CONODONT BIOFACIES ANALYSIS OF SOME WILDERNESS (MIDDLE ORDOVICIAN) LIMESTONES, OTTAWA VALLEY, ONTARIO.

by

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A thesis submitted

in partial fulfillment of the requirements for the

Degree of Doctor of Philosophy

in the

Department of Geology,

University of Ottawa

Ottawa

Ontario

November, 1964.

"There is no necessary connection between the size of an object and the value of a fact....though the objects I have described are minute, the conclusions to be derived from the facts are great."

H. C. Sorby (1858, p. 497)

"One geologist remarked to me, 'Sure every geologist now agrees in principle that there are facies, but the difficulty is in getting some of these fellows to admit that there are facies in some set of beds on which they are working'."

P. B. King (1949, p. 166)

ABSTRACT

In the Ottawa Valley, the Ottawa Limestone Megagroup can be subdivided into the Black River Group (in ascending order: the Pamelia, Lowville, and Chaumont formations) below and the Trenton Group (Rockland, Hull, Sherman Fall, and Cobourg formations) above. The megagroup is of Middle Ordovician age, lying approximately within the Wilderness and Barnveld ($\simeq$ Trenton) stages.

The Chaumont Formation and adjacent strata were studied in detail for 130 miles along the Ottawa Valley. In the eastern region (Hawkesbury to Ottawa), the Chaumont and lower Rockland formations are characterized by fairly uniform, thick-bedded to massive calcarenites (poorly washed pelmicrites and biopelmicrites). The underlying Lowville is primarily of medium-bedded calcilutites and calcisiltites (micrites and pelmicrites) with a 3-5 ft. Tetradium-bearing unit at the top. In the western region (Ottawa to Pembroke), there is considerably more variation in the Chaumont lithologies - most of the carbonate textural spectrum being represented. In particular, interbedded micrites and pelmicrites (typical of the Lowville) indicate that three minor regressions occurred within the overall transgression during Chaumont deposition in this region. The final minor transgressive phase is characterized by a (lower Rockland) succession of medium- to thick-bedded, frequently cross-stratified, coarse calcarenites and calcirudites (intrasparudites and biosparudites), some 50 ft. thick in the west and wedging out eastwards just west of Ottawa.

The Black River Group and lower Rockland Formation are closely analogous to most modern shallow bank carbonate sediments in facies distribution, grain-types, sedimentary features, fauna, and energy regimes. The Pamelia and Lowville formations are regarded as originating as shallow-water, restricted, lagoonal sediments with the Chaumont representing a more open bank environment in a slightly higher energy regime. The lower Rockland calcirudites are considered to have been local, moderate to high energy, shoal banks. All four formations are thought to be essentially lateral facies equivalents of each other and hence on a regional scale diachronous.

The Chaumont and adjacent strata were closely sampled at 25 localities and the conodont fauna obtained from the three westernmost sections is systematically described. Of the 63 species representing 23 genera described, 10 species and one genus are new - all Neurodontiformes. The fauna does not change significantly in generic composition laterally within the Ottawa Valley, although the Chaumont fauna from the type area (Watertown, New York State) is rather impoverished.

In the eastern region, a marked vertical faunal change occurs approximately at the arbitrary Chaumont-Rockland boundary and becomes stratigraphically lower eastwards (with respect to the Lowville-Chaumont contact). The higher (Rockland) fauna occurs at only one locality (at Pakenham) in the western region. Here, the faunal change occurs in the Chaumont, only a few feet above the Lowville-Chaumont boundary; and deposition on the flanks of a now-buried Precambrian monadnock is postulated. In each case, markedly diachronous lithofacies are indicated.

The Chaumont conodont fauna, compared to other Middle and Upper Ordovician faunas, is of North American midcontinental aspect, related to the faunas of the eastern faunal subprovince, and closest to the

Plattin Formation conodonts of Missouri. It is placed within the known evolutionary sequence of Middle and Upper Ordovician conodont faunas.

The provincialism and subprovincialism of the Middle and Upper Ordovician conodont faunas appear to be a reflection of climatic control, faunal migrations being initiated by shifts of climatic belts. A biofacies analysis of the westernmost faunal collections indicates that paleoecological controls were dominant in producing differences in populations from area-to-area and sample-to-sample (microfacies-to-microfacies). Post-mortem effects on conodont redistribution are found to be insignificant with currents weaker than those in the upper lower-flow regime. The most favoured habitat of the conodont-bearing organism is described; evidence is against a burrowing mode of life. High salinities, associated with relatively high temperatures and poor circulation, are shown to be detrimental to the conodont-bearing organism, producing low populations of poor variety which were, at times, possibly dwarfed. In the environments studied, these seem to be the only conditions which greatly affected the generic composition of the assemblages.

Seven distinct groups of phosphatic _incertae sedis_ are systematically described, most seemingly for the first time, and their significance discussed; some may have close biological affinities to conodonts. A partial biofacies analysis also shows that most of these groups have the same preferred habitats as conodonts.

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Purpose and scope

This is a study of the conodont faunas of a formation in the Ottawa Limestone Magagroup with particular attention given to the faunal variations, and with special reference to conodont paleoecology.

The Chaumont Formation was chosen, because it is fairly thin (25-35 ft.) over an extensive area and laterally traceable. Prior to the selection of this formation, spot samples from most of the other formations within the megagroup were used to check conodont yields and some stratigraphic problems were discussed with Dr. B. A. Liberty, Geological Survey of Canada. The formation was studied over about 130 miles between Hawkesbury and Pembroke in the Ottawa Valley (see fig. 1). More than 250 samples (av. weight: 4 lbs.) from 25 stratigraphic sections were used in the study.

The conodont fauna from the three western localities is systematically described and the faunas of the other sampled areas compared with it. Both the paleontologic and stratigraphic significance of the fauna are considered in detail. A biofacies analysis of the fauna reveals the factors involved in the lateral and vertical distribution of the conodonts. Prime consideration is given to the paleoecological and post-mortem criteria affecting the conodonts and the conodont-bearing organism.

In order to elucidate the environments of deposition, and hence conodont habitats, a detailed field description was made for each section, enabling the facies pattern to be determined. The environments suggested by these facies are further investigated with a petrographic study of the

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During the course of the conodont investigation, a variety of phosphatic incertae sedis was encountered. Because they appear to have possible biological affinities to conodonts, they are also systematically described and a partial biofacies analysis attempted.

The study has discovered a number of paleoecological controls upon the conodonts. Very little is known about conodont paleoecology and this knowledge must be forthcoming to evaluate properly their role as index fossils. The faunal description has contributed to knowledge of conodont faunal sequences in the Ordovician, which will ultimately allow a zonal scheme to be erected. Further extension of the systematic paleontology is planned in the near future.

Previous research

The stratigraphic sequence and faunas of the Ottawa Limestone are described by Wilson (1946a, 1946b, 1946c, 1947, 1948, 1951, 1956a, 1956b, 1961), Fritz (1957), and in the Ottawa-Bonnechere graben (Fourth Chute - Pembroke area) by Kay (1942). In particular, Wilson (1946a) includes a useful history of earlier research and bibliography. All formations within the megagroup have previously been regarded as essentially chronostratigraphic units. No recognition of lateral facies changes has been made, nor any interpretation of sedimentary environments. Carbonate petrographic studies have not been previously undertaken, and only Uyeno (1963;Hull Formation conodonts) has investigated some of the conodont faunas.

Field work

This study began in September 1961, the field work taking place primarily during the summers of 1962 and 1963, although the close proximity of the area allowed many additional shorter trips. The Black River-Trenton standard sections between Watertown and Ingham Mills, New York, were examined with Mr. T. T. Uyeno, Geological Survey of Canada. Shorter field excursions in S.W.Ontario and the Montreal area allowed further comparison with the stratigraphic correlatives.

A week's visit, in July, 1964, to Ohio State University enabled examination of the Ordovician conodont collections there and extremely valuable discussions with Mr. T.J.M.Schopf, Dr. S.M.Bergström, and Professor W.C.Sweet. Mr. T.T.Uyeno also kindly allowed examination of the Hull conodont collections.

Physiography and structure of the area studied

The ground examined within the Ottawa Valley is relatively flat-lying with low ridges of faulted limestones or Precambrian metamorphic rocks. Most of the region is covered with a markedly variable thickness of glacial deposits, especially lake clays. Further details of these aspects are presented by Chapman and Putnam (1951). Good exposures of the Chaumont are restricted to roadcuts and quarries. The region studied, between Hawkesbury and Pembroke, is well serviced by paved and dirt roads.

The area lies along the northern edge of the Ordovician basin in the Ottawa-St, Lawrence lowlands. It has been affected by extensive faulting and minor flexuring in the Tertiary (?) which produced the Ottawa-Bonnechere graben. Wilson (1946a) and Kay (1942) both present maps of fault patterns and include additional comments.

Acknowledgements

The writer is deeply indebted to Dr. D.L.Dineley, thesis supervisor, for his constant help, advice, and criticism throughout the study. Other members of the staff in the Department of Geology, University of Ottawa, have also contributed their assistance on specific problems.

Many discussions and some field trips with Mr. T.T.Uyeno and Mr. T.J.M.Schopf have also helped in the formulation of some ideas on both stratigraphy and conodonts. Discussions with and advice on conodont problems from Dr. M.Lindström and Dr. S.M.Bergström, Lund University, Sweden, and Professor W.C.Sweet, State University of Ohio, were gratefully appreciated, likewise the stratigraphic discussions with Dr. G.W.Sinclair and Dr. B.A. Liberty, Geological Survey of Canada. The G.S.C., through the late Dr. A.E. Wilson, kindly allowed the writer to examine some of the unpublished field maps of Dr. Wilson of the area between Ottawa and Pembroke. These, with that of Goudge (1938), were helpful in locating Chaumont outcrops in the western region of the Ottawa Valley.

This work could not have been accomplished without the following sources of financial assistance, all of which are most gratefully acknowledged; National Advisory Committee for Research into Geological Sciences grants to Dr. D.L.Dineley, 1961-65; Ontario Graduate Fellowship, 1963-64; a field expenses grant from Shell Oil Company of Canada, 1962.

CHAPTER 2

FIELD AND LABORATORY PROCEDURES

Field procedures

Most of the outcrop area of the Chaumont was examined and the best sections exposed were studied in detail. At each locality, each bed, including the uppermost Lowville and lowermost Rockland units, were described and measured to the nearest inch, excepting the shale inter-beds which were taken to the nearest quarter-inch.

The writer collected selected single samples rather than continuous vertical samples in order to examine the implications of environment upon the conodont assemblages. These being obtained from the uppermost Lowville and lowest Rockland wherever possible and close to these boundaries within the Chaumont, the remainder were secured at about 2-2½ ft. intervals, more or less equally spaced. As many different lithologies as possible were sampled; the study does not require rigid random sampling methods.

Laboratory procedures

a) Treatment of samples and conodonts

All samples were broken into walnut-size fragments, except for a hand-specimen of each. The fragments were then digested in 10%-15% acetic acid (commercial grade); monochloracetic acid was tried over a period of four months, but very little digestion occurred. Because of restricted space, small plastic boxes (12 x 5 x 6 ins.) were used, with an average of eight changes of acid (twice weekly) per sample being required for complete digestion. Acid changes were made with siphons to minimize loss of sediment, yet allowing maximum drainage.

The insoluble residue was wet sieved and the - 20/+140 fraction retained. After drying, the residues were passed through bromoform (sp. gr. 2.8). The light residue was saved and the heavy residue was run through a Franz isodynamic magnetic separator. A setting of 3° forward and side slope with a current of 1.5 amps. was found to give maximum separation without bringing the conodonts into the upper channel. This was faster than assessing the various settings suggested by Dow (1960). In general, the heavy fraction was split by at least half, thus saving time in hand picking. To reduce the possibility of breakage, a paper "slide" was fitted into the lower collecting bucket. Final picking was made on a holed squared tray with a fine sable-hair brush; mounting was with the aid of Tragacanth gum.

The hand-specimens retained from each sample gave a record of the lithologies and allowed thin-sections, acetate peels, and etchings to be made when desired. Thin sections were produced by the department technicians, in particular, those of the Bahaman carbonate sands by Mr. M.J.Jackson.

Those photographs taken in the field were printed by the writer - nearly all from Kodachrome slides. The photomicrographs and the plates of conodonts were also produced by the writer. This was accomplished with a Cooke, Troughton, and Simms Research Polarizing microscope and (pin-hole) bellows camera using Ilford FP3 cut-film. In the conodont photography, a Leitz objective (x3.2) lens was used.

CHAPTER 3

STRATIGRAPHY AND SEDIMENTARY FEATURES

INTRODUCTION

The Ordovician System is represented in the Ottawa Valley by some 2,200 ft. of sediments that have been described by Wilson (1946a) so that only a brief summary need be given here. Table 1 illustrates the sequence of chronostratigraphic and lithostratigraphic units. Lower, Middle and Upper Ordovician Formations are present, but because of periods of non-deposition and erosion, some stages are not represented. Shoreline fluctuations, it is thought, gave rise to many different lithologies, with deposition within several contrasting environments. Nearly all formations, however, seem to have originated in shallow marginal, or epeiric seas with many aspects of sedimentation influenced or controlled by the surrounding positive areas: the Frontenac Axis, Beauharnois Anticline, "Adirondackia", and probably the Shield area directly north of the Ottawa - St. Lawrence lowlands (see figs. 1,3). As a result of marine fluctuations, many formations are solely distinguished as particular lithofacies and are likely to be time-transgressive.

The oldest Ordovician formation is the Nepean Sandstone, generally a clean-washed, well sorted and cemented, orthoquartzite. This is correlated lithostratigraphically with the Upper Cambrian Potsdam Sandstone of New York, but in Ontario it seems more likely to be of Beekmantown age (Kirwan, 1963). These sandstones grade upwards into impure carbonates (mainly dolomites) - the March and Oxford formations. A Beekmantown age is confirmed by the meagre fauna present in the carbonates.

The overlying Aylmer Group, bounded above and below by unconformities, is composed of shales and siltstones with interbedded sandstones,

FIGURE 1: Regional setting of thesis area and location of stratigraphic sections studied in detail.

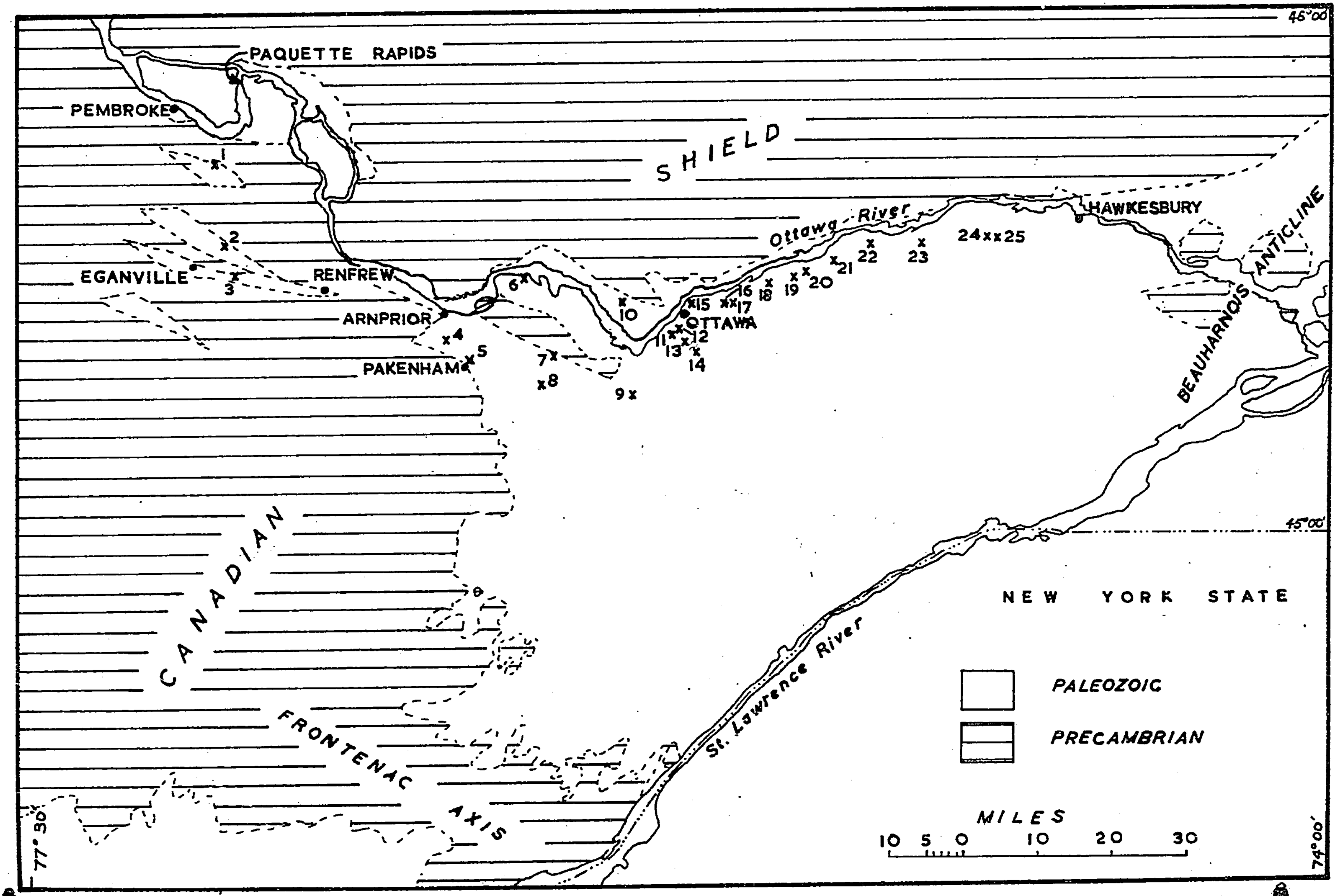
46°00'
PAQUETTE RAPIDS
PEMBROKE
SHIELD
EGANVILLE
RENFREW
ARNPRIOR
PAKENHAM
Ottawa River
OTTAWA
HAWKESBURY
BEAUHARNOIS ANTICLINE
CANADIAN
FRONTENAC AXIS
St. Lawrence River
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FIGURE 1

often of a lensing character, (Rockcliffe Formation); the upper part being predominantly shaly and dolomitic limestones (St. Martin Formation). Hofmann (1963) correlates this group with the Chazy Group of Southern Quebec and discusses the associated problems of chronostratigraphy.

Above the Aylmer lies a continuous sequence of limestones - the Ottawa Limestone Megagroup- which can be divided into seven formations. These grade upwards, via the Eastview Formation, into the fine clastic rocks of the Utica Group and the following Carlsbad, Russel and Queenston formations. Derived from the east and south-east, these fine detrital rocks represent the clastic wedge formed as a consequence of the Taconic Orogeny. Black shales are lowest in this clastic succession followed upward by grey shales with some interbedded dolomitic limestone, and red shales.

With the possible exception of some of the red shales, the local Ordovician strata appear to be of marine origin. No previous detailed sedimentological studies have been conducted on any of the Ordovician formations within the Ottawa Valley and the depositional environments of many remain obscure.

STRATIGRAPHIC NOMENCLATURE -

Most publications concerned with the Ottawa Limestone have been imprecise in their stratigraphic nomenclature and the distinction between lithostratigraphic and biostratigraphic units has been especially vague. Table 1 shows the terminology and classification adopted here. Because of the fluid nature of Ordovician classification, especially with respect to time, some explanations are necessary.

In recent papers on Ordovician chronostratigraphy (e.g. Twenhofel

Series	Subseries	Stage	Megagroup	Group	Formation
Cincinnatian		Richmond			QUEENSTON
					RUSSELL
		Maysville			CARLSBAD
		Eden		UTICA	BILLINGS
					EASTVIEW
Champlainian	Mohawkian	Barnveld	OTTAWA LIMESTONE	TRENTON	COBOURG
					SHERMAN FALL
		Wilderness			HULL
					ROCKLAND
				BLACK RIVER	CHAUMONT
					LOWVILLE
					PAMELIA
	Chazyan				
		Marmor		AYLMER	ST. MARTIN
					ROCKCLIFFE
Canadian		"Beekmantown"			OXFORD
					MARCH
					NEPEAN

TABLE 1

Ordovician chronostratigraphic and lithostratigraphic nomenclature, Ottawa Valley.

et al., 1954; Cooper, 1956; Kay, 1958, 1960; Berry, 1960), differences between the proposed subdivisions are marked. Many other papers on this subject are restricted either stratigraphically or geographically (e.g. Flower, 1957; Fisher, 1962; Templeton and Willman, 1963) and it is clear that the problem is still very much in a state of flux. Thus, the chronostratigraphic units adopted herein are those which appear to be most meaningful to the Ottawa Valley sequence rather than to the Ordovician as a whole. The classifications of Fisher (1962) and Templeton and Willman (1963), developed from work in New York and Illinois respectively, are the most useful in this respect.

The Champlainian is used herein as a series of the Ordovician, with Chazyan and Mohawkian as subseries. The stages proposed by Kay (1958, 1960) seem far too refined for the present methods of time correlation and, hence, those proposed by Cooper (1956) and modified slightly by Fisher (1962) are favoured. Actual placing of these stages within the rock sequence of the Ottawa Valley is beyond the scope of the present study.

Subdivision into lithostratigraphic units is the easier because of the more tangible nature of the criteria. Much argument exists, however, as to the correct status of certain units. Many authors agree to a group status for the Black River and the Trenton so it is logical to refer to the Ottawa Limestone as a megagroup. Swann and Willman (1961) defined the Ottawa Limestone Megagroup; however, the term is at variance with that proposed by the International Subcommission on Stratigraphic Terminology (1960) which recommends the term supergroup. Swann and Willman present cogent reasons for this deviation which is followed here. Their definition (op. cit., p. 478) of the Ottawa Limestone Megagroup is:

"We extend use of the name, in the form of the Ottawa et al., 1954; Cooper, 1956; Kay, 1958, 1960; Berry, 1960), differences between the proposed subdivisions are marked. Many other papers on this subject are restricted either stratigraphically or geographically (e.g. Flower, 1957; Fisher, 1962; Templeton and Willman, 1963) and it is clear that the problem is still very much in a state of flux. Thus, the chronostratigraphic units adopted herein are those which appear to be most meaningful to the Ottawa Valley sequence rather than to the Ordovician as a whole. The classifications of Fisher (1962) and Templeton and Willman (1963), developed from work in New York and Illinois respectively, are the most useful in this respect.

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"We extend use of the name, in the form of the Ottawa

> Limestone Megagroup, to the entire body of Champlainian (Middle Ordovician) carbonates, lying on sandstones, sandy shales, or sandy dolomites usually referred to as the St. Peter, Glenwood, Simpson or Aylmer, and lying beneath shales of Cincinnatian (Upper Ordovician) or of late Champlainian age." That is "...it includes the equivalents of seven formations of Black River and Trenton rocks recognized in New York".

Calvert (1964) has applied the term Ottawa Limestone Supergroup to the Simpson Group carbonates as well as the Black-River - Trenton limestone sequence.

The Chazyan strata are herein termed the Aylmer Group (called the Aylmer Formation by Raymond (1905)). Cooper (1956, p. 17) gives it a formational rank because its component units; the Rockcliffe and St. Martin formations "are partial facies of each other and would be better considered as members of the Aylmer formation". This, however, does not seem to be a valid reason since, for example, many of the higher limestone formations appear to be partial facies of each other, yet are obviously of formational rank and indeed are so credited by Cooper himself. Calling these units the Chazy Group allows confusion with the sub-series term and, moreover, the strata represent only a part of the Chazy Group of Southern Quebec and the type area (Hofmann, 1963) and correlations are uncertain.

The term Black River (Vanuxem, 1842, p. 244) had a variety of meanings and definitions during the latter part of the last, and the first part of the present century. Mainly through the studies of Kay (1929, et seq.) and Young (1943), the Black River Group is now restricted to include the Pamelia, Lowville and Chaumont formations, all being defined from localities in north-west New York State.

Likewise, the Trenton Group has had varied treatment and Kay (1937, p. 237-249) reviews in detail the nomenclatural history of the

Mohawkian components. He (ibid.) defines the Trenton Group as including rocks younger than the Chaumont Formation and older than the Gloucester (Holland Patent). Some disagreement exists as to the position of the top of the Trenton Group. The Utica black shales are lateral facies equivalents of the Cobourg limestones and hence many authors have favoured grouping them together as a single group. In dealing strictly with lithostratigraphic units, it seems advisable to class the distinctive black shale formations as a group and place the top of the Trenton Group at the top of the limestone sequence. This is the logical procedure having defined the top of the megagroup at this level.

Less controversy exists over the units given formational rank. The actual location of boundaries of these formations, however, is often difficult and open to personal interpretation. The Trenton formations are those used by Wilson (1946a). More recent work on the standard New York sections has greatly refined the stratigraphy of the Trenton Group and the formational names of Rockland, Hull, and Sherman Fall have largely been replaced. Until corresponding work is done in this area, it is felt best to adopt these subdivisions herein.

OTTAWA LIMESTONE MEGAGROUP

The present study is primarily confined to certain features of the Chaumont Formation; the writer has, however, spent considerable time examining the other formations of the megagroup in an attempt to understand environments of deposition. In certain cases, groups of formations may be facies equivalents and it is necessary to appreciate the sedimentological features of associated formations. The following part of this chapter will, therefore, be devoted to the main features of each formation.

The thickness of the megagroup is estimated at 690-700 ft. (Wilson 1946a, 1956). A recent bore-hole at Ottawa was cored by the Geological Survey of Canada, under the supervision of Dr. B.A.Liberty. The results, when published, are likely to show discrepancies in the previously published thicknesses, together with a possible stratigraphic revision. Most regrettably, the writer has not been granted permission to examine the core.

The limestones exhibit a variety of facies, of which one tends to dominate a particular formation; thus, it is possible to map formations using gross lithology, but the placing of formational boundaries on purely lithologic grounds, is often arbitrary.

When one is unable to use gross lithology, as at a small exposure, even assignment to one formation can be extremely hazardous. Raymond (1914) initially subdivided the megagroup into biozones (e.g. Prasopora-zone, Dalmanella-zone), but he later adopted only formational names (e.g. Sherman Fall, Rockland). In distinguishing these at Ottawa, Raymond (1913, 1916) relied more on lithological characteristics, with the genera initially cited being merely guide fossils.

Each carbonate facies, it appears, has a particular assemblage of fossils that are environmentally controlled (e.g. Tetradium in the Lowville, Lyopora in the Chaumont, Prasopora in the Sherman Fall). The degree of facies control is often uncertain and the recognition of those forms which are independent of such control is very difficult. In mapping formations, therefore, faunas can be useful for correlation of similar facies but rarely for chronostratigraphy. The faunas, in general, are varied, often abundant, but normally poorly preserved and difficult to extract. Wilson

(1946b, 1946c, 1947, 1948, 1951, 1956, 1961) described much of the paleontology of the megagroup. She believed (1946a, p. 24-25) that the faunal assemblages are largely ecologically controlled with the paleontological limits of the formations being mainly indefinite and only a few fossils having a short time-range.

It would be misleading and over simplified to generalize on the type of carbonates that comprise the Ottawa Limestone. A brief description of the characteristics of each formation will thus follow.

Pamelia Formation

Wilson (1932) divided the Pamelia Formation into two divisions which "are not sharply defined. Both divisions are exceedingly variable" (p. 138). The lower part is characterized by considerable amounts of sandstone and shale together with some thin limestones, locally coarse-textured, and occasional dolomites. The upper Pamelia has a predominance of limestones and dolomites, but also contains some shales and rare sandstones. The limestones are often impure, especially the lower ones and tend to be calcilutites; the dolomites are generally fine grained, thick-bedded, and weather to a rusty colour. Wilson (ibid.) estimates the Pamelia to be somewhat over 69 ft. in thickness. Sedimentary structures are abundant; intraclast conglomerates, mud-cracks, ripple marks and borings are particularly common.

Hofmann (1963, p. 285) believes that "The two phases (of the Pamelia) also contain different faunas (Wilson, 1932a, p. 139-144). The lower one contains obscure pelecypods, gastropods, some ostracods and fragments of a Lingulella (?), all of which are, however, diagnostic of neither the typical Chazy, nor of the typical Black River. The upper

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Wilson (1932) divided the Pamelia Formation into two divisions which "are not sharply defined. Both divisions are exceedingly variable" (p. 138). The lower part is characterized by considerable amounts of sandstone and shale together with some thin limestones, locally coarse-textured, and occasional dolomites. The upper Pamelia has a predominance of limestones and dolomites, but also contains some shales and rare sandstones. The limestones are often impure, especially the lower ones and tend to be calcilutites; the dolomites are generally fine grained, thick-bedded, and weather to a rusty colour. Wilson (<u>ibid.</u>) estimates the Pamelia to be somewhat over 69 ft. in thickness. Sedimentary structures are abundant; intraclast conglomerates, mud-cracks, ripple marks and borings are particularly common.

Hofmann (1963, p. 285) believes that "The two phases (of the Pamelia) also contain different faunas (Wilson, 1932a, p. 139-144). The lower one contains obscure pelecypods, gastropods, some ostracods and fragments of a <u>Lingulella</u> (?), all of which are, however, diagnostic of neither the typical Chazy, nor of the typical Black River. The upper phase contains gastropods, pelecypods, ostracods, fucoids (ichnofossils?), Tetradium and Bathyurus extans (Hall), characteristic of the Black River". The present writer, after an examination of the relevant publications and several sections in the field, but with no detailed faunal study, suggests that the slight difference in faunas is merely a reflection of the change in facies. The lower Pamelia is a near-shore, shallow-water, littoral facies with considerable clastic sediments, indicative of a harsh environment for organisms. However, the upper Pamelia indicates a shallow-water environment further away from shore, with fewer clastics, more carbonates, and probably salinities more favourable to marine faunas. It should be noted that the fossils are only common in the carbonates and these faunas are generally restricted in the variety of species and higher taxa.

The lower boundary of the Pamelia is unconformable to disconformable on the underlying rock; in obscure sections the Chazy is recognised by the presence of species of Camarotoechia. The upper boundary with the Lowville is gradational and arbitrary. Wilson (1932, p. 137) states that:

> "The line between the Lowville and the Pamelia has been placed arbitrarily below the first bed of the fine-grained lithographic limestone which shows Tetradium producing the "birdseye" effect characteristic of the Lowville".

Exposures of the Pamelia are scarce and mostly incomplete. Wilson (1932) described a few measured sections. The upper beds are quarried in the deeper excavations into the Lowville and Chaumont and can be seen at localities 11, 14, and 16 (see Appendix for details of location of all exposures listed in the text).

Lowville Formation

This formation is composed predominantly of pure calcilutites, normally with less than 10% allochems but commonly containing large, little broken, but clearly transported shells, mainly molluscs and brachiopods, together with the primitive coral Tetradium. Even in the very fossiliferous beds, the carbonate matrix is only rarely coarser than very finely crystalline. Oölites are rare, but have been observed in some localities, usually restricted to a few feet of beds; no oölitic beds have been observed elsewhere in the Ottawa Limestone. Many of the silt-sized carbonates are undoubtedly pelletal, but no study of the Lowville limestones has been undertaken to assess the importance of this sediment-type.

The beds are generally in the range of 4-10 ins. in thickness, but are not uncommonly up to 2 ft. thick and are often separated by thin (¼ in.) shale partings. Wilson (1956) gives a total thickness for the formation of some 25 ft.

Mud-cracks, ripple marks and intraclast conglomerates are frequently observed within the Lowville, but there is an obvious decrease in their number from the Pamelia, through the Lowville, into the Chaumont. Borings are frequently observed, but markedly less abundant than in the adjacent formations.

The faunas of the Lowville in New York and S.W.Ontario have been reviewed by Young (1943, p. 237-238); the Ottawa Valley faunas appear to be similar. In general they are concentrated in specific beds alternating with barren calcilutites. As stated previously most of the fossils are obviously transported and exhibit minor degrees of breakage, but are not well preserved and are difficult to extract. The assemblages are much more varied than those of the Pamelia and individuals more numerous. In practice, collecting yields only a few species for each major taxon and the faunas were restricted to a certain degree and the presence of many forms was broken, but clearly transported shells, mainly molluscs and brachiopods, together with the primitive coral Tetradium. Even in the very fossiliferous beds, the carbonate matrix is only rarely coarser than very finely crystalline. Oölites are rare, but have been observed in some localities, usually restricted to a few feet of beds; no oölitic beds have been observed elsewhere in the Ottawa Limestone. Many of the silt-sized carbonates are undoubtedly pelletal, but no study of the Lowville limestones has been undertaken to assess the importance of this sediment-type.

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The Lowville Formation is best seen in the many quarries of the region (e.g. localities 9,11,14,16 and 21); natural outcrops are rare and small. Its upper boundary in the Ottawa Valley is herein drawn at the top of a 2-5 ft. series of beds with profuse Tetradium (mainly T. cellulosum). At this level there is a change from the thinner-bedded calcilutites to the thicker-bedded calcarenites.

CHAUMONT FORMATION

This formation will be described in detail later in this chapter. In its typical development at Ottawa, it consists of 25 ft. of medium grey, thick-bedded fine to coarse calcarenites. Beds are generally 1-3 ft. in thickness and separated by shaly partings. Normally the carbonates are of finer grade in the lower 5 ft. or so and hence tend to be somewhat gradational from the Lowville calcilutites. Fossils are plentiful, mainly poorly preserved and difficult to extract; fossil debris is generally distributed uniformly throughout any particular bed and averages 15%-40% of the total volume. Occasionally, the debris is concentrated in small patches or pockets where the biogenic content averages 30%-60% - often in close association with irregular intrabed shale laminae. Only rarely in the eastern region do thin (2-6 ins.) beds of laminated (sometimes with low-angle cross-laminations) calcarenitic spreads occur.

The Chaumont fauna has been described in general by Young (1943) and more specifically in the Ottawa Valley in part by Kay (1942), by Sinclair (1954) and by Wilson. Compared to the Lowville, the fauna is more varied with many phyla represented and generally with quite large populations. It is clear that life in this environment was fairly prolific, but the preserved skeletal remains have been subjected to some transportation and damage. Since extensive movement is not suggested, it is possible that much of the breakage and fragmentation was caused by the action of organisms. Destructive activity by organisms is further indicated since a) the rate of deposition, and thus burial, appears to have been relatively slow (i.e. if analogous to similar modern sediments), b) there is ample fossil evidence of flourishing benthonic and nectonic life, c) borings, especially in the lower part of the Chaumont, indicate burrowing, substrate-reworking organisms which caused minor disruptions of the internal bedding.

The boundary with the Rockland is arbitrary and in gross lithology the two formations are in most respects identical near Ottawa. Marked lithologic differences occur further up the Ottawa Valley however. Because the Chaumont can be readily recognized there, and also in other areas e.g. New York, the writer does not feel justified in proposing new names or in grouping the Chaumont and Rockland together as a new formation. Exposures are numerous in the Ottawa Valley, this formation being favoured as road-metal and local inferior building stone. The Chaumont, because of its thick beds overlying the thinner bedded and more shaly Lowville, often forms a scarp in the tilted fault blocks, and is commonly exposed in road cuts.

Rockland Formation

To repeat, The Rockland Formation, as noted above, is basically like the Chaumont in gross lithology: medium grey, thick-bedded, fine to coarse calcarenites. Beds are 1-3 ft. thick, again separated by shale partings, which in places may thicken into definite shale or shaly limestone interbeds, generally less than 9 ins. thick. There are rather more of the thin (2-8 ins.) microbedded calcarenitic spreads in the Rockland, but these are of uncertain value in stratigraphic correlation. Possibly they reflect periods of excessive shoaling in the Carp - Pembroke area with extensive transportation of the finer material out from the shoal region. If so, such beds could represent useful marker horizons. The few observed in the Chaumont, however, did not appear to be extensive. The alternative explanation is that these beds represent local increased current activity. These beds are generally of uniform lithology and thickness when exposed, but a few lens out, clearly representing shallow channel deposits. Both the above mechanisms could also operate simultaneously. In many localities the Rockland unit appears slightly more massive and the limestones not quite so argillaceous and often slightly darker grey in colour than the Chaumont units. These very minor differences in places enable one to draw an arbitrary boundary with the Chaumont only in extensive exposures, Hence, in Wilson's paleontological papers, most fossils are only listed as from the "Leray-Rockland beds".

The thickness of the Rockland is generally estimated at some 65 ft. About 40 ft. are exposed at the type section (Stewart Quarry, Rockland; locality 21). The writer agrees with Uyeno (1963, p. 223-230) that the boundary with the overlying Hull Formation can be seen in a small quarry, 1/3 mi. north of the Little Chaudiere Rapids, Hull. Here, the lowest 10 ft. or so of thick-bedded medium calcarenites, bearing Receptaculites, grade rapidly into typical lower Hull. Upper Hull and the lowest Sherman

Fall beds also outcrop close to the quarry. (August, 1964: this quarry is now virtually filled in).

Exposures of the Rockland are generally poor and rarely extensive vertically. The facies variations within the Rockland will be considered later with those of the Chaumont.

Hull Formation

There are two distinct lithostratigraphic units within the Hull Formation which are presumably of member rank, but which will be referred to informally as lower and upper Hull. The very sharp break between these is well exposed in a quarry on the east side of St. Laurent Boulevard, 400 yds. north of Montreal Road, Ottawa. This boundary is also considered to be present in the Canada Cement Co. Quarry (Plant No. 3), Hull. Here, the units are exposed and are, in fact, quarried separately; they conform to the general lithologic descriptions given below. It should be noted that Raymond (1913) referred to two biozones within the Hull - the Crinoid beds below and the Tetradium beds above. Shortly after their introduction, these names were discarded by Raymond (1916), but he still recognized two divisions based on a combination of lithostratigraphic and paleontologic criteria. However, the divisions do not equate with those presented here and the boundary between the biozones lies within the upper Hull.

The lower Hull is characteristically dark-grey, sometimes bluish, fine to coarse crystalline, medium calcarenites, often exhibiting laminations, which are commonly cross-stratified. The beds are thin (averaging 3-7 ins.) and generally with smooth but irregular surfaces, separated by shale partings or very thin shale interbeds. Rarely, platy lumps of dark grey to black chert occur in the lower Hull. Some 50 ft. of such strata are exposed in the lower half of the Canada Cement Co. Quarry, Hull. Fossil debris is usually not clearly visible, but the rather argillaceous upper surfaces of beds often reveal well preserved macrofossils. Except in quarries near Ottawa, the lower Hull is rarely exposed and no new information can be offered concerning its lateral extent or facies change.

The upper Hull is typically composed of coarse calcarenites to medium calcirudites: massive to thick-bedded (9 ins. to 4 ft.) medium light grey, often slightly brown grey, and coarse to extremely coarsely crystalline. Some beds, especially when weathered, show large scale cross-stratification. Very thin (less than ¼ in.), dark, presumably argillaceous laminae within the beds are valuable in determining the internal sedimentary structures. Very little shale is present in the upper Hull and only minor shale partings and stylolites occur. Dark grey and black chert is very common, mostly in lenticular plates, and it is far more plentiful than in the lower Hull. Some large slump and "balled-up" structures occur in one 3 ft. bed in the Canada Cement Co. Quarry, Hull. The individual beds, where exposed in quarries, are fairly regular in thickness. Fossil debris is common to abundant and many beds are richly bioclastic, with considerable amounts of algal material. Macrofossils are rarely well-preserved although some excellent echinoderms have been collected from the thin shaly partings (Sinclair, 1954). The thickness of the upper Hull is in the order of 60-80 ft. Exposures are plentiful because of its usefulness as a building stone and for cement. When traced laterally, the same lithology is encounted at Bertrand et Frère Construction Co. Quarry, near Hawkesbury (see Hewitt, 1960, p. 80 for exact location) and in the Montreal area (Clark, 1952). Kay (1942) describes the Hull in the upper Ottawa Valley where differences in lithology are apparent: the beds are still coarse textured, but thinner and partially dolomitized.

The boundary between the Hull and Sherman Fall is fairly sharp, although the coarse bioclastic beds of upper Hull type persist into the lower few feet of the Sherman Fall. These lower few feet also contain abundant *Prasopora* which can be a useful guide fossil, although it is also abundant in the shaly limestones of the Rockland.

Sherman Fall Formation

Exposures of the Sherman Fall Formation are scarce in the Ottawa Valley, for although the lower few feet are revealed at several localities in the Ottawa area, most of the formation is concealed. However, the Clarence Township Quarry, 3 miles east of Sarsfield (20 miles east of Ottawa) is cut into Sherman Fall strata. Wilson (1940, Map 587A, Casselman, 1: 126,720) mapped the area as Sherman Fall and as the rocks bear little similarity to either the Hull or Cobourg, as exposed at Ottawa, this quarry appears to be one of the few good exposures of Sherman Fall in the Ottawa Valley. The lithologies here also correspond closely to the general descriptions of this formation given in the earlier literature.

The strata are thin (2-9 ins.) and very variable in both carbonate type and bed morphology. Many are basically calcilutitic, but with considerable fossil debris enclosed, whilst others are coarsely crystalline, coarse calcarenites to fine calcirudites, with a higher biogenic content. These are the two most common lithologies, but others occur in minor proportions. Shaly partings are very frequent, although actual thin shale beds are rare. On weathered surfaces the cross-stratification of many beds is etched out and there is a great variety of sedimentary structures e.g. discontinuity surfaces (Jaanusson, 1961) are particularly common. Macrofossils are fairly abundant and are reasonably well preserved. The lower five feet of the formation, as exposed at Ottawa, are rubbly, "pseudo-nodular" calcilutites inter-bedded with much shale with a carbonate: shale ratio of about 60%-70%. Macrofossils are common, especially Prasopora, and are easy to extract and well preserved.

The Clarence Township Quarry exposes about 50 ft. of limestones which, if Wilson's Sherman Fall - Cobourg boundary is accurate in this area, represents the higher parts of the formation. However, the boundary appears to be gradational and arbitrary. Most estimates of the thickness of the Sherman Fall are generally in the order of 125 ft. (e.g. Wilson, 1956a). Because of poor exposures, the lateral facies changes of the formation cannot be clearly ascertained. Clark (1952) and Kay (1942) described the formation (or its equivalents) at Montreal and in the Pembroke area respectively.

Cobourg Formation

The Cobourg Formation has two fairly distinct lithostratigraphic units ("members"). These are both clearly seen in excellent, if rather inaccessible cliff exposures on the south side of the Ottawa River from Chaudiere Falls to Governor's' Bay at Ottawa.

The lower Cobourg is typically medium grey, fine to coarsely crystalline, fine to coarse calcarenites in compact beds, 3-9 ins. thick, with fairly smooth regular surfaces separated by shale partings. Many beds are cross-stratified and intraclasts are fairly common. Macrofossils occur on a few surfaces; fossil debris is plentiful and averages perhaps 20%-40%. Burrows, and trails both on and in beds are common and range up to 1½ ins. in diameter.

The upper Cobourg generally forms beds up to 4 ft. thick, which rapidly break down on weathering to a rubble, so that the thick-bedded nature is obscured. The carbonate type is usually a medium light grey medium to coarse calcarenite which is fine to coarsely crystalline, and argillaceous. Laminae, partings, and thin beds of shale are common. Macrofossils are common and quite well preserved; fossil debris is likewise quite abundant and generally evenly distributed except for occasional bioclastic spreads forming beds up to one foot thick.

Exposures of the Cobourg are relatively good, especially of the upper part which in some places forms a scarp. Only rarely are there extensive vertical sections of the formation outside Ottawa. The writer has no new evidence for lateral facies changes. The boundary between the lower and upper Cobourg is fairly clearcut, a gradational change occurring over about 10 ft. That between the Cobourg and the Eastview Formation is not exposed, but appears from the literature to be also gradational over a few feet.

CHAUMONT FORMATION

Introduction

The term Chaumont was introduced by Kay (1929, p. 664) to include the Leray and Watertown limestones and the Glenburnie Shale. The limestones were traditionally grouped within the Lowville, but Cushing et al. (1910) recognized lithologic and faunal differences and introduced the above names. These two limestone "members" were distinguished in the Watertown area by the abundance of chert in the Leray limestone, but this criterion has only very local significance and recognition of the two divisions beyond the type area is impossible. When traced into S.W.Ontario, a two-foot shale member

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The formation was thus defined in north-west New York as a group of fine and medium calcarenites: thick to massive-bedded, medium to medium dark grey, mainly finely crystalline, with a biogenic content of some 10%-30% and some thin localized shale inter-beds or internal irregular shale laminae. The writer re-examined Klock's Quarry in Watertown described earlier by Cushing et al. (1910, p. 84-87) and referred to by Young (1943, p.210). In June 1963, the quarry was largely filled in (see fig. 16). The description of this section (locality 30) is given in the Appendix and the conodonts obtained from these units are discussed in Chapter 6. The location of this quarry is at Huntington St. and California Avenue North (formerly Clinton St.). The limestones closely resemble those of the Chaumont at Ottawa, only slight differences being apparent.

Raymond (1913) extended the name Leray to the Ottawa Valley and its use was continued by Wilson. Cooper (1956), however, chose to use the term Chaumont. In south-west Ontario, the confusion caused by using lithostratigraphic and biostratigraphic terms synonymously, together with difficulties encountered in correlations with outside areas, has led Liberty (1963a) to introduce a series of new names for these carbonates of the Mohawkian sub-series. Clark (1952) uses the term Leray in the Montreal area, but reports (p. 47-48) that the Glenburnie and Watertown "members" appear to be absent.

Definition in the Ottawa Valley

As noted above, Raymond (1913) referred to limestones between the Lowville and Rockland as the Leray which he described (p. 141-142) as "thick beds of rather impure, grey to black limestone. The fauna is a large one, some of the more common and characteristic species being Columnaria halli, Hormoceras tenuifilum, Bumastus milleri, Dalmanella gibbosa and Strophomena filitexta".

Wilson (1921, et seq.) always used this term but never chose to apply definite lithologic or faunal boundaries, and generally referred to the limestones as the "Leray beds". In 1921, however, she described three measured sections of the Chaumont which reveal some lithostratigraphic limits. Of her three sections, only that at Stewart Quarry, Rockland, is complete. The reasons for placing the boundaries at particular levels are not presented and it seems extremely doubtful that major faunal changes occur between any two beds. Most probably, a gradual vertical faunal change was recognized, and the boundary with the Rockland was placed at the most obvious lithostratigraphic change. Even this break is doubtful, as is apparent from figure 14, which shows the north-west face of Stewart Quarry.

Kay (1937, 1942) is the only other writer who has discussed the Chaumont boundary problem. In mapping, Kay seems to have relied heavily on lithostratigraphic criteria. However, he made detailed faunal analyses of each formation at widely spread intervals along the strike, whilst noting the presence of the more characteristic forms at intervening localities. It is sometimes difficult in places, however, to determine the relative importance given to the lithologic and faunal criteria.

After studying the section at Stewart Quarry, Rockland, Kay (1937) concluded that the "Leray proper" (lower 9 ft. 6 ins.) and the "transition beds" (upper 8 ft. 6 ins.) of Wilson (1921) were all post-Watertown in age. Kay later decided (1942, p. 599) that only the transition beds were post-Watertown and likely to be the Selby member of the Rockland: "The lithology as well as the fauna, of the "transitional beds" resembles that of the Selby member of the Rockland which is post-Chaumont". The writer has not seen the type Selby of S.W.Ontario, but has visited many localities in the Black River Valley of New York and does not agree that the lithology resembles that of the New York Selby (cf. figs. 14 and 17). It is far more closely allied to the New York Chaumont lithology and it is extremely doubtful if, at Stewart Quarry, Rockland, any definite lithologic boundary between the Chaumont and Rockland can be made that is other than arbitrary (see description: locality 21, Appendix). It seems more plausible here on lithologic grounds, to include the "transition beds" within the Chaumont at the type Rockland.

Kay (1937, p. 251) also states that "In localities from Rockland to Pembroke it (the Rockland) is underlain in many exposures by from 3 to 5 feet of shaly limestones in which are large masses of Tetradium sp. cf. T. fibratum Safford; these latter beds are tentatively referred to the upper Black River Chaumont Formation and succeed limestones lithologically like the Lowville limestone, bearing T. cellulosum (Hall). Present experience shows this bed to be an extremely useful marker, occurring in almost every examined exposure of the uppermost Lowville. But T. cellulosum seems to be the most abundant species of the genus rather than T. fibratum, the latter being dominant in only a few localities. The writer has placed this bed in the Lowville and draws the Lowville-Chaumont boundary directly above this unit. Since Kay (1942) reversed his opinion and recognized Chaumont strata above this unit, he also may now wish to regard it as Lowville. The abundance of T. cellulosum and the calcilutitic matrix allies this unit more closely to the Lowville than the Chaumont and marks the change to a different lithology.

For the Ottawa-Bonnechere graben area, the writer is in general agreement with the formational boundaries proposed by Kay (1942). Only three sections were described and sampled in this area and only at Meath Hill (locality 1) was the Lowville definitely recognized. The lowest beds at Fourth Chute (locality 3) are tentatively placed in the Chaumont. Thus the Lowville - Chaumont junction is not so clear-cut in this region as that of the east, but given a good exposure its assignment is not difficult. The Chaumont - Rockland boundary is far easier to place in the field where irregular, thin bedded, platy, cross-laminated, medium dark grey, medium to coarsely crystalline, medium calcarenites (Chaumont) are overlain by even, thick bedded, light brownish grey, coarse to extremely coarsely crystalline, fine calcirudites with high biogenic content, occasionally thinly bedded and sometimes broadly cross-stratified (Rockland).

The latter distinctive calcirudites can be traced as far east as Carp, from there east to Hawkesbury, the upper boundary is arbitrary, since the Rockland is basically the same in lithology. With good exposures, slight changes in gross lithology make it possible to place arbitrary junctions and from Ottawa to Rockland, and perhaps even to Alfred, the formation appears to be 20-25 ft. thick. No macrofaunal evidence has been used to determine this division.

In conclusion, the writer feels it would be best to regard the

Chaumont and Rockland as one formation and to class units such as the western lower Rockland calcirudite wedge as members. Since the Rockland was not studied completely, this recommendation cannot be applied in the current study. The confusion in delineating the Chaumont to the east of Carp should therefore be seen in perspective. The whole megagroup is in need of a complete stratigraphic revision, which through redefinition of units, could solve such problems as those outlined above.

STRATIGRAPHY OF THE CHAUMONT FORMATION

INTRODUCTION

This account of the stratigraphy of the Chaumont is divided into two parts, based on facies change, which will allow generalizations to be made for each area. Details of individual sections are given in the Appendix. The interbedded calcilutites within the Chaumont, and the lower Rockland calcirudites, extend eastwards from the Ottawa - Bonnechere graben to the proximity of Carp (see e.g. localities 6, 7 and 8). These features are absent at localities to the east of Carp. This absence, however, can be predicted for both characters show a gradual weakening in development eastwards from the graben area.

The Chaumont to the east of Carp was studied at 17 localities of which 13 exposed over 75% of the formation. The most easterly sections are at Alfred, some 60 miles east of Carp; unfortunately no adequate localities could be found between Alfred and Hawkesbury. At 12 localities, the Lowville-Chaumont boundary could be ascertained and Rockland strata are believed to be present in at least nine.

Terminology of limestones

The grain-size scale for the limestones is only slightly modified

	Transported Constituents	Authigenic Constituents	
64mm	Very coarse calcirudite	Extremely coarsely crystalline	
16mm	Coarse calcirudite		
4mm	Medium calcirudite		4mm
1mm	Fine calcirudite	Very coarsely crystalline	1mm
0.5mm	Coarse calcarenite	Coarsely crystalline	
0.25mm	Medium calcarenite		0.25mm
0.062mm	Fine calcarenite	Medium crystalline	0.062mm
0.008mm	Calcisiltite	Finely crystalline	0.008mm
	Calcilutite	Very finely crystalline	

TABLE 2

Grain-size scale used for Chaumont carbonates (modified after R.L. Folk, 1959).

from Folk (1959, 1962). The term calcisiltite is still useful and it is here used in place of Folk's coarse, medium and fine calcilutite, the latter term being restricted for grains with a mean diameter of less than .008mm. The subdivisions of the calcisiltite grade can only be recognized in thin section studies and not in the field. Likewise, Folk's fine sand and very fine sand terms are merged to read fine sand (see Table 2) since the distinction cannot be made in the field and it is an over-refinement for the purpose of the petrographic and paleoecological studies that are described in later chapters.

As will be shown in more detail in Chapter 4, the limestones of the Chaumont have granular textures and in addition to the fossil material, generally have a framework of pellets and/or intraclasts (i.e. broadly termed "bahamites" by Beales, 1958). The carbonate granules are not visible in the field, except the coarse varieties after careful etching - a process which was impractical for this study. Thus, to obtain the grain size factor the grade of the fossil debris was used. As will be shown later in this chapter, the debris is generally well distributed within any one bed and is likely to be a reliable parameter reflecting current activity through the degree of abrasion, sorting and concentration of the particles. The grain size allocated was chosen after close examination of each bed, preferably of a weathered surface. The sorting factor was recorded visually where sufficient accuracy could be obtained. An estimation of the percentage of the biogenic content (i.e. total amount of fossil material) within a bed was also recorded. This can be done with reasonable accuracy, except on lichen-covered surfaces and is regarded as being an important factor in considering the carbonate framework and the textural spectrum. The estimation of these percentages is admittedly subjective, but since any error from Folk (1959, 1962). The term calcisiltite is still useful and it is here used in place of Folk's coarse, medium and fine calcilutite, the latter term being restricted for grains with a mean diameter of less than .008mm. The subdivisions of the calcisiltite grade can only be recognized in thin section studies and not in the field. Likewise, Folk's fine sand and very fine sand terms are merged to read fine sand (see Table 2) since the distinction cannot be made in the field and it is an over-refinement for the purpose of the petrographic and paleoecological studies that are described in later chapters.

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It was not possible to use Folk's (1959, 1962) classification in the field because the relative amounts of pellets, intraclasts and fossils could not be determined. The thin sections of many samples from the Chaumont, however, allow a more detailed subdivision of the limestones (see Chapter 4). A comparison of hand specimens and thin sections, acetate peels and etched surfaces, clearly indicates that the units described as fine or very finely crystalline in the field have a microcrystalline matrix (micrite) whereas the coarsely to extremely coarse crystalline carbonates have a sparry calcite cement (sparite). Those designated medium crystalline are generally poorly washed containing both micrite and sparite, but perhaps tending more to the sparry calcite variety (see Folk (1959) for terminology of carbonate petrography).

The colour of the limestones was recorded from fresh surfaces and compared with the Rock Colour Chart (Goddard, 1951). The colours are nearly always a shade of grey, although the Tetradium-bearing calcilutites and the Rockland calcirudites are frequently a light grey-brown.

In addition to the colour, crystallinity, grain size, and biogenic content, many other features were recorded in the field and these are reviewed later in this chapter.

Stratigraphy of the eastern region

The Chaumont to the east of Carp is fairly uniform, (see figs. 14, 15). The limestones are generally medium grey in colour with some medium light grey and medium dark grey units. Crystallinity largely controls the colour observed and as colour variations are always rather subtle, little significance can be attached to them. The usual colour (medium grey) is undoubtedly controlled by the normally fine to medium crystallinity and the fairly high content of argillaceous matter. Any one bed is nearly always of uniform colour, although a few beds exhibit a mottled effect (see Ch:5 - Sedimentary features: borings) in which fine and coarse textures exist together in an intricate pattern with two main colours. As noted earlier, some of the Tetradium - bearing calcilutites of the uppermost Lowville and some of the very coarsely crystalline units have a light brown or light grey brown colour, at times even pinkish. The colour of weathered surfaces varies with the period of exposure and since both fresh and deeply weathered sections were used, this colour was only described if considered to be significant or outstanding. In general, the Chaumont weathers to a sandy or pale buff colour whilst calcilutite units are "dove", whitish, or blue-grey.

The cementing material is calcium carbonate and the size-grade of this is an important factor. Folk (1959), Cronoble and Mankin (1963), and others have shown that a genetic relationship exists between the presence and relative abundance of micrite and sparry calcite. Thus, a carbonate deposited in a zone of vigorous current or wave action will have been winnowed of its microcrystalline ooze (micrite) and the resulting clear-washed sediment will have abundant pore-space available for the growth of sparry calcite cement.

The Chaumont limestones east of Carp are typically fine to medium crystalline. The underlying calcilutites are either very finely or, more rarely, finely crystalline. Some of the rare thin, clean-washed microbedded, medium to coarse calcarenite spreads are coarsely crystalline as are some of the intrabed "pockets" rich in organic debris that will be described later.

Typically, the grain-size of the limestones, based on the fossil debris, is of fine to medium grade, particularly the latter. Fine calcarenites and calcisiltites are typical of the lower five feet or so. Coarse calcarenites are more commonly found in the upper half of the formation and the thin laminated spreads are generally of this grade. The "pockets" of coarse calcarenite frequently observed in medium calcarenitic beds are accounted for in Chapter 5. The grain-size character is clearly genetic, being controlled by current activity which could gather loose shells into coquinas, remove finer debris to quieter water, and remove other carbonate allochems.

The biogenic content of coquinal beds was estimated at a maximum of 75%. The accuracy of the figures, admittedly subjective, is thought to be within ±5%. The debris content, can be estimated quite accurately, except when distribution is patchy. Where layers or pockets of richer fossil debris occur within a bed, two estimates were attempted. In the region under discussion, the beds in the lower five feet or so have biogenic contents in the order of 15%-30%, whereas the rest of the formation has typically 25%-40%. Some beds not uncommonly range up to 55%. Higher percentages, generally associated with conquinal units, are not common and, when present, are usually thin and often impersistent. Beds are normally fairly uniform in their biogenic content, although a few exhibit some grading in either content or grain-size; in this respect, both normal and reverse grading occur.

Bed thicknesses are usually in the range of 9 ins. to 2 ft. 6 ins., commonly closest to 2 ft. The beds tend to be compact and sometimes massive, particularly in the two most easterly sections at Alfred (localities 24 and 25). In outcrop, beds retain a fairly constant thickness, varying only a few inches at the most. Close inspection of such thick compact units often shows them to be composed of subunits - commonly 3 to 5 - not parted by shale laminae, but fused together along surfaces that are frequently bored, rippled, or represent discontinuities. Slight differences in weathering colour help to distinguish the subunits.

Beds of average thickness are usually of typical lithology, whereas those units that are less than 9 ins. thick are often a more extreme type e.g. a calcisiltite or a fossiliferous calcirudite.

Units are invariably separated by thin (up to 1 in., commonly ¼-½ in.) shale partings. In outcrop, these are weathered into the exposure face and determination of the shale's characteristics is normally impossible. Likewise, the recognition of bentonites here is rarely possible. The many conflicting opinions on the identification of bentonites shows that detailed chemical or X-ray tests are necessary.

Beds are generally compact and only rarely rubbly when the argillaceous content is high, which sometimes occurs in their units associated with shaly partings. The surfaces of upper Lowville beds are often subconchoidal, whilst those of fine-textured strata are often hackly, and infrequently "blocky" in the average calcarenites - here the surface is broken into irregular, roughly cubic blocks, usually with a 2 to 6 sq. in. face.

Bedding planes reveal a variety of features which are discussed below. Generally speaking, however, none of these seems to be traceable over any great distance and probably reflects only local conditions.

Within the beds, shale laminae are common to abundant and are rarely absent. They are normally less than 1/8 in. thick and are irregular-they may have an "amplitude" of one or two inches and slight irregularities of ¼ in. or so on the actual laminae. Often discontinuous laterally, they commonly occur at vertical intervals of less than an inch throughout a bed (e.g. see fig. 19).

Signs of organic activity are abundant. Fossils are frequent to abundant in this area. The main types preserved are: brachiopods (e.g. Strophomena, Doleroides, Rhynchotrema, Rafinesquina, Zygospira), gastropods (e.g. Hormotoma, Fusispira, Liospira), cephalopods (e.g. large Actinoceras and Michelinoceras, Oncoceras, Zitteloceras), trilobites (e.g. Isotelus), trepostome bryozoans, crinoid ossicles and some cup corals (e.g. Streptelasma). Preservation is fair but extraction difficult. The amount of abraded fossil debris attests to the extensive destruction of many forms. Burrows are common to abundant in the lower part of the Chaumont, but rare to infrequent in the upper. Fossils are usually fairly evenly distributed within a bed and have random orientation. In some of the coquinal units and the laminated spreads, however, there is clear indication of wholesale transportation.

The Tetradium bed in the uppermost Lowville is formed of these long slender corals which rarely show any evidence of major disruption and appear to be mostly in situ. In beds showing fossils and fossil debris with random orientation and even distribution, there is the possibility of mass reworking by benthos and infauna (see discussion below: sedimentary features.

The overlying Rockland is much the same as the higher Chaumont, though locally the thin shales and shaly limestones of the Rockland (e.g. at localities 16 and 21) contain faunas with prolific bryozoans (especially Prasopora), brachiopods and trilobites.

Stratigraphy of the western region

The western region lies between Carp and Pembroke, a distance of some 60 miles. Here are 8 sections, 5 between Carp and Arnprior and 3 to the west in outliers of Ordovician strata on the Precambrian (see Fig. 1). These show the Chaumont differing both from the eastern region and locally from section to section. The lithologies are variable and several types can be found at any one locality. The descriptions of the sections are given in the Appendix. For the sake of clarity, only six lithologies, the commonest and the most important types and, in some instances, end-members of gradational series, will be described here.

The thickness of the Chaumont here is difficult to determine. Only 3 of the 8 localities reveal the lower boundary and 6 the upper. Moreover the very nature of the upper contact (drawn at the base of the calcirudites) is likely to be strongly diachronous. From the evidence, the formation appears to be in the order of 30ft. (± 3 ft.) thick; the maximum recorded being at Clay Bank (locality 4) where 40 ft. 6 ins. are seen exclusive of the base. There thus seems to be about a 25%-30% increase in thickness of the formation over the eastern region.

The most typical lithologies to be found are described as follows:

1. "Ottawa-type" calcarenites

These commonly make up about 30% of a complete section and closely resemble the calcarenitic limestones of the eastern region and need little elaboration. Thus they are typically:

> Medium grey, finely crystalline, medium calcarenites; biogenic content 25%-35%; shale laminae common; borings infrequent to common; compact beds averaging some 2 ft. in thickness; fracture hackly; shale partings separate beds; slightly lower biogenic content and slightly finer textured, on average, than those of eastern region (see figs. 7, 9, 11).

2."Lowville-type" calcilutites - calcisiltites

In the eastern region these units are confined to the Lowville Formation, but in the west they are interbedded with other lithologies and comprise about 20% of the Chaumont Formation. Two varieties can be distinguished:

a) light grey or pink brown, very finely crystalline to aphanocrystalline, calcilutite; biogenic content variable: less than 5% to 35% when Tetradium is abundant; shale laminae and borings absent: beds very compact, averaging 3-15 ins. thick; fracture poorly conchoidal; beds isolated or in groups (see fig. 8).

b) medium light grey, very finely to finely crystalline calcisiltites; biogenic content 5%-10%, Tetradium present at times but less than in a); shale laminae rare, when present are less irregular than in "Ottawa-type" calcarenites; burrows rare; fine laminations common, cross-laminations rare; irregular upper surfaces infrequent; beds usually in groups rather than isolated, some lateral pinching out of beds; beds usually 2-6 ins. thick, groups commonly 1-2 ft. thick; irregular shale laminae infrequent, less irregular but more persistent laterally than in "Ottawa-type" calcarenites; fracture subconchoidal.

Variety b) predominates over variety a) by about 3:1.

In both varieties of "Lowville-type" calcilutites - calcisiltites, the fossil content is low and is not clearly observable on the weathered surfaces. Macrofossils are few, generally little abraded and usually isolated; fossil spreads being very rare. Tetradium (predominantly T. cellulosum) occurs frequently, sometimes in abundance and the few heads of T. fibratum observed were mainly in their position of growth.

3. Coarse calcarenites - fine calcirudites

These comprise about 10%-15% of a typical section and can be described as:

> medium light grey, sometimes brownish, medium to predominantly coarsely crystalline, rarely very coarsely crystalline, coarse calcarenites to fine calcirudites; biogenic content usually high 50% to coquinal, averaging 60%-65%; shale laminae infrequent, when present are not very irregular and are rather isolated; borings absent; beds fairly compact, evenly bedded, generally 9-18 ins. thick, but thinner ones also present, some impersistant, others with limestone intraclasts (less than 25%); beds generally either isolated or associated with the "Ottawa-type" calcarenites; fossils mainly brachiopods and molluscs, little abraded, fossil debris abundant.

4. Shaly argillaceous calcarenites

These form some 10% of the formation, but are more noticeable as they tend to occur in one or two thick units composed of many beds. Typically, these units are composed of several lithologies, but the one predominating is:

> medium light grey to medium grey, medium to coarsely crystalline, coarse calcarenite; biogenic content 40%-60%, variable, occassionally coquinal; beds usually 2-5 ins. thick, rarely exceeding 8 ins. in units 1½-3 ft. thick, somewhat argillaceous, flaggy, with varying thicknesses; shale partings numerous, generally ½-2 ins. thick and following upper surfaces, medium grey brown, flaky, not very fossiliferous; shale laminae within beds rare; fossils mainly bryozoans, molluscs and brachiopods, prolific in some beds, preservation fair, large heads of Tetradium Fibratum sometimes found in growth position; borings sometimes present in shaly interbeds (see fig. 8).

5. Shaly argillaceous barren limestones

These are very similar to the shaly argillaceous calcarenites just described, except that they are virtually barren of fossil material. They occur in thick units comprised of many beds with considerable shale content, thus becoming rubbly on weathering. This type generally forms less than 10% of any particular section and may be absent in some. Their nature is usually:

> medium to medium-dark grey, fine to medium crystalline limestone; biogenic content less than 5%; beds average 2-5 ins. thick, rarely exceeding 8 ins., individual thickness varies; beds sometimes laminated, occasionally cross-laminated; shale partings plentiful, ½-2 ins. thick, irregular interbeds, medium grey brown, flaky, unfossiliferous; units generally 2-4 ft. thick.

6. Laminated calcarenites - fine calcirudites

These are allied to the laminated spreads that are occasionally seen in sections in the eastern region. Here, they are always present in the upper third of the formation and usually the upper fifth or so is completely dominated by them; hence, they comprise about 15% of the formation. A variety of internal structures is found but the carbonate type is quite constant:

> medium light grey, often brownish, coarse to very coarsely crystalline, especially coarse calcarenites to fine calcirudites; biogenic content usually high, averaging 35%-60%; shale partings common, ¼-¾ in. thick, no shale laminae within the beds; borings rarely present; beds generally less than 12 ins. thick, thickness varying with type of internal stratification: level laminations: 2-5 ins. units, trough cross-lamination 2-7 ins., broad cross-stratification: 4-12 ins.

The level-laminated units are similar to those of the eastern region: usually of uniform thickness with laminae less than ¼ in. thick, essentially horizontal and very even. Low-angle cross-laminations are present at times, generally lower in the section than the other types and mainly as isolated beds. The small-scale trough cross-bedding only occurs in the upper part of the Chaumont; sets of cross-laminae are usually about 3 ins. wide and 1 in. or so thick. They occur in even and fairly regular beds, very compact, and termed "platy" by Kay (1942). The broad cross-stratified units are likewise even and compact, a few pinch-out laterally; laminae are again about ¼ in. thick and dips reach up to 25°. This cross-bedding occurs in single beds which are generally the richest in fossil material. Again these are restricted to the upper Chaumont and are mainly the highest beds which lie beneath the Rockland calcirudites. Fossils in these limestones are usually fragmental and strongly abraded; comminuted fossil debris is abundant. The contact between this type and the Rockland calcirudites is shown in figure 10.

7. Rockland calcirudites

Because this lithology is intimately related to some of the Chaumont types and will be referred to in later chapters, it is described here for the sake of completeness. It occurs in the lower Rockland and is in excess of 20 ft., appearing to grade upwards into calcarenites that closely resemble those of the Rockland in the eastern region. The beds exposed at Paquette Rapids (on the east side of Allumette Island) have been referred to both the "Leray" and the Rockland in the past; Kay (1942, p. 604) assigns them to the higher Rockland. They are medium light brown grey, finely crystalline, calcisiltites, but do contain well preserved isolated fossils that are often partly silicified; *Stromatocerium rugosum* Hall, *Receptaculites Occidentalis* Salter and *Lyopora Halli* (Nicholson) are amongst the commonest of the great number of species that have been described. The lithology is quite unlike the 55 ft. of lower Rockland exposed at the Bonnechere Lime Company quarry, near Eganville (see fig. 12). Kay (1942) reports a Rockland thickness of about 60 ft. but the stratigraphic relationship of the Paquette Rapids beds is not at all clear. Unfortunately exposures are poor and the problem still remains. Sinclair (1954) equates the fauna with that of the type Leray in New York, the Ottawa Valley "Leray" fauna being older than both.

The lower Rockland units, however, are typically:

> medium light brown grey, coarse to very coarsely, rarely extremely coarsely crystalline, fine calcirudites, rarely medium calcirudites; biogenic content high: 55%-75%; shale partings common, shale laminae within beds very rare; burrows absent; beds massive, even, compact, normally 2-4 ft. thick, but 6-15 ins. at Bonnechere Lime Co. quarry; cross-bedding common, large-scale, dips up to 20°; fossils much abraded except larger compound corals, many silicified; fossil debris abundant with algal (mainly Solenopora type) fragments as major constituent; chert nodules rare.

These then are the typical Chaumont lithologies in the Carp-Pembroke region. Chert which is almost non-existent in the eastern region is a little more common in the west. It is found in several localities, usually restricted to one or two beds, and the lithologies in which it occurs seem to be the "Ottawa-type" calcarenites and the laminated calcarenites - fine calcirudites. The lumps are irregular, a few inches across, black and generally badly weathered. Some were found in crossbedded units suggesting an epigenetic origin; it is quite likely that porosity played an important role in controlling its formation.

In summary, the limestones in the eastern region are uniform in texture, bedding, and most other features. They are different from those of the underlying Lowville Formation, but are so similar to the Rockland units above that no lithostratigraphic boundary can be placed with assurance. When traced westwards beyond Carp, the Chaumont is characterized by variable lithologies. In the lower two-thirds the dominant units are "Ottawa-type" calcarenites and "Lowville-type" calcilutites - calcisiltites, above these the laminated coarse calcarenites - fine calcirudites predominate and are capped by the lower Rockland calcirudites. Goudge (1938) and Hewitt (1960) give chemical analyses of several localities (see Table 9); the calcium carbonate content is rarely below 85% and commonly above 90%. Dolomitization is negligible.

The interpretations to be placed on the stratigraphic information, together with that considered in the following pages, are discussed in Chapter 5.

SEDIMENTARY FEATURES OF THE CHAUMONT FORMATION

Close examination of the Chaumont limestones reveals a variety of sedimentary features, many of which help in elucidating environments of deposition. The true value and significance of all may not be appreciated since previous studies of many such features have been superficial and work in areas of modern carbonate deposition has concentrated on possible modes of deposition rather than sedimentary (bottom and internal) features. The significance and interpretation of some minor structures not considered in Chapter 5 will be discussed below. The following account is divided into: a) gross characteristics of beds, b) bedding surfaces, c) structures within beds, and d) organic remains and activity within beds.

1. Gross characteristics of beds

Relationships between bed thickness and carbonate type can be seen. Beds of calcilutite - calcisiltite grade are invariably thin-bedded (less than 12 ins. thick) and thick units of this grade are composed of a series of thin beds. These are compact, dense, with smooth, somewhat irregular upper, and often lower, surfaces and a subconchoidal fracture. Shale partings, common in the calcisiltites, are fewer in the purer calcilutites. Pinching out of beds is seen in some of the laminated calcisiltites; this is especially common in the barren flaggy thick units of calcisiltite grade that have numerous shale partings and are recessive.

Beds of calcarenites, however, are invariably thick (1-3 ft.)

and although some are clearly constructed of several fused subunits, the majority appear to have been deposited without any major widespread pause. Such beds are fairly compact, sometimes massive, and nearly always uniform throughout in broad characteristics. Top and bottom surfaces are fairly flat, but with slight irregularities, and can usually be assigned to one of the types described below. The argillaceous content is mostly in the form of the numerous irregular shale laminae within the beds. Shale partings (¼-3/4 in. thick) usually separate the beds.

Calcirudite beds are more variable and are clearly polygenetic. However, within the Chaumont they rarely exceed 1½ ft. in thickness and the only thick-bedded calcirudites are found in the basal Rockland in the western region. Three main types of calcirudite can be observed. A fairly thick (9-18 ins.), compact, even-bedded type, usually occurs as an isolated bed or as part of a massive calcarenite unit. A second kind, with variable thickness (0-15 ins.), is compact and generally broadly cross-bedded; some are clearly channel fillings, The third type is the cross-bedded calcirudites that normally lie in the upper part of the Chaumont in the western region and which are fairly thin-bedded (6-12 ins.), rather compact and platy, quite even, but in places varying in thickness, exhibiting a variety of cross-stratifications.

The shaly, argillaceous calcarenites together with some of the calcilutites-calcisiltites form rubbly, badly-weathered, recessive units. Individual shale beds never exceed 3 ins. in thickness and the occurrence and regularity of these is associated with the carbonate type; they are rarely fossiliferous to any extent.

Upon weathering, the calcilutites-calcisiltites are usually pale,-

a light grey or dirty white, whilst the coarse grades are somewhat darker:- normally a medium light brown grey.

2. Bedding surfaces

The great variety of top and bottom surfaces noted in the Chaumont formation can be subdivided into the basically a) level and b) irregular.

a) Level bedding surfaces

These comprise three main types: fused, or separated by shale partings or by shale laminae. Fused surfaces (i.e. tightly joined, with no shale) are fairly common, especially in the calcarenites of the eastern region and here largely in the lowest few feet and in the more massive units. Two or more beds are thus found in contact, fused tightly together and are normally only observed upon close inspection; the beds are usually of similar nature with only slight differences, e.g. in colour or texture. Level surfaces are often separated by laminae or partings of shale. They are usually very thin and the lower surface of the succeeding bed is likewise even and scarcely irregular.

b) Irregular bedding surfaces

The following types of irregular bedding surface have been recognized in the Chaumont: discontinuity, rippled, slumped, erosional, and bored; mud-cracked surfaces are also discussed.

1) Discontinuity surfaces

Discontinuity surfaces have been the subject of considerable discussion in the last few years and the various hypotheses involved have been reviewed by Jaanusson (1961). The arguments centre upon whether these surfaces have been produced by submarine or by subaerial agencies. Jaanusson presents strong evidence for subaerial processes, but amongst others, Lindström (1963) has shown that such features can be developed solely by submarine agencies. If both modes of formation exist, it must be determined whether the carbonates involved are essentially deep - or shallow-water types. If the latter, then the probability of occasional exposure will be far greater than in the former case. Both Prokopovich (1955) and Weiss (1957) considered that corrosional surfaces in Middle Ordovician limestones in Minnesota were formed without exposure; however, Weiss (1958) later proposed that subaerial effects were dominant.

There seems little point in further immediate discussion of the problems involved. After a consideration of the literature and the structures found in the Chaumont described below, the writer finds it more plausible to accept the view which invokes some form of subaerial exposure. It seems very doubtful, considering the types of carbonates involved, that wide areas of reducing conditions could occur intermittently to cause corrosion, whilst there seems no problem in envisaging fluctuations in a gradually transgressing sea, causing periodic exposure for short periods of time.

The discontinuity surfaces observed are revealed by their relief, weathering colour, and different carbonate types adjacent to the surface; there is neither staining nor concentration of glauconite or pyrite etc. The most common types are described below. They are not infrequent, but only one or two may occur in any one section and they do not appear to extend from one section to the next. However, for observing these structures, good, clean exposures are necessary, but not extensive weathering of the face. Thus it is possible that some may be useful for correlation under ideal conditions, but in the present study they have not been of value in this respect, as they have, for instance, in much of the Swedish

Ordovician. The Chaumont surfaces are of the same scale as the Swedish types: a relief of up to about two inches, but varying in detailed morphology, allowing a fourfold breakdown outlined below.

a) "Normal" discontinuity surfaces

Included here are those surfaces that are irregular throughout, but with relatively low relief and apparently exhibiting no set pattern. This type is closely comparable to that figured by Jaanusson (op. cit., Fig. 1a). Two sub-types occur: those in which the two carbonate types adjacent to the surface are tightly fused and those in which these are separated by a shale parting up to ½ in. thick.

b) "Corroded" discontinuity surfaces

These surfaces show relatively high relief with elaborate crenulations. The latter are so intricate as to be incompetent had they not been lithified. The depth and delicacy of the parts remaining strongly indicate that some form of corrosion, rather than mechanical erosion, was the prime cause of this type of surface. They resemble closely those figured by Lindström (1963, Fig. 9c) and particularly by Winder (1959, Fig. 1). Again, the two sub-types occur that were described in the preceding section.

c) "Pitted" discontinuity surfaces

Such surfaces, as figured by Jaanusson (op. cit., Fig. 1c) and by Lindström (1963, Figs. 9a, 12) are also present. The bedding plane is pitted with circular to subcircular holes of various sizes, generally with a width-depth ratio of about 3:2. They resemble a series of small potholes, rarely being more than 1-2 ins. in diameter. Their origin is unknown; the most plausible suggestions are that they are a) youthful potholes, or b) formed during intertidal exposure in a similar way to the "marine solution basins" described by Emery (1946), in which the diurnal photosynthesis of micro-organisms is considered to cause an excess of solution of calcium carbonate. Emery's hypothesis seems the more logical; it is based on observed processes and, furthermore, no abrasive material is generally found in the pits. Once again, the surface can be fused or covered with a thin shale film.

c) "Bored" discontinuity surfaces

These surfaces are clearly developed during a depositional hiatus during which the floor is extensively burrowed (cf. Ginsburg, 1957, Fig. 6), giving rise to a highly irregular surface, but one in which individual burrows can be traced. Such surfaces are illustrated by Lindström (1963, Figs. 9d, 10) and are duplicated in the Chaumont limestones. The burrows are normally very complex; "U"-shaped burrows can be observed only rarely. Burrows could have been made by marine organisms or by organisms in the exposed intertidal zone. The elaborate relief suggests that the surface was at least partially lithified and hence the second possibility is favoured here. Both fused and shaly surfaces occur.

This fourfold breakdown of discontinuity surfaces appears to be genetic, but the implications are not fully understood and, unfortunately, their stratigraphic application is limited in this region.

2) Rippled surfaces

These are infrequent in the Chaumont Formation. Some occur in the calcarenites of the eastern region, but have only been seen in section, never being exposed on a bedding plane. The ripples are mainly symmetrical, normally 2-4 ins. in amplitude and about 18 ins. in wavelength. Some show erosion or boring of the crests, whilst others exhibit a partial infilling of the troughs with coarse debris.

In the western region, large-scale symmetrical ripples are sometimes found high in the Chaumont, associated with the cross-stratified units. Typical ripples here measure 3-6 ins. in amplitude and 24-30 ins. in wavelength. These large-scale ripples seem to be associated with the calcirudites; similar types were recorded by Kindle (1914) from the upper Hull limestone of Ottawa, which almost certainly represents a comparable facies to the lower Rockland of the western region.

When occuring within a bed, the ripples usually have a fused upper contact, but when forming the top of a bed, they are commonly succeeded by a thin shale parting.

3) Slumped bedding

Irregular bedding surfaces are also formed in units that appear to have undergone pre-lithification slumping of the sediment. These structures have been observed in a four-foot unit, low in the Chaumont at Burnt Lands (locality 8; fig. 20). Elsewhere they only occur in calcilutite-calcisiltite units high in the Chaumont of the western region. They are restricted to sediments of clay and silt grade that are quite homogeneous, pelletal, and poorly fossiliferous. Shaly partings are present, but in insufficient quantity to suggest load-casting or differential compaction as the origin of this bedding-type. Cross-lamination also occurs in some beds, and in the Burnt Lands exposure certain beds show a balling-up effect, with the curved laminae paralleling the curved bedding surfaces. Therefore, there is evidence that some of the beds have suffered slumping (i.e. lateral movement) and it seems most probable that this was the prime cause for all such bedding. The reasons for slumping cannot be determined from the few exposures in which these structures occur; it is presumed that the instability of the fine-grained muds coupled with deposition on steeper slopes, possibly off islands not found in the eastern region during the transgression, were important factors involved.

4) Erosional channels

Excluding the small-scale discontinuity surfaces considered earlier, there are two main types of erosional surfaces within the Chaumont. Both are in the form of erosional channels and both are found predominantly in the western region.

a) Solitary channels

These are rare, but worthy of note for they indicate the processes of erosion occurring in these environments. The fairly small-scale channels associated with the laminated calcarenite spreads have been described earlier. The other channels are large: one particularly well-exposed channel at Burnt Lands (locality 8) measures 12-15 ins. deep and some 15 ft. in width and is exposed in cross-section on both sides of the road (fig. 21). The channel is cut into thin-bedded quartzose calcisiltites and numerous large (up to 24 x 6 ins. in cross-section), quite angular, tabular blocks of the eroded bed are found close to the flat, but slightly irregular, channel bottom. The sides of the channel are steep (70°-90°) and irregular, suggesting a considerable degree of lithification in the eroded unit. The infilling and probably the scouring material is a coarse bioclastic calcirudite - of typical lower Rockland lithology - restricted to this channel and the overlying 12 ins. bed, and containing uprooted heads of <u>Lyopora</u> together with large limestone intraclasts. The channel axis lies due north-south, but since such axes can rarely be measured, no conclusions can be drawn. Although large-scale, this feature is quite typical of such isolated channels in the Chaumont. They are so infrequent that little inference can be made, but they do indicate that, at times, powerful currents were operative. From their geographic and stratigraphic occurrence, they may well be related to the development of the lower Rockland calcirudite shoal facies.

b) Spur-and-groove channels

These structures are exposed only at Pine Valley (locality 2), and are located in a single bed high in the Chaumont. They are shown in Figs. 22, 23, and Fig. 3 illustrates their paleogeographic relations. A description and interpretation of these structures has been published recently (Barnes, 1964, MS) suggesting that they are a spur-and-groove system developed on a shallow sloping shelf by the undertow, and possibly rip-currents, within the breaker-zone. Thus, these structures are of value as indicators of environmental and paleogeographic details.

5) Mud-cracks

Desiccation cracks are not found in the Chaumont, but shallow cracks are known in the calcilutites and shales of the Lowville beneath. They are frequently very well developed and commonly measure 3-9 ins. across the polygons.

6) Borings

Some structures occur in the Chaumont limestones which appear to be more extreme developments of the "bored" discontinuity surface. Whereas the latter feature is restricted to the top few inches of a bed, these are more extensive down within the bed (fig. 24). They are seen as an intricate network of two types of carbonate, one more coarse-textured than the other. The boundaries between these two types are sharp and islands of one kind can be found floating in the other. They are very similar to structures described by Beales (1956) and attributed to worm burrows, and to the pseudo-breccias of Bathurst (1959) which are developed by partial recrystallization of the carbonate. Thin-section studies of a few of these structures show them to be petrographically comparable to the infilling material of the "bored" discontinuity surface. These are described in detail in Chapter 4, but suffice to say that they are composed of a considerable amount of bituminous material with minor skeletal debris, both cemented with sparry calcite. Rarely, most of the area is filled with a host of dolomite rhombs. Such structures are not very common and generally occur in beds less than one foot in thickness.

These structures probably originated through some form of burrowing activity. The geometry of the beds and the interrelationships between the two carbonate types (particularly the sharp boundaries) preclude the possibility of either slumping or mixing by organisms of two beds of different carbonate type. They are also clearly not formed by processes of recrystallization. The geometry, relatively loose initial packing, and the abundant bituminous matter suggest that these were burrows. The bituminous material may have been derived from the decomposition of fecal pellets to form mucus (see e.g. Folk and Robels, 1964). It is noteworthy that there is no appreciable quantity of pellets or intraclasts. In some borings near the upper surface, there is an alignment of the fossil allochems which would not suggest a fecal origin. Some of the material may merely be associated with a diastem, having been washed into the burrow system, other material may have suffered conversion in passing through the guts of organisms.

7) Load and differential compaction surfaces

The lower bedding surfaces of some limestones are rather irregular, being somewhat bulbous with a relief of an inch or so. These irregularities occur above shale beds of 1-2 ins. in thickness and, in part at least, are interpreted as load cast features. They are small and are never extensively exposed and show no preferred lineation. Other surfaces are best explained solely by differential compaction of the shale, often over an irregular upper surface of the underlying limestone bed. The thin shale beds are thus of slightly irregular thickness; these features are not noticeably developed over shale beds less than one inch thick.

3. Structures within beds

Several types of these features are present; worthy of note are shale laminae, internal bedding, contraction stringers, and chert nodules. Burrows and allied structures will be considered in a later segment of this chapter devoted to biogenic remains.

a) Shale laminae

These are concentrations of argillaceous matter, usually between 1/16 and 1/8 in. thick which have an irregular surface, frequently discontinuous. Within the calcarenites, they are well developed and invariably present. They are thicker, with less irregular surfaces, and more poorly developed in the calcirudites, and rare within the calcilutites-calcisiltites.

In some calcarenitic units, the laminae are spaced as close as ½ in. apart. Numbers of them may be fairly equally developed; elsewhere, when few in number, they are somewhat thicker, more pronounced, and more persistent laterally. In any one unit, the concentration of laminae is quite constant laterally.

The individual laminae are typically undulating, with an average relief in the order of ½-2 ins. over a lateral distance of a yard. On fresh surfaces, the laminae are irregular, even within a very small scale, and thin sections reveal that some have almost styloliti c relief. When traced laterally, most of the laminae pinch out rather abruptly (see figs. 19, 26), with the carbonates beyond showing no sign of a break at that particular level. In a vertical section, some bifurcate laterally.

When present in units that contain changes in microlithology, cross-lamination, etc., it is apparent that the laminae are original bedding surfaces, whose irregular nature is not due to post-depositional changes. It is possible, however, that a minority of the laminae have become irregular through the disrupting activities of burrowing organisms.

In thin-section the laminae appear as fairly homogeneous, bituminous units with considerable surface relief. They contain concentrations of non-carbonate detrital grains e.g. quartz, mica, in greater proportions than the adjacent carbonate. There is no field or petrographic evidence, however, of solution or corrosion of the carbonate to produce these laminae through concentration of insoluble residues, nor should they be regarded as stylolites.

If solution were not a factor in causing the concentration of argillaceous matter into these laminae, then it must be presumed that they were formed by a) an influx of such material periodically, b) periods of non-carbonate deposition, or c) some means of collecting drifting clay and silt particles. The main feature of their morphology that is not easy to explain is their abrupt ending with no sign of any sedimentation break in the surrounding sediment. Explanations a) and b) require some form of current or wave activity to concentrate this material into patches, yet within the areas of concentration to cover completely and uniformly the rather irregular bottom surface. Another explanation suggests that certain irregular patchy areas of the sea floor, particularly during periods of slow or arrested deposition, were covered by a tacky organic mat, especially planktonic micro-organisms. This covered all the irregularities and trapped any detrital material washed by in suspension. Thus, a concentrate of argillaceous matter formed over patchy areas, reproducing the intricate surface of the substrate. The presence of organic material explains the bituminous nature of the laminae. Such areas of sticky organic debris have been observed on the present carbonate sediments of the Bahama Banks (Newell _et_. _al_., 1959, p. 220).

The above hypothesis also explains the variations of the laminae with lithology. Thus, the relative scarcity in calcilutites is a reflection of the lack of organic material in these areas of probable high salinity and/or the lack of currents capable of bringing in sufficient quantities of argillaceous material. Calcirudite accumulation is unlikely to allow areas of such organic material to remain exposed for any length of time or without later reworking of the sediment. The model environment, however, would be that of the intermediate calcarenites where the rate of deposition was less, ample organic matter was present, and the currents were weak enough to prevent wholesale reworking and shifting of the sands, but strong enough to bring in fine argillaceous matter. Here, there was no apparent break in deposition in the areas of carbonate sands not covered by the organic mat that can be observed after lithification.

The theory of an organic trap is appealing, logical and explanatory, but is without conclusive evidence. There is, of course, no need to call upon a sticky mat to trap the argillaceous sediment. Presumably the same effect could be produced by the baffle-action of marine "grass" (Ginsburg and Lowenstan, 1958, Newell _et_ _al_. 1959, Beales, 1963); this was not present during the Ordovician, but other marine plants no doubt played an important role in sediment-binding. One such type could have been a mat of algae, comparable to those producing stromatolites, but trapping only a single layer of sediment before death (e.g. see Black, 1933; Ginsburg, 1960). This too could explain all the sedimentary features of the laminae, but, unfortunately, none of the above suggestions can be conclusively shown to have given rise to the laminae.

b) Internal bedding

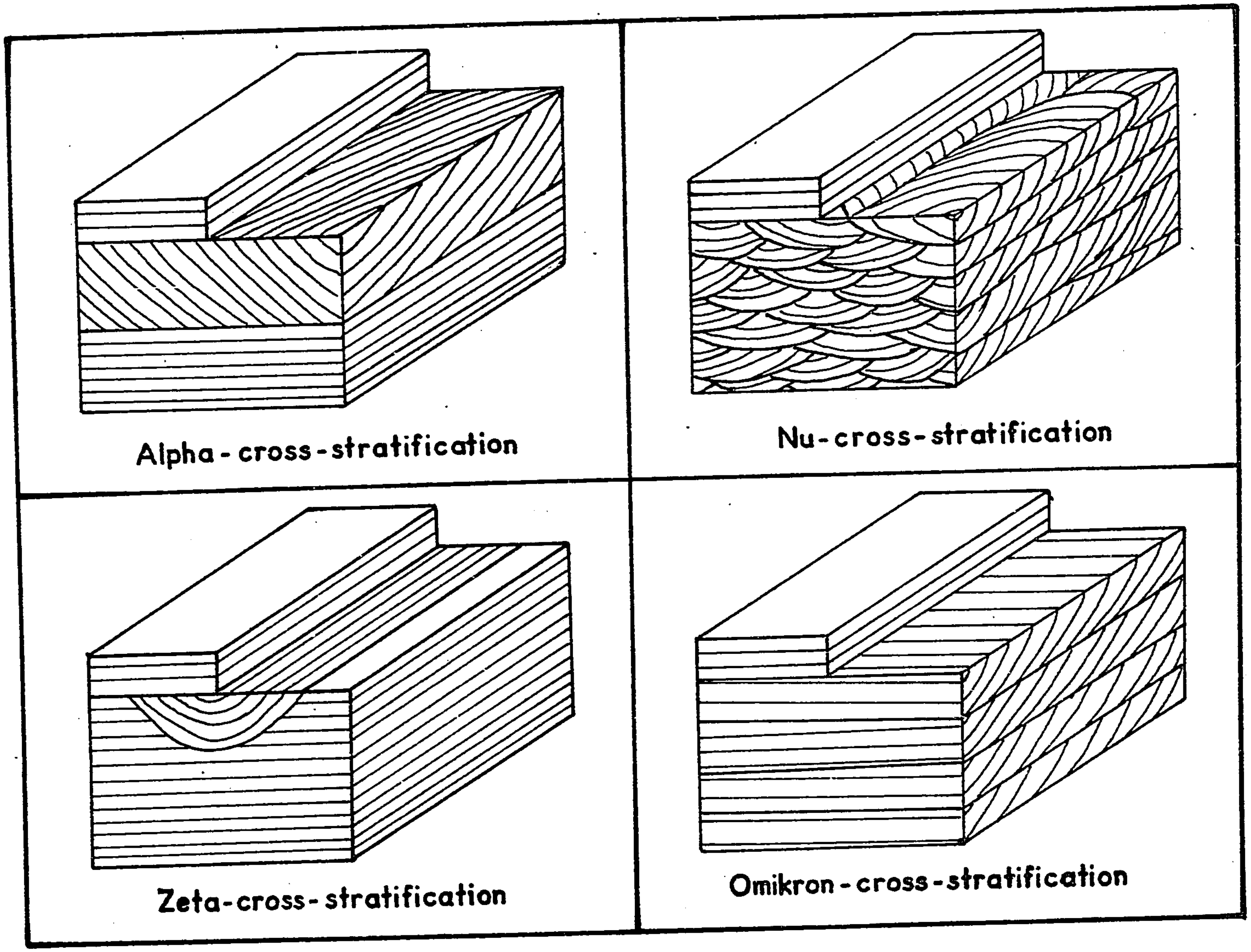
Most observed types of internal bedding are clearly associated with particular lithologies and many have a definite stratigraphic and environmental position and significance. The sections were too widely spaced and too poorly exposed to allow the recording of worthwhile current data.

McKee and Weir (1953) introduced a standardized nomenclature of cross-stratification, which was widely used, but has recently been redefined by Allen (1963). Allen's classification has genetic connotations, some of which seem to be applicable to these limestones. Several of his cross-stratification types necessitate a three dimensional view of the structures, which is unfortunately rarely available with the Chaumont limestones. The morphology of the cross-bedded units is described below and the environmental implications are considered in Chapter 5.

a) Alpha-cross-stratification (Fig. 2) (see Allen, 1963,p.101)

Similar cross-bedding occurs in the Chaumont, but is never large-scale. The solitary sets are almost invariably about 2-6 ins. thick (see fig. 26). They occur either as individual beds separated by shale laminae or within a bed, in which case the limits of the set are still distinct and well defined. The lower bounding surface is non-erosional and the sets are lithologically homogeneous. Within the sets, the individual carbonate laminae rarely exceed ¼ in. in thickness and commonly are between 1/16 and 1/8 in.; the laminae boundaries are not sharp and details are only visible after prolonged weathering. The laminae dip at low angles and apparent dips are frequently in the order of 5°; maximum dips reach up

FIGURE 2: Main types of cross-stratification found in the Chaumont and lower Rockland (from Allen, 1963).



Alpha-cross-stratification

Nu-cross-stratification

Zeta-cross-stratification

Omikron-cross-stratification

FIGURE 2

to 25°. The dips, however, are commonly less than 5° and the sets are often horizontal to sub-horizontal over tens of yards in outcrop. Although the horizontal sets are technically not cross-bedded, they are clearly part of a unit that is so in part, and which is lithologically alike throughout. The cross-laminae never seem to show curved surfaces of the laminae interfaces, and the sets are remarkably constant in thickness wherever exposed.

The carbonate type associated with alpha-cross-stratification is also very constant. Typically it is a fossiliferous pelsparite. Normally the estimation of biogenic content is difficult in the field, owing to the good sorting and the etched banding. The biogenic content is quite low, estimated at 15%-20%, the material is well sorted, abraded, and predominantly of shell debris. Pellets are abundant and form the rest of the allochems; these too show excellent sorting and rounding and are of fine calcarenite grade. Sparry calcite of medium crystallinity normally predominates, but grain growth appears to have occurred and so there may initially have been a higher proportion of interpelletal micrite.

Alpha-cross-stratification sets do not occur uniformly within the Chaumont. In the eastern region, they are rare, occurring only once or twice in a few of the sections examined. However, they become more numerous in the overlying Rockland. In the western region, they are equally infrequent in the lower Chaumont, compared to the same position in the east, but increase in abundance upwards. They are most abundant in a zone about three-quarters up in the Chaumont. This is well seen at Buckham Bay (locality 6), for instance, where between Unit 12 (at 18 ft. 7 in.) and Unit 20 (at 23 ft. 3 in.), exactly half of this intermediate thickness is composed of units, and partial units, exhibiting such alpha-cross-stratification. These units very rarely occur in the upper few feet of the Chaumont, where another type of cross-stratification predominates. They do, however, appear in the lower Rockland, becoming more abundant higher up when associated with finer-grained carbonates.

b) Zeta-cross-stratification (Fig. 2) (see Allen,1963, p.104)

This form is rather rare in the Chaumont and, unfortunately, a three-dimensional view is required for true appreciation of the geometry of the unit. As this is never seen, it is not positive that this is the type of cross-bedding involved. It is possible that, at times, iota-cross-stratification or even theta-cross-stratification (see Allen, 1963) are developed. However, from those observed it seems most likely that the bodies are elongate trough infillings of extensive axial length and thus show zeta-cross-stratification.

The sets are petrographically identical to those of the alpha-cross-stratification type, the main difference being that these sets occupy eroded troughs. The laminae appear to be predominantly concordant, but oblique sections through the troughs, providing only two-dimensional views, do not allow accurate determination.

Although normally associated with the alpha-cross-stratification, zeta-cross-stratification is much rarer, and can only be expected with some certainty to occur in the zone of fairly abundant solitary sets of alpha-cross-stratification i.e. at about two-thirds up in the Chaumont of the western region. Close association in relative abundance, together with the similar lithologies, suggests a fairly close genetic relationship between these two types of cross-bedding. The size of the troughs is somewhat variable, but they are normally wide and shallow with no steep sides; one trough, for instance, measured three feet wide and six inches deep.

Distribution of alpha- and zeta-cross-stratification within the Chaumont

The area can again be considered on a regional basis. To the east, both types are rarely found in the Chaumont. Of the sections studied, four beds were found in limestones that seemed certain to be Chaumont. In some sections, where the boundary problem with the Rockland is particularly troublesome, the descriptions of units was carried up into beds that are almost certainly Rockland. If these are considered, the number jumps to fifteen observed sets. In known lower Rockland elsewhere, these were observed to be more plentiful, but the details were not recorded. There is, therefore, a sharp increase in the number of these sets in passing from the Chaumont into the Rockland. In further considering these fifteen, two occurred as separate beds and the rest within larger units; of this latter group, seven are located at the top of their respective units and six at various levels within the unit, none formed the basal bed. All fifteen were in the order of 3-6 ins. in thickness. Occasionally, the base of these sets is an irregular surface - either erosional (then more correctly termed gamma-cross-stratification) or an irregular, but non-erosional depositional surface. Normally the sets are discrete and have distinct bounding surfaces, but occasionally they may be gradational upwards i.e. from horizontal and sub-horizontal laminated units into non-laminated calcarenites. Zeta-cross-stratification is even more rarely found, although it occurs in several units in the rather anomalous section at Perry Road (locality 10), where three sets reach maximum thicknesses of 9-12 ins. The individual sets are not sufficiently abundant to be correlated from section to section, but it is very doubtful that such thin units, which are frequently seen to vary in thickness and sometimes to wedge out, extend over a distance of a few miles.

c) Nu-cross-stratification (Fig. 2) (see Allen, 1963, p. 107)

Present exposures encountered do not allow precise allocation to one of Allen's subdivisions. It is generally difficult to distinguish between nu-cross-stratification and pi-cross-stratification, although the former is small-scale (i.e. less than 5cms.) whereas the latter is typically of large-scale.

Nu-cross-stratification is found in compact platy beds, invariably less than 9 ins. and more commonly between 3-6 ins. thick. Fairly constant in their thickness throughout an outcrop, several beds generally occur together to make a fairly uniform unit. The sets are composed of laminae 1/8-1/4 in. thick which are convex downward and each set is truncated by usually at least two curved basal erosional bounding surfaces of other scoops or troughs. Apparent dips reach up to 20°-25° but are very variable.

The carbonate type associated with nu-cross-stratification is usually a biopelsparite or pelletal biosparite, infrequently of rudite grade. Biogenic debris is abundant, poorly sorted, abraded, frequently shows signs of incipient silicification and is aligned parallel to the cross-stratification. Pellets are only moderately to poorly sorted and are less abundant than fossil allochems; aggregate lumps may also be present, but are less than 10% of the total allochems. Sparry calcite occurs, but in places is less abundant than the granular mosaic that appears to have developed through grain-growth of micrite. The banding is usually reflected in a segregation into biosparite (fossils and true sparry calcite) and biopelsparite (fossils and pellets with predominantly granular cement). Many, and often the majority of the fossil allochems, and also rarely intraclasts, show recrystallization of the internal calcite to a coarse granular texture, but seemingly never completely obliterating the outline of the allochem.

Within each bed the pattern of interfering troughs is fairly constant. The usual width of these is about three inches and the thickness about a third of their width.

Distribution of nu-cross-stratification in the Chaumont

This type of cross-stratification, and those with which it could be confused, are not found to the east of Carp. They are best developed at Buckham Bay, Fourth Chute, and Pine Valley; although not observed at either Clay Bank or Meath Hill, they may occur in the unexposed parts of the upper Chaumont at these localities. In occurrence, they are restricted to the upper five feet or so of the Chaumont, generally concentrated in one or two units that may be in the order of 12-24 ins. thick. Thus, they lie stratigraphically above most of the alpha-cross-stratification units and below the lower Rockland calcirudites.

d) Omikron-cross-stratification (Fig. 2) (see Allen, 1963, pp. 108, 110)

This cross-bedding type is not present in the Chaumont, but occurs in the lower Rockland calcirudites of the western region. Since these are an integral part of the facies pattern, these structures will be described here.

The beds under discussion are thick, compact, lithologically homogeneous, and are the coarse-textured calcirudites seen for example at Clay Bank, Fourth Chute and Pine Valley, and not the typical Rockland calcarenites that in places (e.g. Buckham Bay) are interbedded with the calcirudite units. The internal stratification is only apparent after prolonged weathering and both horizontal and inclined stratification are present. In a two dimensional exposure, however, it is not possible to ascertain if the horizontal stratification is inclined at right angles to the face observed. Some cosets, normally containing only two or three sets, have a fairly consistant inclination and have the characteristics of the omikron-cross-stratification type. Individual sets are commonly 9-24 ins. in thickness. In any one quarry face, cosets of inclined strata are less abundant than horizontally to subhorizontally bedded units. The best extensive exposure of the lower Rockland calcirudites is the Bonnechere Lime Co. quarry near Eganville (see Kay, 1942, pp. 601, 604). In some cases, individual sets of inclined strata also occur which appear to exhibit alpha-cross-stratification, but again, it cannot be determined that the adjacent units are not cross-stratified if they exhibit horizontal internal bedding.

The sets exhibiting omikron-cross-stratification are rarely comprised of laminae, but of cross-strata of about ¼-1 in. in thickness which are usually ill-defined. The apparent dips are variable, but approach a maximum of 25°.

The typical carbonate types here are biosparudite and intrasparudite. Sparry calcite is wholly dominant as the cement and there is no evidence of any significant amount of micrite having been present. Of the allochems, fossils, intraclasts (aggregates) and pellets are present in variable proportions. The biosparudites are composed essentially of fossils - with bryozoans, algae, and shell debris predominating - with a few large pellets and/or intraclasts. There is frequently incipient silicificalcirudite units. The internal stratification is only apparent after prolonged weathering and both horizontal and inclined stratification are present. In a two dimensional exposure, however, it is not possible to ascertain if the horizontal stratification is inclined at right angles to the face observed. Some cosets, normally containing only two or three sets, have a fairly consistant inclination and have the characteristics of the omikron-cross-stratification type. Individual sets are commonly 9-24 ins. in thickness. In any one quarry face, cosets of inclined strata are less abundant than horizontally to subhorizontally bedded units. The best extensive exposure of the lower Rockland calcirudites is the Bonnechere Lime Co. quarry near Eganville (see Kay, 1942, pp. 601, 604). In some cases, individual sets of inclined strata also occur which appear to exhibit alpha-cross-stratification, but again, it cannot be determined that the adjacent units are not cross-stratified if they exhibit horizontal internal bedding.

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c) Graded bedding

A fairly uniform vertical change in particle size within a bed was observed at some localities in the Chaumont. Overall, this feature is quite rare and seems to be mainly restricted to the thick calcarenite beds or, more rarely, to the beds showing horizontal lamination and/or alpha-cross-stratification. In the graded calcarenites, the visible allochems - mainly biogenic debris - were most frequently coarser and more abundant in the lower parts, grading up over one or two feet into fine and sparsely distributed allochems. A reverse sequence was noticed once or twice. In the graded laminated units, the few beds exhibiting this showed a change over a few inches into typical calcarenites.

All these types of graded beds seem to indicate a gradual, but fairly uniform, change in the energy environment and do not suggest a sudden influx of material with rapid settling of the coarser fraction first, as is characteristic of many greywackes. The environment of deposition of these carbonates would also favour, almost exclusively, the former mode of formation. Because of the lithologies associated with the graded units, they are very rare in the western region and rare to infrequent in the east.

d) Contraction stringers

Within some of the calcilutites in the Chaumont of the western region are small lenses of sparry calcite (see fig. 13). These are usually between ½-1 in. long and 1/16-1/8 in. wide and are invariably aligned normal to the bedding. They may show slight irregularities but are essentially thin and lenticular, dying out at either end, and are filled with pure sparry calcite producing sharp contacts.

These are not known to be allied to mud-crack surfaces since no visible surfaces exist, they are few in number and can occur at varying positions, and they pinch out at either end. It is possible that the channels - later to be filled with spar - were burrows, but this seems most improbable. The most plausible explanation that the features were formed as tension or contraction cracks during the elimination of water from the lime mud. They only occur in carbonate muds and silts and are not infrequent in the Lowville strata. At what time this operated during the processes of lithification and diagenesis and when the growth of sparry calcite occurred cannot be determined. These cracks are too infrequent, too small, and different in shape to be regarded as "birdseyes" that are well developed in the New York Lowville (Raymond, 1931) and which may well be burrows ("_Phytopsis_"). The vertical nature suggests some form of dehydration process rather than pure compaction. Another postulate for this type of structure has been that the spar has infilled channels that were the escape routes of interstitial water (Illing, 1959). No conclusive proof can be deduced for any one of these suggestions.

e) Chert and silicification

1) Chert

Chert occurs in the Chaumont as nodules, very rare in the eastern region, but in the western region, they are more common and usually occur in preferred beds and are not uniformly scattered throughout the formation. The nodules are of dark grey to black, badly weathered, cryptocrystalline chert, rather irregularly shaped, but with rounded surfaces (cf. "exotic potatoes"), usually averaging 1-4 ins. across. In the Chaumont of the western region, they occur in calcarenites but are also observed in cross-stratified units and their relationships here clearly indicate a replacement origin. They are most commonly found scattered throughout units which are more plentiful in the upper part of the formation. It should be stressed, however, that chert is a very minor, almost insignificant, part of the limestones.

Within the megagroup, chert is only common in two formations; the Lowville and more particularly the Hull. The greater occurrence in the Chaumont of the western region would seem to be partly controlled by the proximity of the calcirudite facies, for chert is associated with a somewhat comparable facies in the Hull. Thus, whether the presence of chert is controlled by porosity and sedimentary facies, by organic and biochemical processes, or by some other factor, cannot be determined at present. The relative abundance in both some calcilutites and some calcirudites may reflect a polygenetic origin and would be worthy of a detailed study.

2) Silicification

Silicification of fossils occurs in the upper Chaumont and lower Rockland of the western region. In the Chaumont it is quite rare with bryozoans,algae and corals particularly susceptible. Silicification is more apparent in the lower Rockland and in the calcilutitic Paquette Rapids Beds (Rockland?). Such replacement is often incipient and cannot be recognized in hand specimen; in thin section, however, it is very apparent. Algae are the most susceptible, the silicification proceeding along the internal structure but eventually obliterating all trace of this. The central portions of the algae are generally the first zones to be replaced and porosity may well be an important factor involved in this process.

Thus, the presence of chert and silicified fossils is only conspicuous in the western region and seems to be related to the development of the lower Rockland calcirudites. Their occurrence in the Lowville, being more widespread and lower stratigraphically, may be controlled by other independent and unknown factors. The decomposition of orthoclase felspar to give kaolinite and free silica (to form chert) has been considered the cause of chert formation in the sub-Trenton rocks of the Cincinnati Arch area by Calvert (1964) and this could perhaps be one factor.

4) Biogenic remains

The nature and effect of contemporary organisms was noted whenever possible during field work, but only the conodonts have been studied in detail. The considerable work of Wilson on the paleontology of the megagroup has been published in the G.S.C. bulletins referred to previously. In most of these, however, the "Leray" and Rockland fossils were treated together so little of direct use can be incorporated here. Some phyla may contain certain diagnostic forms in the Chaumont, but detailed research, with tight stratigraphic and facies control, is required to discover this. Reference must be made to the work of Kay (1937, 1942) who leant heavily at times on the paleontological record and gave faunal lists of the Chaumont and Rockland from several places.

The fossil record in the Chaumont presents three main assets to the current study. It provides an idea of the biological associations of the conodonts, useful indications of the environments, and is a valuable criterion for estimating the grade size of the allochems within a unit. The various types of biogenic remains will be considered and also their relation to the three broad groups of carbonates; the calcilutites, calcarenites, and the calcirudites.

a) Incomplete fossils and fossil debris

1) General

As stated previously, fossil debris is of value in determining the allochem grade size and sorting. The latter factor is difficult to assess in beds of low biogenic content or of fine grain size, but becomes progressively easier with an increase of these. Under the term fossil debris is comminuted biogenic material which cannot be readily recognized as belonging to a particular phylum. The single main exception to this is crinoid ossicles, which are recognizable fragments of the original complex organism. These seem capable of withstanding extensive transport without significant abrasion.

In considering this debris it is necessary to attempt to discover how this abrasion and breakage took place. There appears to be only two main factors involved, both of which could have operated at once, or at least prior to fossilization. These are (i) mechanical abrasion and breakage and (ii) partial destruction by organisms. It is not possible from the type of fragments to ascertain which of these two caused the breakdown, but a consideration of the enclosing sediment in some cases favours one of them. For instance, debris "floating" in a calcilutite matrix is likely to have arrived at that state through disintregration by the activities of benthonic or burrowing faunas. Such disintegration has been touched upon in several publications (e.g. Ginsburg and Lowenstam, 1958). Likewise, debris in a cross-stratified calcirudite, which may also contain disrupted coral masses, is likely to have become abraded through mechanical agencies with relatively little organic interference. In general, however, the effects of both micro- and macro-organisms are probably always present, whereas those of mechanical destruction seem to be almost eliminated in some environments, but, conversely, greater developed in others.

These two factors are also dominant in determining the ultimate distribution of the debris within a bed. Constant vigorous turbulence can cause winnowing and good sorting of debris, whilst intermittent current action can result in a heterogeneous distribution. Likewise with organic activity: extensive burrowing will completely homogenize a bed in time (Ginsburg, 1957), whereas incomplete turnover or the variable activities of bottom-dwelling destructive organisms will give rise to a heterogeneous distribution.

2) Debris in calcilutites:

Debris here is frequently scarce, poorly sorted, with little definite orientation; normally it consists of a few large shell fragments floating in the matrix, together with rather more common, much smaller, debris of fine sand to silt grade. In some cases, there may have been extensive reworking of the sediment by burrowers. Occasionally, a unit will have a rather high biogenic content despite the presence of a calcilutitic matrix. Here the debris, predominantly shelly, shows alignment parallel to the bedding with the convex sides of the more complete shells oriented upwards. A probable explanation is that certain areas of the lime mud environment sustained quite dense populations, perhaps on areas of lithified or rocky bottom, which during isolated storms were strongly abraded and spread out over the surrounding ooze. Such storms would be unlikely to remove much of the fine sediment taken into suspension, which would later settle into the interstices between the shell debris.

3) Debris in calcarenites

Biogenic debris here is generally fairly abundant and only very rarely absent. Typical estimated percentages would be in the order of 25%-40% of the total rock, but ranging from less than 5% to coquinal. The debris is normally quite evenly distributed throughout a bed and tends to be rather poorly sorted except in those units with a biogenic content exceeding 60% which are well sorted coquinal beds. Many units, particularly in the eastern region, and in beds well laced with shale laminae, have the debris partly evenly distributed and partly concentrated in pockets. There is no obvious explanation for this as there is little structural evidence within the beds themselves. Many pockets, however, are located close to the steep slope of a rise in an irregular shale lamina . This may indicate that these are concentrates in hollows or irregularities on the old sea floor, many of which may have persisted in one position during the deposition of an inch or so of sediment. Most, if not all, of the pockets could be explained in this way, but owing to the lack of much positive evidence, other unknown factors may have also played a significant role.

Only rarely (e.g. in the alpha-cross-stratified units) does the biogenic debris exhibit any geometric distribution pattern. Considering the amount of recognizable fossil material within the beds, it is surprising that there is not more debris visible. It seems most likely that the debris is constantly being reduced in size eventually to become unrecognizable as fossil material. This too is consistent with modern processes, where other biological agencies in particular persistently attack such material at or just below the sediment-water interface. It is pertinent to question to what extent mechanical or biological agencies are important in the breakdown of biogenic material. If the biologic influences predominate, it is invalid to use this criterion for the determination of the type of energy environment. From a consideration of modern processes, the distribution of the debris, and of the other sedimentary features (e.g. amount of micrite, degree of pellet sorting, etc.), the writer feels that in the "Ottawa-type" calcarenites the biological effects are often more important than mechanical breakdown. Only in the units showing high biogenic content (over 50%) and those showing associated features of transportation (e.g. cross-stratification) do the mechanical effects probably exceed the biological.

4) Debris in calcirudites

Organic material here is normally very abundant, generally exceeding 50% of the total rock. Although sorting is usually good, that of the coarser calcirudites is often quite poor. The reasons for such abundance are fairly clear. The sediment type (see interpretation, Chapter 5) probably represents a high energy shoal area for the calcirudites of the lower Rockland. In such an environment, [illegible] life, particularly small algae, was prolific. The organisms were subject to mechanical transport and abrasion; since fine precipitated carbonate was continually swept into quieter environments, together with the "dust" produced during abrasion, the majority of the material of rudite grade was biogenic debris.

The calcirudites occurring as isolated units appear to have been formed mainly through a sudden reworking and transportation of surface sediments, with a winnowing of the finer material and a concentration of the coarser, and predominantly biogenic, material. In these units sorting is generally good and biogenic content frequently averages 55%-65%.

The associated sedimentary features indicate considerable mechanical transport and presumably this process predominated over the biological agencies in the breakdown of debris. However, even an approximate relationship between the two is impossible to estimate with confidence.

b) Burrows and related structures

1) General

Trace fossils and evidence of burrowing are fairly common features in the Chaumont, (see fig. 24) but exposures are not suitable for revealing their three dimensional pattern. They are generally seen in cross-section as irregular infillings of a different carbonate type to the host rock and are usually circular to subcircular, linear to random burrows, about $\frac{1}{2}$-$\frac{3}{4}$ in. in diameter.

The carbonate type filling the burrows is usually coarser than the host rock and of higher biogenic content; there is considerable variation, however. Upon weathering, the burrows usually adopt a sandy colour and appear to be somewhat more soft and friable than the surrounding carbonate and stand out in low relief. In some cases, it is difficult to distinguish true burrows from irregular channels associated with discontinuity surfaces. Occasionally the infilling sediment bears no resemblance to either the host rock or the overlying unit and the infilling deposit was probably derived from a shifting train of ripples.

Burrows are rare in calcilutites, calcirudites and cross-bedded strata, but frequent in calcarenites and especially calcisiltites. Thus, they are common in the eastern region, particularly in the lower seven feet or so where they are invariably present. They are common in thick massive units and rare in thin beds; in some of the lower Chaumont beds the burrows are estimated to form up to 10%-15% of the rock.

The action of burrowers, in particular worms, has been generally overlooked despite several studies (e.g. Dapples, 1938, 1942; Ginsburg, 1957; Moore and Scruton, 1957). Davison (1891; in Dapples, 1938, p. 58) estimated that lugworms (Arenicola) can eat as much as 3147 tons of sediment per acre per year which would clearly have a profound effect on the sediment and on internal structures, destroying many old ones and creating some new ones.

The burrowers appear, however, to have been few in number if their total burrowings are the ones observable today. Their effect on the sediment was considerable at times, but their overall effect on the formation is small. It should be noted, however, that the burrows are filled with a different type of material. Possibly certain sediment-ingesting organisms burrow through sediment and repack it without any noticeable significant change. In this case, such burrows could pass unnoticed. The shale laminae, however, are indications that such activity, was not extensive in most of the Chaumont calcarenites.

c) Complete fossils

1) Corals

Three main types of corals were noted to be significantly abundant and all seem to be closely controlled by the type of bottom sediment. With each one it is possible to see if the coral is still in a growth position.

First, the Tetradium group is important in both the Lowville and the Chaumont. The species that are abundant in the upper Lowville and which may occur in the calcilutitic beds within the Chaumont of the western region, are T. syringoporoides Ulrich and especially T. cellulosum Hall. These delicate elongate fossils are extremely abundant in the topmost Lowville bed throughout the region. Some are in the position of growth, but most seem to have collapsed to a horizontal or subhorizontal position, but rarely moved any significant distance from their growth location. A few thin beds occasionally reveal a fairly high proportion of transported Tetradium. The robust compact heads of T. fibratum Safford are only found in the Chaumont in calcilutites, calcisiltites, or more rarely, calcarenites. These reach over a foot in diameter and are frequently removed from growth position.

Winder (1960) suggested that these species groups of Tetradium are restricted to certain lithologies and that their occurrence is controlled by current and wave strength. Thus, the species grade from the single slender corals of the (Pamelia-Lowville) quiet lagoonal environments to the massive colonial forms in rough-water conditions. The writer has found this to be essentially correct, although the T. fibratum-bearing units do not seem to indicate such high energy conditions as Winder proposes for the Coboconk of S.W.Ontario. T. fibratum is common in the western region but much rarer in the east.

The second group of characteristic corals is those within the Lyopora-Calapoecia group. These occur as strong, robust colonies, usually between 6-12 ins. in diameter, being common in the west but less so in the east. In the western region they are particularly abundant in the calcirudites of the lower Rockland, but here nearly all have suffered transportation. They are almost non-existent in calcilutites, but frequent in the calcarenites, especially the coarser grades. Hence, they seem to favour a fairly high energy environment, but were apparently incapable of remaining permanently fixed in the environment represented by the lower Rockland calcirudites.

The third and least important group includes the solitary cup corals e.g. Lambeophyllum, Streptelasma. These appear to be almost entirely restricted to the calcarenites and are not particularly abundant; they are perhaps more numerous in the eastern region.

2) Brachiopods

Three main groups are reasonably prolific in the Chaumont and the environment probably strongly influenced their distribution as was recently found by Williams (1963) for some Caradocian brachiopods in Britain. They are not easy to observe since bedding planes are not well exposed.

The orthids (e.g. Plectorthis, Hesperorthis, Dalmanella, Doleroides, Platystrophia) are well represented and are probably the most numerous type. They are closely followed, however, by the strophomenids (e.g. Rafinesquina, Öpikina, Strophomena) which are generally large and reasonably well preserved. The third group, the rhynchonellids, is considerably rarer than the other two, but specimens are by no means uncommon. Typical representatives are Rhynchotrema and Zygospira.

Brachiopods are rare in calcilutites and are rather infrequent in calcirudites, but there is considerable shell debris in the latter and the relative absence of brachiopod shells could be due to post-mortem destruction. They are most readily observable in calcarenites, particularly the "Ottawa-type" and in the rubbly and shaly calcarenitic units of the western region.

Brachiopods are also the main constituent of most coquinal Chaumont units throughout the area. Their concentration in coquinal beds may indicate local areas of high brachiopod populations or they may have merely been concentrated by mechanical transportation.

3) Cephalopods

The Chaumont is characterized by the relative abundance of large endoceroids and actinoceroids which reach several feet in length. Within the megagroup, these are most numerous in the Chaumont, but they are not so abundant as to be of great value in the present study. They are commonly found in the calcarenites, but are not excluded from the other sediment types. Besides these two, the only other important group of cephalopods is the much rarer ascoceroids.

4) Gastropods, Trilobites and Bryozoans

All three are quite common within the Chaumont, particularly the calcarenites, but are generally poorly preserved or fragmentary. This is particularly the case with the trilobites and bryozoans and for the main types found see Wilson (1947) and Fritz (1957) respectively. Bryozoans are very rare in the calcilutites.

The gastropods (Wilson, 1951) are found in all lithologies and the most typical forms found in the Chaumont include Hormotoma, Lophospira, and Liospira. Maclurites occurs very rarely but is much more frequent in the Rockland, particularly the calcirudite facies. Probably the gastropods follow the type of facies control advocated by Winder (1960) i.e. high-spired forms occurring in quiet water conditions and planispiral types being more adapted to the high energy environments. The present study was not sufficiently extensive to confirm Winder's ideas on this point, but

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5) Algae and stromatolites

Algae, possessing preserved cellular structures, occur in the Chaumont, but are small and are not well seen in hand-specimen. In thin section, they are seen to be one of the important biogenic constituents in many samples, particularly some calcirudites. Thin sections also reveal that incipient silicification is common. The explanation for this early silicification is not apparent, although the porous nature of the algal framework may have aided in concentrating the silica. Whilst no attempt was made to identify the algae, those referable to a Solenopora-type were noted to be one, if not the, commonest variety.

Stromatolites are not abundant in the Chaumont and are almost entirely restricted to the western region. Normally, only occasional isolated specimens are found and are of little value, but one unit at Burnt Lands (locality 8) is prolific in these forms (fig. 27). The unit overlies 1-2 ins. of shale which may lie on a discontinuity surface, and is 60 ins. thick, of which the lower 25-30 inch subunit contains the stromatolites. The lithology is essentially of Lowville type i.e. medium dark grey, finely crystalline, pelletal calcisiltites, with a biogenic content (excluding the stromatolites) of 10%-20% which is of medium to coarse calcarenite grade. The unit breaks up into 3-4 in. beds along irregular shale laminae. The stromatolites are very abundant and occur at least every 6 ins. or so along the outcrop of the bed and range from 3-15 ins. in size. More than one type is represented and can be classified in the manner proposed by Logan *et al.* (1964). They are interpreted in the light of Logan's work (1961) on modern stromatolites in western Australia.

All the stromatolites are discrete, with no connecting laminae, and fall into two broad groups: a) vertically stacked hemispheroids composed of close-linked hemispheroidal laminae (see fig. 27), with the structural formula: $\frac{\mathrm{SH - V}}{\mathrm{LLH - C}}$ (see Logan et al., ibid, pp. 73-77) and b) concentrically stacked spheroids with laminae composed of close-linked hemispheroids, the structural formulae being: $\frac{\mathrm{SS - C}}{\mathrm{LLH - C}}$ (see fig. 27). The former are massive columnar units, widening vertically and exhibiting crude broad laminations or banding; these form the largest stromatolites. Members of the latter group are smaller and subcircular in shape. Most of the specimens seem to fall into the Mode "I" group (Logan et al., ibid., fig. 4), with very few, if any, in the other groups. A detailed study of all the stromatolites was not made, hence these comments are based on qualitative evidence only.

In the Chaumont locality, the vertically stacked hemispheroids seem to have given rise, by spalling and scaling, to smaller types. If fixed, these are destined to grow upwards into similar structures, or if moved about, will remain as concentrically stacked hemispheroids - the particular type depending on the degree of rolling and agitation. If this were the case, comments from Logan et al. (ibid., p. 80) on the environmental characteristics of similar types from Australia, may equally apply to those observed in the Chaumont.

They report that:

> "Discrete, club-shaped heads with SH - V arrangement are common in reef developments on headlands and locations where sea waves are moderate....The Shark Bay structures of this type begin from small pieces scaled off other mats and stromatolites during periods of desiccation. These scales are reactivated on the damp littoral substrate and become the nuclei on which hemispheroidal laminae are stacked with progressive sediment binding

> and upward growth....desiccation and induration is mainly at the sides and the tendency is therefore toward upward growth rather than lateral spreading. The stacking continues with binding of detrital sediment in the cap to maturity at a few inches above high water."

Commenting on the SS - I type, they state (ibid., p. 81) that:

> "Such structures may be formed by the spalling-off of the tops of SH stromatolites during storms. Some of these scales fall to the bottom in a concave upward attitude, and, if conditions are suitable, they will begin to grow into new SH structures. However if their renewed growth is interrupted by rapid sedimentation, they will be preserved as SS - I structures. It can readily be seen that a very close relationship exists between SH and SS structures of this type."

The Chaumont stromatolites seem to indicate similar conditions - shallow littoral environment with the growth of SH types, but with fairly vigorous wave action at times causing parts of the stromatolites to spall off. Depending on the persistence of this wave action and on the rate of sedimentation, these either developed into new SH types or into subcircular SS types, particularly the SS - I mode. The calcilutite matrix sediment indicates that vigorous wave action was by no means dominant. It is considered that a return to deeper water led to the disappearance of the stromatolites in the higher subunit.

6) Others

Other faunal groups are represented in the Chaumont by complete fossils e.g. echinoderms, ostracods, pelecypods, but are so infrequent that only their relative absence is worthy of note here.

CHAPTER 4

CARBONATE PETROGRAPHY OF THE CHAUMONT FORMATION

Carbonate studies have undergone profound changes in the past two decades. These have largely been associated with the extensive research on modern carbonate sediments, particularly on the Bahama Banks, and also with the increased attention, especially by R.L. Folk, given to the petrography of ancient limestones. However, an important, though narrowing, gap in our knowledge still exists in relating the sedimentary features of modern to ancient limestones (see Imbrie, 1964).

Little carbonate research has been undertaken on the Ontario and New York Mohawkian rocks. Beales (1958, 1963) has used some Black River units as examples and is currently concentrating on more detailed regional studies of these limestones. However, the only other study has been by Gillot (1963) who compared the petrography of some Pamelia dolomitic limestones from Kingston with a single Black River sample from the Ottawa Valley. Hence, virtually nothing is known of the petrography of the Middle Ordovician limestones in the Ottawa Valley and very little has been published on that of their regional correlatives.

As such work can produce valuable information on the sedimentary environments, the petrography of the Chaumont carbonates was investigated in the present study. This was mainly restricted to those details that would assist in determining environments and was not extended to attack fundamental petrographic problems. About 120 thin sections were used, all from samples that had in part been used for conodont studies. A few acetate peels and etched surfaces were examined, but thin section work was found to be sufficient and, in almost every case, far more informative.

The thin sections were taken from every sample of localities: 1, 2, 3, 8, 13, 14, 16, 17, and 24, together with some miscellaneous slides from special samples which were used to study a specific structure. As in the conodont study, the detailed petrography was based primarily on the 40 samples from the three most western localities. With this as a standard for the Chaumont, the petrography of the eastern area is briefly discussed. Certain common sedimentary structures were studied in thin section to shed more light on their origin and significance. In general, the terminology introduced by Folk (1959, 1962, 1964) is here adopted.

The limestones dealt with are clastic with no biohermal development. As with other limestones, their type is dependent on a) the allochem characteristics and b) the nature of the interstitial and cementing material. Allochems can be classified as: oölites, pellets, intraclasts, and fossils. In the Chaumont units, no oölites are found and intraclasts are a minor constituent in comparison to the other two. The material between the allochems is likewise variable: microcrystalline calcite (micrite), sparry calcite (sparite), or either of these can have undergone recrystallization (neomorphism) to form microspar or a coarser variety of neomorphic calcite. Finally, the limestones may show very minor degrees of dolomitization or silicification. The details of all these components are treated separately below and are then related to the broader rock terms and subdivisions described in Chapter 5.

The quantitative analysis of the 40 samples from the three western sections is given in figure 5. This shows the relative abundance of both allochems and matrix and cement, and hence the carbonate rock types.

ALLOCHEMS

a) Skeletal grains

The proportion of skeletal grains in the Chaumont limestones under discussion varies considerably from almost nil in some micrites (F.9), pelmicrites (M.-3), and dismicrites (P.V.11) to become by far the most dominant allochem in others (e.g. M.4). In general, the amount of such material averages for the same sample about 20%-45% (visual field estimate) or 10%-30% (point-counted).

The proportions of individual fossil groups varies considerably from sample to sample (cf. Stauffer, 1962), but a quantitative study has been attempted only with the conodonts; general comments are included below for the other groups. Generalizations can be made on the relationships between skeletal grains and the other allochems. In pelletal samples, fossil material is usually the secondary grain-type; with intraclast-bearing samples, however, fossil debris sometimes assumes the dominant role, especially if one were to include the skeletal material incorporated within the intraclasts.

The very nature of thin section work precludes satisfactory assessments on the extent of skeletal breakage. Studies of present-day environments have revealed the extensive role of organisms in the breakdown of skeletal material (e.g. Hoskin, 1963; Klovan, 1964, p. 26). Consequently, an extremely careful and detailed analysis would have to be made to determine the exact roles of organic and mechanical processes in this breakdown.

A more reliable parameter for determining ancient environments is the relative proportion of micrite and spar between the allochems. In high-energy environments, the micrite is washed away leaving ample pore space to be occupied by sparry calcite. There are exceptions to this, but in general this relationship has been shown to exist in many geological situations (e.g. Folk, 1959; Cronoble and Mankin, 1963). The variations in micrite, sparite, and neomorphic material are also presented in figure 5.

The articulation of bivalve shells is infrequently observed; these shells are, as expected, always restricted to the poorly washed limestones (fig. 36). However, the action of other organisms must be recognized as a factor in this disarticulation process. Those that are still joined together are generally entirely filled with micrite or other surrounding matrix material. Sometimes, the interior is filled, or partly filled, with spar indicating a pre-existing void (fig. 36).

Johnson's work (1951) has been of great value in the recognition of invertebrate skeletal remains in thin section.

1) Algae

Two algal types can be distinguished in thin section: a stromatolitic alga and a Solenopora-like form. The former is long, thin, probably sheet-like, exhibiting a crenulated fine internal banding of light and dark calcite. It may represent a small stromatolite, but the banding is of very small scale. Such algae are particularly susceptible to silicification; they are never completely replaced and the silicification proceeds along the line of lamination. The long slender shape of these forms does not allow close-packing and they often form ceilings over now spar-filled voids. Their distribution is noteworthy for although they occur infrequently in poorly washed samples, they are common in biosparudites and biointrasparudites. Here, they are in association with bryozoans and bivalves (probably brachiopods), with occasional crinoid ossicles. They are also very susceptible to inclusion within intraclasts.

The Solenopora-like algae have a simple cellular nature, readily distinguished from the bryozoans. Rarely silicified, they are infrequent in carbonates other than biomicrudites and biopelmicrites. However, they still tend to have a close association with a bryozoan-bivalve fauna.

2) Bryozoans

Bryozoans are very common in the more fossiliferous samples, their distribution being particularly confined to biosparudites, biointrasparudites, and biomicrites. Hence, they are a dominant part of nearly all richly biogenic samples, but are much rarer in pelletal limestones or in those which are poorly fossiliferous. Their internal chambers and pores are filled with clear spar while, a few, when sectioned close to the apertures, are mud-filled. The bryozoans are usually fairly complete, somewhat less susceptible to silicification than the stromatolitic algae, and are normally associated with rich, quite varied, faunas especially with bivalves and algae. In most of these assemblages, the bryozoans are the dominant group, at least volumetrically.

3) Bivalve shells

This group includes brachiopods, pelecypods, and ostracods and debris that appears to have been derived from these. Three main types of internal structure are present. One type has a distinct, sharp, outer surface with a thin zone of structureless microcrystalline calcite adjacent; a similar zone may be present on the inner side. The main bulk of the shell, however, is composed of a rather vague fibrous structure, perpendicular to the shell surfaces. A second type has an essentially uniform make-up with structureless microcrystalline calcite throughout, with rarely a thin "skin" of the same material. Finally, the shells may again reveal an outer "skin" of microcrystalline calcite, but the rest of the shell is converted to sparry calcite. In some cases, the whole shell is replaced by coarse calcite; a fine drusy mosaic against the sides passing into coarse spar in the central parts. Often, the inner surface of such shells becomes indistinct since the spar merges into that filling an adjacent void. Whether these three forms of internal make-up are a reflection of taxonomic differences is not known. All three can be found within a single thin section and all are probably the result of neomorphic changes of the original structure, and perhaps represent a continuous sequence leading to a replacement of the whole shell. Those types which show the most extensive neomorphism are perhaps more common in the samples in which sparry calcite predominates, but are by no means excluded from the micritic units.

When still articulated, some shells are only partially filled with detritus, the pre-existing void now being occupied by clear spar (fig. 36). Beales (1964) has warned against assuming that all spar indicates pre-existing voids, but in these instances there seems to be no doubt.

Shell material was never observed to be affected by silicification. It commonly forms a ceiling allowing the preservation of spar-filled voids. Such shell material is common in all fossiliferous samples and seems to have little marked preference for a particular microfacies. It is seemingly subject to breakage more than most skeletal groups, consequently it is difficult to assess the role of the shell-bearing organisms in the various microfacies. One carbonate type, however, does seem to have considerable skeletal debris with very little other biogenic material; this is the intrabiosparite , which is a comparatively minor carbonate type (e.g. F.3)

4) Tetradium

Few samples in the three western sections contain Tetradium. This genus is always restricted to micrites and besides minor shell debris, there are very few other associated fossils. The walls of the coral are converted to a drusy mosaic with coarser calcite towards the centre. The interstices of the skeletal framework are filled with micrite; the walls are sharply delineated and the characteristic cross-sections of Tetradium are clearly seen. No alteration of the skeletal calcite has been observed.

5) Crinoid ossicles

These are very distinctive in thin-section. The axial canal is always filled with the material of the surrounding sediment, which is most commonly pelletal, although this is sometimes more loosely packed with a higher proportion of spar or microspar. The ossicles were susceptible to silicification which has developed first in the central zone of the calcite ring. Restricted mainly to the upper half of the Chaumont where they are present in biomicrudites, biosparudites, and intrabiosparudites, the ossicles are common when associated with other abundant skeletal debris, particularly bryozoan and shell material. The ossicles exhibit syntaxial rim cementation with the surrounding spar.

6) Other biogenic material

Other fossil material present includes non-bivalve molluscan and arthropod debris, together with that of various corals. Unless these adopt a characteristic outline, their taxonomic position can rarely be ascertained. Further, they represent only minor constituents and a statistical study would be required to determine the significance of their stratigraphic distribution and main biological associations. Of those just listed, only gastropods commonly reveal their characteristic outline. Their shells have suffered the same neomorphism as the Tetradium walls; their interiors are normally filled with micrite, although a few seem to have a spiral column of spar, centrally located.

Summary

The identified biogenic remains are, in descending order of abundance: bivalve shells, bryozoans, indeterminate skeletal material, algae, crinoid ossicles, and Tetradium. Each type is most abundant in certain lithologies and often has definite biological associations. Because of biological and mechanical post-mortem effect, however, many probably do not represent natural biocoenoses.

b) Non-skeletal grains

These allochems can broadly be divided into the simple single grains (pellets) and the more complex compound grains (intraclasts). Since their formation is often intimately related to their environment of accumulation, their stratigraphic distribution and allochem associations are noted, together with their petrographic description.

1) Pellets

Folk (1959, p. 6) states that "The bodies are rounded, spherical to elliptical or ovoid aggregates of microcrystalline calcite ooze, devoid of any internal structure" and that they are characteristically well sorted, ranging in size from 0.03 mm to about 0.15 mm and normally averaging 0.04-0.08 mm. Herein, the size range is not regarded as a critical factor since if these pellets are of fecal origin, their size is dependent on that of the anus of the mud-ingesting organisms. Conversely, for this very reason rounding is regarded as characteristic. Markedly angular grains are best included with the intraclasts.

The Chaumont pellets lie in the size range of 0.03-0.2 mm and average 0.06-0.12 mm. They exhibit a high degree of both rounding and sorting (fig. 28); this is particularly so in the uniform pelmicrites, whilst in samples with a significant proportion of skeletal material the sorting factor, and often the rounding, normally decreases. In well-sorted pelmicrites, the grains do not appear to be overly lenticular; probably more than one basic shape exists, but certainly a notable proportion would seem to have a length:width ratio of less than 2:1.

In almost every pelletal sample, the allochems appear to be grain-supported and in those with a micritic matrix there is a high degree of packing. Some of the relatively pure micrites and dismicrites show a vague clotted nature (cf. Hadding, 1957 figs. 1b, 2) in which occasional unmistakable pellets occur. Although appearing to be mud-supported, it is possible that much of the mud material was initially pellets that have since collapsed or merged (e.g. Folk and Robles, 1964, pp. 273-274).

Pelletal units are occasionally laminated, which in thin section appear as slight changes in grain size and the type and proportion of cementing material. Small distinct areas of clear spar are also present at times in these samples, the origin of which may be organic (as, for instance, in many dismicrites), but seems more likely to be of later diagenetic origin in most.

Pellets are sometimes intermixed with intraclasts of a fine grade (fig. 32), but the coarse intraclast samples contain only minor amounts of pellets. There also seems to be a complete gradation from fossiliferous pelmicrites to pelletal biomicrites, but in the Chaumont of the western localities, the latter extreme is quite rare, whereas the former, together with some biopelmicrites, are not uncommon.

The matrix association of pellets is likewise fairly clear. In samples which are loosely packed, with abundant spar cement, pellets are few. They are most abundant when associated with a micritic groundmass or a fine neomorphic cement. Without knowing the nature of the original pellets, it is often difficult to deduce the degree of diagenetic alteration they have suffered. Presumably, they are converted from aragonite to calcite at a relatively early stage, the interstitial aragonite cement being involved too. The pellets are composed of fairly uniform micrite, in which small patches of microspar only rarely occur. A minor proportion of pellets also contains skeletal material (fig. 28). In all other characters, these grains are similar to the surrounding pellets and they should not be classed as true intraclasts. Indigestible skeletal debris should be expected in some pellets (e.g. see Purdy, 1963a, Pl. 1, fig. C). No silicification seems to occur.

2)Intraclasts

Folk's (1959, pp. 4-6) definition embraces both fragments that have been eroded from adjoining parts of the sea bottom and later redeposited, and those particles classed as grapestone (Illing, 1954) which have an accretionary mode of origin. Because it is commonly difficult to distinguish between these two types, they are grouped together. However, in some cases the distinct rounded clusters of grains (grapestone) can be easily seen and are quite separate from the angular fragmentary particles.

The Chaumont intraclasts range from 0.1-10 mm and average about 0.4-1.2 mm. Four main types can be recognized: pelletal, angular, grapestone, and snowball.

a) Pelletal intraclasts

These intraclasts (figs. 34, 35) have the same type of shape and roundness as the pellets considered above, but lie in the intraclast size range. There does not seem to be a gradational increase in size and it appears best to regard them separately. Internally, these are primarily micritic and very uniform. They are restricted to one or two samples in which they are one of the prime allochem constituents.

b) Angular intraclasts

This group appears to be of erosional origin. The grains are angular, sometimes rather tabular, in shape. Internally, they are quite variable: mainly having a biomicritic composition, but a notable proportion are those which have a core of skeletal material. This is predominantly algal or shell debris, coated on one side or entirely with micrite or pelmicrite. Some of these intraclasts seem to have undergone rounding, probably mechanical.

c) Grapestone intraclasts

Aragonite deposition on the outer surface of the grain cluster gives rise to various forms: ultimately the grape-like protrusions may become subdued into a botryoidal to subspherical shape. In thin section, many Chaumont grains show this characteristic bulbous outline and in most, some, if not all, of the grain aggregates can be distinguished (fig. 30).

3) Snowball intraclasts

This name is introduced here for those intraclasts that have a more or less crude concentric internal structure and a smooth, rounded, subspherical outline. In the Chaumont samples (see fig. 32), these are invariably very large grains (commonly 2-5 mm) and appear to be formed by the rolling of disturbed fragments of unconsolidated, sticky sediment. They are primarily of biomicrite or biopelmicrite composition, the outer rim often being of micrite, probably picked up during the rolling. The concentric structure is never very pronounced, but these grains are quite distinctive from the other three types.

Such intraclast samples are generally poorly sorted and only the close-packed pelletal intraclasts and the finer grapestone varieties show even a poor to moderate sorting factor. The rounding of the intraclasts seems to be mainly genetic and little can be deduced of rounding by mechanical processes.

Samples in which intraclasts exceed one-third the total allochems are always grain-supported with a spar matrix. Such samples also have certain other definite associations. The biogenic associations, for instance, are quite characteristic: skeletal material is usually subordinate to the intraclasts and the most significant debris is shell material and secondary amounts of bryozoans and crinoid ossicles. Non-skeletal associations are also fairly constant: pellets are locally present in the more closely-packed samples or with intraclasts of relatively fine grade, but are nearly always only present in accessory proportions.

There are certain apparently diagenetic changes associated with intraclasts that do not affect the pellets. As to be expected with grapestone grains, being rather porous (Illing, 1954; Purdy, 1963a), the interiors sometimes show inter-particle patches of spar. The main diagenetic feature, however, is the apparent neomorphism of some intraclasts, particularly the pelletal variety, to coarse spar. In plane polarized light, such intraclasts appear very similar to the surrounding coarse spar; they are distinguished by their outline, a thin zone of micrite on all or part of the outer surface, and a speckled effect due to a concentration of inclusions (these are discussed further below). Crossed nicols reveal coarse spar with no crystal boundaries within the intraclast which is in optical continuity with the surrounding spar. At maximum extinction, only the faint, and often incomplete, zone of micrite indicates the presence of the grain (cf. figs. 34, 35). In a few instances, even the twin lamellae of the porefill spar sometimes penetrate into the intraclast. Such grains are associated with unaltered intraclasts with no internal spar.

If the internal pore-space of some intraclasts were connected to the grain surface, it would be understandable that the inner and outer spar should be in optical continuity. However, it seems inconceivable that the porosity was so great as to form an essentially hollow shell in so many cases. The explanation would seem to be that the internal material has been converted to spar; the exact mechanism of such conversion being so far unknown.

Silicification is not uncommon, more than one centre of silicification per grain sometimes occurs and those grains largely replaced by spar are equally affected, the quartz now surrounded entirely by calcite. Whether or not the presence of skeletal fragments within the grains favours this replacement cannot be definitely ascertained. Certainly some intraclasts have silicification restricted to the skeletal parts and such grains are probably more susceptible than those of micritic composition.

MATRIX AND CEMENT

Three divisions can be made beneath this heading: microcrystalline calcite, sparry calcite, and microspar and neomorphic material. The matrix and types of cementing material in carbonates has been less studied than the framework allochems. Folk (1959) considered micrite quite extensively, whilst Bathurst (1958, 1959) has studied diagenesis. Most aspects of diagenesis and recrystallization await more detailed investigation using the terminological framework recently proposed by Folk(1964). Within these limitations, the Chaumont carbonates can be briefly examined.

a) Microcrystalline calcite (micrite)

Acicular aragonite crystals, generally 1-4 microns in length, can be precipitated by both biochemical and physicochemical agencies. These needles can then accumulate to form muds, fill the interstices between allochems, or become an integral part of pellets or intraclasts. The former two types will be considered below. Besides converting to calcite at a later date, the needles also undergo a change to blocky crystals, with essentially the same length but with many times the original volume (Hathaway and Robertson, 1961; Shoji and Folk, 1964). This is the state of the micrite when viewed in ancient limestones.

In the Chaumont carbonates, micrite forms the main constituent of some beds whilst occurring as a matrix in many more; essentially the whole carbonate textural spectrum (Folk, 1964, fig. 4) can be duplicated. Some samples (e.g. F.9) are almost entirely composed of micrite (fig. 37), whereas others have increasing proportions of allochems until they are entirely grain-supported. Dismicrites are few; the spar in most probably formed in voids such as tension cracks, rather than in those produced by organisms. In most micritic units having more than 5%-10% allochems, it is common to find quite a variation in microlithologies even within a single slide; this is particularly so in pelmicrites. No silicification occurs within these fine-grained carbonates.

b) Sparry calcite

Sparry calcite is normally formed by precipitation in the pore-space between allochems. Close to the allochems, a drusy mosaic is formed which passes into much coarser crystals in the centre of the pre-existing void (fig. 34).

Such spar is common in the Chaumont, especially in the clean-washed beds in the upper part. Spar also fills occasional fractures with sharply defined boundaries, but which end abruptly against stylolites (fig. 37). Spar occupies the interior of many recrystallized shells and the interior of some intraclasts as described above. Several other examples have been referred to where the spar has grown as a syntaxial overgrowth on crinoid ossicles and some intraclasts.

c) Microspar and neomorphic material

Normal micrite measures 1½-2 microns, very little is found between 3-4 microns, but another peak frequency exists at 5-6 microns (microspar)(Folk, 1964). This distribution pattern is apparently due to the complex crystal energy relations. It also appears that micrite, because of its small size, readily converts to microspar under certain conditions; this process of "grain-growth" was investigated in carbonates by Bathurst (1958), but the mechanisms suggested have been partially rejected by Folk (1964). The methods of determining recrystallized grains (crystals) have been outlined by Bathurst (1958), Harbaugh (1960), and Stauffer (1962), but even many of these have been challenged by Folk (1964) who believes that "The only firmly diagnostic criteria are those based on grosser fabric relations such as transection of allochems, occupation of large areas unsupported by allochems, or presence of undigested inclusions".

The distinction between fine drusy mosaics infilling the pores of, for example, a pelmicrite and coarse microspar or "grain-growth" mosaics between pellets in the same slide is very fine. This is not uncommon in the Chaumont material; in some cases the criteria advocated by Folk are applicable in determining the type of mosaic, but these frequently cannot be applied to those mosaics that are coarser than microspar but less than coarsely crystalline spar e.g. those mosaics figured by Bathurst (1959). Consequently, the accuracy of the point-count analysis for this material is less than for the others.

In the Chaumont examples, such recrystallized mosaics seem to replace patches of micrite that are a minor constituent of the limestone. In true micrites these mosaics are rare but are common in the better washed pelmicrites or pelsparites (fig. 28). It seems possible that the deposition of pore-fill spar against micrite which has only partly filled the pore-space may start the conversion of this micrite to a coarse mosaic. This pattern is seen just as well in poorly washed pelsparites, biopelsparites, etc., but the cleanly washed biointrasparites, for instance, show no such mosaics. The mechanisms of such micrite conversion are beyond the scope of this study. It should be recalled, however, that a similar situation occurs in the intraclasts (figs. 34, 35). Some (those with internal pore-space connected to the exterior?) have been almost entirely converted to spar, whereas the more compact micritic intraclasts are unaffected, as are all the pellets.

ACCESSORY MINERALS AND SILICIFICATION

Excluding the rare heavy minerals, certain other minerals are in places present in noteworthy amounts.

a) Silicification

Details of silicification in the Chaumont samples were given in the descriptions of allochem types. It is more significant in the coarser and spar-rich samples, but never is more extensive than affecting only a minority of the individual allochems.

b) Quartz grains

The only recognizable detrital grains present are angular quartz grains. Their distribution follows two patterns; they are rarely widely, and randomly, scattered throughout a sample, occupying less than 5% of the sample, or they are concentrated in shale laminae or stylolites (fig. 37). In the former case, they are only appreciable in amount at about 3 ft. above and below the boundaries of the formation. These levels were not apparent in all three westernmost localities, but considering the degree of sampling involved and the very minor amounts of quartz, little significance should be attached to this. Their concentration in shale laminae and some stylolites is clearly an indication of either a relatively sudden influx of detrital material or concentration through lack of, or removal of, carbonate accumulation. The grains may form up to 30%-50% of the thin zone, but are normally widely distributed. Considering their shape it is thought that only a small minority of these grains may be authigenic in origin.

c) Inclusions

At high magnifications (e.g. x200 to x400) the details of inclusions in some skeletal and intraclasts can be seen. In their extreme development in some intraclasts, these inclusions form a fine banding or speckling, often normal to the grain surface (figs. 34-36). This banding is formed by fine zones of hazy micritic material alternating with equally thin zones of clear calcite. The micrite layers are often discontinuous and within these especially is concentrated a dark, isotropic, angular mineral (?). In skeletal material, primarily crinoid ossicles, this speckled nature is uniform and not banded; intraclasts show both random and zonal speckling. Whether this is segregated organic matter or not cannot be determined; it is possible that recrystallization has led to zonal segregation. Since all these speckled allochems are those varieties composed essentially of calcite in optical continuity, it seems most likely that the inclusions have been re-arranged during recrystallization. This is particularly suggested by the orientation of the parallel zones along the line of extinction. The inclusions aid in recognizing such allochems under plane polarized light.

d) Dolomite

Extensive dolomitization is not present in the Chaumont and only one mode of occurrence of the mineral has been observed. This is as a concentration of dolomite rhombs within some of the shale laminae (fig. 37), stylolites, and borings. Very few examples are present within the thin sections of the three western localities, but confirmation of such occurrence is forthcoming from other eastern localities. The dolomite rhombs are generally closely packed with a matrix of fine limonitic(?) and/or argillaceous matter; in some, calcite skeletal debris is present and unaffected. Further discussion is given below in consideration of the shale laminae, stylolites, and borings.

PETROGRAPHY OF CERTAIN SEDIMENTARY FEATURES

In Chapter 3, the gross morphology and relationships of certain sedimentary features were described. In order to provide at least an outline of their individual petrographic nature, the writer has studied, in thin section, a few examples of each. They were investigated only as an aid in environmental considerations and hence the following accounts do not embrace every possible aspect of the structures.

a) 1. Shale laminae

Shale laminae occur as irregular bands varying from thin wispy laminae to those nearly ½ in. in thickness (fig. 37). They occur as a paste matrix of varying proportions of micrite, dark argillaceous matter, and brown to rusty limonitic(?) paste. Within this matrix are dolomite rhombs, quartz grains, fossils and rare intraclasts. The micrite tends to form lenses; the dolomite can be extremely abundant; the quartz occurs in very variable proportions and although probably detrital, an authigenic origin cannot be ruled out; the fossils are unaltered. The thickness of these laminae varies considerably and they can end rather abruptly, but when thinning or dying out they often pass into stylolites.

a) 2. Stylolites

The stylolites characteristically are composed of a dark argillaceous matrix and relatively minor additional constituents. The latter are mainly quartz grains or, less commonly, dolomite rhombs (as figured by C.W.Brown, 1959, fig. 5). Whether the quartz grains represent a concentration from the surrounding carbonate through a pressure-solution mechanism or are authigenic in nature (as found by W.W.M.Brown, 1959) cannot definitely be determined. The writer feels that the latter possibility is most likely as detrital quartz is rare or absent in the surrounding limestone, perhaps with the addition of a few grains from the surrounding carbonate.

The main controversy concerning stylolites is whether they were formed before or after consolidation of the sediment; the latter alternative having been the most favoured. The Chaumont material shows several examples of truncated skeletal and intraclast grains with no change in carbonate type adjacent to the stylolite; hence, it seems most unlikely that the sediment was still unconsolidated at the time of formation. Further, their close association with shale laminae and the presence of argillaceous material in the stylolite, even in zones where only very minor pressure-solution has taken place, (shown by stylolites passing through allochems) indicates that much of this matter may be original. That is, the stylolitic seam was initially a fine shale lamina which then developed stylolitic relief, with the addition of some insoluble residue. The possibility that stylolites are often initiated along clay seams has been suggested previously (most recently by Heald, 1959), but has not received the attention it appears to deserve.

In respect to the time of formation of stylolites, besides apparently forming after consolidation, they also appear to have formed prior to the deposition of spar within fractures. Many such spar-filled fractures end abruptly at their junction with these seams (fig. 37). The rather bituminous seams would probably have been less brittle than the surrounding carbonate and less liable to solution.

b) Borings

Two main types of structure interpreted as borings occur in the Chaumont thin sections. The first is seen as a small (0.4-0.8 mm) diameter circular to subcircular structures composed primarily of microspar with some very loosely packed pellets or shell debris. A few thin wisps of micritic material normally occur within the boring and are concentric to subconcentric. The interior does not appear to have been grain-supported, but the extensive neomorphism obscures this, the resultant grain-size being coarser than the surrounding carbonate which is typically a micritic pelletal or skeletal variety.

The second type is that associated with discontinuity surfaces. In thin section, the borings are seen to be composed of a very dark argillaceous or bituminous paste with a few skeletal grains, but with extensive spar growth or rarely dolomite rhombs. Under high magnifications (x200 to x400), the spar can be seen to have many small inclusions of the bituminous paste which envelopes the spar. The latter is of fairly uniform crystal size throughout any one boring; in a few cases, some dolomite rhombs may be scattered throughout, but usually these either occur in great profusion (to the exclusion of the spar) or not at all. It seems fairly certain that the boring was occupied by this fine paste with minor unaltered skeletal debris and micrite. The growth of spar seems to have largely compressed the paste into the intercrystal position and to have incorporated some within it. The origin of the paste is uncertain and is considered in Chapter 5.

LIGHT AND HEAVY RESIDUES

The acetic acid breakdown of the limestone samples allows the collection of insoluble residues, which after heavy liquid separation, is split into light and heavy fractions. Both fractions were retained, but the preliminary binocular microscope study was sufficient to indicate that the residues would be of virtually no assistance in either environmental interpretations or in correlation from section to section.

The light residues are somewhat variable in quantity, but abnormally high or low amounts do not seem to be present in adjacent sections (this again being primarily studied in the three western localities). Most consist of silt flakes or porous pelletoid grains, and micaceous flakes. Others are dominated by silicified allochems, of fragments thereof, thus masking any possible fluctuations in detrital matter. A few scolecodonts were observed.

The heavy fraction is generally composed of small quantities of silt- or fine sand-sized flakes of high iron content (primarily with a rusty limonitic colour) and authigenic pyrite cubes or, rarely, lattice networks. Authigenic pyrite is not a good indicator of sediment-surface environments (Moretti, 1957). A few detrital heavy mineral grains occur, but their scarcity, considering the size of sample digested, is rather surprising; thus an analysis is statistically impractical.

The sieving process removed those insolubles below the 140 mesh size. As noticed during sieving this lost fraction is very variable. For instance, calcilutite samples have little residue on the sieves, but a considerable amount of fine insoluble mud escapes.

It is possible that a study of insolubles (e.g. Carpenter and Schmidt, 1962) is of value in some cases. In the present study, however, no noticeable trends occur and variations are not correlateable, most probably lying within the errors involved in sampling, seiving, etc.

POINT-COUNT ANALYSIS

In order to produce a more objective and quantitative analysis of the limestones than the field descriptions provide, thin sections of the forty samples from the three western localities were used for a point-count study. Because the variation in carbonate type within a bed or even a sample can be quite appreciable, the acceptable theoretical counting error sections (this again being primarily studied in the three western localities). Most consist of silt flakes or porous pelletoid grains, and micaceous flakes. Others are dominated by silicified allochems, of fragments thereof, thus masking any possible fluctuations in detrital matter. A few scolecodonts were observed.

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In the point-count analysis, pellets were fairly unambiguous except when becoming merged. The spar within some intraclasts was counted as intraclast material. However, in some fossils, notably bryozoans, the micrite or spar between the walls was not counted as skeletal material. This explains much of the difference between the petrographic and field-visual methods. Some difficulty is encountered at times in distinguishing between true porefill spar and coarse recrystallized skeletal debris. Micrite and microspar are gradational in size and for the purposes of interpreting samples within Folk's (1962) carbonate textural spectrum, the latter can be regarded as micrite.

Carbonate petrography in the three western localities

The correlations between the three western localities, as shown in figure 5, have been based on the field and petrographic description. As can be seen from the figure, a unit-to-unit correlation can be made between these sections i.e. over about 12 miles. As expected, individual beds of a few inches in thickness cannot be correlated satisfactorily. The slight discrepancies that exist in the petrographic histograms of equivalent units are also to be expected and can be accounted for by a) lateral microfacies changes between sections, b) variations within the unit at each locality, and c) proximity to overlying or underlying microfacies - if these are regarded as lateral equivalents.

At Fourth Chute and Meath Hill, where the Lowville is exposed, the lower units are fairly uniform in petrographic type and are typical of the Lowville elsewhere. Micrites, pelmicrites, and less frequent dismicrites and pelsparites are encountered; skeletal material is present in small proportions or absent altogether. (At Pine Valley, the lowest unit may possibly be placed within the Lowville but on purely lithological grounds it is best regarded as Chaumont). These Lowville micritic units clearly represent very low-energy environments, with only occasional currents to produce the few cross-laminated thin pelsparites .

The lowest Chaumont units (e.g. samples M.1, M.2, P.V.2, F.1, F.2.) are composed of "Ottawa-type" calcarenites which are poorly washed pelmicrites containing minor, but approximately equal, amounts of intraclasts and skeletal debris. Overlying these are units (e.g. samples M.3, P.V.3, P.V.4, F.3, F.4) of similar carbonates that are moderately washed pelmicrites, but the basal portions are predominantly moderately washed intrasparites. A prominent three-foot unit of shaly argillaceous calcarenites follows in all three sections (e.g. samples M.4, M.5, P.V.5, P.V.6, F.5); individual beds are rather variable in lithology, but biomicrites are dominant. Sample F.6 is an example of the laterally impersistent coarse calcarenites - fine calcirudites which are well washed biosparudites with minor proportions of pellets and intraclasts. The overlying set of units (e.g. samples M.6, P.V.7, P.V.8, F.7) are micrites and poorly to moderately washed pelmicrites, comparable to those of the Lowville. Samples M.7, M.8, P.V.9, P.V.10, and F.8 are representatives of a tripart set of units: the lower part being moderately washed biomicrites and fossiliferous pelmicrites, the middle third is of Lowville-type micrites, whilst pellets, intraclasts and fossils are important, but variable, constituents of the well washed upper third. The central micrites probably occur in the covered interval at Meath Hill. Further interbedded units of Lowville-type micrites and poorly washed pelmicrites (cf. samples M.9, P.V.11, F.9) overlie the tripartite group and frequently show low-angle cross-lamination. Higher up, this develops into trough cross-lamination (cf. sample P.V.12) which produces clean-washed fossiliferous pelsparites. These underly the Rockland calcirudites which (cf. samples M.11, P.V.14, F.10) are very clean-washed intrasparudites and biointrasparudites and produce the prominent facies break taken as the Chaumont-Rockland boundary.

Chaumont petrography of the eastern part of the western region

This area has essentially the same pattern as that outlined above. The Chaumont is bounded below and above by quite distinct and fairly uniform poorly washed micrites and pelmicrites and very clean-washed biointrasparudites and intrasparudites respectively. The Chaumont between is basically poorly washed fossiliferous pelmicrites and biopelmicrites with occasional intrasparites and Lowville-type micrites. Some of the latter units e.g. at Clay Bank (locality 4) can be correlated with those found in the three western localities.

Chaumont petrography of the eastern region

The uniformity of microfacies found in the field in the eastern region is reflected in the thin section studies of several localities. There are no interbedded micrites and the only intrasparudites etc. are those associated with the rare impersistent coarse spreads. For the main part, the units are micritic (poorly washed) and generally grain supported with variable proportions of pellets and skeletal material, the former being most abundant. Very few are clean-washed with a spar matrix, but moderately washed samples are not uncommon. Stratigraphic charts were made of every locality and an attempt was made to correlate beds or units from section-to-section. Even between sections only a mile apart, such correlation was unsatisfactory. The uniformity of microfacies caused stress to be laid on associated shale partings, but still no pattern emerged. If point-count charts were made of every sample these might provide a firmer basis for correlation, but on field descriptions alone this was unsuccessful.

CHAPTER 5

INTERPRETATION OF STRATIGRAPHY AND SEDIMENTARY ENVIRONMENTS

Introduction

The information presented on stratigraphy, sedimentary features, carbonate petrography, and conodont faunas (Chapter 6), can now be compiled in an interpretation of the Black River and lower Rockland stratigraphy and of the sedimentary environments represented.

Speculations on Mohawkian sedimentary environments have been rather limited considering the extensive previous stratigraphic studies. This latter work has led to a number of contrasting ideas on stratigraphic correlations and, hence by implication, on sedimentary environments. The conclusions reached appear to be strongly influenced by previous experience and method of approach.

In the following interpretations, a number of approaches are used together with a comparison with modern analogies. Throughout the discussions, two factors are indisputable: the presence of transgressive seas and shallow basinal areas of carbonate sedimentation.

STRATIGRAPHIC INTERPRETATION

1. Possible approaches

The Black River group in the Ottawa Valley has been shown above to be composed essentially of micrites which are markedly impure and partly dolomitized toward the base. The highest (Chaumont) formation shows evidence of a somewhat higher energy regime with rather coarser and more varied sediments, bearing a much larger and more varied fauna. To the west of Ottawa, a wedge of lower Rockland clean-washed biointrasparudites and intrasparudites developed, becoming thicker westwards. In S.W. Ontario, the succession is similar to that *west* of Ottawa, whereas in the standard New York sections the Black River sequence is closely comparable to that *east* of Ottawa (cf. figs 16-18, 14-15), although the lower Rockland (Selby) lithology (cf. figs. 17, 14) is not found in the Ottawa Valley. The micrites of the lower Black River, and perhaps parts of the overlying lithofacies, can be traced as far south as Virginia and Kentucky. Hence, the vertical sequence of units in the Black River, and to a lesser extent in the lower Trenton, is very similar over an extensive area and in more than one sedimentary basin.

Any change in the vertical sequence of lithofacies can be explained either in terms of facies change or by a stratigraphic break. Frequently this is also subject to a philosophical approach as pointed out by Twenhofel *et al.* (1954, pp. 256-257) who illustrate Kay's preference for hiatuses as opposed to Cooper's for continuous deposition and facies change, in many Ordovician sections in eastern North America. The present writer has frequently been unable to find any physical breaks in the stratigraphic record as are proposed by Kay (e.g. 1937, 1942, 1953) in the Ottawa Valley (e.g. between the Chaumont and Rockland) and N.W.New York (e.g. between: the Chaumont and Rockland around Watertown, the Lowville and Rockland and Rockland and Kirkfield in the two quarries at Newport, the Lowville and Kirkfield at City Brook, the Lowville and Rockland at Ingham Mills). Perhaps minor breaks are found in only a few localities and these are extrapolated to cover a wider area. More likely, however, the writer suspects that such breaks have been based on two criteria, both of which can be misleading. First, the assumption that certain lithologies are essentially chronostratigraphic units e.g. that the Lowville at City Brook, N.Y., is of the same age as that of the type area. Second, faunal assemblages seem to have been used in determining such breaks as opposed to lithologic criteria. This latter lithologic method is open to error if the component fossils are essentially ecologically controlled and long-ranging e.g. is the Lowville fauna - impoverished as it is - at City Brook similar to that at Lowville because it is primarily an assemblage of such fossils?

These, therefore, are the problems in attempting Ordovician stratigraphic interpretations and correlations in eastern North America. Although a great deal of basic, and frequently quite detailed, stratigraphy has been accomplished with these shelf and miogeosynclinal sequences, together with extensive associated faunal lists, little has been attempted to outline the evolutionary developments of individual phyla throughout the Mohawkian. Some groups have been studied in part e.g. the brachiopods (Salmon, 1942; Cooper, 1956), the trilobites (Whittington, 1959), the bryozoans (Ross, 1964), and now the conodonts are receiving serious attention and are likely to become the most satisfactory group. Without a knowledge of the phylogenetic development of the faunas involved, the occurrence of some cannot definitely be shown to be part of an evolutionary progression, or faunal migrations, or merely a reflection of a change of lithofacies. This unsatisfactory state of Mohawkian paleontology coupled with "hiatus or facies" philosophical approaches, has led to the development of three main types of stratigraphic interpretation. These are outlined below and are centred around the works of Kay (1929 et seq.), Winder (1960), and Fisher (1962).

Kay's approach has produced correlation diagrams of essentially flat layered sequences. The interpretation appears to be that each Mohawkian formation was deposited as a single entity. Whether Kay would allow any lateral facies development of more than one formation close to the positive areas e.g. the Adirondacks, is questionable. Many of his diagrams (cf. Kay, 1937, Pl.2), if taken "literally", suggest this may be the case, but the situation may be more apparent than real. That the individual formations are basically regarded as chronostratigraphic units is further indicated by his regarding many as stages (Kay, 1960). Kay (e.g. 1931, 1935) has clearly laid considerable stress at times upon the occurrence and location of bentonites and has frequently used their presence as additional proof of correlation. Where these are in excess of about 6 ins., they may well be valuable, but the present writer is rather sceptical of those varying from 0-2 ins. in thickness. Indeed, it is noteworthy that when really detailed stratigraphy of middle Trenton units in New York was undertaken by Chenoweth (1952), bentonites were generally not correlated satisfactorily. Arrhenius (1961, p. 139) also warned against reliance on bentonites after finding that thick near-shore ash deposits did not extend to the slowly accumulating deeper deposits in the East Equatorial Pacific.

The only criteria that can be used at this time for deducing relative times of deposition are bentonites and fauna. The former appear to the writer to be unsatisfactory when used north of Pennsylvania. Kay has treated the faunal criteria by considering whole faunal assemblages. Although there has been little alternative, this does not detract from the point that only a small proportion of these fossils may be relatively independent of the local facies and, hence, of value as zone or index fossils. Most of the corals, bryozoans, gastropods, pelecypods, algae, Receptaculites, and echinoderms appear to be strongly influenced by their environment. The cephalopods, and possibly the brachiopods and trilobites, are probably less affected but are still far too poorly known. The influx of the cryptolithids in the Shorham (lower Sherman Fall), for instance, may illustrate one group that was able to migrate over and into several different facies.

This now leads to the second basic approach to stratigraphic interpretation and correlation. Winder (1960) proposed that all the Black River - Trenton formations were deposited contemporaneously as lateral facies equivalents of each other in the transgressive sea. He supported his theory not only by equating gross lithological changes to certain energy environments, but also by an analysis of the faunas involved. This aspect is treated in far more detail, and more convincingly, in Winder's unpublished thesis (1953). Almost every macrofossil group found was considered and placed within the environmental picture suggested by the gross lithologies. The paper has undeservedly received scant published consideration or discussion, but neither has it been disproved in print. The writer feels that further research along these lines is necessary and the present conodont work was undertaken in partial fulfillment of this. Under the conditions postulated by Winder, the 700ft. or more of the Mohawkian sediments were deposited, if contemporaneously, over probably several hundred miles up to, and away from, the shore-line. Hence, the angle between the depositional surface and the overlapped basement is so small that very extensive studies are required to show transgression of time planes. Liberty (1963a, 1963b) has found that some biostratigraphic units transgress lithostratigraphic units over parts of the 400 mile area he mapped in southern Ontario. Also the present conodont work demonstrates that one marked faunal change does not lie parallel to a distinct lithological change. Because of the complexity of the Mohawkian paleogeography with the presence of sedimentary basins and positive areas, it seems unlikely that the Cobourg could be shown to be equivalent to the Pamelia without study of the few outliers in the Canadian Shield. Hence, from this point of view, consideration of the Mohawkian deposits of the Ontario-New York area as Winder presents (1960, fig. 3) is indeed so diagramatic as to be probably somewhat inaccurate.

This, in turn, leads to the third main approach of stratigraphic interpretation and correlation; that of Fisher (1962). Fisher's interpretation was presented only in chart form and represents a type of compromise between the "extreme" ideas of Kay and Winder. In essence, he proposes that the Black River and Rockland units are diachronous during the onlap onto the Adirondacks. The Pamelia is overlapped by the Lowville and the Chaumont by the Rockland, until immediately prior to the submergence of the Adirondacks, the Lowville passes off-shore into the Rockland and the latter into the Kirkfield. Once complete submergence has been accomplished, the higher Trenton formations are shown to be essentially chronostratigraphic. However, would there be a comparable facies pattern if the more extensive, and perhaps higher, Canadian Shield were substituted for the Adirondacks? Under such circumstances and given a greater scale, would not Winder's arrangement be applicable? To return to Fisher's proposals, it should be noted that he has published very little on Ordovician stratigraphy, but, rather, has re-interpreted the information given in earlier publications and gives no real discussion of the reasons leading him to these conclusions.

These three approaches, therefore, are based primarily upon lithological and faunal criteria - yet are still unresolved despite a wealth of published work. Surely this suggests that these criteria are (as yet) either insufficiently sensitive or are inconclusive by themselves and other approaches must be sought. The writer feels that the crux of the problem is that there has been a gross lack of applied "wet geology" (e.g. Harrington and Hazlewood, 1962), that is, little environmental interpretation. Winder (1960) has made an initial stimulating attempt, but still the realms of carbonate petrography and direct comparison with modern analogies await investigation.

This study has considered both the stratigraphic and faunal aspects together with the carbonate petrography of part of the Mohawkian. The following discussion compares and contrasts as many of these facets as possible with modern counterparts; it is hoped this will add considerably more plausibility to the interpretations of Fisher and, in part, of Winder. The writer's own stratigraphic interpretations and reasons will be outlined after these comparisons. This discussion is included to enable past and present environments to be compared, thereby allowing an interpretation of the sedimentary environments of the Black River and lower Rockland units.

ENVIRONMENTAL INTERPRETATION

1. Stratigraphic comparisons

The gross features of the Black River and lower Rockland stratigraphy can fruitfully be compared directly with certain facies prevalent in some areas of modern carbonate sedimentation. Such comparisons are, in part, restricted by the state of knowledge of these recent deposits and because they cover only a very minor proportion of the globe compared with those of the Ordovician Period. Further, none of the present-day occurrences occupies a comparable situation of transgressive basinal sedimentation against an irregular shield terrain. Despite these initial differences, very close comparisons can still be drawn. The regions of modern carbonate deposition that have been subject to considerable recent study are the Bahama Banks, Florida Bay, the Gulf of Batabano, the Persian Gulf, and some reef complexes and Pacific atolls (see Graf, 1960, for other minor areas).

a) Comparisons with the Pamelia-Lowville calcilutites

Extensive deposits of fine carbonate muds and silts are found in the Bahama Banks (e.g. Illing, 1954; Newell et al., 1951; Newell and Rigby, 1957; Newell et al., 1959; Cloud, 1962; Purdy, 1964a, 1964b; amongst many others), the Florida Bay (e.g. Ginsburg, 1956; Gorsline, 1963), the Gulf of Batabano (Daetwyler and Kidwell, 1959), and the Persian Gulf (Emery, 1956; Houbolt, 1957; Sudgen, 1963; Evans, Kinsman, and Shearman, 1963). Although differences do occur, the following broad generalizations seem to be fairly constant for such lime mud areas.

These regions are characterized by shallow, quiet water in a low energy regime, only occasionally being stirred to take fine particles into suspension; being shallow and subject to high evaporation and poor circulation, high salinities usually prevail. Landward, the muds pass into tidal flats which are subject to periodic exposure with change in sea-level. To seaward, they usually pass into sands, which are considered below. The poor circulation and high temperatures and salinities are mainly responsible for the relative paucity of organisms and their resultant skeletal remains. Likewise, the marine vegetation cover is poor; certain boring and burrowing organisms, however, are by no means uncommon and cause sediment turn-over with the resultant destruction of internal bedding. There is little sediment transport, except in the suspension of the finest particles.

The origin of such muds has been controversial and both physicochemical and biochemical processes have been proposed. Despite supersaturation of the sea-water in $CaCO_3$, there seems to be little evidence of direct precipitation without some form of trigger mechanism. Various organic groups have been suggested for this: bacteria (e.g. Bavendamm, 1931; LaLou, 1957; Oppenheimer, 1960; Greenfield, 1960), local high populations of siliceous diatoms (Wells and Illing, 1963), and algae (Wood, 1941; Lowenstam, 1955; Lowenstam and Epstein, 1957). Doubt has been expressed by Newell et al. (1959) on the conclusions of Lowenstam and Epstein, which were based on oxygen isotope investigations. However, electron microscope studies (Studer, 1963) appear to complement the organic origin theory. Certainly a definite, if largely unknown, relationship exists between the deposition of calcium carbonate and high salinities (Trask, 1937; Emery, 1956).

How then do these general features compare with the Pamelia-Lowville units? The fine grain-size of the carbonates attests to a low energy environment, while mud-cracks, ripple marks, and intraclast-zones, when taken together, indicate near-shore conditions with periodic exposure. It will be recalled that all three decrease in abundance vertically in the Black River. Kay (e.g. 1942, p. 593) has reported occurrences of glauberite ($Na_2SO_4.CaSO_4$) from these units in the Ottawa Valley, Young (1943, Pl. 1, fig. 2) illustrates mineral moulds (sic), and minor gypsum and anhydrite (Beales, 1958; Maycock, 1959) have also been recorded from New York and S.W. Ontario - all suggestive of high salinities. As was stated in Chapter 3, the fauna is meagre and impoverished, but improves vertically throughout the Pamelia and Lowville. The presence of detrital material in the lower Pamelia is also to be expected if these are littoral or intertidal deposits. The dolomitization found in the Pamelia may also be governed by high temperatures and an intertidal environment and perhaps is directly analogous to the dolomite forming today in the Persian Gulf (Illing, 1964) and Florida and the Bahamas (Shinn and Ginsburg, 1964).

Thus, close comparisons can be drawn between the modern and Ordovician carbonates which suggest a similar environment of deposition. Only the main features were considered above since the writer has not studied the smaller sedimentary features in detail, but from numerous field observations these undoubtedly could also be shown to be comparable to modern structures. Some authors have considered a mud flat or lagoonal environment for the Pamelia-Lowville units (e.g. Raymond, 1931; Young, 1943), but the interpretation of Young has been typical of most in that they are not thought of as lateral facies equivalents. The facts mentioned above strongly indicate that the vertical sequence of changes in the Pamelia-Lowville are those experienced in moving seaward across a lagoon from a tidal flat.

b) Comparisons with the Chaumont-Rockland calcarenites

The calcarenites referred to here are those of the Chaumont and Rockland of the eastern region and of the Chaumont of the western region. These units are poorly washed pelletal, rarely intraclast, carbonates bearing a variable proportion of skeletal debris which is generally subordinate to the non-skeletal grains.

Such original pellet muds and sands are common in the four areas named previously, particularly the Bahama Banks and the Gulf of Batabano. These are the seaward facies of the lagoonal muds and are located in slightly deeper water but with better circulation at, or close to, normal salinities. The energy regime is low to moderate and sediment movement, although not extensive, is primarily by bottom traction. Organisms are plentiful, particularly the algae and marine grasses that have a binding, and baffling, action on the sediment. The pellets are of fecal origin and with well washed and only slightly agitated sands these, and other aggregates, become cemented together to form grapestone (Illing, 1954; Purdy, 1964b). The sands pass laterally into coarser sediments of the bank edge e.g. oölitic shoals, skeletal sands, and coarser intraclast sands.

These sediments compare closely with the Chaumont-Rockland calcarenites. The latter clearly lie in a somewhat higher energy regime than the Pamelia-Lowville sediments, but are still poorly washed with much interstitial micrite. The occasional well washed biosparite or intrasparite is encountered as would be expected. The marked increase in both number and variety of fossils indicates a salinity close to normal, particularly with the presence of compound corals. Evidence was presented earlier, in Chapter 3, that the numerous shale laminae and "pockets" of biogenic material are probably the result of the baffle action of marine vegetation (possibly algae with perhaps occasional assistance from bryozoans). There is also evidence of burrowing organisms, but their effect diminishes with an increase in grain size - also typical in modern examples. A few discontinuity surfaces bear testimony to minor regressions, and the lack of mud-cracks, ripple marks, and intraclast zones suggests deeper water and a position further from shore than either the Pamelia or Lowville. Transportation of material appears to be minor, except in the thin "spreads" which are probably caused by storms. Most skeletal breakage is the probably the work of organisms (cf. Hoskin, 1964).

The gross physical and biological aspects of the Chaumont-Rockland calcarenites therefore seem analogous to the stable sands and muddy sands of the outer shelf lagoons of modern banks. Further comparisons of the sedimentary features are made below.

c) Comparisons with the lower Rockland calcirudites

Although coarse skeletal and composite-grain sands occur in the four previously mentioned areas of modern carbonate deposition, they are by far the best developed on the Bahama Banks. Three main sediment types are present, all being well washed: grapestone, oölitic and oölite, and coralgal facies. This variation in sedimentary facies represents differences in the energy regime (and hence sediment movement) and skeletal amounts. The oölites form in areas of greatest and essentially continuous agitation and movement, whereas the grapestone material is only subject to periodic disturbance. Coralgal (coral-algal) debris is derived from the reefs and high organism populations on the bank edge, and forms on the outer flanks of the bank where there is little non-skeletal grain deposition or contamination. The energy regime, therefore, is moderate to high with excellent to good circulation of the bank waters (primarily due to tidal flow) which are essentially at normal salinities. The grapestone and coralgal facies develop in relatively deeper water (e.g. 4-16 fathoms), whereas the oölite shoals tend to form upon the ridges of the submerged Pleistocene karst topography. With fairly rapid sedimentation and with the movement of much of the coarse deposits, the activities of burrowing organisms do not appear to be sufficient to destroy stratification. Further, only parts of the grapestone facies support significant growths of vegetation. The influx of fresh tidal waters, a firm bottom, and clear shallow waters, frequently permit the development of a rich fauna and the growth of reefs. The surrounding sediments therefore contain considerable skeletal debris, with a concentration in the coralgal facies. Finer particles and "dust" produced by abrasion is washed into deeper or quieter environments, but most sediment transport is by bottom traction and minor saltation.

Features of the lower Rockland calcirudites suggestive of a comparable mode of deposition include the geometry; being wedge-shaped and interfingering with Chaumont and other Rockland calcarenites, and indicate a shifting local shoal development. The sediments themselves are coarse and restricted almost entirely to intraclasts and fossil debris. Lack of micrite and cementation by spar testifies to a high energy environment. Sedimentary features are dealt with below and further support these conclusions. There is little indication of significant burrowing, or binding by vegetation; fossil material is plentiful, particularly bryozoans, algae and large compound corals. Oölites require rather critical conditions for formation and their absence is not surprising. Nevertheless, they are present in a similar facies in the Kingston area in the S.W.Ontario basin (Maycock, 1959). The coarse intraclasts, which being the large pelletal, angular, and snowball types, indicate a higher energy regime than the essentially grapestone intraclast beds found within the Chaumont.

d) Summary of stratigraphic comparisons

The writer has attempted to point out the close similarities between the vertical sequence of facies of the Black River and lower Rockland and the lateral, contemporaneous facies found in several modern sites of carbonate deposition, particularly those on the Bahama Banks. The facies of the latter region are presented in a cross-section diagram by Purdy (1964b, fig. 4) and as a map by Imbrie and Purdy (1962). In the latter instance, maps of the facies based on a particle classification (ibid., fig. 10) and on Folk's petrographic classification (ibid., fig.

FIGURE 3: Paleogeographic reconstruction of the region during deposition of the Rockland formation at the type section (modified after Kay, 1937). Arrow indicates position of spur-and-groove structures (locality 2).

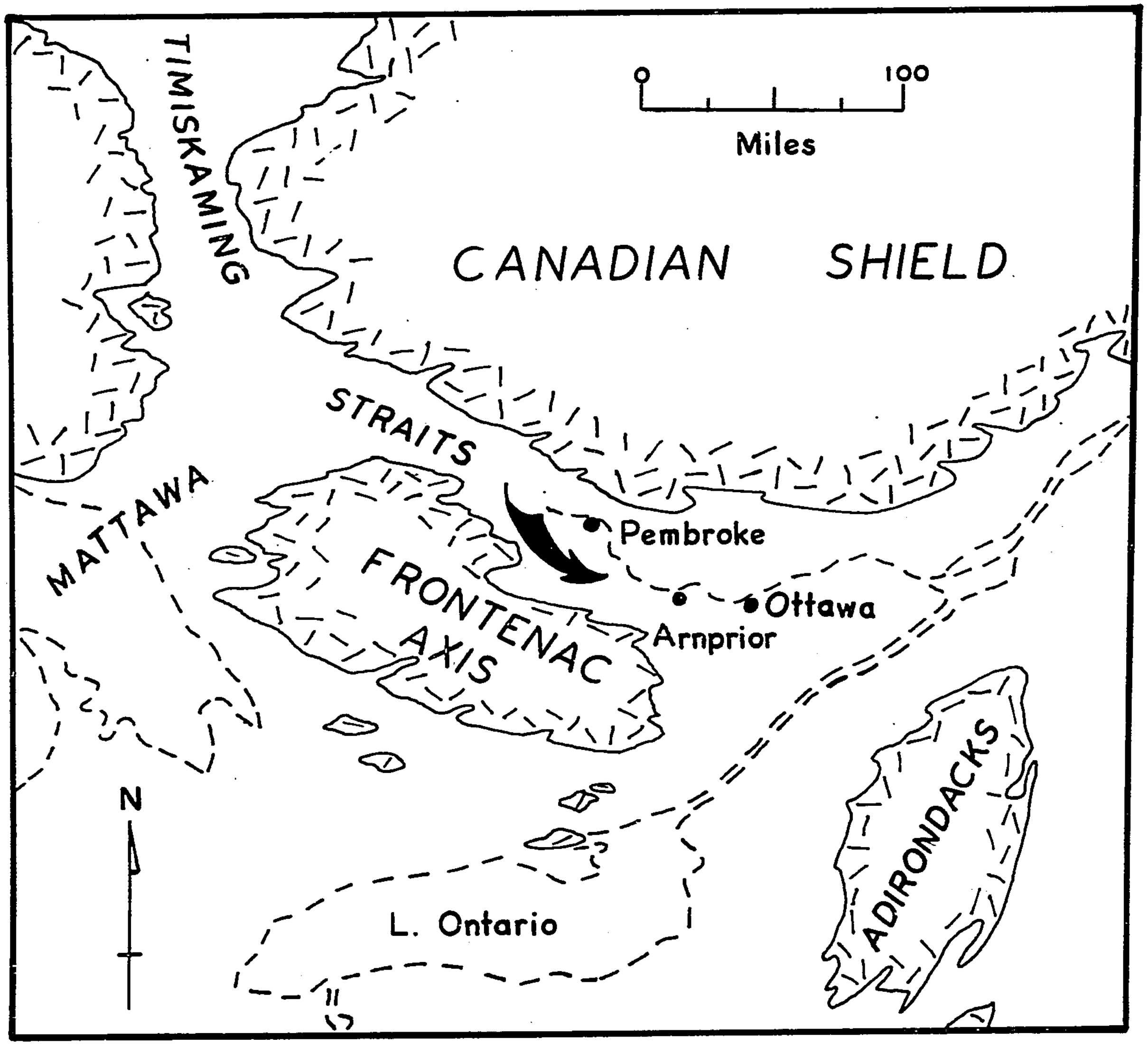
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FIGURE 3

13) are given. If this facies distribution were transferred to the Mohawkian of this region and transgressive seas were in effect, a Black River-lower Rockland sequence could be duplicated.

To determine whether the grain-types of the Chaumont carbonates were exactly akin to those being compared from recent environment, the writer obtained some sands from the Bahama Banks. Dr. D. J. MacLaren very generously presented the writer with many samples from his own collection which are from the oölite, grapestone, pellet, and mixed skeletal sands near to the edge of the Banks. These were examined under the binocular microscope and several made into thin sections which allowed direct comparison with the Chaumont sections under plane polarized light. Except for the different nature of the skeletal material, virtually all grain-types of sand grade occur in both environments, further stressing their similarity. Examples of the Bahaman sections are shown in figures 29, 31, 33.

2. COMPARISONS OF SEDIMENTARY FEATURES

To press this interpretation further, the sedimentary features of the Chaumont and adjacent strata can be compared to modern examples. Some of these are restricted because few such studies have been undertaken on modern sediments. The features will be considered in the same order as those in the Chaumont were described in Chapter 3.

A) Gross characteristics of beds

Unfortunately, there have been very few studies concerned with the internal structures of beds in modern carbonate environments. Some, if not all, of the four types reported by Imbrie (1964) can be duplicated morphologically in the Chaumont, but without further work, equating these

Bahaman environments can only be tentative. If a detailed study of the Chaumont-Rockland cross-stratification were attempted, it might be possible to place this definite sequence of crossbedding more precisely into the flow regimes outlined, amongst others, by Simons, Richardson, and others (1961, 1963). Again, their conclusions are based largely on flume experiments and direct transference to open-sea bank environments can only be tentative at this stage.

Those Chaumont beds that lack internal stratification are micritic and poorly washed. In some, such stratification could perhaps have been destroyed by organisms, but all other factors suggest lack of transportation. Thus the bedform has developed by slow local sedimentation and not through transportation from a nearby area. The type and thickness of the beds is therefore a function of the rate and continuance of deposition. For most of those encountered, this would imply few major breaks, minor surface reworking by organisms, and little lateral transport. The various internally stratified units are considered below.

B) Bedding surfaces

a) Level bedding surfaces

Fused bedding surfaces would seem to indicate a pause in deposition, some consolidation of the sediment and development of a firm planar surface, followed by a resumption of sedimentation, frequently with a slight change in conditions. Shale partings probably reflect an influence of fine detritus, perhaps in conjunction with a minor break in carbonate deposition.

b) Irregular bedding surfaces

1) Discontinuity surfaces

The writer earlier stated his preference to regard the Chaumont examples as indications of subaerial exposure. Modern forms of varying scale can be compared. On the Bahama Banks, minor karst features are developed on the lithified Pleistocene carbonates; lithification, through prolonged exposure, of intertidal surfaces such as that figured by Ginsburg (1957, fig.6) would produce such discontinuities; likewise, the formation of beachrock (Ginsburg, 1953; Russel, 1961) with later corrosion (e.g. Emery, 1946; Revelle and Emery, 1957). These are a few examples of many that are present and which include all four types found in the Chaumont.

2) Rippled surfaces

Few rippled surfaces are found in the Chaumont, as is the case with much of the pellet and skeletal muds, and the grapestone facies of the Bahamas, especially when stabilized by vegetation. The coarser grapestone, oölite, and oölitic facies toward the bank margins, however, do exhibit a variety of rippled surfaces (e.g. see Hoskin, 1963, Pl. 4, figs. F, H: Alacran Reef, Yucatan), even developing into submarine barchan dunes (Purdy, 1961, fig. 7B). Relatively large-scale ripples are restricted to the higher units of the Chaumont in the western region, that is, stratigraphically close to the calcirudite facies.

3) Slumped bedding

The writer knows of no record of slumped areas of muds or pellet-muds from recent carbonates. Since modern deposits are mainly confined to flat banks, rather than encroaching upon terrain with a relief of several hundred feet, this absence is to be expected.

4) Erosional channels

a) Solitary channels

Descriptions of solitary erosion channels that are known to the writer from modern carbonate environments are restricted to surge channels (e.g. Hoskin, 1964) which are generally headward extensions of grooves in the spur-and-groove zone (Newell, 1956, p. 346; Cloud, 1959, p. 410).

b) Spur-and-groove channels

These structures have been compared with modern examples elsewhere (Barnes, 1964; MS). Newell and his associates (e.g. 1956, 1957) and Cloud (e.g. 1959) have described the erosional variety of spur-and-groove structures from atoll, reef, and platform environments. Their morphology and configuration vary considerably, but the Chaumont forms seem to lie within this variation. They are formed by erosion produced by the vigorous undertow currents associated with the surf, or breaker, zone on a shallow, shelving platform. Considering the stratigraphic position of the Chaumont structures (see Appendix, locality 2) and their probable paleogeographic location (fig. 3), they apparently formed on the western side of the lower Rockland calcirudite facies and in very close proximity to them. Hence, this feature, too, can be compared directly with modern examples on the basis of both morphology and environment of formation.

5) Mud-cracks

The absence of mud-cracks in the Chaumont, but their increase in abundance down through the Lowville and Pamelia has earlier been compared to modern environments. Such a position is to be expected with progressively further off-shore facies.

6) Borings

Extensively bored surfaces such as that figured by Ginsburg (1957, fig. 6), if preserved, would be very similar to those found in the Chaumont. These may be formed during brief exposure, which would also allow some lithification, but such burrowings are not restricted to the intertidal zone (Kornicker and Boyd, 1962, p. 654). The Chaumont beds that have been subjected to this boring are generally restricted to beds less than one foot thick. Arrhenius (1961, p. 139, fig. 7) noted that few single worm channels had been observed to penetrate more than 20 cm into sediment from the East Equatorial Pacific. If the Chaumont units were bored after accumulation, rather than penecontemporaneously, this would give one explanation for the relatively shallow depth of penetration. Very similar borings are also well figured and discussed by Koldewijn (1958) from the Paria-Trinidad shelf.

7) Load and differential compaction structures

These sedimentary features are common in both carbonate and non-carbonate sediments whenever coarse sands overlie much finer sediment and both are water-saturated and in a plastic or fluid state.

C) Structures within beds

a) Shale laminae

In Chapter 3, several possible origins for these laminae were proposed. For reasons given there, the normal deposition of detrital material does not explain all the features observed. Several agencies operating in modern areas, however, were shown to be far more conclusive. These included trapping by patches of organic material or algal mats, or by the baffle action of vegetation. Further to this, Folk and Robles (1964) show how the decomposition of fecal pellets result in the accumulation of a film or thin layer of primarily organic matter. This too could clearly produce the type of laminae observed in the Chaumont.

b) Internal bedding:cross-stratification

Four main types of cross-stratification were described, occupying distinct stratigraphic, and hence environmental, positions. The lowest types found are the alpha and zeta variety; both seem to reflect similar conditions, the former being found in thin, but extensive sheets, while the latter are restricted to the infillings of small, shallow channels. Following Allen (1963, Table 2), their origin seems to be due to the submarine migration of solitary banks with curving or linear fronts that in most cases are slip-off faces. The geometry and petrography of the alpha units indicates transportation of the bed material and since the bedform is a plane type, two possible modes of origin are suggested. Firstly, these thin spreads probably resemble those of Type II of Imbrie's (1964) Bahaman structures which are produced on the backshore and foreshore of beaches by the swash and backswash of currents. However, their frequently isolated nature, occasional lateral impersistence, and stratigraphic position do not favour a beach association. The second suggestion seems far more probable; the type (4) cross-stratification described by Harms and Fahnestock (1964) from the Rio Grande is comparable to those under discussion. They interpret it as "a product of plane-bed transport achieved in the upper-flow regime and is preserved as thin sheet-like sets on bar surfaces".

Nu-cross-stratification is the middle variety found high in the Chaumont, a little beneath the lower Rockland calcirudites. This small-scale trough cross-stratification is comparable to type (2) of Harms and Fahnestock (1964) which they interpret as forming "by ripple migration in the lower part of the lower-flow regime".

The large-scale tabular sets (omikron-cross-stratification) that are one of the most frequent varieties in the lower Rockland calcirudites are also found by Harms and Fahnestock (1964, type (3)) which "form by migration of bars or of terrace-like features in the lower-flow regime". Allen (1963, Table 2) interprets both nu- and omikron-cross-stratification as "probably due to the migration of trains of different forms of small-scale or large-scale asymmetrical ripple marks, depending on the size and shape of the sets forming the coset". It is possible that the omikron-cross-stratification is equivalent to Type II of Imbrie's (1964) Bahaman structures which "is found in intertidal-subtidal, unrippled, grapestone bars".

If these comparisons with modern structures are applied to the lateral facies pattern outlined earlier, a clear energy sequence emerges. This can be verified by further considering the grain-size, sorting, and textural spectrum position of the units involved. The lower Rockland calcirudites, with intraclasts and skeletal debris as the only significant allochem types, are well washed and moderately sorted. They exhibit the omikron-cross-stratification. Hence, a moderate to high energy system is suggested, somewhat variable, but normally lying in the upper lower-flow regime with occasional units signifying the lower upper-flow regime (see Simons, Richardson, and Albertson, 1961). Migrating bars within a shoal belt are envisaged; the substitution of the true grapestone grains by the other three intraclast types is taken to indicate rather higher energy conditions than those operating to produce Imbrie's (1964) Type II structures. Hence, they may be more comparable to the true Bahaman oölite shoals, with conditions for oölitization being absent in the Rockland situation. These may have looked very similar to the present-day shoals and bores on the edges of the Bahama Banks (e.g. Newell _et al._, 1951, Pl. 1, figs. 2-6; Harrington and Hazlewood, 1962, figs. 2A, 2B). Indeed Newell _et al._ (1959, p. 220) state that the grapestone facies may be a product of somewhat similar environmental conditions of the unstable oölite facies.

As seen from these and similar aerial photographs, both sharp and gradational limits to the shoals are present. Stratigraphically, these would produce similar contacts, and sudden advancements (such as associated with a period of transgression) would likewise tend to result in sharp contacts with lateral facies. Such is generally the case in the western Ottawa Valley where the shoals overlie thin, rather platy, units characterized by nu-cross-stratification. These are medium and coarse sands (not rudites), only moderately washed in many instances; sorting is poor to moderate and variable. The cross-stratification is seemingly produced by the migration of trains of small-scale asymmetrical ripples in the lower part of the lower-flow regime. Such conditions are to be expected directly to the lagoonal side of the shoals, being somewhat protected and hence in a lower energy regime.

The thin isolated beds characterized by alpha- and occasionally zeta-cross-stratification occur a little beneath the platy units just discussed, Moreover, their frequency becomes significantly less progressively lower in the section. Such beds are usually of medium sand, and composed of well washed, moderate to well sorted pellets and shell debris. The cross-stratification indicates the migration in the lower part of the upper-flow regime of solitary banks with curving or linear fronts that in most cases are slip-off faces. Hence, intermittent periods of high energy occurred, their effects being most noticeable higher in the section. This suggests that storms were possibly the cause, which re-sorted and transported laterally the top few inches of bottom sediment. Some of this material may have been swept from the shoal banks; it is likely that proximity of the latter and associated shallowing caused the storm effects to be most noticeable near to the shoals rather than in the lagoonal regions. This accounts for the mode of occurrence of the alpha-cross-stratified units within the Chaumont. In the eastern region, such beds are only noticeable in the Rockland i.e. at the time when the western shoals had developed.

Taken by itself, each cross-stratified bedform provides significant information on the past energy regimes. It is also clear that high energy areas must be flanked by facies experiencing lower energy conditions. In the case of the lower Rockland calcirudites, herein interpreted as shoals, where were the quieter environments? The evidence revealed by internal bedding and associated lithologies indicates that the Black River and Rockland facies were lateral equivalents.

c) Graded bedding

As discussed in Chapter 3, this feature almost certainly is indicative of a gradual change in energy conditions and hence is to be expected in most comparable modern environments.

d) Contraction stringers

It is doubtful, as expressed in Chapter 3, that these represent "worm" borings or even a mould of a decayed benthonic holdfast (Beales, 1963). The proposed origins: either as escape routes of interstitial water or as tension or contaction cracks during diagenesis, would not seem incompatable for the environments postulated, although this feature does not seem to have been described from modern sediments.

e) Chert and Silicification

Beales (1958, p. 1866) states that silicification "is not prevalent in bahamites presumably due to the lack of siliceous source material" which "may be linked with a lack of silica-secreting organisms" and this "may in turn link with the slight increase in salinity...". This, however, does not seem to explain the formation of chert nodules in parts of the Lowville (and very rarely in the Chaumont) and the silicification only of certain allochem types in the lower Rockland. Until it is determined whether the silica source was organic or inorganic (e.g. Calvert, 1964), the environmental significance of the chert and silicification must remain essentially unknown.

3. BIOGENIC REMAINS

a) Gross characteristics

Although the faunas of some modern carbonate areas have been studied (e.g. Newell et al., 1959; Cloud, 1962; Purdy, 1964b), it is difficult to transfer these results to ancient limestones in order to interpret environments. Much of this work, for example, deals with organisms which would not be preserved in the fossil state. Further, one is not able to estimate the destructive and diagenetic agencies that would affect the modern organisms prior to fossilization. A few general comments can be made, however, for some of the Ordovician groups that appear to be comparable to their modern representatives.

It appears to be the case, as stated in Chapter 3, that extensive lagoonal muds are not populated by numerous or especially varied groups of organisms. The muddy sand and mud habitats of the Bahamas (Newell et al., 1959, pp. 222-224) have a poor epifauna, but a significant infauna. However, of half the species listed, half (the algae and grasses) would rarely, if ever, become part of the fossil record. The stable sand facies of the Bahamas is probably comparable to most of the Chaumont calcarenites. Newell et al., (1959, pp. 220-222) report a rich and diverse community characterized by many echinoderms and molluscs with a heavy floral cover. Although the various Bahaman facies were not explored equally, it is noteworthy that the faunal list contains over three times the number of species than from the muddy sands and muds of the shelf lagoon. It will be recalled that the Chaumont fauna was varied, quite prolific, and primarily molluscan in character.

Because of the more complex outer platform facies of the Bahamas, comparisons are less satisfactory. The unstable sand and coralgal facies contain from 10% to nearly 100% of skeletal material and "the seaward margin (of the unstable-sand facies) rather consistently contains more than 50 per cent of skeletal material" (Newell et al., 1959, p. 217). The unstable shoals, which are subject to extreme mobility, are characterized by a paucity of both fauna and flora. However, as stated previously, the lower Rockland calcirudites are not interpreted as having such abundant mobility and can perhaps be best compared to a fairly high energy unstable sand facies. The relative increase of skeletal material in these Rockland units, however, is clearly comparable to modern carbonate bank environments.

b) Burrows and related structures

Recent examples of burrows and related structures were given above under part 6) of irregular bedding surfaces. It need only be added here that their absence in calcirudite shoals and nearly all cross-stratified units is understandable, the work of Newell et al. (1959)

revealing the relative lack of plant and animal life in the mobile sands (e.g. see unstable oölite sand habitat, <u>ibid.</u>, pp. 218-220).

c) Complete fossils

1. Corals

Certain features of the occurrence of <u>Tetradium</u> merit further discussion. <u>Tetradium</u> is present in many beds within the Pamelia and Lowville, but in the Ottawa Valley it is nearly always found in particular profusion in a 3-5 ft. unit at the top of the Lowville. This boundary also marks the change from muds and fine silts to coarse silts and sands. Only a small minority of the corals stand more or less upright, in an assumed growth-position. Clearly, the origin of this accumulation must be either as a virtually ideal ecological niche for this species or that nearby coral growths were accumulated in a bank by mechanical transport. Recent examples are available for comparisons in both cases. Baars (1963, fig. 7) figures a linear bank accumulation in the Florida Keys of dead fragments of the finger coral <u>Porites</u>, formed by selective growth without assistance from wave or current action. Also, Folk and Robles (1964, figs. 6, 7; Pl. 1, fig. C; Pl. 2, figs.B, C, D) illustrate similar linear banks from the Alcran Reef complex of coral sticks (<u>Acropora</u> <u>cervicornis</u>). These latter ramparts are formed close to shore by transport of dead coral sticks from habitats further off-shore. The wave-action, in this example, causes the coral sticks to become aligned perpendicular to the shore. In the case of <u>Tetradium</u>, it is possible that the lithologic change marks a threshold in wave or current strength, but as the habitat of <u>Tetradium</u> was within the Lowville muds, as there is no noticeable alignment, and because the associated sediments do not indicate removal of interstitial mud, the biogenetic accumulation <u>in situ</u> explanation is favoured herein.

Although the general picture presented by Winder (1960) for the various ecological niches of Tetradium species seems to be applicable, it appears to be oversimplified in certain aspects. The massive heads of T. fibratum, for example, are not restricted to high energy environments and, if anything, perhaps favour environments reflected in thin-bedded, variable calcarenites with moderate to high biogenic contents and appreciable shale partings. Likewise, the massive Lyopora is found in growth position in poorly washed massive fine calcarenites as well as occurring uprooted in the lower Rockland calcirudites. Although both of these forms may be potential reef builders, they would appear to favour only moderately turbulent environments, and can be best compared to present-day genera such as Monastrea and Diploria.

2. Brachiopods, cephalopods, gastropods, trilobites, and bryozoans.

All of these groups are difficult to compare in detail with modern relatives. It is noteworthy, however, that the Pamelia and Lowville muds and the Chaumont calcarenites possess an essentially molluscan fauna. Newell et al. (1959) likewise report a rich, dominantly molluscan fauna from the stable sand facies, which becomes much impoverished in the muddy sand and mud habitats.

3. Algae and stromatolites

These organisms have similar representatives in comparable environments of the present-day. Those described from the Chaumont are indicative of water deeper than the intertidal zone (Ginsburg, 1960; Logan, 1961; Logan et al., 1964), whereas the intertidal forms (e.g. Black, 1933) are absent.

d) Summary of comparisons of sedimentary features

Each significant sedimentary and biologic feature described in Chapter 3 from the Chaumont has been compared, when possible, with modern examples from several areas of recent carbonate deposition. The great majority can be compared directly and many of the remainder only await further study of modern counterparts. Considering the intensity and limitations of both modern studies and the present work, these comparisons show remarkable similarities between the past and present not to be ignored. This is especially the case when combined with the similarities drawn earlier with the broad facies patterns. These comparisons are so strong and the alternative explanations so weak and few that the writer feels fully justified in applying these similarities to greatly strengthen the stratigraphic and environmental interpretations.

Summary of the stratigraphic and environmental interpretations

A) Stratigraphic interpretation

In conclusion, the writer considers that the Pamelia, Lowville, Chaumont, and Rockland formations are lateral facies equivalents of each other. It is extremely doubtful that all four facies were deposited contemporaneously within the present confines of the Ottawa-St. Lawrence lowlands. With the deposition of the Rockland at Ottawa, for example, the Pamelia would presumably have been deposited scores to hundreds of miles away on the Canadian Shield. The Pamelia and Lowville are regarded as originally being extensive lagoonal muds which passed out into the Chaumont pellet sands. The transgression continued, producing a connection with the "Arctic" sea to the northwest and a shoal facies (lower Rockland calcirudites) was developed to the west of Ottawa. This thickened westwards and was bounded on both sides by Chaumont and Rockland pellet sands. This facies interpretation is illustrated in figure 4, with the pattern

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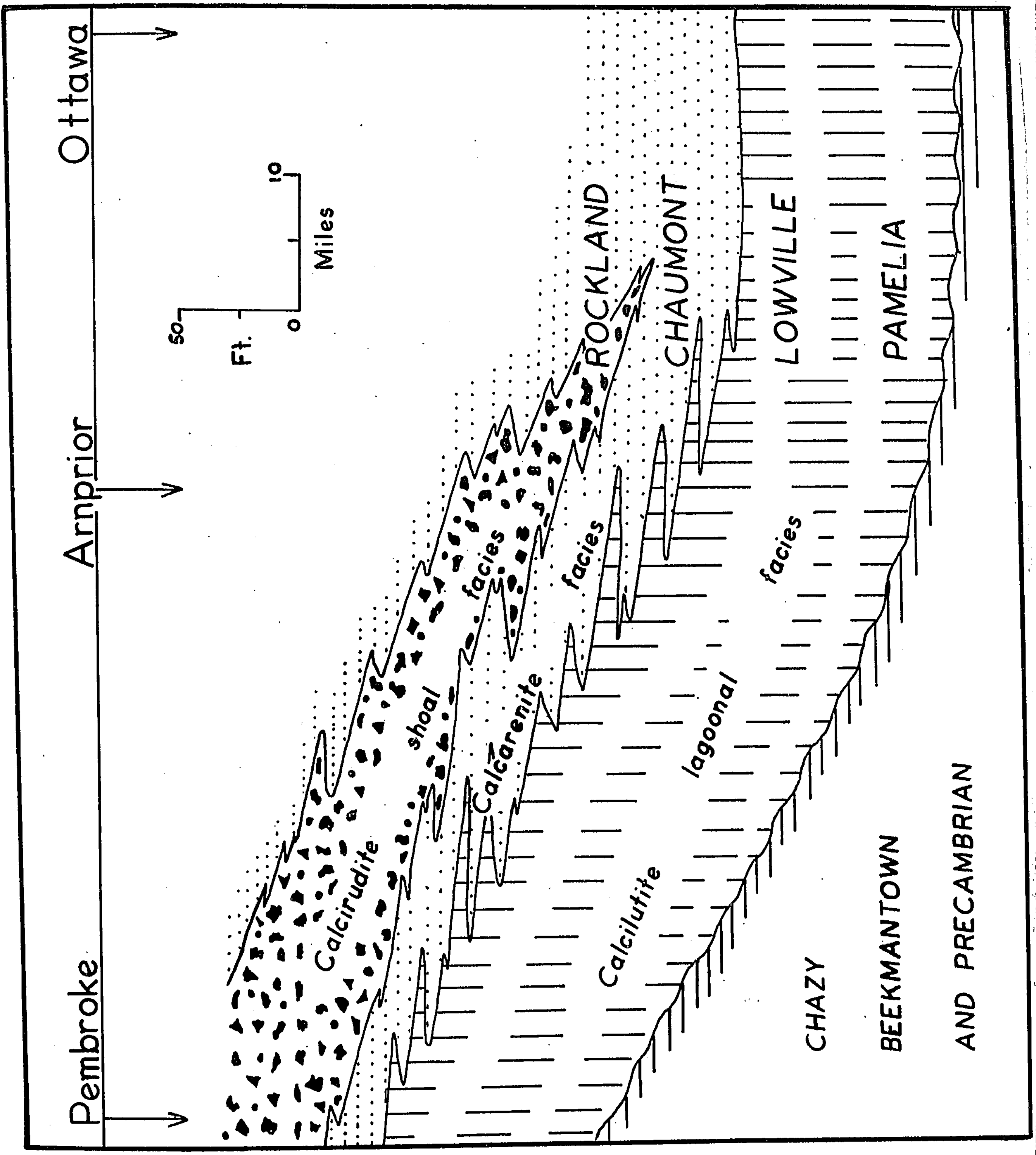
FIGURE 4: Facies interpretation of the Black River group and lower Rockland formation in the western region. The relationships in the eastern region are like those at Ottawa, but with the Lowville-Chaumont boundary also rising eastwards towards the Beauharnois Anticline, but with no interfingering of facies.

FIGURE 4


Pembroke
Arnprior
Ottawa
50
Ft.
0
10
Miles
ROCKLAND
CHAUMONT
LOWVILLE
PAMELIA
Calcirudite
shoal
facies
Calcarenite
facies
Calcilutite
lagoonal
facies
CHAZY
BEEKMANTOWN
AND PRECAMBRIAN

at Ottawa continuing eastwards, but with the Lowville-Chaumont contact rising, possibly over the weak Beauharnois Anticline, but with insufficient relief to cause interfingering of facies.

These conclusions are similar to the interpretations given by Winder (1960) for the S.W. Ontario succession and for that in N.W. New York by Fisher (1962). These views are not widely held, however, and are in conflict with those of Kay, Young (1943), and several contempory workers who favour the formations as essentially chronostratigraphic units. Because of the fundamental nature of these conflicting ideas, the following points are presented which the writer considers the most important for substantiation of the proposed hypothesis. None of these is sufficient proof by itself, but when taken together they present an almost indisputable case.

1. Stratigraphy, based on field work

a) A fairly constant succession of formational lithologies (i.e. environments) over extensive areas and in separate basins.

b) Interfingering of the Lowville-type calcilutites and Chaumont calcarenites within the Chaumont of the western region.

c) Wedge of lower Rockland calcirudites in the western region.

d) Similar calcarenites (Chaumont and Rockland) above and below the calcirudite wedge, with associated interfingering, particularly in the upper part of the wedge.

2. Macrofossils

a) The probability that the great majority of the macrofossils used previously for correlation and as biozones are environmentally controlled. Few of these groups have been studied from the phylogenetic standpoint. Hence, most assemblage correlations for the purpose of determining position within a time sequence are suspect.

3. Sedimentary features

a) Over a score of sedimentary features were described in detail from the Chaumont; nearly all directly support the hypothesis, none deny it.

b) The abundance, distribution and overall assemblages of the major fossil groups suggest habitats represented by the environments proposed.

c) Bentonites, used by some previous authors, are not considered satisfactory in these units in these areas. Only exceptionally detailed work with them - not undertaken in the past - may show them to be correlateable over tens of miles.

4. Carbonate petrography

a) The petrographic information from the units sampled has confirmed detailed similarities to modern sediments, energy relationships proposed, and hence to the facies and environments suggested.

5. Period of transgression; basin sedimentation

a) Being a period of overall marine transgression, lateral shifts in carbonate facies are to be expected and these would be diachronous.

b) Sedimentation was within shallow basins with moderate basement relief in places. Considering the mode of, and factors governing, carbonate deposition and accumulation, several distinct carbonate facies would almost certainly have been present at any one time.

6. Conodont investigations

a) A major change in conodont faunas (at approximately the top of the Chaumont) is found in the eastern region. This becomes progressively lower stratigraphically in the sections in moving eastwards, relative to the top of the Lowville. This change is presumably essentially synchronous, hence suggesting the top of the Lowville to be diachronous.

b) The Rockland conodont fauna in the Chaumont facies of the Pakenham quarry in the western region indicates deposition on an island (the flanks of a Precambrian monadnock), thus confirming transgressive facies and supporting the proposal given above in 6.a).

B) Environmental interpretation

From the descriptions of the stratigraphy and sedimentary features, their comparison with modern analogies, and the interpretations presented, some final brief comments can be made for the sedimentary environments envisaged for Black River and Rockland units.

a) Pamelia-Lowville calcilutite facies

This near-shore lime-mud lagoonal facies was rather impure in places with some dolomitization of the intertidal deposits. The depth of water (as indicated by mud-cracks, rip-clast zones, etc.) appears to have been very shallow - probably less than 15 ft. or so - with fluctuations in the overall transgression causing periodic exposure, the innermost facies being affected more and most frequently. The sediment-type and impoverished fauna suggest higher than normal salinities, probably in excess of 39°/oo (normal: 35°/oo). Likewise, rather higher temperatures are indicated, but the lack of appreciable evaporitic deposits is perhaps due to humid conditions. At the sediment-water interface, no reducing conditions seem to have prevailed (as shown by the heavy minerals) nor the pH value to have dropped below that of normal sea-water (e.g. no abundant extensive corrosion zones). The shallowness of the water probably negated much of the tidal flow and energy conditions are envisaged as being low to very low, producing restricted circulation and only minor turbidity.

The sea floor apparently was fairly even, rather soft, but with possible areas of protruding lithified muds. These latter areas provided the best habitat for most of the epifauna. Overall, the facies was sparcely populated and dominated by a poor molluscan fauna, with some ostracods, trilobites, and Tetradium which became relatively more abundant towards the outer edges of the mud facies. There is likewise little evidence of significant floral cover.

b) Chaumont calcarenite facies

The Lowville muds and pellet muds probably passed sea-ward into the Chaumont calcarenites. These latter were poorly washed pellet sands with appreciable amounts of skeletal debris and some areas of coarser, well washed cross-stratified sands. Somewhat deeper water, perhaps in the order of 15-50 ft., is envisaged with only rare periods of subaerial exposure. The sand facies would lie within the same climatic regime, but salinities seem to have been closer to the norm, judging from the sediment-type and fauna, probably about 37-39°/oo. Again, no reducing conditions or low pH values are indicated at the sediment-water interface. Much better circulation of shelf waters was associated with the low to moderate energy regime. For the most part, currents and wave action were weak to moderate, rarely strong or persistent enough to produce ripples, but occasional storms caused currents in the lower upper-flow regime. The facies is therefore characterized by moderately firm, stable, muddy sands with clear, rarely turbid waters.

Such conditions allowed high populations of many phyla to thrive, but the fauna, as in the mud facies, was still dominated by molluscs. The infauna capable of preservation was far more subordinate to the epifauna and favoured the finer silts close to the Tetradium belt at the edge of the

Lowville mud facies. The activities of the boring and scavenging organisms were the prime cause of post-mortem skeletal breakdown rather than purely mechanical agencies. Sedimentary features also suggest that the binding and baffle action of vegetation was extensive within the calcarenite facies.

This facies was particularly extensive at times e.g. as testified by the Rockland calcarenites of the eastern region. It also appears to have flanked both sides of the calcirudite shoal facies.

c) Lower Rockland calcirudite facies

This wedge of lower Rockland calcirudites and coarse calcarenites is restricted to the western region. The sediments were well washed coarse sands and gravels composed of various intraclast types (composite grains) and skeletal material. Accumulation in shallow water, perhaps less than 20 ft., is indicated; evidence of subaerial exposure is scarce. The general climate, Eh and pH values were probably similar to those of the Chaumont calcarenites, but the salinity may have further approached normal (e.g. 35-37$^{o}/_{oo}$). Excellent circulation of shelf waters occurred and moderate to high energy conditions prevailed. These produced shoals of shifting, unstable sands and a variety of cross-stratification indicating formation primarily in the upper lower-flow and lower upper-flow regimes. The affects of this high energy environment were felt within the adjacent Chaumont facies and increase progressively towards the shoals.

The wave and current action over much of the shoal area was too vigorous to allow large faunal populations to thrive. Many other ecological factors were favourable, however, and protected areas within the shoals probably contained flourishing communities. Their skeletal remains were later incorporated within the shifting sands, mechanical breakdown being dominant over organic processes. Although the resultant thanatocoenoses are still primarily molluscan in nature, there is a notable increase in the compound coral population. There is little evidence of significant growths of vegetation, which, besides, would be unlikely owing to the mobility of the sediments.

The stratigraphic position, geometry, and paleogeographic location of the shoals suggests two possible controlling factors. They might have formed close to the Precambrian positive areas, controlled by a combination of bottom morphology and tidal flow. Such shoals, however, are not present in N.W. New York where the seas lapped up against the Adirondacks and more critical conditions may be required. Such could be postulated in the second possibility where tidal flow is considered to be the most critical factor. Shoal banks are found in the western Ottawa Valley and in the vicinity of the Frontenac Arch to the south. Evidence, primarily based on macrofaunas, was elucidated earlier to show that the Frontenac Arch was probably breached after deposition of the Pamelia on each side. Likewise, it was shown that the shoals of the western Ottawa Valley contain an "Arctic" fauna, thereby indicating a further connection of two seas, probably through fairly restricted straits. As these deepened, the tidal flow would become more pronounced and coarse shoals would develop around the entrances to the straits (cf. edges of Bahama Banks, e.g. Illing, 1954, Pl. 5; fig. 8). Hence the shoals would not develop in the centre of the basin (e.g. in the eastern region of the Ottawa Valley) or around certain areas of coastline (e.g. possibly the Adirondacks).

Many other minor details could be added which were considered in the description and interpretation of the sedimentary features. These clearly fit into the environmental interpretation presented, but for the sake of brevity, have not been reiterated in this final summary.

C) Middle Ordovician paleoclimatology and paleogeography

Having discussed at some length the carbonate environments and marine transgression, it would be inadequate not to relate these limestones to the present status of knowledge of Middle Ordovician paleoclimatology and paleogeography. There is considerable agreement (e.g. Spjeldnaes, 1958, 1961; Nelson, 1959; Bain, 1961) that the so-called "Arctic" fauna was an equatorial assemblage - i.e. that found in the upper Ottawa Valley (Kay, 1939; Ollerenshaw and MacQueen, 1960) - and that the eastern Ontario, S.W. Ontario, and N.W. New York Ordovician carbonate deposits lay in the subtropical to temperate belt. The writer sees no objection to these proposals, which are also compatible with paleomagnetic evidence. Clark (1962) has, however, suggested that a large granite boulder in the lower Trenton, Pont Rouge, Quebec, was transported by ice-rafting; ice-crystal imprints are also figured from the Lorraine shales (Cincinnatian). The latter do not pose much problem, but the ice-raft proposal is of concern because such processes would be anomalous considering that all the other evidence points to a warm climate. As the boulder is only 30 ft. above the basement (stratigraphically), application of the lateral facies concept for these limestones would make a slide origin for the boulder feasible. This, however, Clark (ibid., p. 116) dismisses without discussion.

The paleogeographic interpretation of Kay (1937, Pl. 6) for the "late Rockland" seems to be basically correct from the present information (see figure 3). The location of the Canadian Shield to the north is probably the most tenuous point, for little evidence is available. The conodont information from the eastern region may indicate a stronger effect of the Beauharnois Anticline than Kay shows. There certainly appears to have been connections with the Montreal-Quebec area, S.W. Ontario (and N.W. New York), and, in mid to late Wilderness times, to the "Arctic" sea. The western Rockland macrofauna, of "Arctic" affinities, seems to be one of the earliest occurrences of this fauna which is usually assumed to be late Barnveld or Cincinnatian in age.

CHAPTER 6

CONODONT FAUNA OF THE CHAUMONT FORMATION AND IMMEDIATELY ADJACENT STRATA

One aim of the present study is the description and interpretation of the conodont fauna of the Chaumont formation and immediately adjacent strata.

The descriptions of the 25 sections and the sampling horizons are presented in the Appendix; sampling, field and laboratory techniques are described in Chapter 2. Over 250 samples were collected and after processing have yielded about 25,000 conodonts of known generic status. For the systematic description of the fauna, three sections were chosen where the stratigraphic position of the beds is best known, where distinctive lithologic breaks occur, and where an independent study has previously been undertaken (Kay, 1942). The three sections (localities 1, 2, and 3) are those at Meath Hill, Pine Valley, and Fourth Chute, in the Ordovician outliers at the western limit of the area studied. Forty samples were collected which later yielded a total of 3,839 conodonts identifiable to the generic level. Considerable variation exists in the conodont yields from sample to sample and from section to section; these observations are amplified in Chapter 8. The numbers of conodonts from the three sections are: Meath Hill, 458; Pine Valley, 2,286; and Fourth Chute, 1,095. From these collections were taken the better preserved forms for use in the systematic descriptions; the main collections were then repicked to ascertain that all the species present had been described. Some 600 specimens were used for this purpose and since no individual generic or specific studies were involved, the further sorting of large numbers of specimens for each species was considered unwarranted. A general discussion of the differences between the Chaumont faunas of the eastern and western regions is given below, together with a comparison with the faunas obtained from the Chaumont near the type area in New York State.

1. Chaumont conodont faunas of the three western outliers

The samples from these three localities produced very variable yields, averaging about 100 conodonts per 4 lb. sample, but ranging from 5 to 500, none being barren. The state of preservation is good, although the proportion of broken conodonts (those not identifiable to the generic rank) varies, as will be shown later. In colour, the conodonts are either light or dark amber, some samples (e.g. F.1; F.9) are composed of conodonts of a single shade, but most contain both light and dark coloured forms. Those assemblages or individuals that are overall of small size are invariably pale and are often found in calcilutites. Conversely, large specimens are generally dark in colour. However, certain species may have a predominant colour, independent of size or growth-stage, e.g. specimens of <u>Belodina grandis</u> were pale whilst those of <u>Belodina diminutiva</u> were dark, irrespective of the samples involved. Furthermore, all the "fibrous" conodonts (<u>Stereoconus</u>, <u>Cardiodella</u>, <u>Curtognathus</u>, <u>Polycaulodus</u>, <u>Trucherognathus</u>, N.gen. A, <u>Microcoelodus</u>, <u>Erismodus</u>, and <u>Ptiloconus</u>) are invariably dark in colour. These points indicate that the colour of conodonts is due to a number of factors, which may include the stage of growth, genetic and structural differences. Clearly, factors such as weathering and diagenetic processes can be important, but in the faunas under discussion, these appear to be constant. Lindström (1963, per. comm.) has found that colours darken with an increase in tectonic deformation. Other faunal variations are considered in Chapter 8. Most

TABLE 3

Conodont fauna from the uppermost Lowville, Chaumont, and lowermost Rockland of localities 1, 2, and 3 in the western Ottawa Valley.

N. gen. A n. sp. A

Belodina compressa (Branson and Mehl)
B. diminutiva (Branson and Mehl)
B. grandis (Stauffer)
B. cf. *B. inclinata* (Branson and Mehl)
B. ornata (Branson and Mehl)

Cardiodella diminutiva (Branson and Mehl)
C. divaricata (Branson and Mehl)
C. cf. *C. divisa* (Branson and Mehl)
C. cf. *C. robusta* (Branson and Mehl)
C. n. sp. A
C. n. sp. B

Chirognathus cf. *C. delicatula* Stauffer

Cordylodus dilatus (Stauffer)
C. concinnus Branson and Mehl
C. delicatus Branson and Mehl

Curtognathus coronata Branson and Mehl
C. limitaris Branson and Mehl
C. peculiaris Branson and Mehl

Dichognathus brevis Branson and Mehl

TABLE 3 cont'd.

Drepanodus homocurvatus Lindström
D. suberectus (Branson and Mehl)

Eobelodina fornicala (Stauffer)

Eoligonodina robusta Branson, Mehl and Branson

Erismodus abbreviatus Branson and Mehl
E. cf. *E. digitatus* Branson and Mehl
E. cf. *E. radicans* (Hinde)
E. cf. *simplex* Branson and Mehl
E. n. sp. A

Microcoelodus asymmetricus Branson and Mehl
M. expansus Branson and Mehl
M. intermedius Branson and Mehl
M. unicornis Branson and Mehl
M. n. sp. A

Oistodus inclinatus Branson and Mehl
O. robustus Bergström

Oulodus casteri Pulse and Sweet

Ozarkodina rhodesi Lindström
O. tenuis Branson and Mehl

Panderodus compressus (Branson and Mehl)
P. feulneri (Glenister)
P. gracilis (Branson and Mehl)
P. panderi (Stauffer)
P. striatus (Stauffer)

TABLE 3 cont'd.

Polycaulodus bidentatus Branson and Mehl
P. aff. *P. bidentatus* Branson and Mehl
P. cornulatus Branson and Mehl
P. normalis Branson and Mehl
P. tridentatus Branson and Mehl
P. n. sp. A
P. n. sp. B
P. n. sp. C

Prioniodina robusta (Stauffer)

Ptiloconus gracilis (Branson and Mehl)

Stereoconus n. sp. A

Trichonodella sp. A Uyeno

Trucherognathus cf. *T. disparalis* Branson and Mehl
T. distorta Branson and Mehl
T. parallela Branson and Mehl
T. sinuosa Branson and Mehl
T. n. sp. A
T.? sp.

Zygognathus cf. *Z. maysvillensis* Pulse and Sweet

Ordovician conodont workers have mentioned the occasional presence of bony material attached to the basal cavity of the conodonts. Such whitish, cream-coloured, or rarely dark material was present in a few specimens, predominantly in the "fibrous" types, but also in lamellar types (e.g. *Panderodus*, *Prioniodina*, *Trichonodella*). The internal structure could be discerned as vague concentric laminae in only a few specimens.

Another point of discussion is the status of the "fibrous" conodonts, or Neurodontiformes. Branson and Mehl (1933) erected this term for conodonts they believed to possess an internal structure composed of bundles of fibres rather than lamellae. Hass (1962, p. W 25) re-examined Branson and Mehl's material and found remnants of a lamellar structure in many of the specimens. Consequently, he regarded (1959, 1962) the term Neurodontiformes as invalid and thought that only forms with a lamellar structure should be included in the order Conodontophorida. Sweet and Bergström (1962), however, whilst recognizing that Hass' conclusions may be true, believed (*ibid*., p. 1249) that the "fibrous" types" form a distinctive Ordovician assemblage, in appearance, colour, and form. Furthermore, they appear to have a rather useful, if as yet largely unknown, stratigraphic distribution". The fact that the "fibrous" genera are consistently "altered", even in association with "normal" lamellar conodonts, strongly suggests that they do have certain peculiarities. Rhodes and Wingard (1957), however, have shown them to have essentially the same chemical composition as the lamellar forms.

The Chaumont specimens can be divided into two broad groups: a *Stereoconus*-*Cardiodella*-*Curtognathus*-*Polycaulodus*-*Trucherognathus*-N.gen. A group and another with *Microcoelodus*-*Ptiloconus*; *Erismodus* contains species related to both groups. In the former, the outward indications of the internal structure are invariably present. Here, a small circular pit is located on the aboral surface where the axis of the main cusp intersects the aboral surface. Concentric around this pit can be seen fine laminae, which are not visible on the oral surface. This strongly suggests that a lamellar internal structure exists. Thin-section studies could confirm this and it is hoped to complete such an investigation at a later date.

The Microcoelodus-Ptiloconus group very rarely exhibits these basal features and more closely resembles "normal" lamellar types. Both genera are included in the Neurodontiformes by most previous authors, although Rhodes and Wingard (1957, p. 449) have expressed doubt that Ptiloconus is a "fibrous" conodont.

The reason for this different basal architecture is perhaps explained by "basal inversion" (Lindström, 1955, p. 537, fig. 2), i.e. normally each successive lamina extends beyond the lower rim of the former, thus extending the depth of the basal cavity. When a succeeding lamina fails to extend even as far as its predecessor, a series of receeding laminae produce an "inverted basal cavity". In the Chaumont material, the former group of the Neurodontiformes (Stereoconus etc.) normally exhibits a step-like arrangement of the laminae. Depending upon the degree of this inversion the basal "excavation" can thus be concave, flat or convex. The material at hand does not seem to indicate any genetic controls, i.e. a genus, and sometimes one species, can possess all possible variations. The Microcoelodus-Ptiloconus group very rarely exhibits such inversion, whereas some species of Erismodus do.

Thus, the Chaumont material indicates that the "fibrous" conodonts probably have a form of lamellar structure. The mode of growth, however, may be slightly different from the "normal" conodonts found in association. Certainly the character of extensive basal inversion is restricted to this group, but a detailed X-ray and thin-section study is required to determine if other differences are present. In this connection, it should be recalled that Lindström's (1955) specimens with basal inversion included Oistodus, Drepanodus, Acontiodus, and Distacodus - all "normal" lamellar conodonts. Further, Rhodes and Wingard (1957) performed some X-ray and thin-section studies on some Neurodontiformes and found that they had a minutely fibrous structure parallel to the long axis. However, their experiments were restricted to one species of Stereoconus and clearly much more work is necessary.

The described Chaumont conodont fauna will be used for three types of study: paleontological, stratigraphical, and environmental. The latter two are dealt with in succeeding chapters, whilst the former will be considered here.

In all three studies, it was thought impractical to deal with the fauna at the specific level. At the present state of knowledge of Ordovician conodonts, with several generic ranges still being drastically changed, only a consideration of the faunal aspects at the generic level is meaningful. Moreover, there appears to be no significant change at the generic level in the conodont assemblages within the three western sections considered in detail. Also, the formation is only about 30 ft. thick compared to the 100 ft. of the Hull (Uyeno, 1963) where most of the species restricted to either the upper or lower members can be shown to range elsewhere both above and below that local level. Thus, the following discussion will be restricted to a consideration of the Chaumont genera.

Previous conodont studies have revealed two major faunal provinces during much, if not all, of the Middle and Upper Ordovician. One occupied the midcontinental area of North America, whilst the other stretched from the Appalachians to Britain and Scandinavia. Insufficient work has been done to determine whether a third province, or subprovince, exists in the areas characterized by the so-called "Arctic fauna". The interprovincial generic migration pattern is just beginning to emerge.

The Chaumont fauna is clearly allied to the midcontinental North American province. This is stressed by the high proportion of "fibrous" conodonts present, a type very rarely found in Europe. Panderodus, Oistodus, Drepanodus, Trichonodella, and Belodina occur in both provinces, but their relative abundance in the fauna is more characteristic of the midcontinental region. All the other bar and blade genera are found in both provinces, but at the specific level most forms have only been described from the midcontinental area. The Chaumont fauna, therefore, has strong affinities to the faunas characterizing the latter province and few with those from the Brito-Scandinavian-Appalachian region, which during this time also contained many genera that did not invade the midcontinent until a later date. It should be remembered, however, that the study of Ordovician conodonts is still young and two areas at least are in need of additional work. These are the Appalachian, where only two studies have been published (Ethington, Furnish, and Markewicz, 1958; Sweet and Bergström, 1962), and the standard sections and nearby areas of the Black River and Trenton groups where four projects have been undertaken (Uyeno, 1963; Winder, MS; Schopf, 1964; and the present study). Active research is now underway in several institutions and within the near future the pattern of Ordovician conodont evolution will become much clearer.

For the details of the distribution and abundance of conodont genera in the three western sections, reference should be made to figure 5, Table 4 shows the relative abundance of the Chaumont genera. This table was compiled from the text-figures just referred to by taking one unit to represent one subdivision of abundance (i.e. rare: 1, present: 5, common: 10, abundant: 15; the actual numerical limits being rare: less than 5 conodonts, present: 6-25, common: 26-50, abundant: over 50).

Examination of Table 4 reveals the dominant position of *Panderodus*, its abundance and variety (five species) clearly indicates that it is erroneous to regard these as being characteristic only of the Richmond (Rhodes, 1955; Ethington and Furnish, 1960).

Of those listed under "abundant" and "very common", two groups are found. One, composed of *Trichonodella*, *Dichognathus*, *Belodina*, *Cordylodus*, *Drepanodus*, *Ozarkodina*, and to lesser extent *Prioniodina*, is an assemblage of long-ranging Middle and Upper Ordovician genera known in a great many other areas (see Table 6). The second group, with *Polycaulodus*, *Micrococelodus*, *Erismodus*, *Cardiodella*, and *Ptiloconus*, is an assemblage of "fibrous" conodonts, which as a group are almost entirely restricted to the Middle Ordovician and are only abundant and diversified in the Chazy, Black River, and lowest Trenton units and their stratigraphic equivalents.

In the "common" section of Table 4, the common long-ranging forms are represented only by *Oistodus*, whereas the "fibrous" representatives are *Curtognathus* and *Trucherognathus*. Some genera, although long-ranging only

TABLE 4

RELATIVE ABUNDANCE OF CHAUMONT CONODONT GENERA

(see text for explanation)

Relative abundance	Conodont Genera	% of fauna
Extremely abundant	Panderodus	15.8
Abundant	Polycaulodus	7.8
	Micrococlodus	7.3
	Ozarkodina s.l.	6.8
	Belodina	6.4
Very common	Cordylodus	5.8
	Erismodus	5.5
	Trichonodella	5.5
	Prioniodina	5.4
	Drepanodus	5.2
	Ozarkodina s.s.	4.5
	Cardiodella	4.4
	Ptiloconus	4.4
	Dichognathus	3.8
Common	Curtognathus	3.1
	Trucherognathus	2.9
	Zygognathus	2.7
	"Aphelognathus"	2.3
	Oistodus	2.2
	Eoligonodina	1.8
	Oulodus	1.6
Infrequent	N.gen. A	0.7
	Eobelodina	0.6
	Stereoconus	0.5
Rare	Chirognathus	0.1

Note: Ozarkodina s.l. includes Ozarkodina s.l. and Aphelognathus which are also recorded separately but which are regarded as synonymous.

play a minor role in previously described faunas, if present at all. Chaumont examples in this section are Zygognathus, "Aphelognathus", Eoligonodina, and Oulodus.

The "infrequent" genera are N. gen. A and Stereoconus of the "fibrous" group and the minor, long-ranging, Eobelodina.

The single "rare" genus is Chirognathus which was only found in the upper Lowville.

In summary, therefore, the fauna of the Chaumont is dominated by common long-ranging (Middle and Upper Ordovician) genera and the "fibrous" conodonts. Genera that play a more important but still minor role in the faunas of younger formations, mainly of the bar and blade type, are only present as minor constituents.

At the specific level, this pattern is also borne out. The "fibrous" conodonts were placed in 37 species, the common and long-ranging types into 21, and the remainder (Eobelodina, "Aphelognathus", Eoligonodina, Zygognathus, Oulodus) into only 5 species. It is evident that the "fibrous" conodonts were not only numerically abundant but had undergone considerable speciation, being close to their peak of development, whilst many of the remainder are genera containing a single species and appear to be early developments of those genera which were to become more varied and better established at a later date.

From Table 4, it is also noteworthy, and partly to be expected, that the six least abundant genera are each represented by a single species. Conversely, the three most abundant genera contain 18 species.

Ten new species and one new genus have been described, all

TABLE 5

List of genera present in total fauna but absent from individual formations sampled.

UPPERMOST LOWVILLE	CHAUMONT	LOWERMOST ROCKLAND
Stereoconus Eobelodina	Chirognathus	Chirognathus N. gen. A Eobelodina Zygognathus Ozarkodina S.S.

belonging to the "fibrous" conodonts which form such a varied group in the fauna.

2. Chaumont conodont faunas of the eastern region

The Chaumont was sampled laterally to determine the effect of major facies changes on the faunas, the degree of faunal variation laterally in a formation and, if possible, to use the faunas to determine possible Chaumont diachronism over the area mapped. The latter was only possible in the eastern region, but the writer is optimistic that if the whole Mohawkian sequence of conodont faunas were in the Ottawa Valley, it would be possible to show diachronous formational units with the aid of conodonts. The assessment of lateral faunal change and the effects of local facies will be considered in a later chapter. At this point, the general differences in fauna will be outlined.

There has been no detailed study of the species present in the eastern region, but observations at the generic level have been made. Whereas the sections in the west had essentially uniform faunas, the eastern sections show a vertical assemblage change. This change takes place over about five feet or so and at about the stratigraphic level used herein for the Chaumont-Rockland boundary. Where there is no lithologic break, e.g. at Alfred (locality 24; fig. 15), the faunal change is still apparent over one or two samples.

Before the change takes place, i.e. in most if not all of the Chaumont as near as can be seen, the fauna is very similar to that described from the western localities. That is, there is a high proportion of "fibrous" conodonts and common, long-ranging, genera, with less frequent other bar and blade types.

The more obvious difference is the presence of *Phragmodus*, *Dichognathus*, and *Prioniodina* in "very common" to "abundant" proportions. It will be recalled that the former was absent from the western fauna. Also, the latter two genera were each represented by a single species, whereas in the east several others occur. *Phragmodus* is a very common genus in Middle and Upper Ordovician faunas and its absence in the western localities is rather puzzling.

Panderodus and the "fibrous" conodonts are present in approximately the same proportions with perhaps *Ptiloconus* being relatively more important. Of the remainder, those showing an increase in relative abundance include *Oistodus*, *Eobelodina*, and perhaps *Oulodus*; those exhibiting a decline include *Eoligonodina*, "*Aphelognathus*", and *Zygognathus*. *Chirognathus* was not observed, but all other western genera occur in the Chaumont of the east.

Besides *Phragmodus*, at least two other genera are found in the east, namely *Icriodella* and *Strachanognathus*(?) . The latter occurs in the upper Chaumont and only a single specimen (U.O. S.7(1)13) was found which may be a pathological drepanodid (from sample S.7, locality 21). *Strachanognathus* has not been recorded from the North American midcontinental province before and its earliest known occurrence in Europe is in the Llandeilian Crassicauda Limestone of Sweden (Lindström, 1960). *Icriodella* occurs in several samples both in the upper units of the Chaumont (U.O. S.1115; U.O. O.C.S. 9(4)13) and in samples within the higher fauna. The previous oldest known occurrence of *Icriodella* was from the Hull formation, Ottawa.

The higher fauna is probably characteristic of most, if not all, of the Rockland. This fauna is referred to below as the Rockland fauna for the sake of clarity rather than accuracy. As will be shown shortly, it may occur in the upper Chaumont in the extreme east and it certainly continues throughout a 57 ft. section (locality 25), thus extending up to at least 73 ft. above the top of the Lowville. Whether or not it extends throughout the whole Rockland has not been ascertained and this may be difficult to verify since the upper Rockland is so rarely exposed in the Ottawa Valley.

As to this Rockland fauna itself, a typical assemblage would include abundant *Panderodus*, *Phragmodus*, *Dichognathus*, *Drepanodus*, *Belodina*, and *Oistodus*, with the less abundant forms including *Prioniodina*, *Oulodus*, *Ozarkodina*, *Cordylodus*, *Eobelodina*, and *Trichonodella*, and with the rare genera including *Zygognathus*, *Icriodella*, and *Sagittodontus*. The latter genus e.g. in samples S.11 (U.O. S.1113) and Ad. 1 (U.O. Ad.113) was also found by Uyeno (1963) in the Hull and this lowest Rockland occurrence represents the earliest known presence in midcontinental faunas. The samples yield comparable numbers of specimens to those from the Chaumont, but most appear to be rather restricted in the range of generic and specific variation within the assemblages.

Besides the new generic additions, the Rockland fauna lacks some forms that are present in the Chaumont, notably the "fibrous" conodonts. The transition samples show mixed faunas, but the higher samples have only rare specimens of Neurodontiformes. These are generally absent, but a few may occur in occasional samples. This type of occurrence is similar to the Hull faunas, where Uyeno (1963) found in the whole fauna only a few specimens of *Polycaulodus*, *Curtognathus*, and *Trucherognathus*. Besides the "fibrous" types, other Chaumont genera that show a decrease in abundance are:

"Aphelognathus", Eoligonodina, Zygognathus and possibly Ozarkodina, and Prioniodina.

It will be recalled that the writer's study is essentially confined to the Chaumont, but that the lithological distinction between these two included formations in the eastern region is mostly arbitrary. Most sections, where possible, were sampled to include higher units than was perhaps necessary. After the conodonts obtained had been sorted, each section was checked for the type of fauna present, and possible vertical change. Table 7 gives the details of this survey. Of the 18 sections studied, 9 contained only the Chaumont fauna, 3 only the Rockland fauna, 4 contained both and 2 had their highest sample yielding a questionable, mixed, or indeterminable fauna. In all, 36 samples contained an undoubted Rockland fauna. The three sections that produced only a Rockland fauna were 6 ft. 3 ins., 21 ft. 8 ins., and 57 ft. 3 ins. in thickness, thus giving a reasonable picture of the vertical extent and composition of the fauna. No other apparent faunal change occurred in these Rockland assemblages.

Of the 18 sections listed in Table 7, are three that can be ignored in the following discussion. Section 10 has rather anomalous features and its true stratigraphic position is in doubt (see discussion in Appendix). Sections 12 and 14, whose highest samples yielded an uncertain fauna, are probably best regarded as Chaumont, but nevertheless do not affect the following suggestions.

It is of interest to consider the stratigraphic position at which the faunal change takes place. Around Ottawa (sections 11-17), no Rockland faunas were observed despite samples being collected up to 28 ft. above the top of the Lowville. Moving eastwards, at locality 18,

LOCALITY		CRITICAL SAMPLES C.: Chaumont fauna R.: Rockland fauna (?): Indeterminate fauna	COMMENTS	HEIGHT OF SAMPLE ABOVE BASE OF CHAUMONT					
No.	ABBREVIATION			C.		(?)		R.	
				Ft.	ins.	Ft.	ins.	Ft.	ins.
9	D.F.	All C.		6	3				
10	P.	All C.	Part Lowville?	26	6				
11	F.D.	All C.		21	0				
12	M.R.	C.up to M.R.4;M.R.5(?).		11	3+	18	4+		
13	H.B.	All C.		26	0				
14	D.M.	C.up to D.M.5; D.M.6(?).		19	1	21	3		
15	H.	All C.		25	0				
16	O.C.S.	All C.		22	11				
17	A.	All C.		28	0				
18	B.	B.1;C;B2(?);B.3 up: R.		1	8+	9	1+	24	4+
19	Cu.	All R.	Section: 21 ft. 8 ins.						
20	C.	All C.		11	5				
21	S.	C.up to S.8;S.9,S.10:(?); S.11 up: R.		18	4	20 22	10 1	24	3
22	W.	All C.		4	0				
23	J.	C.up to J.5.;J.6.:(?);J.7 up: R.		13	6	14	9	20	10
24	Af.	C.up to Af.5;Af.6:(?);Af.7 up: R.		14	4	16	6	19	2
25	Ad.	All R.	Section: 57 ft. 3 ins.						

TABLE 7

Stratigraphic occurrence of the Chaumont and Rockland conodont faunas in the sections of the eastern region.

(see fig. 1) the Rockland fauna is found but the sampling is widely spaced and the Lowville is not exposed. At Rockland (locality 21), some 20 miles east of Ottawa, the higher fauna is first found at 24 ft. 3 ins. above the top of the Lowville with the last sample bearing the true Chaumont fauna at 18 ft. 4 ins. Ten miles further to the east, at Jessop Falls (locality 23) these two levels have fallen to 20 ft. 10 ins. and 13 ft. 6 ins. respectively, whilst at locality 24, a further ten miles eastwards, they are 19 ft. 2 ins. and 14 ft. 4 ins. respectively.

It seems evident, therefore, that the level at which this faunal change occurs becomes progressively stratigraphically lower to the east with respect to the top of the Lowville. Since the Lowville-Chaumont boundary is conformable, several explanations can be proposed to explain this: a) the Chaumont thins markedly eastwards, b) the change is essentially a time-plane and cuts across the time-transgressive rock units, or c) the change itself is markedly time-transgressive owing to facies control of the fauna.

It is doubtful that there is significant thinning of the Chaumont eastwards to the extent required by the faunal change. The calcarenite facies of both the Chaumont and the Rockland is fairly uniform throughout and in considering the mode of deposition, it is difficult to see why the rate of accumulation of the sediments should be significantly less in the east. Further, the thickness of the "Leray" (23-24 ft.) in the Montreal area (Clark, 1952) is similar to that in the Ottawa Valley. It is a possibility, however, that cannot be completely disregarded.

Since the Ordovician sea was transgressive at this time and the rock units were probably likewise transgressive and facies equivalents of each other in many instances, the faunal change, if regarded as a time plane, would cut across the facies belts. It would explain the problem at hand if the Chaumont was an off-shore facies of the lagoonal Lowville somewhere to the east or north. The fauna, with such early representatives as Icriodella and Sagittodontus, probably had close links with the Appalachian fauna but could have arrived via the Montreal area or over the Frontenac Axis.

The migration of new faunas is regarded by the great majority of paleontologists as having occurred very rapidly by geological time standards (see, however, Cheetham, 1963, for an opposing example). Taking all the conditions into account, there seems to be no reason (in this hypothesis) for the new fauna to have advanced so slowly westwards. It may be possible that it was influenced by the shoal area to the west of Ottawa, the migration of which controlled that of the conodonts. However, the environment seems to have been similar throughout the eastern region, making this explanation extremely doubtful.

Of these three possible explanations, the writer strongly favours the second one. It seems best to fit the observed facts, but the writer must acknowledge that as it suggests diachronous rock units; some personal bias exists on this point. To determine whether this diachronism exists, more extensive studies, both vertically and laterally, would be required. Also in discussing the introduction of a new fauna, it should be recognized that all of the dominant constituent genera were also found in the Chaumont of the eastern region, but mostly in minor abundance. Hence, if for reasons unknown, the "fibrous" conodonts were to disappear, the other forms would be able to expand in numbers, giving rise to a recognizably different fauna without significant introductions from elsewhere. The evidence, however, that does suggest an influx of new stocks is the presence of new genera e.g. Icriodella, Sagittodontus, and many new species of some existing genera e.g. Oistodus, Dichognathus. Until the time ranges of Ordovician genera have been established, it is largely speculative to discuss the patterns of migration much beyond this area of study.

3. Chaumont conodont faunas in the eastern part of the western region

The physical aspects of the specimens from this area are similar to those previously described. No new genera were observed and none of those described from the west are missing. In general, the fauna seems more closely allied to that of the west. The genus Phragmodus, for instance, is only observed in the following samples: B.B.5, B.B.6, B.B.13 (locality 6); B.L.4a, B.L.10 (locality 8); and Pa.3, Pa.4, Pa.5, Pa.6 (locality 5). Only in the latter four samples is the genus associated with a Rockland fauna, which is its only definite occurrence in localities 4-8.

This Pakenham section (locality 5) and its conodont faunas require some explanation to account for this unusual occurrence. It reveals (see Appendix) typical Lowville overlain with possible disconformity by 13 ft. 9 ins. of Chaumont limestone. The section is rather unusual in that there is an absence of the Tetradium unit at the top of the Lowville and that the Chaumont is particularly massive in the lower 6 ft. with a predominance of richly biogenic calcirudites (contact shown in figure 13). The higher units are typical Chaumont calcarenites with characteristic borings and numerous shale laminae. The lowest two samples taken from the Chaumont have a typical Chaumont fauna with abundant "fibrous" conodonts, but sample Pa.3 and those higher contain the Rockland fauna with an absence of "fibrous" forms and a relative abundance of Dichognathus, Phragmodus, etc. Thus the change occurs between 3 ft. and 6 ft. above the base of the Chaumont. As this change was found nowhere in the other sections nearby, and much higher even in the most easterly sections, this section is particularly anomalous. To the writer, only one explanation fits all the observed facts. This considers the limestones to have been deposited on the flanks of a Precambrian monadnock and necessitates adoption of the idea of lateral facies equivalents of the formations concerned.

The pattern of previous marine incursions seems to indicate that the Ottawa Valley-St. Lawrence lowlands area was relatively low, with probably little relief. Further, basement irregularities would have been smoothed out by the deposition of the Nepean, Beekmantown, and Chazy strata. At the basin margins relief would be greater and thickness of sediments less, consequently the shoreline of the transgressive Black River-Trenton sea would be quite irregular in this area, with numerous islands formed by Precambrian knobs or monadnocks. Between Ottawa and Renfrew, several inliers of Precambrian occur but whether these are definitely faulted has not been satisfactorily ascertained since no detailed geologic study has been published. However, such features have been recognized by workers in the equivalent situation in S.W. Ontario, on the other side of the Frontenac Axis. In reference to these, Hewitt (1964b, p. 12) stated that "Similar structures due to buried Precambrian hills are common in Eastern Ontario, indicating the relief of the buried Precambrian surface to be in order of that of the exposed Precambrian, that is from 500 to 700 feet". Ambrose (1964) has also arrived at the same conclusion.

It may be assumed, therefore, that a reasonably large island (now a buried inlier) was in the vicinity of Pakenham (the present faulted(?) Precambrian outcrops on the other side of the village) and was undergoing gradual submergence. For a while, it would presumably retain a lagoonal (Lowville) facies, with or without a Tetradium zone. As the transgression, and hence the submergence, continued the outer calcarenite facies would encroach onto the calcilutites. Probably as the submergence became almost total, the lagoonal facies would disappear and a vigorous local shoal zone might develop, ultimately to sweep across the island. Such a sequence would explain all the stratigraphic observations (calcilutites, possible disconformity, calcirudites, normal "Ottawa-type" calcarenites). Also, the time involved in this submergence, of say even 100-200 ft., would be considerable and it is quite plausible, if not almost essential, to forsee the presence of a Rockland fauna. Hence, this explanation would account for both the stratigraphic and faunal anomalies.

4. Chaumont conodont fauna at Watertown, New York

In order to compare the Chaumont faunas with those of the type area, one well-known section was described and sampled (see Appendix, locality 30). The locality chosen - Klock's Quarry, Watertown, New York - had previously been described and its stratigraphic position ascertained with macrofossils and field mapping (Cushing et al., 1910; Young, 1943). It is the only such section that is essentially complete, well-known, and which is in the vicinity of Chaumont Bay which Kay (1929) chose as the type area for the formation.

SAMPLE NO: Wa.	1	2	3	4	5	6	7	8
SAMPLE WEIGHT (LBS.)	2½	4	3	4	4½	3½	5	4½
GENERA	NUMBER OF SPECIMENS							
Panderodus		17	23	6	28	14	23	90
Oistodus		3	2		3		1	11
Drepanodus		5	4	1	5	2	3	20
Cardiodella		3				1		
Polycaulodus		2	1					
Micrococlodus		2				1		
Ptiloconus		1						
Eobelodina			4	1	1			3
Belodina		5	13	4	5	1	1	24
Cordylodus		4	2				1	1
Trichonodella		2	1					
Dichognathus		1	1					1
Prioniodina		1	1	1				
Phragmodus							1	1
NO.OF SPECIMENS/SAMPLE	0	46	52	13	42	19	30	151
NO.OF UNIDENTIFIABLE FRAGMENTS	0	16	2	0	0	0	0	21

TOTAL NO. OF SPECIMENS: 353
TOTAL NO. OF FRAGMENTS: 39

TABLE 8

Conodont genera and their abundance in the Chaumont Formation, Klock's Quarry, Watertown, N.Y.

Eight samples were taken, of which only the lowest was barren of conodonts. Faunas from the remaining samples were identified to the generic level and, with their abundance of specimens, are listed in Table 8. The aspect of the fauna, *in toto*, is of an impoverished Chaumont fauna of the Ottawa Valley. Fifteen genera are represented and those others that were found in the western Ottawa are: *Stereoconus*, *Curtognathus*, *Trucherognathus*, N. gen. A, *Chirognathus* (Lowville), *Erismodus*, *Eoligonodina*, *Zygognathus*, *Ozarkodina*, "*Aphelognathus*", and *Oulodus*. One genus, *Phragmodus*, is represented at Watertown but which is absent from the western part only of the Ottawa Valley. The fauna, therefore, is clearly similar to that of the Ottawa Valley Chaumont, perhaps with closest links to that of the east, but certainly not to the higher (Rockland) fauna. The physical character of the specimens is also very similar, although the yield per pound is rather lower at Watertown. These results are opposed to those of Sinclair (1954) who considered the Chaumont of the Ottawa Valley to be older than that of the Watertown region.

CHAPTER 7

STRATIGRAPHIC SIGNIFICANCE OF THE OTTAWA VALLEY CHAUMONT CONODONT FAUNAS

Detailed study of Upper Devonian conodonts has shown them to be valuable index and zonal fossils. Whether conodonts may be so used in the Ordovician is at present uncertain owing to the lack of information. Intensive work, however, is at present under-way in both Europe and North America and most previous publications on Ordovician conodonts are listed in three bibliographies: Fay (1952), Ash, (1961), and Ellison (1962, 1963). The best known faunas are from formations of late Champlainian and early Cincinnatian age as shown by Winder's (MS) recent study of the Cobourg in S.W. Ontario, in which only a few new species were found and few ranges significantly extended. Conodonts from earlier or later formations have received much less attention and it is quite usual for studies such as the present one to extend considerably the ranges both of genera and species. Whereas much work has recently been published on upper Barnveld (=Trenton), Eden, and Maysville conodonts, very little recent research has been undertaken on the Porterfield and Wilderness faunas of the midcontinent province. Studies in the Brito-Scandinavian-Appalachian province have been devoted primarily to the Lower and Upper Ordovician; consequently, faunal comparisons with the Chaumont material are somewhat unsatisfactory.

Under these circumstances, comparisons at the generic level are both valid and valuable, but those at the specific level (for the Chaumont) are difficult. Generic definitions have become more stabilized in recent years and many of the older descriptions can be reinterpreted, but at the specific level this is frequently impossible without direct comparisons

TABLE 6: Stratigraphic distribution of Middle and Upper Ordovician conodont genera and comparison of faunas.

Formations Genera	Fort Peña	Pratt Ferry	Dutchtown	Deadwood	Joachim	Glenwood	Harding	Lower Bighorn	Upper Bighorn	McLish	Plattin	CHAUMONT	Winnipeg	Woods Hollow	Llandeilo	Bromide	Viola	Kimmswick	Whitewood	Decorah	Hull	Prosser	Stewartville	Dubuque	Ludibundus	Stony Mountain	Shamattawa	Maquoketa	Maravillas	Upper Bighorn	Eden	Maysville	Richmond	Penn-y-garnedd	Gelli-grin	Keisley	Erratics, Poland	Crug
STEREOCONUS					X	X	X	X				X																						X				
COELODUS			X	X	X		X	X																														
NEOCOELODUS			X	X			X	X												X																		
MIXOCONUS							X																															
LEPTOCHIROGNATHUS				X						X						X																						
CHIROGNATHUS		X	X			X	X	X			X		X						X																			
ERISMODUS			X			X	X	X		X	X	X	/			/	/													X								
MICROCOELODUS			X	/	X	X	X	X				X	X			X			X	X										X			/			/		
PTILOCONUS		X	X	X	X		X	X	/	/	X	X	X					/	/	X																		
POLYCAULODUS			X		X			X			X	X	X			X				/	X																	
CARDIODELLA			X		X						X	X				X																						
CURTOGNATHUS					X		X			X	X	X				X				X	X																	
TRUCHEROGNATHUS					X						X	X		X		X					X																	
N. GEN. A												X																										
SCOLOPODUS		X					X						X	X																	X							
LIGONODINA		X													X										X									X	X	X		X
PRIONIODUS			/																/	X					X						X					X	X	X
SCANDODUS		X																			X																	
DISTACODUS						X							X							X	X	X	X	X	/												X	
ACODUS	X	X		X																				X												X		X
BRYANTODINA	X		X			X		X					X					X			X														/			
SCYPHIODUS							X						X							X	/																	
EOBEOLODINA	X											X								X	X										X							
PERIODON	X	X											X	X								X		X														
FALODUS	X	X											X	X								X	X	X	X												X	
POLYPLACOGNATHUS		X					X											X		X	X							/										
EOLIGONODINA							/					X	X					/	X	/	X			X		X	X			X	X	X	X					
PRIONIODINA	X	X										X									X	X	X	X		/	/	X		X	X	X	X				X	X
ZYGOGNATHUS						X						X			/				/		X	X	X	X						/	X	X	X		/			X
SAGITTODONTUS		/																			X			X							X				X			
ICRIODELLA																					X			X										X	X	X		X
COELOCERODONTUS		X																					X	X														
TETRAPRIONIODUS		X																						X	X					X		X					X	
AMBALODUS															X								X	X	X			X	X	X	X	X		X	X	X	X	X
AMORPHOGNATHUS															X								X	X	X			X	X	X	X	X		X	X	X	X	X
STRACHANOGNATHUS																									X											X	X	
KEISLOGNATHUS																							X	X						/	X	X				X	X	
APHELOGNATHUS												X																				X	X			X		
OULODUS						X					X	X						X		X	X					/	X			X	X	X						
DICHOGNATHUS	X				X	X	X				X	X	X		X		X	X		X	X	X			X	X		X			X	X						
PHRAGMODUS			X		X	X	X			X	X		X				X	X		X	X	X		X		X		X	X		X	X		X		X		
OZARKODINA			X		X	X	X				X	X	X		X			X	X	X	X	X	X	X		X	X	X	X		X	X					X	X
TRICHONODELLA					X	X	X			/	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
CORDYLODUS	/	X	X			X	X	X		X	X	X	X	X	X	X	/	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	X
ACONTIODUS	X	X		X					X				X	X				X	X	X	X	X	X	X													X	
DREPANODUS	X	X		X		X	X	X	X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OISTODUS	X	X		X		X				/	X	X	X		X		X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X
PANDERODUS	X	X				X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
BELODINA		X			X	X			X		X	X	X					X	X	X	X	X	X	X		X	X	X	X	X	X	X						

TABLE 6

Formations Genera	Fort Peña	Pratt Ferry	Dutchtown	Deadwood	Joachim	Glenwood	Harding	Lower Bighorn	Upper Bighorn	McLish	Plattin	CHAUMONT	Winnipeg	Woods Hollow	Llandeilo	Bromide	Viola	Kimmswick	Whitewood	Decorah	Hull	Prosser	Stewartville	Dubuque	Ludibundus	Stony Mountain	Shamattawa	Maquoketa	Maravillas	Upper Bighorn	Eden	Maysville	Richmond	Penn-y-garnedd	Gelli-grin	Keisley	Erratics, Poland	Crug
STEREOCONUS					X	X	X	X				X																						X				
COELODUS			X	X	X		X	X																														
NEOCOELODUS			X	X			X	X												X																		
MIXOCONUS							X																															
LEPTOCHIROGNATHUS				X						X						X																						
CHIROGNATHUS		X	X			X	X	X			X		X						X																			
ERISMODUS			X			X	X	X		X	X	X	/			/	/													X								
MICROCOELODUS			X	/	X	X	X	X				X	X			X			X	X										X			/			/		
PTILOCONUS		X	X	X	X		X	X	/	/	X	X	X					/	/	X																		
POLYCAULODUS			X		X			X			X	X	X			X				/	X																	
CARDIODELLA			X		X						X	X				X																						
CURTOGNATHUS					X		X			X	X	X				X				X	X																	
TRUCHEROGNATHUS					X						X	X		X		X					X																	
N. GEN. A												X																										
SCOLOPODUS		X					X						X	X																	X							
LIGONODINA		X													X										X									X	X	X		X
PRIONIODUS			/																/	X					X						X					X	X	X
SCANDODUS		X																			X																	
DISTACODUS						X							X							X	X	X	X	X	/												X	
ACODUS	X	X		X																				X												X		X
BRYANTODINA	X		X			X		X					X					X			X														/			
SCYPHIODUS							X						X							X	/																	
EOBEOLODINA	X											X								X	X										X							
PERIODON	X	X											X	X								X		X														
FALODUS	X	X											X	X								X	X	X	X												X	
POLYPLACOGNATHUS		X					X											X		X	X							/										
EOLIGONODINA							/					X	X					/	X	/	X			X		X	X			X	X	X	X					
PRIONIODINA	X	X										X									X	X	X	X		/	/	X		X	X	X	X				X	X
ZYGOGNATHUS						X						X			/				/		X	X	X	X						/	X	X	X		/			X
SAGITTODONTUS		/																			X			X							X				X			
ICRIODELLA																					X			X										X	X	X		X
COELOCERODONTUS		X																					X	X														
TETRAPRIONIODUS		X																						X	X					X		X					X	
AMBALODUS															X								X	X	X			X	X	X	X	X		X	X	X	X	X
AMORPHOGNATHUS															X								X	X	X			X	X	X	X	X		X	X	X	X	X
STRACHANOGNATHUS																									X											X	X	
KEISLOGNATHUS																							X	X						/	X	X				X	X	
APHELOGNATHUS												X																				X	X			X		
OULODUS						X					X	X						X		X	X					/	X			X	X	X						
DICHOGNATHUS	X				X	X	X				X	X	X		X		X	X		X	X	X			X	X		X			X	X						
PHRAGMODUS			X		X	X	X			X	X		X				X	X		X	X	X		X		X		X	X		X	X		X		X		
OZARKODINA			X		X	X	X				X	X	X		X			X	X	X	X	X	X	X		X	X	X	X		X	X					X	X
TRICHONODELLA					X	X	X			/	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
CORDYLODUS	/	X	X			X	X	X		X	X	X	X	X	X	X	/	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	X
ACONTIODUS	X	X		X					X				X	X				X	X	X	X	X	X	X													X	
DREPANODUS	X	X		X		X	X	X	X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OISTODUS	X	X		X		X				/	X	X	X		X		X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X
PANDERODUS	X	X				X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
BELODINA		X			X	X			X		X	X	X					X	X	X	X	X	X	X		X	X	X	X	X	X	X						

TABLE 6

ADDITION TO TABLE 6

List of rare genera not included in the formations of Table 6.

FORT PENA: *Ulrichodina*

PRATT FERRY: *Haddingodus*, *Pygodus*, "*Cordylodus*", "*Phragmodus*", "*Eoligonodina*", "*Tvaerenognathus*".

DUTCHTOWN: *Stephanodus*, *Multioistodus*.

GLENWOOD: *Euprioniodina*.

HARDING: *Prioniognathus*.

PLATTIN: *Lepodus*.

WINNIPEG: *Oneotodus*.

WHITEWOOD: *Lepodus*.

DECORAH: *Ancyrognathus*, *Euprioniodina*, *Pravognathus*.

DUBUQUE: *Rhynchognathodus*, *Goniodontus*.

LUDIBUNDUS: *Paltodus*, *Paracordylodus*, *Tvaerenognathus*.

STONY MOUNTAIN: *Plectodina*, *Plegagnathus*, *Pristognathus*.

SHAMATTAWA: *Plectodina*, *Plegagnathus*.

MAQUOKETA: *Goniodontus*.

UPPER BIGHORN: *Pristognathus*.

RICHMOND: *Rhipidognathus*.

PENN-Y-GARNEDD: *Balognathus*.

GELLI-GRIN: *Balognathus*, *Holodontus*.

KEISLEY: *Rosagnathus*.

ERRATICS, POLAND: *Pygodus*, *Spathognathodus*.

CRUG: *Ctenognathus*, *Hindeodella?*, *Trapezognathus*.

with the type material. Bearing these problems in mind, a comparison of the Chaumont fauna with those of a like age can be attempted.

Comparison with other Middle and Upper Ordovician faunas

The conodonts from the Chaumont were referred to 63 species and 23 genera. The genera and those of nearly all other Middle and Upper Ordovician faunas described have been plotted in Table 6, the formations being arranged from oldest to youngest as far as can be determined. This form of tabulation has been frequently employed in the past for similar comparisons, but in most the total number of genera listed were those from the described unit, or at best, a few additional genera were included. This method of comparison is misleading since the reader is often unaware of the other genera from the formations being compared. Consequently, Table 6 lists the great majority of the genera reported and those genera recorded only once or twice are listed below. The writer has also incorporated many of the changes in synonomy that have been given by later authors and has included a few generic reassignments of his own, when these have appeared obvious. Genera either listed or considered to be of doubtful assignment have been marked with a single diagonal, instead of a cross. The table also groups the conodonts into "fibrous" types, very common long-ranging forms, and the remainder. The obvious patterns so produced show the "fibrous" elements clustered in the older formations, the common types extending uniformly throughout, and the others being more abundant in the Upper Ordovician faunas. As no sharp break is present, it follows that in comparison of faunas, the relative abundance of the various genera must be considered. Unfortunately, this is frequently not given and the only other factor which may sometimes be of help, in the degree of speciation of either a genus or a group of genera.

In considering the stratigraphic correlation of units in the preparation of Table 6 and thus for appreciation of the sequence of conodont faunas, the most important texts available are Twenhofel *et al.* (1954), Cooper (1956), and Templeton and Willman (1963); they each supply numerous additional references to specific areas. The faunal comparisons will be discussed by grouping together various formations which appear to have comparable assemblages.

A) McLish, Dutchtown, Deadwood, and Fort Peña faunas

a) McLish fauna, Oklahoma: Branson and Mehl, (1943).

The formation has been placed all, or in part, in the Marmor to Wilderness stages. The fauna is dominated strongly by *Leptochirognathus*; a few other "fibrous" genera are present, together with four long-ranging genera.

b) Dutchtown fauna, Missouri: Mehl and McLaughlin (*in* Branson, 1944), Youngquist and Cullison (1946); both are combined in Table 6.

Both faunas are dominated by quite a varied group of "fibrous" genera (e.g. *Microcoelodus*, *Ptiloconus*, *Chirognathus*, *Erismodus*, *Stephanodus*) with no distacodids and only minor numbers of four long-ranging bar and blade conodont genera.

c) Deadwood fauna, North Dakota: Carlson (1960).

Apparently, distacodids dominate the assemblage with minor, but conspicuous, proportions of "fibrous" genera (e.g. *Leptochirognathus*, *Microcoelodus*, *Ptiloconus*).

d) Fort Peña fauna, Marathon Basin, Texas: Graves and Ellison (1941).

No "fibrous" genera are present and besides common distacodids, *Dichognathus* and *Periodon* and also *Bryantodina* and *Prioniodina* are recorded.

One cone, *Ulrichodina*, is a common Lower Ordovician form.

Chaumont comparisons

The whole aspect of the Fort Peña assemblage strongly suggests an alliance with the Appalachian faunas (e.g. to some extent the Pratt Ferry fauna) and with little influence from the midcontinent conodonts. The McLish and Dutchtown faunas are quite similar and the differences in assemblage composition may be due to subprovincial effects rather than dissimilar ages. In these, the strong dominance of "fibrous" forms and the absence of distacodids suggests an age older than the Chaumont. The Deadwood fauna has closer affinities to the Chaumont, but the presence of *Leptochirognathus*, *Coelodus*, and *Neocoelodus*, together with a scarcity of the advanced bar and blade genera indicates a slightly older age.

B) Harding, Lower Bighorn, Bromide, Joachim, Plattin, and Glenwood faunas

a) Harding fauna, Colorado: Branson and Mehl (1933), Sweet (1955).

"Fibrous" genera are the most numerous and *Chirognathus* is abundant; besides long-ranging distacodids and bar and blade genera, *Scyphiodus* and *Polyplacognathus* are present, which both seem to have an important potential as index fossils.

b) Lower Bighorn fauna, Wyoming: Amsden and Miller (1942).

"Fibrous" genera again predominate, with an abundance of *Chirognathus*, and the only other genera found are *Cordylodus*, *Bryantodina*, and *Drepanodus*.

c) Lower and Upper Bromide faunas: Branson and Mehl (1943).

In both faunas, "fibrous" genera predominate; in the Lower Bromide *Trucherognathus* and *Microcoelodus* are particularly numerous, whereas their counterparts in the Upper Bromide are *Cardiodella* and *Polycaulodus*.

One cone, Ulrichodina, is a common Lower Ordovician form.

Chaumont comparisons

The whole aspect of the Fort Peña assemblage strongly suggests an alliance with the Appalachian faunas (e.g. to some extent the Pratt Ferry fauna) and with little influence from the midcontinent conodonts. The McLish and Dutchtown faunas are quite similar and the differences in assemblage composition may be due to subprovincial effects rather than dissimilar ages. In these, the strong dominance of "fibrous" forms and the absence of distacodids suggests an age older than the Chaumont. The Deadwood fauna has closer affinities to the Chaumont, but the presence of Leptochirognathus, Coelodus, and Neocoelodus, together with a scarcity of the advanced bar and blade genera indicates a slightly older age.

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"Fibrous" genera are the most numerous and Chirognathus is abundant; besides long-ranging distacodids and bar and blade genera, Scyphiodus and Polyplacognathus are present, which both seem to have an important potential as index fossils.

b) Lower Bighorn fauna, Wyoming: Amsden and Miller (1942).

"Fibrous" genera again predominate, with an abundance of Chirognathus, and the only other genera found are Cordylodus, Bryantodina, and Drepanodus.

c) Lower and Upper Bromide faunas: Branson and Mehl (1943).

In both faunas, "fibrous" genera predominate; in the Lower Bromide Trucherognathus and Microcoelodus are particularly numerous, whereas their counterparts in the Upper Bromide are Cardiodella and Polycaulodus.

A few long-ranging bar genera occur together with rare specimens of Drepanodus.

d) Joachim fauna, Missouri: Branson and Mehl (1933).

The fauna is characterized by an abundance of "fibrous" genera, in particular Cardiodella, Polycaulodus, Trucherognathus, Curtognathus, and Microcoelodus. Other genera are few and only present in minor proportions; the presence of Belodina and Dichognathus and the absence of distacodids are worthy of note.

e) Plattin fauna, Missouri: Branson and Mehl (1933).

The "fibrous" genera are still numerous (Polycaulodus and Ptiloconus are important, Microcoelodus is absent), but the abundance of other genera, notably Dichognathus, Belodina, Phragmodus, and Oistodus, gives a much more varied and balanced assemblage.

f) Glenwood fauna, Minnesota: Stauffer (1935a).

" Fibrous" conodonts are not dominant and are represented by only a few genera, although Chirognathus is abundant. Most of the fauna is composed of specimens of Dichognathus, Phragmodus, Cordylodus, and Bryantodina. Lesser constituents include a variety of distacodids, Oulodus, and Belodina.

Chaumont comparisons

The faunas with abundant Chirognathus i.e. from the Harding, Lower Bighorn, and Glenwood, are all from western and north-western parts of the midcontinent, suggesting a possible subprovincial fauna. Bryantodina is also important in these western localities. Although each of these three formations have several genera that also occur in the Chaumont, the composition of the assemblages are significantly different. This may indicate a different age, but although these formations appear to be older than the Chaumont from all lines of evidence, the faunal differences suggest that separate and quite distinct assemblages occurred contemporaneously in the midcontinental province. Further weight is given to this proposal by analysis of the Joachim, Plattin, and Lower Bromide faunas. These more easterly faunas lack the dominant chirognathid element and their important "fibrous" genera are closely akin in both type, variety and abundance to the Chaumont forms. Differences from the Lower Bromide and Joachim are evident when considering the remainder of the faunas which is far less numerous and variable than that of the Chaumont. Far more comparable is the Plattin assemblage, having various "fibrous" types which seem to comprise about half the total fauna, together with a variety of distacodids and bar and blade genera. Upon closer scrutiny, it is seen that the Plattin genera not found in the Chaumont are *Lepodus* (probably a fish plate), *Chirognathus* (found in the uppermost Lowville), and *Phragmodus* (found in the eastern Ottawa Valley). Those Chaumont genera that are not recorded from the Plattin are *Stereoconus*, *Microcoelodus*, N. gen. A, *Eobelodina*, *Eoligonodina*, *Prioniodina*, *Zygognathus*, and "*Aphelognathus*".

Branson and Mehl (1943) note that the McLish fauna is quite distinct from that of the Bromide which compares closely with the basal Joachim assemblages. The upper Joachim fauna is stated to be quite different from that of the lower part and is itself closely allied to the immediately overlying Plattin fauna.

The Chaumont conodonts thus seem to be separate from, and possibly younger than, those of the Harding, Lower Bighorn, and Glenwood. Whilst being certainly younger than both the Bromide and Joachim assemblages, the Chaumont fauna compares very closely with that of the Plattin. The additional bar and blade genera of the Chaumont may reflect closer proximity to the

Appalachian faunas, but would otherwise suggest a very slightly younger age.

C) Winnipeg, Whitewood, Upper Bighorn, and Woods Hollow faunas

a) Winnipeg fauna, North Dakota: Carlson (1960)

The lower part of the Icebox member yielded a fauna with common Chirognathus, and Bryantodina elements and was compared to the Glenwood, whereas the middle and upper Icebox contained conodonts similar to the Decorah formation. The fauna of the Roughlock member above was reported to be akin to that of the upper Decorah.

b) Whitewood fauna, South Dakota: Furnish, Barragy and Miller (1936) - from the Whitewood shale (Icebox) and Whitewood siltstone (Roughlock).

Chirognathus is present only in the shale, but seems to be a minor constituent. The authors report that the differences between the two faunas is not marked and that together compare best with the upper Plattin and Decorah conodonts.

c) Upper Bighorn, Wyoming: Amsden and Miller (1942).

The genera given are Acontiodus, Belodina, Drepanodus, Panderodus, and Ptiloconus? (probably Eoligonodina). The poor material is significant because, of these, only Drepanodus occurs in the Lower Bighorn fauna secured below.

d) Woods Hollow fauna, Marathon Basin, Texas: Graves and Ellison (1941).

Of the six genera listed, Periodon, Falodus, and Trucherognathus seem to be the most significant.

Chaumont comparisons

The Whitewood and Winnipeg faunas both seem to extend over a considerable period of time, probably the upper Wilderness and lower Barnveld stages. The lower assemblages with Chirognathus and Bryantodina seem to be comparable to, or slightly younger than, the Glenwood. Presumably, the Chaumont is equivalent to parts of both of these formations, but the significant elements in the Chaumont fauna cannot be duplicated. Again, subprovincial factors probably hamper correlation with these western faunas. The Upper Bighorn fauna by itself is of little significance, only a consideration of the lower fauna suggests that it is a little younger than the Chaumont. In the Woods Hollow fauna, the presence of Falodus and Periodon suggest the continued influence of the Appalachian fauna. However, the midcontinental "fibrous" forms are represented by Trucherognathus.

D) Viola, Decorah, Kimmswick, and Hull faunas

a) Viola fauna, Oklahoma: Branson and Mehl (1943)

The figured specimens of Ptiloconus? appear more likely to be Cordylodus. This small and probably unrepresentative collection was compared to the Plattin fauna, but the apparent lack of "fibrous" genera may indicate an early Barnveld age.

b) Decorah fauna, Minnesota and Iowa: Stauffer (1935a).

The fauna is characterized by abundant Phragmodus, Cordylodus, Belodina, Ozarkodina, fewer numbers of Dichognathus and Polyplacognathus, a variety of distacodids and few "fibrous" forms.

c) Kimmswick fauna, Missouri: Mehl and Strothmann (in Branson, 1944).

This fauna is very similar to that of the Decorah. "Fibrous" elements are restricted to Ptiloconus, but most, if not all, of those illustrated as such, belong to Eoligonodina.

d) Hull fauna, Ontario and Quebec: Uyeno (1963).

The conodonts described are closely comparable, in toto, to those of the Kimmswick and Decorah.

Chaumont comparisons

All of the four faunas noted above are apparently similar, particularly the latter three; the conodonts are comparable at both generic and specific levels. They are clearly younger than the Chaumont for they lack the prominent "fibrous" elements and the bar types in particular are far more numerous and varied. Scyphiodus and Polyplacognathus are important, if frequently minor, constituents of the fauna of this time, although it should be recalled that both occur in the older western fauna of the Harding Sandstone. These faunas can be allocated to a Barnveld age.

e) Upper Ordovician faunas

Several Upper Ordovician units have yielded conodonts and include the Upper Bighorn of Wyoming, the Stony Mountain and Shamattawa of Manitoba, the Galena and Maquoketa of the upper Mississippi Valley, the Marvillais of Texas, the Eden and Maysville units of Ohio, the Richmond of Kentucky and Indiana, and the Cobourg of S.W. Ontario. Of these, the Galena and Cobourg appear to extend into the late Barnveld and early Eden. All of those listed above, with the exception of the Marvillais, have been described within the last thirteen years and no review is necessary. They are clearly younger than the Hull, Kimmswick, and Decorah conodonts. Not only are new genera present but some invasions from the Brito-Scandinavian-Appalachian province occur in the early Eden units (Sweet et al.,1959).

f) Brito-Scandinavian-Appalachian faunas.

Listed in Table 6 are several faunas found in this province. These are predominantly from the Upper Ordovician and those that are post-Marmor-pre-Eden include the Pratt Ferry fauna from Alabama, the Llandeilo of Wales, the Martinsburg of New Jersey, the Ludibundus of Sweden, and the *Ampyx* limestone of Norway. These five faunas probably lie in the early Porterfield, Ashby, Wilderness-Barnveld, Barnveld, and Porterfield respectively. All the faunas are quite different from the Chaumont in overall generic composition and no correlations can be attempted.

g) Other faunas

Middletown core fauna

Sweet and Rust (1961) briefly reported a succession of conodonts from a 650 ft. core drilled near Middletown, Ohio. They state that:

> "The lowest recognized assemblage zone (in the Tyrone formation) is characterized by "fibrous" conodonts and *Polyplacognathus*; this is succeeded, in the basal Lexington, by a thin interval containing no "fibrous" forms, but dominated by *Polyplacognathus*; above this, *Polyplacognathus* disappears and *Amorphognathus* replaces it. From this level upward into the basal few feet of the Cynthiana, *Ambalodus elegans*, *A. pulcher*, *Icriodella*, *Rhynchognathus*, *Sagittodontus*, and other principally European forms are dominant elements."

Thus, the core apparently penetrates from the Eden down to the late Wilderness. The assemblage from the Tyrone (of Lowville lithology) is probably a little younger than the Chaumont since *Polyplacognathus* is known only from the Hull, Kimmswick, and Decorah units in the east and from the Harding in the west.

Summary of Chaumont comparisons

In comparing the Chaumont fauna of the Ottawa Valley with those from the Ordovician of the midcontinent, a sequence of faunas has been demonstrated. Both older and younger faunas are present, but the one comparing best is from the Plattin of Missouri. Other faunas to the west of the Mississippi seem to reflect subprovincial differences that hinder accurate correlation. However, if these are taken into account then all, or parts, of the following formations may be equivalent: the Winnipeg of North Dakota (probably only the upper Icebox member), the Whitewood of South Dakota (particularly the upper siltstone member), the Upper Bighorn of Wyoming (of Amsden and Miller, 1942), and the Woods Hollow of Texas. Clearly, despite the problems raised by provincialism, conodonts have the potential to become one of the best index or zonal fossil groups in the Middle and Upper Ordovician.

Extension of generic ranges by the Chaumont fauna

Several genera found in the Chaumont have not been described from significantly older formations. Besides the new genus, "Aphelognathus" has only been reported from the Upper Ordovician, but this genus is regarded herein as a synonym of Ozarkodina. Zygognathus is prominent in the Upper Ordovician although it was first described from the Glenwood. Eoligonodina may occur in the Harding (as Cordylodus primus). Eobelodina was found in the Fort Peña, which seems to be a little older than the Chaumont, but not in the other older midcontinent faunas. Species of Icriodella, Sagittodontus, and possibly Strachanognathus(?) which occur in the Chaumont and lowest Rockland of the eastern Ottawa Valley are also the earliest recorded representatives of these genera in the midcontinent province.

Of the genera that seem to make their first appearance in the Chaumont, only N. gen. A can be cited.

These are important extensions and some of the conclusions made by several of the recent authors publishing on Upper Ordovician faunas have been based on the assumption that Zygognathus, Aphelognathus, and Eoligonodina were characteristic of that time. Consequently, some of their conclusions may require re-examination.

Ordovician conodont evolution in North America

A few comments should be made in an attempt to place the Chaumont conodonts within the sequence of faunas already known from the Middle and Upper Ordovician. As yet, no published work has seriously considered this.

In Ashby and Porterfield time, the conodonts of the midcontinent were primarily "fibrous" forms and other types were both rare and long-ranging. The Brito-Scandinavian-Appalachian faunas of this time were far more varied and "advanced", with almost no "fibrous" representatives. Faunas such as the Fort Peña may have contained admixtures of both provincial faunas.

During the Wilderness, the midcontinent faunas seemed to develop into at least two subprovinces. One to the west of the Mississippi contained a "fibrous" group completely dominated by chirognathids, and Bryantodina was also invariably common to abundant. The fauna of the Mississippi area and to the east developed into a far more varied group of "fibrous" forms in which the chirognathids played only a very minor role. The later Wilderness faunas (e.g. the Rockland fauna) were characterized by a sharp decline of "fibrous" types to a very minor position; Polyplacognathus was often an important constituent of these later assemblages.

The Barnveld stage saw the almost total extinction of the "fibrous" genera and the rapid development and speciation of bar types. Polyplacognathus died out and was replaced late in the Barnveld by the Amorphognathus-Ambalodus group. The late Wilderness and the Barnveld were apparently affected by a series of generic incursions from the other province, but which failed to extend very far into the midcontinent.

In early Edenian, a marked invasion of European stocks took place and extended into at least the upper Mississippi Valley. By middle and late Eden these additions apparently returned to the Brito-Scandinavian-Appalachian province. The Richmond faunas are quite distinctive and Sweet *et al.*(1959, p. 1038) suggest that these may represent an influx from the north and north-west. This latter area of the midcontinent may ultimately prove to be significant in faunal migration. The problems with the Richmond faunas are allied to the problem of the "Arctic fauna". Discussions of this have appeared, amongst others, in Twenhofel *et al.* (1954), Miller *et al.* (1954), and Stone and Furnish (1959), with diverse opinions proposing an age for the fauna ranging from late Wilderness to Richmond. Since the Rockland strata in the western areas of the Ottawa Valley contain elements of this fauna (e.g. *Receptaculites*, *Maclurites*, "*Lyopora*", *Calapoecia*), this Arctic sea may have supplied some of the genera one supposes to have migrated from the Brito-Scandinavian-Appalachian province. Extensive study of the Wilderness-Barnveld conodonts from the Arctic or sub-Arctic areas would prove of exceptional interest and perhaps solve many problems.

CHAPTER 8

BIOFACIES ANALYSIS OF THE CONODONT FAUNAS

Introduction

One of the present aims has been to determine, as far as possible, the influence of environment upon the distribution of conodonts. Climate and possibly major physiographic features (e.g. geosynclinal belts) seem to be the main factors in the establishment of provincial and subprovincial faunas. A single study of this nature is only able to consider a few particular environments. If such studies were undertaken with many varied lithotopes, valuable information should emerge concerning the paleoecology of the conodont-bearing animal. The only comparable work has been that of Rexroad (1958) in the Glen Dean Formation. Present knowledge on conodont paleoecology has been summarized by Ellison (1957) and Muller (1962, pp. W87, W89); the brevity and generalized nature of these reviews being largely a reflection of the present lack of information.

If conodonts are to become valuable index and zone fossils, it is necessary to determine the degree of facies control on all forms, and whether or not these are constant throughout the paleontologic record. Such relationships are likely to be complex and will necessitate varied and intensive studies. That the writer's own conclusions are in partial conflict with those of Rexroad (1958) is therefore not unexpected.

Paleoecological implications of provincial and subprovincial Ordovician conodont faunas

During the Middle and Upper Ordovician, two distinct and very different provincial faunas existed: the Brito-Scandinavian-Appalachian and the North American midcontinental. Sweet et al. (1959) showed that an invasion of the former into the midcontinent occurred during early Eden time, but was nullified by middle Edenian. Recent work, closer to the Appalachian area, in the Trenton (Schopf, 1964) and the Chaumont (the present study) shows several earlier invasions which were apparently of lesser geographic extent than that of the early Edenian.

Within the midcontinent province, two subprovinces seem to have existed, at least throughout much of the Middle Ordovician. The western fauna is dominated by chirognathid-Bryantodina elements, whereas in the eastern these are scarce and their positions are taken by a varied group of Neurodontiformes.

From published data, this appears to be the broad pattern of faunas. If the distribution of Ordovician climatic belts, outlined in Chapter 5, is accepted, the three faunal realms appear to parallel the Ordovician climatic zones. Sweet et al. (1959) discussed the Eden conodont migrations in terms of shifts in these belts and it seems that many invertebrate groups also show comparable changes. The conodonts may therefore be tropical (western subprovince), sub-tropical to warm temperate (eastern subprovince), and cool temperate (Brito-Scandinavian-Appalachian province) faunas. Both the "fibrous" and lamellar are affected in this distribution. If this pattern is borne out by future work, it may indicate that the conodont-bearing animal was strongly influenced by climate. This, in turn, would mean the restriction of new faunal migrations and lessen, to some extent, the value of conodonts for long-range stratigraphic correlation. It is not certain whether faunal provincialism is well developed in all systems during conodont evolution, but it is present at times during the Mississippian in North America (Rexroad and Clarke, 1960).

It seems very doubtful that the provincialism of Middle Ordovician conodont faunas could be explained purely through differences in physiographic environments (e.g. geosynclinal, shelf). The gross environment of the two subprovinces, for instance, was alike and the faunas of the geosynclinal area could migrate onto, and populate, the shallow shelf regions. Thus, climatic factors appear to have been the prime cause of provincialism and sudden migrations.

Biofacies analysis of the Chaumont conodont faunas

A) Methods of approach

Much of the present work has been directed towards the elucidation of the sedimentary environments in order to see how the conodont assemblages varied with changes in ecology (Dineley and Barnes, 1963). The remainder of the study has been devoted to amassing all relevant data on the conodont faunas. The resultant conodont biofacies analysis has allowed certain conclusions concerning ecological controls on the conodont-bearing organism.

Imbrie (1955) has elaborated upon seven lines of approach in the study of biofacies (the total biological characteristics of a sedimentary deposit). Not all are immediately applicable when concentrating on one fossil group, others have to be modified.

a) Taxonomic analysis

Based upon faunal lists which were derived from a systematic study of the conodont fauna, inferences can be made from known stratigraphic, geographic, and ecologic ranges. In practice, this is rather limited with Ordovician conodonts because of the relative lack of published data. The stratigraphic ranges of most Middle and Upper Ordovician genera are presented in Table 6; this, and the overall composition of the faunas, was used for an age correlation of the Chaumont. Even less understood are the generic geographic ranges, although the faunal comparisons presented in Chapter 7 revealed the extent of provincial and subprovincial influences governing geographic ranges. Likewise, the actual known extent of genera is also included in Table 6 as the formations are arranged, as far as can be determined, in a time sequence. Ecologic ranges and controls are virtually unmentioned in nearly all previous works. Beyond comparisons with faunas from other periods, the present results must stand by themselves. Only the broader influences of, for example, paleoclimate have been considered by other Ordovician conodont workers.

Taxonomic diversity is also very apparent in the Chaumont conodonts. The reasons for this may be complex and are considered below.

b) Morphologic analysis

Morphologic analysis deals with characters not considered in the taxonomic analysis. Factors such as colour, size, and sorting are considered for the conodonts. Various kinds of statistical analyses can be made of morphological details; the size of conodonts rather inhibits this, but more important, the value of such work is questionable as their biologic function is unknown. For example, specimens of the same species may grow to different sizes by functioning on different parts of the body - would these be regarded as various growth-stages, poor to no post-mortem sorting, or mixed faunas? For such reasons, these analyses have not been attempted.

c) Frequency-distribution analysis

This form of analysis extends the statistical morphologic analyses when the latter are continued vertically or laterally in the geologic section.

d) Abundance analysis

Conodonts, being common and frequently abundant, yield themselves especially to this type of approach. Not only do they indicate environmental influences, but, as results show they can provide excellent unit-to-unit correlation between sections. Moreover, because they can be counted by quantitative complete-specimen methods, the accuracy of the analysis is ensured.

e) Incomplete specimen analysis

With conodonts, only the fragmentation analysis can be applied and, within this, recording the average size of the broken fragments is of limited value.

f) Compositional analysis

When considering a single fossil group of essentially uniform composition, this mode of analysis is largely unprofitable, at least until isotopic studies can be applied to conodonts.

g) Textural analysis

The method of obtaining conodonts from limestones precludes information being gathered concerning their arrangement within the rock.

B) Results of analyses

a) Taxonomic analysis

Most of these results were given in preceeding chapters. The list of 63 species in 23 genera of conodonts clearly represents considerable faunal diversity, especially in the Neurodontiformes with 37 species representing 10 genera. The reasons for such diversity are unlikely to be simple, but the dominant factors seem to be ecology and stage of evolution. Samples taken from within the Lowville and Lowville-type lithologies of the Chaumont were nearly all poor in conodonts, both in yield and variety.

Thus, ecological factors are indicated as has been shown to be the case for many of the macrofossil groups. However, the virtual disappearance of the Neurodontiformes within the uniform Chaumont-Rockland calcarenites indicates that ecological factors were not exclusive and that evolutionary changes were also prominent at times. It may be possible that a local climatic shift caused the migration, but as this group shows a sharp decline at approximately this time throughout the eastern subprovince, evolutionary factors seem to have been operative.

b) Morphologic analysis

Colour, average size, and sorting were each visually estimated for the forty samples of the three western localities and are given in figure 5.

1. Colour

The assemblages were divided into light or dark amber when containing over 2/3 of one colour, or mixed when lying between 1/3 and 2/3. No simple patterns or relationships are apparent from these variations and this suggests that several factors have produced a complex arrangement. In Chapter 6, it was concluded that the cause of these variations may include stage of growth, genetic and structural differences. Depending upon the composition of the assemblages, these three will be of variable significance and, consequently, it has not been possible to resolve their individual importance.

2. Average size

A few samples bear assemblages of either larger or smaller conodonts than the remainder. Figure 5 shows these anomalous samples. Three samples each bore a faunule of small conodonts; all were from Lowville-type calcilutites; one being a micrite and two were mud-supported pelmicrites. This might suggest dwarf faunas, but several other Lowville samples yielded average-size conodonts. This does not exclude the possibility of dwarfing, but shows that the present criteria are not sufficiently sensitive to determine slight differences in paleosalinities.

Four samples yielded assemblages of large conodonts, two being from the lower Rockland calcirudites and two from the Lowville-type calcilutites. That two out of the three samples from these calcirudites yielded large-conodont faunules suggests that some sorting was operative and that smaller conodonts were either winnowed away or segregated during transport. The reasons for such faunules occurring in the Lowville are difficult to explain. No mechanical agencies can be invoked and it must be assumed that ecological factors were prominent. In this respect, it is possible that population pressures forced the more senile conodont-bearing organisms into less hospitable habitats. Other evidence has shown that the Lowville-type muds did not seem to present a suitable environment, nor are large populations of conodonts generally found within them.

3. Sorting

The sorting factor is difficult to interpret because of several important unknowns. To see if a distinct pattern emerged, the sorting value of each conodont sample was visually estimated as poor, fair, good, or excellent (see figure 5). Overall, there are very few relationships between this and the other parameters plotted. Only the calcirudites seem to show some form of pattern. The cross-stratified calcirudites (e.g. F.6, F.10, P.V.14, M.11) show a fair to good sorting value whereas the cross-stratified coarse calcarenites and calcirudites of the lower energy regimes (e.g. P.V.12, P.V.13, M.8) are characterized by poor sorting values. In this case, mechanical agencies seem important in governing the conodont sorting. An explanation for the values just quoted may be that the finer fragments produced in the higher energy shoals were winnowed into the adjacent lower energy facies and added to the small-size fraction, thereby lowering the sorting value. A natural conodont biocoenose would most likely have a good sorting value, but until their biologic function is discovered, this is open to question. No satisfactory explanation can be given for the other variations in the sorting factor owing to the large number of unknowns and the apparent absence of variation with other parameters.

c) Abundance analysis

Conodont totals (identifiable to the generic level) were counted for each sample and these corrected to a standard 4 lb. sample weight; these too are plotted in figure 5. Allowing for the different numbers of conodonts and that the samples are not taken from exactly the same levels in the three sections, remarkable correlations can be made. The trends in all three are virtually the same and allow very close correlation of unit-to-unit between sections. An abundance peak in the uppermost Lowville or lowest Chaumont is followed vertically by a sharp decline in numbers throughout approximately the lower 6 ft. of the Chaumont. Another peak is present in the following 5 ft. of thin-bedded biomicrites with common Tetradium fibratum. The next three feet of micrites and pelmicrites produce a prominent zone with low conodont yields, but another sharp rise in abundance is characteristic of the overlying 5 ft. of thin-bedded biosparites and biomicrites. The yields again show a marked decline in samples from the following 2-3 ft. of micrites and pelmicrites. Finally, the overlying cross-stratified coarse calcarenites and lower Rockland calcirudites produce another, if rather moderate, maximum frequency peak. All these variations can be traced through each section, although those from Meath

Hill (M.) are rather weakly developed, having a lower total conodont population.

Three explanations may answer this distinct pattern of variation: rate of sedimentation, natural conodont populations, and microfacies control. The differential rate of sedimentation has frequently been quoted (e.g. Collinson, Rexroad, and Scott, 1959) to explain variations in the abundance of conodonts throughout a section. Even with a relatively thin succession of limestones, as in the Chaumont, this problem is not removed and can rarely be resolved. However, the method of sampling and the similarity of the three sections allows the assumption that many of the unknowns are constant and certain conclusions can then be drawn. For example, there are marked variations in the total conodont yields of the sections (e.g. average conodont yields per pound are M.: 10, P.V.: 40, F.: 25). Because the units can be correlated from section to section, with little change in lithology, and as the sections are of comparable total thickness, it is doubtful that the rate of sedimentation is a prominent factor. Further, the lowest maxima abundance-peak (in samples M.-2, P.V.1, F.-1) occurs in a micrite, pelmicrite, and a pelsparite respectively and it is unlikely that these units were characterized by the same rate of sedimentation. This might be expected to be the same, for example, in samples M.11 and P.V.14 being at the same stratigraphic level, the same microfacies development, and almost exactly the same petrographic make-up. However, the yields are 23 and 143 conodonts/4 lb. sample respectively.

In the Chaumont, it is therefore possible to show that the differential rate of sedimentation, by itself, is not always the cause of varying conodont yields and, hence, this should not be proposed unless positive evidence substantiates it.

The second explanation of variable natural conodont populations would then be applicable. Certainly, there can have been no wholesale removal of conodont-elements from most of the individual sections. Neither can differential preservation be invoked with any basis in fact. Consequently, the remaining explanation is that there were quite variable densities of natural conodont populations. The causes of this are presumably fine ecological distinctions of the order that have failed to leave any geological record, e.g. food supply.

Such variations would explain differences in average yields in the sections, but more profound effects must have caused the marked sample-to-sample variations correlateable between all three sections. In this instance, too, the role of sedimentation rate seems to be minor; the interbedded calcilutites within the Chaumont yield extremely poor faunules, whilst similar lithologies (e.g. M.-2) in the uppermost Lowville produce a conodont abundance-peak. Again, the evidence suggests that local ecological controls are dominant over the rate of sedimentation. In the case of the calcilutites just quoted, a probable explanation is that the uppermost Lowville represents sediments immediately adjacent to the Chaumont facies with conditions being less hostlie than those further into the Lowville lagoon. The interbedded calcilutites in the Chaumont represent minor regressions, bringing the latter lagoonal environments into the area. As these are extensive, and some traceable to Clay Bank (locality 4), they probably represent the middle or inner rather than the outer zone of the Lowville lagoonal facies. Thus, the conodont-bearing organism probably found high salinites (i.e. possibly in excess of 39o/oo) detrimental, and possibly high temperatures too.

The ecological pattern in these limestones is as follows. Many

Lowville lagoonal muds are poor to barren of conodonts, except for a thin zone close to the outer edge of this facies. (The favourable conditions in this zone are not clear and may also have left no geological record). Further off-shore, the poorly washed pelmicrites, with minor skeletal debris and noticeable borings, have fairly poor yields, but these improve outward to a sharp maximum within the biomicrites and biosparites, often of rudite grade locally and with common Tetradium fibratum. Higher stratigraphic units follow, with low yields and seem to represent a minor regressive phase, causing a return of the inner Chaumont poorly washed pelmicrites and possibly some of the outer Lowville facies. The yields again increase to reach the third maximum within rather similar lithologies to the second. However, besides biomicrites and biosparites, with local coarser beds and Tetradium fibratum, there are appreciable amounts of pellets in some samples. A further regressive period elapsed producing almost barren micrites and pelmicrites. The final units represent the next transgressive phase bringing cross-stratified coarse sands advancing in front of the main shoal banks. Conodont yields from the sands are a little variable, but together they form a fourth abundance peak.

d) Incomplete specimen analysis

The numbers of fragments of conodonts (i.e. those not identifiable to generic rank) were counted for each sample in the three western sections (fig. 5). The pattern, clearly, is very similar to that of conodont numbers and the majority of samples produced a number of fragments that was close to half the conodont yield. Each sample population was then checked to determine the percentage of broken specimens (i.e. those still identifiable at the generic level). In the higher populations, 100 specimens, in random areas of the slide, were counted for this purpose. The results are also included in figure 5. Each broken specimen produced at least one fragment, which in turn may have been further broken. By using a 140 mesh sieve during the preparation, even very small fragments were thereby recovered. It would be unusual, therefore, to find a population in which there were significantly fewer fragments than broken specimens. In such cases, it would be likely that the population had been mechanically sorted and the fragments winnowed away. Because of the resistant nature of conodonts, it is doubtful whether these fragments are reduced by abrasion to a fine dust. The two sets of figures for the conodont fragment yields and the percentage breakage were compared to see which samples bore less fragments than broken conodonts.

Only seven samples produced this relationship and each (after weight correction) contained less than 13 fragments, so this may be statistically meaningless. If, however, those that had equal quantities are included and only those samples with 10 or more fragments analysed, then a distinct pattern emerges. Eight samples (F.-2, F.10, P.V.12, P.V.13, P.V.14, F.1, M.-3, M.7) fall into this category, and of these, the former five show marked evidence of sediment transport. Winnowing of conodont fragments, therefore, seems definitely to have occurred in many, but not all, of the beds showing marked sediment transport. It is more than likely that some of the smaller conodonts initially in these beds suffered the same fate, but that the conodont population as a whole was only slightly affected. Because representatives of the majority of genera are found, it is also doubtful that selective winnowing of certain morphologic types is significant.

e) Generic analysis

In addition to those analyses proposed by Imbrie (1955), it is possible to note the frequency distribution of the component genera or species of a fauna. It would have been presently most advantageous to analyse the specific variations, but the writer felt that larger conodont yields would be required to permit statistically significant results. Such a study, however, be of value in attempting to check supposedly natural groupings of species that possibly occurred within natural species of the conodont-bearing organism. This is still possible for natural groupings at the generic level, but with much reduced sensitivity and value. Besides generic associations, it may be possible to see which genus, or group of genera, are affected by changes in environments, and by their relative abundance, which habitats they favour most. The frequency distribution of each genus is plotted in figure 5.

The figure shows that the units characterized by abundance peaks also contain a great many genera producing a particularly varied fauna. This would seem to indicate further that these represent the most suitable ecological niche for the conodonts as a whole. The Chaumont pelmicrites and more especially the Lowville-type calcilutites not only yield low numbers, but also very few genera. This restriction in variety also is evidence against explaining the low yields solely by relatively rapid sedimentation. The individual generic abundance peaks also occur in samples yielding the higher total populations.

Most genera develop a pattern of frequency distribution that can be compared to one or more other genera. Exceptions to this are: Panderodus, which is the only other genus occurring in every sample; Chirognathus, the only genus restricted to the Lowville; Eobelodina, infrequently found, but in both poor and rich faunas; and Oulodus, with few occurrences, but always in rich faunas.

On the figure 5, the genera were arranged into morphologic groups (single cone, "fibrous", belodinid, bar, and blade genera), and these have similar frequency distribution patterns. Because of the unequal numerical distribution of genera within the known "natural" assemblages, the relative abundance of individual genera should receive little consideration compared with their actual distribution.

Drepanodus is only a little less extensive than *Panderodus*, and *Oistodus* does not occur where the former is absent. The "fibrous" genera appear to form a separate group, in that the distribution of other genera is not comparable to any individual "fibrous" genus. Within the group, *Microcoelodus*, *Erismodus*, and *Ptiloconus* are quite comparable, but the remainder contain several exceptions producing rather weak comparisons. It is noted that N. gen. A nearly always occurs in association with *Trucherognathus*.

Belodina has a unique distribution. Within the bar generic group, two subgroups have equivalent occurrences: *Cordylodus* with *Eoligonodina*, and *Zygognathus* with *Trichonodella*. Likewise, in the blade generic group, *Prioniodina* and *Ozarkodina* s.l. are rather similar and *Dichognathus* also has a comparable distribution to these.

It seems, therefore, that the component genera of these broad morphological groups have similar distributions and often comparable frequency distributions. Even within some (e.g. the bar group), closest comparisons are between those genera most alike morphologically. Moreover, direct comparisons between the major groups are unsatisfactory and contain many individual anomalies. It is impossible to tell which genera may have formed natural conodont genera, but the fact that the various major groups appear distinct in their frequency distribution is rather disconcerting considering the mixture of groups found in the Pennsylvanian natural assemblages (Rhodes, 1952, 1962).

Unfortunately, there are insufficient facies changes within the sections to allow further conclusions or to strengthen those tentatively made above. This method of approach does seem both valid and valuable and given thicker and more variable sequences bearing higher conodont populations some important information would be forthcoming. Such a situation would then allow this type of approach at the specific level which would be much more meaningful.

Summary and interpretation of conodont paleoecology and biofacies analysis

a) Most Middle and Upper Ordovician conodont faunas seem to be strongly influenced by climatic belts which may have been the principal cause of the establishment of faunal provinces and subprovinces. Conodont migrations, particularly shifts in provincial faunas, may also be due to climatic shifts.

b) Conodont faunas do not seem to be significantly controlled by the type of megaenvironment (e.g. shelf as opposed to geosynclinal).

c) Within a basin area, such as the Ottawa Valley, other minor paleoecological controls on the conodonts become apparent:

1. The conodont-bearing organism does not seem to have been adaptable to marine seas of high salinity (perhaps in excess of 39°/oo), associated with moderately high temperatures and poor circulation. Faunas in these environments are poor in variety, low in populations, and frequently absent.

2. The ideal habitat (within those investigated) was in near normal salinities (perhaps 35-37°/oo), fairly shallow water (perhaps 15-50 ft.), with good circulation and aeration, and with variable bottoms ranging from poorly washed muddy fine sands to well washed coarse skeletal sands. A rich invertebrate fauna was present, but this may reflect environment more than some form of interdependence. This macrofauna is dominated by molluscs and bryozoans, but with also common brachiopods and compound corals.

3. The conodont animal was capable of existing in a great variety of energy environments, but seemingly with preference to a moderate regime.

4. The paucity of conodonts in those sediments with common borings and greater abundance in those that would inhibit an infauna indicate that the organism lived above the sea bottom and was not primarily a burrower.

5. Analysis of the conodont fragments and the percentage breakage within the assemblages shows that winnowing of fragments, and hence probably the smallest conodonts, occurs only in sediments that have been transported in the upper lower-flow regime and lower upper-flow regime. The sorting values also tend to support this conclusion.

6. Some of the Lowville-type calcilutites are characterized by small faunas which are possibly dwarfed because of high salinities. These are not always found, however, and further sampling would be required to confirm this.

7. There are marked sample-to-sample variations in individual sections which cannot be explained through differential rates of sedimentation and must reflect the influence of environment on the conodont organism.

8. Likewise, the marked differences in total yields from section-to-section also suggests subtle ecological controls on a broader scale.

9. Overall, however, the generic composition of the Chaumont fauna in the Ottawa Valley is fairly constant, but the impoverished fauna from the Watertown section, for example, shows the advisability of using numerous widely spaced localities in formational conodont studies.

10. The introduction of the Rockland fauna in the essentially uniform Chaumont-Rockland calcarenites indicates that evolutionary changes were dominant over the local ecological effects at certain times.

Certain authors have considered the broad ecology of conodonts, but these have been little more than generalizations, frequently conflicting. Not all this opposing evidence can be explained by lack of information, it seems likely that it reflects a naturally complex situation. Rhodes (1953) and Rexroad (1958), for example, find similar faunas in different sedimentary facies. Whereas Orr (1964) finds different faunas in a shale-siltstone-micrite succession as opposed to crinoidal biosparites in the Lingle Formation (Middle Devonian). Collinson, Rexroad, and Scott (1959) found that the Louisiana and McCraney limestones (Upper Devonian and Lower Mississippian) contained very few conodonts. These are both pure lithographic limestones - i.e. like the Lowville - and may, as shown here, represent unfavourable ecologic habitats rather than rapid rates of sedimentation, which was the favoured explanation of the authors.

The argument for a differential rate of sedimentation is cyclic. Those who found more conodonts per unit weight in shales than limestones (e.g. Rhodes, 1954; Collinson, Rexroad, and Scott, 1959) believed that limestones represent a faster accumulation. Those who found the reverse (e.g. Rexroad and Clarke, 1960) believed the limestones to be more slowly accumulated than the shales. Little attention appears to have been given to positive evidence for rates of deposition or for later compaction.

Many shales are known to have been reduced considerably in thickness upon compaction, but this seems to be very minor in limestones, even in calcilutites (Pray, 1960; Beales, 1964).

Another prominent statement in conodont paleoecology has been that many species have world-wide distribution. The lower Ordovician faunas of Australia, western North America, and Europe are very similar (Bergström, Ethington, per comm., 1964), but these may lie in one climatic belt if the paleoclimatic zones outlined earlier, and the pre-drift continental reconstructions, are accepted. This may likewise be true for the Upper Devonian of these general areas which are reported to have similar species (Müller, 1956, pp. 1337-1338).

Conflicting statements also concern the faunal associations of conodonts. Association with fish remains (e.g. Youngquist, 1952; Müller, 1956, pp. 1333-1334) has frequently been observed and used, in part at least, as an example for their biological affinities. Exceptions to this have been found (e.g. Rhodes, 1954, p. 433; McCrone, 1963). Others (e.g. Müller, 1962, p. W87) have noted the lack of abundant conodonts in units with dominant corals or calcareous algae, but some of the highest abundance peaks found in the present study were in such units. One (P.V.6) was from the same level as a small biostrome of Tetradium fibratum (see Appendix, locality 2).

The paleoecological aspects of conodonts have been largely ignored in the attempts to describe faunas and establish faunal sequences. The true picture can be obtained only through analysing many different environments in several other systems. Such work must be detailed and not based on uncertain assumptions. That paleoecological factors, at all levels, have affected Middle Ordovician conodonts to some degree has been shown in this study. Somewhat different results can be expected in other environments and in different geologic systems.

CHAPTER 9

SYSTEMATIC PALEONTOLOGY OF THE CHAUMONT CONODONT FAUNAS

Style of synonymy adopted

In some papers, conodont synonymies have been unnecessarily long. The approach to be used herein is to refer only to a) the original author or the author first using a revised name, b) authors having contributed to the knowledge of the species or its identification, c) an author giving a detailed synonymy of earlier descriptions, and d) those authors whose specific identification is questioned or rejected. For almost every species dealt with, further synonymies can be obtained from the particular authors cited or by reference to Fay (1952) or Ash (1961); Ellison (1962) is of assistance with generic information and bibliography.

In the Repository code numbers given in the systematic descriptions, U.O. is an abbreviation of University of Ottawa, the first five digits represent the slide number, and the last three digits record the stratigraphic location: the first digit being the locality number and the last two the sample number in that section.

Genus N. gen. A

Type species. N. gen. A n. sp. A Barnes.

Diagnosis. Base flat, long, narrow, lenticular; oral surface set with several discrete, markedly incurved denticles.

Description. See below for the description of the type species.

Discussion. This new genus includes forms that superficially resemble Trucherognathus, but with denticles uniformly and markedly directed inwards as opposed to a pattern of unequal, divergent denticles. Structurally, this genus is a member of the Neurodontiformes, and is a distinctive unit that has not been described previously.

N. gen. A n. sp. A

Plate 3, figure 1

Diagnosis. Base flat, lenticular, length greater than five times the width, surmounted by series of moderately long denticles, discrete, subcircular in outline, and strongly incurved, nearly reaching the plane of the base; denticles largest in centre, becoming progressively smaller towards the extremities.

Description. Base flat, showing vague laminae, no central pit, outline lenticular with length over five times the width, ends pointed. Oral surface set with a series of moderately long denticles, commonly 6 to 12, discrete, subcircular in outline, sharp-pointed, sharply recurved almost to reach the plane of the aboral surface; denticles largest in centre, decreasing in size progressively towards the extremities. Oral surface from the basal rim to base of denticles smooth and concave on inner side, ribbed (along denticle axes) and convex on outer side.

Remarks. The specimens are fairly uniform, varying in denticle number, size, and to a lesser degree in the straightness of the unit. All specimens clearly belong to the Neurodontiformes and most closely resemble Truchero-gnathus, the denticle arrangement precludes assignment to this genus, however. Neither can the species be referred to Lonchodus since Ulrich and Bassler (1926, p. 42) find that the only use "...for the name is to continue to employ it for species based upon similar imperfect and generically indeterminable material." Rhodes (1952, p. 900) has referred complete units as opposed to a pattern of unequal, divergent denticles. Structurally, this genus is a member of the Neurodontiformes, and is a distinctive unit that has not been described previously.

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Specimens studied. 3.

Repository. Holotype, U.O. 27113/208.

Genus Belodina Ethington, 1959

Type species. Belodina grandis Stauffer, 1935b.

Discussion. Ethington (1959, pp. 271-272) proposed the name Belodina for those species, formerly assigned to Belodus, which bear a relatively small number of blade-like, crowded or fused denticles and whose cusp is deeply excavated.

Each species found in the Chaumont appears to retain a single type of basal cavity, which may represent a stable character. This, together with symmetry, outline, ornamentation, denticle number and inclination, lateral compression, and sharpness of the oral edge seem to be valid features for specific identification.

Belodina is very common in the Chaumont, only being absent from seven samples and ranges into both the Lowville and Rockland. The specimens have been allocated to five species.

Belodina compressa (Branson and Mehl)

Plate 1, figure 10

Belodus compressus Branson and Mehl

1933. Branson and Mehl, p. 114, Pl. 9, figs. 15-16.

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Belodus compressus Branson and Mehl

1933. Branson and Mehl, p. 114, Pl. 9, figs. 15-16.

Belodina compressa (Branson and Mehl)

1959. Stone and Furnish, p. 220, Pl. 31, Fig. 14.

1959. Sweet, Turco, Warner, and Wilkie, pp. 1042-1044, Pl. 133, figs. 12, 15.

? 1960. Carlson. tab.2, Pl. 2, fig. 19.

1963. Uyeno, pp. 80-82, Pl.4, fig 5.

Belodus wykoffensis Stauffer

1935b. Stauffer, p. 604, Pl. 72, figs. 51, 52, 55, 58, 59.

Belodina wykoffensis Stauffer

1959. Ethington, p. 272, pl. 15, fig. 16.

Remarks. This species is laterally compressed and has a bifid basal cavity, it is sharply recurved so that the denticles are essentially entirely erect and the sharp-pointed main cusp projects only a short distance beyond them. This contrasts with *B. grandis* in which there is a wide, normally round-pointed, main cusp which projects much further both orally and anteriorly in respect to the heel. Although these are relatively slight differences two distinct groups seem to exist which are interpreted here as being of specific rank. *B. wykoffensis* (Stauffer) is clearly allied to the *B. compressa* group rather than that of *B. grandis* as Sweet and Bergström (1962) suggest, unless all three are to be regarded as synonymous.

Specimens studied. 6.

Repository. Hypotype, U.O. 04419/111.

Belodina diminutiva (Branson and Mehl)

Plate 1, figure 15

Belodus diminutivus Branson and Mehl

1933. Branson and Mehl, p. 125, Pl. 10, fig. 27.

<u>Belodina</u> <u>compressa</u> (Branson and Mehl)

1959. Stone and Furnish, p. 220, Pl. 31, Fig. 14.

1959. Sweet, Turco, Warner, and Wilkie, pp. 1042-1044, Pl. 133, figs. 12, 15.

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<u>Belodus</u> <u>wykoffensis</u> Stauffer

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<u>Repository</u>. Hypotype, U.O. 04419/111.

<u>Belodina</u> <u>diminutiva</u> (Branson and Mehl)

Plate 1, figure 15

<u>Belodus</u> <u>diminutivus</u> Branson and Mehl

1933. Branson and Mehl, p. 125, Pl. 10, fig. 27.

Diagnosis. Unit short and high, not laterally compressed; rounded aboral margin sharply recurved producing short sharp-pointed cusp. Inner lateral face smooth, convex; outer lateral face flat with groove running whole length of unit just beneath dental series. Four to six close-spaced erect denticles; basal cavity not bifid, posterior denticles therefore not penetrating deeply into unit.

Remarks. The outline resembles *B. compressa* but the basal cavity, ornamentation, and lateral compression are not comparable. It probably includes *B. profunda* (Branson and Mehl) but the types of both species appear to be immature forms and their re-examination is required. All forms that have since been referred to *B. profunda* seem to belong to a separate species than that of the figured holotype.

Specimens studied. 22.

Repository. Hypotype, U.O. 04155/107.

Belodina grandis (Stauffer)

Plate 1, figure 11

Belodus grandis Stauffer

1935b. Stauffer, pp. 603-604, Pl. 72, figs. 46, 47, 49, 53, 54, 57.

Belodina grandis (Stauffer)

1959. Ethington, p. 272, Pl. 40, fig. 14.

? 1962. Sweet and Bergström, p. 1224, Pl. 170, figs. 16, 17.

1963. Uyeno, p. 83 for extensive synonomy.

Belodina inclinata (Branson and Mehl)?

1960. Pulse and Sweet, pp. 250-251, Pl. 37, figs. 10, 11.

Remarks. This species is characterized by being laterally compressed, with a bifid basal cavity and with an aboral margin that is not sharply recurved; frequently the anteriormost denticles are forward-inclined. Further discussion is given under B. compressa.

Specimens studied. 5.

Repository. Hypotype, U.O. 04219/1(-1).

Belodina cf. B. inclinata (Branson and Mehl)

Plate 1, figure 12

Belodus inclinatus Branson and Mehl

cf. 1933. Branson and Mehl, pp. 125-126, Pl. 10, fig. 24.

Belodina inclinata (Branson and Mehl)?

non 1960. Pulse and Sweet, pp. 250-251, Pl. 37, figs. 10, 11.

Belodina inclinata (Branson and Mehl)

cf. 1960. Ethington and Furnish, p. 269, Pl. 38, fig. 13.

Description. Unit is fairly slender and broadly curved; proximal third of aboral surface straight, forming a right angle with the posterior edge, whilst there is a fairly sharp break in curvature and distal two thirds is broadly curved and somewhat proclined anteriorly. Posterior edge moderately long, being about one-third to one-half the length of aboral margin, but unit narrows markedly and is quite thin at mid-length. Posterior part is laterally compressed orally in the "heel" region, but is expanded aborally to give broadly rounded aboral margin, which is less expanded anteriorly. Inner lateral face fairly flat, but marked by two furrows. One lies near or at the base of the dental series and continues to the posterior edge to give rise to a "crimping" of the margin; it continues anteriorly but is less prominent. A broader groove is located near and parallel to aboral margin, and is associated with an off-set costa which lies aborally to it, forming a sharp edge with rounded aboral margin. This latter groove and costa extend to anterior end, but do not extend quite to posterior margin, fading into the expanded area. Outer lateral face convex and essentially smooth, only the slightest furrow occurring where denticles emerge from body of cone and solely restricted to this central area. Expanded aboral posterior region is still noticeable and this fades both orally and anteriorly.

Denticles commonly number five; they are confluent and laterally compressed. Anterior two or three are inclined forward; heel region also laterally compressed, and is a fairly wide, prominent feature. Basal cavity does not appear to be bifid, extending from oral and aboral extremities of the posterior margin to a point close to aboral margin and rather more than half-way along denticulated region.

Remarks. As stated in the discussion of B. grandis (Stauffer) the specimens described as B. inclinata (Branson and Mehl)? by Pulse and Sweet (1960) are considered to conspecific with B. grandis. Only two other descriptions have been given for B. inclinata and both are based on broken specimens. The original description of Branson and Mehl indicates only one significant difference from the Chaumont material in that the posterior region is stated to be compressed. Also no furrow is described from the base of the dental series on the inner lateral face. Ethington figures his single broken specimen referred to this species. There is no description but the figure shows that the off-set shoulder along the aboral margin continues right to the posterior margin.

The Chaumont specimens are also frequently damaged but reveal sufficient details to suggest that they lie within this species.

Specimens studied. 6.

Repository. Hypotype, U.O. 04313/306.

Belodina ornata (Branson and Mehl)

Plate 1, figure 13

Belodus ornatus Branson and Mehl

1933. Branson and Mehl, pp. 124-125, Pl. 10, figs. 26, 28.

part 1957. Glenister, pp. 730-731, Pl. 87, fig. 7 (non figs. 9a, 9b, 10).

Remarks. This species is comparable to B. diminutiva except that it is the inner lateral face that possesses the groove beneath the denticles and the flat outer lateral face that is smooth. The writer would exclude from this species certain forms figured by Glenister (1957). Her figure 9 illustrates a specimen bearing costae on both lateral faces which is not characteristic of B. ornata, but is found in others e.g. B. kirki Stone and Furnish and B. leithi Ethington and Furnish, although both of these possess more denticles. Further, her figure 10 not only has a different type of ornamentation, but is far more broadly curved and is probably close to B. inclinata (Branson and Mehl).

Specimens studied. 4.

Repository. Hypotype, U.O. 04515/108.

Genus Cardiodella Branson and Mehl, 1944

(=Cardiodus Branson and Mehl, 1933)

Type species, Cardiodus tumidus Branson and Mehl, 1933.

Discussion. The genus includes those forms whose aboral surface is dominated by a large cusp which is flanked by two limbs, usually directed forward making an angle of about 90°. The limbs, symmetrical or asymmetrical, are surmounted by denticles, normally ranging from one to six, that are usually discrete and laterally compressed. A denticulated posterior process may occur in some species. The aboral surface is widest and best developed beneath the main cusp and exhibits fine laminae concentric around a small circular pit located at the intersection of the central axis of the main cusp and the aboral surface.

The orientation suggested by Branson and Mehl (1933) does not conform with the currently accepted form where the denticles are inclined posteriorly. Branson and Mehl oriented the apical region anteriorly, thus the denticles pointed forward. Herein, the inclined dentition points posteriorly and the apical region is normally posterior to the angled limbs. Moreover, the writer feels that this is a natural orientation, since these forms appear to have originated from the gradual posterior migration of a central denticle in a Curtognathus or Polycaulodus ancestral type.

The aboral surface of Cardiodella shows great variation and sometimes exhibits an "inverted basal cavity". The criteria for specific identification appear to be the orientation of limbs to the apical cusp, the pattern of dentition, the type of limbs, and associated posterior extension of the "basal excavation" and, in some, the presence of a denticulated posterior process.

The genus occurs in all three formations and in a total of 20 samples.

Cardiodella diminutiva (Branson and Mehl)

Plate 3, figure 15

Cardiodus diminutivus Branson and Mehl

1933. Branson and Mehl, p. 83, Pl. 6, fig. 15.

Cardiodus diminutivus Branson and Mehl?

1946. Youngquist and Cullison, pp. 580-581, Pl. 89, fig. 11.

Description. Aboral surface slightly convex or concave under main cusp, showing laminae concentric around a posteriorly disposed small circular pit. Two slender limbs meet at an angle of about 90°, posterior margin sharply concave, anterior margin convex, often with a sharp convex expansion beneath the apical cusp. Cusp dominant, being long, slender, sharp-pointed, and discrete, the posterior face is flat with sharp edges and the anterior edge sharply convex. To one side of the apical cusp lies a short limb bearing a single discrete, slender denticle, while to the other, the longer limb bears two laterally compressed, discrete denticles: the one adjacent to the apical cusp is moderately long and slender and longer than the single denticle on the opposing limb; the second denticle is small and repressed, almost node-like. The denticles are all slightly inclined posteriorly - the apical cusp more so than the limb denticles and is commonly markedly inclined.

Remarks. The Chaumont specimens show considerable variation but all stand fairly close to the type material from the Joachim. This species may have given rise to other species of Cardiodella. Upon becoming massive and with the denticles less discrete, this species would be comparable to C. robustus (Branson and Mehl); on becoming more slender, the limbs longer and the apical cusp more offset posteriorly, they would approach C. n. sp. A.Barnes. However, they do seem to form a separate specific group.

Specimens studied. 3.

Repository. Hypotype, U.O. 07317/111.

Cardiodella divaricata (Branson and Mehl)

Plate 3, figure 17

Cardiodus divaricatus Branson and Mehl

1933. Branson and Mehl, pp. 82-83, Pl. 6, fig. 16.

Description. Basal outline sharply and asymmetrically curved with blunt, pointed ends. Aboral surface broadly convex transversely and irregular linearly with slight swells under each of the denticles; laminae well developed with the small circular pit located beneath the apical denticle and close to the anterior edge. The oral surface is completely occupied by denticles; the posterior edge, merging with the incurved denticles, forms a markedly concave recess, the anterior edge is smoothly convex, sheathing the lower parts of the denticles and making them less discrete. In cross-section the denticles thus have a flat anterior face, sharp edges and a sharply convex posterior face. They generally number seven: two on the shorter limb, four on the larger and an apical denticle; the latter is somewhat larger than the rest and the denticle on each side is also the largest on their respective limbs. The central axes of the limbs form a sharp angle of 90°-100°.

Remarks. The specimens are closely comparably to Branson and Mehl's figured holotype and description except that they note a small denticle on the apex of the base immediately beneath the apical denticle. This is not present in the Chaumont forms. They also report that the aboral surface is concave, but as seen in the species of Polycaulodus, the "inverted basal cavity" can occur seemingly in any one species, thus the shape of the aboral surface is not a diagnostic specific character.

Specimens studied. 4.

Repository. Hypotype, U.O. 07217/308.

Cardiodella cf. C. divisa (Branson and Mehl)

Plate 3, figure 7

Cardiodus divisus Branson and Mehl.

cf. 1933. Branson and Mehl, pp. 83-84, Pl. 5, fig. 10.

Description. Basal outline very sharply curved, asymmetrical, with pointed ends. Aboral surface slightly convex; laminae well developed together with a fine groove running from one end to the other, close to the anterior edge and passing through the small circular pit located beneath the apical denticle. Limbs asymmetrical meeting at a rounded point and at an angle of about 60°. One short limb occupied by two denticles and a longer limb also with two denticles, but deflected aborally quite sharply in the anterior third. Denticles number five, discrete, moderately long and somewhat incurved, the largest (apical) one to the extent of lying almost horizontal; they are slightly keeled and laterally compressed, except the apical which is subcircular.

Remarks. This species agrees quite closely with C. divisus Branson and Mehl, but the authors record eight denticles, two of which occupy the apical position. Since this is the only description available, it is uncertain to what extent these variations can be accomodated within C. divisus. The arrangement of denticles and the forward - directed limbs are very characteristic, however, and do not occur in any other described species of Cardiodella and therefore it is likely that the Chaumont forms are conspecific with the type Joachim material.

Specimens studied. 2.

Repository. Hypotype, U.O. 07415/305.

Cardiodella cf. C. robusta (Branson and Mehl)

Plate 3, figure 11

Cardiodus robustus Branson and Mehl.

cf. 1943, Branson and Mehl, p. 382, Pl. 64, figs. 23-26.

Description. Unit short, strong, massive. Aboral surface slightly concave or convex; laminae concentric around a subcentral small circular pit. Anterior margin sigmoidal, outer limbs convex but central third concave; posterior margin broadly convex but central third to half sharply convex. Oral surface dominated by a moderately long, discrete, stout cusp that is inclined posteriorly at an angle normally less than 40° to the horizontal over the convex extension of the posterior basal margin. Central cusp flanked by two limbs, one shorter than the other and bearing one denticle, the larger bearing two. These flank denticles are smaller, slightly laterally compressed and keeled, stout, discrete when mature, and only slightly inclined posteriorly. The central cusp is flattened on the anterior side with sharp edges and a deeply convex posterior face and is quite sharply pointed; the posterior side of the cusp merges aborally with the basal posterior extension, producing the very massive cusp.

Remarks. All the Chaumont specimens follow this general morphological type with slight variations in the number of limb denticles and in the length and stoutness of the main cusp. Branson and Mehl (1943, Pl. 64. figs. 23-26.) figure four specimens of their new species of which only one (fig. 23) closely resembles the Chaumont forms. They note that the species shows considerable variation, particularly from young to old forms. Within this variation the Chaumont specimens can be compared to certain forms and is here designated C. cf. robusta, until the exact degree of variation is understood.

Specimens studied. 3.

Repository. Hypotype, U.O. 07617/307.

Cardiodella n. sp. A

Plate 3, figure 12, 13

Diagnosis. Two slender, slightly aborally directed limbs meeting at an angle of about 90° give an expanded basal area beneath the apical cusp. Limbs essentially symmetrical, each surmounted by two or three slender, laterally compressed, widely spaced, slightly posteriorly inclined denticles. Apical cusp either strongly inclined posteriorly and large, or suberect, and subequal, with a small denticle beneath on a prominent process.

Description. Aboral surface of limbs slightly convex transversely, meeting under the apical cusp and expanding slightly since cusp is set a little to the posterior to the intersection of the two limbs. Small circular pit is located in centre of expanded area, but laminae are indistinct on aboral surface. The straight, slender, slightly aborally directed, essentially symmetrical limbs are each set with two or three denticles that are widely spaced, slender, laterally compressed, suberect, and slightly posteriorly inclined. Apical cusp is subcircular in outline and longer than the limb denticles, if a posterior process is present, it is suberect and a little inclined posteriorly. If the process is absent, it is longer and markedly inclined, almost approaching horizontal. This process, when present, is also slightly aborally directed, lying directly beneath the apical cusp and bearing one small denticle.

Remarks. This species seems to stand near to *C. tumida* (Branson and Mehl), but lacks the expanded base that extends to incorporate the limbs (e.g. Branson and Mehl, 1944, Pl. 93, figs. 17-18) and this species also has eight closely spaced denticles. The presence of the posterior process may be a specific character, but with the material available both varieties are included within this new species.

Specimens studied. 3.

Repository. Holotype, U.O. 07515/208.

Cardiodella n. sp. B

Plate 3, figure 18, 19

Diagnosis. Unit dominated by central, erect, stout cusp flanked on either side by short stout limbs each usually bearing one moderately long, erect denticle or two short stout nodes. Posterior to main cusp lies a stout process bearing a single moderately long denticle. Limbs slightly unequal in length.

Description. Unit compact and strong. The discrete central cusp is much the largest of denticles and is sub-circular in outline, stout, erect, and sharp-pointed. It is flanked by limbs each bearing either a single, moderately long, erect denticle or two small, short, stout nodes. Both limbs short, but one is slightly longer than the other. Posterior to main cusp extends a short stout process, slightly smaller than shortest limb, which bears single erect, moderately long denticle. Denticles on main unit are all aligned, whereas the axis of the posterior process meets this dental axis at about 70°-80° to the shorter limb. Both anterior and posterior sides of unit are moderately convex, the process projecting sharply out from posterior side, and anterior side opposite the process increasing slightly in curvature. Aboral surface is broadly concave, becoming flat on extremities of blunt limbs; a small circular pit is located under main cusp; laminae are indistinct.

Remarks. These specimens appear to represent an undescribed species and are quite distinctive. It is possible that these are closely related to C. bifida (Branson and Mehl), but the description and illustration (1933, p. 82, Pl. 5, fig. 9.) are rather obscure. They record "Denticles four, of which two of nearly the same size occupy the apical position flanked by a smaller unit on each lateral lobe....." The general form of this species seems closely allied to the Chaumont forms but it is not clear whether a definite posterior process is present in those from the Joachim. Because this seems doubtful and as more than four denticles appear at times, the Chaumont specimens are referred to a new species.

Specimens studied. 3.

Repository. Holotype, U.O. 07119/1(-2).

Genus Chirognathus Branson and Mehl, 1933

Type species. Chirognathus duodactyla Branson and Mehl 1933.

Discussion. Branson and Mehl (1933, p. 28) defined the genus to include complex denticulated forms consisting of more or less conical denticles of unequal sizes, fused at the base to a somewhat hand shaped-unit which is cupped or excavated on the inner aboral side, thus there is no real restricted "pulp cavity." A great many species were described by Branson and Mehl (1933) and by Stauffer (1935a), the irregular nature of the dentition allowing either very few or a great many species to be erected. On the basis of general form, dentition and the features of the basal cavity, the Chaumont specimens are tentively referred to one previously described species of Chirognathus.

Specimens of the genus are very rare and are confined to samples (M-2, F-1) that are best regarded as upper Lowville.

Chirognathus cf. *C. delicatula* Stauffer

Plate 2, figure 12

Chirognathus delicatulus Stauffer

cf. 1935a. Stauffer, p. 136, Pl.9, figs. 1-3, 7-13, 17-19, 21.

? 1936. Furnish, Barragy and Miller, Pl. 1, fig. 12.

cf. 1942. Amsden and Miller, Pl. 41, fig. 27.

Chirognathus delicatula Stauffer

cf. 1955. Sweet, p. 237, Pl. 27, figs. 14, 22.

Description. Outer aboral margin convex laterally, with small process developed aborally beneath the main apical cusp. Inner margin almost straight laterally. Outer basal face directed aborally, inner face flaring and directed inwards and only slightly aborally. Basal excavation expansive, widest under main cusp, but extending to extremities of unit. Aboral surface set with six to nine discrete, laterally compressed, sharp-pointed, slender denticles. Denticles asymmetrical; suberect main cusp nearer to anterior end and flanked on that side by two or three suberect denticles, and on the posterior side by three to five posteriorly inclined denticles.

Remarks. The description is based on two complete specimens. The specimens are similar in all respects except in the size of the denticles. Stauffer shows considerable variation of forms within this species from the Glenwood and the Chaumont specimens are believed to lie within this variation.

Specimens studied. 2.

Repository. Hypotype, U.O. 29115/1(-2).

Genus Cordylodus Pander, 1856

Type species. Cordylodus angulatus Pander, 1856.

Discussion. Pander's original generic description was very broad and subsequently several genera were erected, particularly by Stauffer, for essentially the same type of conodont-element. In revising the genus, Sweet et al. (1959, p. 1044) presented the following diagnosis:

> "Based on Cordylodus angulatus, the genus Cordylodus seems to include only compound conodont-elements with denticulated posterior processes, undenticulated anterior costae (more or less distinctly developed) and no lateral ribs, ridges, costae, or processes."

Within this interpretation of Cordylodus, three species have been found in the Chaumont. The genus is still in need of further revision; Stauffer (1930) figured some new forms, but their descriptions are inadequate and once their types have been re-examined, these may have priority. Several species groups seem to exist within the genus and their limits will only be determined with the study of large collections. In the present study, the main characters used for specific breakdown were the presence or absence of lateral bowing and the discreteness or confluence of denticulation. The shape of the anterior edge of the cusp may be significant. The position of C. plattinensis Branson and Mehl is uncertain, it contains a prominent postero-lateral costa on the cusp and basal sheath which may be significant and indicate specific validity.

Specimens of Cordylodus were found in all three formations and in 20 samples.

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Discussion. Pander's original generic description was very broad and subsequently several genera were erected, particularly by Stauffer, for essentially the same type of conodont-element. In revising the genus, Sweet *et al.* (1959, p. 1044) presented the following diagnosis:

> "Based on Cordylodus angulatus, the genus Cordylodus seems to include only compound conodont-elements with denticulated posterior processes, undenticulated anterior costae (more or less distinctly developed) and no lateral ribs, ridges, costae, or processes."

Within this interpretation of Cordylodus, three species have been found in the Chaumont. The genus is still in need of further revision; Stauffer (1930) figured some new forms, but their descriptions are inadequate and once their types have been re-examined, these may have priority. Several species groups seem to exist within the genus and their limits will only be determined with the study of large collections. In the present study, the main characters used for specific breakdown were the presence or absence of lateral bowing and the discreteness or confluence of denticulation. The shape of the anterior edge of the cusp may be significant. The position of C. plattinensis Branson and Mehl is uncertain, it contains a prominent postero-lateral costa on the cusp and basal sheath which may be significant and indicate specific validity.

Specimens of Cordylodus were found in all three formations and in 20 samples.

Cordylodus concinnus Branson and Mehl

Plate 1, figure 16

Cordylodus? concinnus Branson and Mehl

1933. Branson and Mehl, p.

? 1941. Graves and Ellison, Pl. 3, fig. 30.

Subcordylodus? inaequalis Stauffer

1935b. Stauffer, p. 618, Pl. 73, figs. 2, 3, 17, 22, 26.

Cordylodus elongatus Rhodes

1953. Rhodes, pp. 299-300, Pl. 21, figs. 114-118.

1964. Hamar, p. 262, Pl. 4, fig. 20.

Remarks. Specimens referred to this species are those in which the main cusp lies in the same plane as the posterior bar and in which the denticles are discrete and quite widely spaced. These seem to be the essential characters of Subcordylodus? inaequalis Stauffer, whereas C. dilata (Stauffer) is laterally bowed. Rhodes (1953) notes the similarity of his C. elongatus to C. concinnus, but points out differences in the shape of the cusp and its aboral extension. Such fine distinctions seem impractical at present; further, examination of Mr. T.J.M. Schopf's topotype material of Rhodes' C. elongatus indicates its synonymy with C. concinnus.

Specimens studied. 4.

Repository. Hypotype, U.O. 13121/210.

Cordylodus delicatus Branson and Mehl

Plate 1, figure 17

Cordylodus? delicatus Branson and Mehl

1933. Branson and Mehl, p. 129, Pl. 10, figs. 1-3.

Cordylodus delicatus Branson and Mehl

1959. Sweet, Turco, Warner, and Wilkie, pp. 1044-1045, Pl. 132, figs. 12, 14, 17.

1963. Uyeno, pp. 89-91 for extensive synonymy.

Remarks. This species is characterized by being laterally bowed and possessing closely spaced to confluent denticles; this differs from C. dilata which has discrete denticles.

Specimens studied. 1.

Repository. Hypotype, U.O. 13313/110.

Cordylodus dilatus (Stauffer)

Plate 1, figure 18

Plectodina dilata Stauffer

1935a. Stauffer, p. 152, Pl. 11, figs. 43, 47.

Subcordylodus rectilineatus Stauffer

1935b. Stauffer, p. 154, Pl. 11, figs. 30, 32.

Cordylodus serratus Stauffer

? 1930. Stauffer, p. 124, Pl. 10, fig. 7.

Prioniodus aculeatus Stauffer

? 1930. Stauffer, p. 126, Pl. 10, fig. 12.

Prioniodus cristulus Stauffer

? 1930. Stauffer, p. 128, Pl. 10, fig. 19.

Remarks. These specimens are characterized by being laterally bowed and with discrete denticles, often becoming progressively larger posteriorly. C. dilatus (Stauffer) shows a somewhat sinuous outline of the aboral anterior edge of the cusp in lateral view; in C. rectilineatus (Stauffer) this edge is uniformly curved. It is uncertain whether this represents a stable character, so for the present the latter species is grouped in synonymy with C. dilatus.

Specimens studied. 5.

Repository. Hypotype, U.O. 13213/209.

Genus Curtognathus Branson and Mehl, 1933

Type species. Curtognathus typa Branson and Mehl, 1933.

Discussion. Curtognathus was defined to include comparatively narrow arched bars with an excavated aboral surface and an oral surface occupied by discrete, slender, subequal, divergent denticles lying in the plane of the arched base. It is clearly related to Trucherognathus, Polycaulodus and Cardiodella but differs from the former two in being arched and from the latter in that the denticles are set essentially in one plane. Other minor differences are found, but intermediate forms occur between all four genera. It should be noted that all have the unexcavated base with laminae concentric around a small subcentral pit, thus the growth pattern of all four appears to be essentially the same. They are all closely related with very similar geological ranges.

Curtognathus was found in 25 samples from the Lowville to the Rockland and subdivided into three species.

Curtognathus coronata Branson and Mehl

Plate 3, figure 14

Curtognathus coronata Branson and Mehl

1933. Branson and Mehl, p. 88, Pl. 5, fig. 26.

1943. ______, p. 384, Pl. 64, fig. 47.

Description. Basal outline lenticular; aboral surface moderately and evenly arched, base flat to slightly concave transversely and showing laminae concentric around a small subcircular pit. Oral surface occupied by seven discrete, diverging denticles of moderate length and subcircular in outline. The largest is centrally situated, with three others on either side which become progressively smaller towards the extremities. Denticles vary slightly in their lateral inclination and thus do not lie in a perfect vertical plane.

Remarks. The specimens closely conform to the material of Branson and Mehl given in the synonomy, except that they reported keeled denticles, this, however, is unlikely to be of specific importance. The specimens are rather similar to Cardiodella arcuatus (Branson and Mehl), but the latter are more strongly arched and do not have the prominent central denticle. Branson and Mehl (1933, p. 82) state that this species is not typical of Cardiodella and that it may be considered an abnormal representative of Curtognathus. From the descriptions and illustrations, the latter would seem the most plausible, but clearly the type specimens need re-examination.

Specimens studied. 2.

Repository. Hypotype, U.O. 06415/111.

Curtognathus limitaris Branson and Mehl

Plate 3, figure 20

Curtognathus limitaris Branson and Mehl

1933. Branson and Mehl, p. 88, Pl. 5, figs. 17, 23, 25.

1943. ______, p. 384, Pl. 64, fig. 49.

1955. Sweet, p. 249, Pl. 29, fig. 16.

1963. Uyeno, pp. 95-97, Pl. 3, fig. 12.

Curtognathus limitaris? Branson and Mehl

1943. Branson and Mehl, p. 386, Pl. 64, fig. 20.

Description. Basal outline sublachrymal; aboral surface arched, but rather weakly for the genus, normally flat or concave transversely, and showing concentric laminae around a small subcentral circular pit, beneath the largest denticle. Oral surface occupied by usually five discrete denticles, normally strong, subcircular in outline, and rarely keeled. Basal asymmetry is reflected in denticle pattern: largest denticle is normally the second from the rounded end, rest are subequal, smallest normally at extremities. Largest denticle generally occupies a central position with the limb containing the most denticles being sharp-pointed and extending further aborally.

Remarks. This is a rather variable species, but distinguished by its asymmetry. The specimens are closely comparable to those figured by Branson and Mehl (1933, 1943) and Uyeno (1963) but are by no means as strongly arched as Sweet's figured specimen. Uyeno proposed that Polycaulodus chatfieldensis Stauffer (1935b, p. 613-614, Pl. 71, fig. 44) should be regarded as a junior subjective synonym of C. limitaris. Stauffer's figured specimen should certainly be brought to Curtognathus, but the specimen is broken and this writer considers that it cannot be included in this species with certainty since its asymmetry is not apparent and it may also lie close to C. peculiaris Branson and Mehl.

Specimens studied. 10.

Repository. Hypotype, U.O. 06323/209.

Curtognathus peculiaris Branson and Mehl

Plate 3, figure 16

Curtognathus peculiaris Branson and Mehl

1933. Branson and Mehl, p. 89, Pl. 5, figs. 20, 22.

Description. Basal outline lenticular; aboral surface tightly arched, surface flat to slightly concave transversely with a small circular central pit under the central denticle. Oral surface occupied by strong to slender, subequal, discrete, blunt-pointed denticles. The longest is centrally located and is flanked by either two or three smaller denticles on each limb. Dental series lies essentially in one antero-posterior plane, but their may be a slight incurving.

Remarks. The Chaumont material agrees quite closely with that of Branson and Mehl, but since this is the only other description, the degree of intraspecific variation is uncertain. In some forms, for instance, the large central denticle becomes laterally inclined and the whole unit slightly curved in oral view. Thus, it begins to approach *C. cordiformis* Branson and Mehl and resemble an arched type of *Cardiodella*. In typical forms, however, the unit is straight and shows a marked degree of symmetry.

Specimens studied. 10.

Repository. Hypotype, U.O. 06223/214.

Genus *Dichognathus* Branson and Mehl, 1933

Type species. *Dichognathus prima* Branson and Mehl, 1933.

Discussion. The detailed, revised diagnosis and the extensive discussion of *Dichognathus* presented by Sweet *et al.* (1959, pp. 1046-1047) is accepted. All the Chaumont specimens are referred to one species, *D. brevis* Branson and Mehl, which has been interpreted to give it broader scope.

Some 17 samples yielded specimens of *Dichognathus* which were taken from all three formations.

Dichognathus brevis Branson and Mehl

Plate 4, figures 11, 14

Dichognathus brevis Branson and Mehl

1933. Branson and Mehl, p. 113, Pl. 9, figs. 24-26.

1957. Glenister, p. 734, Pl. 88. figs. 10, 12.

1959. Sweet, Turco, Warner, and Wilkie, p. 1047, Pl. 132, fig. 7.

1963. Uyeno, p. 101 for extensive synonomy.

Dichognathus decipiens Branson and Mehl

1933. Branson and Mehl, pp. 99-100, Pl. 6, figs. 24, 25.

Dichognathus variabilis Stauffer

? 1935a. Stauffer, p. 141, Pl. 11, fig. 7.

1935b. Stauffer, pp. 604-605, Pl. 73, figs. 14, 24, 30, 31, 34-37, 40, 44, 50, 59; Pl. 75, fig. 8.

Remarks. Sweet et al. (1959, p. 1047) considered the size of the outer process angle to be the most diagnostic character of this species and this to measure between 35° and 45°. This species is also characterized by short limbs meeting at about 90° and a prominent cusp. The Chaumont material includes forms that possess: a) two subequal denticulated processes or b) a denticulated posterior process and a weakly denticulated to smooth inner lateral process or c) a weakly denticulated to smooth posterior process and a denticulated inner lateral process. All three types (previously called D. brevis, D. variabilis, and D. decipiens respectively) appear to be gradational. The size and development of the processes are variable, although in all three the denticles are discrete. The size of the outer process angle in D. decipiens and D. variabilis was not given in the original descriptions, but from the illustrations and the Chaumont material, they appear to fall into the high angle D. brevis range. This broadening of the specific limits of D. brevis is advisable for the reasons given above and also since other authors had already included forms with only one denticulated bar, without comment or comparison with D. variabilis (e.g. Pulse and Sweet, Pl. 35, fig. 9).

It would appear that a comparable grouping of some of the more straight, laterally compressed forms with a short cusp may also be advisable (Schopf, 1964, per comm.).

Specimens studied. 22.

Repository. Hypotypes, U.O. 19113/1(-1), 19117/308, 19123/208, 19223/208.

Genus Drepanodus Pander, 1856

Type species. Drepanodus arcuatus Pander, 1856.

Discussion. In 1955, Lindström redefined the genus Drepanodus to allow its recognition to be based on more objective criteria. Thus he states (1955, p. 558):

> "I have regarded all symmetrical or subsymmetrical species with smooth lateral faces, sharp anterior and posterior edges, and the posterior edge of the cusp meeting the oral margin in a curve, as belonging to Drepanodus."

This definition has been unanimously adopted in subsequent literature and is likewise followed herein.

Two species have been recognized in the Chaumont: D. homocurvatus is common whereas D. suberectus is fairly rare.

Drepanodus homocurvatus Lindström

Plate 1, figure 6

Oistodus curvatus Branson and Mehl

1933. Branson and Mehl, pp. 110-111, Pl. 9, figs. 4, 10, 12.

1953. Rhodes, p. 295, Pl. 21, figs. 82, 89, 90; Pl. 22, figs. 157-161.

Oistodus brevis Stauffer

? 1935b. Stauffer, p. 609, Pl. 74, fig. 32.

Drepanodus homocurvatus Lindström

1955. Lindström, p. 563, Pl. 2, figs. 23, 24, 39; text-fig. 4D.

1957. Glenister, p. 725, Pl. 86, fig. 13; Pl. 87, figs. 1-6, 8.

1959. Stone and Furnish, p. 222, Pl. 31, fig. 8.

1961. Bergström, pp. 39-41, Pl. 2, figs. 13, 14; Pl. 5, fig. 19; text-figs. 3E, 4A.

1962. Sweet and Bergström, p. 1226, Pl. 169, fig. 9.

1963. Uyeno, pp. 108-110 for extensive synonomy.

Remarks. In revising the generic diagnosis of Oistodus and Drepanodus, Lindström brought the species O. curvatus Branson and Mehl to Drepanodus. D. curvatus was already occupied, however, (Stauffer, 1932, p. 259, Pl. 40, fig. 1) so D. homocurvatus was adopted. This species is extremely common and widespread in the Ordovician and has been well described previously. Considerable variation exists within the species, much of which has been figured by Glenister (1957). The Chaumont specimens are dominated by two varieties. The most common type has the basic shape, curvature, and basal cavity features of the figured cotypes of Branson and Mehl's O. curvatus, but is perfectly symmetrical. The other variety, however, is markedly asymmetrical and closely comparable to one of Branson and Mehl's cotypes (1933, Pl. 9, fig. 4). The outer lateral side is quite uniformly convex, but the inner lateral face is characterized by a flattened and flexed area bordering the anterior edge and present along the whole length of the cusp, including the basal sheath. Moreover, in these specimens the basal sheath on the inner side is more flaring than on the outer face and its junction with the inner side is sharply defined. These forms are normally twisted or flexed inwards distally. This latter variety of the species is much less numerous, and if included within the species would mean very broad specific limits. Much of the previous literature on this species includes these rather asymmetrical types and it seems best at present to refer both Chaumont varieties to D. homocurvatus. With more material and a comparison of the types, it may be possible to subdivide this species. Some of the more asymmetrical forms clearly lie close to D. concavus (Branson and Mehl). This species may be synonomous with D. homocurvatus; in the Chaumont material there is a complete gradation between the two extremes described above and thus all specimens are referred to D. homocurvatus.

Specimens studied. 30.

Repository. Hypotype, U.O. 03213/209.

Drepanodus suberectus (Branson and Mehl)

Plate 1, figure 7

Oistodus suberectus Branson and Mehl

1933. Branson and Mehl, p. 111, Pl. 9, fig. 7.

Oistodus giganteus Stauffer

1935b. Stauffer, p. 610, Pl. 74, fig. 45.

Oistodus? suberectus Branson and Mehl

1957. Glenister, pp. 726-727, Pl. 84, figs. 12, 14.

Drepanodus suberectus (Branson and Mehl)

1955. Lindström, p. 568, Pl. 2, figs. 21, 22.

1960. Pulse and Sweet, p. 253, Pl. 35, figs. 2, 7.

1961. Bergström, p. 41, Pl. 5, fig. 7; text-figs. 3K, 4B.

1962. Sweet and Bergström, p. 1226, Pl. 169, fig. 8.

1963. Uyeno, pp. 111-112 for extensive synonomy.

Remarks. Within the specimens from the Chaumont there are slight differences in the shape of the cross-section and in the amount and shape of flaring of the basal sheath. These are only minor, however, and lie well within the range of variation shown in previous illustrated accounts of this species.

Specimens studied. 3.

Repository. Hypotype, U.O. 03113/302.

Genus Eobelodina Sweet, Turco, Warner, and Wilkie, 1959

Type species. Oistodus fornicalus Stauffer, 1935.

Discussion. Sweet et al. (1959, p.1050) considered Oistodus fornicalus Stauffer to have a gross superficial resemblence to typical Oistodus, but also several other features that were clearly allied to Belodina, e.g. "The posterior margin is bent inward, the basal excavation is deep, capacious, and imperfectly bifid, and the surface of the entire element is finely striated." They diagnosed Eobelodina as follows:

> "Bowed, individually asymmetrical, simple conodont-elements, with massive, erect, longitudinally striated cusp, compressed in cross-section. Upper margin of base produced into stout compressed flange-like "heel", the anterior end of which joins the posterior cusp margin in an acute angle. Base only slightly expanded on inner side, "crimped" along posterior margin, and constricted horizontally near mid-height so that the capacious asymmetrically subconical excavation is divided into two interconnected cavities. Thread-like extension of basal extension of basal excavation apex in lower subdivision."

Eobelodina is a rare form, occurring in only eight samples, all of which can be regarded as Chaumont. All specimens are referred to the single species of this genus.

Eobelodina fornicala (Stauffer)

Plate 1, figure 14

Oistodus fornicalus Stauffer

1935b. Stauffer, p. 610, Pl. 75, figs. 3-6.

1959. Ethington, p. 282, Pl. 39, fig. 19.

1960. Carlson, tab. 2, Pl. 2, fig. 18.

Eobelodina fornicala (Stauffer)

1959. Sweet, Turco, Warner, and Wilkie, pp. 1050-1051, Pl. 133, fig. 11 (includes synonomy through 1959).

Remarks. The Chaumont specimens of Eobelodina are all referrable to this species and there seems to be little variation within the figured and described material of this species. Uyeno gives a detailed description of his Hull material and reports that the basal cavity is not imperfectly bifid as described by Sweet et al. (1959) but the two parts are entirely separate, with their own individual openings. The Chaumont specimens do not exhibit this feature and the cavity resembles that described by Sweet et al.: it is imperfectly bifid, the upper part being the larger and is broadly curved, whilst the lower is more restricted and extends farther into the cusp as a sharply-pointed thread. The opening at the base is single but constricted along the line of extension of the part separating the two cavities.

The characteristic fine striae parallel to the posterior margin of the cusp are inconspicuous in these specimens.

Specimens studied. 2.

Repository. Hypotype, U.O. 26113/204.

Genus Eoligonodina Branson, Mehl and Branson, 1951

Type species. Eoligonodina robusta Branson, Mehl and Branson, 1951.

Discussion. The authors (1951, pp. 14-15) defined the genus to include complex dental units consisting of a relatively long, slender, recurved terminal denticle with deeply excavated thin-walled base, expanded in the plane of curvature and extended on the oral edge into a denticulated bar, approximately normal to the terminal denticle. From the opposite antero-aboral edge of the expanded base, the main denticle is continued as a denticulated bar in the same plane as the denticle and its other denticulated bar and bears denticles directed about normal to this plane.

Much discussion has arisen (see Uyeno, pp. 116-117 for review) over the validity of the genus, various authors wishing to incorporate it within either Ligonodina or Zygognathus. The present state of North American opinion seems to favour retention of the genus and to this the writer concurs. Besides the aforementioned genera, Eoligonodina is undoubtedly gradational into Cordylodus; intermediate species always present difficulty, but the genus is sufficiently distinctive to allow generic identification in most forms.

One species of Eoligonodina was found in the Chaumont, which ranges into the Lowville and Rockland.

Eoligonodina robusta Branson, Mehl and Branson

Plate 1, figure 19

Eoligonodina robusta Branson, Mehl and Branson

1951. Branson, Mehl and Branson, p. 15, Pl. 4, figs. 33, 35-37.

1963. Uyeno, pp. 118-119, Pl. 3, fig. 5.

Eoligonodina richmondensis Branson, Mehl and Branson

1951. Branson, Mehl and Branson, p. 15, Pl. 4, figs. 23-27.

1959. Ethington and Furnish, p. 543, Pl. 73, fig. 1.

Pteroconus n. sp.

? 1944. Mehl and Strothmann (in Branson), Pl. 12, figs. 3-6.

Remarks. The specimens at hand are closely comparable to the type material from the Richmond of Kentucky and Indiana. The posterior bar is usually broken, but up to eleven denticles were observed on Chaumont specimens. Likewise, the aboral process is commonly damaged and up to five denticles were recorded. Clearly, the number of denticles is dependent upon the growth-stage of the element. The authors (1951, p. 15) state that E. robusta "is more sturdy than E. richmondensis and has a more lobate inner and outer free margin of the basal cusp, and the posterior bar denticles are more nearly erect." These distinctions do not seem to warrant specific separation and can be accomodated in either normal specific variation or difference in growth-stage.

Mehl and Strothmann figure specimens named Pteroconus n. sp. but which undoubtedly belong in Eoligonodina and probably in E. robusta.

Specimens studied. 16.

Repository. Hypotype, U.O. 14129/209.

Genus Erismodus Branson and Mehl, 1933

Type species. Erismodus typus Branson and Mehl, 1933.

Discussion. Branson and Mehl's diagnosis (1933, p. 25.) of Erismodus was given as follows:

"More or less bar-like arched units with median or apical

> cone the somewhat excavated base of which is emphasized by a buttress on each side, that of the outer face extending as a boss or process below the aboral margin of the arched bar. Oral edge of bar produced into a few low rounded denticles. In some species bars very short and non-denticulate. The bar excavated lengthwise on the aboral side to clasp the jaw."

Very little well preserved material of this genus has been figured, and thus presumably studied. Consequently, most of the species, especially the denticulated ones, are poorly defined and comparisons with them are not satisfactory. A restudy of the types is required with more detailed descriptions and a determination of the true specific characters.

Erismodus is found in all three formations (23 samples) and five species are recognized, one of which has not been previously described.

Erismodus *abbreviatus* Branson and Mehl

Plate 2, figure 2

Erismodus *abbreviatus* Branson and Mehl.

1933. Branson and Mehl, pp. 25-26, Pl. 1, figs. 8, 17.

1944. Mehl and McLaughlin, *in* Branson, Pl. 8, figs. 12-19.

1955. Sweet, p. 233, Pl. 28, fig. 10.

Description. Robust units with little basal elaboration. Apical cusp erect to slightly incurved, sides convex, often sharply, and meeting as a sharp or slightly keeled edge; point sharp. Anterior side of cusp continues down as a prominent aboral process, rounded at the base; the posterior side has a similar, but shorter process which is directed aborally and inwards. Some forms are without lateral bars and the basal cavity appears as a notch when viewed laterally. In others the keels of the cusp continue laterally as immature short bars or processes, which may bear one denticle; in these the basal cavity is a deep sub-conical hollow.

Remarks. Most forms agree closely with the cotypes figured by Branson and Mehl (1933). Only rarely are these units denticulated and no forms were observed which had more than one denticle or even one on each side. Those figured by Branson (1944, figs. 15-19) that have two denticulated processes with more than one denticle should perhaps be placed in a new species. The writer feels that the forms that are undenticulated, or that support single immature denticles, should be grouped as *E. abbreviatus*. Others with definite denticulated processes should be referred to another species (e.g. *E.* n. sp. Barnes).

Specimens studied. 32.

Repository. Hypotype, U.O. 11115/307.

Erismodus cf. *E. digitatus* Branson and Mehl

Plate 2, figure 6

Erismodus digitatus Branson and Mehl

cf. 1933. Branson and Mehl, p. 26, Pl. 1, fig. 36.

cf. 1944. Mehl and McLaughlin, *in* Branson, Pl. 9, figs. 27, 28.

Description. Cusp long, slender, sharp-pointed, subcircular to laterally compressed, and erect to slightly recurved or inclined laterally. No isolated aboral processes, but sides expanded down as flanges between the bars, giving a deeply excavated basal cavity. One lateral bar is short, bearing at least one small, sharp-pointed denticle, and directed only slightly inward and downward. The other bar is much longer and is directed inwards and markedly downwards, the prominent change in direction occuring on the bar itself; about five or six small, sharp-pointed, discrete, denticles occur here. Apical cusp, if recurved, curves slightly over, or towards, this longer downflexed bar.

Remarks. The specimens figured previously (see synonomy) all have a broken lateral bar, so the true nature of the lateral bars and their dentition is unknown. Hence, Chaumont specimens that compare closely with these previous descriptions can only questionably be referred to this species. The specimens at hand also have one lateral bar broken, but sufficient remains to show that the unit is asymmetrical.

Specimens studied. 3.

Repository. Hypotype. U.O. 11617/208.

Erismodus cf. E. radicans (Hinde)

Plate 2, figure 7

Prioniodus radicans Hinde

cf. 1879, Hinde, pp. 356-357, Pl. 15, figs. 1-5.

Erismodus radicans (Hinde)

cf. 1933. Branson and Mehl, p. 156, Pl. 12, figs. 14, 18, 19.

cf. 1955. Sweet, p. 234, Pl. 29, figs. 22, 29.

Erismodus radicans? (Hinde)

? 1944. Mehl and McLaughlin, in Branson, Pl. 8, figs. 20, 21.

Description. Apical cusp long, slender, laterally compressed producing keeled edges, sharp-pointed, and erect or slightly inclined inwards. Anterior aboral process prominent, convex, rounded, but less than one quarter the cusp length; process extends vertically downward or may be deflected towards a shorter lateral bar if marked asymmetry is present. Posterior buttress arched, directed inwards and aborally and joined laterally to the bars. Basal cavity thus moderately excavated. Two lateral bars directed aborally and slightly inward are slender and ungrooved, both symmetrical and asymmetrical. Bars denticulated with small, sharp-pointed, laterally compressed, sometimes slightly incurved denticles of variable number; one large mature asymmetrical specimen bore six denticles on one bar and four on the other. The range of denticle number on longer limbs seems to be four to six, those on the shorter limb usually one to two less than the other.

Remarks. The species of *Erismodus* characterized by long denticulated lateral bars are: *E. radicans* (Hinde), *E. digitatus* Branson and Mehl, *E. dutchtownensis* Youngquist and Cullison, *E. symmetricus* Branson and Mehl, *E. tantus* Stauffer, and *E. typus* Branson and Mehl. With the partial exception of *E. radicans*, all have been described and figured from broken material and most of the descriptions are inadequate and the specific characters uncertain to allow subsequent allocation of the Chaumont specimens of this type to one or more of these species with confidence. Most of these species badly need revision. The most complete forms are of *E. radicans*, but Hinde's material is embedded in limestone and hence is only partially visible. After examination of these specimens, Branson (*in* Branson and Mehl, 1933, p. 156) reported that this species was very broadly defined. The Chaumont specimens of the genus with denticulated lateral bars have been placed in three species of *Erismodus*: *E.* cf. *E. digitatus*, *E.* cf. *E. radicans* and *E.* n. sp.A. The forms allocated to *E.* cf. *E. digitatus* are rather extreme types and those to *E.* n. sp.A. are a well defined group which appears to be of specific rank. The rest of the specimens are referred to *E.* cf. *E. radicans*; a few of these may belong to the other species listed earlier, but the poor nature of the type material does not allow a finer subdivision.

The important specific characters of *E. radicans* seem to be the erect or suberect prominent cusp, with small but prominent aboral extensions and two lateral bars set with several discrete denticles. The unit can be symmetrical or slightly asymmetrical.

Specimens studied. 11.

Repository. Hypotype, U.O. 11521/208.

Erismodus cf. E. simplex Branson and Mehl

Plate 2, figure 1

Erismodus simplex Branson and Mehl.

cf. 1933. Branson and Mehl, p. 26, Pl. 1, figs. 15, 16.

cf. 1955. Sweet, p. 234, Pl. 29, fig. 19.

Description. Apical cusp sharp-pointed and with edges that are sharp to faintly keeled; anterior and posterior faces are sharply convex and normally carinate in the lower two-thirds, thus giving a subquadrate-shaped outline in the lower part. Anterior process is prominent and rounded and is directed slightly outward as well as aborally. Posterior process is smaller and directed more inwards than aborally. Two lateral processes are developed which are directed outwards but only slightly aborally; they are thin, deep and plate-like but without any distinct denticulation. Basal cavity wide, but quite shallow compared to most species of Erismodus.

Remarks. The Chaumont specimens are all extremely robust with all processes being large and massive. The specimens are comparable to E. simplex Branson and Mehl but appear to be far more massive and with a larger cusp. However, the presence of undenticulated lateral bars is considered a major specific character and the specimens are referred to E. cf. simplex.

Specimens studied. 4.

Repository. Hypotype, U.O. 11219/1(-2).

Erismodus n. sp. A

Plate 2, figures 3, 4

Diagnosis. Moderately long cusp, produced aborally into anterior process and posterior buttress, inclined laterally at about 90° with a shorter denticulated bar whilst forming a continuous line with the longer denticulated bar. Bars slightly directed inwards, usually suporting two and three denticles respectively.

Description. Apical cusp is moderately long, keeled, sharp-pointed, and inner side is weakly carinate. From the basal junction, it is inclined markedly laterally over the shorter bar, the angle between these two approximating 90°. Angle between the axes of cusp and longer lateral bar is about 180°. Cusp is produced aborally as an anterior rounded process, less than one-quarter the length of cusp, and a weakly flaring buttress. Basal cavity is thus conical and moderately excavated. Lateral bars are rarely longer than apical cusp and are directed slightly inwards. Shorter bar commonly bears two or three denticles, longer one three or four; denticles short, discrete, subequal, and are either slender, sharp-pointed, slightly incurved, and laterally compressed or strong blunt nodes, subcircular in outline. Bases of bars flat, ungrooved.

Remarks. These specimens are distinguished by the marked asymmetry and the inclined cusp over the shorter lateral bar. Two varieties occur: one type is robust, with no lateral compression and whose denticles are small, blunt, and node-like; the other kind is small, delicate, laterally compressed, and whose denticles are slender, and sharp-pointed. Also in the latter, the bars may be of subequal length and have an equal number of denticles. These two types may be distinct types or merely represent different growth-stages, the basic plan of the unit is constant and seems to be a valid new species. It should be noted, however, that as stated in the remarks of *E.*

radicans most of the species of the genus are unsatisfactorily described and illustrated, hence good comparisons are rarely possible. Of the previously described species, E. tantus (Stauffer) (see Stauffer, 1935a, p. 143, Pl. 12, fig. 7; also Stone and Furnish, 1959, p. 223, Pl. 32, fig. 11) seems to lie quite close to the Chaumont specimens, but does not appear to be conspecific.

Specimens studied. 7.

Repository. Holotype, 11417/210.

Genus Micrococelodus Branson and Mehl, 1933

Type species. Micrococelodus typus Branson and Mehl, 1933.

Discussion. Branson and Mehl (1933, p. 89) defined the genus as follows:

> "Dental units consisting of a dominant median cone which is recurved above its conspicuously expanded, deeply cupped base. This is laterally flanked by basal wings or bars of varying length, but usually short, on each side, set with sharp discrete denticles of minor size. The main cone has more or less conspicuous lateral carinae and is somewhat flattened on the recurved side. A growth axis is evident throughout the length of the main cone."

Branson and Mehl (1933) erected many new species within the genus and the distinctions between some may be insufficient to substantiate a specific rank. Some of these possible synonyms are referred to below in considering the Chaumont representatives of the genus. Those forms referred to this genus by Stauffer (1940) and Cooper (1939), from the Devonian may be stratigraphic admixtures and this material, particularly that of Cooper, requires restudy to determine the true position of these conodonts. Certain species of Micrococelodus stand quite close to Ptiloconus.

The genus is very common, being absent in only eight samples and the specimens have been placed in five species, one of which is new. Micrococelodus occurs in all three formations sampled.

Microcoelodus asymmetricus Branson and Mehl

Plate 2, figure 10

Microcoelodus asymmetricus Branson and Mehl

1933. Branson and Mehl, p. 91, Pl. 7, figs. 5, 10, 11, 14, 15.

1943. ______, pp. 383-384, Pl. 64, figs. 37, 39, 41, 46.

1955. Sweet, p. 243, Pl. 28, fig. 4.

Remarks. This species appears to incorporate quite a wide range of morphological variations. The great bulk of the Chaumont forms are closely comparable to figures 10, 11 of Branson and Mehl (1933, Pl. 7) that is: a slender, recurved or inwardly inclined, slightly twisted, keeled cusp flanked on one side by one to three denticles and on the other by none or rarely one; the base is thus asymmetrical, the cavity extending under the denticulated limb. A few specimens are more robust with both limbs denticulated and these are comparable to figures 14, 15 of Branson and Mehl (1933, Pl. 7). Two other species of Branson and Mehl: M. magnicornis and M. unilateralis closely resemble M. asymmetricus and the differences between them may not be of specific value; a study of the type material is required.

Specimens studied. 35.

Repository. Hypotype, U.O. 10621/207.

Microcoelodus expansus Branson and Mehl

Plate 2, figure 13

Microcoelodus expansus Branson and Mehl

1933. Branson and Mehl, p. 93, Pl. 6, fig. 7; Pl. 7, fig. 16.

1935a. Stauffer, pp. 145-146, Pl. 12, figs. 10, 15.

1955. Sweet, pp. 243-244, Pl. 27, figs. 3, 19.

Remarks. The Chaumont forms compare very closely with those of Branson and Mehl from the Joachim. The specimens are fairly uniform, all showing slight asymmetry and an expanded basal cavity to include the lateral bars, of which one has one or two more denticles than the other. The denticles show lateral compression and possess keeled edges; the apical cusp is large, dominant, and slightly incurved and inclined. The flank denticles are generally very slender, discrete, and sharp-pointed.

Specimens studied. 20.

Repository. Hypotype, U.O. 10215/307.

Microcoelodus intermedius Branson and Mehl

Plate 2, figure 11

Microcoelodus intermedius Branson and Mehl

1943. Branson and Mehl, p. 384, Pl. 64, figs. 38, 40, 53.

Microcoelodus sp.

1933. Branson and Mehl, Pl. 7, fig. 6.

Microcoelodus intermedius Branson and Mehl?

1946. Youngquist and Cullison, pp. 583-584, Pl. 90, fig. 6.

Remarks. The Chaumont specimens agree well with the figured material of Branson and Mehl from the lower Bromide and Joachim. This species lies quite close to *M. expansus* Branson and Mehl, but has greater symmetry, is more recurved, and the prominent basal cavity is deeper and more confined to beneath the apical cusp. Also, *M. intermedius* normally has a better developed anterior, aboral, downward-directed tongue or broad anti-cusp.

Specimens studied. 22.

Repository. Hypotype, U.O. 10319/201.

Microcoelodus unicornis Branson and Mehl

Plate 2, figure 9

Microcoelodus unicornis Branson and Mehl

1933. Branson and Mehl, p. 96, Pl. 6, fig. 33.

Microcoelodus unicornis? Branson and Mehl

1933. Branson and Mehl, Pl. 7, figs. 20, 24, 25.

non 1942. Amsden and Miller, Pl. 41, fig. 5.

1955. Sweet, p. 244, Pl. 28, fig. 21.

Remarks. This species would appear to exhibit wide variation, but is distinguished by short, slender, strongly incurved limbs bearing one or two small slender denticles; the base is markedly arched on the posterior margin producing a deep restricted cavity. Most of the Chaumont forms fall close to M. unicornis? as figured by Branson and Mehl. These appear to be conspecific with M. unicornis and are included in synonymy. Some Chaumont specimens are rather shorter, more robust types, with the aboral posterior margin showing no marked arching. These seem to lie close to M. simplex Branson and Mehl; the latter authors (1933, p. 95) state that this species is quite similar to M. unicornis, the differences listed, however, may well be only those of relative growth-stage and the two may be conspecific. Until a comparison of the types can be undertaken, the Chaumont forms are referred to M. unicornis.

Specimens studied. 8.

Repository. Hypotype, U.O. 10415/210.

Microcoelodus n.sp.A

Plate 2, figure 14

Microcoelodus sp. (?)

?1933. Branson and Mehl, Pl. 7, figs. 22, 26.

Diagnosis. Base flat, with a shallow, centrally restricted basal cavity. Erect, sharp-edged and pointed, slender cusp is flanked by moderately extended bars each bearing two or three small denticles; bars only slightly deflected inwards, if at all.

Description. Base flat, straight, elongate, expanding in width below apical cusp; basal cavity shallow and restricted beneath cusp. Cusp is long, quite slender, erect or weakly inclined to slightly recurved inwards, and slightly laterally compressed producing sharp edges and point. Lateral limbs extend from cusp at right angles, only slightly directed inwards, if at all, and bearing two or three small, discrete, sharp pointed denticles. The unit is thus essentially symmetrical in posterior and anterior views.

Remarks. Specimens of this type do not appear to have been described previously. However, Branson and Mehl figured two broken specimens (see synonymy) which appear to be very similar to the Chaumont types. They both lack one of the lateral bars and contain few denticles on the other, but the general form seems to the same and they may be conspecific.

Specimens studied. 4.

Repository. Holotype, U.O. 10113/303.

Genus Oistodus Pander, 1856

Type species. Oistodus lanceolatus Pander, 1856.

Discussion. Pander's original description of the genus was too broad and consequently several different generic types have been referred to Oistodus. This problem has been resolved by Lindström (1955) who redefined the genus as follows (p. 573):

?1933. Branson and Mehl, Pl. 7, figs. 22, 26.

Diagnosis. Base flat, with a shallow, centrally restricted basal cavity. Erect, sharp-edged and pointed, slender cusp is flanked by moderately extended bars each bearing two or three small denticles; bars only slightly deflected inwards, if at all.

Description. Base flat, straight, elongate, expanding in width below apical cusp; basal cavity shallow and restricted beneath cusp. Cusp is long, quite slender, erect or weakly inclined to slightly recurved inwards, and slightly laterally compressed producing sharp edges and point. Lateral limbs extend from cusp at right angles, only slightly directed inwards, if at all, and bearing two or three small, discrete, sharp pointed denticles. The unit is thus essentially symmetrical in posterior and anterior views.

Remarks. Specimens of this type do not appear to have been described previously. However, Branson and Mehl figured two broken specimens (see synonymy) which appear to be very similar to the Chaumont types. They both lack one of the lateral bars and contain few denticles on the other, but the general form seems to the same and they may be conspecific.

Specimens studied. 4.

Repository. Holotype, U.O. 10113/303.

Genus *Oistodus* Pander, 1856

Type species. *Oistodus lanceolatus* Pander, 1856.

Discussion. Pander's original description of the genus was too broad and consequently several different generic types have been referred to *Oistodus*. This problem has been resolved by Lindström (1955) who redefined the genus as follows (p. 573):

> "To Oistodus belong simple conodonts with a more or less wide basal cavity. The posterior edge makes a sharp angle with the oral edge. As a rule, either or both of the lateral faces are carinate."

Two species of Oistodus were found in the Chaumont; the genus was recovered from 16 samples and from all three formations.

Oistodus inclinatus Branson and Mehl

Plate 1, figure 8

Oistodus inclinatus Branson and Mehl

1933. Branson and Mehl, p. 110, Pl. 9, fig. 8.

1959. Sweet, Turco, Warner, and Wilkie, pp. 1053-1054, Pl. 131, fig. 6.

? 1961. Wolska, p. 351, Pl. 3, figs, 2a, 2b.

1963. Uyeno, pp. 127-128 for extensive synonomy.

Remarks. Chaumont forms compare closely with those figured and described by Branson and Mehl (1933) and by Sweet et al. (1959). All other published examples seem to be conspecific, with the possible exception of those described by Wolska (1961). There would appear to be confusion at times with Oistodus excelsus Stauffer. Figured material of this latter species varies considerably and it seems likely that this is synonymous with O. inclinatus; for instance, Stauffer's figured holotype (1935b, Pl. 74, fig. 43) and Bergström's material (1961, Pl. 2, figs. 18, 19) of O. excelsus appear to be conspecific.

Specimens studied. 8.

Repository. Hypotype, U.O. 02115/201.

Oistodus robustus Bergström

Plate 1, figure 9

Oistodus robustus Bergström

1961. Bergström, p. 45, Pl. 3, figs. 7-10, text-fig. 3F.

1964. Hamar, p. 269, Pl. 3, figs. 1, 2, 7, 14.

Falodus n. sp. 1 Lindström

? 1960. Lindström, fig. 4, no. 8.

Falodus sp.

? 1963. Spassov, p. 78, Pl. 1, figs. 8a, 8b, 9.

Falodus parvidentatus Sergeeva

? 1963. Sergeeva, pp. 103-104, Pl. 8, figs. 4-7.

Falodus simplex Sergeeva

? 1963. Sergeeva, pp. 104-105, Pl. 8, figs. 8-10.

Remarks. The Chaumont specimens agree closely with the specific description of Bergström. They differ in having a rather longer and more prominent cusp and a more extended anterior edge; the latter may also have very weak denticulation in the form of one or two tiny denticles or nodes. Bergström has examined these specimens and has stated (1964, per. comm.) that all these variations are found on unfigured material that he has included in this species. Hence, weakly denticulated forms of this type may be more appropriately placed in Oistodus rather than Falodus (see synonomy). Bergström also has specimens that exhibit weak denticulation on the posterior oral edge which may suggest that some forms of this species may stand quite close to some early representatives of Prioniodina. The presence of this species is noteworthy since it is a long-ranging European form (Bergström 1964, per. comm.), but this is its first recorded occurrence in the midcontinent province.

Specimens studied. 8.

Repository. Hypotype, U.O. 02225/3(-1).

Genus Oulodus Branson and Mehl, 1933

Type species. Oulodus mediocris Branson and Mehl, 1933.

Discussion. Sweet et al. (1959, p. 1054) have given a more precise and extensive diagnosis of the genus than the original of Branson and Mehl (1933, p. 116). They also proposed a revised mode of orientation and included Stauffer's Gyrognathus within Oulodus.

Oulodus is represented in this material by one species and found in only six samples but from all three formations.

Oulodus casteri Pulse and Sweet

Plate 4, figure 16

Oulodus casteri Pulse and Sweet

1960. Pulse and Sweet, pp. 255-256, Pl. 36, figs. 1, 8, 12.

1963. Uyeno, pp. 130-131, Pl. 4, fig. 1.

Oulodus mediocris Branson and Mehl?

? 1959. Sweet, Turco, Warner, and Wilkie, pp. 1054-1055, Pl. 133, fig. 5.

Remarks. Chaumont specimens brought to this species closely conform to the figured descriptions of the type material from the Eden. The cusp is fairly prominent and laterally compressed together with the limb denticles; the two denticulated bars are subequal in length, normally bearing about 7 and 5 denticles respectively, and are slightly twisted distally in opposite directions, lying essentially in a single plane proximally. The base is quite deeply grooved, being greatest beneath the apical cusp, with an associated flaring posterior sheath. The syntypes of this species were examined and are more robust (a characteristic of Maysville conodonts), have relatively shorter limbs, have somewhat closer-spaced denticles, and with a shallower and more expansive basal cavity. Other Maysville specimens referred to this species were almost identical to those from the Chaumont.

Specimens studied. 4.

Repository. Hypotype, U.O. 21113/3(-1).

Genus Ozarkodina Branson and Mehl, 1933

Type species. Ozarkodina typica Branson and Mehl, 1933.

Discussion. This long-ranging genus has presented considerable difficulty with specific subdivision and even in allowing a satisfactory generic diagnosis. Branson and Mehl erected the genus from Silurian material and Sweet et al. (1959, p. 1055) have recently reviewed the taxonomic problems. In an attempt to distinguish between the gradational genera of Prioniodina and Ozarkodina they state that:

> "...even though this distinction may prove to be overly artificial, we are including in Ozarkodina only those of our arched, blade-like specimens in which the limb-denticles are compressed and laterally confluent. We are referring to Prioniodina several species of bar- or blade-like conodont-elements in which the limb-denticles are discrete and peg-like or not strongly compressed."

The Chaumont specimens of the genus are referred to two species. In one, O. tenuis Branson and Mehl, the denticles, in part at least, are usually discrete and laterally compressed. Many of the earlier descriptions and illustrations of this species also exhibit this feature. The arched nature, the wide and deep basal cavity extending the full length of the unit, and the relatively small apical denticle, strongly favour placement within Ozarkodina and the above distinction between Prioniodina and Ozarkodina does indeed seem overly artificial.

In the other, O. rhodesi Lindström, the denticles are confluent but this is regarded as merely a feature of maturity. These latter specimens are of the "Aphelognathus" type, this genus having been brought herein into synonomy with Ozarkodina. All previously described species of Aphelognathus show features normally associated with blade-like conodonts in late growth-stages; there is no stable feature of generic significance to separate it from Ozarkodina.

Specimens of O. tenuis are found quite commonly in both the Lowville and the Chaumont, but never in the Rockland; those of O. rhodesi occur in all three formations. Together they are found in 24 samples.

Ozarkodina rhodesi Lindström

Plate 4, figure 13

Ozarkodina rhodesi Lindström

1959. Lindström, p. 441, Pl. 1, figs. 1-9, text-fig. 3:6.

Aphelognathus irregularis Pulse and Sweet

1960. Pulse and Sweet, pp. 249-250, Pl. 36, figs. 15, 17.

Remarks. No specific distinction is apparent between O. rhodesi and Aphelognathus irregularis, the morphologic differences being seemingly only those of growth-stage.

In the Chaumont specimens, both the confluent and discrete denticle types found on the anterior limb vary slightly in number: five and four respectively are the most common. Other forms show considerable variation that may exclude them from this species: in some, the posterior bar is much reduced, with only one or two crowded denticles lying posterior to the main cusp; in others the denticles (up to six) lying on each side of the cusp are all fused, forming one single ridge, with discrete denticles further along the bars. Many of these variations seem related to growth-stage. They are included within this species until further study of the Chaumont collections can be undertaken; their morphology is certainly much closer to *O. rhodesi* than to any of the two *Aphelognathus* species of Branson, Mehl and Branson (1951) or the single one of Rhodes (1955).

Specimens studied. 12.

Repository. Hypotype, U.O. 20113/208.

Ozarkodina tenuis Branson and Mehl

Plate 4, figure 14

Ozarkodina tenuis Branson and Mehl

1933. Branson and Mehl, p. 128, Pl. 10, figs. 19-21-23.

1953. Rhodes, p. 320, Pl. 22, figs. 187, 197-200.

Ozarkodina concinna Stauffer

1935a. Stauffer, p. 148, Pl. 10, figs. 41, 45, 46.

1959. Ethington, p. 283, Pl. 41, figs. 15, 16; includes synonomy to 1959.

1959. Ethington and Furnish, Pl. 73, fig. 16.

1960. Carlson, Pl. 2, figs. 7, 12.

Ozarkodina pauperata Stauffer

1935b. Stauffer, p. 611, Pl. 71, figs. 16, 24.

non 1955. Sweet, p. 260, Pl. 29, fig. 4.

Ozarkodina robusta Stauffer

1935b. Stauffer, p. 612, Pl. 71, figs. 1, 3, 6, 7, 9-13, 15, 21.

1959. Sweet, Turco, Warner, and Wilkie, p. 1055, Pl. 133, fig. 14.

1960. Pulse and Sweet, p. 256, Pl. 35, figs. 18, 19.

1963. Uyeno, pp. 132-134, Pl. 2, figs. 12, 13; Pl. 4, figs. 6, 15.

Remarks. The Chaumont specimens show some variation in size and robustness, but all are characterized by a fairly uniform dentition pattern, normally with laterally compressed denticles, a weaker posterior limb, a very deep basal cavity extending the length of the unit, wide flaring thin lateral walls, the outer of which is produced into a carinate central expansion, the inner being smooth, and a generally slightly crescentic plan and arched lateral view; the limbs meet at a very variable angle but normally between 110°-130°.

The writer feels that the differences in morphology which have led to the erection of those species listed in the synonymy can all be accounted for in the growth stages of one species (O. tenuis having priority). Previous assignments of O. pauperata seem to represent immature varieties, those to O. concinna and O. tenuis as mature forms, and to O. robusta, the late growth-stage types. The hypotypes of O. robusta of Sweet et al. (1959) and Pulse and Sweet (1960) were examined in this connection. Glenister's (1957) O. inclinata may be a separate species, characterized by the pronounced uniform inclination of the denticles, and is omitted from the synonomy.

Specimens studied. 13.

Repository. Hypotype, U.O. 12127/3(-1).

Genus Panderodus Ethington, 1959

Type species. Paltodus unicostatus Branson and Mehl, 1933.

Discussion. Ethington (1959, p. 284) proposed this new genus for forms that had previously been placed in Paltodus which had a basal cavity that extended to at least mid-height. His diagnosis of the genus Panderodus is:

> "In this genus are placed simple asymmetrical curved cones which have a deep, tapered, basal cavity generally extending at least to mid-height. Lateral faces are ornamented by costae or grooves; cross section of the tooth may be used for specific identification. Basal outline tends to be broadly rounded anteriorly and narrow posteriorly."

Cross-sections were rarely given in the description of most of the species prior to 1950 and three dimensional interpretation are often difficult. Further, there has frequently been no consistant level at which cross-sections were taken, nor care in securing mature specimens. Thus the specific boundaries are often vague and, as Sweet and Bergström (1962) suggest, the genus is badly in need of revision. Five species of this genus are recognized from the Chaumont.

Specimens of this genus were found in every sample.

Panderodus compressus (Branson and Mehl)

Plate 1, figure 2

Paltodus compressus Branson and Mehl

1933. Branson and Mehl, p. 109, Pl. 8, fig. 19.

1951. Branson, Mehl and Branson, p. 7, Pl. 1, figs. 16-22.

Panderodus compressus (Branson and Mehl)

1959. Ethington, p. 284, Pl. 39, fig. 4.

1963. Uyeno, pp. 140-141 for extensive synonomy.

Paltodus cornutus Stauffer

1935b. Stauffer, p. 612, Pl. 74, figs. 1, 2, 11, 13-15, 19.

Panderodus cornutus (Stauffer)

1961. Wolska, p. 353, Pl. 4, figs. 1a, 1b.

1963. Uyeno, pp. 142-143, Pl. 1, fig. 20.

Remarks. Forms referred to this species include laterally compressed, evenly curved, broad cones with a smooth outer lateral face occasionally bearing a faint costa close to the anterior edge in the central part of the cone, and an inner lateral face bearing a prominent groove close and parallel to the posterior edge. The anterior and posterior edges are normally sharp, but in a few are somewhat rounded, more especially the anterior. The basal cavity extends to about two-thirds the length of the cone. In the Chaumont specimens it is common to find a weak broad carina anterior to the groove and occupying the lower third of the cone. This widens from a point to occupy the whole area between the groove and the anterior edge at the basal margin. There seems to be no essential difference between P. compressus (Branson and Mehl) and P. cornutus(Stauffer); they are grouped in synonomy, the former having priority.

Specimens studied. 20.

Repository. Hypotype, U.O. 01419/207.

Panderodus feulneri (Glenister)

Plate 1, figure 5

Paltodus feulneri Glenister

1957. Glenister, p. 728, Pl. 85, fig. 11.

Panderodus feulneri (Glenister)

1959. Stone and Furnish, p. 225, Pl. 31, fig. 3.

1959. Ethington, pp. 284-285, Pl. 39, fig. 2.

Remarks. Chaumont specimens referred to this species closely conform to the description given by Glenister and slightly ammended by Stone and Furnish. They all reveal the characteristic ornamentation of the inner lateral face, there being some variation in the strength of development of the costa. The anterior edge, however, is not sharply keeled in most specimens, but is narrowly rounded. Further, the minor groove commonly reported on the outer lateral face is generally absent. The specimens at hand are large and robust, a feature which has also been recorded by Glenister, Stone and Furnish, and Uyeno (1963).

Specimens studied. 6.

Repository. Hypotype, U.O. 01713/105.

Panderodus gracilis (Branson and Mehl)

Plate 1, figure 4

Paltodus gracilis Branson and Mehl

1933. Branson and Mehl, p. 108, Pl. 8, figs. 20, 21.

1951. Branson, Mehl and Branson, pp. 6-7, Pl. 1, figs. 1-8.

1957. Glenister, p. 728, Pl. 85, figs. 2-5.

Panderodus gracilis (Branson and Mehl)

1959. Ethington, p. 285, Pl. 34, fig. 1.

1959. Sweet, Turco, Warner, and Wilkie, p. 1056, Pl. 131, fig. 1.

1962. Sweet and Bergström, p. 1233, text-fig. 1H.

1963. Uyeno, pp. 144-145 for extensive synonomy.

Paltodus equicostatus Rhodes

1953. Rhodes, p. 297, Pl. 21, figs. 106-109; Pl. 22, figs. 162, 165.

Paltodus elegans Stauffer

1935b. Stauffer, pp. 612-613, Pl. 74, figs. 4, 7.

Remarks. This is an extremely common species throughout the Middle and Upper Ordovician and the many descriptions and illustrations of this species have revealed considerable variation. In some Chaumont forms, the costa at the junction of the rounded anterior edge and the inner lateral face is not as sharp as those commonly figured. Typical forms of P. gracilis are only slightly asymmetrical; other Chaumont specimens show a complete gradation from these to a distinctly asymmetrical type where the inner lateral face is flat and the outer lateral face is inclined towards it. These latter types can be regarded also as slender forms of P. arcuatus (Stauffer). The writer would prefer the latter species to be restricted to broad cones and to include P. intermedius (Branson, Mehl and Branson). Within P. gracilis, Bergström (1964) has included P. equicostatus (Rhodes) and the present writer would also include P. elegans (Stauffer).

Specimens studied. 42.

Repository. Hypotype, U.O. 01115/207.

Panderodus panderi (Stauffer)

Plate 1, figure 3

Paltodus panderi (Stauffer)

1940. Stauffer, p. 427, Pl. 60, figs. 8, 9.

1957. Glenister, pp. 728-729, Pl. 85, figs. 8, 9.

Panderodus panderi (Stauffer)

1959. Stone and Furnish, p. 226, Pl. 31, fig. 4.

1959. Ethington, p. 285, Pl. 39, fig. 5, includes synonomy to 1959

1959. Ethington and Furnish, p. 541, P.73, fig. 9.

Remarks. Stauffer and Glenister give thorough descriptions of this fairly distinctive species, and there can be little confusion with other species. The specimens at hand certainly correspond closely to the previously figured and described material.

Specimens studied. 2.

Repository. Hypotype, U.O. 01615/106.

Panderodus striatus (Stauffer)

Plate 1, figure 1

Paltodus striatus (Stauffer)

1935b. Stauffer, p. 613, Pl. 74, figs. 3, 16.

1957. Glenister, p. 729, Pl. 5, fig. 6.

Panderodus striatus (Stauffer)

1959. Sweet, Turco, Warner, and Wilkie, p. 1057, Pl. 131, fig. 4.

Remarks. This species is characterized by its slender, laterally compressed form and in having an offset costa on the flattened outer lateral side with the anterior margin acutely rounded, passing posteriorly into a broadly convex carina on the inner lateral face. In Chaumont specimens, a furrow is generally present immediately posterior to the carina; the posterior margin is sharply keeled. The units are commonly slightly twisted, as was also noted by Stauffer.

Specimens studied. 9.

Repository. Hypotype, U.O. 10527/208.

Genus Polycaulodus Branson and Mehl, 1933

Type species. Polycaulodus inclinatus Branson and Mehl, 1933.

Discussion. The genus was defined to include bar or plate-like conodonts with a nearly flat aboral surface. The oral surface is occupied by subcircular or compressed, discrete, slender denticles which are straight or somewhat curved of which one is conspicuously the larger. This latter, however, may take any position relative to the others.

Eight species of this genus have been recognized, of which three, and possibly a fourth, are new. This is a very common genus, only absent in eleven samples and occurring in all three formations.

Polycaulodus bidentatus Branson and Mehl

Plate 4, figure 6

Polycaulodus bidentatus Branson and Mehl

1933. Branson and Mehl, p. 106, Pl. 8, figs. 1-3.

1943. ______, p. 382, Pl. 64, fig. 29; p. 385, Pl. 64, fig. 15.

1955. Sweet, p. 250, Pl. 28, fig. 5.

1963. Uyeno, pp. 153-154, Pl. 3, fig. 11.

Description. Base is sub-lachrymiform in shape, being widest beneath larger denticle at posterior end. Maximum width is about half length of base. Aboral surface slightly concave, generally slightly twisted anteriorly and contains a small circular pit located at the point where central axis of larger denticle would intersect basal excavation. Oral surface contains two diverging denticles whose basal area occupies most of the surface. The sharp pointed denticles are most commonly aligned in an antero-posterior plane, a smaller anterior one is sub-circular in cross section whereas a larger slender posterior denticle is commonly slightly keeled on its anterior and posterior edges. In size, larger denticle is always greater than twice the length of smaller one. Denticles are erect, slightly inclined inwards and occasionally the larger one may be somewhat recurved inwards distally.

Remarks. The specimens agree closely with type material from the Plattin and with Uyeno's figured material. The figured material of Branson and Mehl (1943, p. 385, Pl. 64, fig. 15) has a rather massive base and denticles that are not truly discreet and thus shows marked variation within the species. Only the Chaumont forms and Uyeno's Hull material are reported to have slightly keeled denticles.

Specimens studied. 4.

Repository. Hypotype, U.O. 05119/210.

Polycaulodus aff. P. bidentatus Branson and Mehl

Plate 4, figure 5

Diagnosis. Unit essentially bilaterally symmetrical about a vertical plane passing between two denticles. Basal margin subcircular to elliptical; aboral surface concave. Oral surface occupied by two discrete subcircular denticles which are curved inwards.

Description. Being essentially bilaterally symmetrical, this unit poses the problem of orientation. Despite the inward curvature of the denticles it is felt best to retain the orientation used for the genus Polycaulodus i.e. the antero-posterior axis lying along the dental axis. Thus in these specimens it is usually impossible to designate which end is anterior or posterior, and the curvature of the denticles is to the inner lateral side.

Basal margin normally subcircular in outline but commonly eliptical and rarely pointed in antero-posterior axis. Aboral surface slightly concave with small circular pit occupying subcentral position. This lies between the intersection of the two subvertical dental axes and the aboral surface, and is in the same plane as the dental axes. Thus, it is commonly located nearer to the outer edge, depending upon the degree of curvature of the denticles. In slightly asymmetrical forms, when one denticle is longer than the other, the pit is located nearer to axis of the larger. Oral surface is occupied by two discrete denticles, subcircular in cross-section and quite sharp-pointed. They are occassionally of equal length, but usually subequal with one never less than half the length of the other. There is always markedly uniform inward curvature of denticles.

Remarks. The specimens show significant differences to *P. bidentatus* Branson and Mehl, which may require the erection of a new species. The symmetry of the unit is not a character of the type specimens or of any that have since been referred to this species. Intermediate forms, however, undoubtedly exist; a few such specimens occur in the Chaumont but until it is known whether there is a fairly abrupt change between *P. bidentatus* and *P.* aff. *P. bidentatus*, the erection of a new species does not appear valid.

Specimens studied. 7.

Repository. Holotype, 05821/214.

Polycaulodus cornulatus Branson and Mehl

Plate 4, figure 3

Polycaulodus cornulatus Branson and Mehl

1933. Branson and Mehl, p. 106, Pl. 8, figs. 9, 12.

1955. Sweet, p. 250, Pl. 29, fig. 20.

Description. Basal outline lenticular, length three times the maximum width. Aboral surface flat, no laminae or pit visible. Oral surface occupied by three discrete denticles, subcircular in outline; the central denticle is at least twice as long as the other two and is erect but slightly inclined posteriorly.

Remarks. The specimens have the most posterior denticle represented as a small node, perhaps because of damage, but it should be noted that both of Branson and Mehl's figured specimens have the anterior one of the two smaller denticles the longest; Sweet's illustration shows only two denticles. This may prove to be of value in the recognition of this species.

Specimens studied. 2.

Repository. Hypotype, U.O. 05513/214.

Polycaulodus normalis Branson and Mehl

Plate 4, figure 2

Polycaulodus normalis Branson and Mehl

1933. Branson and Mehl, p. 86, Pl. 6, figs. 20, 21; p. 107, Pl. 8, fig. 18.

1963. Uyeno, pp. 154-155, Pl. 3, fig. 9.

Remarks. Chaumont specimens have a flat to concave aboral surface, in which the subcentral pit is only weakly developed, if at all. The denticles most commonly number four and five and are divergent. They closely agree with Branson and Mehl's material from the Plattin and Joachim.

Specimens studied. 5.

Repository. Hypotype, U.O. 05613/213.

Polycaulodus tridentatus Branson and Mehl

Plate 4, figure 4

Polycaulodus tridentatus Branson and Mehl

1933. Branson and Mehl, p. 106, Pl. 8, figs. 5-7, 10.

1943. ______, p. 382, Pl. 64, figs. 27, 28.

1955. Sweet, p. 251, Pl. 28, figs. 2, 19.

1963. Uyeno, pp. 155-157, Pl. 3, fig. 10.

Polycaulodus tridentatus? Branson and Mehl

1943. Branson and Mehl, p. 385, Pl. 64, fig. 14.

Description. Basal outline is lachrymiform, maximum width, near the posterior end, is about half the basal length. Aboral surface commonly either slightly concave or slightly convex, rarely flat and a shallow circular pit is always located where the central axis of the largest cusp intersects the aboral surface. The aboral surface nearly always exhibits fine striations, which are clearly growth lamellae, concentric to the small pit. Three discrete denticles slightly laterally compressed producing faint keels, occupy the whole oral surface and are arranged with the largest posteriorly, and show a progressive decrease in size anteriorly. Denticles are normally posteriorly inclined, rarely recurved, and all tend to lie in a near vertical antero-posterior plane. In some, the base is slightly arched so that denticles are slightly divergent.

Remarks. In the original description, Branson and Mehl (1933) state that the denticles are inclined anteriorly; this does not conform to the conventional orientation and is therefore not used here. The rather convex aboral surface of many specimens, with the lamellae concentric around the small pit, appears to be an example of inverted basal cavity as described by Lindström (1955, p. 537).

Specimens studied. 25.

Repository. Hypotype, U.O. 05217/107.

Polycaulodus n. sp. A

Plate 4, figure 7

Diagnosis. Unit resembles P. tridentatus Branson and Mehl in all respects except that a fourth and smallest denticle occurs at the anterior end of dental series.

Description. Unit closely comparable to P. tridentatus Branson and Mehl, but has an additional fourth denticle. This is situated at anterior end and is smallest of all; the four denticles increase in size progressively, and are inclined towards the posterior. Concentric lamellae on the aboral surface are present, but not well developed and none had an inverted basal cavity; one specimen had an attachment of grey-white "bony" material on the aboral surface which also exhibited concentric laminae.

Remarks. No previous specimens of this kind appear to have been figured or described. It is outside the definition of P. tridentatus although it is clearly very closely related. Since this form is easily recognized and cannot be confused with any other species of Polycaulodus, it is considered to be a valid new species which may well be stratigraphically significant.

Specimens studied. 6.

Repository. Holotype, U.O. 05313/208.

Polycaulodus n. sp. B

Plate 4, figure 1

Diagnosis. Basal outline lenticular, aboral surface concave to convex, margin flat. Oral surface occupied by three or four short, subequal, discrete denticles, subcircular in outline.

Description. Unit rather massive. Basal outline lenticular with maximum width (at centre) being about one-third of the length; margin flat. Aboral surface flat, convex or concave, normally showing concentric laminae around a small circular pit with a raised rim. Oral surface occupied by three or four, short, strong, discrete denticles, subcircular in outline and subequal in length, although those slightly larger occupy central positions. These lie in a vertical antero-posterior plane and show no curvature, the specimens with somewhat longer denticles show weak divergence.

Remarks. These specimens cannot be placed within any existing species of *Polycaulodus*, their denticle pattern being quite distinct and different to other described species. Some specimens again exhibit an "inverted basal cavity". A further specific subdivision, based on denticle number, may be possible in the future, when the significance of this form is appreciated.

Specimens studied. 8.

Repository. Holotype, U.O. 05715/104.

Polycaulodus n. sp. C.

Plate 4, figures 8, 9

(?)*Polycaulodus* sp.

1933. Branson and Mehl, p. 106, Pl. 8, fig. 17.

Diagnosis. Basal outline sublachrymal to lenticular, oral surface surmounted by four or five denticles of which the anterior three or four show progressive increase in size posteriorly with a small denticle lying posterior to the largest in the series.

Description. Basal outline usually sublachrymal, more rarely lenticular. Aboral surface usually slightly concave, sometimes flat, sometimes convex; small circular pit usually present under the largest denticle; laminae not visible. Oral surface occupied by four or five discrete denticles subcircular in outline or showing slight lateral compression; they may show some incurving, but are always inclined posteriorly. Denticles number four or five; the most posterior is always small and of comparable size to the most anterior, whereas the denticles anterior to the most posterior one show a progressive decrease in size anteriorly. Thus, the largest denticle is always adjacent to the most posterior one. All denticles tend to lie in one antero-posterior plane; occasionally one may be slightly offset laterally.

Remarks. These specimens are clearly similar in all respects to *P. bidentatus* Branson and Mehl and *P. tridentatus* Branson and Mehl, except that they have developed a small posterior denticle, thus producing forms that are significantly different and which can be recognized objectively. They are therefore grouped as a separate new species; later study may reveal that this can be subdivided into two meaningful species i.e. separate variations of *P. bidentatus* and *P. tridentatus*.

Specimens studied. 7.

Repository. Syntypes, U.O. 05425/210, 05415/204.

Genus *Prioniodina* Bassler, 1925

Type species. *Prioniodina subcurvata* Ulrich and Bassler, 1926.

Discussion. The generic diagnosis presented by Sweet *et al.* (1959, p. 1059) is accepted here:

> "Compound, individually asymmetrical, arched, blade-like conodont-elements with a relatively large, erect or distally reclined cusp and anterior and posterior processes that bear discrete denticles and are continuous with more or less well defined anterior and posterior costae on the cusp. Under cusp surface deeply sheathed in early species; sheath inverted and basal cavity less well defined (except beneath cusp) in later species."

These authors use the combined properties of prominent arch, large cusp, and discrete denticles to distinguish the genus from Ozarkodina, although, once again, there are intermediate forms that present difficulties in generic assignment.

Prioniodina was found in all three formations in 23 samples; one species has been described.

Prioniodina robusta (Stauffer)

Plate 4, figure 10

Euprioniodina robusta Stauffer

1930. Stauffer, p. 123, Pl. 10, fig. 1

Pteroconus robustus (Stauffer)

1935b. Stauffer, p. 617, Pl. 75, figs. 15-17, 20, 21.

Pteroconus tortus Branson and Mehl

1933. Branson and Mehl, p. 112, Pl. 8, fig. 33.

Ptiloconus tortus (Branson and Mehl)

1955. Sweet, p. 246, Pl. 28, fig. 11.

Cyrtoniodus complicatus Stone and Furnish

part 1959. Stone and Furnish, pp. 221-222.

Cyrtoniodus sinclairi Ethington and Furnish

1960. Ethington and Furnish, pp. 270-271, Pl. 38, fig. 16.

Prioniodus cultellatus Stauffer

? 1930. Stauffer, p. 126, Pl. 10, fig. 11.

Remarks. This species is fairly common throughout much of the Middle and Upper Ordovician, but has been referred to a number of separate species. It is characterized by the dominant, wide, keeled cusp, deep and frequently sheathed basal cavity, closely spaced to confluent, laterally compressed, posterior bar denticles and discrete, more widely spaced, round, peg-like, anterior bar denticles. The lateral bars generally diverge at an angle of about 80°-100°.

Specimens studied. 16.

Repository. Hypotype, U.O. 16221/102.

Genus Ptiloconus Sweet, 1955

Type species. Pteroconus grandis Branson and Mehl, 1933.

Discussion. In addition to changing the generic name, Sweet (1955, p. 245) condensed Branson and Mehl's original diagnosis to read as follows:

> "Comparatively slender, recurved cones with moderately expanded, deeply excavated, laterally compressed bases. Oral surface of base on posterior side of cusp bears a few short, sharp-pointed, nearly recumbent denticles. One or two small, sharp, inclined denticles rise from near the aboral margin of the cusp in a position nearly opposite to the denticles on the oral margin."

The terminology and orientation of this genus has been confused; that of Sweet (1955, fig. 6) is adopted here with the cusp directed posteriorly with anterior and posterior denticulated wings or limbs and, because of the twisting and asymmetry of the unit, an inner and outer side is recognized.

Only one species, P. gracilis, was found in the Chaumont but is common throughout, occurring in 23 samples and in all three formations.

Ptiloconus gracilis (Branson and Mehl)

Plate 2, figure 8

Pteroconus gracilis Branson and Mehl

1933. Branson and Mehl, p. 111, Pl. 8, figs. 28, 30, 32, 35.

1935b. Stauffer, p. 617, Pl. 75, fig. 1.

Ptiloconus gracilis (Branson and Mehl)

1955. Sweet, p. 246, Pl. 28, figs. 6, 20.

Description. Base slightly elongate, somewhat expanded on the inner side; basal cavity conical, asymmetrical, point lying closest to the anterior edge. Oral surface dominated by a long slender recurved sharp-pointed cusp, directed or twisted to point posteriorly. Cusp edges keeled, outer side convex, inner side slightly convex distally, more so aborally, but inner side flattened near keeled edges. At base of main cusp, small denticles occur on the anterior and posterior oral edges of the base; these are small discrete, subcircular or laterally compressed in outline, sharp-pointed and slightly incurved. Number of small denticles variable, normally less than three; those on the posterior side being generally best developed.

Remarks. Chaumont specimens are clearly conspecific with the type material. They show little variation except in the degree of twist and in the number and size of flank denticles. In a few specimens, the posterior side of the base is extended posteriorly and aborally, causing marked basal asymmetry and bearing the majority of flank denticles. The degree of recurvature of the cusp is remarkably constant for the Chaumont specimens, as is the sudden change in curvature of the cusp, at a position about one third the length distally from the base.

Specimens studied. 27.

Repository. Hypotype U.O. 09143/306.

Genus <u>Stereoconus</u> Branson and Mehl, 1933

<u>Type species</u>: <u>Stereoconus gracilis</u> Branson and Mehl, 1933.

<u>Discussion</u>. Branson and Mehl (1933, p. 27) erected this genus to include:

> "Comparatively slender more or less curved cones without basal excavation or "pulp cavity"; lateral faces varying from slightly concave to slightly convex; rounded anterior and posterior edges; longitudinally fibrous rather than laminar structure."

Of these general characters, the form of the basal cavity appears to be the most significant. The only Chaumont species, which is new, is suberect, has sharp edges and markedly convex lateral faces, thus, not in full agreement with the generic diagnosis. However, the diagnosis was established mainly upon the features of the three species of the genus described by Branson and Mehl. With the description of more species there may well have to be a revision of this diagnosis; the very limited Chaumont material does not permit this.

<u>Stereoconus</u> is a rare form, occurring in only seven samples, yet in all three formations. The material is placed in a single new species.

<u>Stereoconus</u> n. sp. A

Plate 2, figure 5

<u>Diagnosis</u>. Robust cone, suberect, inclined slightly posteriorly, sharp pointed with prominently convex sides meeting at the sharp, slightly keeled edges. Base massive, aboral surface slightly concave with a small subcentral pit.

<u>Description</u>. Robust cone is suberect, being slightly inclined posteriorly with prominently smooth equi-convex sides meeting at sharp, slightly keeled edges and producing a sharp terminal point. Basal region expanded and

basal outline widely lenticular; aboral surface slightly concave, exhibiting faint laminae concentric around a small subcentral pit.

Remarks. The unexcavated base of this simple cone places it in the genus Stereoconus Branson and Mehl. All species of this genus, as described by Branson and Mehl, are reported to have rounded edges. Most of Sweet's (1955) Harding material possesses sharp anterior and rounded posterior edges however, so this factor would seem to have no significance in the generic diagnosis. Four species of Stereoconus have been described, but all are recurved forms and the Chaumont specimens undoubtedly lie within a new species.

Specimens studied. 2.

Repository. Holotype, U.O. 17113/306.

Genus Trichonodella Branson and Mehl, 1948

Type species. Trichognathus prima Branson and Mehl, 1933.

Discussion. Sweet et al. (1959, pp. 1063-1064) have recently presented a thorough review of Trichonodella and related genera. They included the following diagnosis of the genus:

> "Trichonodella includes unpaired, compound, symmetrical or very slightly sub-symmetrical conodont-elements, consisting of an erect or recurved cusp, denticulate lateral processes of essentially equal development, and, in many species, a more or less distinct, for the most part non-denticulate extension or expansion of the proximal posterior margin of the cusp. The base is deeply excavated beneath the cusp, lateral processes, and the posterior extension or expansion of the cusp base."

The specimens referrable to this genus are common, being absent in ten samples, and are placed in one species that was recently proposed by Uyeno (1963).

Trichonodella sp. A Uyeno

Plate 4, figure 15

Trichonodella sp. A. Uyeno.

1963. Uyeno, pp. 183-185, Pl. 2, fig. 7.

Remarks. Some Chaumont specimens closely agree with Uyeno's description and illustration of this apparently new species. The angle of divergence of the limbs is between 40°-50°, rather than 50°-60°; the apical cusp is flat on the anterior side giving rise to two sharp edges upon meeting the sharply rounded posterior side; the lateral limbs each commonly bear six or more denticles. These slight differences from Uyeno's material, however, do not seem sufficient for removal from that species. The robust nature and the relatively large number of close-set denticles places this species close to T. undulata Branson, Mehl, and Branson but the lack of both a denticulated posterior process and grooves beneath the lateral limbs seem to allow specific separation, although these may well represent an evolutionary line, with later "inversion" of the cavities.

Other Chaumont specimens are smaller, more delicate, with denticles more discrete and fewer in number. These compare quite closely with T. recurva (Branson and Mehl). Uyeno also noted similarities between his T. sp. A and T. recurva, but believed them to be specifically distinct. The writer feels that these smaller forms may possibly be immature forms of T. sp. A Uyeno, for intermediate forms are present and so they are included within this species rather than in T. recurva.

Specimens studied. 9.

Repository. Hypotype, U.O. 25139/104.

Genus Trucherognathus Branson and Mehl, 1933

Type species. Trucherognathus distorta Branson and Mehl, 1933.

Discussion. Trucherognathus includes those complex dental units that consist of a nearly straight, solid, bar- or plate-like base from which rise a longitudinal row of more or less discrete, fairly slender denticles which point in diverse directions. Normally any larger denticles are fairly centrally located.

This genus poses a problem in orientation. Herein, the units are stated to have outer and inner sides, a predominant deflection of denticles laterally being designated inwards. Those forms with convex sides and no predominant inclination or distortion of the denticles are very difficult to apply this terminology to, although the denticles may arise from one side of the unit which may provide a basis for determining outer and inner sides.

The genus differs from Polycaulodus in that the denticles are arranged and oriented in a very irregular fashion. The specific breakdown is largely based on basal outline, and the number, arrangement, and orientation of denticles. Hence problems arise with immature forms but there are, as yet, only a dozen or so species in Trucherognathus and these are fairly distinctive.

Five species of Trucherognathus are found in the material at hand, of which one is new; another specific group of conodonts is also tentatively referred to this genus. Trucherognathus occurs in all three formations and was recovered from 19 samples.

Trucherognathus cf. T. disparalis Branson and Mehl

Plate 3, figure 3

Trucherognathus disparalis Branson and Mehl

cf. 1933. Branson and Mehl, p. 85, Pl. 5, figs. 3, 8.

1963. Uyeno, pp. 194-195, Pl. 3, fig. 7.

Trucherognathus disparalis? Branson and Mehl.

? 1933. Branson and Mehl, Pl. 5, fig. 2.

Description. Aboral surface slightly concave, filled with a shallow disc of grey-white "bony" material showing concentric laminations. Basal outline elongate; length twice the width, outer anterior side flat to slightly convex, inner posterior side asymmetrically broadly and deeply convex, producing one pointed and one broadly rounded end. Oral surface occupied by few slender discrete sharp-pointed denticles. Over the pointed end lies a short denticle, laterally compressed and faintly keeled and subererect, a similar but slightly longer one is set over the rounded end; between these two are two long denticles, subcircular in outline, that are inclined sharply inwards at essentially the same angle.

Remarks. This specimen is comparable to those allocated to this species by Branson and Mehl and by Uyeno. The most important feature of comparison seems to be the two, central, inclined denticles, flanked by smaller suberect ones. There are fewer denticles on the Chaumont specimen and it is not so elongate as those previously described. It is possibly a juvenile form (although it is a fairly large specimen) and is here designated T. cf. T. disparalis Branson and Mehl.

Specimens studied. 1.

Repository. Hypotype, U.O. 08713/209.

Trucherognathus distorta Branson and Mehl

Plate 3, figure 2

Trucherognathus distorta Branson and Mehl

1933. Branson and Mehl, p. 84, Pl. 5, fig. 1.

1943. ______, p. 385, Pl. 64, figs. 30, 33.

1944. ______, Pl. 93, figs. 2, 3.

Description. Aboral surface essentially flat to slightly convex; concentric laminae visible, small pit absent. Aboral margin straight, very long and narrow; sides slightly convex and ends pointed. Oral surface surmounted by six to nine (normally eight) denticles. Some denticles compare very closely with the type material in being moderately long, slender, sharp-pointed, subcircular or slightly laterally compressed, discrete, with pronounced incurving and slight distortion in inclination. Most specimens, however, have denticles that are short, wide, sharp-pointed, laterally compressed, keeled, and only slightly incurved posteriorly with their anterior face being flattened, and almost no individual variation or distortion in their inclination.

Remarks. The Chaumont specimens thus show some variation in their dental pattern, but both types are clearly so closely related that since the minority type is almost identical to the type Joachim forms, there is no hesitation in referring all specimens to T. distorta.

Specimens studied. 5.

Repository. Hypotype, U. O. 08313/308.

Trucherognathus parallela Branson and Mehl

Plate 3, figure 6

Trucherognathus parallela Branson and Mehl

1933. Branson and Mehl, p. 105, Pl. 8, fig. 14.

Description. Aboral surface essentially flat, laminae normally visible but small pit generally absent. Anterior margin straight to slightly sigmoidal, posterior margin asymmetrically convex with a pronounced expansion towards one end; margins meet at pointed ends. Oral surface surmounted by five to seven, discrete, laterally compressed, keeled, moderately long, quite slender, sharp-pointed denticles which are notably incurved posteriorly. The incurving is most pronounced in the central denticles which approach an inclination parallel to the aboral surface. The denticles near the extremities are generally shorter and less incurved. One denticle is commonly considerably larger than the others but occupies no set position, except never at the end.

Remarks. Branson and Mehl's Plattin material is reported to have eight, rounded, short denticles. In all other respects the Chaumont forms agree very closely with the figured holotype and are referred to this species without question.

Specimens studied. 4.

Repository. Hypotype, U. O. 08515/210.

Trucherognathus sinuosa Branson and Mehl

Plate 3, figure 10

Trucherognathus sinuosa Branson and Mehl

1933. Branson and Mehl, p. 84, Pl. 6, fig. 10.

?1941. Graves and Ellison, pp. 5, 7, Pl. 2, fig. 3.

Description. Aboral surface slightly arched, essentially flat, with concentric laminae only occasionally distinct; the small circular subcentral pit is normally absent. Aboral margin long, narrow, and sigmoidal in outline. Oral surface occupied by a row of small, laterally compressed, keeled, closely set, fairly discrete, sharp-pointed denticles, usually numbering seven or eight. The denticles are fairly well aligned except for the central one to three which are off-set and inclined laterally (posteriorly) over the convex expansion in the lateral sigmoidal margin; the other denticles are suberect.

Remarks. The Chaumont specimens are all closely comparable to the type Joachim material described by Branson and Mehl. The only other described species with which there could be possible confusion is *T. irregularis* Branson and Mehl, but this appears to be rarely arched and to have fewer, more irregularly-displaced denticles, some of which are carinate. One difference shown between the Chaumont and the Joachim forms of *T. sinuosa* is in denticle length: those from the Joachim are considerably longer, but this is unlikely to be of specific importance.

Specimens studied. 5.

Repository. Hypotype, U. O. 08119/208.

Trucherognathus n. sp. A

Plate 3, figures 8, 9

Diagnosis. Basal outline slightly arcuate longitudinally. Oral surface occupied by eight laterally compressed, suberect denticles showing slight variation in inclination.

Description. Aboral surface quite strongly convex transversely and exhibits well-developed concentric laminae around a small circular subcentral pit. Basal outline arcuate with broadly concave and convex sides; ends rather blunt-pointed. Oral surface surmounted by eight discrete, laterally compressed, keeled, short, round-pointed denticles. The denticles rise close to the concave posterior edge and are subequal in size and most are suberect, two of the smaller ones being inclined inwards.

Remarks. The shape of the unit and the denticle pattern does not correspond to any other previously described species of *Trucherognathus* and is therefore placed in a new species.

Specimens studied. 5.

Repository. Holotype, U. O. 08213/306.

Trucherognathus? sp.

Plate 3, figures 4, 5

Description. Aboral surface long, narrow and straight, convex transversely and exhibiting longitudinal concentric laminae. Oral surface surmounted by six, closely spaced, laterally compressed, keeled, short, wide, partly discrete denticles, all well aligned. At one end this bar curves inwards and is occupied by a much stouter short cusp, with correspondingly a slight basal expansion. The bar is evidently further incurved, but this part is broken off in the specimens.

Remarks. The dentition and general aspect of the bar closely agree with the majority of forms placed in *T. distorta* Branson and Mehl, except for the quite pronounced convex aboral surface. However, the obvious recurving at one end and the appearance of a stout prominent cusp with the probability of further dentition on the broken extension, give cause for doubt as to the generic assignment.

Specimens studied. 2.

Repository. Holotype, U.O. 08213/210.

Genus Zygognathus Branson, Mehl and Branson, 1951

Type species. Zygognathus pyramidalis Branson, Mehl and Branson, 1951.

Discussion. Included in Zygognathus are paired, individually asymmetrical conodont-elements with a prominent cusp and denticulated lateral processes that are continuous with the lateral cusp costae. The outer lateral process curves posteriorly, usually separated from an undenticulated, somewhat flaring, posterior margin of the cusp base by a narrow, shallow, trough-like depression. The inner lateral process is generally short and usually included in the curved surface defined by the anterior cusp margin. The base is deeply excavated beneath the cusp and processes.

This genus has caused problems in orientation, definition, and its morphological affinities. Sweet et al. (1959, pp. 1065-1066) have revised the orientation and this is adopted in the present study. The genus is gradational into others and those compared to Zygognathus have included: Microcoelodus, Ptiloconus, Trichonodella, and Eoligonodina. A single species was found in the Chaumont collection.

Zygognathus was recovered from 21 samples, but from only the Lowville and Chaumont.

Zygognathus cf. Z. maysvillensis Pulse and Sweet

Plate 4, figure 17

Zygognathus maysvillensis Pulse and Sweet

cf. 1960. Pulse and Sweet, p. 262, Pl. 37, figs. 9, 12.

Remarks. The Chaumont specimens appear to be conspecific with the Maysville forms, differing in only two characters. In the specimens at hand, the denticles are fairly uniformly inclined along the lateral processes and generally becoming slightly more erect closer to the main cusp; the reverse is found in the type material. Second, a distinct posterior process is present in the Chaumont forms and one specimen bears a single, but quite stout, denticle on this process. No such denticulated process has been described previously in _Zygognathus_ which is homologous to that in _Trichonodella_, _Hibbardella_, etc. (Bergström, 1964, p. 39). The two limbs of the units are usually broken, hence it cannot be determined which, if either, is the longer. Some of Stauffer's (1935a, 1935b) asymmetrical specimens of _Trichonodella recurva_ Branson and Mehl may also lie close to these from the Chaumont. Until it is ascertained which are the stable characters for this genus, the specimens are questionably referred to _Z. maysvillensis_, rather than erecting a new species.

Specimens studied. 5.

Repository. Hypotype, U.O. 24117/210.

CHAPTER 10

INCERTAE SEDIS OF THE CHAUMONT FORMATION

Discussion

During sorting of the conodonts from the heavy residue, all other microfossils were extracted. Of the great variety of forms present, the main types ("vertebrae", "dermal denticles", "plates", "rods","frilled rods", "eyes", and "caps") are described here and their stratigraphic distribution within the Chaumont of the western region is discussed below. The only other common *incertae sedis* are the small spherical opaque balls. They are usually black, amber, or pale green and some have a tiny hole in the surface. They are probably synonomous with the "egg-cases" of Stauffer (1935b, p. 620, Pl. 75, figs. 54-56); these are possibly chitinozoans or (S.M. Bergström, 1964, per. comm.) forms related to *Tasmanites*. A few comments on the groups described are in order here, but it should be noted that the synonymies given in the systematic descriptions are not necessarily complete, the writer not having made a thorough investigation of all the diverse literature.

The "vertebrae" closely resemble their name-sakes, and do not appear to have been described previously. It is perhaps possible that they represent asymmetrical fish scales (e.g. cf. the symmetrical Silurian scales figured by Spjeldnaes, 1950, Pl. 1, figs. 2a-b, 5a-b, 6a-b). However, they have been observed fused end-to-end and the writer has also had the opportunity to study a specimen from the Middle Ordovician of Minnesota found by Mr. G. Webers. This is shown in figure 38 and consists of a type of "frilled plate". There is no central rod on the

FIGURE 38: Sketch of _incertae sedis_ specimen (courtesy G. Webers) from Middle Ordovician of Minnesota, showing "vertebrae" attached to underside of a "frilled rod". Approximately x 75.

A. View of under surface.

B. View of upper surface.

C. Lateral view (inverted).

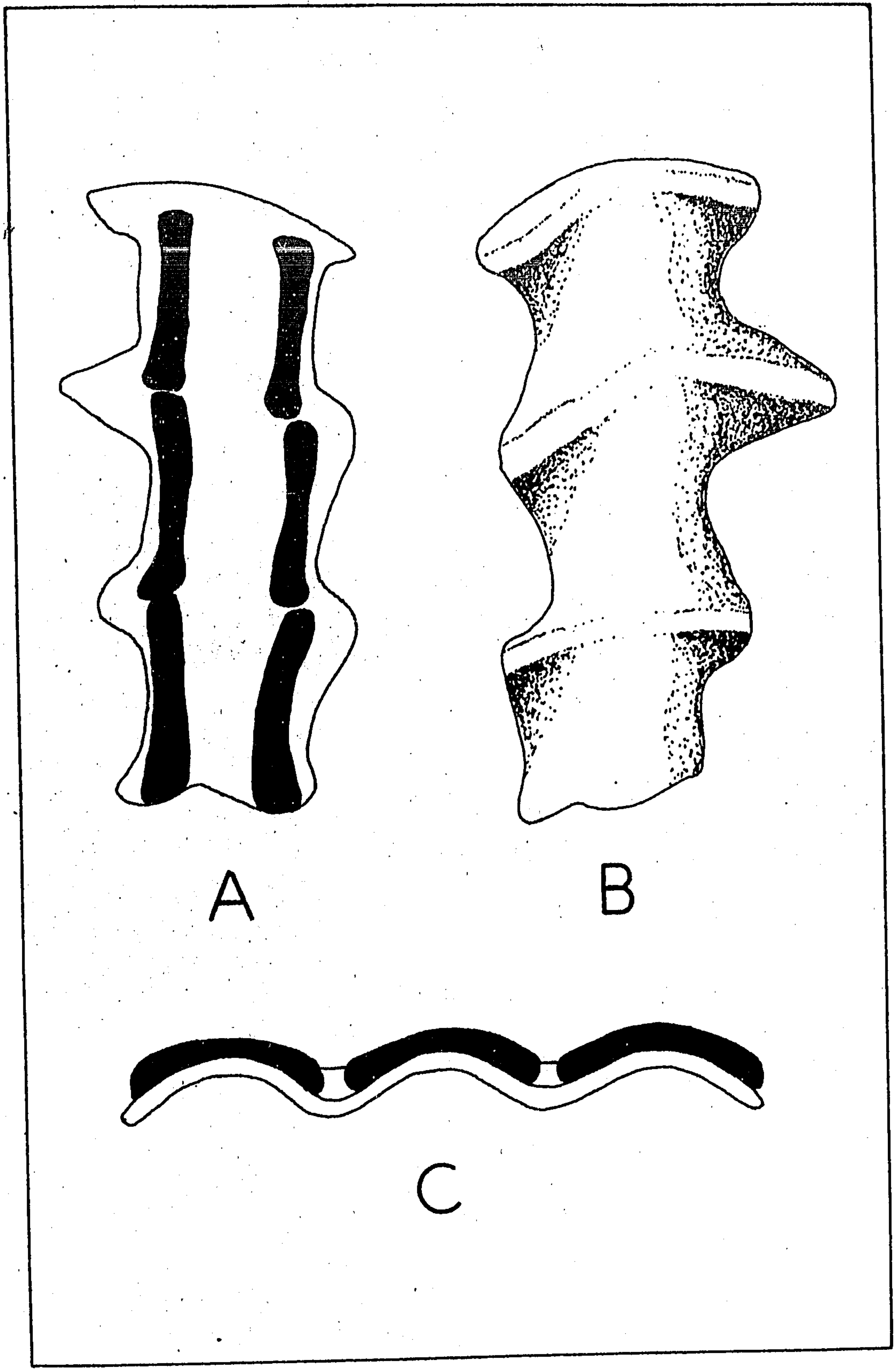

FIGURE 38

lower surface, but there are two rows of apparent "vertebrae" arranged end-to-end although not quite in contact. These two rows are parallel, but slightly off-set longitudinally and although their function is unknown, it stresses the probability that several of the incertae sedis are closely related.

The "dermal denticles" of Type A are undoubtedly the exoskeletal tubercles of early ostracoderms (superorder Heterostraci, order Astraspida). They are always found separated from the parent plates and are variable in shape. The two forms in Type A are seemingly early growth-stage tubercles (Ørvig, 1958) since they exhibit marked ribbing; whether they belong to Pycnaspis or Astraspis is not known. They are significant since they occur in an undisputably marine sequence of limestones and, unlike most of the previously described occurrences, it is difficult to see how they could have been transported from a non-marine environment. Type B of the "dermal denticles" does not seem to have been described before and its origin is uncertain, although again it appears to be some form of dermal ornament.

Likewise, a vertebrate origin for the "plates" can only be inferred at this time. Only a small minority resemble those forms referred to Eriptychius, and these seem to have a different internal structure to the other kinds of "plates".

No previous record of either the "rods" or"frilled rods" is known to the writer. The "rods" have a lamellar internal structure resembling that of the "vertebrae" and possibly that of Type B of the "dermal denticles", hence it is suspected that these have a similar development, if not origin. Whether they are vertebrate remains, belong to the conodont-bearing animal, or to some other fossil group cannot be determined at present. Foss (1960) showed that the Neurodontiformes and _Astraspis_ scales have essentially the same chemical composition, thereby suggesting a vertebrate affinity for the former. If this is the case, (and the writer believes that there is probably only a small taxonomic difference between the Neurodontiformes and the Conodontiformes), these other _incertae sedis_ may belong to an allied organism. It is therefore suggested that their occurrence should be noted in further investigations. Detailed chemical and histologic studies may show other similarities between all these groups, thereby increasing the evidence for strong vertebrate affinities of conodonts.

The "eyes" and "caps" are relatively minor elements of the _incertae sedis_. The former, for which the writer knows of no previous reference, may be some form of dermal ornament, but this is purely speculative. The "caps" are more likely to be nepionic shells e.g. of an inarticulate brachiopod. Branson and Mehl (1933, Pl. 9, fig. 3) figured a "cap" as _Oistodus_ sp., stating that it approximated to the size and shape of the basal cavity of some of the larger oistodids. S.M. Bergström (1964, per. comm.) has also found them within the basal cavities of large drepanodids. The "eyes" are normally only in association with abundant _incertae sedis_, whilst the "caps" are usually absent and occur mainly in calcilutitic units with poor conodont faunas.

The _incertae sedis_ are sometimes more abundant than the conodont and because of their close association and, in most, a seemingly similar structure and composition, they are worthy of attention. Many may have been found, but ignored, during earlier conodont investigations. C.G. Winder (1964, per. comm.) has found several of these forms (e.g. "eyes", "caps", "dermal denticles" of Type B) in the Cobourg of S.W. Ontario; T.J.M.Schopf, T.T.Uyeno, and G. Webers (per. comm. 1964) have also encountered many of these during their respective conodont studies. The writer hopes that future authors will at least note the presence of such forms in order that their stratigraphic range and geographic extent may become known. In this way their true taxonomic position may be discovered, which may in turn provide an answer to the question of conodont affinities.

Biofacies analysis of *incertae sedis*

Biofacies study of the *incertae sedis* has not been so intensive as that for the conodonts. However, because of their possible relationship to conodonts certain aspects are worthy of consideration. Again, the textural and compositional analyses (Imbrie, 1955) have not been applied.

From conversations with other workers on Middle and Upper Ordovician conodonts who have found similar forms, the number of different types present in these samples does seem to represent a relatively diverse fauna.

General comments on other notable morphological features are given in this chapter, and the results of a frequency-distribution analysis is presented in figure 5. It shows that the *incertae sedis* are only common in about one quarter of the samples; in these, however, they are generally abundant, usually outnumbering the high conodont yields. They also exhibit the similar yield per pound differences from section-to-section that was found with the conodonts. Moreover, their maximum yields are from the samples bearing the high conodont populations.

Their individual distribution patterns show that the "caps" are a distinct group. The "rods" and "frilled rods" are certainly very similar, but the rest show a few anomalies that may suggest some individuality.

Ecologically, they are found in those habitats outlined above which were most favoured by the conodonts. They seem to be far more sensitive, however, as they are absent in many samples; further, they are virtually absent in the high energy lower Rockland shoals. If all or part of the *incertae sedis* are accepted as ostracoderm remains, it would indicate that the ostracoderms indeed favoured a normal marine environment as opposed to a fresh-water or brackish habitat.

"Vertebrae"

Plate 5, figures 1, 3

Polygnathus? simplex Hinde

? 1879. Hinde, pp. 367-368, Pl. 17, fig. 18.

Fragmentary plates

1935a. Stauffer, p. 157, Pl. 12, figs. 39, 40, 43, 44.

Description. Individuals are short elongate rods with flat expanded ends, resembling asymmetric vertebrae. In the central part, the cross-section is asymmetrically lachrymiform, the outer edge being rounded whilst the inner, fairly flat, sides meet as a sharp ridge, normally off-set asymmetrically relative to the rounded outer edge. At each end, the unit expands and is drawn out to a blunt point as an inward extension; hence the end view has a sublachrymiform shape. These end expansions are usually directed away from the outer edge at an obtuse angle and only infrequently form a right angle. The ends have a flat to slightly concave outer surface and a convex inner surface. The central part of the unit sometimes shows two or three faint furrows. When broken, the internal structure appears as concentric laminae. Rarely, two such units have been observed joined end-to-end, forming a straight line along their outer edges.

Remarks. These forms are abundant in several samples and are found throughout the formation and over the whole area sampled. Their shape is certainly like some types of vertebrae and are so referred to herein. Their alignment is also suggestive of a vertebral column, but figure 38 illustrates similar forms attached to a plate in a way that would not favour this inference. They are phosphatic and have the same colour, size, state of preservation, etc. as the conodont-elements. Their lamellar internal structure also suggests that a genetic relationship between the two may exist.

"Dermal denticles"

Plate 5, figure 6, 7

Lepodus minutus Branson and Mehl

1933. Branson and Mehl, p. 38, Pl. 1, figs. 33, 34.

Lepodus sp.

? 1936. Furnish Barragy, and Miller, p. 1334.

Form alpha (fish remains ?)

1936. Furnish, Barragy, and Miller, p. 1334, Pl. 2, figs. 4-6.

Pycnaspis splendens Ørvig

1958. Ørvig, pp. 6-16, Pl. 1, figs. 1-6; Pl. 2, figs. 1-3; text-fig. 2.

1962. Cygan, p. 62, Pl. 3, fig. 13; Pl. 4, figs. 7-10.

Ring-like objects, N. gen. n. sp. Cygan

1962. Cygan, p. 80, Pl. 2, fig. 3.

Description. a) Type A: Subcircular to lachrymiform, phosphatic forms with a smooth, slightly concave base and a convex upper surface. The latter bears ornamentation, generally in the form of ribs radiating either from the centre of circular types or from the pointed end of the lachrymiform varieties. They are slightly translucent and normally pale amber in colour.

b) Type B: Circular phosphatic discs of dark amber colour. The discs are composed of concentric lamellae, some of the central ones generally being absent; thus a hole commonly occupies the centre. In the more complete specimens, this hole is small and the outer surface is built up as the lower parts of a dome-like structure. This surface is particularly smooth and glossy, without prominent growth-lines.

Remarks. These two forms both seem to be dermal denticles of primitive ostracoderms. Both are found throughout the formation and over the whole area studied. They are never present in large numbers and Type B is several times more common than Type A.

"Plates"

Plate 5, figures 12, 13

Sculptured plates

1921. Bryant, pp. 11-12, Pl. 14, figs. 3-7; Pl. 15, figs. 1-5; Pl. 16, figs. 1-6.

Fragmentary plates

1935a. Stauffer, p. 157, Pl. 12, figs. 37, 38, 41, 42, 45-48.

Form beta (fish remains?)

1936. Furnish, Barragy, and Miller, Pl. 1, fig. 4; Pl. 2, fig. 2.

Remarks. A variety of fragmentary phosphatic "plates" are often present in the samples, particularly those with abundant "rods" and "frilled rods". The "plates" are thin, with a smooth under surface and an upper surface exhibiting a variety of ornamentation. The two most common types of ornamentation are an irregular set of polygonal ridges or parallel lines of small nodes. The upper surfaces are glossy and the under ones dull. No definite internal structures could be discerned in most, but a small minority have a spongy, bony texture similar to *Eriptychius* or the bone to which the *Pycnaspis splendens* Ørvig tubercles are attached (Ørvig, 1958).

"Rods"

Plate 5, figures 14, 15

Description. Long, subcylindrical, straight rods have a subcircular cross-section, invariably with a fine longitudinal projection, or keel, underneath. The internal structure shows concentric laminae around a centre close to, and clearly associated with, the fine projection. The outer surface is usually smooth, but fine longitudinal striations occur close to the projection where individual laminae did not extend completely over the earlier ones. In width, the rods approximate to large distacodid conodonts, but in length can reach several millimetres, and even then are invariably fragmentary.

Remarks. The "rods" are apparently composed of the same phosphatic material as conodonts and have a similar mode of lamellar growth. They occur at levels throughout the formation and over all the area sampled, being usually very abundant in a few samples and absent in the rest.

"Frilled rods"

Plate 5, figures 10, 11

Description. A long straight rod or thin narrow plate has a thin frilled canopy attached to the top. This is bilaterally symmetrical with two thin sheets of phosphatic material arching out from the rod, to reach down below the level of the rod. The sheets dip down where they are joined to the rod and hence, from above, form a broad central linear groove. They are frilled along the outer margin and the ribbing normally extends over all the sheet. The outer surface of the sheets are glossy, whereas the inside is dull.

Remarks. The "frilled rods" are very distinctive and some of the forms termed "rods" may have had frilled sheets removed. However, in general there seem to be two distinct types. The mode of growth of the thin sheets is not apparent from the present study. The "frilled rods" are of about the same size as the "rods", except that the rod portion of most "frilled rods" is blade-like or smaller than the typical "rods". They have the same stratigraphic distribution pattern as the "rods".

"Eyes"

Plate 5, figures 4, 5

Descriptions. These forms are made of fairly thin phosphatic material, are elliptical in outline, and are concavo-convex. The under concave surface is smooth and dull; the upper is glossy and covered with tiny spikes which are sharp-pointed, but relatively robust and of small relief. The colour is generally amber.

Remarks. The term "eyes" is used because of the likeness to certain trilobite eyes which have a host of facets (rather than points). Their true affinity is entirely unknown, although these too may be some form of dermal ornament.

"Caps"

Plate 5, figures 8, 9

Oistodus sp.

1933. Branson and Mehl, p. 109, Pl. 9, fig. 3.

Description. The "caps" are subconical, with a three sided base with rounded corners, the apex curving slightly towards one of the corners. The cone is formed of very thin phosphatic material and often has a small hole in the apex. Fine striations, seemingly concentric around the cone, can sometimes be perceived.

Remarks. These forms are represented by only a few specimens, but are distinctive and fall into the normal conodont size-range. They do not appear to be conodonts and their distribution does not seem to be linked to any other microfossil group recorded in the Chaumont. They have a pale buff colour and are opaque, thus quite different from the other incertae sedis.

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APPENDIX

DESCRIPTIONS OF STRATIGRAPHIC SECTIONS

Introduction

Each of the twenty-five sections used in this study are described below together with that at Watertown, N.Y. Table 9 lists those sections that have been referred to by previous authors. The following descriptions have been condensed as far as is practical and a list of the abbreviations used is included. The stratigraphic range, of each section where known is shown in figure 6, with the top of the Lowville taken as a datum plane; discussion of the stratigraphic position of individual sections is included with the descriptions. The occurrence of the few minor covered intervals in some sections is not shown in figure 6, but is given in the descriptions.

LOCALITY		REFERENCES			
Number	Abbreviation	Goudge (1938)	Hewitt (1960)	Hewitt (1964a)	Others
1	M	DC			Kay(1942),D
2	PV				Kay(1942),D
3	F				Kay(1942),D
5	Pa	DC			
7	E	DC			
9	DF			D	
11	FD	D	DC	I	
12	MR	DC			
13	HB	DC			
14	DM		DC	I	
16	OCS		DC	I	
21	S	DC			Wilson(1921),D; Kay(1937),D; Kay(1942),D.
24	Af	DC			
30	Wa				Cushing,Ruedemann *et al.* (1910), D; Young(1943),D.

D ____________ Direct reference

I ____________ Indirect reference

C ____________ Includes chemical analysis

TABLE 9: List of previous references to Chaumont localities.

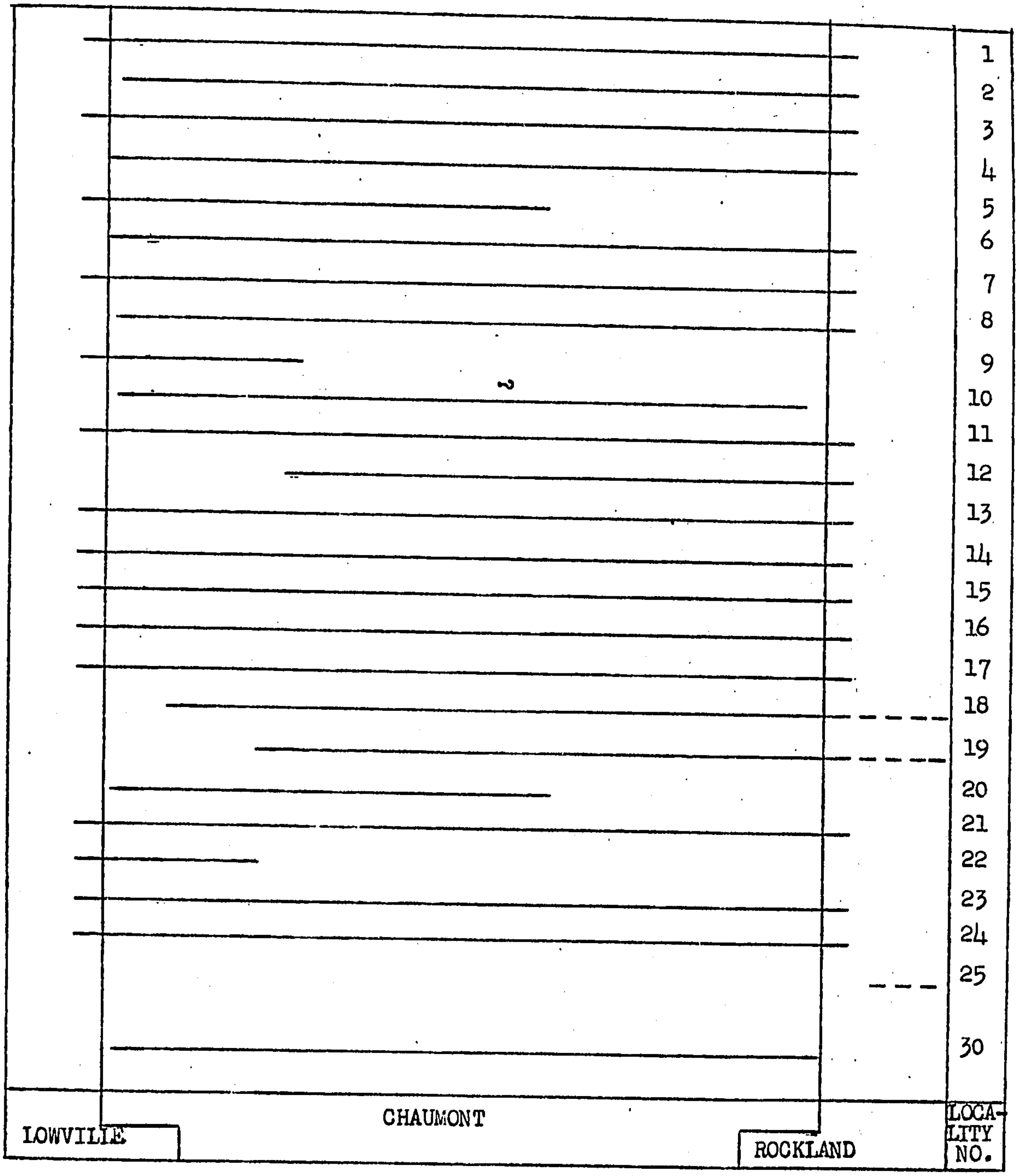


FIGURE 6

Approximate range of measured sections with respect to the Chaumont boundaries (diagrammatic).

Abbreviations used in the Appendix

c'lut.	calcilutite
c'silt.	calcisiltite
c'aren.	calcarenite
c'rud.	calcirudite
ls.	limestone
cryst.	crystalline
sh. lam.	shale laminae
sh. ptg.	shale parting
in.	inch
ft.	foot
yd.	yard
ml.	mile
no.	number
fine	finely
med.	medium
coarse	coarsely
av.	average
c.	about, approximately
esp.	especially
indet.	indeterminate
B.C.	biogenic content
T.	*Tetradium*
Hy.	Highway

Locality 1. MEATH HILL

Most of the Chaumont Succession is exposed in a disused quarry at Meath Hill, Westmeath township, Renfrew county. This lies about 1/2 ml. S.S.E. of Meath Station and 70 yds. N.E. of the junction between Hy. 17 and a dirt road. Higher units are exposed up the slope to the north along the dirt road and in a small disused quarry some 300yds. to the north of the main section. A detailed map of the area is given by Kay (1942, pp. 595, 613, Pl. 3A).

Unit No.	Sample No.	Unit Description	Unit Thickness	Cumulative Thickness
-4	M.-3 (upper half)	Light brownish grey, calcareous shales and siltstones; weathering light grey; subunits 3-6ins. thick, showing very thin bedding (c. 1/4in. separation) which is flat and even; compact when fresh; base not visible; top flat, even.	5 1	5 1
-3	M.-2	Med. light grey, med. cryst., rubbly argillaceous ls. (probably med. c'aren. with B.C. 20%-30%); weathering dirty while grey; no *Tetradium* seen, but surface obscure.	0 7-8	5 8
-2		Basal 4 ins.: as Unit -3. Next 10 ins.: light pinkish grey, fine cryst., c'silt.; weathering whitish "dove" colour; typical Lowville lithology; purer, less argillaceous than lower units; compact; top flat, even; some *T.* cf. *T. cellulosum.* Top 2-3 ins.: badly weathered, argillaceous ls.; weathering pale sandy colour.	1 4	7 0
-1	M.-1 (middle subunit)	Basal 3 ins.: light pink grey, fine to med. cryst., c'silt, and fine c'aren.: sometimes cross-laminated, top rippled. Next 5 ins.: light pinkish grey, fine cryst. with coarse spar flecks, c'silt; weathering whitish "dove" colour; compact; some *T.* cf. *T. cellulosum.* Top 5 ins.: weathered, argillaceous, fine cryst., fine to med. c'aren.; B.C. c. 20%-30%, variable; tending to form separate unit.	1 2	8 2

Base of Chaumont.

1	M.1 (base of middle subunit) M.2 (middle of upper subunit)	Massive unit, several subunits: Basal 8 ins.: Med. pink grey, med. cryst. (variable), coarse c'aren. (variable); alternation of fossil spreads with beds of lower B.C.; beds less than 1 ins.; basal contact sharp. Next 14ins.: med. greenish grey, fine to med. cryst. (generally fine cryst. with coarse spar flecks), med. c'aren.; B.C. c. 45%-50%; compact; orange patches on weathered surface; base somewhat irregular, top flat, very even. Upper 34ins.: med. green-pink grey, fine to med. cryst., coarse c'aren. (variable); B.C. c. 30%, rarely up to 60%, sorting fair; basal 6ins. more compact than rest which breaks into c.1 in. beds along irregular sh. lam.	4	8	4	8
2	M.3	Lower 12 ins.: med. light grey, very coarse cryst., fine c'rud.; B.C. over 60%, sorting good; fairly compact, sometimes breaking into 3-5 in. subunits. Upper 19 ins.: light grey, coarse cryst., coarse c'aren.; B.C. 45%-55%, sorting good, <u>Lyopora</u> (up to 6 ins. diameter) found throughout unit.	2	7	7	3
3	M. 4 (middle of second subunit) M. 5 (lower 9 ins. of fifth (subunit)	Basal 6 ins.: light brownish grey, calcareous shales; weathering light grey; very thinly bedded (c. ½ in. separation) flat, even; very similar to Unit -4. Next 17 ins.: argillaceous ls.: barren calcareous shales and argillaceous fine c'rud.; B.C. very variable; many sh. lam. Next 7 ins.: med. grey brown, fine cryst., c'silt.; B.C. generally less than 10%, mainly fairly complete macrofossils; very compact; top level. Next 9 ins.: med.grey, med.cryst., med.c'aren.; B.C. c. 35%, a large inverted head of <u>T. fibratum</u> at base; quite argillaceous; weathering white in places. Upper 24 ins: very compact, two divisions; lower 9ins.: med. grey, coarse cryst., fine c'rud.; B.C. variable c. 55%, sorting poor; top 15 ins.: med. grey brown, fine cryst., c'silt., B.C. c. 10%.	4	8	11	11
4		Shaly ls.; badly weathered to sandy colour.	0	2-3	12	2
5	M.6 (base)	Compact ledge: light brown to pink grey, fine to med. cryst., med. c'aren.(variable), B.C. variable, sorting very poor, several silicified shells, esp. in lower part.	1	8	13	10

6	M. 7	Med. light brown grey, fine to med. cryst., flaggy ls. (type and B.C. variable); beds 1-3 ins. thick separated by sh. ptgs.; beds very fossiliferous to barren.	3	4	18	2
		Units 5 and 6 only found at north end of quarry Top of exposure in quarry. Section continues in second smaller quarry on its western face.				
1	M. 8 (middle subunit)	Basal 8ins.: light grey pink, fine cryst., c'silt. (?); compact; sh.lam. at top. Next 10ins.: light grey brown, very coarsely cryst., coarse c'aren. to med. c'rud.; B.C. high, obscure. Upper 9ins.: as in middle subunit, separated by prominent sh. lam.	2	3	2	3
2	M. 9	Light brownish grey, med. cryst., med.(?) c'aren.; B.C. indet.; compact; sh. ptg. at base.	0	10	3	1
3	M.10 (middle)	Rather variable, in general: light brownish to pinkish grey, fine to med. cryst., med. c'aren.; B.C. av. 25%-30%, range 25%-45%, sorting generally poor; beds 2-4 ins. thick, separated by sh. lam.; upper part includes 2 in. beds of fine laminated coarse c'aren. spreads, cross-laminated at low angles.	3	8	6	9
4		Covered interval between quarry top and bed exposed ar roadside at top of scarp.	1	3	8	0
5	M. 11	Light brownish grey, coarse cryst., coarse c'aren. to fine c'rud.; B.C. 60%-70%, sorting good; weathering sandy colour.	0	6	8	6

Remarks. The upper Lowville units (8 ft. 2 ins. exposed) occur in the larger quarry and are overlain by 18 ft. 2 ins. of Chaumont. The smaller quarry exposes 6 ft. 9 ins. and lithologically appears to represent the uppermost Chaumont, with the highest unit exposed at the roadside almost certainly being Rockland. From field observations and the detailed geological map of Kay (1942, Pl. 3A), only about three feet of strata seem to be unexposed between the highest unit in the larger quarry and the lowest in the smaller. It should be noted that in Kay's figure the smaller one is labelled "Quarry" and the larger one is unlabelled, but marked by the abrupt arcuate contour pattern in the southern part of the map. The writer would thus place the Chaumont-Rockland boundary a few feet higher than Kay has apparently done. Kay (ibid., p. 595, table 4) gives a description of this Meath Hill section and the following differences found are noteworthy. Kay seems to omit either the writer's Unit -2 or -1 and places his Lowville-Chaumont contact a little lower. The highest two Chaumont units described by him were located between the two quarries, but are no longer exposed. Neither seems to occur within the small quarry, although they total 11 ft. 8 ins. and are followed by 8 ft. of unexposed units before typical Rockland was found by Kay. The situation is rather anomalous; thus Kay favours a total thickness of 35-40 ft. for the Chaumont, whereas the writer believes it to be within one or two feet of 30 ft. Kay (ibid., p. 597, table 5) lists the fauna from the smaller quarry, which he believes to be entirely Rockland.

A new (1963) roadcut was excavated some 500 yards north-west of the larger quarry. The writer has not been able to examine this in detail, but it appears to be thick-bedded calcarenites and may be of value in any later study.

Locality 2

PINE VALLEY

This outcrop is formed by a roadcut on the Eganville-Cobden road, Bromley township, Renfrew county, one mile S.S.W. of Pine Valley hamlet and 5 1/2 miles S.S.W. of Cobden. Two outcrops occur on the hill, a higher one exposes 10ft. or so of Rockland, about 15ft. below is covered and then the lower outcrop exposes some 20ft. of Chaumont and 3-4ft. of Rockland. The Chaumont was sectioned along the east side of the roadcut; the lower 5ft. or so are only partially exposed.

1	P.V.1	Med. light grey brown, med. to fine cryst., med. c'aren.; B.C. 20%-30% in lower part rising to 50% in upper; sh. lam. numerous, well developed.	0	11	0	11
		Covered.	0	5	1	4
2		Med. light brownish grey, med. cryst., med. c'aren.; B.C. c. 20%; some sh. lam., unit more compact than Unit 1; borings numerous as buff-coloured, coarse-textured tubes. Top of bed marks base of well exposed main outcrop.	1	1	2	5
3	P.V.2 (basal 12 ins.)	Thick, massive; subunits rather gradational: Basal 16 ins.: med. greenish grey, med. cryst., with coarser flecks of spar, coarse c'aren.; B.C. 25%-30%; buff to sandy weathering colour. Next 1-3 ins.: med.light grey, fine to med. cryst., fine to med. c'aren.; B.C. c. 20%,; laminated, broadly crossbedded (low angles: less than 5°). Next 20 ins.: med.light grey, fine to med. cryst., fine to med. c'aren.; B.C. low, 15%-25%; uniform, except 2 in. band at 11 in. level: fine c'rud., B.C. 55%, mainly indistinct coral and crinoid debris. Top 8 ins.: med. light grey, fine to med. cryst., med. c'aren. to fine c'rud.; B.C. 35%-55%, av. 45%, sorting poor; sh. lam. at base. Sh.ptg., ½ in., at base of unit.	3	7	6	0

4	P.V.3	Med. light greenish grey, very coarse cryst., fine c'rud.; B.C. 75%-85%, coquinal, sorting good; possibly broadly cross-bedded in places.	0	3	6	3
5		Med. light grey, fine cryst., med. c'aren.; B.C. c. 20%, some larger coral fragments (up to $\frac{1}{2}$ in.); top irregular.	0	4-5	6	8
6	P.V.4 (middle)	Massive; sh. ptg. at base; Unit 5 forming basal subunit in places. Fairly uniform: med. light grey, med. cryst., coarse c'aren.; B.C. 30%-40%; pockets and lenses of fine c'rud., B.C. up to 55%, coral fragments and solitary corals frequent; sh. lam. very well developed at 5-7 in. intervals.	2	10	9	6
7		Med. brownish grey, med.cryst., med. to esp. coarse c'aren.; B.C. variable, 20% -35%; several sh. lam. giving rubbly appearance.	0	3	9	9
8		Compact; crossbedded; two subunits: Basal 7-8 ins.: med. grey, med. cryst., med. to esp. coarse c'aren; crossbedded spreads (angles: 5°-15°). Top 2-3 ins.: med. grey, coarse to very coarse cryst., fine c'rud., rarely med. c'rud.. Distinct but welded break between subunits; B.C. high in both, sorting good in spreads of lower subunit, brachiopods, corals, and crinoid ossicles most frequent.	0	10	10	7
9	P.V.5 (basal 3 ins.) P.V.6 (middle at *T. fibratum* level)	Thin bedded ls. and thin sh. ptgs. (up to 3/4 in.). Ls. fairly uniform: med. grey to med. brown grey, med. to very coarse cryst. (av. coarse cryst.), med. c'aren. to fine c'rud. (mainly fine c'rud); beds 1-4 ins. thick separated by sh. lam. or sh. ptgs., basal third least shaly. In middle, small bioherm of *T. fibratum*, 6-8 ft. long, up to 1 ft. high.	3	9	14	4
10		Med. light grey, slightly pinkish, very fine cryst., c'lut.; B.C. c. 25%, *T. cellulosum* common; sh. ptg. at base, top flat and level, firmly welded to Unit 11; weathering "dove"-grey; typical Lowville-type unit.	0	3	14	7
11	P.V.7 (basal 6 ins.)	Med. grey, med. cryst., with some spar flecks, coarse c'aren.; B.C. c. 40%-50%; weathering darker than Unit 10;	0	8-9	15	4

		very compact, no sh. lam.; some black chert nodules: 3-6 ins. long, 2-3 ins. high, variable shape and size, spaced about 3ft. apart, not always linear to bedding, probably entirely secondary.		
12		Shale, breaking into thin brown films; weathering dirty ash colour; base flat, top very irregular with shales basal protrusions of Unit 13.	c.0 2	15 6
13		Light greyish pink to light pink, very fine cryst.; c'lut.; B.C. very low; compact, a few sh. lam. having stylolitic relief.	1 10	17 4
14	P.V.8 (basal 4 ins.)	Med. light pink grey, fine cryst., fine c'aren.; B.C. 25%-30%, sorting poor; a more fossiliferous variety of Unit 13, more sh. lam. breaking up unit; top flat.	0 11	18 3
15	P.V.9 (middle)	Med. dark grey, coarse to very coarse cryst., fine c'rud.; B.C. c. 60%-70%; weathers med. blue grey, distinctive; bedding planes covered with bryozoans, brachiopods, crinoid ossicles; some sh. ptgs. weathering blue ash white; beds 4-8 ins. thick.	1 3	19 6
16		Med. grey, fine cryst., c'silt.; dense with "ribbed" subconchoidal fracture; B.C. very low, macrofossils rare; uniform, with a few vertical contraction stringers; beds 3-8 ins. thick, variable, a few of shaly ls.; a few large heads of <u>T. fibratum</u>; some beds show slump features with balling-up of micro-laminae (rarely seen).	1 1	20 7
17	P.V.10 (9 ins. above base)	Med. grey, coarse cryst., coarse c'aren. (fine c'rud. in places); B.C. c. 55%-70%, variable; compact, 4-8 ins. beds separated by sh. lam. and ptgs., but rarely found within the beds; beds fairly uniform, rather irregular surfaces; some intraclasts, mainly restricted to top 15 ins. (1-1½ ins. long, tabular, rounded corners); heads of <u>T. fibratum</u> common; top 10 in. bed cut by deep grooves (4-15 ins. wide, 0-7 ins. deep, steep and undercut sides), 25-30 parallel grooves visible, found on both sides of the road (see Barnes, 1964; MS for details).	2 6 to 3 6	23 7

18	P.V.11 (middle)	Med. grey (brownish in places), fine cryst., c'silt.; B.C. very low, macrofossils very rare; dense, compact, with vertical spar contraction stringers; beds 1-3 ins. thick, separated by sh. ptgs., microbedding rarely seen; lowest beds fill grooves of Unit 17, pinching out over spurs.	1	3	24	10
19	P.V.12 (middle)	Med. grey to med. dark grey, fine to esp. coarse cryst., fine to coarse c'aren.; B.C. up to 60%; beds 2-4 ins. thick, slightly variable, showing trough cross-lamination (angles c. $15^\circ \pm 10^\circ$); interbeds of ls. type found in Unit 18.	0	10	25	8
20	P.V.13 (middle)	Med. dark grey to med. grey, coarse to very coarse cryst., fine to med. c'rud.; B.C. c. 65%-75%; beds 2-5 ins. thick, some intraclasts near base (up to $1\frac{1}{2}$ ins. long, tabular, rounded corners).	0	9	26	5
		Top of Chaumont.				
21		Med. light grey, fine cryst., med. c'aren. (variable); B.C. 35%-45%; rubbly ls. with shale.	0	2	26	7
22	P.V.14 (base)	Massive, compact; med. grey (rather greenish), coarse to very coarse cryst. (med. cryst. at top); lower 2/3: coarse c'aren. to fine c'rud.; B.C. 60%-70%; top 1/3: med. to coarse c'aren.; B.C. 35%-40%; sh. lam. only concentrated in top 6 ins., becoming rubbly; <u>Stromatocerium</u> (?) at base.	2	4	28	11

<u>Remarks</u>. Kay (1942, pp. 597, 616) briefly refers to this locality, but presents few details. The lower contact with the Lowville is not definitely seen, but since the scarp may be produced, at least in part, by recession of the more flaggy Lowville, the contact may be only a few feet below the lowest unit exposed. Thus some 26 ft. of Chaumont is fully exposed and the upper contact is drawn at the base of the massive, coarse textured calcirudites.

Locality 3

FOURTH CHUTE

Probably the whole of the Chaumont succession is exposed in a falls section on the Bonnechere River at Fourth Chute, 6 miles east of Eganville, in Bromley township, Renfrew county. The Bonnechere Caves are developed on the northern side of the falls. The section was described and sampled along the southern side, beginning 50 ft. downstream from the base of the falls opposite the high northern cliff and extending up to the beds at the top of the falls which are clearly Rockland.

-2	F.-2	Med. light brown, slightly pinkish, fine cryst., c'silt.; B.C. indeterminate, probably low; unit fairly compact, more rubbly towards top.	1	2	1	2
-1	F.-1	In general: med. light brownish-grey, fine cryst., c'silt. and c'aren.; argillaceous and rubbly in basal 18 ins. middle 20 ins. developed as compact beds up to 4 ins. thick, finely laminated, often broadly cross-laminated, top and bottom of beds irregular, "wavy" with many sh. lam. and sh. ptgs. (up to ½ in.); upper 10 ins. return to rubbly, argillaceous, "nodular" ls.	4	0	5	2
		Base of Chaumont (?).				
1	F. 1 (basal 2 ins.)	3 Subunits: Basal 12 ins.: Med. brown-grey, fine cryst., fine to med. c'aren.; B.C. variable but c. 20%-25%. Middle 4-5 ins.: med. brown-grey, fine cryst., c'silt. to fine c'aren.; B.C. low, less than 15%; sh. lam. at top and bottom.	2	8	2	8
	F. 2	Upper 14 ins.: med. brown-grey, fine to med. cryst., med. c'aren.; B.C. c. 35%. Whole unit is massive, compact, with abundant borings seen as buff, sandy channels.				
2	F. 3 (top 6 ins.)	Med. brown-grey, med. cryst., fine c'aren.; B.C. c. 25%-30%; compact, lower 3 ins. more argillaceous with more sh. lam. than rest; basal sh. ptg.; borings common. Units 1 and 2 form a massive section giving rise to lowest falls.	1	10	4	5

3		Med. pink-grey, fine cryst., c'silt,; B.C. indeterminate, certainly very low; rubbly, breaking into irregular 1-2 ins. beds.	1	3	5	8
4	F. 4	Med. grey, slightly brownish, med. cryst., med. c'aren.; B.C. c. 20%-25%; compact with few borings; basal 2-3 ins. rather shaly; top surface irregular.	1	0	6	8
5	F. 5 (at lft. 8 ins.)	Thick, fairly uniform unit of loose shaly ls., generally: med. grey (with brownish tint), fine cryst., c'silt. to fine c'rud.; B.C. variable, up to 60%; individual beds up to 4 ins., difficult to trace laterally; <u>T. fibratum</u> common.	4	0	10	8
6		Unit divides into 3 beds: Lowest two; total 9-10 ins.: med. grey, fine cryst., ls.; ls. type and B.C. indeterminate - probably c'silt., B.C. low. Top 3 ins.: light pink-grey, coarse cryst., med. c'rud.; B.C. 55%-60%. Divisions along sh. ptgs.; few sh. lam. and borings.	1	1	11	9
7	F. 6 (top 4 ins.)	Light pink-grey, coarse cryst., med. c'rud.; B.C. 55%-60%; compact, broadly cross-bedded, shells convex upwards; very few sh. lam., sh. ptgs. at top and bottom.	0	11	12	8
8		Med. grey-brown, very fine cryst., c'silt.; B.C. low, less than 20%; some sh. lam., quite compact.	0	11	13	7
9		Med. pink-grey, very fine cryst., c'silt. to c'lut.; B.C. very low; sh. lam. common.	0	8	14	3
10	F. 7 (top)	Light pink, fine cryst.with coarse spar flecks, med. c'rud.; B.C. 25%-30%, large shells in c'silt. matrix; compact.	1	0	15	3
11		Light pinkish-grey, fine cryst., fine c'aren.; B.C. c. 20%; compact; base flat, top irregular.	1	0	16	3
12		Med. Pink-grey, fine cryst., c'silt to fine c'aren.; B.C. indet.; top and bottom flat.	0	3	16	6
13		Med. brown-grey, fine cryst., c'silt to c'lut.; B.C. very low; rubbly.	c.0	6	17	0
14		Med. grey pink, fine cryst., med. c'aren.; B.C. c. 25%; compact; no sh. lam.	0	10	17	10

15	F. 8 (top)	Med. brown-grey, fine cryst., fine to med. c'aren.; B.C. variable, T. cellulosum possibly present; flaggy, shaly, unit beds thicker (4 ins.) and more compact towards top.	1	4	19	2
		Med. pink-grey, fine cryst., fine to med. c'aren.; unit breaking into beds 1-3 ins. thick, laminated; top rippled: amplitude 1¼ ins., wavelength 8 ins., symmetrical, axial direction E/W.	1	7	20	9
17	F. 9	Med. brownish-grey, fine cryst., c'silt. and fine c'aren.; B.C. low, less than 20%; beds platy, laminations rare; beds lens, varying in thickness: ¼-4 ins; compact, little shale; rippled surfaces common.	2	8	23	5
18		Med. grey, med. to coarse cryst., med. to coarse c'aren.; B.C. moderate; beds thin (2-5 ins.), marked trough cross-lamination; flat surfaces, even thicknesses.	1	6	24	11
		Top of Chaumont.				
19	F. 10 (basal 2 ins.)	Med. light brown-grey, med. cryst., coarse c'aren; B.C. high, fossils commonly silicified, Lyopora common; unit massive, compact.	3	0	27	11

Remarks. Kay (1942, p. 595, 597, 616) records some of the details of this section. He states that the lower contact of the Chaumont is below water-level whilst the upper is located at the top of the falls, with 37 feet exposed. The lower contact with the Lowville may, in fact, be a few feet below the lowest units exposed or it may lie at the level indicated below, if so then the lithologic change would be atypical. The upper contact with the Rockland is quite obvious and not in dispute. The writer measured an exposed thickness of about 25 ft. of Chaumont exposed at the falls, Kay, as noted, records 37 ft. which may be a misprint for 27 ft. or may, as at Meath Hill, represent a genuinely different measurement; it is difficult to see, however, how an additional 10 ft. of strata could be exposed at the falls. The Chaumont-Rockland boundary can still be observed at the Bonnechere Lime Co. Ltd. quarry, ½ ml. westwards along the road to Eganville, where some 50 ft. of overlying Rockland is quarried. The higher Rockland units are also exposed in the Shane quarry, $\frac{1}{4}$ ml. to the S.W. of Fourth Chute where only some 10 ft. or so are seen.

Locality 4 CLAY BANK

A fairly complete Chaumont outcrop is located 1½ miles E.S.E. of Clay Bank, McNab township, Renfrew county. A superior dirt road turns through 90° at the scarp front, but a poorer dirt road ascends the scarp and continues to the S.E., the lowest exposures are located on the lower road but most are found on the south side of the road up the scarp.

1	C.B.1 (top 2 ins.)	Small outcrop on south side of lower road; 40 yds. east of junction with higher road: med. grey, fine cryst., c'silt. to esp. fine c'aren.; B.C. low to very low; compact, many sh. lam.	1	3	1	3
		Covered.	c.3	0	4	3
2		Top 2 ins. of unit exposed: med. grey med. cryst., med. c'aren.; B.C. 20%-25%; "mottled" when sh. lam. intersect surface.	0	2	4	5
3	C.B.2 (middle)	Outcrop by wire fence, south side of hill road: med. grey, fine cryst., c'silt. to fine c'aren., a few patches of med. c'aren.; B.C. low, c. 10%-15%; many sh. lam.; characteristic of lower Chaumont at Ottawa.	1	6	5	11
		Covered.	c.6	0	11	11
4	C.B.3 (top 3 ins.)	Only top 9 ins. exposed: med. grey to med. light grey, coarse cryst., coarse c'aren. to fine c'rud.; B.C. c. 45%, sorting moderate; unit breaking along sh. lam. or ptgs. into irregular flaggy beds c. ½-1 in. thick.	0	9	12	8
5		Med. grey, fine to esp. med. cryst., fine to med. c'aren,; B.C. 15%; compact, sh. lam. common.	0	11	13	7
6	C.B.4 (middle)	Med. brownish grey, med. to coarse cryst., coarse c'aren,; B.C. 45%-50%, sorting moderate to good; rather flaggy, breaking along sh. lam.	0	6	14	1
		Covered.	c.2	0	16	1
7		Only top 6 ins. exposed, probably forms most of covered interval below: med. grey, fine to esp. med. cryst., med. c'aren.;	0	6	16	7

		B.C. c. 20%; compact, sh. lam. common.				
		Covered	c.0	9	17	4
8	C.B.5 (middle)	Med. grey, very fine cryst., c'lut.; B.C. less than 10%; beds c. ½-1 ins. thick, some surfaces have spreads of fine c'rud. debris, not seen within beds; borings and thin, vertical contraction stringers present - some of the latter may be incipient mud cracks.	0	9	18	1
9		Med. grey, brownish, med. to coarse cryst., coarse c'aren.; B.C. 30%-40%; breaking into thin flaggy beds.	c.0	10	18	11
10	C.B.6 (9 ins. from top)	Med. grey, fine cryst., med. to esp. coarse c'aren.; B.C. 20%-25%; sh. lam. and borings common; typical of Chaumont at Ottawa.	1	9	20	8
		Covered	c.5	0	25	8
11	C.B.7 (9 ins. from top)	Med. light brown grey to light grey, very fine cryst., c'lut.; B.C. less than 10%; flaggy, thinbedded recessive, white weathering unit; light grey beds may be somewhat siliceous.	2	6	28	2
12		Med. grey, esp. fine to very fine cryst., med. c'aren.; B.C. c. 10%; compact; resembles lowest Chaumont units at Ottawa.	1	6	29	8
13		Exactly as Unit 12.	1	9	31	5
14	C.B.8 (3 ins. from base)	Med. grey, fine to very fine cryst., c'silt.; B.C. variable, low, some surfaces show spreads of fossil debris; borings (up to ½ in. diameter) in relief at base of some beds, beds flaggy, ½-1 in. thick, separated by sh. lam. and ptgs.	1	6	32	11
15	C.B.9 (top 6 ins.)	Med. grey, very fine cryst., c'lut.;dense, compact; upper 5-7 ins. shows several sub-units; slightly irregular surfaces with two 1 in. zones with *T. cellulosum* common (B.C. 20%-30% in these units).	0	10	33	9
16	C.B.10 (top 6 ins.)	Med. grey, fine to med. cryst., coarse c'aren., med. c'aren. in basal 10 ins.; B.C. 30%-40%, in basal 10 ins.: 10%-15%; sh. lam. and borings common; resembles upper Chaumont at Ottawa.	2	4	36	1

		B.C. c. 20%; compact, sh. lam. common.				
		Covered	c.0	9	17	4
8	C.B.5 (middle)	Med. grey, very fine cryst., c'lut.; B.C. less than 10%; beds c. ½-1 ins. thick, some surfaces have spreads of fine c'rud. debris, not seen within beds; borings and thin, vertical contraction stringers present - some of the latter may be incipient mud cracks.	0	9	18	1
9		Med. grey, brownish, med. to coarse cryst., coarse c'aren.; B.C. 30%-40%; breaking into thin flaggy beds.	c.0	10	18	11
10	C.B.6 (9 ins. from top)	Med. grey, fine cryst., med. to esp. coarse c'aren.; B.C. 20%-25%; sh. lam. and borings common; typical of Chaumont at Ottawa.	1	9	20	8
		Covered	c.5	0	25	8
11	C.B.7 (9 ins. from top)	Med. light brown grey to light grey, very fine cryst., c'lut.; B.C. less than 10%; flaggy, thinbedded recessive, white weathering unit; light grey beds may be somewhat siliceous.	2	6	28	2
12		Med. grey, esp. fine to very fine cryst., med. c'aren.; B.C. c. 10%; compact; resembles lowest Chaumont units at Ottawa.	1	6	29	8
13		Exactly as Unit 12.	1	9	31	5
14	C.B.8 (3 ins. from base)	Med. grey, fine to very fine cryst., c'silt.; B.C. variable, low, some surfaces show spreads of fossil debris; borings (up to ½ in. diameter) in relief at base of some beds, beds flaggy, ½-1 in. thick, separated by sh. lam. and ptgs.	1	6	32	11
15	C.B.9 (top 6 ins.)	Med. grey, very fine cryst., c'lut.;dense, compact; upper 5-7 ins. shows several sub-units: slightly irregular surfaces with two 1 in. zones with <u>T. cellulosum</u> common (B.C. 20%-30% in these units).	0	10	33	9
16	C.B.10 (top 6 ins.)	Med. grey, fine to med. cryst., coarse c'aren., med. c'aren. in basal 10 ins.; B.C. 30%-40%, in basal 10 ins.: 10%-15%; sh. lam. and borings common; resembles upper Chaumont at Ottawa.	2	4	36	1

17		Med. grey, coarse cryst., coarse c'aren.; B.C. c. 50%; many macrofossils; unit breaking into thin (over 1 in.) beds along sh. lam.; weathers sandy colour.	1	0	37	1
18	C.B.11 (top 3 ins.)	Med. grey, med. cryst., coarse c'aren.; B.C. 40%-45%; compact, not so flaggy as Unit 17, sh. lam. frequent.	1	2	38	3
		Covered	c.1	0	39	3
19	C.B.12 (6 ins. above base)	Med. grey, med. cryst., coarse c'aren to med. c'rud.; B.C. 35%-40%, sorting poor, many macrofossils, all grades of damage; compact, sh. lam. frequent.	1	3	40	6
		Top of Chaumont				
20	C.B.13	Med. light grey, coarse cryst. to esp. very coarse cryst., fine to med. c'rud.; B.C. c. 65% with <u>T. fibratum</u>, <u>Stromatocerium</u> (?), orthocone cephalopods, brachiopods, gastropods.; intraclasts frequent; allochems clearly transported.	0	6	41	0

<u>Remarks</u>. The base of the Chaumont almost certainly lies below the lowest unit recorded. The Lowville-Chaumont boundary may well have been temporarily exposed on the N.E./S.W. dirt road, 1½ miles S.S.E. of Clay Bank. Here, besides scattered outcrops, were found loose blocks, excavated for a telephone pole, replete with <u>T. cellulosum</u> (sample C.B.14). The Chaumont at the main section thus seems to exceed 40 ft. in thickness. Unit 20 is certainly lowest Rockland and a fairly thick succession of similar units is poorly exposed to the S.E. in another scarp to the south of the upper road.

17		Med. grey, coarse cryst., coarse c'aren.; B.C. c. 50%; many macrofossils; unit breaking into thin (over 1 in.) beds along sh. lam.; weathers sandy colour.	1	0	37	1
18	C.B.11 (top 3 ins.)	Med. grey, med. cryst., coarse c'aren.; B.C. 40%-45%; compact, not so flaggy as Unit 17, sh. lam. frequent.	1	2	38	3
		Covered	c.1	0	39	3
19	C.B.12 (6 ins. above base)	Med. grey, med. cryst., coarse c'aren to med. c'rud.; B.C. 35%-40%, sorting poor, many macrofossils, all grades of damage; compact, sh. lam. frequent.	1	3	40	6
		Top of Chaumont				
20	C.B.13	Med. light grey, coarse cryst. to esp. very coarse cryst., fine to med. c'rud.; B.C. c. 65% with <u>T. fibratum</u>, <u>Stromatocerium</u> (?), orthocone cephalopods, brachiopods, gastropods.; intraclasts frequent; allochems clearly transported.	0	6	41	0

<u>Remarks</u>. The base of the Chaumont almost certainly lies below the lowest unit recorded. The Lowville-Chaumont boundary may well have been temporarily exposed on the N.E./S.W. dirt road, 1½ miles S.S.E. of Clay Bank. Here, besides scattered outcrops, were found loose blocks, excavated for a telephone pole, replete with <u>T. cellulosum</u> (sample C.B.14). The Chaumont at the main section thus seems to exceed 40 ft. in thickness. Unit 20 is certainly lowest Rockland and a fairly thick succession of similar units is poorly exposed to the S.E. in another scarp to the south of the upper road.

Locality 5 PAKENHAM QUARRY

The lower Chaumont is exposed in a disused quarry east of the Mississippi River, to the N. of the road leading up the hill out of Pakenham to Antrim, Pakenham township, Lanark county. Most of the units were described from the western end, except for the highest units which only outcrop at the eastern end of the quarry.

-1	Pa.-1 (top bed)	Med. grey to med. dark grey, fine cryst., c'silt. (and some c'lut.); B.C. less than 10%; beds compact, ½-2 ins. thick with undulating surfaces; even and cross-stratified laminated beds fairly common; thin vertical spar contraction stringers common; top of unit, undulating, possibly a disconformity with a 1-3 in. erosion amplitude; ¼ in. sh. ptg. at top in places.	1	5	1	5
		Base of Chaumont				
1	Pa.1 (lowest 9 ins.) Pa.2 (at 40-48 ins.level) Pa.3 (top 4 ins.)	Very massive, compact; several subunits; Lowest 9 ins.: med. grey to med. light grey, coarse cryst., coarse c'aren. to esp. fine c'rud.; B.C. c. 50%; intraclasts of c'silt. or c'lut. (normally less than ½ in. diameter, rounded); crossbedded or cross-laminated throughout: lower 5 ins.: unidirectional, upper 4 ins.: small scale trough variety, separated by distinct surface; lower surface of unit irregular; upper surface fused, but rather irregular and erosional, amplitude 1-2 ins. Next 3 ins.: med. light-grey, very coarse cryst., med. c'rud.; B.C.70% (coquinal), probably not persistant laterally. Next 18 ins.: med. grey, fine cryst., med. to coarse c'aren.; B.C. c. 30%; sh. lam. every 1 in. or so; possible borings; top surface erosional, 2-3 ins. amplitude. Next 3-6 ins.: med. light grey, extremely coarse cryst., med. to coarse c'rud.; B.C. c. 75% (coquinal), brachiopods, algae (*Soleropora* - type), intraclasts (up to 1 in. long, well rounded); upper surface gradational over ½-1 in. Next 6 ins.: med. grey, med. cryst., coarse c'aren to fine c'rud.; B.C. 25%-30%, sorting poor; top surface irregular, not definitely	6	2	6	2

		erosional; weathers paler than adjacent subunits. Next 6-8 ins.: med. light grey, med. to coarse cryst., med. to coarse c'aren.; B.C. 30%-35% sorting moderate to poor; basal 2 ins. sometimes evenly laminated; possible borings; top quite irregular. Next 0-1 in.: med. light grey, very coarse to extremely coarse cryst.; med. c'rud.; B.C. 75% (coquinal), mainly rounded algae (<u>Soleropora</u> - type). Top 33 ins.: in general: med. grey, med. cryst., coarse c'aren.; B.C. 30%-35%; many sh. lam. fairly uniform with 0-3 in. beds of med. light grey, coarse to very coarse cryst., fine to med. c'rud.; B.C. 70% (coquinal), mainly rolled algae; often capping irregular surfaces.				
2	Pa.4 (9 ins. above base)	Massive, compact, fairly uniform: med. grey, med. cryst., esp. coarse c'aren. to fine c'rud.; B.C. 35%-40% sorting poor to moderate; sh. lam. numerous; ¼ in. sh. ptg. at base.	2	8	8	10
3	Pa.5 (top 6 ins.)	Massive, compact: med. grey, med. cryst.; coarse c'aren to fine c'rud.; B.C. 35%-40%, sorting poor; borings common in weathered surfaces.	2	9	11	7
4	Pa.6 (top 3 ins.)	Med. grey, med. cryst., coarse c'aren. to fine c'rud.; B.C. 35%-40%; very similar to Units 2 and 3, but borings more abundant; basal 3 ins. have low-angle cross-lamination at one place.	2	2	13	9

<u>Remarks</u>. Some 15 ft. of thin-bedded, rather shaly, calcisiltites and calcilutites, bearing some chert, (no <u>Tetradium</u> seen) lie beneath the Chaumont. These Lowville units were sampled as follows:

Pa.-2	3 ft. 0 ins.	down from contact	3 ins. bed
Pa.-3	6 ft. 0 ins.	" " "	4½ ins. "
Pa.-4	8 ft. 9 ins.	" " "	2½-3 ins. "
Pa.-5	12 ft. 6 ins.	" " "	5 ins. "

Base of Chaumont possibly a disconformity; section reveals nearly 14 ft. of Chaumont to the top of the quarry.

Locality 6 BUCKHAM BAY

Discontinuous scarp exposures below an abandoned farm on south side of dirt road, 2 miles E. of MacLaren's Warf, to the east side of a small valley with creek and opposite the mail-box of John Roy. Outcrop described below the buildings on either side of the road into the old farm. These lie in Torbolton township, Carleton county.

1a	B.B.1a (middle)	Light-grey, med. cryst., med(?) c'aren.; B.C. indet.; compact, dense, no sh. lam. or borings; breaking into 3-4 beds; lichen covered.	1	0	1	0
1b		Light grey, med. cryst., med.(?) c'aren.; B.C. indet.; few borings; top surface very flat and even; unit weathering white like Unit2.	0	3	1	3
1c		Light grey, coarse cryst., coarse c'aren.; B.C. c. 45%; laminated, possibly low-angle cross-laminated; top rather irregular.	0	3	1	6
1d	B.B.1 (middle)	Med. grey, fine to esp. med. cryst., coarse c'aren.; B.C. 30%-35%, sorting poor; compact, few sh. lam. and borings present; fossil debris in pockets in places.	1	1	2	7
2	B.B.2	Med. light brown-grey, very fine cryst., c'lut.; B.C. 20%-25% (10%-15% in middle 2-3 ins.), mainly <u>T. cellulosum.</u> (av. 15%-20% total B.C.), most abundant in top and bottom parts, also gastropods, both helical - and plani-spiral types; few borings; weathers white.	0	8	3	3
3		Med. grey, fine cryst., med. c'aren.; B.C. 25%-30%, sorting moderate to poor, some local dispersed concentrations, macro-fossils mainly gastropods; compact, sh. lam. and small borings present.	1	4	4	7
		Covered	0	4-6	5	0
4	B.B.3	Med. grey, esp. fine to med. cryst., coarse c'aren.; B.C. 10%-15%, sorting poor, patchy distribution; compact, quite dense, some sh. lam. borings rare to absent.	0	9	5	9

5	B.B.4 (top 6 ins.)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. 30%-35%, macrofossils very common e.g. Stromatocerium, Lyopora, cup corals, brachiopods, crinoid ossicles, some dolomitized, debris well distributed, sorting moderate, macrofossils all sizes, corals in growth position; compact, sh. lam. abundant, giving "blocky" effect on weathering, large borings abundant with coarse to very coarse texture.	3	0	8	9
		Covered	1	2	8	11
6		Med. grey to med. light grey, esp. med. to coarse cryst., coarse c'aren.; B.C. 15%-20%, debris content low, macrofossils (normally damaged) quite common; compact, sh. lam. and large borings common to abundant.	1	7	10	6
		Covered	0	6	11	0
7	B.B.5 (6 ins. from base)	Med. grey, fine cryst with coarse spar flecks, med. c'aren.; B.C. 20%-25%; fairly compact, borings rare, sh. lam. common, prominent at 9 ins. level.	c.3	0	14	0
8		Med. light brownish grey, very fine to esp. fine cryst., c'lut. to esp. c'silt.; B.C. less than 10%, macrofossils very rare; top fairly regular; compact but with N/S joints or fractures breaking up unit.	0	6	14	6
9	B.B.6 (6 ins. from base) B.B.7 (15 ins. from top)	Compact, quite massive, varying slightly vertically but in general: med. light to esp. med. light grey, esp. fine to med. cryst., esp. fine - med. c'aren.; B.C. low c. 10%-20%, few macrofossils - one Lyopora and one Stromatocerium(?) in growth position near top; a few local laminated thin subunits; basal 12 ins. usually breaks into 3 or 4 platy lumps of very badly weathered, yellow-brown chert; upper 22 ins., more regular with sh. lam. and some borings.	3	10	18	4
10	B.B.8	Med. light grey, med. cryst., fine to med. c'aren.; B.C. moderate, sorting moderate to good, compact, even-laminated; top and base flat, possible sh. ptg. at base.	0	3	18	7
11		Med. brownish grey, med. cryst., fine c'aren.; B.C. c. 15%-20%; quite compact, fairly uniform, sh. lam. present, four of which are prominent.	1	6	20	1

12	B.B.9 (top 3 ins.)	Light grey, slightly tan coloured, fine to med. cryst., med. c'aren.; B.C. low, unit laminated, with prominent laminae at $\frac{1}{4}$-$\frac{1}{2}$ in. intervals, less laminated in top 2 ins.; no sh. lam. or borings; $\frac{1}{4}$-$\frac{1}{2}$ in. sh. ptg. at base	0	9	20	10
13		Med. light grey, med. cryst., fine to med. c'aren.; B.C. low, less than 20%; laminated; $\frac{1}{4}$ in. sh. ptg. at base.	0	4	21	2
14		Med. grey, fine cryst., fine c'aren.; B.C. low, less than 15%; unit breaking into 4-6 beds along sh. lam.; no borings; top 3 ins. often laminated.	1	1	22	3
15	B.B.10 (basal 6 ins.)	3 subunits: Basal 6 ins.: med. light grey, med. cryst., med.(?) c'aren.; B.C. indet.; compact, laminated, with 2-3 ins. lumps of badly weathered chert. Middle 4 ins.: med. grey, fine cryst., fine c'aren.; B.C. low; breaking into 3 thin beds along irregular sh. ptgs. Top 9 ins.: med. light grey, med. cryst., med.(?) c'aren.; B.C. indet.; laminated throughout with 2-3 ins. lumps of badly weathered chert.	1	7	23	10
16		Med. grey, slightly brownish, coarse cryst., coarse (?) c'aren.; B.C. indet.; compact, no sh. lam. or borings; laminated with trough crossbedding with trough widths av. 3 ins.; $\frac{1}{2}$ in. sh. ptg. at base.	0	6	24	4
17	B.B.11	Unit exactly as Unit 16; $\frac{1}{4}$ in. sh. lam. at base.	0	7	24	11
		Top of Chaumont				
18		Med. light brown grey, coarse to very coarse cryst., fine c'rud; B.C. c. 25%-30%; middle 4 ins. includes many intraclasts (av. $\frac{1}{4}$-$\frac{1}{2}$ in. diameter, rounded rather than platy), many macrofossils: <u>Stromatocerium</u>(?), cup corals etc. - all clearly transported. Top and basal 4 ins.: few intraclasts; 3-4 sh. lam. present, laminated.	1	0	25	11
19		Med. light grey, coarse to esp. very coarse cryst., fine to med. c'rud.; B.C. indet., probably over 25%; compact, laminated with trough cross-laminated sets; $\frac{1}{4}$ in. sh. ptg. at base.	0	7	26	6

20	B.B.12	Med. light to light grey, coarse cryst., fine c'rud.; B.C. high, probably over 50%; cross-laminated, dips up to 25°, unit lenses out laterally over 15 yds.; unit penetrated by a few, $\frac{1}{4}$ in. diameter, vertical borings.	0	6	27	0
21		Light grey, brownish, very coarse cryst., esp. med. to coarse c'rud.; B.C. coquinal in lower 6 ins. (predominantly crinoid ossicles) decreasing vertically to c. 40%; fairly compact with sh. lam., no borings.	1	4	28	4
22	B.B.13 (top 3 ins.)	Med. light grey, coarse to very coarse cryst., fine to med. c'rud. with a few beds of coarse c'aren.; B.C. variable: 30%-70% av. 55%-65%; sh. lam. present - often between subunits; subunit boundaries both sharp and gradational.	c.2	6	30	10

Remarks. The Lowville does not appear to be exposed; Unit 2 with abundant T. cellulosum seems more likely to be interbedded with Chaumont lithologies than to represent the highest Lowville unit. This boundary most probably lies only a few feet below the lowest unit exposed. The upper boundary, with the Rockland, is located at the change to coarse textured calcirudites, thus some 25 ft. of Chaumont are almost completely exposed. Above Unit 20, the Rockland calcirudites persist for another 8 ft. or so and then gradually give way to thick-bedded calcarenites that are characteristic of the formation at Ottawa and the type section.

Both Wilson (1921, p. 28) and Kay (1942, Table 3) have described a discontinuous section of Lowville, Chaumont and Rockland units at MacLaren's Warf, 2 miles to the east. The writer examined this section and found it very incomplete and unsatisfactory for this study; this Buckham Bay locality is far superior and higher Rockland units are also exposed further to the east.

Locality 7 ELM

A discontinuous section exists close to the paved road running N.W. from Elm and lying about 3¼ miles E.S.E. of Kinburn, Fitzroy township, Carleton county. There are three main localities: the highest beds outcrop on the north side of the road by a 40 ft. scarp; patchy outcrops exist between here and a small shallow, disused quarry some 80-100 yds. to the east in a field, a repeated section, caused by faulting, of the lower part of the quarry occurs a further 150 yds. to the east, beyond the gully and near the fence on the knoll. The section at the latter location is given first:

-1a	E.-1a (middle)	Med. brown grey, very fine cryst., c'lut.; B.C. 45%-60% (predominantly T. cellulosum); base not exposed, weathering rubbly.	2	6	2	6
		Base of Chaumont				
1a	E.1a (middle)	Massive, lowest 8 ins. not visible: med. brown grey, very fine cryst. at base to fine cryst. at top; fine to med. c'aren.; B.C. 10%, poorly sorted but evenly distributed; sh. lam. and borings present; Unit 2 may be part of Unit 1 elsewhere.	2	1	2	1
2a		Med. grey, slightly brownish, fine cryst., med. c'aren.; B.C. less than 10%; sh. lam. abundant; laminated spread belonging to overlying unit occasionally seen.	0	9	2	10

Continuing the section in the shallow quarry and then across to the roadcut:

-2	E.-1 (9 ins. from top)	Med. brown grey, very fine cryst., c'lut.; B.C. 15%-35% in lower part, 45%-55% in upper - predominantly T. cellulosum; fairly compact with several persistent sh. lam.	2	9	2	9
-1		Light pink grey, very fine cryst., med. c'aren.; B.C. c. 45%, some complete brachiopods and cephalopods; ¼ in. sh. ptg. at base.	0	5	3	2
		Base of Chaumont				

1	E.1 (between 3-9 in. level) E.2 (between 26-32 in. level)	Massive, several subunits: Lowest 3 ins.: med. green grey, very fine cryst., med. c'aren.; B.C. 20%-25%, some *T. cellulosum*; $\frac{1}{4}$ in. sh. ptg. at base; Lowville lithology but fused to subunit above. Next 23 ins.: med. grey, fine cryst., fine c'aren., B.C. c. 15%-20%, sorting moderate, distribution quite even, some local concentrations; borings frequent; sh. lam. very common to abundant. Next 6-7 ins.: med. grey to med. dark grey, fine cryst., fine c'aren.; B.C. c. 45%, sh. lam. and borings frequent; base often indistinct, top sharp and distinct. Top 7 ins.: med. grey, fine cryst., c'silt.; B.C. very low, c. 5%-10% with layers of coarse c'aren. in lowest $\frac{1}{2}$ in. or so; borings common; sh. lam. very common, one persistent at 5 ins. from top. Compact, massive unit, also outcroping in the roadcut; very minor dolomitization in places; $\frac{1}{4}$ in. sh. ptg. at base.	3	2	3	2
2	E.3 (middle)	Poorly exposed, seen at top of small quarry: med. grey, fine to med. cryst., fine to med. c'aren.; B.C. 20%-30%; many sh. lam.; rubbly, rather argillaceous; top possibly not seen.	1	1	4	3
3		Exposed in field, near gate leading to paved road: med. dark grey, fine cryst., med. c'aren.; B.C. 10%-15%; no good sh. lam.; compact, dense; borings common, giving mottled effect; base not exposed but unit not exceeding 9 ins. thick.	0	7	4	10
		Covered	c.2	6	7	4
4	E.4	6 yds. N.W. of path in from gate: med. grey, esp. med. to coarse cryst., med. c'aren.; B.C. indet., probably 25%-30%; very compact, laminated; no borings or sh. lam.; only 6 ins. exposed, could be thicker.	0	6	7	10
		Covered: between 4-8$\frac{1}{2}$ ft.	av.6	0	13	10
5	E.5 (top 4 ins.)	Basal unit of roadcut section: Med. dark grey, fine cryst., med. c'aren.; B.C. 15%-20%; dense, compact, beds 2-4 ins. some separated by sh. lam.; poorly exposed.	1	0	14	10

6	E.6 (between 24-26 ins. above base)	3 subunits: Lowest 14 ins.: med. pink grey, very fine cryst., fine c'rud.; B.C. 35%-40%, c'lut. matrix with many fairly complete fossils: esp. brachiopods, crinoid ossicles, pelecypods, large heads (up to 12" radius) T. fibratum, and occasional stromatoporoids (up to 7 ins. diameter); several persistent sh. lam. Next 12 ins.: med. grey, brownish, very fine cryst., c'lut.; B.C. c. 30%-40%, almost entirely T. Cellulosum, some of which are probably partly transported; some sh. lam. Top 8 ins.: med. grey pink, very fine cryst., c'lut.; B.C. 15%-20%, mainly T. cellulosum some minor fossil debris of fine c'aren. grade; borings and sh. lam. common; weathers palest of three subunits. Subunits separated by ¼ in. sh. ptgs.	2	9	17	7
7		Med. dark grey, fine cryst., c'silt. to fine c'aren.; B.C. variable, 5%-25% with some complete fossils, a few T. cellulosum in topmost c'silt. subunit, sorting very poor; beds 2-4 ins., quite compact, separated by sh. lam.; ¼ in. sh. ptg. at base.	1	0	18	7
8		Brown earthy shale and thin, laterally impersistent, argillaceous ls. beds.	0	3	18	10
9	E.7 (top 5 ins.)	Compact, two subunits: Lowest 3 ins.: med. brown grey, fine cryst., c'silt.; B.C. c. 15%, mainly T. cellulosum; top marked by irregular sh. lam. Upper 16 ins.: med. grey, med. cryst., med. to coarse c'aren.; B.C. 30%-35%, up to 50% in a 1-2 ins. laminated spread, 1/3 rd. up; lower 1/3 rd. mottled - probably extensive borings.	1	7	20	5
10		Med. light grey, fine cryst., fine c'aren.; B.C. 35%-50%; sh. lam. common, every ½ in. av.; weathers on rather rusty orange.	0	4	20	9
11		Med. light grey, fine cryst, fine c'aren.; B.C. fairly low, probably 20%-25%; fairly compact, no persistent sh. lam.; ¼ in. sh. ptg. at base.	0	7	21	4
12		Med. grey, fine cryst., med. c'aren.; B.C. 15%-20%, compact, no sh. lam.; ½ in. sh. ptg. at base.	0	5	21	9
13		Shale and shaly ls.	0	1	21	10

14		3 small subunits, separated by $\frac{1}{4}$ in. sh. lam.: Basal 2-3 ins.: med. grey, med. cryst., coarse c'aren.; B.C. probably 25%-35%; few sh. lam. Middle 2 ins.: med. grey, fine cryst., fine c'aren.; B.C. low c. 10%-20%; compact, no sh. lam. Top 1 in.: as in lowest subunit.	0	6	22	4
15	E.8.	Med. grey, fine cryst., fine c'aren.; B.C. obscure, c. 10%-25%; compact, horizontally laminated; base: level, even: top: irregular with abundant crinoid ossicles.	0	4-5	22	9
16	E.9 (11 ins. from top in non-laminated subunit)	Massive, compact; alternating fine c'aren. (dominant) and fine c'aren. spreads: med. grey, fine cryst., esp. fine to med. c'aren.; B.C. obscure, c. 15%-25%, crinoid ossicles most abundant macrofossil; laminated spreads of fine c'aren. with low angle cross-laminations in places, spreads at following levels: 13 ins. (1 in. thick); 16 ins. (4-5 ins. thick) 33 ins. (4 ins. thick), often abutting against irregular sh. lam.	3	2	25	11
		Top of Chaumont(?)				
17	E.10	Med. light grey, coarse cryst., fine c'rud.; B.C. 60%-70%, <u>Lyopora</u> common, often complete, crinoid ossicles plentiful; intraclasts (pale c'lut. type) common.	6	9	26	6
		Covered	c.3	0	29	6
18		In field, N.W. of road, 20 yds. from Unit 17. Massive, compact units: med. grey, fine to med. cryst., med. c'aren. (variable); B.C. rather obscure, c. 35%-45%, up to 45%-55% in coarse c'aren., <u>Lyopora</u>, <u>Stromatocerium</u>(?), cup corals; some zones of fossilferous c'aren.; one 2 in. laminated spread $\frac{1}{2}$ way; sh. lam. common.	2	9	32	3

<u>Remarks</u>. The contact with the Lowville is exposed as are discontinuous lower units including oölitic beds. The top of the Chaumont may well lie at the top of Unit 16, but Units 17 and 18 are not the characteristic calcirudites of the lower Rockland in more westerly exposures. As the latter units are not seen to the east, this locality probably is transitional in this respect. Placing Unit 17 as Rockland, the Chaumont here is therefore about 26 ft. in thickness.

Locality 8 BURNT LANDS

This outcrop of Chaumont strata occurs in an extensive roadcut on a hill on Hy. 44, 8 miles S.W. of the junction of Hys. 17 and 44, near Carp, in Huntley township, Carleton county. The units outcrop on both sides of the road, and the N. side was chosen for sampling. A quarry, exposing almost exactly the same strata, occurs just to the south of the road at this locality.

1	B.L.1 (top 6 ins.)	Med. dark grey, fine cryst., med. c'aren.; B.C. c. 25%; rather obscure buff-coloured borings; only top 12 ins. visible.	1	0	1	0
2		Med. dark grey, slightly brownish, fine cryst., c'silt. to med. c'aren.; B.C. 5%-25%, more sublithographic than Unit 1; a dirty "dove" weathering colour.	0	10	1	10
3		Brownish, weathered, very shaly ls.	0	1-2	2	0
4	B.L.2 (top 4 ins.)	Med. dark grey to dark grey, fine cryst.; coarse c'aren.; B.C. 10%, sorting very poor; compact, dense; sh. lam. common, well developed; top irregular, 2 ins. amplitude and top 6 ins. are "burrowed" - filled with coarse cryst., coarse c'aren., B.C. 35%.	0	12-14	3	1
5		Grey fissile shale	0	2	3	3
6	B.L.3 (18 ins. from base)	Thick unit; thinbedded uneven ls: med. dark grey, fine cryst., fine c'aren.(?); B.C. indet. probably less than 10%; dense, siliceous(?); even- and cross-laminated beds; beds generally 1-5 ins. thick, very variable individually, often separated by sh. ptgs. up to ½ in.; three zones of slight slumping interbedded with laterally continuous units (see Fig. 20); unit quite uniform throughout.	0	53-57	8	10
7	B.L.4a (quartzose ls.)	Med. light grey, med. cryst., fairly dense, quartzose ls. (med. c'aren.(?); B.C. very low, less than 10%, if not below 5%; beds uniform, 2-6 ins. thick, occasionally evenly laminated; sh. lam. separate subunits, thin and even. At E. end of roadcut, unit	1	8	10	6

	B.L.4b (12 ins. above base in channel, at same level as B.L.4a)	cut by channel: 15 ft. wide, 16-20 ins. deep, sides steep (70°-90°) angular; filled with very coarse cryst., fine c'rud.; B.C. high c. 60%-65%, heads of *Lyopora*, not in growth position; tabular boulder (up to 2 ft. across, 6 ins. deep) of the quartzose ls., esp. near base of channel; channel seen on both sides of roadcut, almost due N./S. orientation of axis. (see Fig. 21).				
8	B.L.5 (18 ins. from top, in coarse textured subunit)	Lowest 18 ins.: alternations of two ls. types in equal proportions overall: a) med. grey to med. light grey, med. cryst., med. to coarse c'aren.; B.C. less than 10% even-and-cross-laminated beds (dips up to 15°). b) med. grey, very coarse cryst., fine to med. c'rud.; B.C. very high, indet.; weathers darker. Upper 26 ins.: two ls. types: a) as in b) above, comprises only 35% of this subunit. b) Med. grey, med. cryst., med. c'aren.; B.C. 20%-30%; compact, weathered surface pitted with holes 1/8 in. diameter. Beds 5-10 ins., even bedding of subunits; sh. lam. infrequent but well developed; bed above channel filling in Unit 7 not quite the same lithology.	3	7	14	1
9	B.L.6 (12 ins. from base) B.L.7 (15 ins. from top)	2 major subunits Lower 25-30 ins.: In general: med. dark grey, fine cryst., med. to coarse c'aren.; B.C. 10%-15%, sorting poor; thinbedded, beds 3-4 ins. thick; top even; basal 2 ins. dark, shaly, forming distinctive marker line; lower part (esp. lowest 9 ins.) have abundant stromatoporoids (3-15 ins. diameter), occurring every 6 ins. or so, rarer upwards. (see Fig. 27); a few *Lyopora* present also; stromatoporoids mainly concentric subspherical forms, a few columnar types; beds both even and irregular, separated by sh. lam. Upper 30-35 ins.: med. dark grey to dark grey, fine cryst., c'silt. to med. c'aren.; B.C. normally c. 10%, up to c. 25% in places; compact, beds up to 12 ins. thick; pitted weathered surface; borings frequent; sh. ptgs. between beds; very similar to Unit 1. Stewarts Quarry (Locality 21).	5	0	19	1

10	B.L.8 (12 ins. from base)	In general: med. dark grey, fine cryst., fine to med. c'aren.; B.C. 25%-35%; beds compact, 9-15 ins. thick, sh. lam. every ½-1½ ins. One or two shallow (3 ft. wide, 6 ins. deep) troughs of laminated c'aren.; mainly in upper 12 ins., merging with Unit 11.	3	11	23	0
11	B.L.9 (middle)	Med. grey, med. to coarse cryst., med. to coarse c'aren.; B.C. variable; beds 4-6 ins., some dense, siliceous(?), others more fossiliferous; even-and cross-lamination common; subunits even, level, separated by sh. lam.	1	6	24	6
12	B.L.10 (12 ins. from base)	Med. dark grey, fine cryst., fine to med. c'aren.; B.C. 25%-30%; sh. lam. numerous; occasional even laminated subunits.	1	8	26	2
		Top of Chaumont (?)				
13	B.L.11 (10 ins. from top)	Med. dark grey, med. cryst., coarse c'aren. to fine c'rud.; B.C. variable c. 35%-65%; lower half weathering darker, mottled, very fossiliferous (esp. *Solenopora*-type algae); unit flaggy, beds 2-4 ins. thick; sh.lam. numerous, between beds.	1	10	28	0

Remarks. The units seem lithologically more allied to the three most westerly localities. The Lowville is not exposed although the writer feels it can only be a few feet beneath Unit 1. The highest unit is probably Rockland, again of transitional lithology between the westerly calcirudites and eastern calcarenites; as such the Chaumont is at least 26 ft. in thickness at this locality.

Locality 9 DIBBLEE'S QUARRY, FALLOWFIELD

This quarry is located just N.E. of the junction of two paved main roads, 1 2/3 miles E. of Fallowfield, Nepean township, Carleton county, and operated by the Dibblee Construction Co. The extensive quarry is some 45 ft. deep and cut primarily into Lowville strata. Lower Chaumont units are found in the N.W. corner and the dip slope further to the N.W., the section was described at this point.

-2	D.F.-2 (6 ins. from base)	Med. dark grey brown, very fine cryst., c'lut.; B.C. 25%-35%, mainly <u>T. cellulosum</u>, only abundant at this level; massive, compact, esp. top 8 ins., thicker than Lowville strata below which av. 4-10 ins.; sh. lam. numerous, every 1-3 ins., producing rubbly nature or weathering.	3	5	3	5
-1		Very flaggy, shaly unit, varied lithologies: some uniform, barren, c'lut., others c'rud. spreads of high B.C., mainly gastropods and <u>T. cellulosum</u> (transported); some intraclasts; beds up to 3 ins., usually ½-1 in., separated by sh. ptgs. and some sh. lam.; beds persistent laterally; unit allied to Unit-2; capped by sh. ptg.	0	8-9	4	1
		Base of Chaumont				
1	D.F.1 (basal 6 ins.) D.F.2 (9 ins. from top)	Massive, compact, several subunits: Basal 11 ins.: med. brownish grey, fine to med. cryst., med. c'aren.; B.C. 20%-30%; sh. lam. common; borings common; base flat, even; top rippled (wavelength 15-18 ins., amplitude 2-3 ins.), crests composed of more coarser bioclastic debris. Next 10 ins.: med. dark brownish grey, fine cryst., fine to med. c'aren.; B.C. 15%-20%; few sh. lam., but more borings; coarser near base, esp. in troughs of ripples; top also rippled to same degree, but without coarse crests. Next 2-4 ins.: med. grey, slightly brownish, med. cryst., med. c'aren.; B.C. 30%-40%; few sh. lam, but a prominent one at half way; top rippled as before, sh. lam. tend to parallel upper wavey surface.	2	6	2	6

		Next 9 ins.; med. dark brown grey, fine cryst., fine to med. c'aren.; B.C. 20%-25%; few sh. lam. borings numerous; coarser in troughs of ripples below; top shaly, flaggy, merging into Unit 2.				
2	D.F.3 (middle)	Med. grey, fine to esp. med. cryst., med. to coarse c'aren.; B.C. 35%-40%; unit often flaggy with 1-2 ins. discontinuous beds; sh. lam. and borings common; upper half mottled with a soft, buff or sandy coloured ls. in patches up to 3 ins.; <u>Lyopora</u> present rarely.	2	1	4	7
3	D.F.4 (upper half)	Med. grey, fine to med. cryst., med to coarse c'aren.; B.C. 30%-40%; sh. lam. and borings common; more compact than Unit 2; fairly common, perhaps slightly coarser in lower parts: small (up to 4 ins.) lumps of black chert, rare; top surface mottled.	1	10	6	5

<u>Remarks</u>. There are excellent exposures of Lowville and the contact with the Chaumont is well exposed, the <u>Tetradium</u> unit being well developed. Above this some 6½ ft. of Chaumont are exposed, being closely comparable to Ottawa sections but showing well-developed mottled surfaces.

Locality 10 PERRY ROAD

These outcrops are located on and to the east of Perry Road, between the intersections of Pink Road and Cooke Road, Hull township, Gatineau county, some 4 miles N.N.W. of Aylmer, Quebec. About 2/3rd mile north of the intersection of Perry and Pink Roads, a roadcut is produced in a small north-facing scarp. The discontinuous section was traced, beginning near to and at the roadcut, around the scarp to the east as far as a N./S. wood-and-wire fence, the highest units being on the top of the scarp between the fence and road.

1	P.1 (base)	Light grey, brownish, med. cryst., fine c'aren.; B.C. indet., low; beds ½-1 in. thick, flaggy, recessive, many discontinuous laterally; large (over 6 ft.) crossbedded channel present; weathering dirty white or dirty green-grey.	2	9	2	9
2	P.2 (base)	Med. light grey, med. cryst., dense ls. (probably fine or esp. med. c'aren.). B.C. obscure, very low; unit flaggy at base, more compact upwards.	1	11	4	8
3	P.3	Light brownish grey, coarse to extremely coarse cryst., c'rud.; B.C. obscure, very high; top and bottom surfaces rather irregular. ½ in. sh. ptg. at base.	0	5-6	5	2
4		Med. brownish grey, med. to coarse cryst., fine to med. c'aren.; B.C. low, probably less than 20%; beds ½-2 ins. thick, more thinly bedded in upper half; top probably rippled in places.	3	5	8	7
5		Med. light brownish grey, coarse cryst., med. c'rud.; B.C. c. 75%; compact, crossbedded, lensing out laterally base rather irregular.	0-10		not included	
6		Med. grey, sometimes brownish, fine to coarse cryst., (mainly med. to coarse), med. c'aren.; some fine c'rud. spreads; B.C. variable 25% - c. 65%, av. 30%-35%; beds 2-4 ins. thick, separated by sh. lam.	1	6	10	1

7	P.4	Med. brownish grey, with orange flecks, coarse cryst., fine c'rud.; B.C. c. 60%; details obscure, probably crossbedded; compact in lower part; only lower 15 ins. visible.	1	3	11	4
		Section above described from roadcut; following details from area some 100 yds. E. of roadcut; Unit 7 can be traced to this new locality.				
		Covered (probably rest of Unit 8).	1	3	12	7
8		Light brown grey, fine cryst., fine to med. c'aren.; B.C. low, less than 25%; fairly compact.	1	8	14	3
		Covered, 12-15 ins.	1	2	15	5
10	P.5	Med. light grey, fine cryst., fine c'aren.; B.C. low, less than 20%, some macrofossils esp. gastropods; rather compact and dense, c. 12 ins. exposed.	c.1	0	16	5
		Covered.	1	0	17	5
11		Med. light grey, fine cryst., c'silt.; B.C. indet., some gastropods, cephalopods; compact, c. 9 ins. exposed.	0	9	18	2
		Covered c. 2½-3 ft.	2	9	20	11
12		Surface exposure of: med. light grey, fine to med. cryst., med. c'aren.; B.C. low, c. 15%-25%: sh. lam. producing rubbly surface.	0	6	21	5
		Covered.	1	0	22	5
13	P.6	Light pinkish grey, med. to coarse cryst., med. c'aren.; B.C. indet., some large macrofossils.	1	0	23	5
		Covered. c. 3 ft.	3	0	26	5
14	P.7	Some 70 yds. to S.S.W. are surface exposures: med. grey, very fine cryst., c'lut.; B.C. c. 25%, mainly *T. cellulosum*.	0	3	26	8

Remarks. This is not a very satisfactory section: neither boundary can be located and much of the section is covered. The 11 ft. of almost completely exposed strata at the base is variable in lithology and resembles some of the more westerly localities. The upper 15 ft. is rather discontinuous, but the exposed units are typical of the Chaumont at Ottawa. The presence of the *Tetradium* unit at the top of the section is difficult to account for. The writer feels that the section is almost certainly entirely Chaumont, but that it is atypical in many respects. Loose heads of *Lyopora* and *T. fibratum* were found in the trees on the scarp, although they were not observed *in situ*.

Locality 11 FRAZER DUNTILE QUARRY

The Frazer Duntile Quarry is located at the south end of Clyde Road near the Queensway, Ottawa. The section of the Chaumont was described and measured from the extreme N.E. quarry face, by the main gravel tips.

-1	F.D.-1	Med. brown grey, very fine cryst., c'lut.; B.C. moderate, predominantly T. cellulosum; top 3-4 ins. forms separate bed in places; weathering light grey; top surface, level, sharp.	1	11	1	11
		Base of Chaumont.				
1	F.D.1 (basal 5 ins.)	Massive, compact; several subunits: Basal 5 ins.: med. grey, fine cryst., c'silt.; B.C. low; top and bottom: flat, even; weathers darker than adjacent beds. Next 6-7 ins.: med. grey, fine cryst., c'silt.; B.C. low; greater "hackly" fracture than subunit below; top surface, irregular, borings filled with ls. from subunit above; sh. lam. frequent Next 4-6 ins.: as in subunit below; slight difference in weathering colour; top surface smooth, but rippled (14 ins. wavelength; 2 ins. amplitude). Top 12-14 ins.: med. grey, fine cryst., fine c'aren.; B.C. c. 25%, includes crinoid ossicles, trilobite fragments; sh. lam. more numerous in upper 9-12 ins. basal 0-2 ins. of subunit or conglomeratic (rounded intraclasts less than ½ in. long); another thin intraclast zone higher up dies out laterally.	2	4	2	4
2		Med. brown-grey, very fine cryst., c'lut.; B.C. low, occasional macrofossils, mainly brachiopods; subunits separated by irregular surfaces (mainly "corrosion" zones); burrows abundant; top bored, irregular.	0	9-10	3	2
3	F.D.2 (at 10 in. level)	Massive, compact unit; several subunits: Basal 4-8 ins.: Med. grey, brownish, fine to med. cryst., fine c'aren.; B.C. fairly low, mainly brachiopods; argillaceous, many sh. lam.; weathers rubbly; base conglomeratic in parts; top broadly rippled Next 6-10 ins.: med. grey, fine to med. cryst.,	2	1	5	3

		c'aren.; B.C. variable, some limited spreads, some large macrofossils; compact; top rather irregular. Next 6-8 ins.: as in lowest subunit; few intraclasts; some concentrations of fossil debris at base. Next 6-8 ins.: as in second subunit; top flat, but irregular, holes filled with fossil debris.				
4		Shale or shaly ls., badly weathered, a dirty ash colour; unfossiliferous.	0	1-2	5	4
5	F.D.3 (top subunit)	Massive, compact; several subunits, slightly varying laterally: Basal 7 ins.: med. grey, brownish, fine to med. cryst., fine c'aren.; B.C. fairly low; argillaceous, many sh. lam. Next 10 ins.: med. grey, fine to med. cryst., c'silt. to fine c'aren.; B.C. fairly low; mottled, grey and buff weathering colour in 50:50 ratio. Next 5-6 ins.: med. grey, med. cryst., c'aren.; weathering light greenish grey, slightly mottled, grey and pale grey, weathering ls.; slightly conglomeratic at base. Next 3 ins.: concentration of irregular sh. lam. in the ls. Next 14-15 ins.: med. grey, fine to med. cryst., fine c'aren.; B.C. moderate, evenly distributed; frequent sh. lam.	3	4	8	8
6		Med. grey, slightly brownish, med. cryst., med. c'aren. to fine c'aren. at top; B.C. fairly high; ½ in. sh. ptg. at base.	0	9	9	5
7		Shale	0	1	9	6
8		Med. grey, fine cryst., c'aren.; B.C. indet.; badly weathered.	0	1-2	9	8
9		Shale	0	1	9	9
10	F.D.4	Med. grey, fine cryst., c'aren.; B.C. high, debris uniformly distributed; rather argillaceous, no definite sh. lam.	9-10		10	6
11		Shale, very fissile	0	2	10	8
12		Fissile shale with argillaceous c'silt.; badly weathered.	0	7	11	3
13	F.D.5 (at 4 in. level)	Med. grey, fine cryst., fine c'aren.; 2 in. bed, 1 in. from top, is coquinal with level top and bottom; top ½-1 in.	0	6	11	9

		is a fine cryst. c'silt. The 2 in. bed (med. grey, coarse cryst., coarse c'aren.) was sampled.				
14		Med. grey, med. cryst., c'silt., c'aren. in top $\frac{3}{4}$ in; top and bottom level; $\frac{1}{2}$ in. sh. ptg. at base.	0	4	12	1
15	F.D.6 (middle subunit)	Compact; subunits separated by sh. lam.: Lower 9 ins.: med. grey, fine cryst., c'silt.; argillaceous Next 6-7 ins.: med. grey, med. to coarse cryst., coarse c'aren.; B.C. high. Top 6-7 ins.: med. grey, fine cryst., c'aren.; B.C. moderate. $\frac{1}{2}$ in. sh. ptg. at base.	1	9	13	10
16		Med. grey, fine cryst., c'silt., for 9 ins. above base; top 4-5 ins.: med. brown-grey, med. cryst., coarse c'aren.; B.C. high.	1	2	15	0
17		Mainly: med. grey, fine cryst., c'silt. Unit includes 2 subunits in lower half of: med. brown grey, med. to coarse cryst., coarse c'aren.; B.C. high; base irregular, top gradational into host ls.; $\frac{1}{4}$ in. sh. ptg. at base.	0	11	15	11
18	F.D.7	Med. brown grey, fine cryst. with coarse spar flecks, c'aren.; B.C. moderate, uniformly distributed; rather argillaceous in top 4-5 ins. $\frac{1}{4}$ in. sh. ptg. at base.	0	11	16	10
19		Med. grey, fine cryst., ls.; lowest 5 ins.: c'silt., middle 5 ins.: fine c'aren.; top 4 ins.: very argillaceous, badly weathered; subunits separated by sh. lam.; $\frac{1}{4}$ in. sh. ptg. at base.	1	2	18	0
20		Med. brown grey, fine cryst. with coarse spar flecks, coarse c'aren.; B.C. moderate, evenly distributed; 3-4 sh. lam. present; $\frac{1}{4}$ in. sh. ptg. at base.	1	4	19	4
21	F.D.8 (at top)	Med. grey, fine to med. cryst., c'aren.; B.C. variable; few sh. lam.	1	6	20	10

Remarks: In the quarry, upper Pamelia, Lowville and Chaumont strata are well exposed. The top of the Lowville is characterized by the unit replete with *Tetradium*. There is no indication that Rockland units are present, but since these two formations are lithologically very similar at Ottawa, this cannot be proved. The writer, however, regards, on the slender evidence available, all of these higher beds to be Chaumont.

Locality 12 FOSTERS QUARRY, MERRIVALE ROAD

This shallow disused quarry is located about $\frac{1}{4}$ mile east of Locality 11, off Merrivale Road, at the end of Mayview Road, Ottawa, and bounded by Morisset Ave. on the north. Opposite the quarry entrance on Morisset Ave., a road leads down the scarp and a few lower units are exposed in the gardens, including the <u>Tetradium</u> unit at the base of the scarp. The lowest 12 units were described from an excavation in the middle of the quarry (being filled in, August 1962), the remainder from the southern corner of the main quarry wall.

1	M.R.1	Med. grey, fine cryst., c'silt.; argillaceous; coarse c'aren., high B.C. between 7 in. and 10 in. level; badly weathered.	1	2	1	2
2		Med. grey, esp. fine to med. cryst., fine c'aren.; B.C. c. 25%, fairly well distributed; sh. lam. only common in upper 9 ins; $\frac{1}{4}$ in. sh. ptg. at base.	1	8	2	10
3		Med. grey, fine cryst., c'aren.; B.C. c. 60% esp. brachiopods; some sh. lam.	0	7-8	3	6
4		Shale	0	1-2	3	8
5	M.R.2	Med. grey, fine to med. cryst., c'aren.; B.C. c. 45%, well distributed; more argillaceous towards top and bottom; bottom surface irregular.	0	7-8	4	4
6		Shale	0	1-2	4	6
7		2 subunits separated by sh. lam.: Lower 5 ins.: med. grey, fine cryst., c'aren.; B.C. c. 50% Upper 3 ins.: med. grey, med. to coarse cryst., c'aren.; B.C. c. 60%.	0	8	5	2
8		Med. grey, fine to med. cryst., c'aren.; B.C. c. 50%, well distributed, some large brachiopods and cup corals; few sh. lam.; $\frac{1}{2}$-$\frac{3}{4}$ in. sh. ptg. at base.	0	11-13	6	3
9		Shale with thin variable ls. subunits, $\frac{1}{2}$-$2\frac{1}{2}$ in. thick.	0	3-4	6	7

10	M.R.3	Lower 2 ins.: Med. grey, fine cryst., c'aren. Middle $2\frac{1}{2}$ ins.: Light brown grey, med. to coarse cryst., c'aren.; B.C. high. Top $\frac{1}{2}$ in.: light brown grey, fine cryst., c'silt.	0	5	7	0
11		Med. grey, fine cryst., fine c'aren.; bottom few inches covered; top irregular.	1	3	8	3
12		Med. grey, med. cryst., c'aren.; B.C. 30%-45%, well distributed; sh. lam. present.	1	1	9	4
13		Lower 6-8 ins.: med. grey, fine cryst., bands of coarse and fine c'aren. Upper 10-12 ins.: med. grey, fine cryst., c'aren.; B.C. 35%-45%. Includes 2 or 3 prominent sh. lam.; $\frac{1}{4}$ in. sh. ptg. at base.	1	6	10	10
14	M.R.4	Med. brown grey, fine to med. cryst., bands of fine to coarse c'aren.; some sh. lam.	0	7	11	5
15		Lower 4 ins.: med. grey, med. to fine cryst., coarse c'aren.; sh. ptg. at top. Middle 5-6 ins.: med. grey, fine cryst., c'silt.; argillaceous; sh. lam. abundant. Top 2-3 ins.: med. grey, med. to coarse c'aren.; B.C. high $\frac{1}{4}$ in. sh. ptg. at base.				
16		Lower 3 ins.: med. grey, coarse cryst., coarse c'aren.; B.C. c. 60%. Upper 11 ins.: med. grey, fine cryst., fine c'aren.; argillaceous; sh. lam. abundant.	1	2	12	7
17		Med. dark grey, fine cryst., fine c'aren.; B.C. c. 25%, some pocket concentrations of B.C. 45%; many sh. lam.	1	7	14	2
18		Med. grey, fine to med. cryst., c'aren.; B.C. fairly low; middle part rather argillaceous; massive.	2	2	16	4
19	M.R.5	Med. grey, fine to esp. med. cryst., c'aren.; B.C. c. 45%, up to 60% in top 2-3 ins.; few prominent sh. lam.	1	2	17	6

Remarks. As stated above, the base of the Chaumont is exposed at the base of the scarp. The quarry is excavated in the top of the scarp and the units exposed must lie high in the Chaumont or perhaps low in the Rockland. At least some of the units seem to lie higher than those in the Frazer Duntile Quarry (locality 11) to the west.

Locality 13 HOGS BACK

A disused, partially flooded quarry is located behind the Sir Charles Tupper Building, 50 yds. north of Hogs Back Road and 300 yds. east of the Rideau River, near Mooney's Bay, Ottawa. Minor faulting is visible at the western end of the quarry and a slight flexure at the east. About 10 ft. of higher beds are exposed in an old shallow quarry between this quarry and the Hogs Back Road. The section in the main quarry was started in the N.W. corner and continued in the centre of the southern side.

-1	H.B.-1 (9 ins. from top)	Med. greenish grey, very fine cryst., c'lut.; B.C. 30%-35%, mainly T. cellulosum; sh. lam. numerous; weathers darker than higher units.	3	0	3	0
		Base of Chaumont				
1	H.B.1 (6 ins. from base)	Med. grey, slightly greenish, fine cryst., fine c'aren.; B.C. very low, less than 10%; borings abundant (med. to coarse cryst.); sh. lam. few; compact, many thin vertical spar-filled joints.	2	4	2	4
2		As Unit 1 in all respects.	0	10	3	2
3	H.B.2 (basal 5 ins.) H.B.3 (top 6 ins.)	Massive, compact, many subunits: Lowest 5 ins.: med. grey, med. cryst., med. to esp. coarse c'aren.; B.C. 50%-55%. Next 11 ins.: Med. grey, esp. fine to med. cryst., med. c'aren.; B.C.20%-25%; quite compact; borings common; sh. lam. few; broadly undulating top surface. Next 4-6 ins.: med. light grey, coarse cryst., fine c'rud.; B.C.60%-70%, sorting fairly good; intraclasts up to 1/3 in., up to 10% of subunit; top often rather gradational. Next 17 ins.: med. grey, esp. fine to med. cryst., med. c'aren.; B.C. 25%-30% at base to 15%-20% at top; quite compact; borings common; sh. lam. common.	3	5	6	7
4	H.B.4 (top 6 ins.)	Med. grey, fine to esp. med. cryst., fine to med. c'aren. with pockets of coarse c'aren.; B.C. usually 30%-40%; sorting poor; compact; sh. lam. common; borings	3	3	9	10

		infrequent to uncommon. Lowest 16 ins.: fairly uniform. Next 10 ins.: concentration of sh. lam. Next 2-3 ins.: no sh. lam. or borings, base sharp, top less so. Top 10 ins.: few sh. lam.				
5		Brown grey, badly weathered, calcareous shale with a compact ls. near top: med. blueish grey, med. cryst., med. c'aren.; B.C. less than 20%; compact; good marker bed; 30 ft. below quarry top at east end.	0	7-9	10	6
6	H.B.5 (at 12 ins. level)	Compact, two subunits: Lowest 15 ins.: med. grey, greenish, fine cryst., fine c'rud.; B.C. 25%-35%; sh. lam. few, one prominent at 15 ins. Top 8 ins.: med. grey, greenish, fine cryst., fine c'aren. with pockets and lenses of med. to esp. coarse c'aren.; B.C. 15%-25%, up to 35% in pockets; sh. lam. few.	1	10	12	4
7		Parting of shaly ls.	0	1	12	5
8	H.B.6 (at 14 ins. level)	Med. grey, fine cryst., fine to coarse c'aren., - mainly fine c'aren., with discontinuous layers of coarse c'aren. with brachiopods and cup corals; B.C. variable av. 20%-25%, up to 50% in coarse c'aren.; sh. lam. common, well developed. (see Fig. 19).	3	8	16	1
9	H.B.7 (middle)	Med. grey to med. dark grey, med. cryst., coarse c'aren.; B.C. variable; mainly 35%-45%, only 15% in places, esp. in top 6 ins.; a single (1 in.) intraclast seen; sorting moderate; some sh. lam.	2	11	19	0
10	H.B.8 (top 4 ins.)	Section transferred to central south side: Med. grey to med. dark grey, coarse c'aren.; B.C. 30%-45%, patchy distribution; some sh. lam.	2	1	21	1
		Top of Chaumont(?).				
11		Shale parting	0	1	21	2
12	H.B.9 (top 12 ins.)	Med. grey, fine to med. cryst., med. to coarse c'aren.; B.C. 20%-30%, fairly well distributed. some sh. lam., persistant ones at 11 ins. and 17 ins.; fairly compact	1	11	23	1

13		Shaly ls. (as in Unit 14), esp. shaly at top and bottom parts; allied to Unit 14.	0	5	23	6
14	H.B.10 (basal 3 ins.)	Med. dark grey, fine cryst., med. c'aren.; B.C. low, c. 20%; many well-developed sh. lam. in lower half, almost none in upper; thin (½-1 in.) brachiopod coquina in lower half, mainly strophomenids, valves convex upwards.	1	6	25	0
15		Thick massive compact; in general: med. dark grey, fine to med. cryst., med. c'aren. (very variable); B.C. variable av. 20%-30 %, some layers up to 60%; lowest 9 ins. shaly, almost separate unit; numerous sh. lam., some brachiopod concentrations (B.C. 50%-60%); unit fairly uniform.	6	1	30	1

Remarks. The upper Lowville beds and the contact with the Chaumont are well exposed. The boundary with the Rockland is rather arbitrary on lithologic grounds, in the field location above Unit 10 seems the most likely or possibly above Unit 14, but these are rather meaningless. Another 6 ft. or so above Unit 15 are exposed between the large quarry and the Hogs Back Road to the south.

Locality 14 DIBBLEES QUARRY, MACCARTHY ROAD

This quarry exposes upper Pamelia, Lowville and Chaumont strata and is located just east of MacCarthy Road, Ottawa between Mooney's Bay and Uplands Airport. The lowest 5 units are described from the east side of the quarry, the remainder from the west.

-1	D.M.-1 (top 6 ins.)	Med. grey, slightly pinkish, very fine to coarse cryst., c'lut. to fine c'rud. (very variable); top 2-3 ft. have abundant <u>T. cellulosum</u> (20%-30% of subunit); flaggy, shaly.	5	0	5	0
		Base of Chaumont.				
1	D.M.1 (basal 3 ins.)	Lower 5 ins.: med. dark grey, fine cryst., med. to coarse c'aren.; B.C. 25%-35%, sorting poor; gradational upwards; borings rare. Upper 10 ins.: med. dark grey, fine cryst., fine to med. c'aren.; B.C. 20%-25%; borings abundant; few sh. lam. <u>Lyopora</u> frequent in unit.	1	3	1	3
2	D.M.2 (at 12 ins. level)	Med. grey, slightly brownish, fine to very fine cryst., fine to med. c'aren.; B.C. 10%-15%; borings common; an inverted <u>Lyopora</u> observed; ½ in. sh. ptg. at base.	1	8	2	11
3		Shale ½-1 in.	0	1	3	0
4	D.M.3 (at 6 in. level) D.M.4 (9 ins. from top)	Rather inaccessible, 4 subunits separated by prominent sh. lam.; in general: med. dark grey, fine cryst., fine to coarse c'aren. (esp. fine to med. c'aren.); B.C. also variable, c. 35%-50%; borings common; subunits: 18 ins., 12 ins., 12 ins., 6 ins., lowest three compact, top 6 ins. rather flaggy.	3	9	6	9
5		Shale ½-1 in.	0	1	6	10
6	D.M.5 (base)	Med. grey to med. dark grey, fine to med. cryst., med. c'aren.; B.C. 20%-30%, well distributed, slight vertical variations; 3 or 4 prominent sh. lam., weathers paler than adjacent units.	2	8	9	6
7	D.M.6	Med. grey, fine to med. cryst. with some coarse spar flecks, med. c'aren.; B.C. 25%-35%; very similar and probably allied to Unit 6.	0	11	10	5

8		Med. grey, med. to coarse cryst., med. c'aren.; B.C. 45%-55%, well distributed; one prominent sh. lam. 2/3 up from base; ½ in. sh. ptg. at base.	1	4	11	9
9		Shale and irregular argillaceous ls.	0	2-3	12	0
10	D.M.7 (base)	Med. grey, fine to med. cryst., med. to coarse c'aren.; B.C. moderate, brachiopods and cephalopods noted; frequent sh. lam.	2	5	14	5
11		Very argillaceous, badly weathered, impure c'rud.; B.C. c. 60%, many macrofossils esp. brachiopods.	0	3	14	8
12	D.M.8	Med. dark greenish grey, med. cryst., med. c'aren.; B.C. c. 45%, well distributed, sorting fairly poor.	0	10	15	6
13		Med. greenish grey, med. cryst., med. c'aren. with pockets of med. to coarse c'rud.; B.C. fairly high with esp. brachiopods, cephalopods and some cup corals; ½ in. sh. ptg. at base.	0	11	16	5
14		Shale and shaly ls.	0	2-3	16	8
15		Med. grey, fine to med. cryst., med. c'aren.; rubbly, argillaceous.	0	5	17	1
16		Shale and intermittent shaly ls.	0	2	17	3
17	D.M.9 (upper part)	Med. grey, fine to med. cryst., med. to coarse c'aren., with some lenses of med. c'rud. (B.C. predominantly brachiopods) esp. in middle of unit; B.C. av. 50%, variable laterally, vertically, up to 75% in places; sh. lam. frequent, esp. in lower half.	1	10	19	1
18	D.M.10 (upper part)	Dark grey, med. cryst., med. c'aren. to med. c'rud. (esp. coarse c'aren.); B.C. high, variable, mainly brachiopods, cephalopods, some crinoid ossicles, bryozoans and trilobite debris; sh. lam. common, breaking unit into 1-3 in. beds; sh. ptg. breaking unit into 2 subunits (lower 11 ins., upper 15 ins.) of essentially same lithology.	2	2	21	3

Remarks. The base of the Chaumont is again characterized by the Tetradium unit which is overlain by some 21 ft. of strata that appear to be entirely Chaumont; again, the upper beds could be Rockland, but this seems unlikely to the writer.

Locality 15

HEMLOCK ROAD

This section is located on the south side of Hemlock Road, Ottawa, just east of the junction with Juliana Road and opposite house 205, Hemlock Rd. The section begins near the top of the small cliff and continues as a discontinuous sequence into the wooded area behind (Beechwood Cemetery).

-4		Med. pink-grey, very fine cryst., c'lut.; B.C. c. 40%-50%, predominantly *T. cellulosum* with a few heads of *T. fibratum*; massive but numerous sh. lam. cause rubbly development upon weathering.	2	0	2	0
-3		Shale, badly weathered, poorly exposed.	0	1-2	2	1
-2	H.-1	Med. pink grey, fine cryst., c'silt.; B.C. indet., large head of *T. fibratum* seen; weathers very light grey.	0	3-4	2	5
-1		Med. pink grey, fine cryst., c'silt.; B.C. c. 25%, poorly sorted; few sh. lam., but rubbly; ¼ in. sh. ptg. at base; c. ½ in. sh. ptg. at top.	0	4	2	9
		Base of Chaumont.				
1	H.1 (base)	Med. grey to med. dark grey, fine cryst., med. c'aren.; B.C. 35%-45%; fairly uniform except: basal 0-1½ ins.: coquinal (med. c'rud.), lenses in erosion hollows(?). Next 7 ins.: very few sh. lam. and borings. Next 14 ins.: numerous borings and sh. lam. (at ½-2 ins. intervals). Next 1-3 ins.: sh. lam. and borings absent. Next 0-1 ins.: intraclast conglomerate; sorting fair to poor (size range 1-12 mm, av. 3-5 mm) rounding good; irregular but smooth base, gradational, fairly abrupt upper surface. Top 2-4 ins.: numerous borings and sh. lam. (at intervals of ½-2 ins.).	2	2	2	2
2		Med. grey, coarse cryst., fine c'rud.; B.C. c. 60%-70%; base often conglomeratic, bottom irregular but unit normally allied to Unit 1; top less irregular, but more distinct.	0	2-4	2	5
3	H.2 (base)	2 distinct subunits separated by sh. ptg.: Lower 13-14 ins.: med. grey, slightly pinkish, fine cryst., med. c'aren.; B.C. less than 15%,	1	8	4	1

		increasing slightly upwards; sh. lam. with ½-1 in. separation. Upper 6-7 ins.: med. grey, med. cryst., med. c'aren.; B.C. c. 20%; sh. lam. as in lower subunits.				
4		Med. light grey, fine cryst., c'silt.in fine c'aren.(?); B.C. low, obscure; compact.	0	2-3	4	4
5		Shale parting, up to 1 in.	0	1	4	5
6		Med. grey, fine cryst., med. c'aren.; B.C. low, variable, usually less than 20%; many sh. lam; rubbly.	0	10	5	3
7	H.3 (base)	2 subunits: Lower 11 ins.: med. grey, fine cryst., med. c'aren.; B.C. c. 25%-30%; few sh. lam.; borings frequent; top smooth, flat. Upper 8-9 ins.: med. grey, fine cryst., med. to coarse c'aren.; B.C. 15%-25%; less compact; more sh. lam. and borings than subunit below.	1	8	6	11
8		Shale ptg., up to 1 in.	0	1	7	0
9		Med. grey to med. light grey, fine cryst., med. c'aren.; B.C. 20%-30%; few sh. lam.	0	5	7	5
10		Shale	0	1	7	6
11	H.4 (middle)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. variable, c. 25%-30%; sh. lam. present, more in upper part.	1	3	8	9
		The section below was exposed in the cliff-face, the rest outcrops higher in the wood.				
		Covered	c.4	6	13	3
12		Med. grey, coarse cryst., coarse c'aren.; B.C. c. 40%; top of a covered unit.	0	3	13	6
13	H.5 (upper half)	Med. grey, med. and coarse cryst., med. to coarse c'aren.; B.C. 40%-45%, many macro-fossils at top, debris concentrated in bands; sh. lam. frequent.	1	0	14	6
14		Med. grey, fine cryst. with coarse spar flecks; coarse c'aren.; B.C. c. 25%; few sh. lam.	0	9	15	3
15		Med. grey, fine cryst., coarse c'aren.; B.C. c. 30%-35%.	0	5	15	8
		Covered: 2 to 2½ ft.	2	3	17	11

16	H.6 (top)	Med. grey, fine cryst., fine (?) c'aren.; B.C. variable, less than 20%; compact, generally 2 or 3 beds.	1	3	19	2
		Covered: 2 to $2\frac{1}{2}$ ft.	2	3	21	5
17	H.7	Med. pink grey, coarse cryst., coarse c'aren.; B.C. indet., many macrofossils on top surface; sh. lam.frequent; only 5 ins. exposed.	0	5	21	10
		Covered.	0	9	22	7
18		Med. grey, med. cryst., med. c'aren.; B.C. 30%-45%; some sh. lam.	0	9	23	4
		Covered.	0	6	23	10
19	H.8 (middle)	Med. grey, med. to coarse cryst., med. c'aren.; B.C.c. 45%; sh. lam. frequent; subunits: lower 5 ins., upper 20 ins., on slight variations.	2	1	25	11

Remarks. Some 15-20 ft. of Lowville strata are exposed; the contact with the Chaumont, as defined, is clearly seen. The Chaumont sequence is discontinuous, particularly in the upper part and although nearly 26 ft. of strata are revealed in part, above the base of the formation, no firm evidence is present to allow even a suggested location of the Chaumont's upper contact.

Locality 16 OTTAWA VALLEY CRUSHED STONE QUARRY

The large quarry is located ¼ mile S.E. of the intersection of the Montreal Road and the Queensway (Hy. 17), just east of Green Creek. The quarry exposes upper Pamelia to lower Rockland units and the Chaumont section was described from the southern face.

-1		Med. brown grey, very fine cryst.; c'lut.; B.C. moderate, predominantly <u>T. cellulosum</u>; many sh. lam.; beds 1 in. thick; rubbly; top flat but bored, infilled with c'aren.	1 0	1 0
		Base of Chaumont.		
1	O.C.S.1 (top subunit)	Massive, compact; several subunits: Four lowest subunits, each 5-6 ins.: med. dark grey, fine to med. cryst., esp. fine to med. c'aren.; B.C. c. 45%; subunits vary slightly, separated by irregular sh. lam. or irregular surfaces. Top 7-8 ins.: med. dark grey, fine cryst., c'silt.; B.C. low. Borings throughout unit.	2 7	2 7
2	O.C.S.2 (middle)	Basal 2 ins.: fine c'aren., often conglomeratic, intraclasts less than ½ in. long; base slightly irregular, top smooth. Middle 11 ins.: med. grey, fine to med. cryst., fine c'aren.; B.C. 25%-40%, fairly uniform; few sh. lam.; top smooth, rippled (amplitude 2 ins.) Top 4-6 ins.: med. dark grey, fine cryst., fine c'silt.; sh. lam. more numerous.	1 5	4 0
3	O.C.S.3 (top)	Med. brownish grey, med. cryst., med. c'aren., B.C. moderate; sh. lam. frequent; borings (filled with coarser material) very common.	0 9	4 9
4		Med. grey, fine to med. cryst., fine c'aren.; B.C. 25%-35%; sh. lam. frequent; ¼-½ in. sh. ptg. at base; difficult of access.	1 3	6 0
5	O.C.S.4 (top)	Med. grey, med. cryst., fine c'aren.; B.C. 25%-35%; sh. lam. only prominent in top 6 ins.; ½-¾ in. sh. ptg. at base.	1 6	7 6

6	O.C.S.5 (top)	Thinly bedded; two main ls. types: a) med. grey, fine cryst., c'silt.; B.C. low. b) med. brown grey, med. to coarse cryst., coarse c'aren., B.C. high to coquinal; type a) dominant, with minor interbeds of type b); beds 2-4 ins. thick, separated by sh. lam. and sh. ptgs.; tops and bottoms often irregular, frequently bored; flaggy unit between adjacent compact thick-bedded units; unit rather inaccessible.	3	4	10	0
7		Largely inaccessible, massive unit; several subunits separated by sh. lam. or sh. ptgs.: Basal 4-6 ins.: more shaly than others Next 15-18 ins.: compact, probably with about 4 minor fused beds within. Next 9 ins.: similar to top subunit. Top 4 ins.: med. dark grey, med. cryst., c'aren.; top 2 subunits weather med. light grey, lower 2 subunits weather light brownish grey.	2	9	13	7
8	O.C.S.6	Med. dark grey, med. cryst., c'aren.; thin-bedded subunits, 3-4 ins. thick; some sh. lam.	0	11	14	6
9		Shale.	0	2	14	8
10		Units 10, 11, 12, closely related, forming a super-unit. Med. grey, fine to med. cryst., fine c'aren.; B.C. 35%-45%; compact, few sh. lam.	1	1	15	9
11		Med. dark grey, esp. fine to med. cryst., coarse c'aren.; B.C. c. 60%, evenly distributed; rather argillaceous, rubbly, forming irregular thin beds.	0	9	16	6
12	O.C.S.7	Med. grey, fine cryst.,c'aren.; B.C. av. 35%-45%, up to 65% in lower half; compact, few sh. lam.	1	0	17	6
13	O.C.S.8 (top)	Rather inaccessible; massive, compact; top 12 ins. separated by prominent sh. lam., only part to be examined: med. grey, fine to med. cryst., med. c'aren.; B.C. c. 45%-55%.	2	7	20	1
14	O.C.S.9 (top)	Massive, compact; several subunits: Basal 7 ins.: med. grey, fine cryst., c'aren.; B.C. 20%-25%. Middle 18 ins.: med. brownish grey, fine cryst., fine to med. c'aren.; B.C. c. 35%;	2	10	22	11

		rubbly; many sh. lam. Top 8-9 ins.; med. grey, fine to med. cryst., fine c'aren.; compact; weathers med. blue grey.				
		Top of Chaumont(?)				
15	O.C.S.10	Med. dark grey, slightly brownish, fine cryst.; c'rud.; B.C. moderate, many fairly complete macrofossils, e.g. brachiopods, *Prasopora*, trilobites, gastropods; shaly, giving "pseudo-nodular" appearance to ls..	1	10	24	9
		Similar, but thinner, rubbly shaly units occur at 1½ ft. and 4¾ ft. above Unit 15.				

Remarks. A complete Chaumont section is exposed in this quarry, although some of the units are not readily accessible for detailed inspection. The *Tetradium* unit is present at the base. The top is arbitrarily placed below Unit 10; above this, there lies a series of prominent shaly units (e.g. Unit 10) interbedded with typical thick bedded compact calcarenites.

Locality 17 ARMY SUPPORT AND TEST WING

A disused quarry and roadcut are located $\frac{3}{4}$ mile east of locality 16 within the Army Support and Test Wing north of the old Hy. 17, 2 miles west of Orleans, Gloucester township, Carleton county. The section was taken along the roadcut on the south-west side of the road ascending the scarp, south of the main buildings.

-1		Med. pink grey, very fine cryst., c'lut.; B.C. moderate, mainly T. cellulosum; beds few inches thick, separated by sh. lam. and sh. ptgs., top irregular, bored in part.	1	10	1	10
		Base of Chaumont.				
1	A.1 (12 ins. above base)	Fairly compact; two gradational subunits: Lower 15-17 ins.: med. grey, slightly greenish, med. cryst., coarse c'aren.; B.C. c. 45%-50%; few borings; many sh. lam. Upper 12-14 ins.: med. grey, fine cryst., fine to esp. med. c'aren.; B.C. c. 30% numerous borings; many sh. lam.	2	5	2	5
2		Med. green grey, fine cryst., fine c'aren.; B.C. less than 25%; top and bottom level with $\frac{1}{4}$ in. sh. ptgs.; borings numerous, usually parallel to bedding.	1	0	3	5
3	A.2 (upper part)	Basal 6 ins.: med. grey, med. cryst., med. c'aren.; B.C. c. 35%-45%; many sh. lam.; upper boundary wavey, smooth. Top 7 ins.: med. grey, med. cryst., med. c'aren.; B.C. c. 25%. Slight differences in weathering colour.	1	1	4	6
		Covered	0	9	5	3
4		Med. grey, med. cryst., med. c'aren.; B.C. 25%-35%; many sh. lam.; base not exposed.	0	9	6	0
		Covered	0	3	6	3
5		As Unit 4, but with few sh. lam.	0	5	6	8
6	A.3 (middle)	Med. grey, med. cryst., med. c'aren.; B.C. c. 35%-40%; compact, few sh. lam.; weathers med. blue grey.	1	8	8	4

7	A.4 (middle)	Med. grey, fine to med. cryst., with coarse spar flecks, med. to coarse c'aren.; B.C. c. 45%, some large macrofossils esp. cephalopods; beds 1-6 ins. thick separated by sh. lam.; carbonate type variable.	3	0	11	4
8		Med. grey, med. cryst., med. to coarse c'aren.; B.C. 40%-50%; compact, but many sh. lam. in basal 9 ins. and top 6 ins.	2	9	14	1
9	A.5 (middle)	Med. grey, med. cryst., coarse c'aren.; B.C. 55%-65%; argillaceous with shaly layers - up to 1 in. thick - at levels 0, 3, 6, and 18 ins.	1	9	15	10
10		Shale with rubbly weathers ls. in thin 1 in. beds; allied to upper part of Unit 9.	0	4	16	2
11	A.6 (middle)	Compact, massive; 3 subunits: Lower and upper 14 ins.: compact, few sh. lam.; middle 13 ins.: numerous sh. lam.; ls. in general: med. grey, med. cryst., coarse c'aren.; B.C. 45%-55%, many macrofossils.	3	5	19	7
12	A.7 (top)	Med. grey, med. cryst., coarse c'aren.; B.C. c. 55%, variable; bottom 10 ins. and top 9 ins. have many sh. lam.; middle compact.	3	9	23	4
13	A.8 (middle)	Med. grey, med. cryst., coarse c'aren.; B.C. c. 45%, variable; many sh. lam. except in top 9 ins., $\frac{1}{4}$-$\frac{1}{2}$ in. sh. ptg. at base.	3	2	26	6
14	A.9	Med. grey, med. cryst., coarse c'aren.; B.C. 30%-40%; compact; weathering a pale grey; few sh. lam.	1	6	28	0

<u>Remarks</u>. The base of the Chaumont is marked by the unit replete with <u>Tetradium</u>, some 20 ft. of Lowville are also exposed. No upper boundary can be placed; the shaly units of locality 16 are not evident, but if of equivalent thickness they would lie above Unit 11.

Locality 18

BORRIS QUARRY

This quarry is located behind the house of Mr. R. Borris, 335, Montreal Road, between the old and new Hy. 17, ½ ml. east of the Carleton-Russel county boundary, Cumberland township, Russel county. The east face of the quarry was sectioned; the first two units are exposed in the field to the east of quarry entrance; top of Unit 2 forms quarry floor.

1	B.1	Med. grey, med. cryst., coarse c'aren.; B.C. 45%-55%; several sh. lam.	2	0	2	0
		Covered; a few patches of rubbly ls. like Unit 1.	6	0	8	0
2	B.2	Med. light grey, med. to coarse cryst., coarse c'aren.; B.C. c. 35%-45%, sorting moderate, top flat, base not visible.	1	3	9	3
		Covered: 12-18 ins.	1	3	10	6
3		Med. grey brown, fine cryst., c'silt.; B.C. variable, some fossiliferous layers, sorting poor; abundant sh. lam. giving rubbly nodular appearance.	2	0	12	6
4		Med. grey brown, fine cryst., c'silt.; B.C. less than 15%; persistant bed.	0	2-3	12	9
5		Lower half: med. grey brown, fine cryst., fine to med. c'aren.; B.C. c. 25% Upper half: med. light grey, med. to coarse cryst., coarse c'aren.; sh. lam. at base of subunit. Top and bottom of unit slightly irregular, ½ in. sh. ptg. at base.	0	5	13	2
6		Med. brown grey, fine cryst., fine to med. c'aren.; B.C. c. 30%; shaly, rubbly.	0	7	13	9
7		Med. grey to med. light grey, coarse cryst., coarse c'aren. to fine c'rud.; B.C. c. 45%, sorting moderate to poor.	1	3	15	0
8		Med. grey, med. cryst., med. c'aren.; B.C. 50%, sorting poor; rubbly unit, shale c. 30% of unit; ls. beds discontinuous except one 2 in. bed at top.	0	11	15	11
9		Shale: 1-1½ in.	0	1	16	0

10		Compact; in general: med. grey, med. cryst., esp. fine to coarse c'aren.; B.C. 50%-60%, esp. crinoid ossicles; lower 4-5 ins.: several sh. lam., with higher B.C. c. 60%-65%, sorting poor; two higher subunits separated by irregular, probably bored, surface.	2	11	18	11
11		Nodular shaly ls.; allied to Unit 10.	0	2	19	1
12		Med. grey, med. cryst., coarse c'aren. to fine c'rud.; B.C. 35%-45%, sorting poor; compact, no sh. lam.	0	10	19	11
13		Light grey, fine cryst., fine to med. c'aren.; B.C. c. 30%; base irregular; weathers paler than Unit 12.	0	3	20	2
14		Med. grey, fine cryst., fine c'aren.; B.C. 15%-25%; nodular, shaly unit.	1	9	21	11
15	B.3	Med. dark grey, med. cryst., med. c'aren.; B.C. 20%-30%; top and basal 6 ins. have many sh. lam.; lower half the more argillaceous.	2	8	24	7
16		Med. dark grey, med. cryst., fine to med. c'aren.; B.C. 15%-25%; allied to Unit 17.	0	9	25	4
17		Med. grey, coarse cryst., esp. coarse c'aren. to fine c'rud.; compact, few sh. lam.	1	9	27	1
18		Shale; good marker bed	0	3-4	27	5
19		Med. grey, med. cryst., fine to esp. coarse c'aren.; B.C. very variable, 20% coquinal, debris concentrated in thin spreads; unit splits into 3-4 beds along sh. lam.; top 3-4 ins. broadly cross-laminated, lensing out laterally.	1	8	29	1
20		Med. grey, med. to coarse cryst., coarse c'aren. to fine c'rud.; B.C. very variable, 30% to coquinal, with concentrations in thin spreads, crinoid ossicles and trilobite fragments recognizable, sorting poor; compact; several sh. lam.	1	10	30	11
21		Med. grey, fine to coarse cryst., fine to coarse c'aren.; B.C. less than 10% to coquinal, concentrated in thin spreads, sorting poor; many sh. lam.; $\frac{1}{2}$ in. sh. ptg. at base.	1	5	32	4

22	B.4	Med. grey, med. to esp. coarse cryst., coarse c'aren. with fine c'rud. in thin beds or lenses; B.C. 45%-55% debris more evenly distributed than lower units; compact; several sh. lam.	2	10	35	2
23		Med. grey to med. dark grey, esp. med. to coarse cryst., med. c'aren.; B.C. 35%-45%, debris well distributed; top 3 ins. cross-laminated, paler weathering and with lower B.C.	1	4	36	6
24		Med. grey, med. cryst., med. to coarse c'aren.; B.C. 25%-35%, debris well distributed; several sh. lam.	2	5	38	11
25		Med. dark grey, coarse cryst., med. to coarse c'aren.; B.C. c. 35%, brachiopods and <u>Receptaculites</u>; few sh. lam.	0	10	39	9
26		Lower 12 ins.: med. light grey, med. cryst., fine to med. c'aren.; B.C. c. 35% Upper 10 ins.: med. grey, coarse cryst., coarse c'aren.; B.C. c. 40%, sorting good; irregular lower surface. ¼ in. sh. ptg. at base of unit.	1	10	41	7
27		Med. light grey to med. grey, coarse cryst., med. c'aren.; B.C. c. 45%; in middle: 3 in. laminated and cross-laminated spread; a less noticeable similar bed, 2 ins. thick, lies at or near top.	2	7	44	2
28	B.5	Med. grey, coarse cryst., med. c'aren.; B.C. c. 55%, sorting good; flat top and bottom; some sh.lam; weathers slightly darker than lower units.	0	9	44	11

Remarks. At this locality, the stratigraphic relations are not clear. No Lowville units seem to be exposed and above Unit 17, at least, the beds appear to be Rockland, with the fossil debris generally coarser and frequently occurring in thin concentrated spreads. The lower units seem to be Chaumont but the upper boundary cannot be placed with certainty.

Locality 19 CUMBERLAND ROADCUT

This locality lies 1 1/3 ml. S.W. of Cumberland , Cumberland township, Russel county. It occurs at the "kink" in the N./S. road that is the second west of the Cumberland - French Hill road. The lowest exposures are in the field, 40 yds. west of the road between the power lines. Equivalent upper units outcrop in the roadcut near the top of the small scarp.

1		Med. brown grey, fine cryst., fine c'aren.; B.C. less than 25%; base more irregular than upper surface.	0	2-4	0	3
2		Med. grey, fine cryst., med. c'aren.; B.C. c. 25%; massive; sh. lam., 2-4 ins. apart.	3	8	3	11
3		Med. grey, fine cryst., fine to esp. med. c'aren.; B.C. c. 25%; some sh. lam.; ¼ in. sh. ptgs. at top and base.	0	11	4	10
4	Cu.1 (middle)	As units 2 and 3; but with more sh. lam.	1	0	5	10
5		Med. light grey, fine cryst., med. c'aren. to fine c'aren. at top; B.C. c. 25%; sh. lam. present; ½ in. sh. ptg. at base.	1	6	7	4
6		Med. light brown grey, med. cryst., fine to med. c'aren.; B.C. less than 25% lower half very thinly bedded, upper part compact.	0	5	7	9
7		Med. light grey, med. cryst., fine c'aren.; B.C. c. 20%; compact, laminated.	0	4	8	1
8		Med. light grey, fine to med. cryst., med. c'aren.; B.C. c. 25%; many sh. lam.	0	5	8	6
9	Cu.2	As Unit 7.	0	4	8	10
10		Med. grey, med. cryst., med. c'aren.; B.C. c. 30%; numerous sh. lam.	0	9	9	7
11		Med. grey, med. cryst., med. c'aren.; B.C. c. 25%; few sh. lam.	1	10	11	5
12	Cu.3	Med. light grey, fine cryst., fine c'aren.; B.C. low, obscure; many sh. lam., rather rubbly.	0	10	12	3

13		Med. light grey, fine to med. cryst., coarse c'aren., rarely fine c'rud., at base to med. c'aren. at top; B.C. 50% at base to 30% at top; very few sh. lam.	1	0	13	3
14		Med. green grey, med. cryst., med. to coarse c'aren.; B.C. 30%-35%, many sh. lam.	1	10	15	1
15	Cu.4 (4 in. bed)	Med.light grey, fine to esp. med. cryst., med. c'aren.; B.C. 40%-45%; many sh. lam.; 4 in. bed near base; a med. c'rud. coquina of crinoid ossicles.	2	1	17	2
16	Cu.5 (base)	Med. grey, med. cryst., med. c'aren.; B.C. c. 40%, uniform; many sh. lam.	2	6	19	8
17	Cu.6 (middle)	Med. light grey, fine to med. cryst., fine to med. c'aren.; B.C. 15%-25%; numerous sh. lam.	2	0	21	8
		This top bed can be traced to the road-cut where it outcrops by the gate at the top of the exposure.				

Remarks. The units exposed are typical of the Chaumont - Rockland lithofacies in the eastern region. If the approximate boundaries on Wilson's (1940) map (Map 587A, Casselman 1: 126,720) were accepted all would be included in the Chaumont with an additional 15 ft. or so unexposed at the base. No Lowville exposures could be found nearby, so it is on slender evidence that the writer suggests most of the exposure is of Chaumont with possibly some Rockland towards the top.

Locality 20 CUMBERLAND QUARRY

This small disused quarry is situated 1¼ miles S.E. of Cumberland, Cumberland township, Russel county. On the topographic map (Thurso, 31 G/11 West, 1: 50,000) its position lies where the 300,325 and 350 ft. contours are closest.

-1		Med. pink grey, very fine cryst., with coarse spar flecks, c'lut.; B.C. low; compact.	0	7	0	7
		Base of Chaumont.				
1	C.1 (base)	Med. grey, fine cryst., med. c'aren.; B.C. c. 30%, rather obscure; compact, few sh. lam.; ½ in. sh. ptg. at base.	2	6	2	6
2		Med. grey, fine to esp. med. cryst., med. c'aren.; B.C. obscure, fairly low; compact. ½ in. sh. ptg. at base.	1	1	3	7
3		Shale	0	1	3	8
4	C.2 (base)	Med. grey, fine cryst., med. c'aren.; B.C. indet.; lowest 7-8 ins. possibly a separate subunit.	2	2	5	10
5	C.3 (top 3 ins.)	Lower 8 ins.: med. light grey, fine cryst., med. c'aren.; several sh. lam. Top 3 ins.: med. green grey, med. cryst., med. to esp. coarse c'aren.; B.C. 45%-55%; compact.	0	11	7	9
6		Shale	0	1	7	10
7		Med. brownish grey, fine cryst., esp. med. to coarse c'aren.; B.C. c. 50%; few sh. lam., mainly near top.	1	11	9	9
8		Flaggy, badly weathered ls.; weathering whitish colour.	0	3	10	0
9		Med. grey to med. light grey, fine cryst. with coarse spar flecks, coarse c'aren.; B.C. c. 30%; very few sh. lam.	1	2	11	2
10		Shale	0	1	11	3
11		Med. grey, fine to med. cryst., med.	1	2	12	5

c'aren.; B.C. c. 35%; some sh. lam., one
prominent at middle.

Remarks. The lowest unit is considered to be Lowville. Numerous loose blocks around the quarry are replete with *T. cellulosum* and this characteristic upper Lowville unit must lie just below Unit -1. The beds above are typical compact, thick bedded calcarenites of the Chaumont.

Locality 21 STEWART QUARRY, ROCKLAND

This large disused quarry is located one mile south of Rockland, Clarence township, Russel county, in the scarp just west of the dirt road. The section is described from the N.W. side of the quarry.

-1		Med. grey, very fine cryst., c'lut.; B.C. variable, up to 70%, mainly T. cellulosum many sh. lam., rather rubbly esp. top 6 ins.; weathers darker than Unit 1.	4	2	4	2
		Base of Chaumont.				
1	S.1	Med. grey, slightly greenish, fine cryst., c'silt.; B.C. low, occasional large macro-fossils; one 3 in. bed near base; med. c'rud., brachiopod coquina; some borings; compact; pale weathering forms main floor of quarry.	1	1	1	1
2	S.2 (middle)	Med. grey, fine cryst., c'silt.(?); B.C. low; compact; numerous borings; one noticeable break 8 ins. from top along ½ in. fine c'aren. layer; ½ in. sh. p'tg. at base.	3	5	4	6
3	S.3 (6 ins. above base) S.4 (top)	Massive, two subunits: Lower 26 ins.: med. grey, fine to med. cryst., fine to coarse c'aren.; B.C. c. 30%-35%, debris in pockets and lenses; many sh. lam., esp. in lowest 5 ins., rubbly. Upper 36 ins.: as above, but compact, very few sh. lam. except in top 3 ins. Fused contacts within subunits visible in places.	5	2	9	8
4		Shale gradational between Units 3 and 4.	0	2	9	10
5	S.5 (middle)	Med. grey, med. cryst., coarse c'aren.; B.C. c. 45%; compact, except rather rubbly lower third.	2	1	11	11
6	S.6 (top)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. c. 40%; compact, with 3 prominent sh. lam. in upper half; top 8 ins.: coarse c'aren., B.C. c. 60%; top 5 ins. argillaceous.	2	4	14	3
7		Shale	0	2	14	5

8	S.7 (top)	Med. dark grey, med. cryst., med. to coarse c'aren.; B.C. c. 45%; several sh. lam. in upper part.	1	9	16	2
9		As Unit 8; ½ in. sh. ptg. at base.	1	7	17	9
10		Med. grey, med. cryst., coarse c'aren.; B.C. 45%-55%; prominent sh. ptgs. at top and bottom; good marker bed.	0	4	18	1
11	S.8 (base)	Med. grey, fine to med. cryst., med. c'aren.; B.C. 35%-45%, few sh. lam.	1	4	19	5
12		Thin band of concentrated sh. lam. in ls.	0	2	19	7
13	S.9 (middle)	Med. grey, med. cryst., med. c'aren.; B.C. 35%-45%; top 6 ins. rubbly, with numerous sh. lam.	2	2	21	9
14	S.10 (lower 6 ins.)	Med. grey, med. cryst., med. c'aren.; B.C. c. 35%; few sh. lam.; compact.	1	0	22	9
15	S.11 (middle)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. 35%-45%; fairly uniform but subdivided by sh. lam. into: lower 14 ins.: less compact, several sh. lam. middle 19 ins.: very compact, few sh. lam. top 5 ins.: a little rubbly, many sh. lam.	3	2	25	11
16	S.12 (middle)	Med. grey, med. cryst., fine c'aren. in lower part to med. to coarse c'aren. in upper; B.C. 30%-35% in lower half, 35%-45% in upper; subunits: lower 12 ins.: compact, lowest 4 ins. rubbly middle 16 ins.: compact, few sh. lam. except in top 6 ins. top 6 ins.: compact, no sh. lam.	2	10	28	9
17	S.13	Rubbly very shaly ls.; no distinct beds; several well preserved fossils esp. brachiopods, bryozoans.	0	6	29	3

Above Unit 17 lie 15 ins. ls.; 7 ins. shale; 15 ins. ls.; 6 ins. shale; 30 ins. ls.; 5 ins. shale.

Remarks. Some 20 ft. of Lowville strata are exposed beneath the *Tetradium* bed. Above the latter bed lie 60 ft. of Chaumont and Rockland calcarenites. The boundary between the latter two formations may lie at the top of Unit 14, where there is a slight change in gross lithology. If the shaly units are equivalent to the rubbly beds at locality 16, the junction should perhaps be placed at the top of Unit 16, which would give quite a thick section.

Locality 22 WENDOVER

This locality is 3 miles W.S.W. of Wendover and ½ mile south of Hy. 17, Clarence township, Russel county. The exposures are 50 yds. west of the abrupt easterly turn in an old north-south road, in the wooded scarp. The Lowville-Chaumont boundary is exposed nearly three-quarters the way up the scarp.

-2	W.-2	Med. grey to med. light grey, coarse cryst., fine c'rud.; B.C. c. 50%-60%; details obscure; compact; few, if any sh. lam.	0	5	0	5
-1	W.-1 (at 12 ins.)	Med. dark grey, very fine cryst., c'lut.; B.C. c. 40%, mainly T. cellulosum; flaggy 1 in. beds; recessive.	1	8	2	1
		Base of Chaumont.				
1	W.1 (lower part)	Basal 11 ins.: med. grey, brownish, very fine cryst., c'silt.(?); B.C. c. 20%; borings common; sh. lam. few; compact; fused top surface; subunit possibly Lowville. Top 3 ins.: med. grey, fine cryst., fine c'aren.; B.C. 20%-25%; some sh. lam.; borings present.	1	2	1	2
2	W.2 (lower part)	Med. dark grey, fine cryst., fine to med. c'aren.; B.C. 20%-25%; compact, few sh. lam.; borings abundant; sh. ptgs. at base and esp. at top.	1	8	2	10
3		Med. grey, fine to med. cryst. with coarse spar flecks, med. to coarse c'aren.; B.C. c. 25%-35%, obscure.	0	1-2	3	0
4	W.3 (lower 6 ins.)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. c. 30%; compact, few sh. lam.; borings abundant; top of unit covered.	1	0	4	0

Remarks. This small section exposes the base and lower few feet of the Chaumont. The units are very similar to others at this stratigraphic level throughout the eastern region.

Locality JESSOP FALLS

The Chaumont is exposed in a section on the South Nation River, where crossed by Hy. 17, Plantagenet North township, Prescott county. The exposures occur on the east bank; the lower and upper boundaries of the Chaumont outcropping some 70 yds. and 10 yds. respectively downstream from the bridge.

-4		Med. light grey, coarse cryst., fine c'rud.; B.C. high, abundant Tetradium, esp. T. fibratum and brachiopods, ostracods; compact; cross-laminated at top.	0	8	0	8
-3		Shaly rubbly ls.; ls. as in Unit -4, but less continuous; B.C. high, many Tetradium but smaller than in Unit -4.	1	1	1	9
-2		Dark grey, fine cryst., c'lut. with coarse spar flecks; B.C. low; dark spar flecks aligned parallel to bedding; rest of unit weathers yellowish grey.	0	3	2	0
-1	J.-1 (base)	Med. dark grey, fine cryst., c'silt.; B.C. less than 20%, some debris concentrations, esp. in lower part; weathering very light grey; basal 3 ins. shaly, flaggy; separates from Unit 1 upon weathering.	1	2	3	2
		Base of Chaumont				
1	J.1 (middle)	Med. dark grey to med. grey, fine to med. cryst., coarse c'aren. rarely to fine c'rud.; B.C. c. 25%, up to 70% in upper 2 ins.; weathers light grey, base irregular; some concentrations of fossil debris near base; sh. lam. numerous.	0	5-7	0	6
2		Shale	0	1	0	7
3	J.2 (top)	Med. grey, fine cryst., med. c'aren.; B.C. 10%-15%; top and bottom level; few sh. lam.; compact; lowest 9 ins. tend to separate from unit upon weathering.	2	1	2	8
4		Med. grey, fine to med. cryst., esp. fine to med. cryst., B.C. c. 15%-20%; weathers to give "blocky" surface.	0	8	3	4
5	J.3 (top)	Med. grey, med. cryst., coarse c'aren.; B.C. c. 15%-20%, evenly distributed;	2	5	5	9

		compact; few sh. lam.; weathering as Unit 4.				
6		Med. grey to med. dark grey, med. cryst., med. to coarse c'aren.; B.C. c. 35%; weathering and sh. lam. content as Units 4 and 5.	1	11	7	8
7		Med. grey, fine to med. cryst., med. c'aren.; B.C. 25%-30%; only one prominent sh. lam. at 2/3 level; ½ in. sh. ptg. at base.	1	1	8	9
8	J.4 (top)	Med. dark grey, fine to med. cryst., med. to esp. coarse c'aren.; B.C. c. 25%; sh. lam. break unit into 2-3 separate beds.	0	10	10	7
9		Med. grey, fine cryst., med. c'aren.; B.C. c. 20%; subunits: lowest 7 ins. compact, next 2 ins. laminated and low-angle cross-laminated, top 9 ins. broken up by sh. lam.; ½ in. sh. ptg. at base.	1	6	12	1
10		Shale	1	0	12	2
11		Med. dark grey, fine cryst., fine to med. c'aren.; B.C. 20%; compact; few sh. lam.	1	4	13	6
12	J.5	Med. grey, fine cryst., med. c'aren.; B.C. c. 30%; concentrations of sh. lam. at top and bottom.	0	4	13	10
13		Med. grey, fine to esp. med. cryst., med. to coarse c'aren.; B.C. 35%-45%; some sh. lam.	1	0	14	10
14		Shale	0	1	14	11
15	J.6 (middle)	Med. grey, fine to med. cryst., coarse c'aren.; B.C. c. 25%; compact; some sh. lam.	1	7	16	6
		Unit 15 outcrops directly below old lime kiln, the river bank immediately to the south is covered and up to one ft. of ls. may be covered between Units 15 and 16.				
16		Med. grey, fine cryst., med. c'aren.; B.C. less than 10%; compact but rubbly at top and bottom.	2	8	19	2
17		Med. grey, fine cryst., fine c'aren.; B.C. c. 15%; compact; no sh. lam.; ½ in. sh. ptg. at base.	1	0	20	2

		compact; few sh. lam.; weathering as Unit 4.				
6		Med. grey to med. dark grey, med. cryst., med. to coarse c'aren.; B.C. c. 35%; weathering and sh. lam. content as Units 4 and 5.	1	11	7	8
7		Med. grey, fine to med. cryst., med. c'aren.; B.C. 25%-30%; only one prominent sh. lam. at 2/3 level; ½ in. sh. ptg. at base.	1	1	8	9
8	J.4 (top)	Med. dark grey, fine to med. cryst., med. to esp. coarse c'aren.; B.C. c. 25%; sh. lam. break unit into 2-3 separate beds.	0	10	10	7
9		Med. grey, fine cryst., med. c'aren.; B.C. c. 20%; subunits: lowest 7 ins. compact, next 2 ins. laminated and low-angle cross-laminated, top 9 ins. broken up by sh. lam.; ½ in. sh. ptg. at base.	1	6	12	1
10		Shale	1	0	12	2
11		Med. dark grey, fine cryst., fine to med. c'aren.; B.C. 20%; compact; few sh. lam.	1	4	13	6
12	J.5	Med. grey, fine cryst., med. c'aren.; B.C. c. 30%; concentrations of sh. lam. at top and bottom.	0	4	13	10
13		Med. grey, fine to esp. med. cryst., med. to coarse c'aren.; B.C. 35%-45%; some sh. lam.	1	0	14	10
14		Shale	0	1	14	11
15	J.6 (middle)	Med. grey, fine to med. cryst., coarse c'aren.; B.C. c. 25%; compact; some sh. lam.	1	7	16	6
		Unit 15 outcrops directly below old lime kiln, the river bank immediately to the south is covered and up to one ft. of ls. may be covered between Units 15 and 16.				
16		Med. grey, fine cryst., med. c'aren.; B.C. less than 10%; compact but rubbly at top and bottom.	2	8	19	2
17		Med. grey, fine cryst., fine c'aren.; B.C. c. 15%; compact; no sh. lam.; ½ in. sh. ptg. at base.	1	0	20	2

18	J.7 (top)	Med. grey, fine cryst., fine c'aren.; B.C. c. 25%; few sh. lam., mainly in upper part.	1	7	21	9
19	J.8 (top)	Med. dark grey, fine cryst., med. c'aren.; B.C. 25%-30%; compact, no prominent sh. lam.; top irregular; ½ in. sh. ptg. at base.	1	2	22	11
		Top of Chaumont (?)				
20		Med. grey, fine cryst., fine c'aren.; B.C. c. 10%; top pitted, hollows av. 1 in. diameter, ¾ in. deep.	0	3	23	2
21		Shale	0	1	23	3
22	J.9	Med. grey, fine cryst. with coarse spar flecks. med. to coarse c'aren.; B.C. 35%-45%, fossils esp. numerous on top surface e.g. crinoid ossicles, *Maclurites*; top surface very irregular.	0	6	23	9

Remarks. The upper Lowville strata are very variable and the *Tetradium* unit contains *T. fibratum* rather than *T. cellulosum*. The upper boundary is again arbitrary and is here placed where a slight change in gross lithology occurs and beneath *Maclurites*-bearing beds.

Locality 24 ALFRED ROADCUT

The exposure is located ¾ mile north of Hy. 17 on the first north-south road east of Alfred, Alfred township, Prescott county. The lowest exposures are found in the wood immediately to the west of the roadcut, at the base of the north-facing scarp. The main exposure was described from the western side of the roadcut.

-2	Af.-2	Med. pink brown, very fine cryst., c'lut.; B.C. 25%-30%, mainly *T. cellulosum*; compact.	1	2	1	2
-1	Af.-1 (top)	Flaggy, rubbly ls.; ls. type variable, generally fine cryst., c'aren.; B.C. low; beds 4-6 ins. thick; top 5 ins. exposed in roadcut; unit 3-4 ft. thick.	3	6	4	8
		Base of Chaumont.				
1	Af.1 (6 ins. from base) Af.2 (6 ins. from top)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. 30%-40%, evenly distributed, sorting fairly good; compact; sh. lam. present, only prominent at 23 ins., 31 ins., and in top 4 ins.	4	6	4	6
2		Med. grey, med. cryst., med. to coarse c'aren.; B.C. c. 35%; some sh. lam., one prominent in middle.	0	5	4	11
		Covered, probably shale	0	3	5	2
3	Af.3 (middle)	Med. grey, med. cryst., coarse c'aren.; B.C. 35%-45%, fairly evenly distributed, a few "pockets" of debris; sorting only fair, some macrofossils esp. brachiopods and cephalopods; sh. lam. present, unevenly distributed.	3	9	8	11
4		Brown shale; breaking into very small pieces; weathering yellowish white.	0	1	9	0
5	Af.4 (middle)	Med. grey, med. cryst., med. to esp. coarse c'aren.; B.C. c. 45%, sorting fair; sh. lam. prominent at 11 ins., 20 ins., and 21 ins.; compact.	2	9	11	9
6	Af.5 (top 6 ins.)	Med. dark grey, med. cryst., coarse c'aren.; B.C. c. 45%; compact; one prominent sh. lam. at 6 ins.	1	8	13	5

7		Med. dark grey, med. cryst., coarse c'aren.; B.C. 40%-50%, sorting fair to good; compact, one prominent sh. lam. at 17 ins.	1	7	15	0
8		Shale, as Unit 4	0	1	15	1
9	Af.6 (upper part)	Med. dark grey, med. cryst., coarse c'aren.; B.C. 35%-45%; sh. lam. at 2-4 ins. intervals; compact.	1	9	16	10
10		Covered, probably shale.	0	2	17	0
11	Af.7 (2 ft.from base) Af.8 (9 ins. from top)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. av. 30%-45%, a few "pockets"; top 18 ins. are fine to med. c'aren.; massive, compact; prominent sh. lam. at 9 ins., 20 ins., 33 ins., 42 ins., and 50 ins.	5	10	22	10
12		Shale, as Unit 4	0	2	23	0
13		Med. dark grey, med. cryst., coarse c'aren.; B.C. 25%-40%, patchy distribution; lower 13 ins. very compact, sh. lam. in top 2 ins.	1	3	24	3
14	Af.9	Med. dark grey, med. cryst., fine c'rud.; B.C. c. 25%, fairly well distributed; compact; no sh. lam., $\frac{1}{4}$ in. sh. ptg. at base; unit faintly mottled because of two ls. types: a) med. cryst., coarse c'aren.; B.C. 20%-25%, dominant type, and b) coarse cryst., coarse c'aren. B.C. c. 60%; contacts between a) and b) sharp, highly irregular, with some areas of b) "floating" in a).	0	7	24	10
15		Med. dark grey, med. cryst., coarse c'aren.; B.C. 25%-30%; no prominent sh. lam.; $\frac{3}{4}$ in. sh. ptg. at base.	0	6	25	4
16		Shale, as Unit 4.	0	2-3	25	7
19	Af.10 (20 ins. from base) Af.11 (at 59ins.) Af.12 (6 ins. from top)	Very massive; in general: med. dark grey, med. cryst., coarse c'aren., rarely to fine c'rud.; B.C. 30%-50%, av. 35%-45%; sh. lam. common, 2 prominent ones at 30 ins., 59 ins., give rise to 3 similar subunits; lower two subunits are partly mottled as in Unit14, two ls. types: a) as in Unit 14 and b) fine cryst., fine c'aren., B.C. moderate.	8	2	33	9

<u>Remarks</u>. The upper Lowville units are quite similar to those at Jessop

Falls (locality 23) although the single head of T. fibratum seen was not in situ. The thick-bedded calcarenites are very uniform throughout. Only one factor, that of bedding, may be of value in determining a Chaumont-Rockland lithological boundary. Above Unit 10 the section is dominated by the two very thick massive units, 11 and 19. A slight change in weathering colour also takes place at the top of Unit 10, being a slightly darker sandy buff.

Locality **ALFRED QUARRY**

This is located 1½ miles N.E. of Alfred, Alfred township, Prescott county to the south of the first dirt road parallel to, and to the north of, Hy. 17. The highest units are well exposed in a small disused quarry with lower units discontinuously revealed in the field nearer to the road. Unit 1 is situated 120 yds. west of the quarry by the roadside.

1	Ad.1 (middle)	Med. grey, med. cryst., med. c'aren.; B.C. 20%-25%; many sh. lam.; exposed for 35 yds. on south side of road.	3	4	3	4
		Covered. c. 10 ft. (± c. 18 ins.)	10	0	13	4
2	Ad.2 (middle)	Med. grey, med. cryst., med. to coarse c'aren.; B.C. 20%-30%, sorting poor; sh. lam. and borings common to abundant.	2	3	15	7
		Covered	c.2	0	17	7
3	Ad.3	Med. grey, med. cryst., med. to coarse c'aren.; B.C. 20%-25%; compact; few sh. lam.	0	7	18	2
		Covered	0	6	18	8
4	Ad.4 (middle)	Med. grey to med. light grey, med. c'aren.; B.C. 20%-30%; many sh. lam.; compact.	1	6	20	2
5	Ad.5 (top)	5 ft. of partially exposed strata, top 12 ins. best exposed; ls. as in Unit 4.	5	0	25	2
6	Ad.6 (top)	Med. grey, fine to med. cryst., med. c'aren.; B.C. 20%-30%, sorting poor; some sh. lam.; few borings; top surface exposed behind barn.	1	6	26	8
		Covered. Includes top of Chaumont(?)	5	0	31	8
7		Med. grey, fine to med. cryst., fine (?) c'aren.; B.C. low, c. 20%; compact; few sh. lam.; poorly exposed.	0	6	32	2
		Covered.	1	6	33	8
8	Ad.7 (middle)	Med. grey, fine (?) cryst., fine(?) c'aren.; B.C. low; compact; few sh. lam.; poorly exposed to west of barn.	1	3	34	11

9		Partially covered; strata rubbly; ls. as Unit 10.	3	0	37	11
10	Ad.8 (base) Ad.9 (middle of top subunit)	Massive "wall" to west of barn: Lowest 22 ins.: med. grey, fine cryst., fine to med. c'aren.; B.C. 15%-20%; many sh. lam.; some borings; compact. Middle 3 ins.: med. grey, fine to med. cryst., fine to med. c'aren.; B.C. 20%-25%; level laminations; compact; no sh. lam.; few borings; base flat, top grading into upper subunit. Upper 25 ins.: med. grey, med. cryst., med. to coarse c'aren.; B.C. variable, av. 20%-30%; abundant sh. lam.; rubbly.	4	2	42	1
		Higher units exposed in quarry.				
11	Ad.10 (20 ins. from base)	Med. grey, med. cryst., fine c'aren. to fine c'rud. (mainly coarse c'aren.); B.C. 25%-50% (av. 40%-45%), unevenly distributed in thin spreads with no sharp boundaries; massive, compact; some sh. lam.; borings common; one prominent sh. lam. at 22 ins.	4	6	46	7
12	Ad.11 (3rd subunit)	Compact; 5 subunits: Lowest 8 ins.: med. grey, med. cryst., fine c'rud.; B.C. 35%-45%; some sh. lam.; borings infrequent. Next 2 ins.: med. dark grey, coarse cryst., fine c'rud.; B.C.c. 55%; bottom and top flat; weathers dark grey. Next 10 ins.: med. grey, med. cryst., med. to coarse c'aren.; B.C. 30%-40%; sh. lam., borings present. Next $\frac{1}{2}$-$\frac{3}{4}$ in.: as 2nd. subunit Top 1-2 ins.: as 3rd. subunit	1	10	48	5
13	Ad.12 (35 ins. level)	Med. grey to med. dark grey, med. cryst. with coarse spar flecks, coarse c'aren. to fine c'rud.; B.C. 20%-60% (av. 40%-45%); sh. lam. common; 2 subunits: 25 ins. and 21 ins. thick, both have coarse, frequently cross-bedded, layers in top 2 ins.	3	10	52	3
14		Med. grey, rarely med. dark grey, med. cryst., coarse c'aren.; B.C. c. 45%-50%; sh. lam. common, esp. in top 6 ins.; more uniform than Unit 13.	3	8	55	11
15	Ad.13 (middle)	Med. grey, med. cryst., coarse c'aren.; B.C. 35%-45%, sorting better than lower units; sh. lam. common; quite rubbly in lowest 6 ins.	1	4	57	3

Remarks. The lower boundary of the Chaumont is not exposed here but probably lies beneath Unit 1. The top boundary is again arbitrary but on the rather slender lithological evidence seems to lie within the 5 ft. covered interval between Units 6 and 7. In this case much of the formation is obscured.

Locality 30 KLOCK'S QUARRY, WATERTOWN, N.Y.

Klock's quarry lies adjacent to the Black River close to the junction of Huntington St. and California Avenue North (formerly Clinton St.), Watertown, New York. It is now largely infilled but a continuous, if laterally restricted, section is still available.

1	Wa.1 (9 ins. from base) Wa.2 (top 6 ins.)	Beginning at water-level on 21st July 1963. Massive, compact; med. grey, med. cryst., med. c'aren.; B.C. 20%-30%; weathers med. blue grey; sh. lam. common, major sh. ptgs. at 12 ins., 26 ins., and 50 ins.; black chert present throughout - irregular, tabular, 1-3 ins. lumps; some silicified fossils; borings present throughout.	5	0	5	0
2	Wa.3 (top 3 ins.)	Med. grey, fine cryst., fine to med. c'aren.; B.C. c. 10%; compact; weathering colour as Unit 1; some sh. lam.; chert and borings present, less common than in Unit 1; some silicified fossils.	2	1	7	1
3	Wa.4 (12 ins. from base) Wa.5 (15 ins. from top)	Med. grey, med. cryst., coarse c'aren.; B.C. 25%-35%; massive, compact; sh. lam. very common, only prominent parting at 36 ins.; borings common; unit fairly uniform throughout; chert rare to absent; silicified fossils much fewer; weathers pale sandy grey.	6	1	13	2
4	Wa.6 (12 ins. from base) Wa.7 (48 ins. from base) Wa.8 (top 3 ins.)	Med. grey, med. cryst., coarse c'aren. to fine c'rud.; B.C. 25%-30%; few "pockets" with B.C. up to 50%; massive, compact; sh. lam. common, only one major sh. ptg. at 49 ins.; chert absent.	7	2	20	4

Remarks. The section is clearly divisible into two "members", with the boundary between units 2 and 3. The lower two units are generally finer-textured, darker in weathering colour, contain abundant chert plates and silicified fossils, and are not so massively bedded as the higher units. This boundary has been drawn in the past to separate the Leray below and the Watertown above. A disconformity between them has been reported, but was not observed at this locality.

PHOTOGRAPHS (Figures 7-27)

PHOTOMICROGRAPHS (Figures 28-37)

AND

PLATES (Plates 1-5)

FIGURE 7: Meath Hill, locality 1; lower part of section with Lowville-Chaumont boundary just below top of hoop; two massive "Ottawa-type" calcarenitic units occur above hoop.

FIGURE 8: Meath Hill, locality 1; higher part of Chaumont section with shaly argillaceous calcarenites overlying a compact bed of "Lowville-type" calcilutite-calcisiltite. The beds below the latter are the highest ones shown in figure 7.

Figure 7

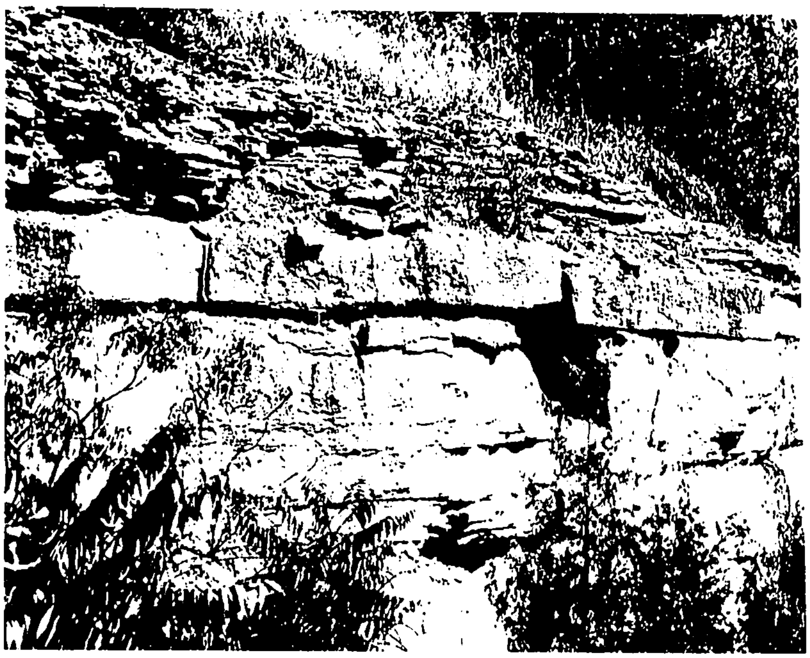


Figure 8

FIGURE 9: Pine Valley section (locality 2); compact beds at base and middle of Chaumont section are "Ottawa-type" calcarenites; massive bed at top of section is basal unit of lower Rockland calcirudites.

FIGURE 10: Pine Valley section (locality 2); contact between Chaumont and Rockland formations; massive Rockland fossiliferous intrasparudites overlying upper Chaumont platy micrites and pelmicrites, biosparites in highest foot; hammer length: 11 ins.

Figure 9

Figure 10

Figure 9

Figure 10

FIGURE 11: Fourth Chute section (locality 3); compact, massive beds near base and middle of Chaumont section are "Ottawa-type" calcarenites; recessive unit at base considered as Lowville; highest bed Rockland.

FIGURE 12: Bonnechere Lime Quarry, near Fourth Chute; lower Rockland calcirudites exhibiting a variety of cross-stratification, bedding rather thinner than usual; thick, compact, "Ottawa-type" calcarenite bed at one-third up in section.

Figure 11

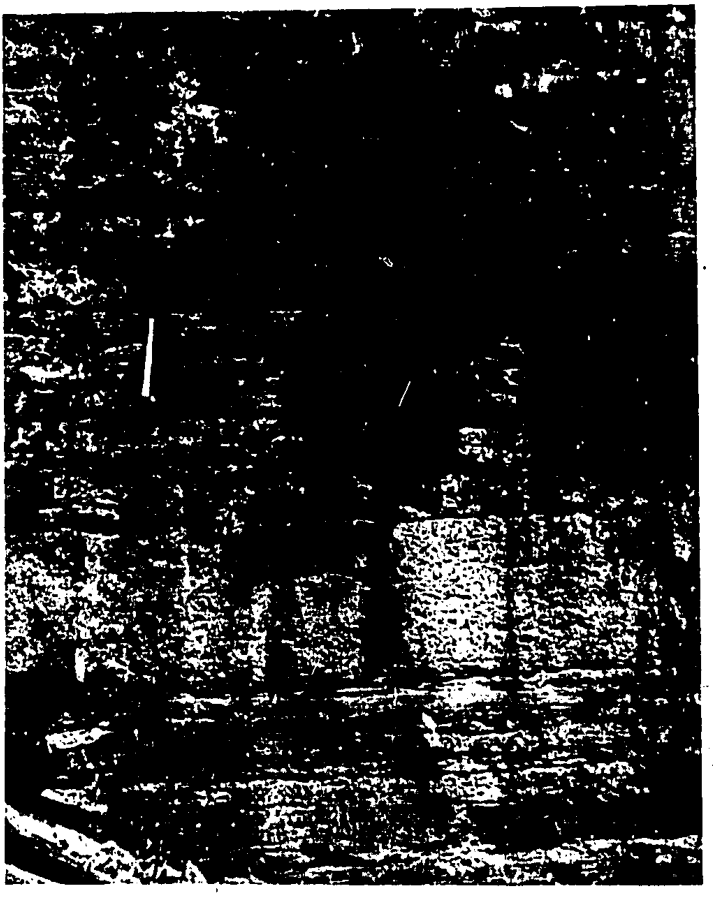


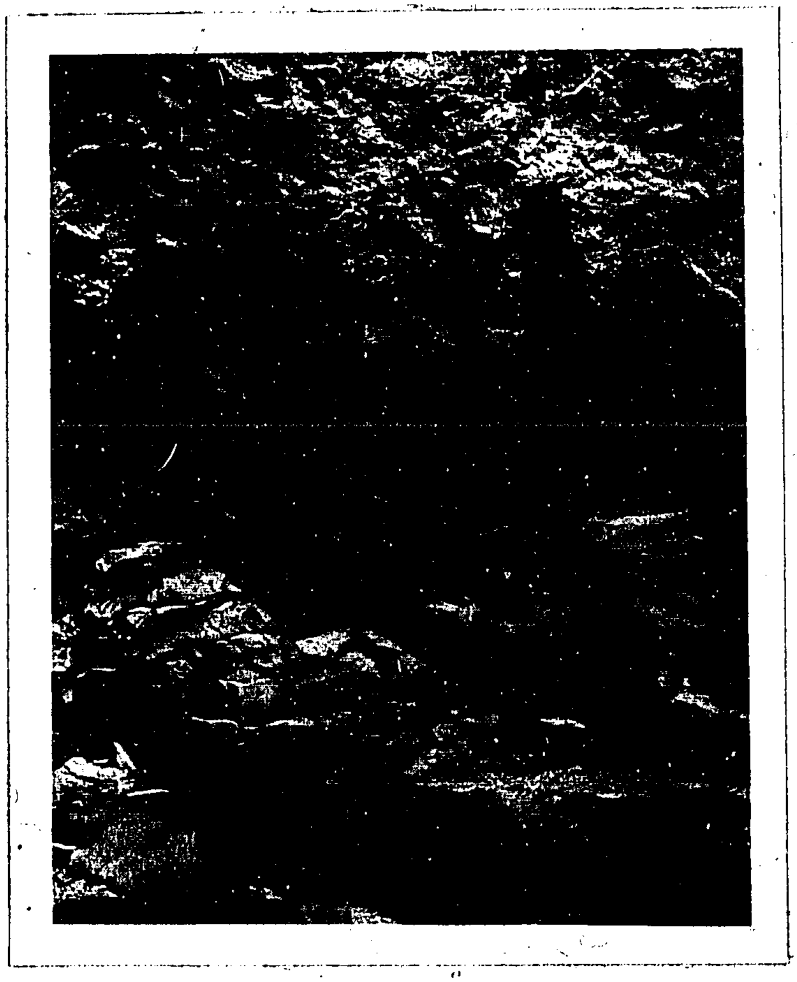
Figure 12

Figure 11

Figure 12

FIGURE 13: Pakenham Quarry (locality 5); thin-bedded Lowville calcilutites-calcisiltites containing some spar contraction stringers (c) overlain, with possible slight disconformity, by anomalous fine calcirudites and coarse calcarenites of the Chaumont.

FIGURE 14: Northwest face, Stewart Quarry, Rockland (locality 21); uppermost Lowville (<u>Tetradium</u> unit at top) underlying thick-bedded, uniform, Chaumont calcarenites. Arbitrary boundary with lithologically similar Rockland calcarenites drawn at man's hand.



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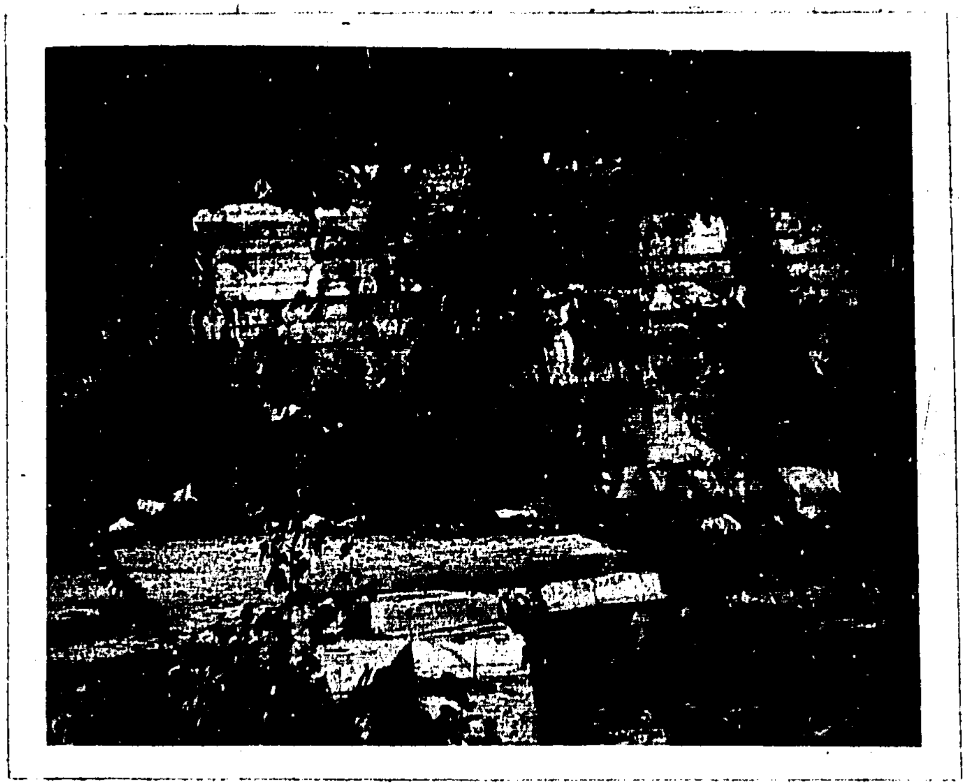

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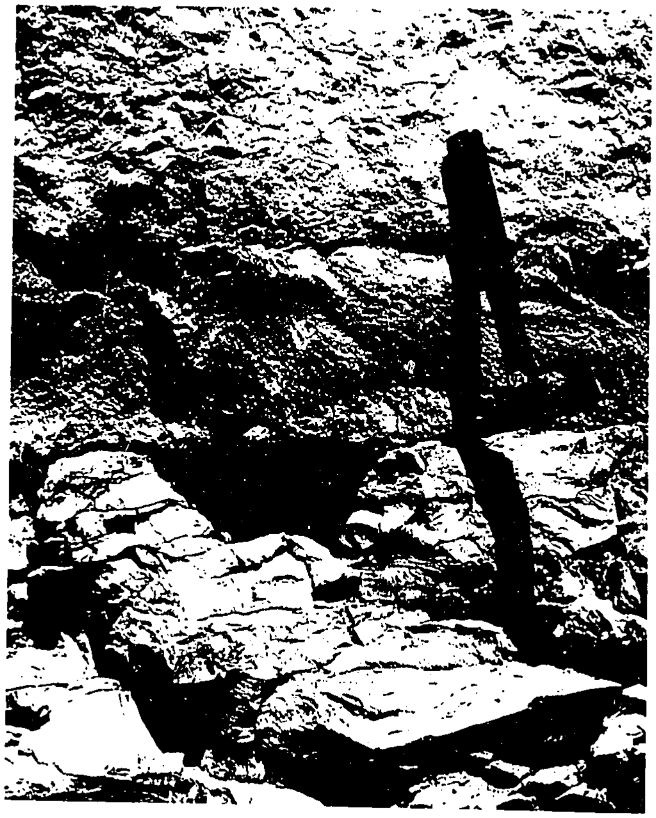
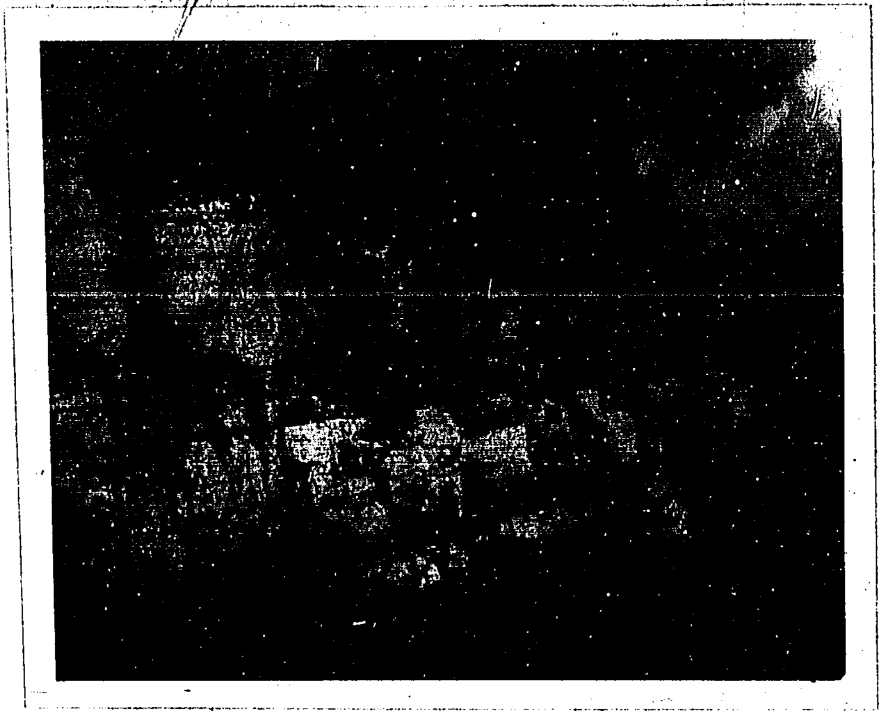


Figure 13

Figure 14

FIGURE 15: Alfred roadcut, (locality 24); thick-bedded to massive, uniform, Chaumont calcarenites; Lowville exposed below lowest bed shown in photograph.

FIGURE 16: Klock's Quarry, Watertown, N. Y. (locality 30); thick-bedded to massive, uniform, Chaumont calcarenites.



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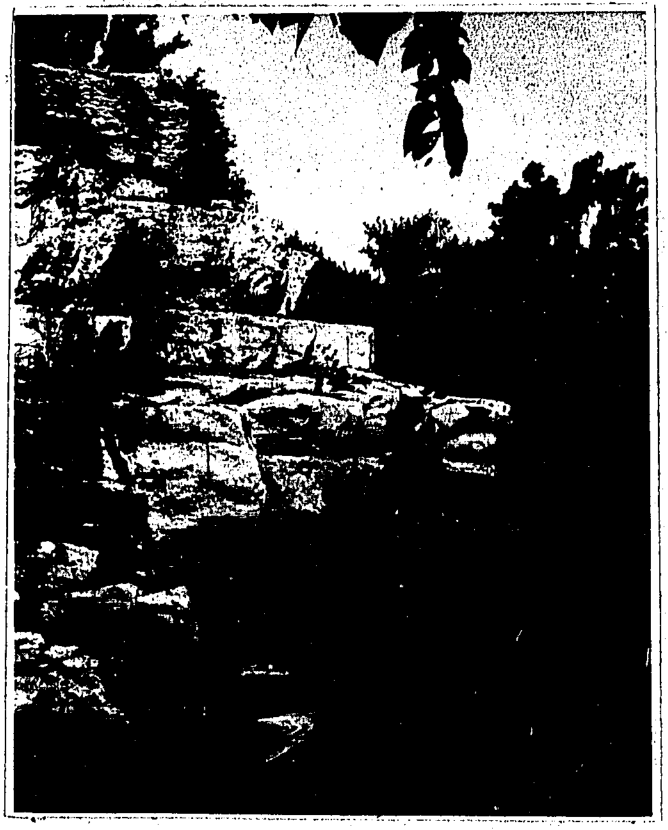

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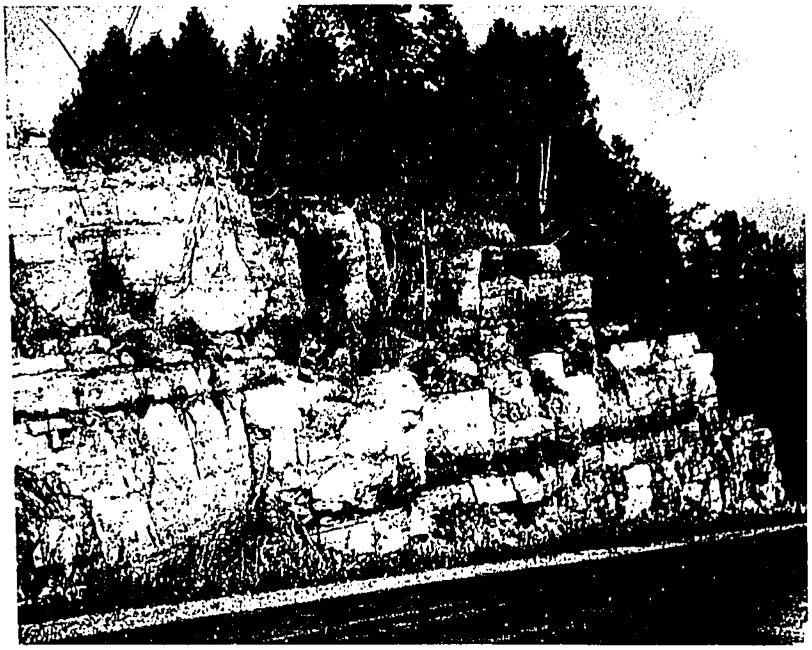


Figure 15

Figure 16

FIGURE 17: Mill Creek, Lowville, N. Y.; massive, chert-bearing, Chaumont calcarenites overlain by thin-bedded Rockland (Selby) calcilutites to fine calcarenites with numerous shale partings.

FIGURE 18: Quarry one mile north of Newport, N. Y.; thick-bedded, uniform, Rockland calcarenites ("Ottawa-type") underlain by thin-bedded Lowville calcilutites (see Kay, 1953).

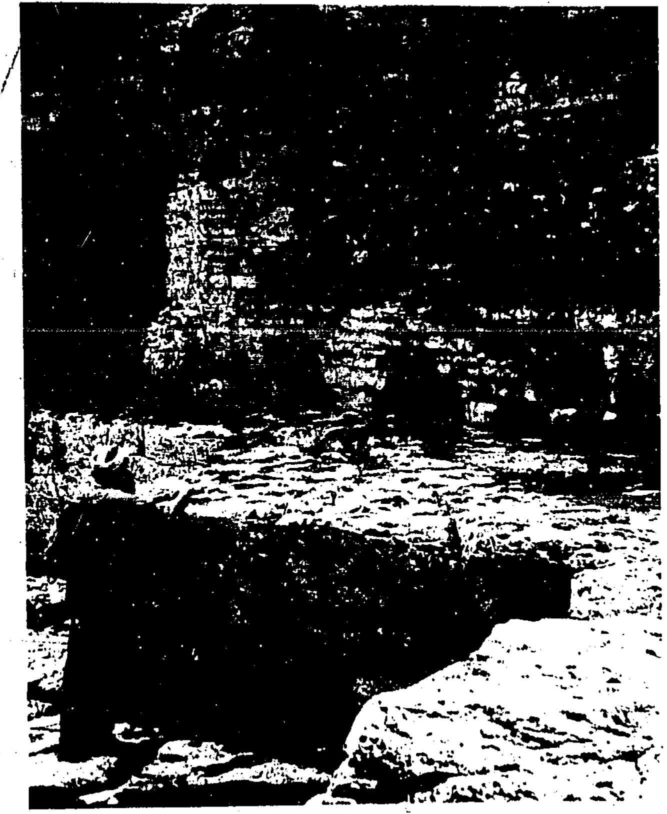


Figure 17

Figure 18

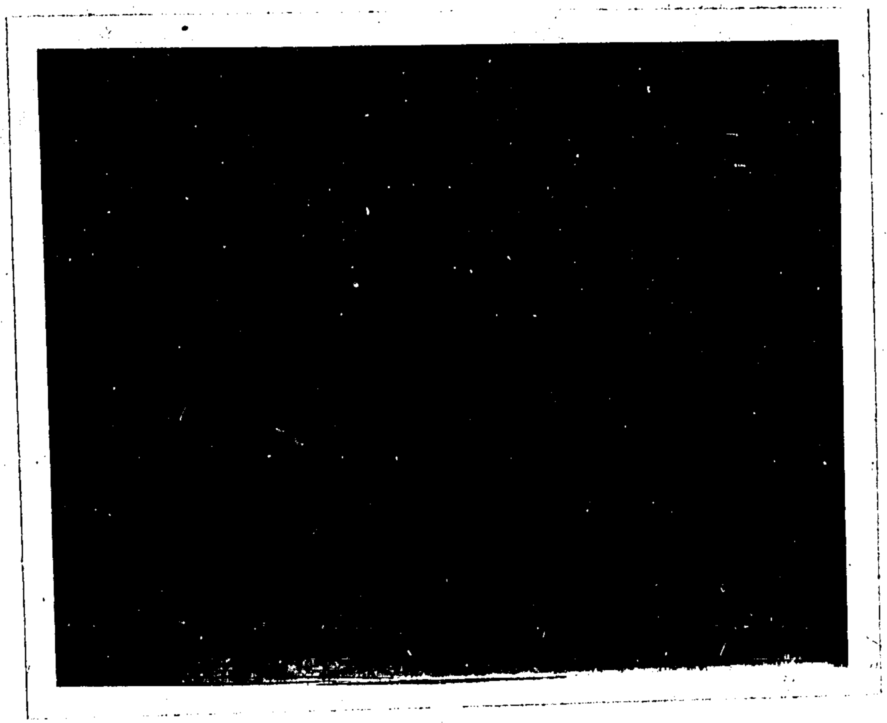
Figure 17

Figure 18

FIGURE 19: Details of irregular shale laminae within "Ottawa-type" calcarenites and associated "pockets" of skeletal debris (s); shale parting between two units at hammer head.

FIGURE 20: Slumped bedding, Burnt Lands, locality 8; note curved bedding planes of slumped beds and a few persistent undisturbed beds.

Figure 19



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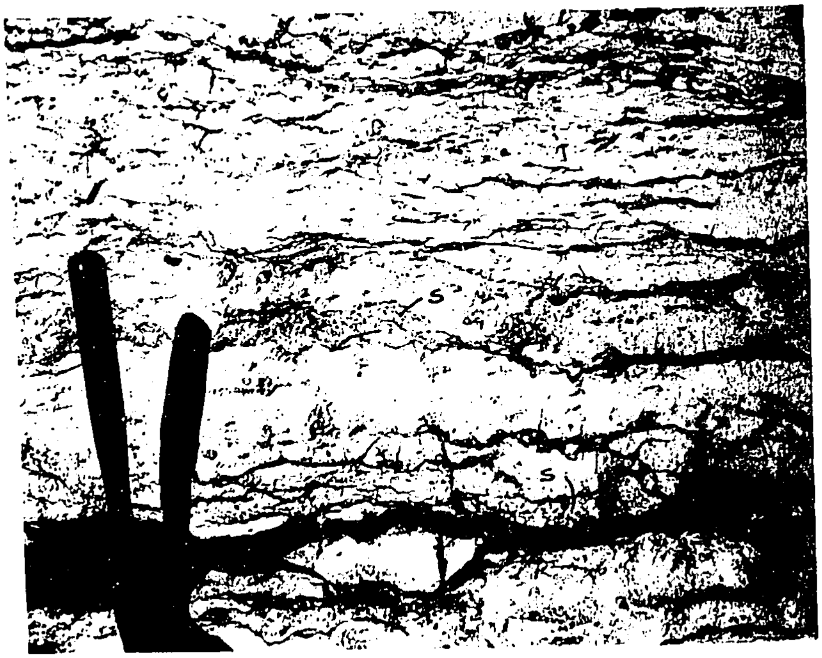


Figure 19

Figure 20

FIGURE 21: Solitary erosion channel, Burnt Lands, locality 8; irregular base of channel at hammer head with near-vertical channel wall directly above it; large blocks of limestone seen within channel-filling calcirudites; channel dimensions: 15 ft. wide, 1 ft. deep, at least 60 ft. long.

FIGURE 22: Spur-and-groove structures on the top of one unit of the upper Chaumont at Pine Valley (locality 2); some 30 parallel spurs are exposed, occasionally diverging (at hammer).

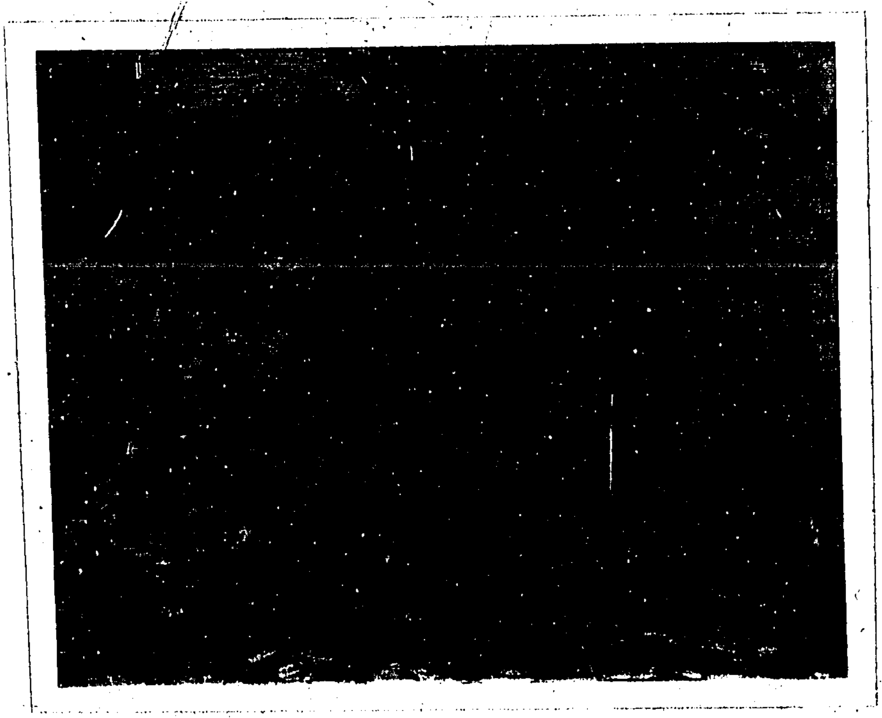
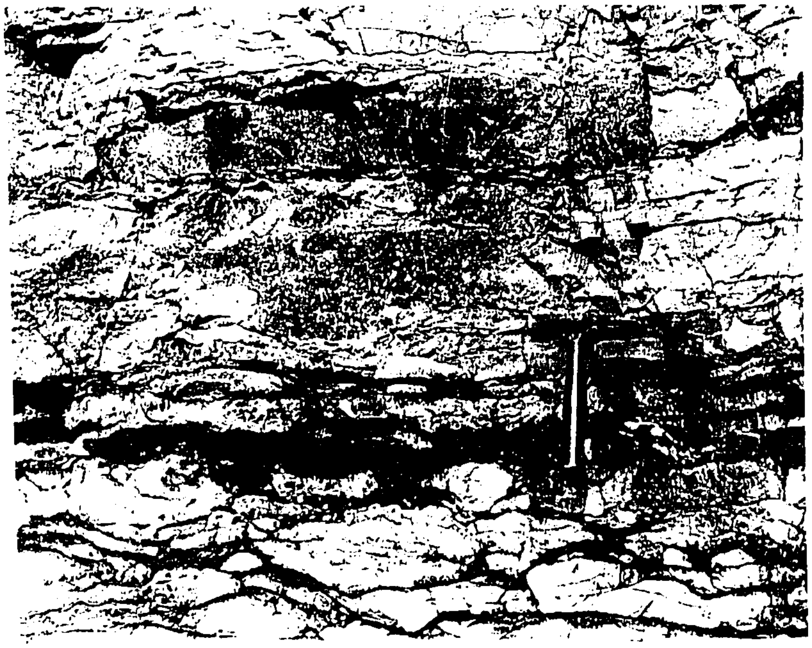


Figure 21

Figure 22



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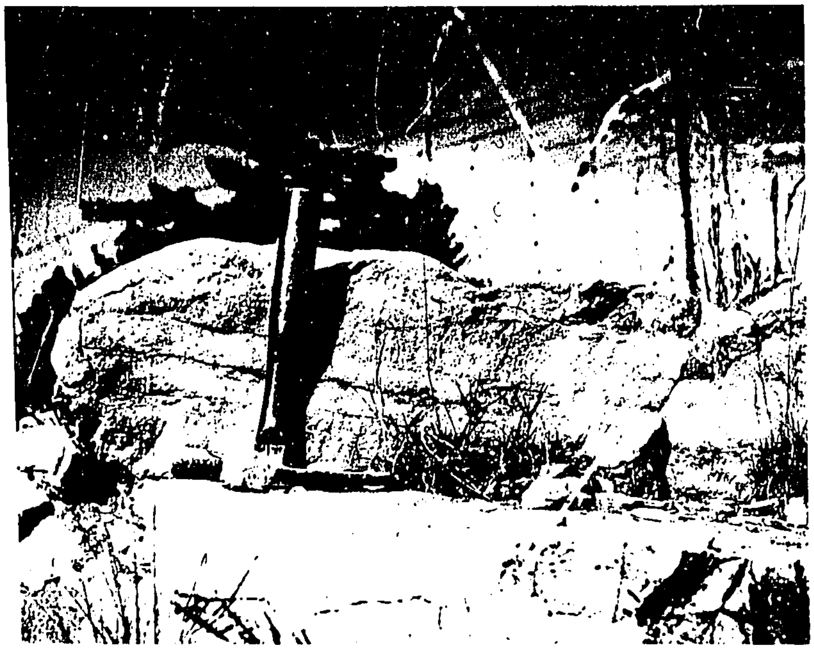


Figure 23

Figure 24

Figure 23

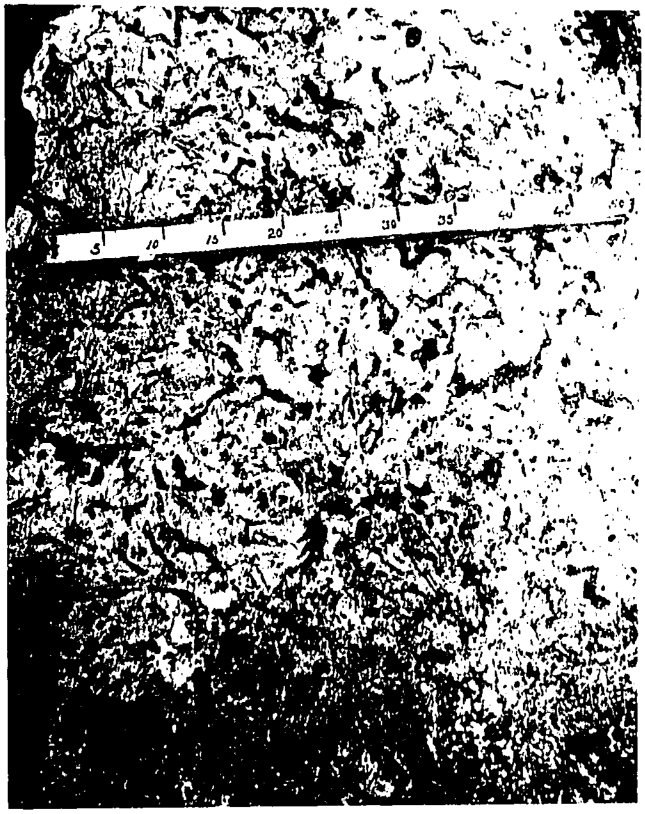


Figure 24

FIGURE 25: Vertical section of bed exhibiting mottling due to complex association of two carbonate types.

FIGURE 26: Typical Rockland unit of eastern region: uniform calcarenites with numerous shale laminae; even, thin, finely laminated bed above hammer head probably with alpha-cross-stratification, pale-weathering bed above this is probably comprised of a similar set, but top is discontinuity surface.

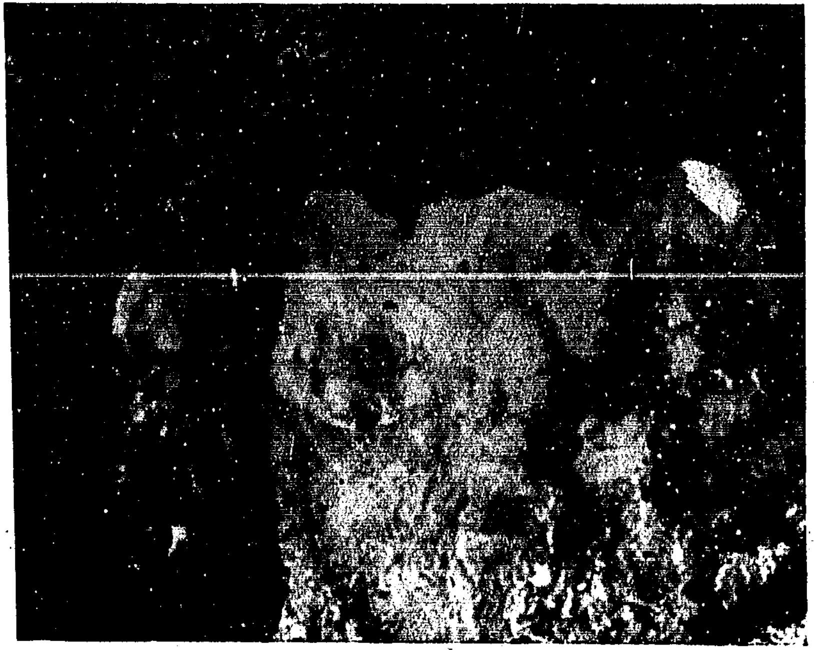


Figure 25

Figure 26

Figure 25

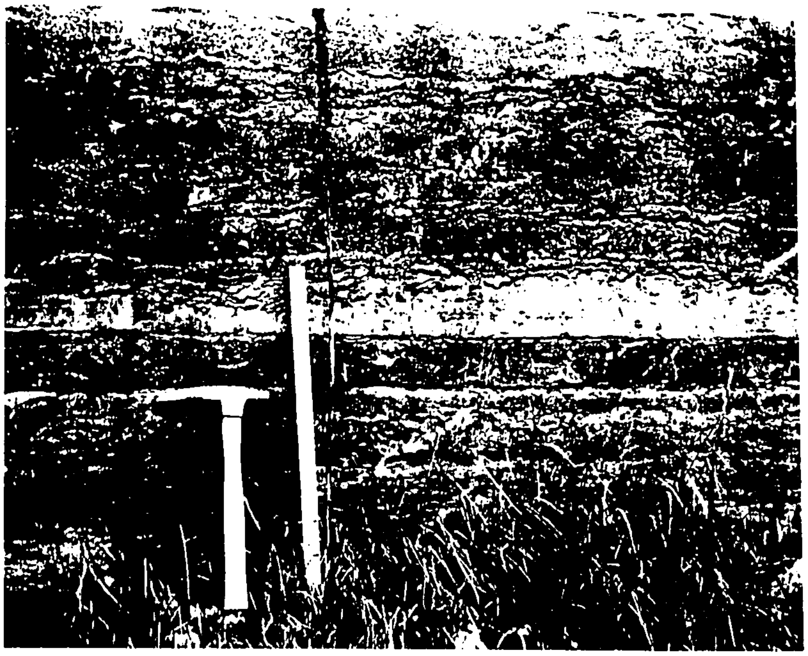


Figure 26

FIGURE 27: Stromatolites, Burnt Lands (locality 8); both vertically stacked hemispheroids (v) and concentrically stacked spheroids (c) present.

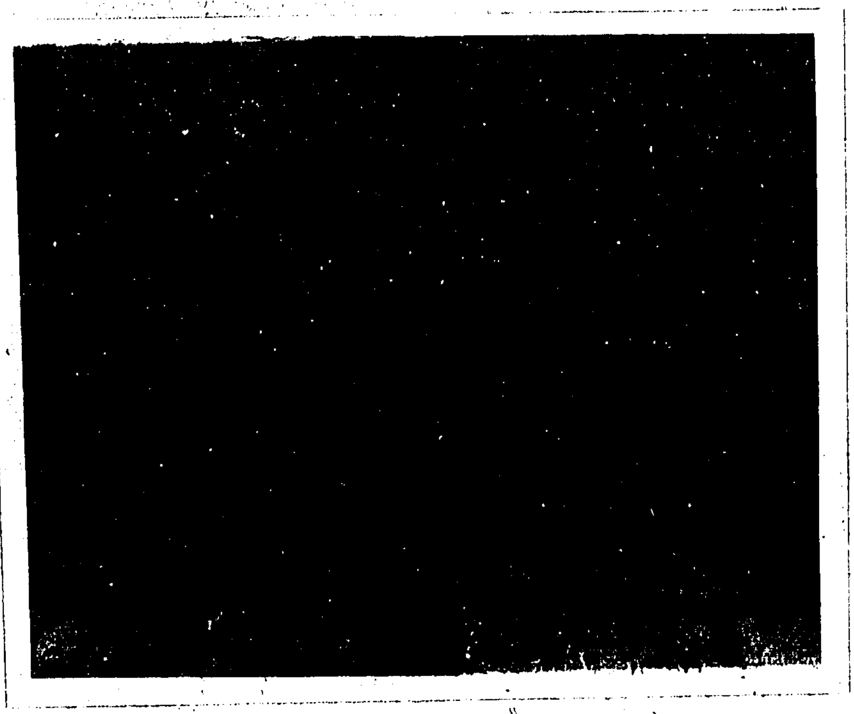


Figure 27

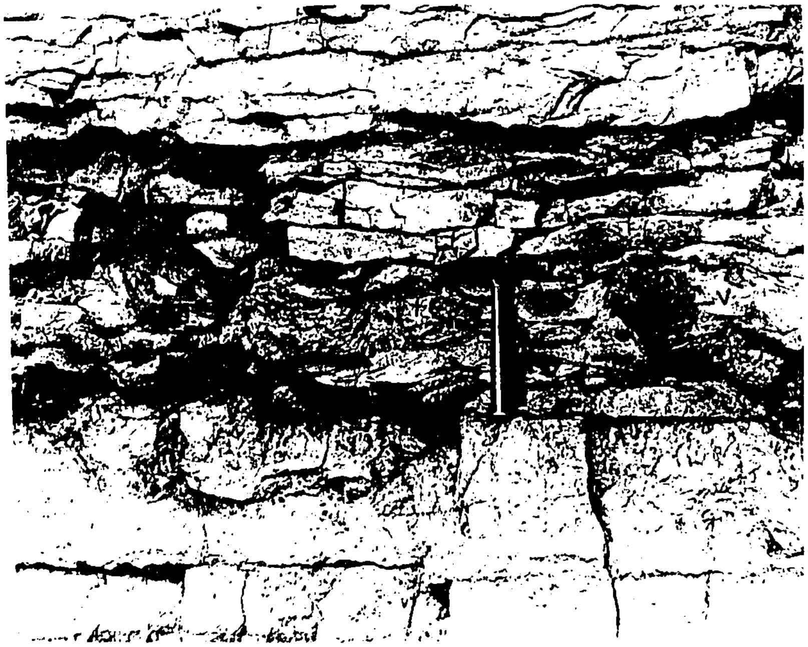
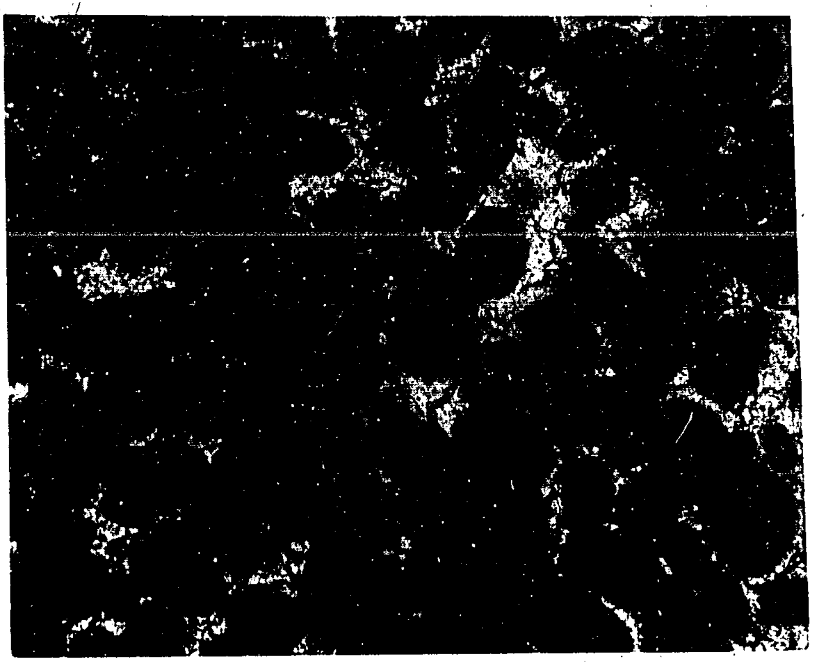


Figure 27

FIGURE 28: Chaumont pelsparite; pellets well sorted with only minor amounts of interstitial micrite (hazy); some pellets contain fine biogenic debris; compare with figure 29. x 75.

FIGURE 29: Pellet sand from Bahama Banks (impregnated with canada balsam); moderate to well sorted; some pellets contain fine biogenic debris; some exhibit superficial oölitic skins. x 55.



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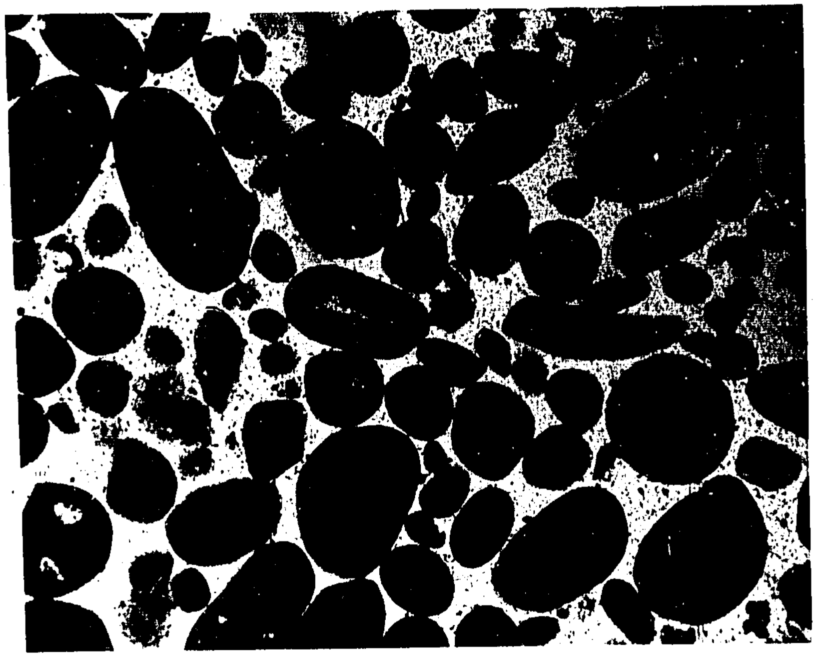


Figure 29

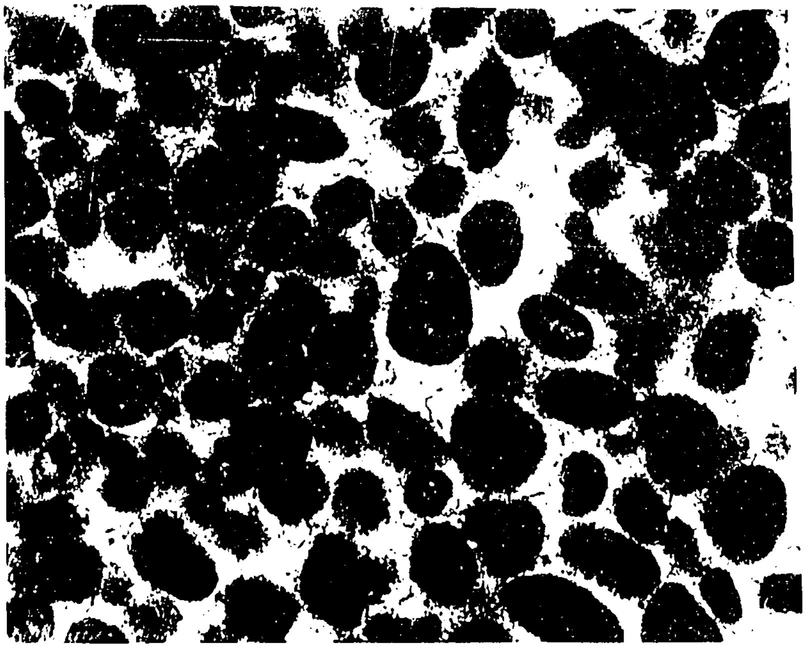


Figure 28

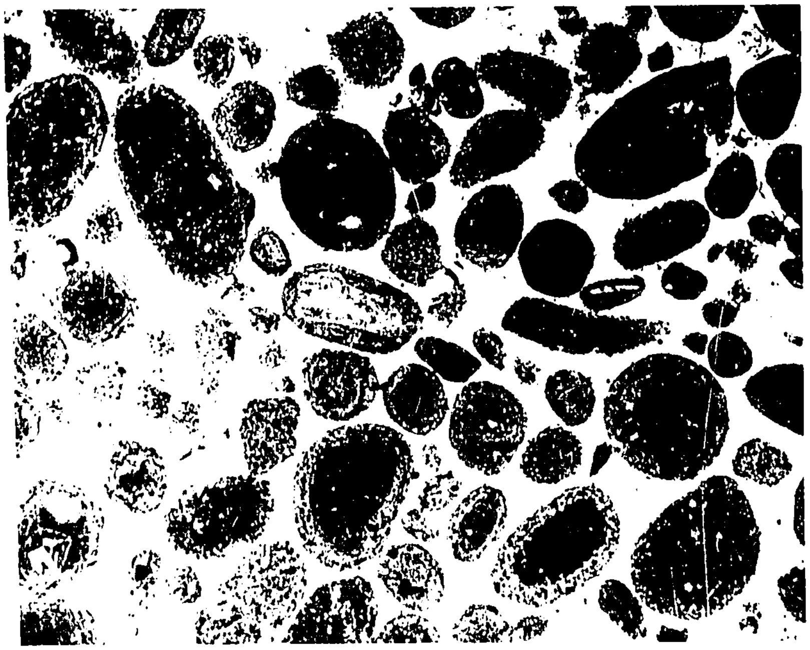


Figure 29

FIGURE 30: Chaumont intrasparudite; aggregate grains with characteristic irregular outline; almost no interstitial micrite; moderate sorting; compare with figure 31. x 55.

FIGURE 31: Aggregate-grain sand from the Bahama Banks; grains show characteristic irregular outline and internal constituent grains. x 55.

Figure 30

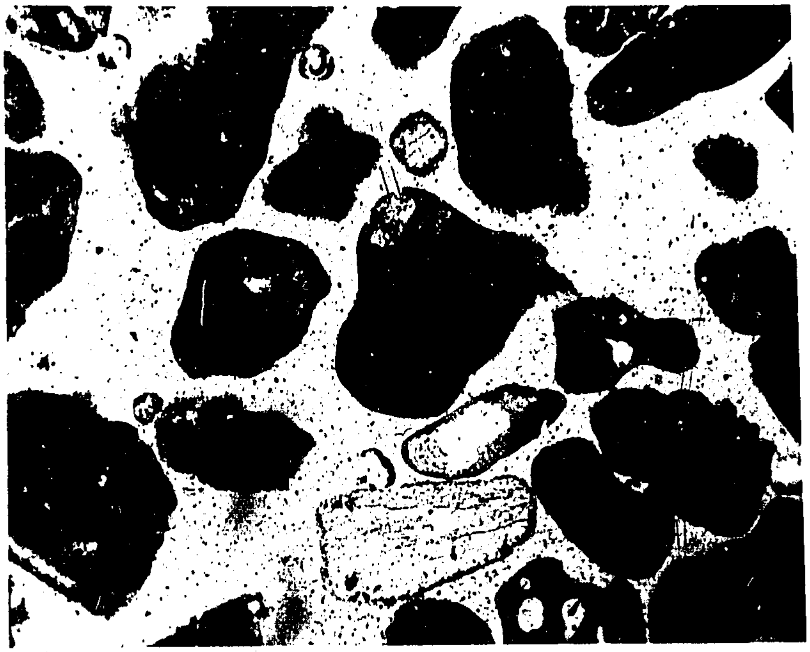


Figure 31

Figure 30

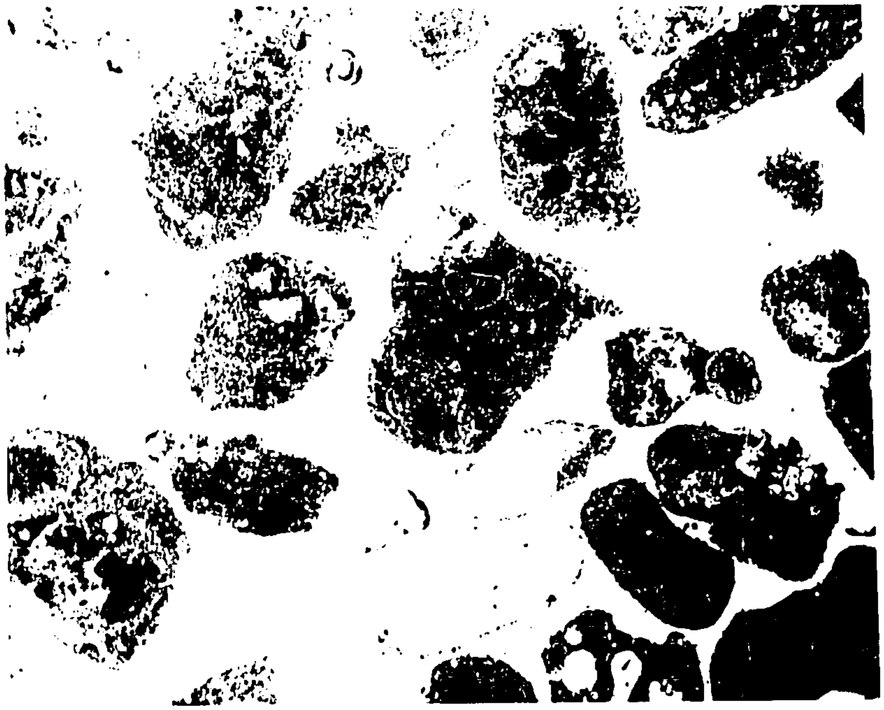
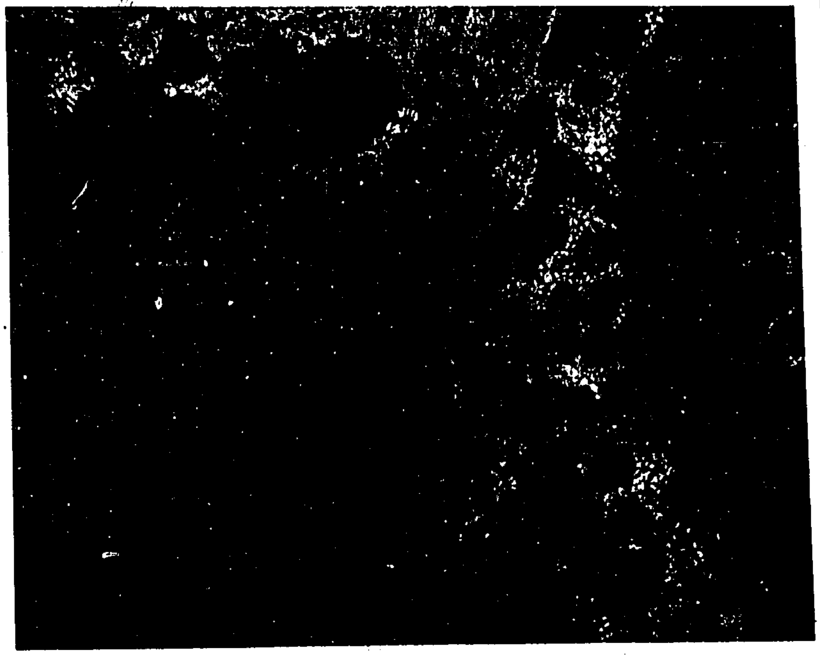


Figure 31

FIGURE 32: Chaumont intrapelsparite; poorly sorted pellets and intraclasts; part of large snowball intraclast on extreme right; minor proportions of microspar, particularly in lower left quadrant; compare with figure 33. x 50.

FIGURE 33: Carbonate sand from Bahama Banks; moderately to poorly sorted pellets and aggregate grains. x 55.



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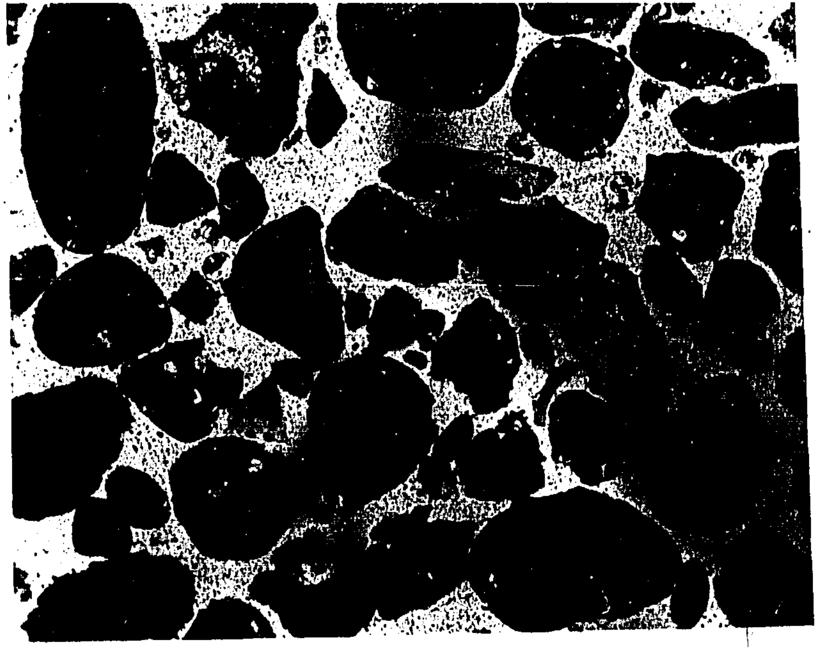

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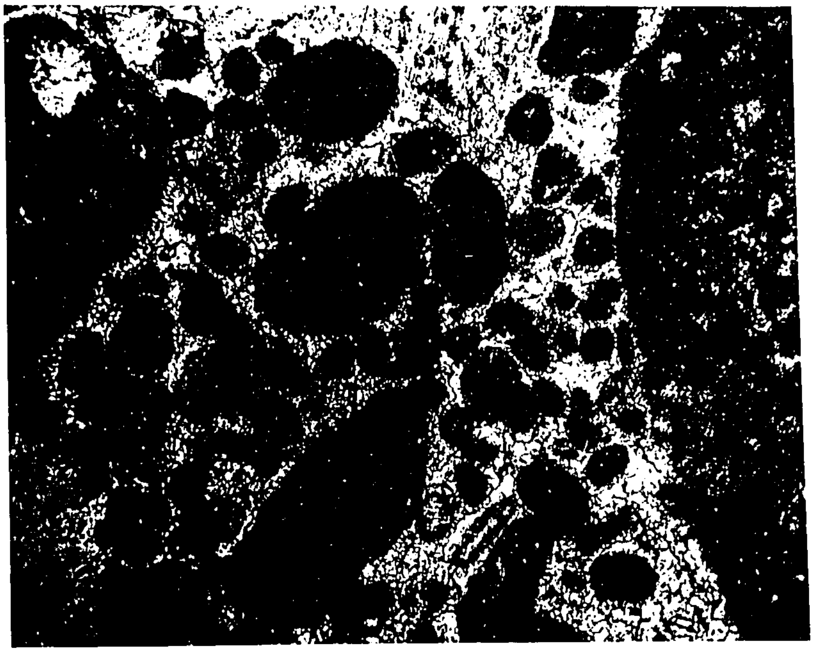

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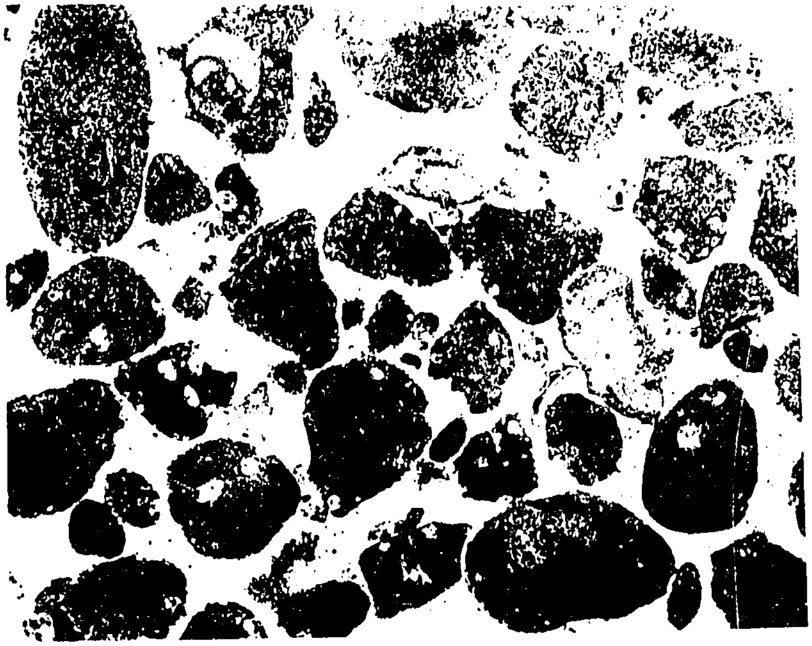


Figure 33

FIGURE 34: Chaumont intrabiosparudite; intraclasts are the pellet variety, the one on the extreme right exhibiting zoned inclusions; skeletal material mainly bryozoan; much coarse spar, some drusy mosaics along the surface of many allochems; compare with figure 35. x 55.

FIGURE 35: Same thin section as shown in figure 34, rotated through about 45°; note optical continuity of spar cement and smaller pellet intraclast immediately adjacent to that showing zoned inclusions (see figure 34), outline of intraclast shown by micritic skin. x 55.

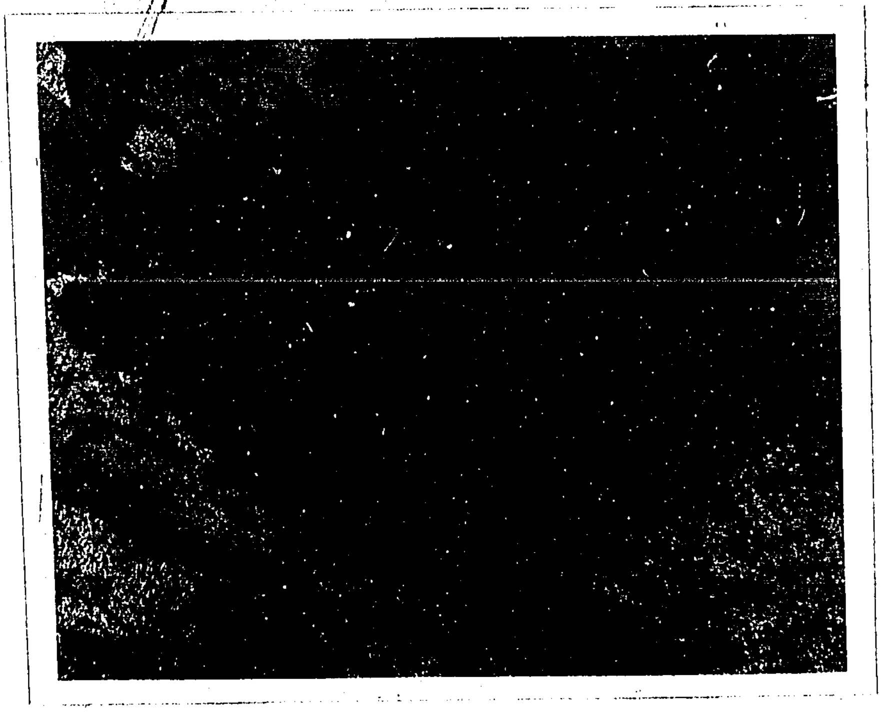
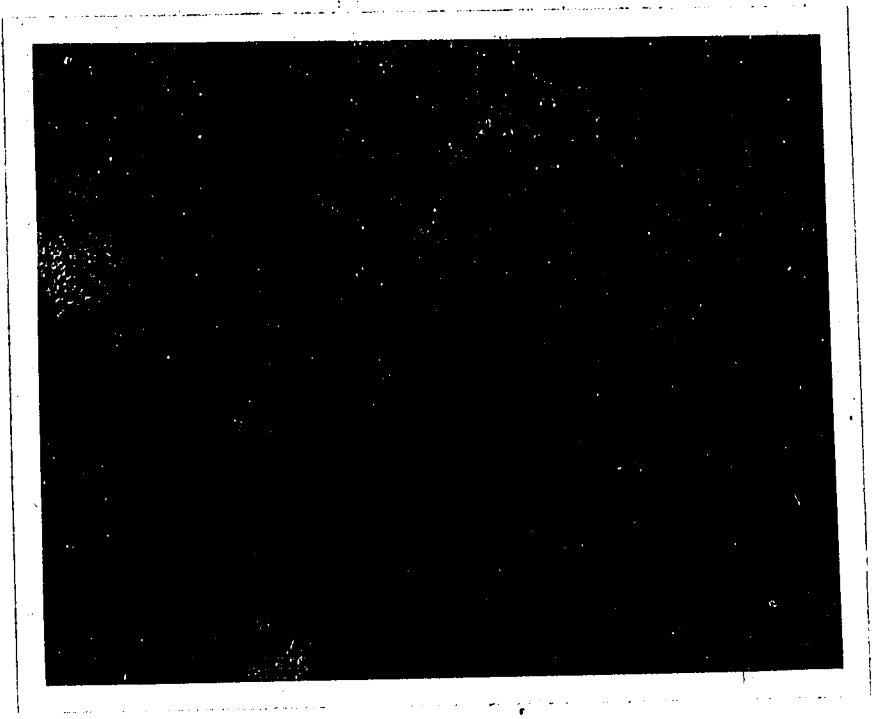


Figure 34



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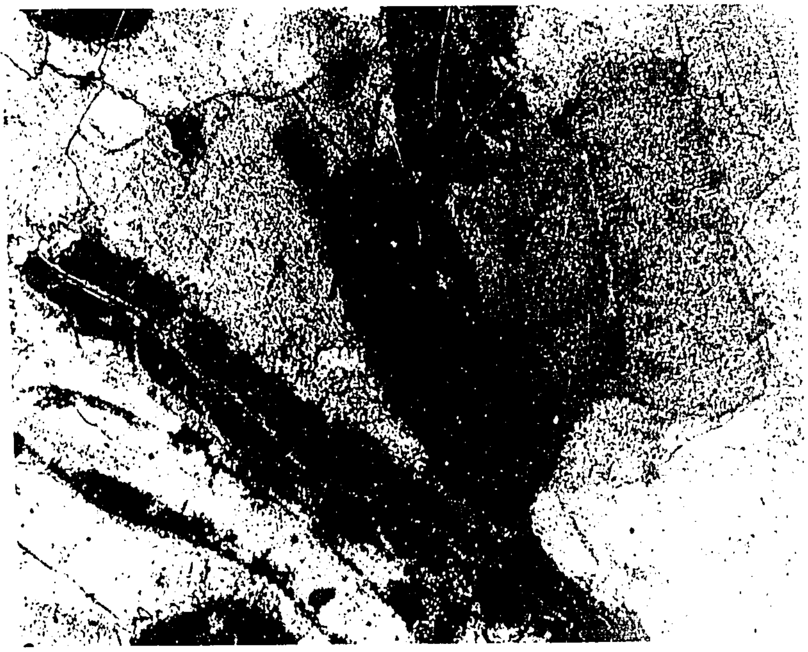

Figure 34

Figure 35

FIGURE 36: Chaumont biomicrudite; thin section of sample (P.V.9) producing highest conodont yield; allochem in lower centre exhibits zoned inclusions; bivalves at right and left hand edges only partly filled with micrite, upper void space now filled with spar. x 50.

FIGURE 37: Chaumont micrite; stylolite passes into shale lamina containing a concentration of quartz grains and dolomite rhombs; spar-filled fractures end abruptly at stylolite. x 55.

Figure 36

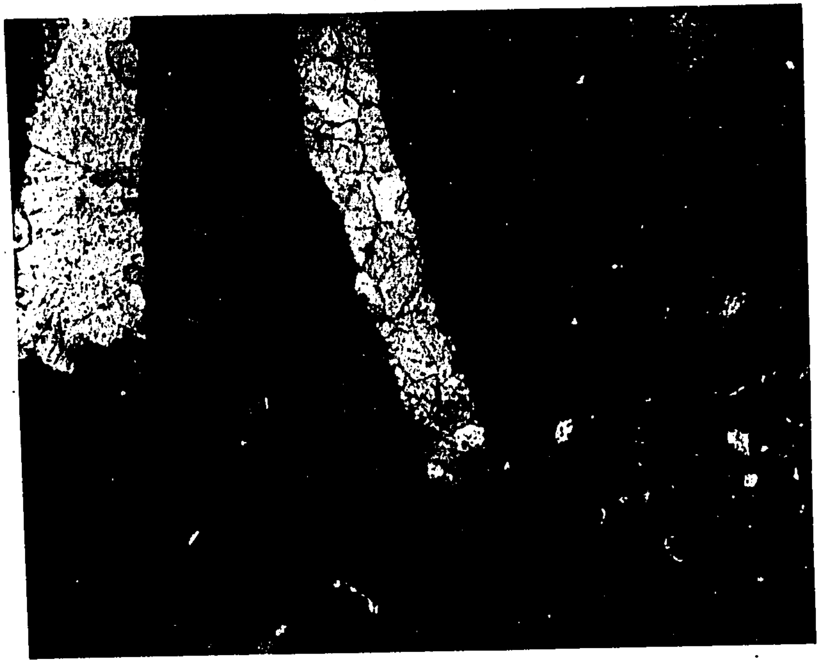

Figure 37

Figure 36

Figure 37

FIG. 13: Belodina ornata (Branson and Mehl). Hypotype, inner lateral view, x 65. U.O. 04515/108; p. 195.

14: Eobelodina fornicala (Stauffer). Hypotype, outer lateral view, x 65. U.O. 26113/204; p. 217.

15: Belodina diminutiva (Branson and Mehl). Hypotype, outer lateral view, x 65. U.O. 04155/107; pp. 191-192.

16: Cordylodus concinnus Branson and Mehl. Hypotype, inner lateral view, x 65. U.O. 13121/210; p. 206.

17: Cordylodus delicatus Branson and Mehl. Hypotype, inner lateral view, x 65. U.O. 13313/110; pp. 206-207.

18: Cordylodus dilatus (Stauffer). Hypotype, inner lateral view, x 65. U.O. 13213/209; pp. 207-208.

19: Eoligonodina robusta Branson, Mehl, and Branson. Hypotype, inner lateral view, x 45. U.O. 14129/209; pp. 218-219.

PLATE 1

Slightly retouched photographs of uncoated conodonts from the Chaumont Formation and adjacent strata, western Ottawa Valley.

FIG. 1: Panderodus striatus (Stauffer). Hypotype, inner lateral view, x 65. U.O. 10527/208; p. 242.

2: Panderodus compressus (Branson and Mehl). Hypotype, inner lateral view, x 65. U.O. 01419/207; pp. 238-239.

3: Panderodus panderi (Stauffer). Hypotype, inner lateral view, x 65. U.O. 01615/106; pp. 241-242.

4: Panderodus gracilis (Branson and Mehl). Hypotype, inner lateral view, x 65. U.O. 01115/208; pp. 240-241.

5: Panderodus feulneri (Glenister). Hypotype, inner lateral view, x 65. U.O. 01713/105; pp. 239-240.

6: Drepanodus homocurvatus Lindström. Hypotype, lateral view, x 30. U.O. 03213/209; pp. 213-215.

7: Drepanodus suberectus (Branson and Mehl). Hypotype, lateral view, x 30. U.O. 03113/302; pp. 215-216.

8: Oistodus inclinatus Branson and Mehl. Hypotype, inner lateral view, x 45. U.O. 02115/201; p. 231.

9: Oistodus robustus Bergström. Hypotype, outer lateral view, x 65. U.O. 02225/3(-1); pp. 232-233.

10: Belodina compressa (Branson and Mehl). Hypotype, outer lateral view, x 65. U.O. 04419/111; pp. 190-191.

11: Belodina grandis (Stauffer). Hypotype, inner lateral view, x 65. U.O. 04219/1(-1); pp. 192-193.

12: Belodina cf. B. inclinata (Branson and Mehl). Hypotype, inner lateral view, x 65. U.O. 04313/306; pp. 193-195.

PLATE I

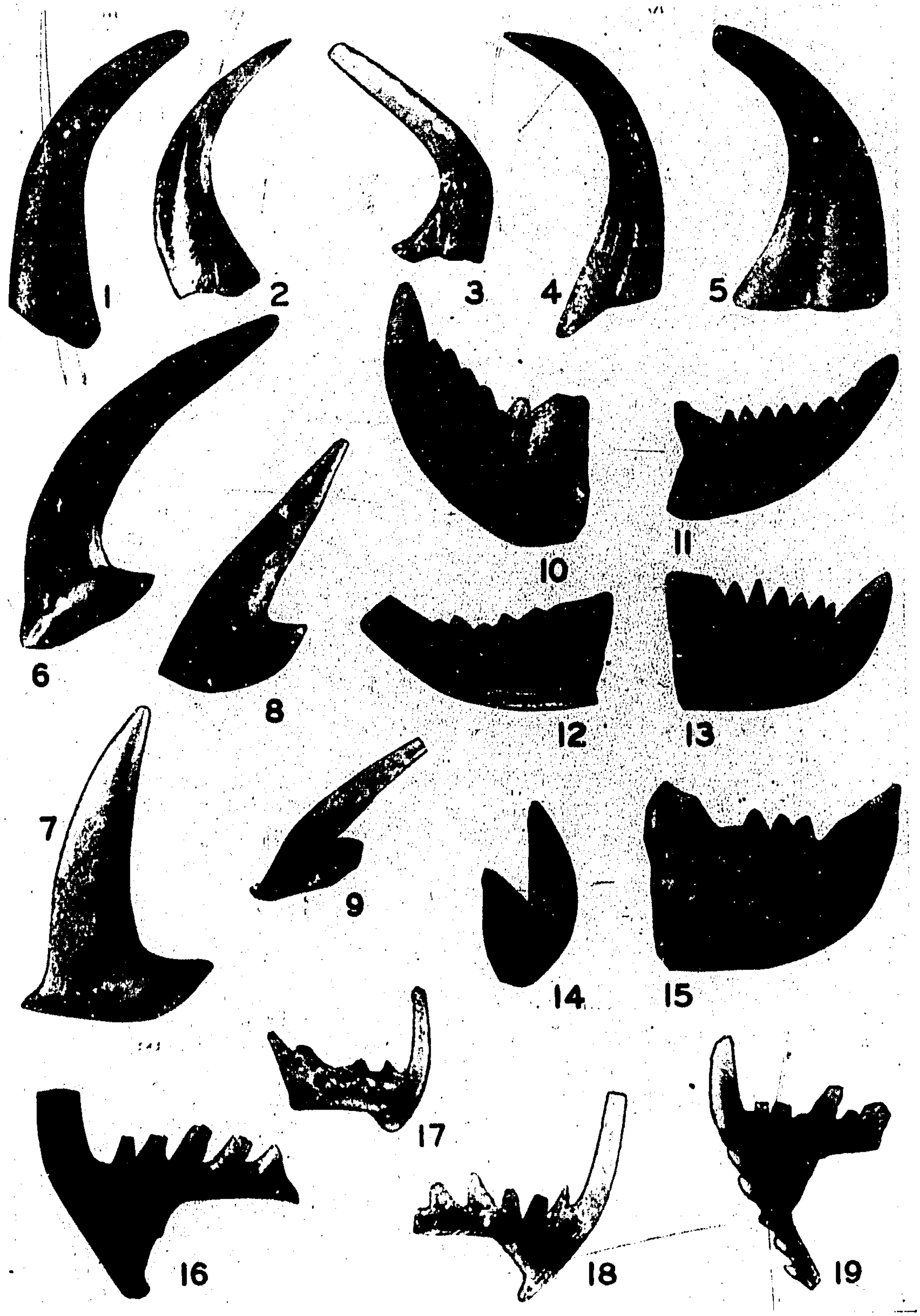

PLATE I


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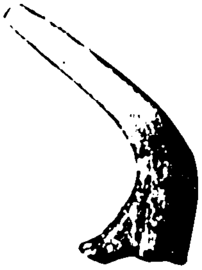
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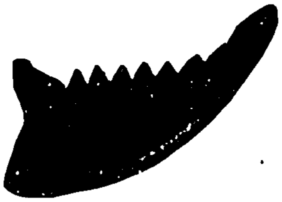
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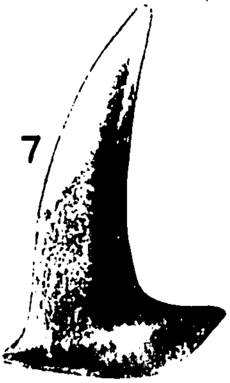
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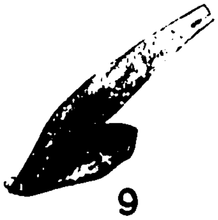
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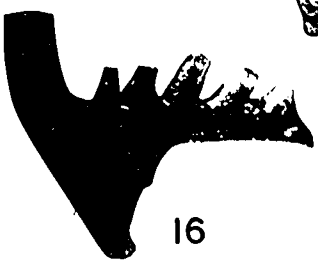
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PLATE 2

Slightly retouched photographs of uncoated conodonts from the Chaumont Formation and adjacent strata, western Ottawa Valley.

FIG. 1: *Erismodus* cf. *E. simplex* Branson and Mehl. Posterior view, x 35. U.O. 11213/306; p. 224.

2: *Erismodus abbreviatus* Branson and Mehl. Posterior view, x 45. U.O. 11117/208; pp. 220-221.

3, 4: *Erismodus* n. sp. A Barnes. Holotype, posterior and anterior views, x 45. U.O. 11417/210; pp. 225-226.

5: *Stereoconus* n. sp. A Barnes. Holotype, lateral view, x 45. U.O. 17113/306; pp. 254-255.

6: *Erismodus* cf. *E. digitatus* Branson and Mehl, Hypotype, posterior view, x 65. U.O. 11617/208; pp. 221-222.

7: *Erismodus* cf. *E. radicans* (Hinde). Hypotype, posterior view, x 40. U.O. 11521/208; pp. 222-224.

8: *Ptiloconus gracilis* (Branson and Mehl). Hypotype, inner lateral view, x 45. U.O. 09143/306; p. 253.

9: *Microcoelodus unicornis* Branson and Mehl. Hypotype, aboral view,x. 40. U.O. 10415/210; p. 229.

10: *Microcoelodus asymmetricus* Branson and Mehl. Hypotype, posterior view, x 45. U.O. 10621/207; p. 227.

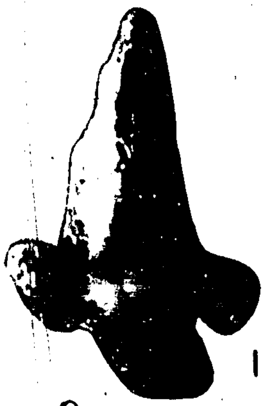
11: *Microcoelodus intermedius* Branson and Mehl. Hypotype, posterior view, x 40. U.O. 10319/201; p. 228.

12: *Chirognathus* cf. *C. delicatula* Stauffer. Hypotype, inner lateral view, x 65. U.O. 29115/1(-2); p. 204.

13: *Microcoelodus expansus* Branson and Mehl. Hypotype, posterior view, x 45. U.O. 10215/307; pp. 227-228.

14: *Microcoelodus* n.sp. A Barnes. Holotype, posterior view, x 45. U.O. 10113/303; pp. 229-230.

PLATE 2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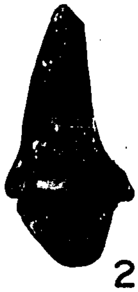
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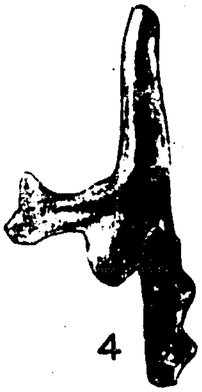
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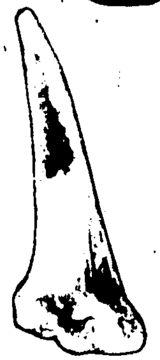
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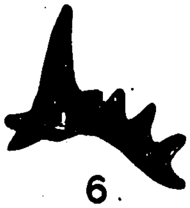
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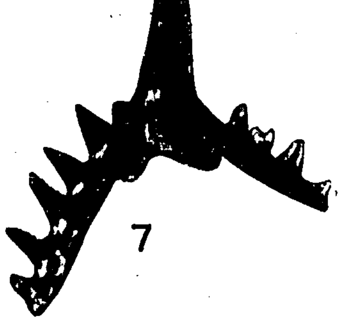
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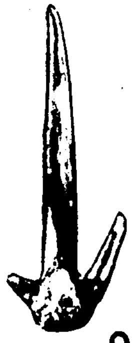
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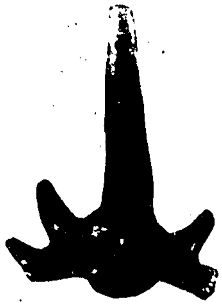
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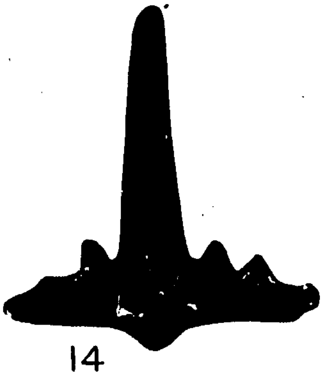
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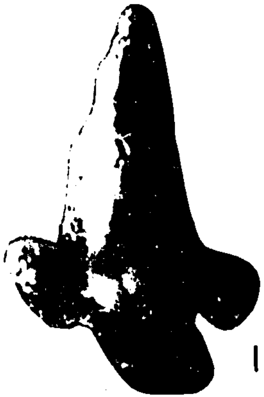
PLATE 2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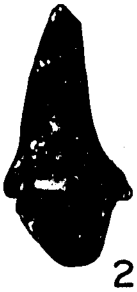
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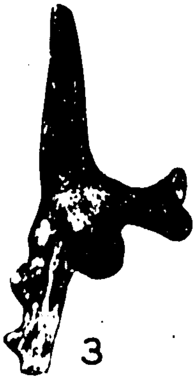
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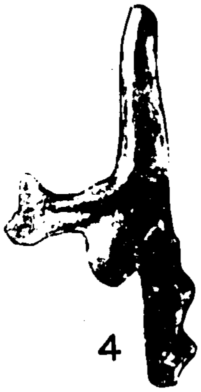
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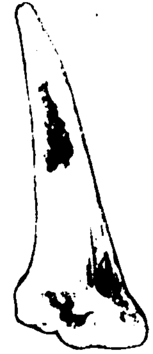
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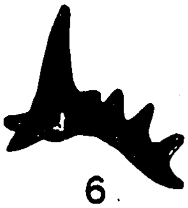
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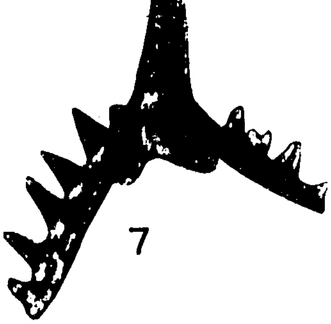
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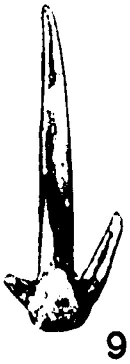
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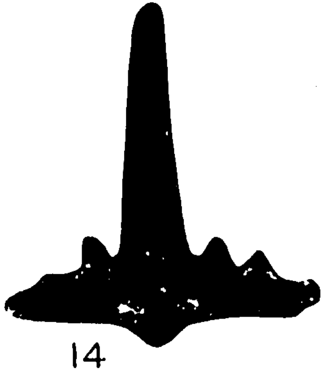
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FIG. 16: *Curtognathus peculiaris* Branson and Mehl. Hypotype, inner lateral view, x 45. U.O. 06223/214; pp. 210-211.

17: *Cardiodella divaricata* (Branson and Mehl). Oral view, x 45. U.O. 07219/213; p. 198.

18, 19: *Cardiodella* n. sp. B Barnes. Oral and posterior view, x 65. U.O. 07113/308; pp. 202-203.

20: *Curtognathus limitaris* Branson and Mehl. Hypotype, inner lateral view, x 45. U.O. 06323/209; pp. 209-210.

PLATE 3

Slightly retouched photographs of uncoated conodonts from the Chaumont Formation and adjacent strata, western Ottawa Valley.

FIG. 1: N. gen. A n. sp. A Barnes. Genotype, oral view, x 65. U.O. 27113/208; pp. 189-190.

2: *Trucherognathus distorta* Branson and Mehl. Hypotype, oral view, x 45. U.O. 08313/308; p. 259.

3: *Trucherognathus* cf. *T. disparalis* Branson and Mehl. Hypotype, inner-aboral view, x 45. U.O. 08713/209; p. 258.

4, 5: *Trucherognathus?* sp. Inner-lateral and oral views, x 45. U.O. 08213/210; p. 262.

6: *Trucherognathus parallela* Branson and Mehl. Hypotype, oral view, x 65. U.O. 08515/210; pp. 259-260.

7: *Cardiodella* cf. *C. divisa* Branson and Mehl. Hypotype, oral view, x 65. U.O. 07415/305; p. 199.

8, 9: *Trucherognathus* n. sp. A Barnes. Holotype, inner-lateral and oral views, x 45. U.O. 08213/306; pp. 261-262.

10: *Trucherognathus sinuosa* Branson and Mehl. Hypotype, lateral view, x 45. U.O. 08119/208; pp. 260-261.

11: *Cardiodella* cf. *C. robusta* (Branson and Mehl). Hypotype, oral view, x 65. U.O. 07617/307; pp. 200-201.

12, 13: *Cardiodella* n. sp. A Barnes. Holotype, antero-lateral and oral views, x 45. U.O. 07515/208; pp. 201-202.

14: *Curtognathus coronata* Branson and Mehl. Hypotype, inner lateral view, x 65. U.O. 06415/111; pp. 208-209.

15: *Cardiodella diminutiva* (Branson and Mehl). Hypotype, oral view, x 65. U.O. 07317/111; pp. 196-197.

PLATE 3

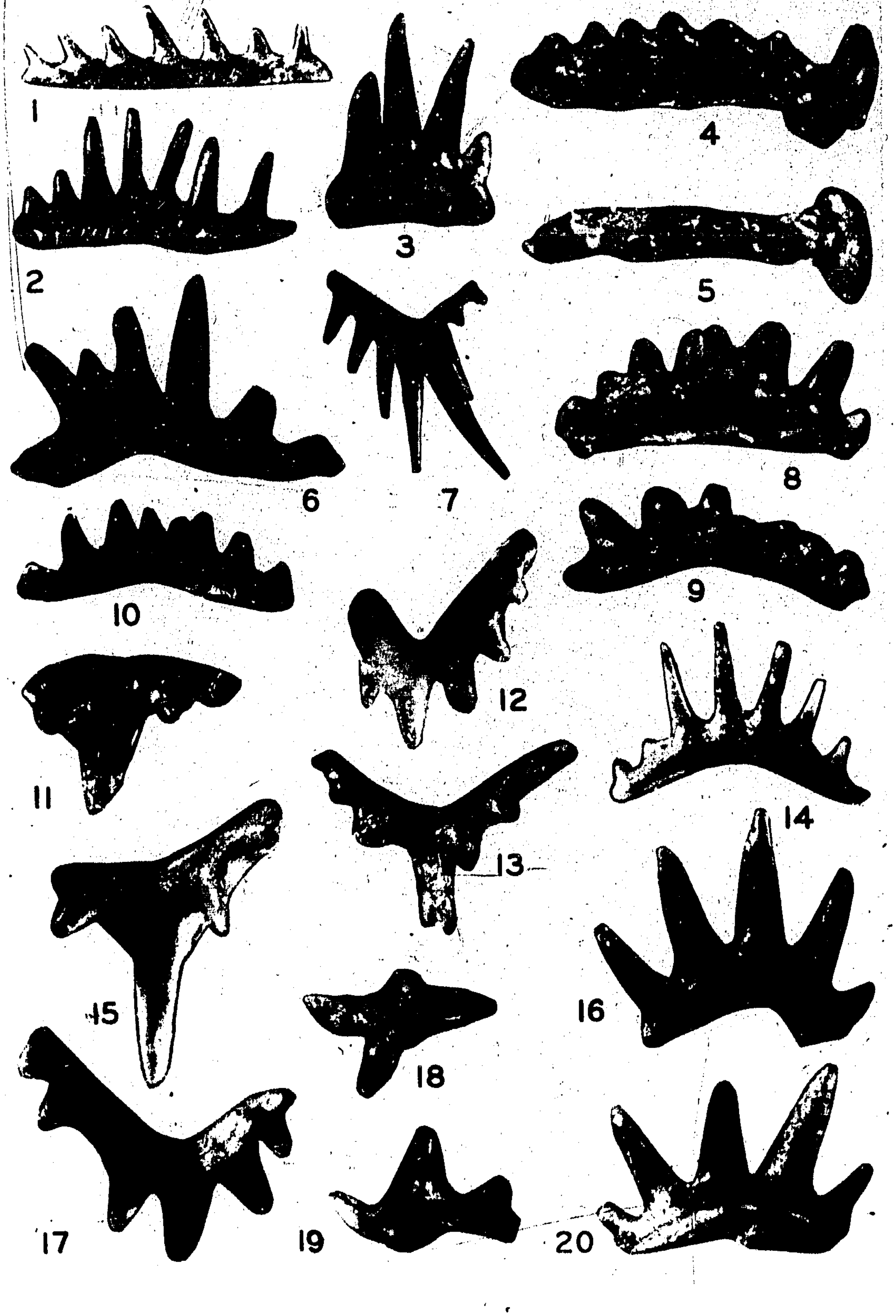

PLATE 3


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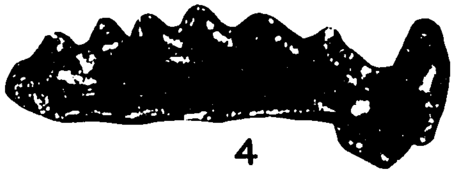
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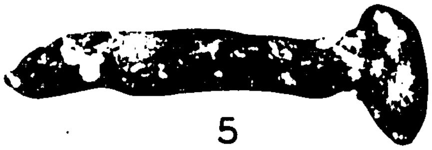
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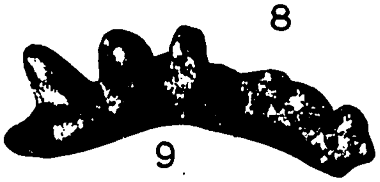
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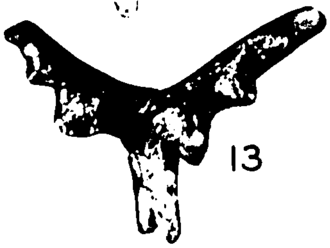
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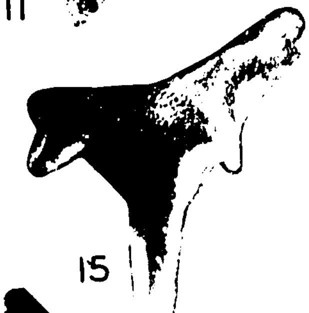
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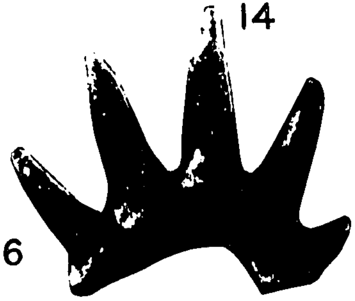
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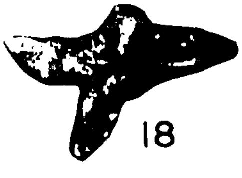
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U.O. 08213/306; p. 256.

FIG. 16: Oulodus casteri Pulse and Sweet. Hypotype, posterior view, x 45. U.O. 21113/3(-1); pp. 233-234.

17: Zygognathus cf. Z. maysvillensis Pulse and Sweet. Hypotype, posterior view, x 65. U.O. 24117/210; pp. 263-264.

PLATE 4

Slightly retouched photographs of uncoated conodonts from the Chaumont Formation and adjacent strata, western Ottawa Valley.

FIG. 1: Polycaulodus n. sp. B Barnes. Holotype, lateral view, x 65. U.O. 05715/104; pp. 248-249.

2: Polycaulodus normalis Branson and Mehl. Hypotype, lateral view, x 45. U.O. 05613/213; p. 246.

3: Polycaulodus cornulatus Branson and Mehl. Hypotype, lateral view, x 65. U.O. 05513/214; pp. 245-246.

4: Polycaulodus tridentatus Branson and Mehl. Hypotype, lateral view, x 65. U.O. 05217/107; pp. 247-248.

5: Polycaulodus aff. P. bidentatus Branson and Mehl. Hypotype, aboral view, x 65. U.O. 05821/214; pp. 244-245.

6: Polycaulodus bidentatus Branson and Mehl. Hypotype, lateral view, x 65. U.O. 05119/210; pp. 243-244.

7: Polycaulodus n. sp. A Barnes. Holotype, inner lateral view, x 45. U.O. 05313/208; p. 248.

8, 9: Polycaulodus n. sp. C Barnes. Cotypes, outer and inner lateral views, x 65. U.O. 05415/204, 05425/210; pp. 249-250.

10: Prioniodina robusta (Stauffer). Hypotype, inner lateral view, x 45. U.O. 16221/102; pp. 251-252.

11, 12: Dichognathus brevis Branson and Mehl. Hypotypes, inner lateral views, x 65. U.O. 19113/1(-1), 19123/208; pp. 212-213.

13: Ozarkodina rhodesi Lindström. Hypotype, inner lateral view, x 45. U.O. 20113/208; pp. 235-236.

14: Ozarkodina tenuis Branson and Mehl. Hypotype, inner lateral view, x 45. U.O. 12127/3(-1); pp. 236-237.

15: Trichonodella sp. A Uyeno. Hypotype, posterior view, x 45.

PLATE 4


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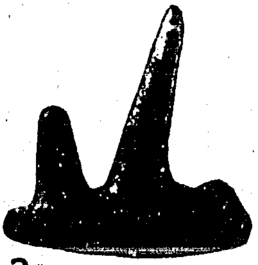
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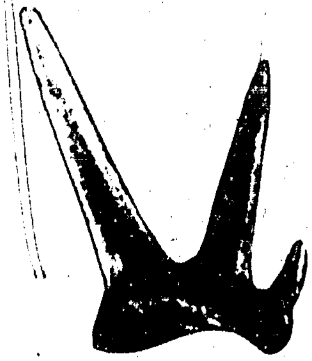
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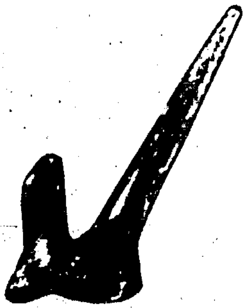
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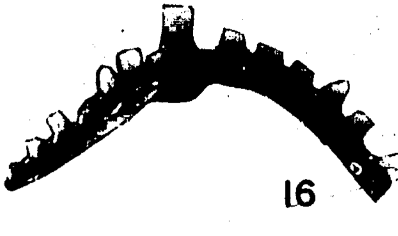
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PLATE 4


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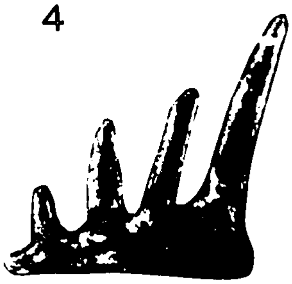
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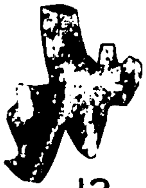
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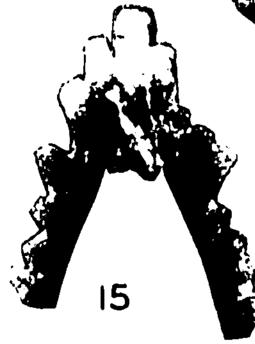
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PLATE 5

Slightly retouched photographs of uncoated incertae sedis from the Chaumont Formation and adjacent strata, western Ottawa Valley.

FIG. 1-3: "Vertebra". Lateral, outer axial, and end views, x 120. U.O. IS121; pp. 269-270.

4,5: "Eye". Upper and lower views, x 120. U.O. IS617; p. 273.

6: "Dermal denticle" Type A. Upper view, x 55. U.O. IS213; pp. 270-271.

7: "Dermal denticle" Type B. Upper view, x 120. U.O. IS223; pp. 270-271.

8,9: "Cap". Upper and lower-lateral views, x 120. U.O. IS717; p. 274.

10,11: "Frilled rod". Upper and lower views, x 45. U.O. IS521; p. 273.

12,13: "Plates". Upper views, x 45. U.O. IS319, IS323; pp. 271-272.

14: "Rod". Lower-lateral view, x 30. U.O. IS425; p. 272.

15: "Rod". Cross-section, x 120. U.O. IS413; p. 272.

PLATE 5


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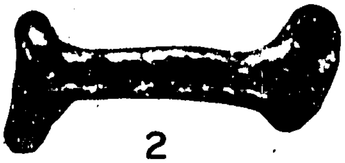
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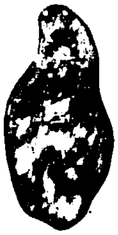
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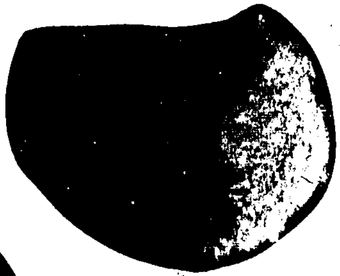
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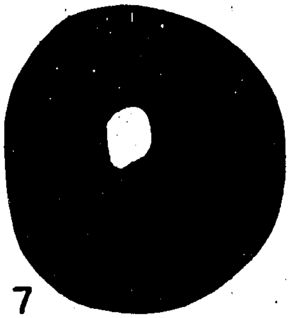
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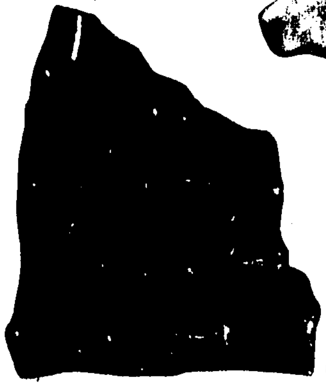
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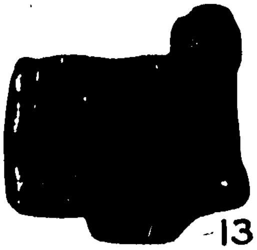
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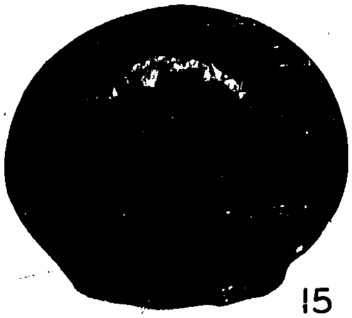
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PLATE 5


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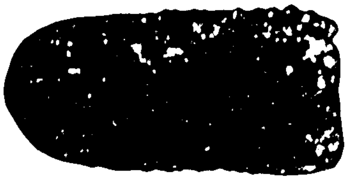
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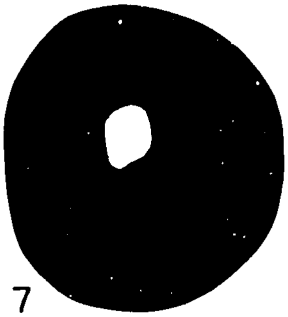
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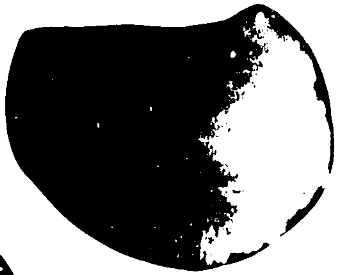
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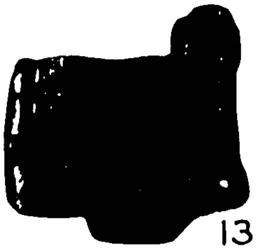
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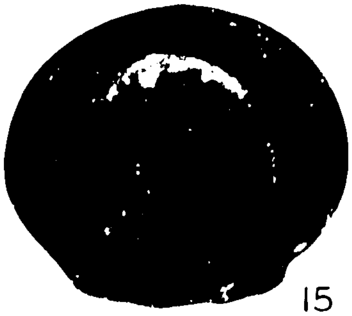
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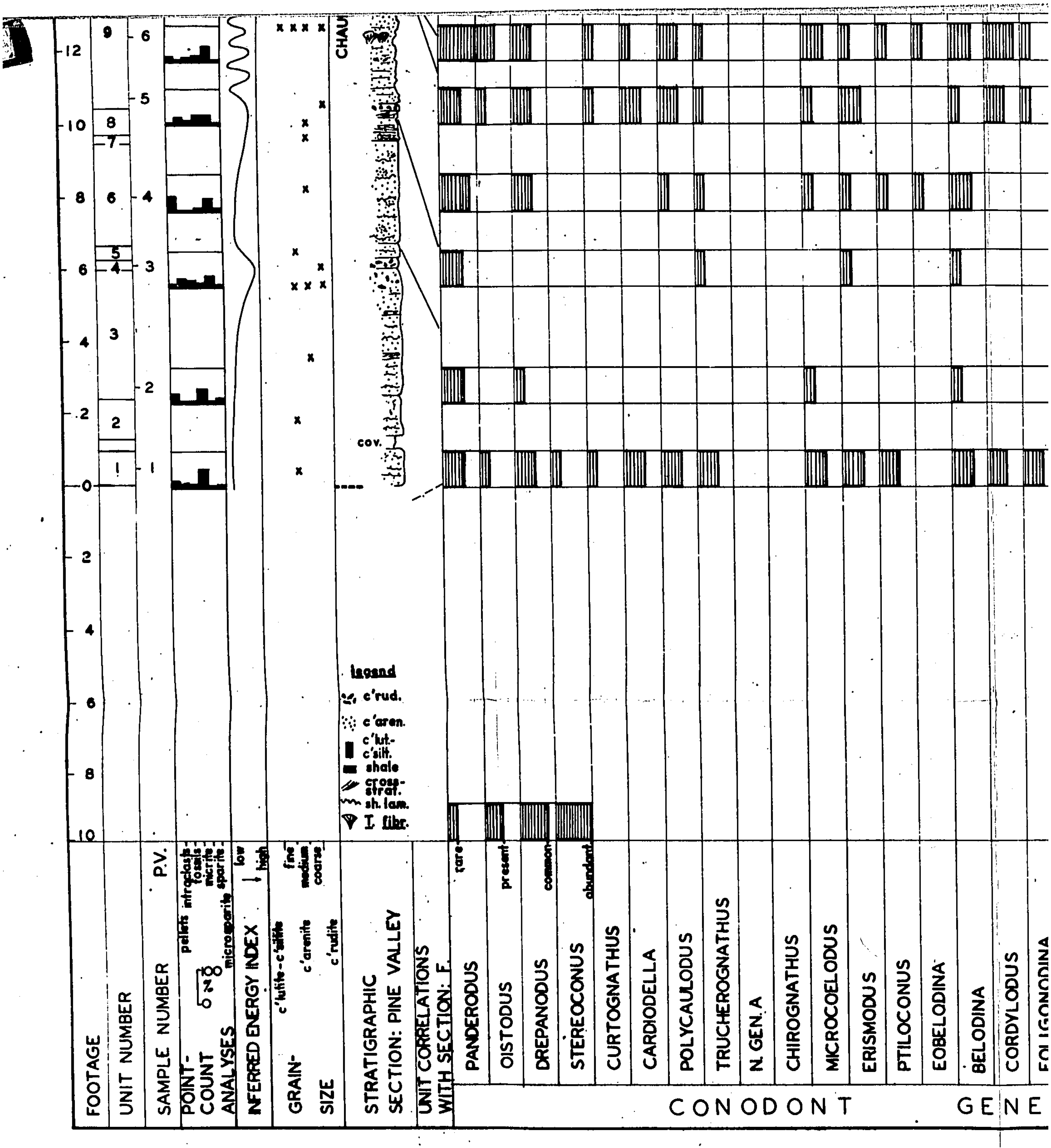

FIG. 5: CARBONATE POINT-COUNT, AND CONODON
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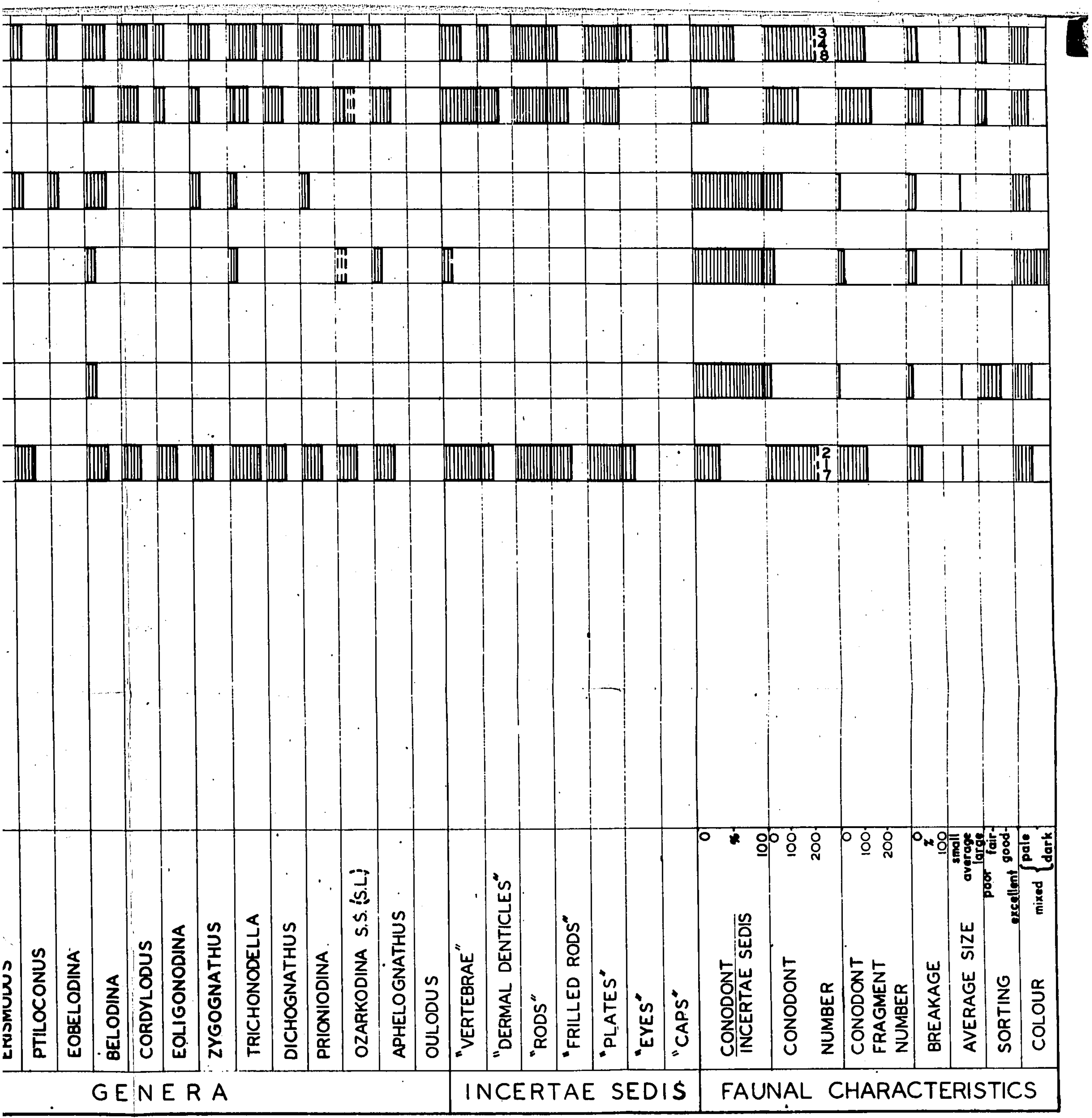
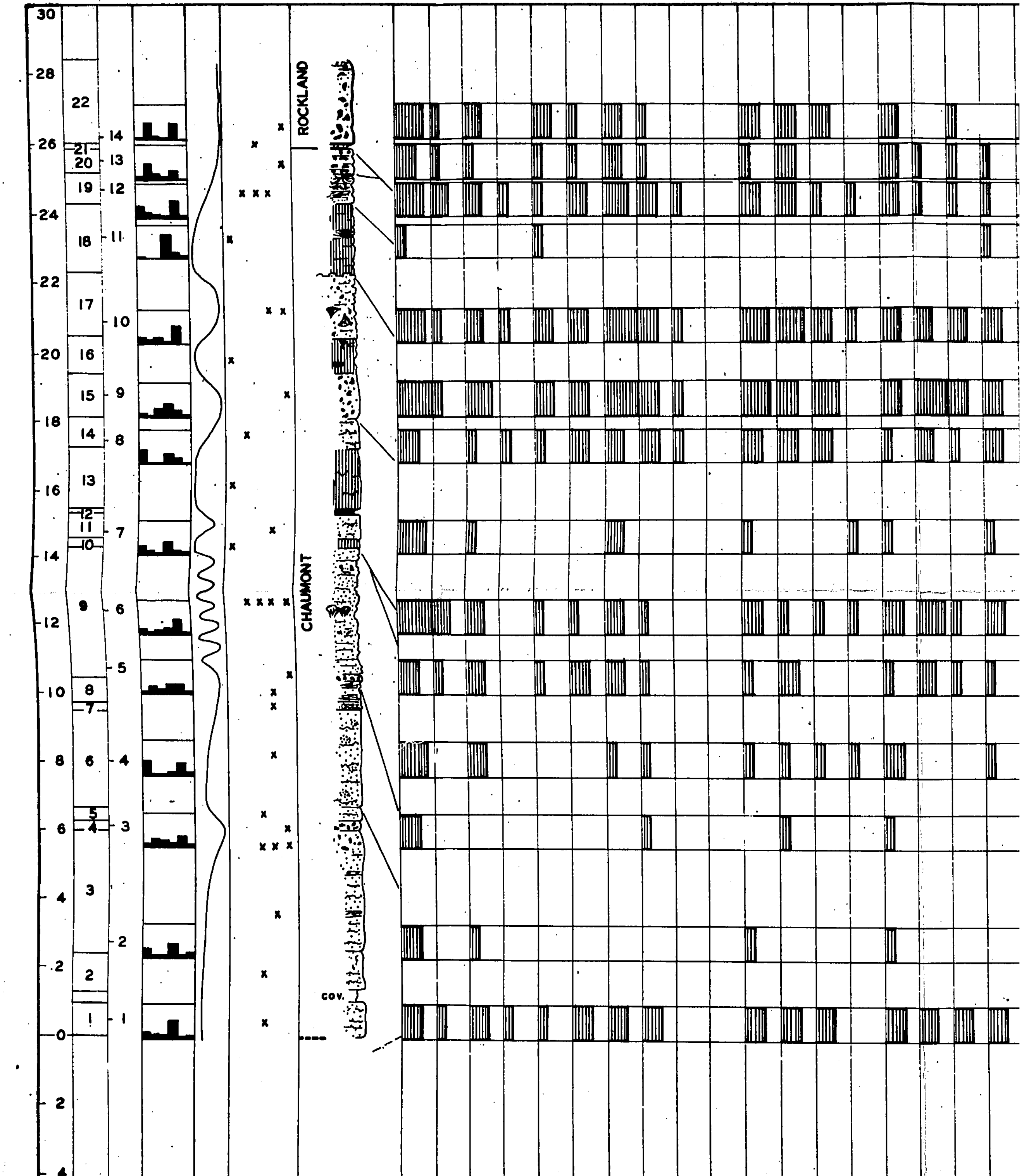


CONODONT AND INCERTAE SEDIS BIOFACIES ANALYSES
IREE WESTERNMOST SECTIONS
B: PINE VALLEY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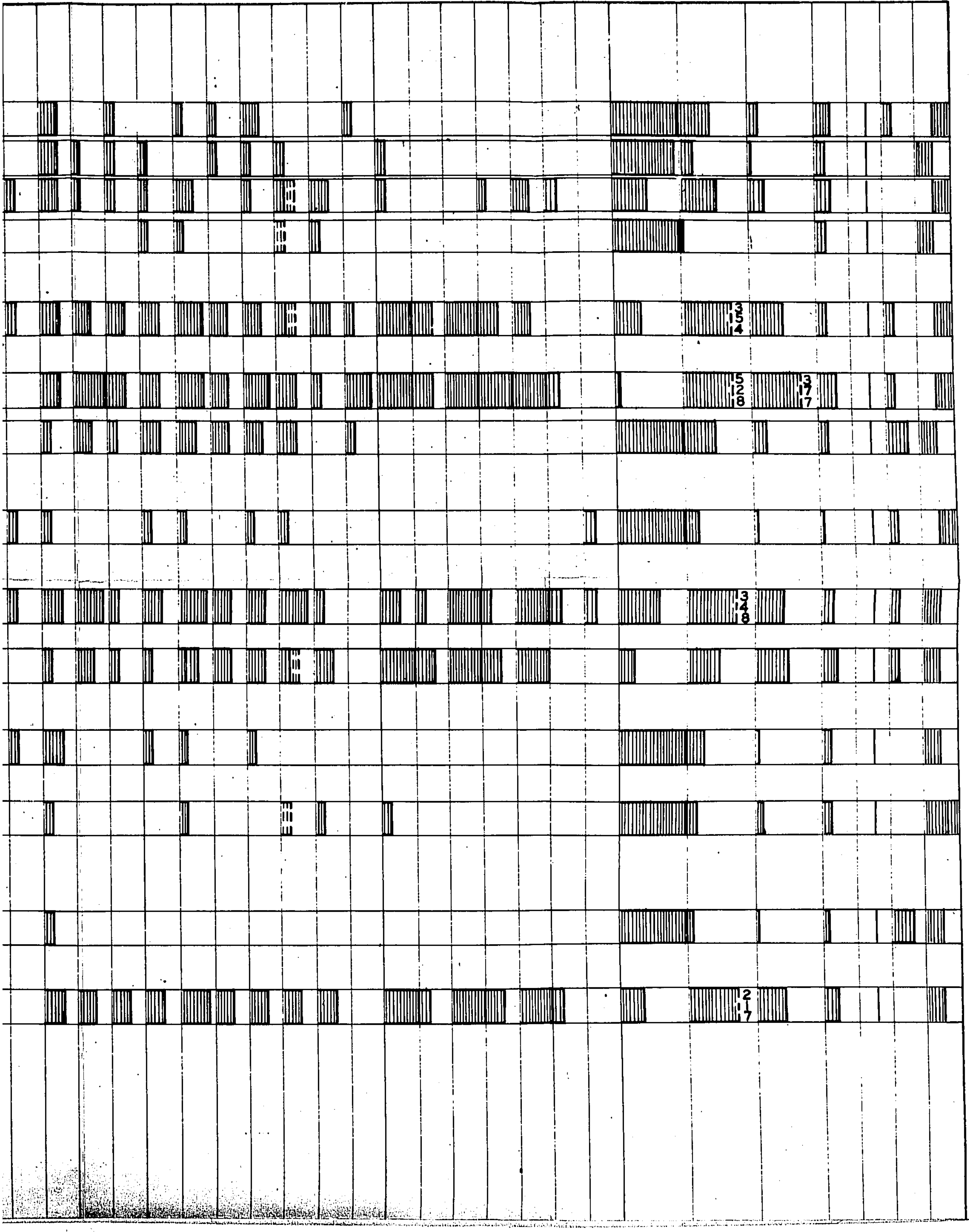
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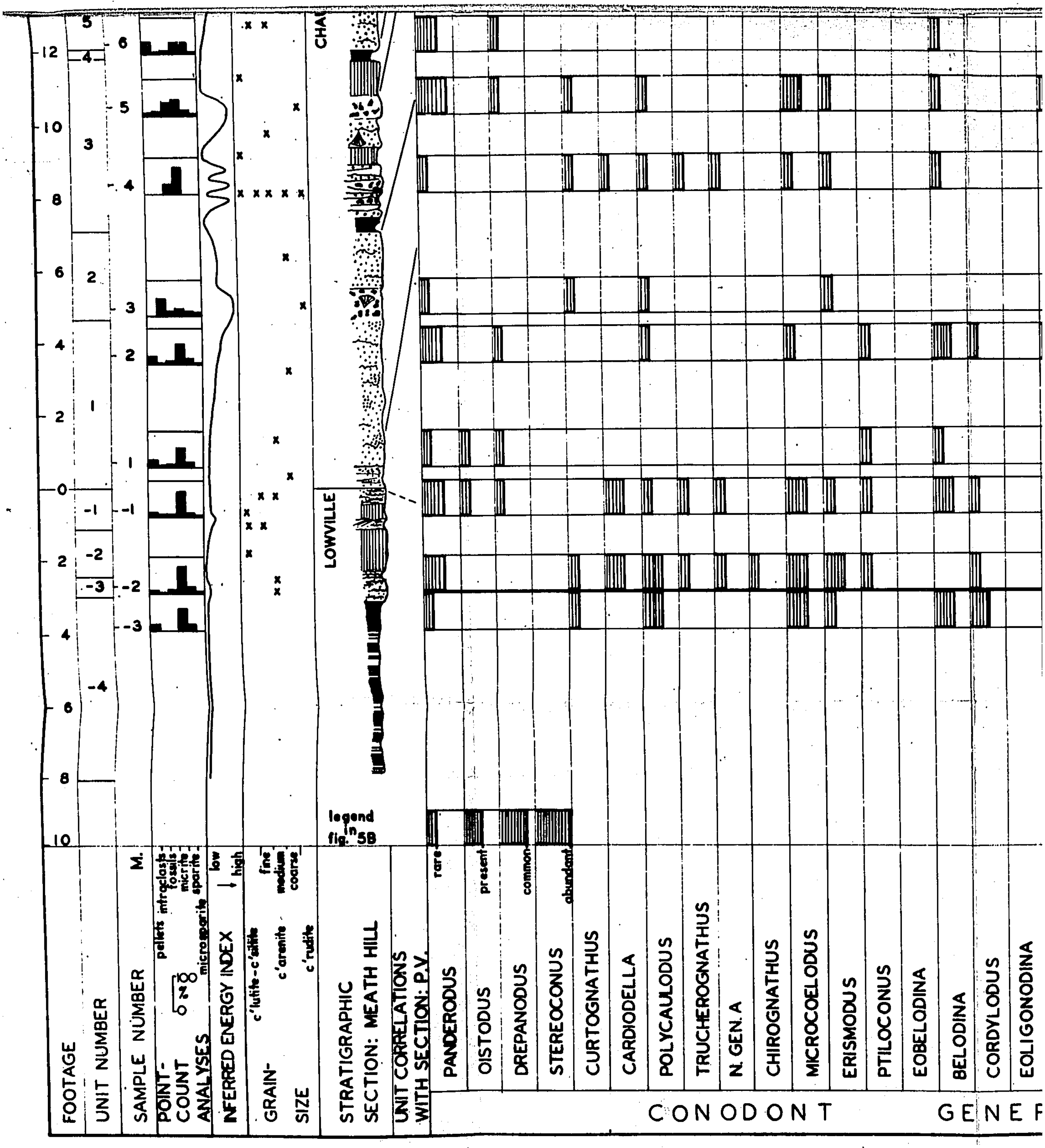
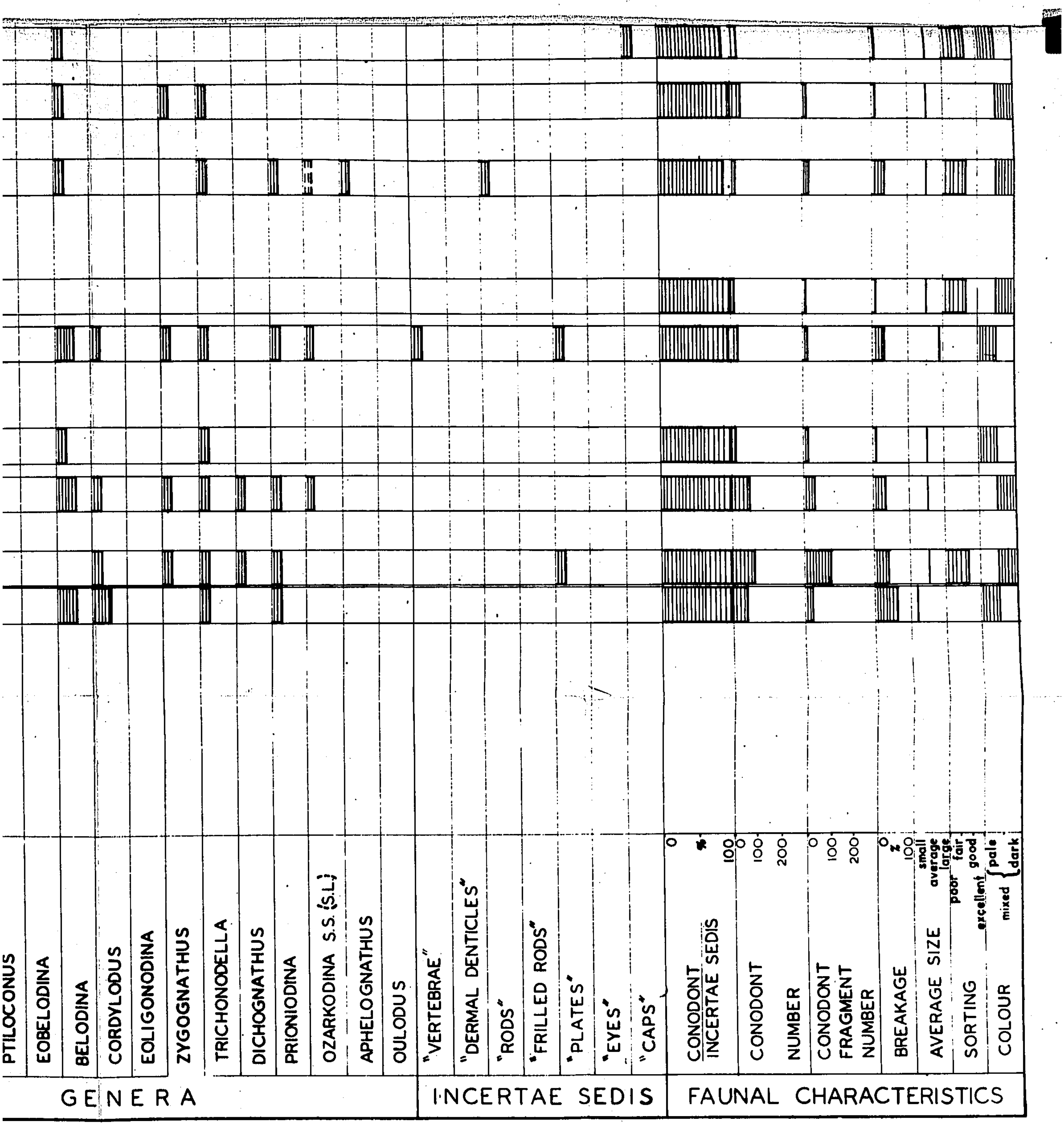


FIG. 5: CARBONATE POINT-COUNT, AND CONODONT
FROM THE THREE WESTE
A: MEATH



CONODONT AND INCERTAE SEDIS BIOFACIES ANALYSES

EE WESTERNMOST SECTIONS

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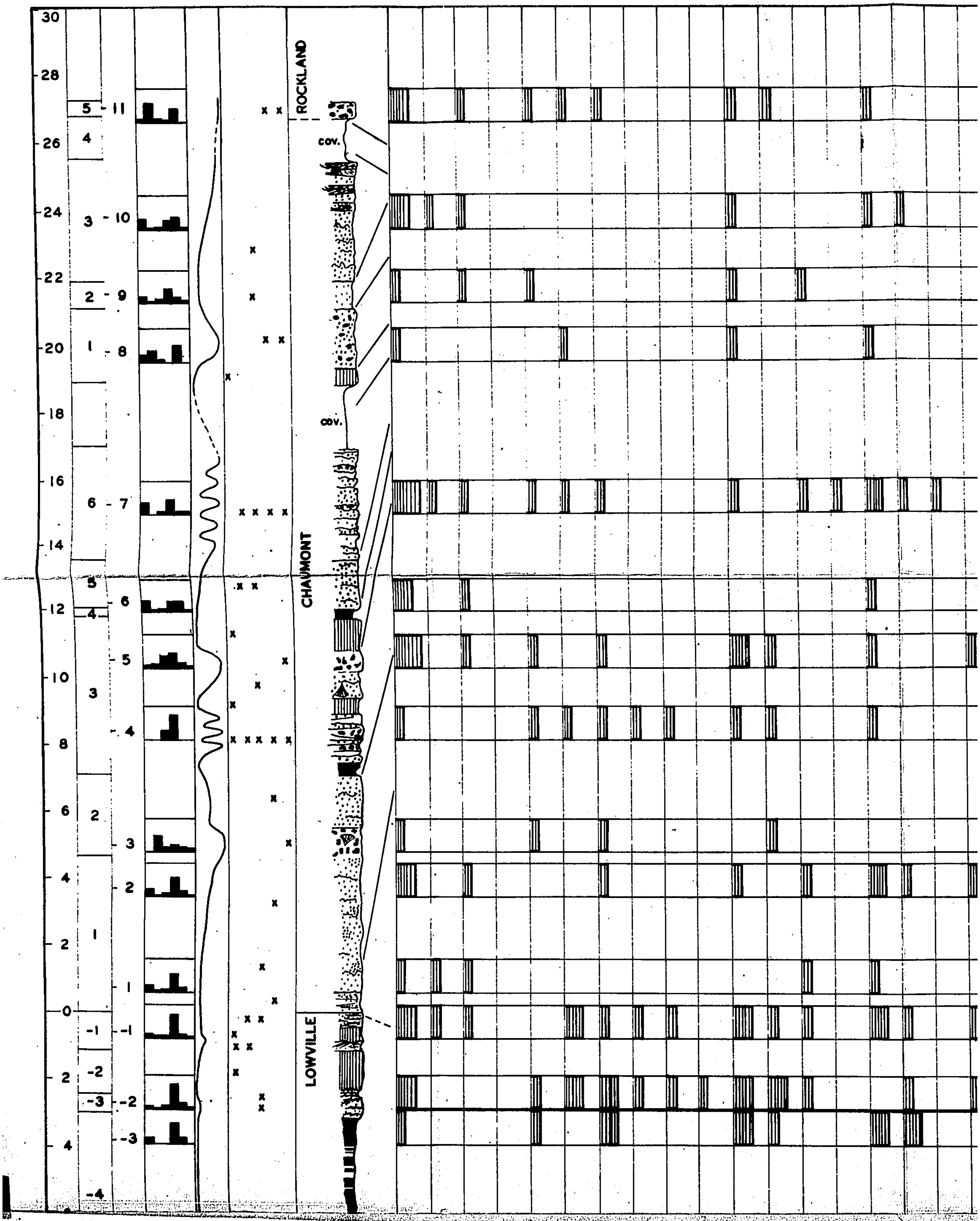
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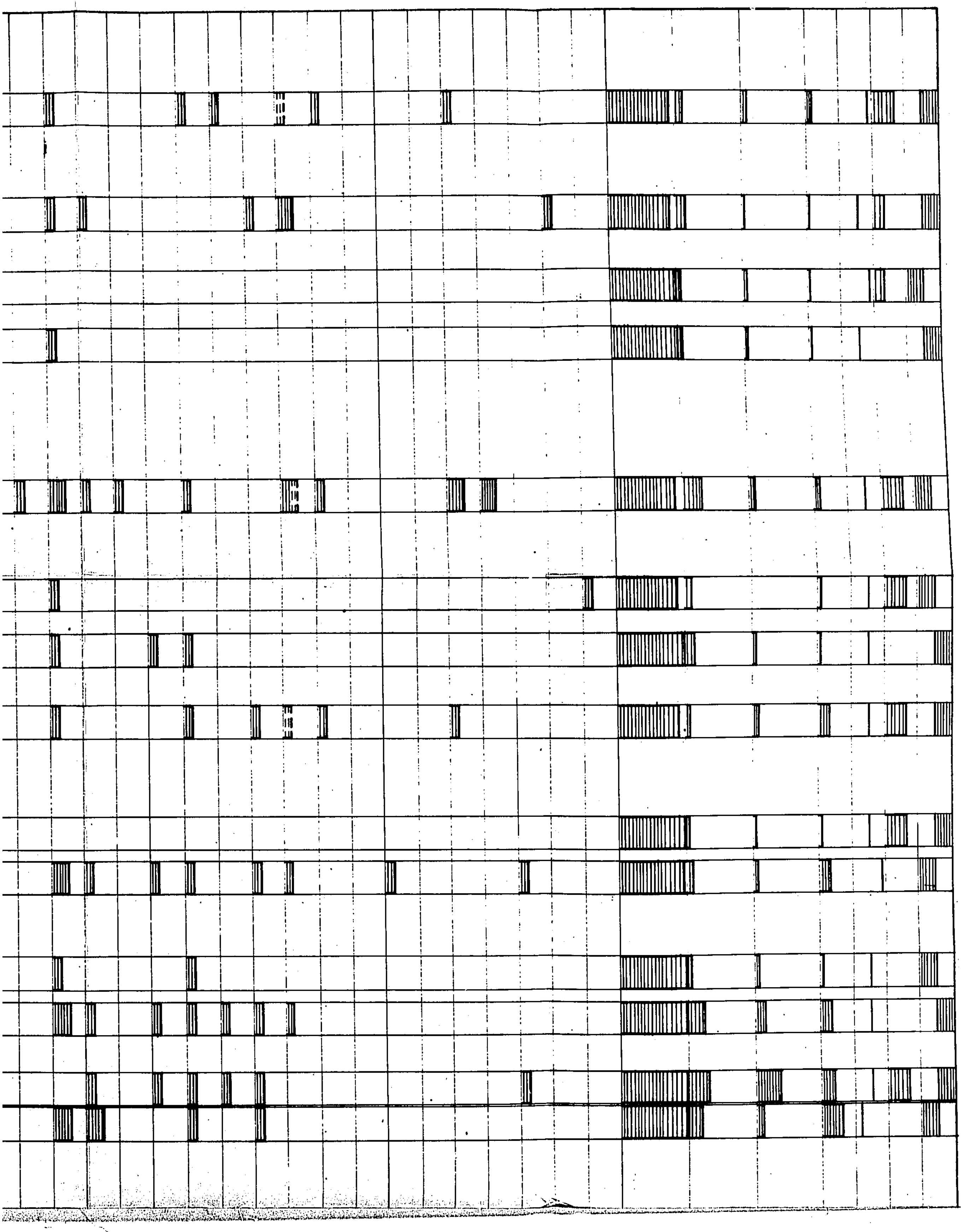


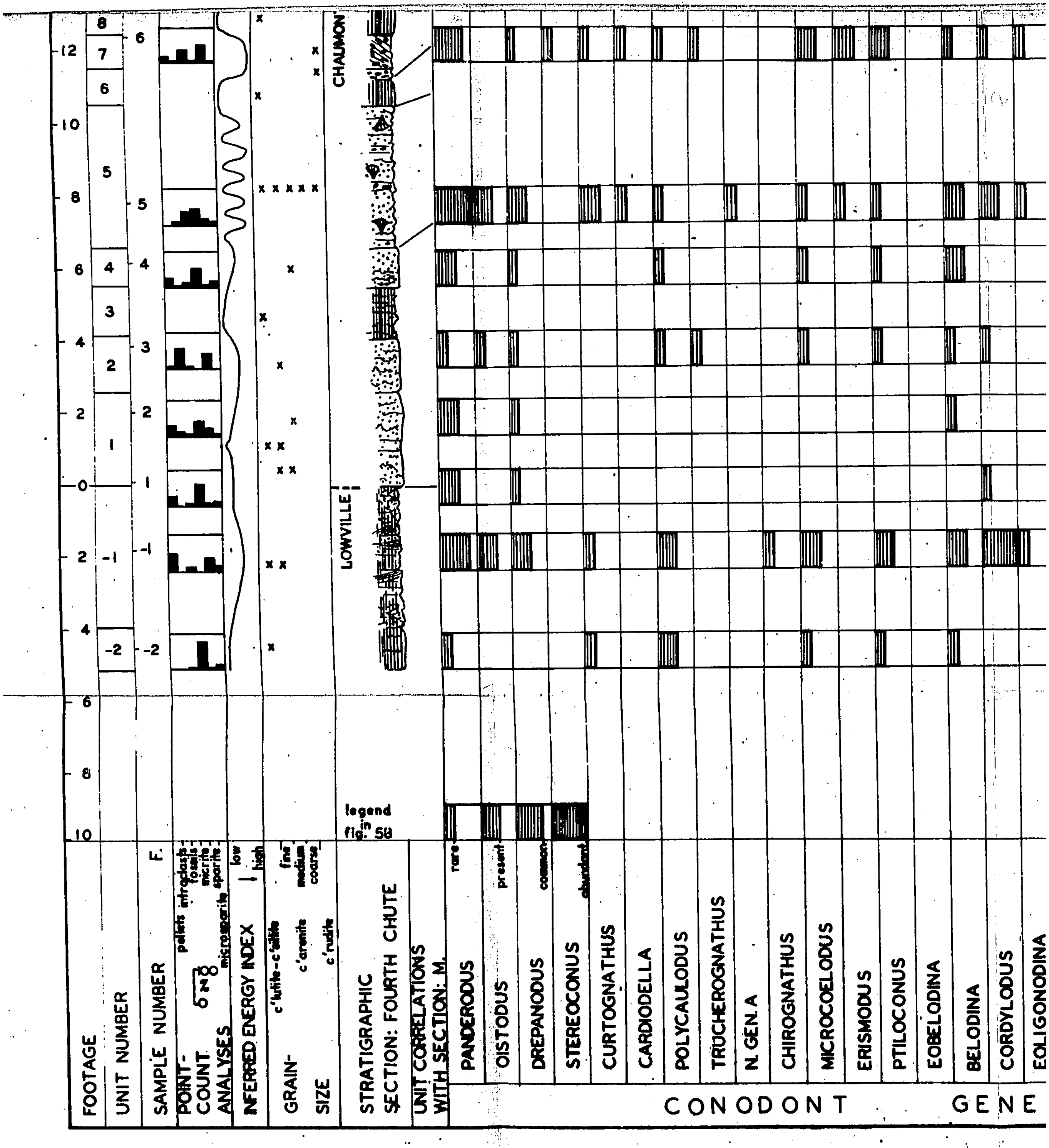
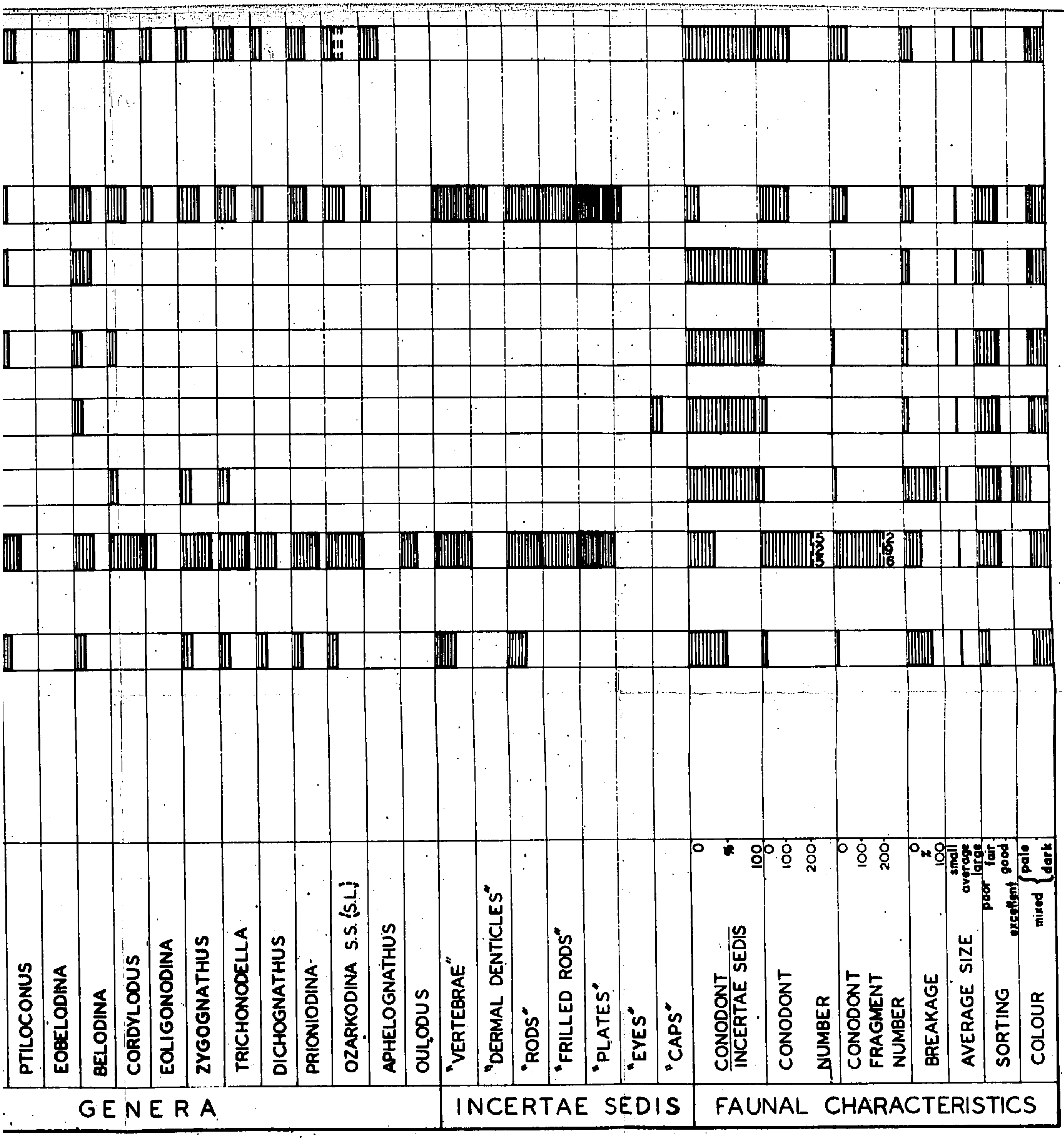


FIG. 5: CARBONATE POINT-COUNT, AND CONODON
FROM THE THREE WESTE
C: FOURTH



CONODONT AND INCERTAE SEDIS BIOFACIES ANALYSES
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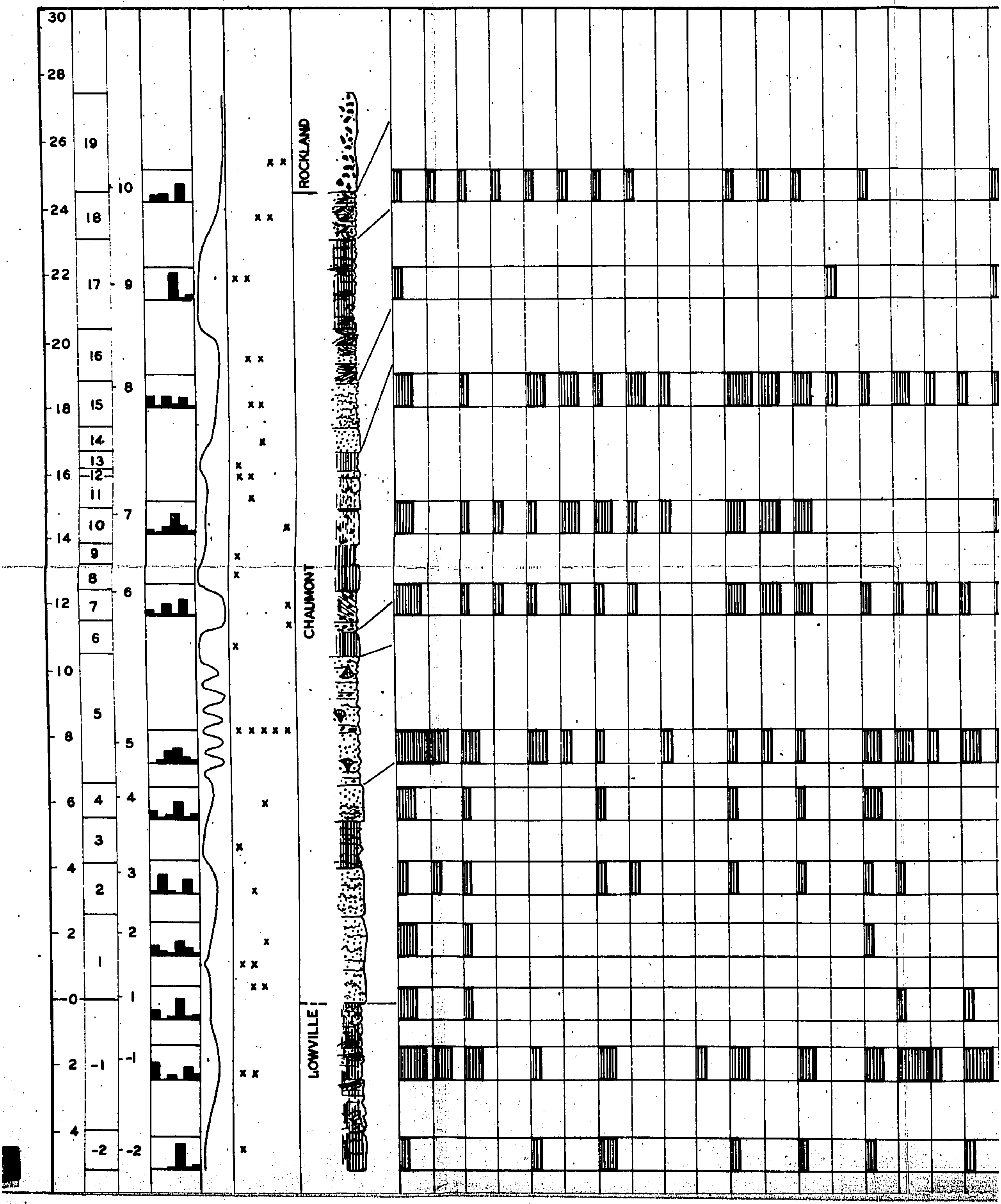
: FOURTH CHUTE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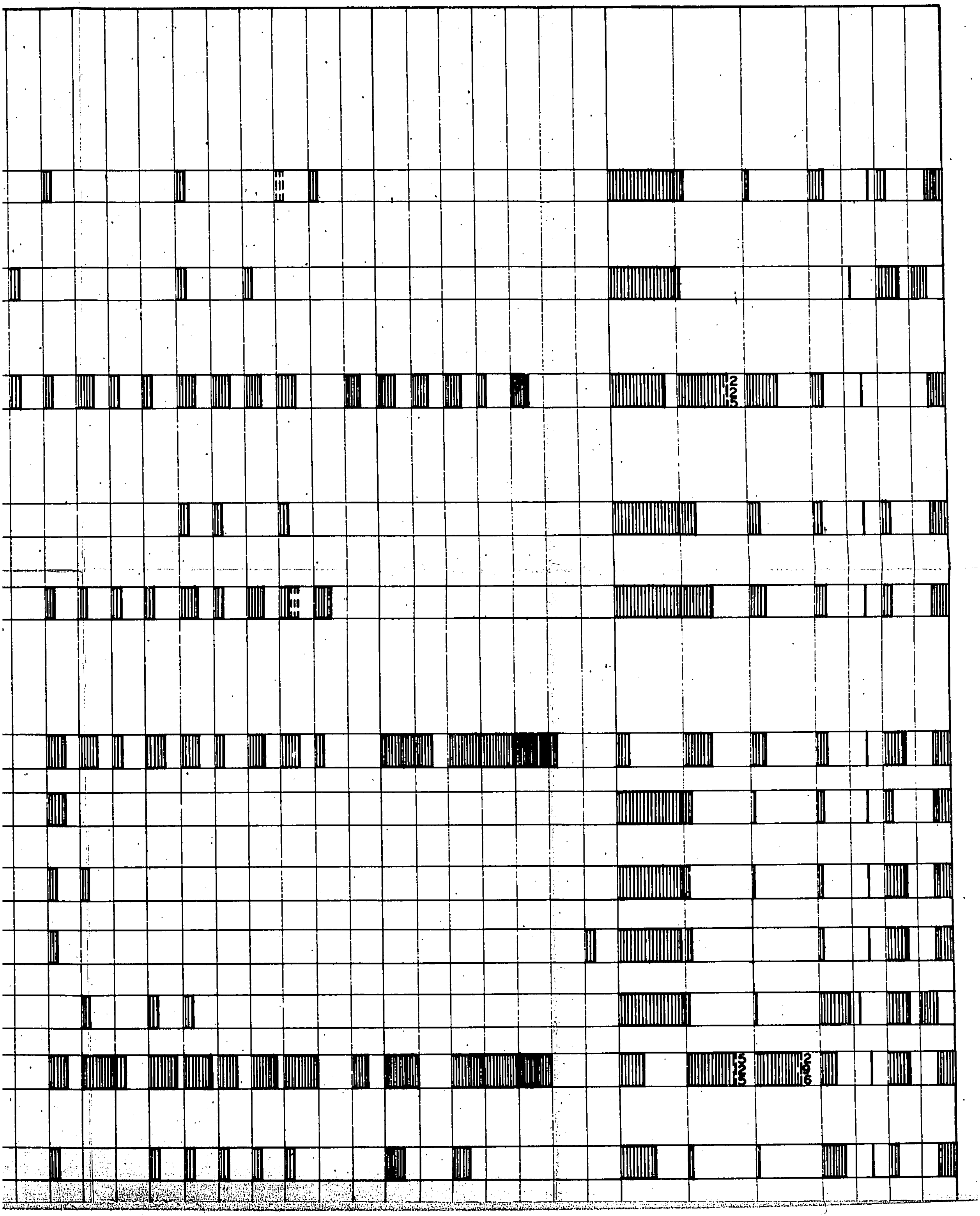
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