 15 | | 3 | 2 | 2 | 15 | 14 | 7 | 7 | | 24 | | | | 25 | 16 | 16 | 26 | 12 | 14 | 14 |
| Irond. | | | | 8 | 8 | 4 | 5 | | 5 | | 7 | 11 | 11 | 4 | 4 | 5 | 5 | | 4 | | | | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| Total | | | | 34 | 33 | 34 | 33 | | 34 | | 20 | 26 | 26 | 28 | 26 | 30 | 29 | | 41 | | 18 | | 38 | 42 | 42 | 39 | 31 | 35 | 37 |

W. - H. Y. Williams
B. - T. E. Bolton
A. - H. S. Armstrong
S. - E. S. Spurgeon

* Sydenham Road Cut
— prominent limonite stained shale band
— minor reddish shale band
J jarosite
D disturbed bedding
x cross bedding

It has been the writer's experience that even locally there are significant differences in the thickness of Gasport sediments. The reasons for these differences will be dealt with later. Within the area the thickness varies from a minimum of five feet at Highway 20, to a maximum of sixteen feet along the Sydenham road cut (Table 2). A glance at the different measurements by various workers indicates that field determination of its contacts is difficult, and in part subjective.

## Lower Contact

At its type section in Gasport, New York, the contact between the crinoidal limestone and the underlying argillaceous limestone is quite sharp. In the vicinity of Hamilton, Ontario, the Gasport has a wavy contact with the underlying DeCew formation (Rochester at Ancaster). The generally massive, resistant Gasport stands out in contrast to the less resistant and thin-bedded, blocky weathering DeCew limestone. This is especially evident at Webster Falls, Ancaster, and along the Sydenham road cut. Six inches of intraformational conglomerate are present at the contact at Clappison Cut, Highway 20, Jolley Cut, and Ancaster.

## Upper Contact

The main reason for the disagreement about the thickness of Gasport sediments is the difficulty of accurately placing the upper limit. The contact is gradational. Following Caley's suggestion (1940) it has been placed at the level at which chert nodules which define the overlying Ancaster beds become a dominant factor in the lithology. Where these beds are absent, it is more difficult to limit the Gasport, and the crinoidal character and thick bedding must be relied upon.

Unfortunately, the crinoidal nature is often poorly exhibited in the upper portion of the Gasport, and scattered chert nodules may occur well below the upper contact.

## Sampling Procedure

Sampling was undertaken with a view to providing information on both lateral and vertical variations in lithology. Separate suites of specimens were therefore collected at each outcrop. A sampling interval of five inches was used and vertical sampling was extended for one foot into overlying and underlying formations.

## Rank of the Gasport

The Gasport dolomite is defined by its crystalline texture and crinoidal character. Its field identification is dependent on this lithology and on its position between the overlying chert beds and underlying argillaceous limestones.

On the basis of the definition that a formation is a mappable unit the Geological Society of America's Committee on Silurian Correlation has elevated the Gasport to formational rank. However Williams, Caley and Bolton described the Gasport as only a member, - a designation with which the writer is in complete agreement.

As pointed out, the main criterion for field identification of the Gasport is its abundance of crinoids, and consequently from one point of view the Gasport essentially represents a biostratigraphic unit. Ashley et al (1933) pointed out that a unit distinguishable from enclosing rocks only by its fossils should not in general constitute a formation, but should be classified as a paleontologic zone. However, if the fossils are plentiful enough to constitute an important element of the lithology such a restriction need not necessarily apply.

It appears that during Gasport time conditions favourable to crinoidal growth (and accumulation of their debris) were essentially continuous over the area covered by the present study. The contemporaneous deposition of crinoids has produced locally a mappable unit. But the Gasport beds exposed along the escarpment, down dip to the southwest lose their identity, so that crinoids occur in zones throughout the whole of the Lockport formation.

Since the Gasport dolomite is mappable over only a relatively short distance, it should be considered a member as defined by Ashley: "A specially developed part of a varied formation."

## Lithology

### Composition

Binocular microscope examination and thin section study shows that about 90% of the Gasport is dolomite. The commonest accessory minerals are: calcite, quartz, chalcedony, pyrite, limonite, and clay minerals. The mineral estimates in table 3 were arrived at by comparing the thin sections with percentage estimation charts as devised by Folk (1951).

The rock is very homogeneous, the only exception being a slight increase in argillaceous content and the presence of glauconite in the upper beds. This association is quite reasonable as there is evidence that glauconite may form during diagenesis from clay minerals (Hendricks and Ross, 1941).

### Colour

The colours of the rocks were determined by means of the Rock Color Chart (Goldman and Merwin, 1928). Samples taken from different stratigraphic levels at each locality were examined, and the wet colour

TABLE 3

**Composition**

Stoney Creek Falls

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite | 90 | | 88 | 87 | | 93 | 95 | 96 | 96 | 97 | 96 | 96 | 96 |
| Calcite | 5 | | 10 | 10 | | 5 | 2 | 2 | 2 | 1 | 2 | 2 | 2 |
| Quartz | 1 | Stained | ½ | ½ | Stained | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Chalcedony | 1 | | | 1½ | | | | | | | | | |
| Pyrite | 1½ | Limonite | 1½ | 1 | Limonite | 1 | 2 | 1 | 1 | | 1 | 1 | 1 |
| Galena | 1½ | | | | | | | | | 1 | | | |
| Argillaceous Material | + | + | + | + | | + | + | ++ | ++ | ++ | + | + | ++ |
| Glauconite | | | | | | | | | | + | | | + |

# Samples 2 to 8, are from disturbed beds

Highway 20

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite | 97 | | 97 | 97 | 95 | 97 | 96 | 97 | 95 | 96 | 94 | 96 | |
| Calcite | 1 | | 1 | 1 | 3 | 1 | 2 | 1 | 3 | 2 | 3 | 2 | |
| Quartz | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Stained |
| Chalcedony | | | | | | | | | | | | | |
| Pyrite | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Argillaceous Material | + | + | + | + | + | + | + | + | ++ | ++ | 1 | + | Limonite |
| Glauconite | | | | | | | | | + | | + | + | |

of their fresh surfaces recorded. The average colour, greyish-green, corresponds to the code number $35^{0-5}$.

The value (lightness) of the colour was found to be more useful for comparing the dolomite than the hue or chroma (saturation). On fresh wet surfaces the value ranges from "j to d" (increased whitening indicated by letters "a - g"; increased blackening indicated by letters "h - n").

The greyish-green colour of the surfaces of freshly broken hand-samples is probably due to illite clay minerals present in the dolomite.

While these surfaces show only a small value differential, weathered surfaces exhibit a striking colour contrast, changing from a greyish-green in the lower beds, to a buff colour in the upper beds.

Thin section study and binocular examination reveals a very slight upward increase in argillaceous content. The clay mineral has been identified by X-ray diffraction methods as illite. It is thought that the presence of illite resulted in a slight increase in iron content in the upper beds and on weathering the iron has been oxidized.

The degree of facility in recognizing this colour change in weathered surfaces is a function of the freshness of the exposure. The colour change is easily recognized in fresher sections, but much less noticeable in older excavations.

Colours of Fresh Rock Surfaces

| | Sample | Code No. |
|---|---|---|
| Ancaster: | | |
| | 12' above base | $35^{b-5}$ |
| | 9' " " | $35^{d-5}$ |
| | 7' " " | $35^{b-5}$ |
| | 2' " " | $35^{j-5}$ |

| | | |
|---|---|---|
| Highway 20: | | |
| | 30" above base | 35 b-5 |
| | 10" " " | 35 0-5 |
| Clappison Cut: | | |
| | 10' above base | 35 j-5 |
| | 7' " " | 35 b-5 |
| | 1' " " | 35 b-5 |

Texture

The Gasport dolomite is generally a massive porous phaneric rock which retains much of its original clastic crinoidal appearance especially in its lower part. The crystal size is typically less than 0.1 mm (Paurograined class: 0.1 mm to 0.01 mm). Exceptions to this fine grain size are spherulites of chalcedony, authigenic quartz and replaced crinoidal columnals. In the past some authors have described the Gasport as coarsely crystalline. This misconception arises from the fact that each crinoid ossicle consists of calcite which behaves as part of a single crystal and breaks along cleavage planes.. Consequently a fractured surface of the rock may give the deceptive appearance of a coarsely recrystallized limestone owing to the abundant large and conspicuous cleavage surfaces. While this applies in New York state where the Gasport is a limestone it does not apply locally. Here, dolomitization has destroyed the majority of ossicles and the remaining crinoids, while conspicuous, make up less than five per cent of the total rock.

The interlocking mosaic of dolomite anhedra is made of irregular-shaped closely packed, cloudy crystals. Cementing material is indistinguishable, probably due to the fact that the dolomite cement is in optical continuity with the rhombs. The cloudiness of the crystals may be caused by limonite staining or it may be the result of the replacement of calcite by dolomite.

Occasionally the margins of the dolomite anhedra are clear, representing minor secondary enlargement. Scattered subhedra of larger size (still in fine sand size range) represent recrystallization of smaller anhedra. This process has developed scattered subhedra disseminated through the rock.

The anhedra do not exhibit original clastic forms but appear to have been fitted together by adjustive processes of solution and precipitation. The original shape of the crinoidal fragments is not apparent but probably they were no larger than now. In such a well sorted sediment, it would be reasonable to assume that the fine sand size fragments were deposited with other clastics of comparable sizes.

The porosity decreases upward, so that the rock becomes more dense as it approaches the Ancaster cherty dolomite; outcrop and laboratory examination have shown an analogous increase in argillaceous and a corresponding decrease in crinoidal material.

Whether the present porosity of the Gasport represents primary porosity or has resulted from dolomitization or subsequent groundwater leaching is not evident.

Paragenesis

The sequence of events in a dolomite rock is difficult to reconstruct. Usually the original fabric of such a rock is almost wholly destroyed by dolomitization. The strong idiomorphic character of dolomite makes paragenetic evidence based on textural relationships very difficult to interpret and at the best only suggestive!

But, if this suggestive paragenesis is considered in conjunction with, and modified by what is known concerning the depositional environment, the micro-organisms and authigenic minerals present, and the mode of preservation of macrofossils, then it is possible tentatively to reconstruct the sequence of events.

In order to suggest a paragenesis for the Gasport, several different methods were attempted to show textural relationships.

Etching Tests:

Polished surfaces were etched with hydrochloric and acetic acids of various concentrations, for varying lengths of time. The results of all of these tests were of little value as an extremely fine grained rock such as the Gasport does not appear to lend itself to etching methods.

Staining Methods:

(a) On polished surfaces Lembergs' stain was used to colour the calcite, but the results were confusing due to the porosity of the rock.

(b) On thin sections Lembergs' stain was used with considerable success. It was found that best results were obtained when the slide was immersed in the solution for ten minutes, and excess stain gently washed off with distilled water. Although it was found that the stain had a tendency to crack on drying, this in no way interfered with the results. This tendency can be overcome by a slight modification in the process (Rodgers, 1940).

Two suites of thin sections were studied, (Stoney Creek Falls, Highway 20) and a few sections from other localities. Although the former two localities are very close, it was thought at first, although later disproved, that of the exposures examined these two showed the greatest lithologic dissimilarities.

All thin sections except slides which were badly stained by limonite were treated with Lembergs' stain, which not only aided textural interpretations, but permitted estimation of the percentage of calcite present in each slide.

Staining of the calcite reveals that it may occur either:

(a) As isolated calcite anhedra within the dolomite, or

(b) Interstitially, between dolomite rhombs.

The relationship of the interstitial calcite is not clear; it may have formed either prior to, contemporaneously with, or after the dolomite rhombs.

That dolomitization has occurred is evident. The Gasport was originally crinoidal. Unaltered crinoid ossicles are composed of calcite (Moore, 1938). But these fragments are now composed of dolomite. Furthermore, the rock shows evidence of recrystallization, and the dolomite rhombs are cloudy and contain calcite anhedra. Although it is not clear whether dolomitization occurred soon after deposition of the original crinoidal fragments (possibly together with some biochemical calcite) or much later, the shallow water environment with abundant carbon-dioxide as a result of the prolific plant growth, and stable conditions all favour penecontemporaneous dolomitization (Hatch, Rastall, and Black, 1952).

Free silica occurs within the Gasport as authigenic quartz and chalcedony. Thin sections show both authigenic quartz and dolomite rhombs corroded by chalcedony so that chalcedony is younger than some of the authigenic quartz and dolomite. But the relationship of silicification and dolomitization is not definite. However, many sponge spicules were found in insoluble residues from the Gasport. These spicules originally consisted of opal (Shimer & Shrock, 1942) which is appreciably soluble, especially in alkaline environments (Rankama and Sahama, 1949) and has a marked tendency to dissolve and reprecipitate in crystalline form. Folk and Weaver (1952, p. 508) found:

> --- spacing of the initial centers of crystallization governs whether microcrystalline or chalcedonic quartz will form. Replacement generally favors close spacing, resulting in the formation of microcrystalline quartz. Direct precipitation into cavities favors wide spacing and the formation of bubbly chalcedonic quartz.

Examination of insoluble residues revealed that all fragments of brachiopod valves and corals were replaced by chalcedony, but no crinoid ossicles or plates were seen in thin section, under the binocular microscope or in the outcrops, to be similarily replaced. Several possible explanations for this may be offered:

(1) Dolomitization affected the crinoid plates earlier than other fossils - a process which later silicification could not overcome.

(2) Silicification was selective in action regardless of the time of dolomitization. Small crinoid plates may have provided too little room for nucleation, or, since even large crinoids are rarely ever silicified, perhaps the general rule applies because of some unknown chemical factor.

(3) Silicification may have occurred before dolomitization and subsequently been overcome in part by dolomitization.

It appears that no definite criteria can be set up for establishing a paragenesis between chalcedony and dolomite. Whichever is earlier the idiomorphic tendency of dolomite is dominant. The analysis of such a situation is a matter of judgment. For the following reasons, it is the writer's opinion that chalcedony formed in the late diagenetic stage.

(1) Textural evidence shows that chalcedony is younger than some of the authigenic quartz and dolomite.

(2) The formation of bubbly chalcedonic quartz is favored by direct precipitation into cavities (Folk and Weaver, 1952).

(3) The presence of open cavities necessary for the nucleation of chalcedony is more likely to be found in later stages when the rock is more or less consolidated.

Briefly summarizing this discussion, since no evidence was found that contradicts the widely held view that shallow alkaline waters and stable epicontinental conditions favor penecontemporaneous dolomitization, it is the writer's opinion that the original clastic crinoidal sediment was dolomitized shortly after deposition, while it was still essentially unconsolidated. Silicification may have been initiated prior to dolomitization, but the evidence seems to indicate that the precipitation of chalcedony represents crystallization in a late diagenetic stage.

Crinoidal Character

Generally speaking the Gasport dolomite is easily recognized by its abundant crinoid components which have been identified by Bolton (1955b) as Dimerocrinus occidentale (Hall) and Eucalyptocrinites sp.

Locally the abundance of crinoids exhibits both vertical and lateral variations. As a rule they become fewer toward the top of the Gasport. This reflects a change in the local depositional environment which is borne out by an upward increase in argillaceous content. The presence of glauconite in some of the upper beds shows a change from oxidizing to reducing conditions.

The extent to which the crinoids are fragmented is directly related to the thickness of the Gasport beds. They are least broken where the beds are thickest and become increasingly fragmental as the thickness decreases. The most complete crinoids were observed at the Sydenham road cut.

## Paleontology

Locally, the scarcity of well-preserved fossils in the Gasport beds prevented a detailed paleontological study of its faunal assemblage. However the following fossils were recorded from various outcrops and from insoluble residues. For a more comprehensive treatment of the subject see Bolton (1953b).

| | |
|---|---|
| PORIFERA: | Unidentified hexactinellids. |
| ANTHOZOA: | Enterolasama caliculum (Hall). |
| BRACHIOPODA: | Pentamerids, strophomenids and Atrypa sp. |
| CEPHALOPODA: | One unidentified actinoceroid. |
| CRINOIDEA: | Stem fragments only. |

## Primary Structures

### Disturbed Bedding

Underlying the crinoidal beds at Stoney Creek Falls, Highway 20, Albion Falls and the Jolley Cut is a four-foot zone of disturbed bedding. With the exception of the beds at Stoney Creek Falls this zone has been mapped as part of the DeCew sediments. At Stoney Creek Falls, the zone has been tentatively considered to represent a more argillaceous facies of the Gasport. It has been referred to by Bolton (1953b) as an inter-reef facies.

The zone consists of interbedded dolomite and grey shale. The individual dolomite beds vary from four inches to a foot thick, while individual shale beds average half an inch in thickness. It is characterized by an overlapping series of well-defined, slightly asymmetrical, anticlinal crests and synclinal troughs having amplitudes of approximately six inches and wave lengths of from four to eight feet. Thin interbedded shales pinch and swell between adjacent dolomite beds. The lower contact of this zone is conformable with the underlying sediments. But the lower contact of the overlying crinoidal beds is characterized by an undulating surface.

The length of the waves and their slightly asymmetric form suggests that the disturbed beds represent para-ripples produced over a relatively small area agitated by currents. Twenhofel (1926) points out that the term para-ripple had been introduced by Bucher to describe the large ripples in many limestones. The water must have been deep enough to allow sufficient sediment to be thrown into suspension to cover the ripples when agitation had ceased.

Cross Bedding

Poorly preserved cross bedding is associated with the disturbed beds at Stoney Creek Falls. At Ancaster the basal ten-inch bed of fossiliferous dolomite exhibits well preserved cross bedding.

Intraformational Conglomerate

At the base of the Gasport dolomite at Highway 20, Ancaster, Clappison Cut and the Jolley Cut, an intraformational conglomerate occurs which averages six inches in thickness. The pebbles are mainly composed of argillaceous dolomite, but some shale pebbles also occur. In general the subrounded pebbles vary from 1/4 to one inch in length, with occasional pebbles measuring up to four inches in length. The smaller pebbles measure from 1/4 to 1/2 inch across, while the larger pebbles measure one inch across. The latter appear to be elongated in a north-south direction.

Since the intraformational conglomerate overlies the undulating current rippled lower Gasport contact, it is probable that the fragments were the result of scour action.

Coquinite Structure

At the Jolley Cut the upper three feet of Gasport is separated from the lower, darker blue-grey weathering dolomite by a smooth surface. H. S. Armstrong (1953) noted that at the Jolley Cut several small "reef" structures were developed on this surface. The largest one measures four feet long by nine inches high and can be seen directly opposite the steps at the Jolley Cut.

The structure is characterized by a fairly steep lee slope and a long stoss slope which dips to the south at approximately ten degrees. The knobbly weathering material is a lighter grey in colour than the enclosing dolomite. The structure is composed of siliceous dolomite and contains many disarticulated fossils, especially crinoids.

The shape and content of this structure suggest that it is the result of deposition of current-carried detritus, and might aptly be described as a coquinite: - "a fully cemented mass of mechanically deposited shells or shell fragments" (Rodgers, 1954). Glauconite in the upper beds indicates environmental conditions that would prevent reef growth at this time and place.

## Insoluble Residues

The term "insoluble residue" is used in this paper to describe that portion of a dolomite which remains after digestion with cold, dilute, (1:1) technical hydrochloric acid.

While the Gasport is almost wholly dolomitic it contains minor argillaceous material, pyrite, secondary silica etc. The presence of secondary silica and pyrite makes the Gasport unsuitable for correlation by insoluble residue techniques (J. E. Lamar, 1926). But as pointed out by Singewald and Reed (1935), although isolated residues from dolomitic limestones have little diagnostic value, groups of residues from several beds within a narrow stratigraphic range have distinctive features.

Samples from each section were separated into three size ranges: oversize, sandsize, silt and clay size, and their percentages computed and components identified.

## Preparation and Examination

### Digestion

1. Samples of 5.3 grams each were selected from the original handsamples (5-inch sampling), in order to give a representative sample of the formation.
2. Each sample was placed in a 500 ml. beaker and covered with 20 cc. of cold dilute (1:1) technical hydrochloric acid. After the initial reaction had settled down, excess acid was added to ensure complete digestion.
3. The sample was allowed to stand cold for 24 hours to ensure that digestion was complete.
4. The liquor was then decanted and the residue washed several times.

### Separation

Each sample was subsequently dried and sieved with Tyler Standard Sieves into three grade sizes:

(a) oversize: + 10 mesh : more than 1.981 mm.

(b) sandsize: 10 to 250 mesh : 0.061 to 1.981 mm.

(c) silt and clay size: -250 mesh : less than 0.061 mm.

Some clay sized material was separated from the silt size by the subsidence method, for the identification of clay minerals. (A few cc's of NaOH solution is added to prevent flocculation of the clay. The particles are allowed to settle for 2 minutes in a 6 inch column of water. The material which does not settle is of clay size.) Elutrations were repeated until the water was clear.

The clay size fraction consisted mainly of colloidal silica and clay minerals which included illite, but the relative amounts of each could not be established.

Examination

1. The residues were examined by means of a binocular microscope (10X).
2. For mineral identification, immersion mounts were made under the petrographic microscope.
3. The clay-sized material was identified by X-ray diffraction methods.

Method of Analysis

Mineral grains were counted from representative samples taken from each residue in order to establish their relative abundance.

Petrological Characteristics of Insoluble Residues:

Listed below are the principal constituents found in the residues:

1. Quartz

(i) Euhedral: well formed crystals, prismatic and often terminated, majority clear, few pale brown: authigenic

(ii) Anhedral: clear grains; authigenic

(iii) Aggregates: anhedral to subhedral quartz crystals

(iv) Chalcedony: spherulites or aggregates, surface may be white or black (finely dissiminated pyrite); the most abundant mineral present

(v) Colloidal silica: (X-ray diffraction identification)

2. Chert

Microcrystalline: hard, brittle, white, fine grained material, has a porous appearance

3. Gypsum

Fibrous aggregates: soft white

4. Pyrite

(i) Massive and finely granular, pale brass yellow

(ii) Crystals showing interpenetration twins

5. Sphalerite

Massive, golden brown, vitreous lustre, many cleavage faces

6. Galena

Subhedral cubes, silt size

7. Glauconite

Anhedral grains, soft greenish black (X-ray identification)

8. Celestite

Pale blue tabular mineral

9. Muscovite

Pale brown, hexagonal crystals

10. Clay Minerals

Illite (X-ray identification)

11. Fossil remains

(i) Silicified brachiopod shell fragments

(ii) Silicified corals

(iii) Sponge spicules

(iv) Fragmental porcellanous shell material

## Conclusions

Since the oversize and sandsize fractions consisted mainly of fossils, chert and gypsum, only the silt and clay sized fractions were used in comparing results from different localities. Furthermore, because it was impossible to ensure complete separation of the silt and clay sizes, these were combined into a single fraction.

The relative values for the silt-clay fraction are shown in Table 4 and Fig. 4.

TABLE 4

Insoluble Residues

| Location | % Insoluble Residue | Insoluble Silt-Clay Fraction (% of Rock) |
|---|---|---|
| Stoney Creek Falls | 7.5 | 7.4 |
| Highway 20 | 7.6 | 5.8 |
| Albion Falls | 7.1 | 5.5 |
| Jolley Cut | 8.1 | 5.7 |
| Ancaster Road Cut | 4.0 | 1.8 |
| Sydenham Road Cut | 4.6 | 3.7 |
| Clappison Cut | 1.7 | 1.5 |

## AN OCCURRENCE OF JAROSITE

At Highway 20, unusually rapid erosion in October, 1954, undermined part of the highway revealing the presence of a thin discontinuous yellowish-white band associated with a two-inch limonite-stained shale bed. Subsequent reexamination of other sections showed the presence of this yellowish-white band at Ancaster and Clappison Cut.

Although the associated limonite-stained shale layer was found at other localities deep weathering of the shale made recognition of this yellowish-white band impossible.

X-ray identification of the yellowish-white mineral showed it to be jarosite - an iron potassium sulphate hydrate compound.

JAROSITE $K_2O_3Fe_2O_34SO_3.6H_2O$


Diffraction Pattern

*Analytical Data

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [1]"d" | 5.9 | 5.0 | 3.6 | 3.06 | 2.83 | 2.52 | 2.27 | 1.96 | 1.81 | 1.53 | 1.50 |
| Sample | 5.9 | 5.1 | 3.7 | 3.08 | 2.86 | 2.54 | 2.28 | 1.98 | 1.82 | 1.53 | 1.51 |
| [2]1/1, | 40 | 40 | 40 | 100 | 40 | 60 | 80 | 80 | 80 | 60 | 80 |

Time 12 hours; Iron radiation, manganese filter. Run at 35 KV. and between 7 and 8 ma. Phillips powder camera 114.83 mm. diameter.

* A.S.T.M. - X-ray Diffraction Data - Card No. 2-0602

[1]"d" - planar spacing in amstrong units

[2]1/1, - intensity of lines - maximum recorded as 100

## Field Relations

In cross section (Plate 4) the jarosite consists of:

(a) an upper yellowish-brown (limonite) weathered shale which averages one inch in thickness.

(b) a thin 1/16 inch yellowish-white band of jarosite.

(c) pyritic shale averaging one inch in thickness. In fresh occurrences the pyritic shale is not limonite stained.

Gypsum occurs throughout the two-inch shale band. At Highway 20 the jarosite is underlain by shale (Rochester) although at Clappison Cut it is underlain by argillaceous limestone and at Ancaster it lies between beds of massive fossiliferous dolomite. Table 2, page 11, illustrates the various stratigraphic occurrences of jarosite and the limonite-stained shale layer.

## Origin

According to Winchell, jarosite is a member of the alunite group, often found in association with limonite. It has been suggested that it forms as an intermediate stage in weathering of pyrite to iron hydroxide.

L. I. Briggs (1951) reported occurrences of jarosite in the California Tertiary sediments. Here the formation of jarosite was attributed to the reaction of sulphate-bearing interstitial solutions with glauconite. S. N. Daviess (1946) noted that the jarosite did not occur in deeply buried sediments and concluded that the diagenetic formation of jarosite in Tertiary sediments was a near-surface phenomenon.

A slightly different view is that of B. K. Breshenkov (1946) who cited examples of the formation of jarosite from limonite in oxidation zones of many of the large pyrite deposits in the Urals. Such a mode of formation is made possible by the reversibility of the reaction -

$$Fe_2(SO_4)_3 + mH_2O \rightleftharpoons Fe(OH)_3 + 3H_2SO_4 + nH_2O$$

According to Breshenkov this reaction may be reversible under varying conditions of the groundwater table or a transgressing sea.

In the escarpment the jarosite is associated with limonite. But it is not possible to say whether the jarosite formed intermediate to the formation of or as an alteration of limonite. Again, it is not definite whether the formation of jarosite is the result of diagenesis or of more recent percolating groundwaters.

It is debatable whether this easily recognizable layer was deposited everywhere at the same time. Originally, on the basis of its appearance and stratigraphic position, the band was thought to represent an altered volcanic ash bed. Subsequent investigation along this line was inconclusive. Dr. F. B. VanHouten[1], Princeton University, reported that examination of samples sent to him showed no definite characteristics of the montmorillonite clay minerals but its appearance was suggestive of bentonite. Obviously such an important matter warrants further investigation.

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1. Personal Communication.

## PALEOGEOGRAPHY

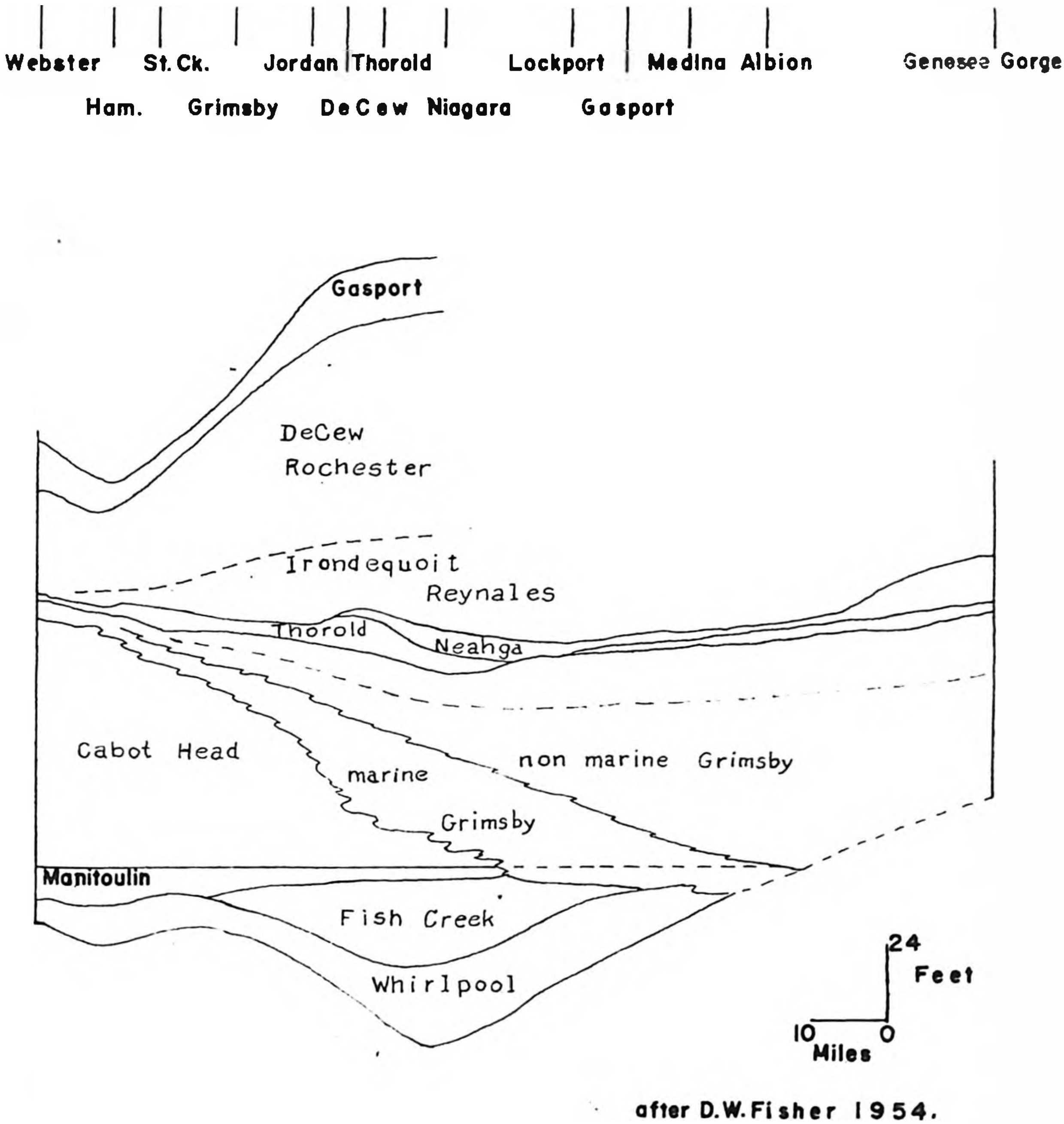
Lithofacies and clastic ratio maps drawn by T. W. Amsden (1955) show that in Early Silurian times the Taconic Orogenic belt was supplying large quantities of clastics to the depositional sites south-east of the area now occupied by Lake Ontario, but in southern Ontario, the sediments represent normal marine deposition.

D. W. Fisher (1954) has shown that the Medinan represents a closing phase of submarine deltaic deposition. By using the Manitoulin dolomite essentially as a time plane, Fisher was able to reconstruct the history of Medinan sedimentation as shown in Fig. 2.

In 1953(a) Bolton stated that the results of his work suggest the presence of a broad shelf extending from Owen Sound to Hamilton which influenced sedimentation especially in Niagarian times, but did not restrict faunal migration (Fig. 3). A period of non-deposition marks Middle Clinton time in the Niagara escarpment (Williams 1919, Caley 1940, Bolton 1953a). In the eastern part of the escarpment the Rochester shale, which was deposited in a regressing sea, thins rapidly westward, and pinches out at Hamilton. It is possible that the Rochester shale represents a subsidiary continuation of the Medinan deltaic deposition.

In effect, while Clinton sedimentation appears to have been initiated on a sea floor with relatively little relief, by the end of Clinton time the area was characterized by a broad shelf (Fig. 3, which sloped toward the south and southwest. Its eastern attitude is not known.

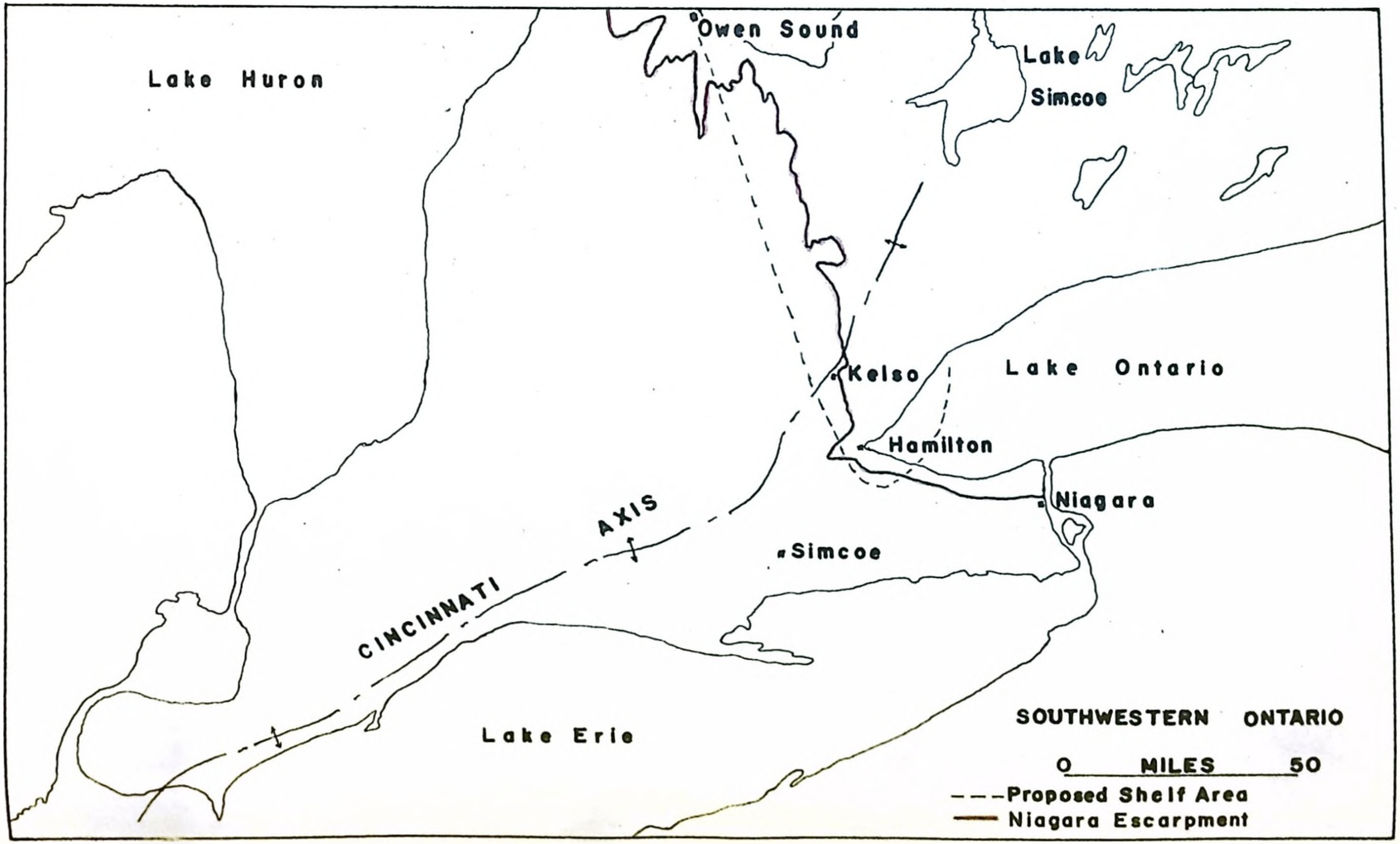
## CROSS SECTION




after D.W. Fisher 1954.

Fig. 2

Fig. 3


Owen Sound
Lake Huron
Lake
Simcoe
Kelso
Lake Ontario
Hamilton
Niagara
CINCINNATI AXIS
Simcoe
Lake Erie
SOUTHWESTERN ONTARIO
0 MILES 50
Proposed Shelf Area
Niagara Escarpment

It was previously stated that the DeCew sediments at Stoney Creek Falls, Highway 20, Albion Falls and the Jolley Cut all exhibit disturbed bedding. A possible exception is at Stoney Creek Falls where the disturbed beds have been tentatively included in the Gasport. Since current bedding is associated with some of the disturbed beds and associated intraformational conglomerates contain subrounded, elongated pebbles, it is suggested that these disturbed beds represent para-ripples formed by current action.

It is interesting to note that the earlier literature does not mention disturbed bedding other than along what would be the margin of the shelf (Fig. 3).

The sediments lying upon the elevated shelf were in a slightly different environment from those off the margin. This change is reflected in several ways. The thinner, shallow-water sediments are characterized by very fragmented crinoids while the crinoids of the thicker marginal deposits are much less broken (Fig. 4). Within the map area the silt-clay fraction of the insoluble residue decreases westward, the higher proportions being found in the thinner beds (Fig. 4). There are two possible explanations:

(1) the eastern part of the map area was closer to the source area.

(2) on the shelf the shallower water was warmer and more alkaline and hence there would be a greater tendency for flocculation of clay particles. Over such a small area it is probable that these points taken together explain this difference in the proportion of silt and clay in the Gasport dolomite.

The Niagara seaway advanced, probably from the southwest. Within the map area the thickest Gasport sediments occur in the west indicating

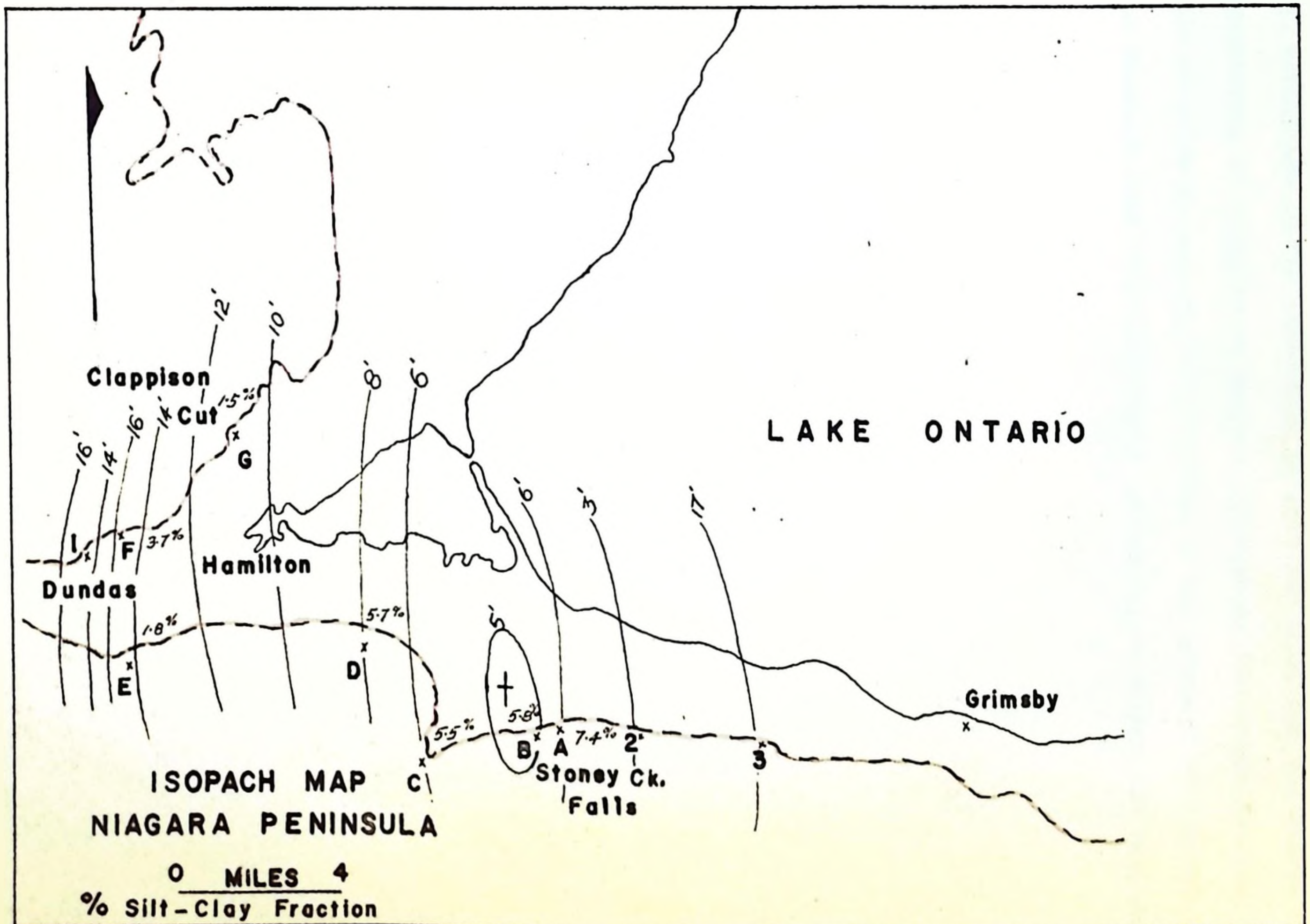

Clappison
Cut
Dundas
Hamilton
LAKE ONTARIO
Grimsby
Stoney Ck.
Falls
A
B
C
D
E
F
G
1
2
3
1·5%
3·7%
1·8%
5·7%
5·5%
5·8%
7·4%
16'
14'
16'
14'
12'
10'
8'
6'
6'
6'
3'
1'
ISOPACH MAP
NIAGARA PENINSULA
0 MILES 4
% Silt-Clay Fraction

Fig. 4

a longer period of deposition (Fig. 4). If the variations in Gasport thickness are considered in conjunction with occurrences of disturbed bedding, variations in the percentage of silt and clay, and the degree of fragmentation of crinoids at various localities, then there is considerable evidence to support Bolton's idea of the presence of a broad shelf in Niagaran time which influenced sedimentation within the region.

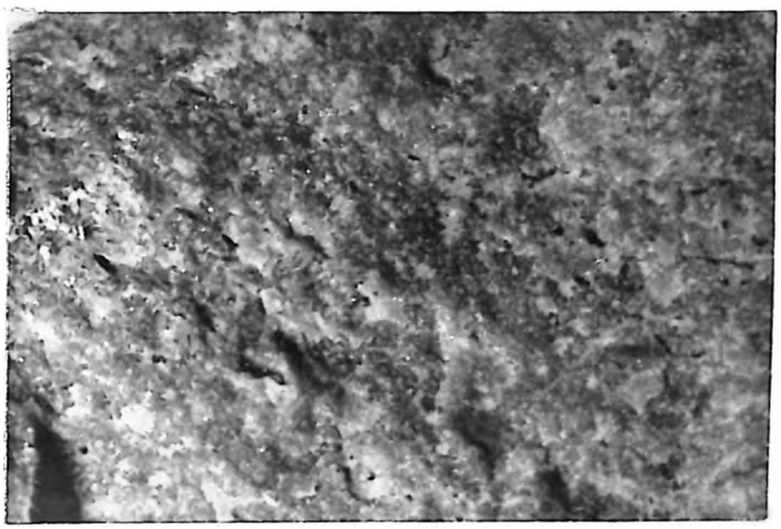
## SUGGESTIONS FOR FURTHER STUDY

Although we seem to have a fairly clear idea of conditions in the Silurian seas, several points warrant further investigation.

(1) The jarosite-bearing band suggests bentonite both in appearance and stratigraphic relations. More detailed analysis and field examination is called for.

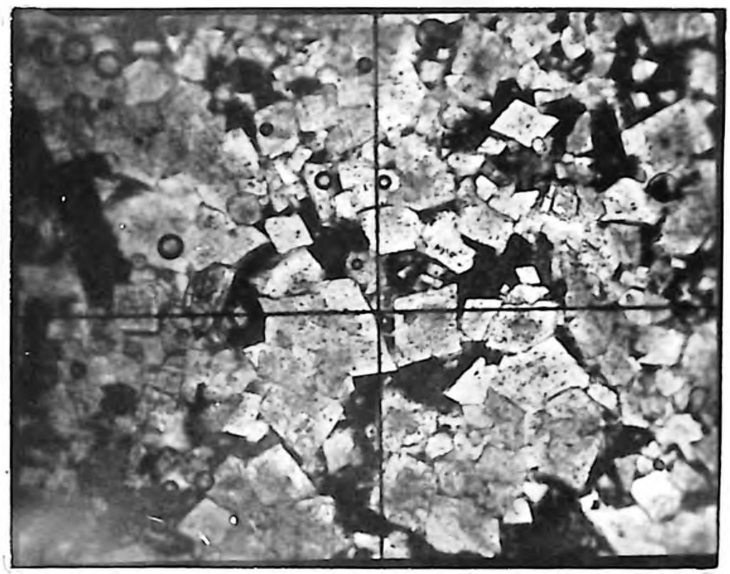
(2) Since the Ancaster chert beds seem to be local, there may be some relation between its presence and the observed variations both in thickness and composition of the Gasport.

PLATE I



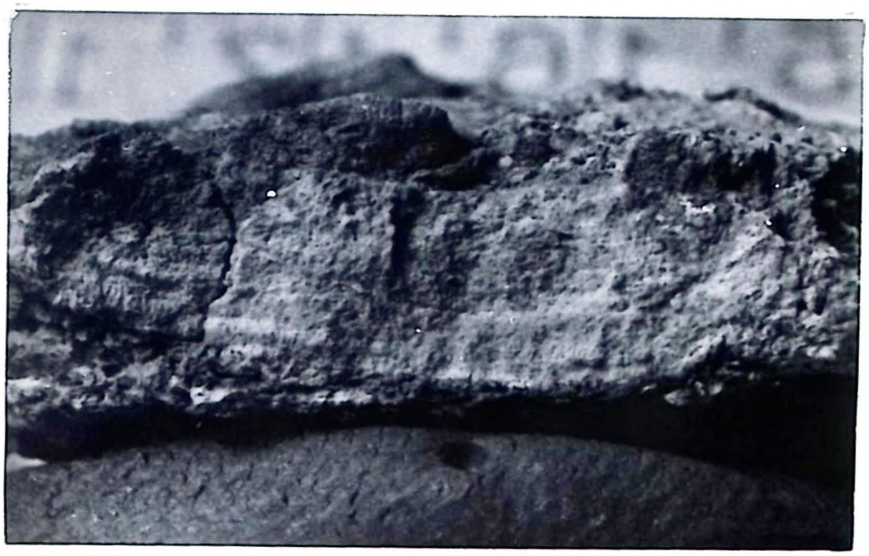
Gasport dolomite from lower beds exhibiting porous texture. The rock has the deceptive appearance of being coarse grained. Mag. x4.

PLATE III



Mosaic of interlocking, cloudy anhedral and euhedral dolomite crystals. Mag. x 80.

PLATE IV



Thin white band of jarosite overlain by limonite stained shale. Mag. x 4.

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# APPENDIX

**Section:** STONEY CREEK FALLS

Gasport Dolomite - 5'7" to 7'

6" - Transition zone of dense, buff-weathering dolomite with a few chert nodules and solutional cavities.

24" - Thick-bedded, buff-weathering, porous dolomite. Zone is characterized by its thick porous beds and lack of shale partings. A few fossils are present in this zone, along with a few scattered chert nodules and solutional cavities.

4' - Flaggy-bedded dolomite (avg. 3") with shale partings (avg. 1"). The bedding planes are very wavy, and the shale partings tend to pinch and swell. The buff-weathering surface has a sandy appearance and is poorly cross-bedded. Fossils are absent. A thin ($\frac{1}{2}$") discontinuous iron-stained shale layer occurs 3'6" above the base. A thin discontinuous band of galena was found one foot above the base. The dolomite has a wavy contact with the underlying DeCew formation.

**Section:** HIGHWAY 20

Gasport Dolomite - 4'8".

11" - Transition zone of dense, buff-weathering dolomite much like the overlying Ancaster beds. A few chert nodules and gypsum-filled solutional cavities are present.

5" - Dense, buff-weathering dolomite containing a few gypsiferous vugs.

16" - Dense, buff-weathering dolomite. The upper 32" of buff-weathered dolomite is sharply separated from the lower beds.

24" - Greenish-grey porous dolomite containing many fossils; crinoid fragments, Enterolasma sp., Atrypa sp. The contact with the underlying, disturbed DeCew beds is undulating and overlain by 5 inches of intraformational conglomerate. The subrounded pebbles are composed of argillaceous dolomite and measure with few exceptions from 1/4 inch to one inch in length and from 1/4 inch to 1/2 inch across.


West side of Highway 20 looking north. Broken lines mark contacts of the massive Gasport beds. Underlying the Gasport is 4 fee of disturbed DeCew beds.

**Section:** ALBION FALLS

Gasport Dolomite - 5'6"

10" - Transition zone of dense, buff-weathering dolomite with a few scattered chert nodules.

20" - Dense, buff-weathering dolomite with minor shale partings.

5" - Porous, buff-weathering, fossiliferous dolomite.

14" - Dense, buff-weathering dolomite. Lower bedding plane is irregular.

17" - Porous, fossiliferous, buff-weathering dolomite. Crinoid fragments, Enterolasma sp. and Atrypa sp. are present. The contact with the underlying DeCew beds is irregular. An occasional 2 inch red clay seam separates the Gasport from the DeCew.

**Section:** JOLLEY CUT

Gasport Dolomite - 8'

13" - Dense, light grey to buff-weathering dolomite with a few isolated chert nodules. At the contact there is a definite indentation of a narrow band of dolomite containing crinoid fragments.

23" - Porous, light grey to buff-weathering dolomite in beds 6 inches to one foot thick. This zone is extremely fossiliferous. The lower contact is sharp. Along this contact several small coquinite structures have been formed. The largest one measures 4 feet long and 9 inches high.

52" - Porous, dark-grey-weathering dolomite in beds 8 inches to 20 inches thick.

8" - Intraformational conglomerate overlying the lower wavy contact.

**Section:** CLAPPISON CUT

Gasport Dolomite - 10'8"

20" - Transition zone of dense, buff-weathering dolomite containing solutional cavities.

4'6" - Massive, porous, crinoidal, light grey to buff-weathering dolomite in beds up to 22 inches thick.

4'6" - Massive, less porous and crinoidal dark grey dolomite in beds up to 24 inches thick in sharp contact with overlying beds. The contact with the underlying beds is irregular and the dolomite contains shale pebbles.

Upper portion of Gasport. Broken line marks contact between lower dark grey weathering dolomite and the upper lighter coloured rocks.

<u>Section:</u> <u>ANCASTER ROAD CUT</u>

Gasport Dolomite - 14'

12" - Transition zone of dense, buff -weathering dolomite containing chert nodules and solutional cavities.

22" - Dense, buff-weathering dolomite containing a few crinoids. Isolated chert nodules and solution cavities occur throughout this bed. Contact with underlying beds is sharp.

10' - Massive, porous, greenish-grey weathering dolomite. Crinoids are more abundant towards the base. A few chert nodules occur at the upper contact of this zone. At the base there is a 6 inch bed of coarse, fossiliferous dolomite containing crinoids, <u>Enterolasma</u> and <u>Atrypa</u> species. The lower contact is irregular, overlying a 19 inch bed of crossbedded dark grey dolomite containing fossils similar to the preceding species. Separating these two beds is a thin (2"), discontinuous, iron-stained shale band, containing jarosite.

<u>Section:</u> <u>SYDENHAM ROAD CUT</u>

Gasport Dolomite - 16'

15" - Trancition zone of dense, buff to grey weathering dolomite containing chert nodules.

8'3" - Massive, porous, bluish-grey-weathering dolomite. Crinoid stems are least fragmented in this outcrop.

6' - Massive, dark-grey, porous, knobby weathering dolomite. The lower contact is wavy.

# INSOLUBLE RESIDUE DATA

## STONEY CREEK FALLS

INSOLUBLE RESIDUE: (for sieve sizes see page 26 )

A. (1) percentage of oversize ............... = nil

(2) " " sandsize ............... = 7.4%

(3) " " silt-clay size ............... = 0.1%

B. PREDOMINANT CONSTITUENTS: Sandsize

Minerals

(1) Chalcedony ......... 50%

(2) Pyrite ......... 20%

(3) Chert ......... 10%

(4) Quartz ......... 15%

(5) Glauconite )

(6) Galena ) ...... 5%

(7) Silicified shale)

Fossil Remains:

(1) Sponge spicules

## HIGHWAY 20

INSOLUBLE RESIDUE:

A. (1) percentage of oversize ............... = 0.6%

(2) " " sandsize ............... = 1.2%

(3) " " silt-clay size ............... = 5.8%

B. PREDOMINANT CONSTITUENTS:

(1) Oversize

Minerals

(1) Quartz

Fossil Remains:

(1) *Enterolosma* sp.

(2) Brachiopod valve fragments

(ii) Sand size

Minerals

| | | | |
|---|---|---|---|
| (1) | Chalcedony | ............ | 55% |
| (2) | Pyrite | ............ | 20% |
| (3) | Chert | ............ | 5% |
| (4) | Quartz | ............ | 10% |
| (5) | Glauconite ) | | |
| (6) | Celestite ) | | |
| (7) | Sphalerite ) | | 10% |
| (8) | Silicified shale) | | |
| (9) | Gypsum ) | | |
| (10) | Galena ) | | |
| (11) | Muscovite ) | | |

Fossil Remains:

(1) Broken sponge spicules

(2) Crinoid columnal- replaced by celestite

ALBION FALLS

INSOLUBLE RESIDUE:

A. (1) percentage of oversize .................. = 0.6%

(2) " " sand .................. = 1.0%

(3) " " silt-clay size .................. = 5.5%

B. PREDOMINANT CONSTITUENTS:

(1) Oversize

Minerals

| | | | |
|---|---|---|---|
| (1) | Chert | .......... | 40% |
| (2) | Chalcedony | .......... | 26% |
| (3) | Quartz | .......... | 7% |
| (4) | Gypsum | .......... | 7% |

Fossil Remains:

(1) crinoid columnal segments - silicified - 20%

(ii) Sandsize

Minerals

(1) Chert .......... 40%

(2) Quartz .......... 25%

(3) Glauconite .......... 20%

(4) Chalcedony .......... 10%

(5) Pyrite )

(6) Gypsum ) .......... 5%

(7) Muscovite )

Fossil Remains:

(1) Sponge spicules

(2) unidentified fragments of porcellanous shell

JOLLEY CUT

INSOLUBLE RESIDUE:

A. (1) percentage of oversize .................... = 0.98%

(2) " " sand size .................... = 1.5%

(3) " " silt-clay size .................... = 5.7%

B. PREDOMINANT CONSTITUENTS:

(i) Oversize

Minerals

(1) Chert

Fossil Remains:

(1) *Enterolasma* sp.

(2) Pentamerid

(ii) Sandsize

Minerals

| | | | |
|---|---|---|---|
| (1) | Chalcedony | .............. | 45% |
| (2) | Quartz | .............. | 25% |
| (3) | Pyrite | .............. | 20% |
| (4) | Chert | .............. | 5% |
| (5) | Glauconite ) | | |
| (6) | Muscovite ) | ............. | 5% |
| (7) | Gypsum ) | | |

Fossil Remains:

(1) Sponge spicules

CLAPPISON CUT

INSOLUBLE RESIDUE:

A. (1) percentage of oversize ...................... = nil

(2) " " sandsize ...................... = 0.2%

(3) " " silt-clay size ..................... = 1.5%

B. PREDOMINANT CONSTITUENTS:

(i) Sandsize

Minerals

| | | | |
|---|---|---|---|
| (1) | Pyrite | ........... | 50% |
| (2) | Chalcedony | ........... | 20% |
| (3) | Quartz | ............ | 20% |
| (4) | Chert | ............ | 8% |
| (5) | Silicified shale | ........ | 1% |
| (6) | Glauconite | ........... | 1% |

Fossil Remains:

(1) Sponge spicules

ANCASTER

INSOLUBLE RESIDUE:

A. (1) percentage of oversize .................. = 0.2%

(2) " " sandsize .................. = 1.9%

(3) " " silt-clay size .................. = 1.8%

B. PREDOMINANT CONSTITUENTS:

(i) Oversize

Minerals

(1) Quartz

(2) Pyrite

Fossil Remains:

(1) Brachiopod valve fragments

(ii) Sandsize

Minerals

(1) Chalcedony ............... 55%

(2) Pyrite .............. 25%

(3) Quartz .............. 10%

(4) Chert .............. 5%

(5) Muscovite .............. 3%

(6) Glauconite .............. 2%

Fossil Remains:

Nil

SYDENHAM ROAD CUT

A. INSOLUBLE RESIDUE:

(1) percentage of oversize ..................... = nil

(2) " " sandsize ..................... = 0.9%

(3) " " silt-clay size .................. = 3.7%