STRATIGRAPHY, SOURCE ROCK POTENTIAL MINERAL AND SOURCE DIAGENESIS OF THE NEW ASSOCIATED CONSOLIDATED PAPER (N.A.C.P.) ANTICOSTI NO. 1 BORE-HOLE ANTICOSTI ISLAND

Co-ordination and edition:	A. ACHAB
Petrography:	R. BERTRAND
Palynology:	A. ACHAB
Clay mineralogy:	A. CHAGNON
Reflectometry:	J.L. PITTION
Organic matter carbonization (colour):	A. ACHAB
Total organic carbon and carbon ratio:	Y. HEROUX
Porosity and permeability:	Y. HEROUX
Page-setting, drawing, typing:	A. ACHAB, B. de CONDE Y. HOUDE, L. MICHARD

(This report is a translation of the original French version)

Author: INRS-Pétrole/AA/lm 19.05.76
Addressee: Natural Resources
Department, Quebec
Reference: MRN-76 N.A.C.P.

ABSTRACT

The New Associated Consolidated Paper Anticosti No. 1 (N.A.C.P.) bore-hole drilled in the island center cuts 5770 feet of sediments which are Lower Ordovician to Lower Silurian in age. The Becscie, Ellis Bay, Vaureal, Macasty, Mingan and Romaine Formations were recognized in this bore-hole.

With the graptolites, Riva (1969, 1974) has established the correlations between the ordovician formations of the Anticosti Island and those of the Saint Lawrence Lowlands. The following table give the relations between these areas as proposed by Riva (1969, 1974). To these data is added the correlation table given for the International Geologic Congress by T.H. Clark (1972).

Saint Lawrence Lowlands	Anticosti Island	Graptolite zones	Stages
		C. prominens elongatus	Ashgillian
	Vaureal	*D. complanatus*	
Lower Lorraine		*C. manitoulinensis*	
		C. pygmaeus	—?—?—?—
Utica	Macasty	*C. spiniferus*	Caradocian
		O. ruedmani	
Trenton		*C. americanus*	
Black River Chazy	—?—?—?—?—?— Mingan (this work) = Trenton + Black River + Mingan pro parte (Clark)	*D. multidens* ? *N. gracilis* ?	—?—?—?— Llandeilian Llanvirnian —?—?—?—
Beckmantown	Romaine (this work) = Mingan pro parte + Romaine (Clark)		Arenigian

The microfacies study and the comparison of the lithologies with those in the type sections leads to a new subdivision of the series met in the N.A.C.P. well; this subdivision is fairly different from that proposed by other authors (Clark, Roliff). The main modification is the inclusion of the limestones underlaying the Macasty Formation in the Mingan Formation.

The studied sequence shows the characteristics of a shallow marine platform type of sedimentation excepted in the case of the Macasty and Vaureal Formations which would correspond to a deepening of the platform.

It is shown that the palynology is a good stratigraphic tool in the Upper Ordovician. In fact, there is a good correlation between the graptolite zones and the chitinozoan zones. Six well defined chitinozoan associations were recognized.

The clay minerals distribution is fairly comparable to that observed in the Saint Lawrence Lowlands; illite, chlorite and mixed-layer minerals of illite-smectite are present in the Upper Ordovician formations (Lorraine-Vaureal). The chlorite proportions decrease in the carbonate formation underlying the Utica Group in the Lowlands and the Macasty Formation in Anticosti.

The organic carbon content of the studied rocks is normal with an increase at the base of the Vaureal and Macasty Formations. The lithofacies 4 (4200-4400') of the Mingan Formation also shows an increase in total organic carbon (T.O.C.). The organic carbon/insoluble residue ratio indicates a low source rock potential for the level; this potential is higher in the Macasty Formation. The amount of organic matter remaining after the palynological preparation shows the same variations. The optical characteristics of this organic matter (colour, reflectance (R.O.)) show that it is little mature to mature and that its diagenetic evolution is still, at 4400 feet, favourable to preservation of liquid hydrocarbons.

The porosity measurements done on 10 samples with favourable looking, dolomites of the Romaine Formation, give the following results: 8 samples show 1 to 4% of porosity, and 2 show the relatively high values of 7.6 and 11.8%.

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

PLATES

INTRODUCTION

LOCATION

The New Associated Consolidated Paper Anticosti no. 1 bore-hole (fig. 1) located in the West central part of the island (co-ordinates 63°26'20"; 49°37'20") begins in Silurian limestones of the Becscie Formation and ends at 5770 feet in the dolomites of the Romaine Formation.

REGIONAL GEOLOGY

On Anticosti Island, outcrops a continuous sequence of sediments with a very low-angle dip towards the South-West and which are Upper Ordovician to Middle Silurian in age. The Middle Silurian formations (Chicotte, Jupiter, Gun River) which outcrop in the southern part of the island were not cut by the N.A.C.P. drilling. In subsurface, the Becscie, Ellis Bay Formations and the upper part of the Vaureal are comparable to the same formations studied in surface works. Moreover, the N.A.C.P. bore-hole permits the observation of units which were not observed on outcrops such as the lower part of the Vaureal Formation and the Macasty Formation. The latter uncomformably overlies (J. Riva 1969), the limestones of the Trenton Group (included in the Mingan in this study). The bore-hole ends in the dolomites of the Romaine Formation.

PREVIOUS WORKS

Only the geological subsurface works will be discussed herein. Many authors, under several different aspects, were interested in the data which could come from the study of the cores coming from the Anticosti Island wells. Among them, Bolton, Riva (palaeontological studies), Roliff (oil exploration) and Clark (lithology and stratigraphy). A study of the Arco Anticosti well was also carried out for the Natural Resources Department of Quebec by INRS-Pétrole.

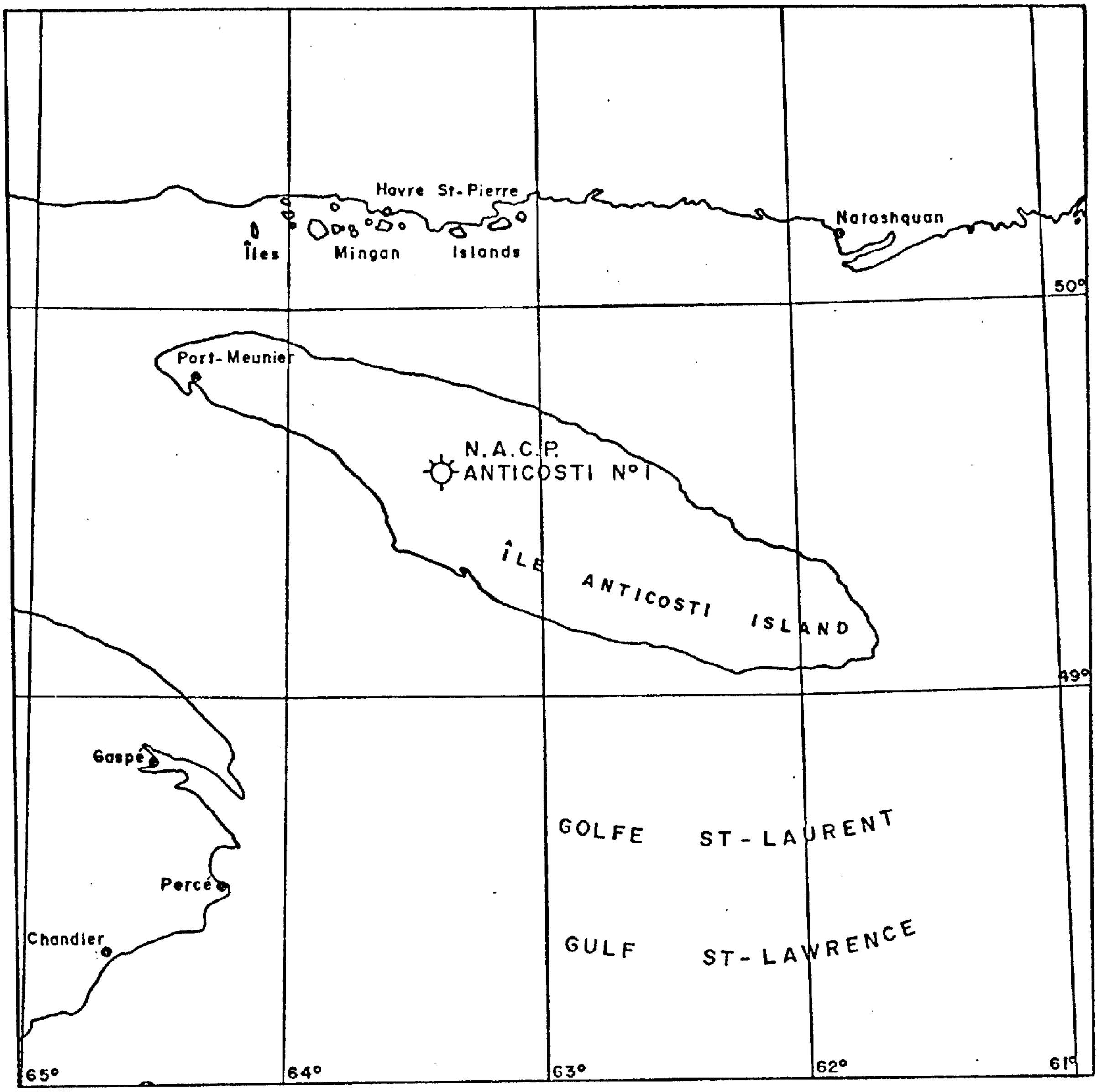


Fig. 1 Localisation du Sondage
Well Location

New Associated Consolidated Paper
Anticosti No.1

Echelle 0 32
Scale

METHODS

This work may be subdivided into two parts:

a) Lithostratigraphic study: including
  - the microfacies analysis and the reconstitution of the environments of deposition;
  - the analysis of the palynomorphs in order to establish a palynostratigraphic scale;
  - the clay minerals analysis;

b) A study of the mineral and organic diagenesis and of the hydrocarbon potential of the sequence from:
  - index clay minerals and illite crystallinity;
  - determination of the source rock potential with total organic carbon (T.O.C.) and insoluble residue (I.R.);
  - the carbon ratio measurements;
  - evaluations of the organic matter maturity by measuring the reflectance (R.O.) of organic matter debris and the colour of the microfossils (carbonization degree).

Some porosity determinations were also carried out on dolomite samples of the Romaine Formation to establish a reservoir potential.

I. LITHOSTRATIGRAPHY

A - SEDIMENTOLOGY

B - PALYNOLOGY

C - CLAY MINERALOGY

A. SEDIMENTOLOGY

I. OBJECTIVES

The purposes of the petrographic study of this bore-hole are the following:

1) to recognize in subsurface the lithostratigraphic units known by surface studies;
2) to give the main outlines of the paleoenvironmental evolution of the well area during the Ordovician and basal Silurian times;
3) to underline some aspects of the diagenetic processes having affected the various present units.

II. METHODS

The work was carried out in the following chronological order:

1) sampling and core logging
2) microscopic description of 106 thin sections treated with red alizarin
3) preparation of a litholog, and illustration of some encountered microfacies
4) determination of the major minerals (quartz, calcite, dolomite) by X-Rays diffraction (CORCOM) on 41 selected samples
5) compilation and sedimentological interpretation of the results.

III. MICROFACIES PETROGRAPHY

A detailed description of the core can be found in appendix M1. This litholog is a resumé of the mesoscopic description which was monitored by thin sections and X-Rays (CORCOM) analysis.

The description of the observed microfacies were inscribed on

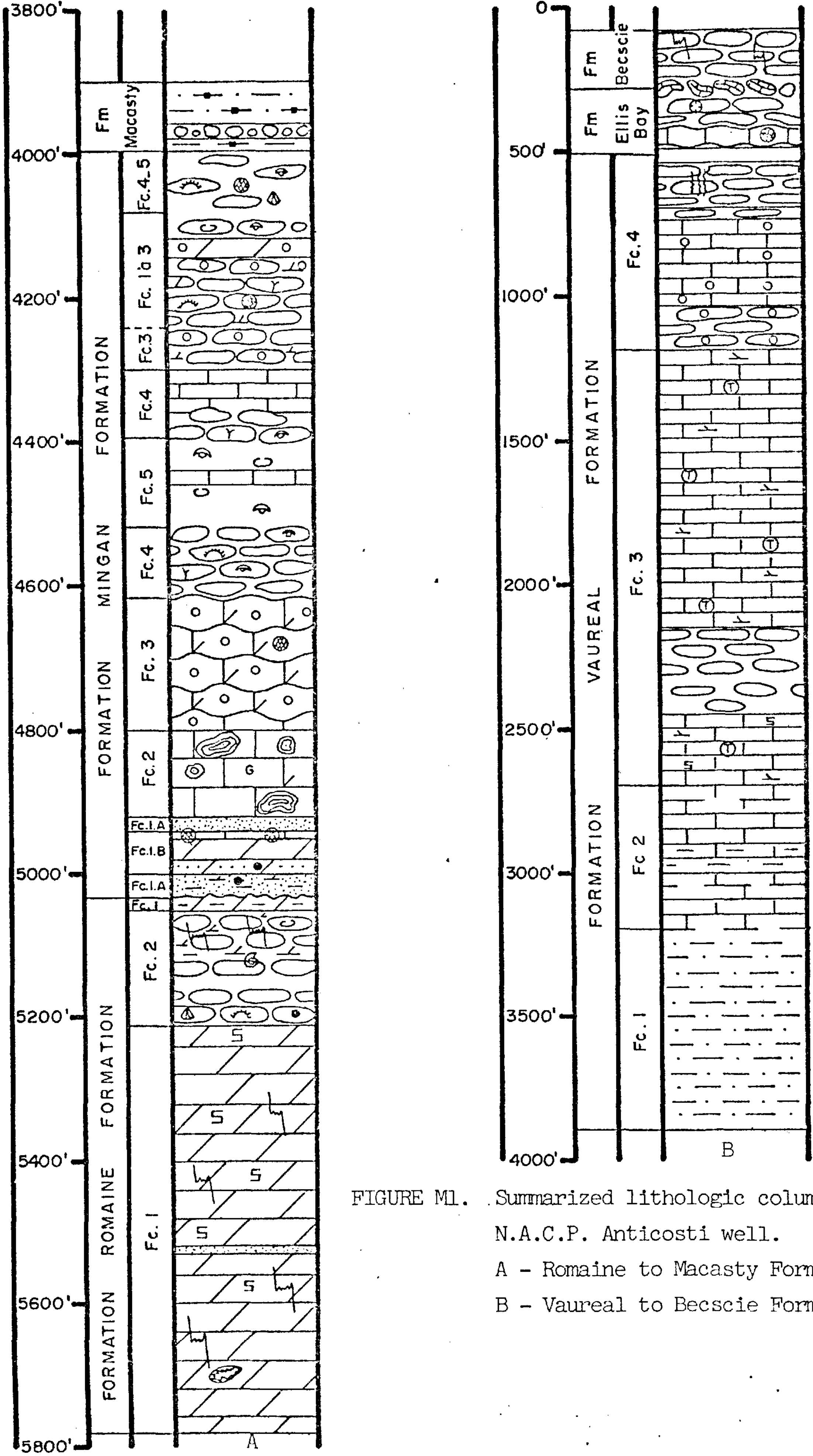


FIGURE M1. Summarized lithologic column of N.A.C.P. Anticosti well.

A - Romaine to Macasty Formations

B - Vaureal to Becscie Formations.

INRS-Pétrole standard card-index. The computerized descriptions are presented in details in appendix M2.

In a first step, the microfacies having between them petrographic affinities or being typical a specific environment, are grouped together in lithofacies.

The following paragraphs describe the petrography of the microfacies and lithofacies identified in the Romaine, Mingan, Macasty, Vaureal, Ellis Bay and Becscie Formations.

Romaine Formation

The Romaine Formation is subdivided into two lithofacies. The basal lithofacies (Fc1) is identical to that described at the type section by Twenhofel and Schuchert (1910, 1925-1938). The upper lithofacies (Fc2) is calcareous and nodular. This last interval was previously attributed to the Mingan Formation by Clark (1964), Roliff (1968) etc. In this work, it is included in the Romaine Formation for reasons which will be discussed later.

Lithofacies 1 (5211-5775, 5031-5043.5'; Pl. M-XII, M-XIII)

This lithofacies is almost exclusively made up with dolomites. However, it can be subdivided into two sub-units:

- the lower unit (5771-5775') is a coarse marbled dolomite, slightly argillaceous with stylolites; locally, it shows abundant vacuoles and fractures which are filled with sulfates (No INRS 9614, 5673') or Spongiostromata (Stromatolites).

- The upper unit (5211-5270') contains only laminated dolomites, stratified, dark and light, with cross-beds and always with stylolites. Locally, dolomites which may be argillaceous, calcareous, brecciated or microtectonited are noted. This interval also contains a dolomite cemented quartz arenite (No INRS 9710, 5521').

Lithofacies 2 (5043.5-5211'; Pl. M-XI)

The gradual contacts of this lithofacies with the underlying lithofacies justify its inclusion in the Romaine Formation.

It is in such a way that the dolomites of the lower lithofacies 1 become argillaceous, then lumps of fossiliferous packstone-wackestone appear inbedded in a dolomarly matrix (5195-5211'). Afterwards, there is a nodular limestone with an argillaceous dolomite matrix, but where there still are dolomite beds (No INRS 9698; 5143').

Nodules of mudstone (limestone) and of Ostracods and Gasteropods wackestone inbedded in a claystone or a dolomitic mudstone matrix form the major part of this lithofacies (Fig. M1; appendix M1).

These limestones show more and more stylolites towards the top to become dissected by subvertical narrow veins of dolomite.

These limestones are finally replaced successively by argillaceous and pure dolomites, like those observed at the top of the lithofacies 1.

The upper contact is placed at the base of the oblique microstratified quartz wackes of the Mingan Formation.

A brecciated level with argillaceous dolomite fragments is interbedded between the 7 feet thick light dolomite and the 6 feet thick dark grey or green argillaceous dolomites at the top of the Romaine Formation.

Mingan Formation

The Mingan Formation was first described by Schuchert and Twenhofel (1910) and by Twenhofel (1925, 1938). In the type area, the Mingan Formation lies uncomfortably over the Romaine Formation and its base is underlined by a sandstone level (Schuchert and Twenhofel 1910, p. 689), which is not present in all the area (Twenhofel 1938, p. 7-18).

The Mingan is herein subdivided into 5 lithofacies among which many look like very much the same as in the type area.

Lithofacies 1 (4915-5037', 4172-4153'; Pl. M-VIII, M-IX)

This lithofacies is characterized by its sandstones (Fc1A). These sandstones are identical to those found in the type area. The other lithologies in this facies are mainly dolomites (Fc1B), more or less sandy, and at the top, Spongiostromata and Porostromata limestones (Fc1C). All these lithologies have an equivalent in the type area at the base of the Mingan Formation. This is why it is considered that this lithofacies indicates the base of this formation.

Lithofacies 2 - 5 (3991-4112', 4153-4915'; Pl. M-V, M-VII)

These lithofacies are made up of a great number of lithologies which may vary from very limy to very argillaceous, and this, in a very gradual and cyclic manner when going up in the sequence (Annex 1, fig. 2, appendix M1, fig. 2).

The upper contact of the Mingan Formation is placed where the nodular limestones disappear below the black mudstones of the Macasty Formation.

Discussion concerning the Mingan Formation

Clark (1964) and Roliff (1968) include the sequence corresponding to the lithofacies 2 - 5 in the Trenton and Black River Groups. Herein, this interval is placed in the Mingan Formation for the following reasons:

1) the sedimentation seems to be continuous from the base of the Mingan Formation (below the lithofacies 1 of sandstones and dolomites) to the top of the Macasty Formation. It is thus not necessary, like in the Saint-Lawrence Lowlands where breaks in the sedimentation are known, to split this sequence into three different groups;
2) there is no portion in this formation that could be biostratigraphically and chronostratigraphically corrolated with the Trenton Group (Trentonian). The Graptolites (Riva 1969, p. 389, 1972, p. 8) clearly show that the sequence corresponding to lithofacies 3 to 5 (Trenton Group of Clark) is at the youngest Black-Riverian. Moreover, the presence of the alga *Nuia* (Maslov 1954) which has a minimum age Chazyan (Gilbault 1975, table 2), in all the limestone in this interval, confirm its equivalence with the Chazy Group of the Saint Lawrence Lowlands;
3) the lithologies studied in thin sections in this well are very similar to those(studied with the same method) of the type area and, moreover, they are noticeably different from those in the Trenton Group of the Saint Lawrence Lowlands.

Macasty Formation (3900-3991'; Pl. M-IV, fig. 3)

This formation is formed of little or very little bituminous black claystones and mudstones.

Discussion

Riva (1969) considers that the Macasty Formation lies uncomfortably, with an hiatus, over the underlying limestones. This hypothesis could not be confirmed in this work. However, the presence of a break in the sedimentation of this formation seems very possible because in the lower unit of the Macasty Formation (Upper Canajoharie = Upper Trentonian) limestone fragments conglomerate with *Nuia* fragments coming from the underlying Mingan Formation is found (No INRS 9653; 3970-3973', Pl. M-IV fig. 3). On the other hand, the alkali feldspars are more abundant than the plagioclase feldspars in the Mingan and Romaine Formations but the contrary is observed in the overlying formations. The top of the Macasty Formation is underlined by the appearance of very silty mudstones and much lighter than they are in the Vaureal Formation (appendix M).

Vaureal Formation (528-3900'; Pl. M-II fig. 2, Pl. M-IV fig. 2)

The Vaureal Formation is divided into four lithofacies. The lithofacies 1 and 3 are the major lithofacies, the lithofacies 2 and 4 are transition lithofacies (fig. M1, appendix M1).

Lithofacies 1 (3213-3900')

This lithofacies is essentially made up of average to very dark grey, micaceous, very silty, more or less laminated or with oblique stratifications mudstones. The minor associated lithologies are:

1) in the upper part, fossiliferous and calcareous siltstones or fine-grained sandstones;
2) in the middle interval, argillaceous dolomites;
3) in the lower part, marly beds.

The contact with the overlying lithofacies is gradual.

The lithologies in this facies look very like those of the Nicolet River Formation in the Saint Lawrence Lowlands.

Lithofacies 2 (2704-3293')

In this lithofacies, there is a more or less regular or rhythmic alternation of the following lithologic types:

1) dark, muddy marls
2) light silty and laminated wackestones in 1 to 4 inches beds

The muddy marl (detrital rocks) are always more abundant than the wackestones (carbonate rocks). The contact with the overlying facies is gradual.

Lithofacies 3 (1210-2704'; Pl. M-III, M-IV, fig. 2)

This lithofacies is dominated by a calcareous turbidite sequence, in rhythms varying from 1 inch to 5 feet in thickness, with an average between 1 and 2 feet. In decreasing abundance order, the second lithologic type is a nodular limestone made up of micrite and wackestone (50-85%), inbedded in a marly matrix (15-50%) (2154-2469').

The limestone rhythms show the following sedimentary structures: graded bedding, oblique stratifications and parallel laminations. By decreasing abundance order, these rhythms are formed of micrites and marles, wackestones, grainstones and some siltstones or fine sandstones. The turbidites become gradually richer in bioclastic grainstones towards the top.

The appearance, near the top of the lithofacies, of pelletoids in the wackestones and packstones and also the bioturbation structures indicate the beginning of the overlying lithofacies.

Lithofacies 4 (528-1210')

Nodular limestones (60%), limestones with wavy bedding surfaces (25%) and turbidites which are very rich in grainstone and packstone (10%) form this lithofacies. The minor lithologies are: arkose, lithoclastic grainstone (limestone conglomerate), coral wackestone, micrite and argillaceous wackestone.

The nodular limestones are made up of wackestone and micrite and the matrix may be a marle or a marly mudstone. Bioturbation is present everywhere in this lithofacies. In the non-nodular limestones, stylolite dissolution structures are very frequent.

The upper contact is placed over the last turbidite level, under a very argillaceous facies which is included in Member 1 (Bolton 1972, p. 8) of the Ellis Bay Formation.

Ellis Bay Formation (295-528'; Pl. M-II fig. 1)

Four of the six members described by Bolton are recognized in this formation. The identification of the two upper members are more doubtfull; the thickness of the member 5 of Bolton being, for example, very different from the interval having the same type of lithology in this well. For the clarity of this report, the term "lithofacies" will still be applied to the lithologic units which will be compared with the members defined by Bolton.

Lithofacies 1 (508-528')

The lower half of this facies is represented by nodules of micrite with big brachiopods, in a marly mudstone matrix. The upper half is made up of calcareous mudstones interbedded with some grainstones. This description is closed to the description of the member 1 of Bolton (1972, p. 8).

Lithofacies 2 - 4 (417-507')

These lithofacies 2 to 4 are:

2 - micrite slightly nodular with some rare Echinoderms levels

3 - micrite and Echinoderm and Bryozoan wackestone nodules
4 - regularly bedded Echinoderm, Brachiopod and algae packstones-wackestones.

Lithofacies 5 - 6 (315-417'; Pl. M-II, fig. 1)

These lithofacies are respectively:

5 - nodular micrites in a slightly to very argillaceous matrix
6 - bioturbated, non-nodular micrites and wackestones with halysitides levels (member 6 of Bolton 1972, p. 8).

Becscie Formation (85-315'; Pl. M-I, M-II, fig. 1)

The determination of the contact between the Ellis Bay and Becscie Formations is quite arbitrary, because no important and clear difference was observed between them. In accordance with the description of Bolton (1972), the contact was placed at the top of halysitides facies previously mentioned.

When such delimited, the Becscie Formation shows a sequence where the limestone beds (fossiliferous micrite-wackestone-grainstone) are regular to irregular in thickness in alternance with a sequence where the limestones are nodular. Abundant lithoclastic grainstone levels were also noted.

IV. ENVIRONMENTS OF DEPOSITION

The origins of the facies in the Romaine and Mingan Formations are very different from the origins of the facies in the Macasty, Vaureal, Ellis Bay and Becscie Formations. The facies in the former are derived from restricted marine environments whereas the facies in the latter originate from an open marine environment.

Discussion and elaboration of sedimentary models will be done for each lithostratigraphic unit.

Romaine Formation

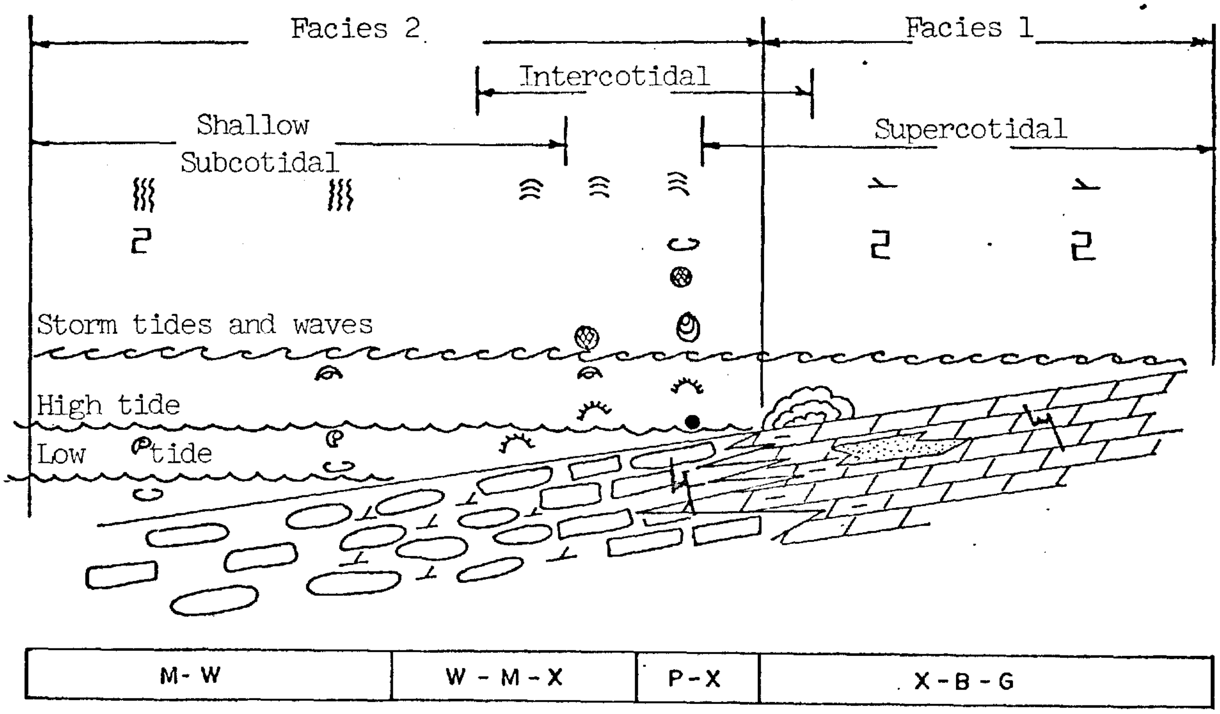
The two lithofacies in the Romaine Formation are typical of shallow to very shallow restricted marine environments. The lithologies by importance order are: X-stones, mudstones, wackestones, boundstones and grainstones. The deposition paleoenvironment interpretations and the illustration of the petrographic and structural-sedimentary elements which characterize this formation are shown on figure M2.

Mingan Formation

The fine lithofacies in the Mingan Formation are, like those in the Romaine Formation, typical of very to moderately shallow restricted marine environments. Exceptionnally, the lithofacies 1A may possibly be paralic. However, the connection with the main or high sea seems to be more important here than it was for the underlying formation. The deposition paleoenvironment interpretations and the illustration of the petrographic and structural-sedimentary elements which characterize the Mingan Formation are shown on figure M3.

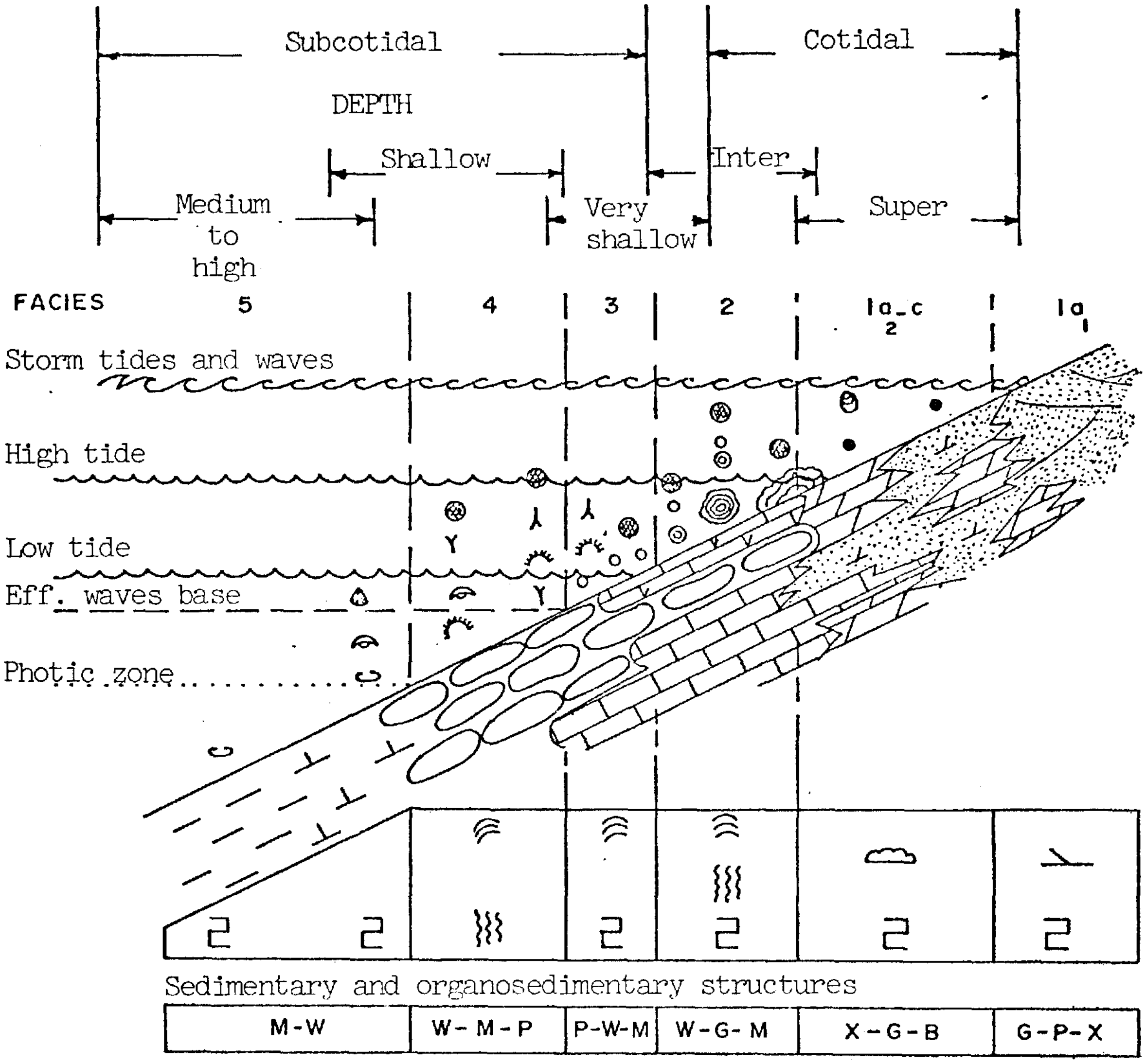
Macasty - Vaureal - Ellis Bay - Becscie Formations

The formations included in these groups are described all together, because they are considered as being typical of an open marine environment. The deposition environment deepness, decreases gradually from deep subcotidal below the carbonate compensation levels at the top of the Macasty Formation, to shallow subtidal at the top of the Becscie Formation.



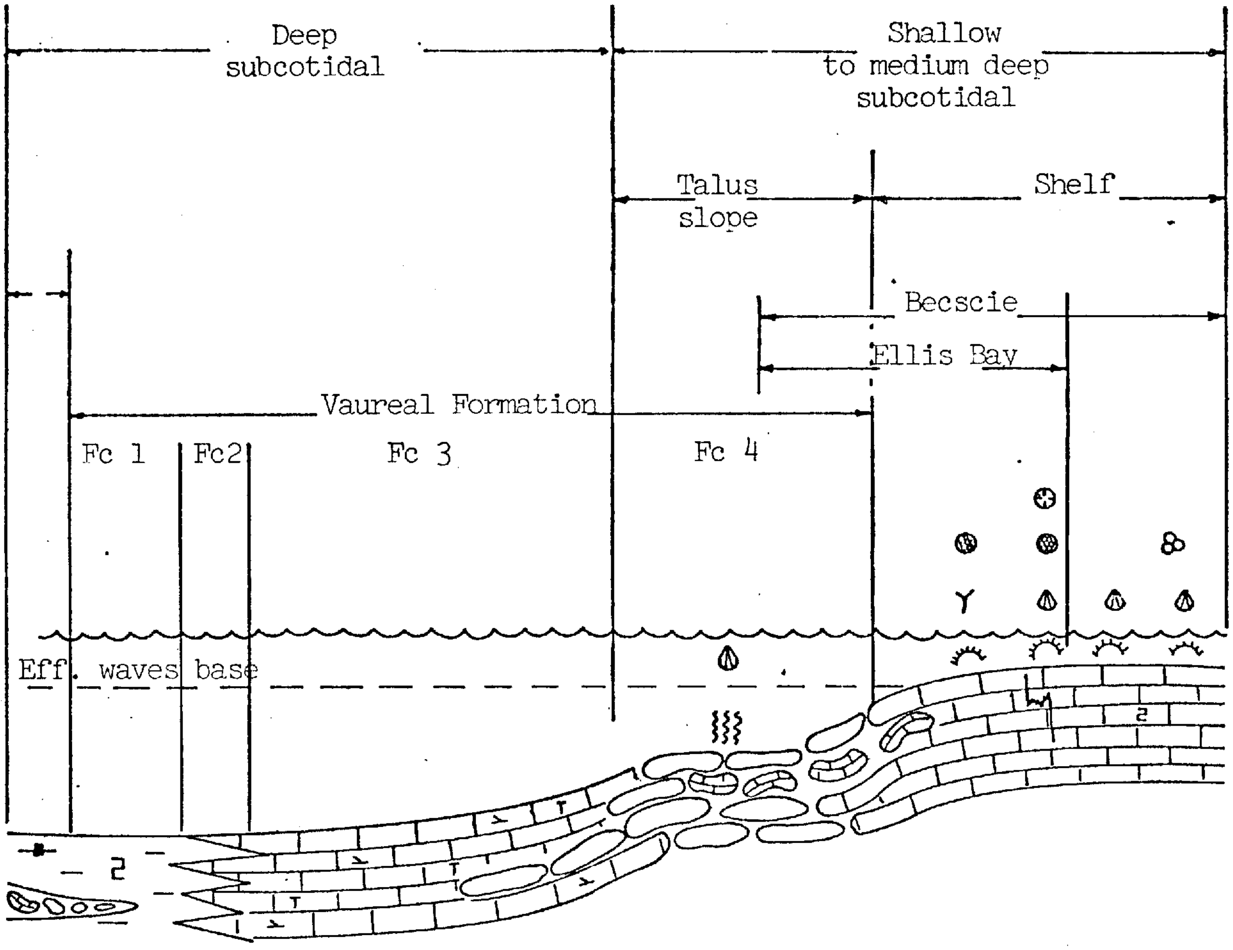
Depositional textures (Dunham 1959), with relative importance decreasing towards the right.

FIGURE M2. Paleoenvironments of Romaine Formation. The sedimentary, organo-sedimentary and diagenetic structures as well as the allochems, typical in these environments, are illustrated.



Depositional textures (Dunham 1959), with relative importance decreasing towards the right.

FIGURE M3. Paleoenvironments of Mingan Formation. The sedimentary, organosedimentary and diagenetic structures as well as the allochems, typical in these environments, are illustrated.



M-W	M-W-G	M-G-W-P	W-M	G-W

Depositional textures (Dunham 1959), with relative importance decreasing towards the right.

FIGURE M4. Paleoenvironments of Becscie to Macasty Formations. The sedimentary, organosedimentary and diagenetic structures as well as the allochems, typical in these environments, are illustrated.

It is thus concluded that the Macasty Formation was sedimented during the deepening of the Chazyan platform. Its low thickness and the time period represented by this sequence (Riva 1969) lead to the conclusion that this sequence was sedimented very slowly in deep and little oxygenated water, far from a detrital sediments source area.

These sediments were sporadically eroded by conglomeratic flows coming from the Chazyan platform (Pl. M-IV, fig. 3).

The interpretation of the paleoenvironments of deposition and the illustration of the petrographic and structural-sedimentary elements of these formations are shown on figure M3.

Origin of the sedimentary deposits

In the terrigenous fraction of the Mingan and Romaine Formations, the feldspars present are mainly potash feldspars whereas in the overlying sediments, plagioclase feldspars are found. This indicate a change of the terrigenous sediments source. The terrigenous detrital sediments of the Romaine and Mingan Formations seem to originate from acid igneous rock erosion, whereas those from the Macasty Formation would originate from more basic rock erosion. Even if these deductions could only be confirmed by more detailed work, the following evolutive pattern seems the most probable.

1) During the deposition time of the Romaine and Mingan Formations, the Chazyan platform was feeded by a low detrital income coming from the erosion of the grenville rocks of the Canadian Shield.

2) After the collapsing of the platform (Roliff 1968, p. 22-33), the detrital material is more likely coming from the southward taconic range which was still rising at this time.

V. DIAGENESIS

The diagenesis of the sediments in the different formations is only studied when the discussions can:

1) give more informations to corroborate a stratigraphic conclusion (Romaine - Mingan Formations contact);
2) permit to know better the porosity evolution in the levels which could theoritically be good reservoirs.

Romaine Formation

Lithofacies 1 (Pl. M-XII, M-XIII)

The rocks in this facies are essentially dolomites. The precipitation of primary dolomites being neither very wide-spread nor well proven, this general dolomitisation is certainly due to some diagenetic process.

The presence of sedimentary and organosedimentary structures (Fenestrelles - Spongiostromata), which are typical of inter or super cotidal environments, leads us to conclude to a sabka or bahama type of dolomitisation (Heckel 1972, p. 247, 253).

Lithofacies 2 (Pl. M-XI)

This limestone lithofacies shows very clear dolomitisation evidences. The nodular limestones were affected by two types of dolomitisation. In the first type, even if the dolomitisation is very important (as much as 45%), only the matrix is dolomitised; the calcareous bioclasts are not affected. This is observed only at the base of lithofacies 2. In the second type, which is observed at the top of lithofacies 2, the nodular limestones also have a dolomitic matrix but, moreover, there are stylolites and small vertical veins of dolomite cutting through nodules and fossiles (not illustrated on plates).

These observations permit to conclude that the first dolomitisation is of a reflux and penecontemporary type (Deffeyes et al 1972). The second is the result of an infiltration of magnesium rich water. This water could only have come from the top since the small veins disappear towards the base of the section. This dolomitisation must have happened when the water, rich in magnesium, dissolved from the overlying dolomites, percolated in the microfractures present in this lithofacies.

Mingan Formation

Lithofacies 1

- The sandstones

The major diagenetic effect in this facies is the complete cementation of the sandstones.

Based on their mineralogical composition, three types of cement may be recognized:

1) argillo-siliceous
2) silico-carbonate
3) carbonate.

The basal sandstones in the lithofacies 1 (5002-5030') are argillo-siliceous, but become rapidly silico-carbonate at the end of the lower third of the interval.

The uppermost sandstones in the same lithofacies (4920-4930') are exclusively carbonate.

- The dolomites

The dolomites in this lithofacies are silty-sandy, lithoclastic and they contain broken calcareous fossils which are not dolomitised. They are more often associated with Spongiostromata. These characteristics and their stratigraphic position indicate an early dolomitisation of supercotidal or sabka type.

Lithofacies 2 to 5 and other overlying formations

Only the limestones of grainstone type which are interesting from a diagenetic cementation aspect will be discussed. The other muddy limestones which show no reservoir potential will be discarded.

All the grainstones in the lithofacies 2 of the Mingan Formation and those at the base of the rhythmic sequences in the Vaureal and Becscie Formations may be

1) cemented by syntaxic sparite around the Echinoderms
2) cemented by mosaic of sparite in the center of the intergranular spaces and associated with small crystals around the grains (Vaureal and Mingan Formations).

Moreover, the grainstone levels in the Becscie and Mingan Formations always show abundant stylolites. This diagenetic structure reduce the probability to find intact the pore network of this limestone.

VI. SEDIMENTOLOGICAL CONCLUSIONS

The sedimentological study of the N.A.C.P. Anticosti bore-hole coupled with a bibliographic review lead to the following conclusions:

1) the Lower Paleozoic of the studied area is characterised by three major sedimentary episodes of regression-transgression.

2) In the two first episodes, shallow restricted marine environments are involved. The Romaine and Mingan Formations are the traces left by these two sedimentary episodes. The rocks of the Romaine Formation are the remains of a slow transgression followed by a more rapid regression. On the other hand, the rocks of the Mingan Formation are the remains of a successively transgressive, regressive and transgressive sea.

3) The limits established in this work between these two formations are different from those accepted in the litterature.

4) The third sedimentary episode involves open marine environments, deep at the base of the section and shallow at the top. The stratigraphic units left by this episode are the Macasty, Vaureal, Becscie and Ellis Bay Formations. The rocks of these formations were formed by the continuous filling of a marine basin, originally fairly deep, during only one slow marine regression.

5) It is noted that all the sedimentary rocks which could be reservoir rocks are well cemented. The only observed porous lithologies are the vacuolar dolomites at the base of the lithofacies 1 in the Romaine Formation.

REFERENCES

BOLTON, T.E. 1972. Geological map and notes on the Ordovician and Silurian litho- and biostratigraphy, Anticosti Island, Quebec. Geol. Surv. Canad., Paper 71-19, pp. 1-44.

CLARK, T.H. 1964. Preliminary report on log of New Associated Consolidated Paper Anticosti # 1. Department of Natural Resources, Quebec. 5 p. - log.

DEFFEYES, K.S. et al 1965. Dolomitization of Recent and Plio- Pleistocene sediments by marine evaporite water on Bonaire Netherland Antilles. In Lloyd C. Pray & Murray R.C. (Editors). Dolomitization and limestone diagenesis (A Symposium). Soc. Economic. Paleontol. Mineral. Sp. Pub. 13: 71-88.

DUNHAM, R.G. 1959. Classification of carbonate rocks according to depositional texture. In W.E. Ham (Editor), Classification of carbonate rocks (A Symposium). American Assoc. Petrol. Geologist Mem. 1: 108-121.

GILBAULT, J.P. 1975. Algues ordoviciennes des Basses-Terres du Saint-Laurent et des régions limitrophes. Mémoire de maîtrise non publié. Université de Montréal, 163 p.

HECKEL, P.H. 1972. Recognition of ancient shallow marine environments. In J.K. Righy & Hemblin, W.K. (Editors). Recognitions of ancient sedimentation environments Soc. Economic. Paleontol. Mineral. Sp. Pub. 16: 226-286.

MASLOV, V.P. 1954. Sur le Silurien inférieur de la Sibérie orientale. In Questions sur la géologie de l'Asie, tome 1 (en russe). Izd. An SSSR, pp. 495-529.

RIVA, J. 1969. Middle and Upper Ordovician Graptolites faunas of Saint Lawrence Lowlands of Quebec and Anticosti Island. Am. Assoc. Petrol. Geol., Mem. 12: 513-556.

RIVA, J. 1972. Géologie des environs de Québec. Excursion B-19. 24ième Congrès Géologique International, 60 p.

ROLIFF, W.A. 1968. Oil and gas exploration - Anticosti Island, Quebec. Geol. Assoc. Canada, Proceeding 19: 31-36.

SCHUCHERT, C. and TWENHOFEL, W.H. 1910. Ordovic- Siluric section of Mingan and Anticosti Islands, Gulf of Saint Lawrence. Bull. Geol. Soc. America 21: 677-716.

TWENHOFEL, W.H. 1925. Geology of Mingan Island. Bull. Geol. Soc. America 37: 535-550. .

TWENHOFEL, W.H. 1938. Geology and palaeontology of the Mingan Island, Quebec. Geol. Soc. Canada. Sp. Paper: 11.

B. PALYNOLOGY

I. INTRODUCTION

The palynological study of samples coming from the New Associated Consolidated Paper Anticosti No. well was carried out in order to establish the main chitinozoan associations present in the studied sequence. This should be a base to the establishment of a palynostratigraphic scale of the Siluro-Devonian series of the Anticosti Island.

As a graptolite study was done on the Upper Ordovician formations of this well, the results obtained with the chitinozoans were compared with those obtained with the graptolites (J. Riva, 1969, 1973) in order to integrate the resulting zonation in the international stratigraphic scale.

In general, the samples which are rich in graptolites are also rich in chitinozoans. In the same way, the formations which contain a few or no graptolites are also poor in chitinozoans.

The distribution of the main observed forms is schematized in table Pl. 1 (out of text).

The zonation made with the chitinozoans happen to be very satisfactory; however, it could be made more precise by using the acritarchs zonation, but this type of study was not taken up in the present work.

II. CHITINOZOA ASSOCIATIONS

200 - 300'	Samples poor in fossils. The association is made up of specimens related to the *Sphaerochitina* and *Ancyrochitina* genus.

350 - 450' The assemblage of chitinozoans is essentially made up of: *Cyathochitina kuckersiana*, *Conochitina* sp., *Conochitina* aff. *capitata*, *Ancyrochitina* sp.

525 - 550' These levels are characterized by the presence of: *Conochitina* sp., *Cyathochitina kuckersiana* and *Ancyrochitina* sp.

700 - 2373' This interval is marked by the presence of chitinozoans of *Hercochitina* genus, which are characterized by a longitudinally arranged ornamentation. This interval may be subdivided as follow:

700 - 1000' - Presence of *Hercochitina crickmayi* and of *Cyathochitina kuckersiana patagiata*

1050 - 1850' - Beside *Hercochitina crickmayi*, the presence of *Tanuchitina* sp., *Ancyrochitina* sp., *Parachitina curvata*, *Conochitina* sp., *Cyathochitina kuckersiana patagiata* are noted. In this interval, the *Hercochitina crickmayi* forms become diversified with specimens which are related to the *normalis* form (1300', 1600', 1700') or the *spinetum* form (1800-1850'). At the base, the presence of *Conochitina dolosa* is noted.

1900 - 2373' - Appearance downward of *Cyathochitina vaurealensis* associated with *Hercochitina crickmayi*, *Conochitina* sp., *Conochitina dolosa*, *Tanuchitina* sp., *Conochitima schopfi*. At the 1950 and 2000 feet levels, there is a population of *Conochitina* characterized by a very developed spiny ornamentation reaching 20µ. At the base of this sequence, there is *Acanthochitina barbata*, *Ancyrochitina merga*, *Rhabdochitina gallica*.

2425 - 3100'	This zone is characterized by the disappearance of *Hercochitina crickmayi*. *Cyathochitina vaurealensis* is still there and *Conochitina schopfi* is an abundant form of this association. In the upper part of this interval, the presence of *Tanuchitina* sp. is noted. The association is also characterized by *Rhabdochitina gallica*, *Conochitina bulmani*, *Ancyrochitina merga*, *Conochitina hirsuta* and *Acanthochitina barbata*.
3200 - 3900'	Appearance downward of *Kalochitina multispinata* and of *Cyathochitina kuckersiana lotipagium* associated with *Conochitina* aff. *bulmani*, *Conochitina* aff. *schopfi*, *Rhabdochitina* sp., *Ancyrochitina* sp.; the presence of a specimen of *Acanthochitina barbata* is noted at the 3400 feet level.
3950 - 3975'	Presence of *Kalochitina multispinata* associated with *Cyathochitina* aff. *jenkinsi*.
4000 - 4050'	Non characteristic *Conochitina* aff. *schopfi* association.
4390 - 4492'	*Desmochitina* sp., *Conochitina* aff. *hirsuta*, *Conochitina* sp., *Cyathochitina jenkinsi* and *Lagenochitina* sp. association.

III. CONCLUSIONS

Comparison between the chitinozoan zonation and the graptolite zonation

The analysis made on the chitinozoans of the Siluro-Devonian series met in the N.A.C.P. bore-hole indicate that a separation into palynological zones based on the chitinozoans distribution is possible.

Based on the graptolites distribution as established by Riva (1969), a good correlation is seen between the frequency and the distribution of the graptolites and of the chitinozoans.

Ellis Bay and Becscie Formations (N.A.C.P. 0 - 700')

Three associations of chitinozoans can be observed:

- 200-300': *Sphaerochitina* sp. association
- 350-450': *Conochitina* aff. *capitata* and *Cyathochitina kuckersiana* association
- 525-550': *Conochitina* sp. and *Ancyrochitina* sp. association

Vaureal Formation (700-- 3900')

In this formation, the following zones may be recognized:

- A *Hercochitina crickmayi* (700-2400') zone which may be subdivided into many sub-zones:
  - A *Hercochitina crickmayi* and *Cyathochitina kuckersiana patagiata* sub-zone;
  - A *Hercochitina crickmayi* and *Tanuchitina* sp. zone;
  - A *Hercochitina crickmayi* and *Cyathochitina vaurealensis* zone.

This zone seems to be equivalent to the *Climacograptus prominens elongatus* graptolite zone ans thus should be of Ashgillian age (J. Riva 1969, 1974).

According to Riva (1969), these levels are not very rich in graptolites which are included in the *Dicellograptus complanatus* zone.

Macasty Formation (3900 - 3991')

Even if they are rich in organic matter, the studied samples coming from this formation are quite poor in chitinozoans among which *Cyathochitina* aff. *jenkinsi* is found (3950-3975'). It was thus not possible to establish any correlation with the graptolite zonation and to show the paracomformity detected by J. Riva (1969).

Mingan Formation (3991 - 5031')

Only one level (4390-4492') shows an assemblage of chitinozoans among which *Cyathochitina jenkinsi*, *Conochitina* aff. *hirsuta*, *Lagenochitina* sp. and *Desmochitina minor* were recognized. In this level, were also found some graptolites such as *Glyptograptus euglyphus* and *Dicellograptus sextans* (J. Riva 1969) in the *D. multidens* zone of Caradocian age.

Comparison with some other chitinozoan associations

Among the identified chitinozoans, many species were described in Ordovician series in Europe and America. We will try to establish some relations between the associations defined in the studied well and those found in the literature. We will discuss the *Hercochitina crickmayi*, *Acanthochitina barbata* and *Kalochitina multispinata* associations because the informations concerning these forms are more abundant.

Hercochitina crickmayi zone

Hercochitina crickmayi is a species which has been previously recognized only in the Upper Ordovician in Northern America by Jansonius in the Vaureal Formation of the Anticosti Island and by Jenkins (1970) in the Viola Limestone in Oklahoma. This species is associated in the upper part of the Vaureal Formation, with *Tanuchitina* sp. which is probably a new form and, in the middle interval of the formation with *Cyathochitina vaurealensis*, also a new form.

This zone seems to be equivalent to the *Climacograptus prominens elongatus* graptolite zone which is Upper Ashgillian and that Riva correlate with the *Dalmanitina* beds of Scania. Unfortunately, the data concerning a population of chitinozoans from which many components do not seem to have been otherwise described.

Acanthochitina barbata and *Cyathochitina vaurealensis* zone

The numerous species found in this zone were proviously described in the Ordovician series of Europe.

The presence,at Anticosti, of *Acanthochitina barbata* is important because this species is considered in Europe as being characteristic of the Caradocian-Ashgillian limit.

The *Acanthochitina barbata, Rhabdochitina magna, Lagenochitina* association is noted by Eisenack in the Ordovician F1 in Estonia.

Jenkins (1969) pointed out the presence of *Acanthochitina barbata* associated with *Lagenochitina baltica* and with *Angochitina communis* (= *Conochitina hirsuta*) in the upper part of the Onnia Beds of Shropshire.

Finally, *Acanthochitina barbata* and *Lagenochitina baltica* are described in Sweden by Laufeld (1967) in the Fjacka Formation in which graptolites of the *Pleurograptus linearis* zone are also present and thus should be of Lower Ashgillian age (Kjellström 1971).

Kalochitina multispinata and *Cyathochitina kuckersiana latipatagium* zone

The holotype of *Kalochitina multispinata* was reported by Jansonius (1964) in the Maeford Dundas Formation in Ontario. Jenkins (1970) noted the presence of this species in the Sylvan Shale of Oklahoma.

The presence of *Kalochitina multispinata* was also noted by Martin (1975) in the Utica Formation at the Montmorency River Falls. This species also seems to exist in the Lower Lorraine Group in some wells from the Saint Lawrence Lowlands.

It is finally noted that the presence of *Cyathochitina jenkinsi*, *Desmochitina minor* and *Lagenochitina* sp. in the 4390-4492 feet interval, brings together this association and that of the Port au Port Peninsula of Western Newfoundland as described by Neville (1974).

REFERENCES

CLARK, T.H. 1972. Stratigraphy and structure of the Saint Lawrence Lowlands of Quebec. Field excursion C-52, 24ième Congrès Géologique International.

JANSONIUS, J. 1964. Morphology and classification of some Chitinozoa. Bull. Can. Petrol. Geol. 12, pp. 901-918.

JENKINS, W.A.M. 1967. Ordovician chitinozoa from Shropshire. Palaeontology 10, pp. 436-488.

JENKINS, W.A.M. 1969. Chitinozoa from the Ordovician Viola and Fernvale Limestones of the Arbuckle Mountains Oklahoma. Palaeontology, sp. Paper no. 5, pp. 1-44.

JENKINS, W.A.M. 1970. Chitinozoa from the Ordovician Sylvan Shale of the Arbuckle Mountains Oklahoma. Palaeontology 13, pp. 261-288.

MARTIN, F. 1975. Sur quelques chitinozoaires ordoviciens de Québec et de l'Ontario, Canada. Can. J. Earth Sci. 12, pp. 1006-1018.

NEVILLE, R.S.W. 1974. Ordovician chitinozoa from Western Newfoundland. Review of Palaeobotany and Palynology 18, pp. 187-221.

RIVA, J. 1969. Middle and Upper Ordovician graptolite faunas of Saint Lawrence Lowlands of Quebec and of Anticosti Island. Mem. Am. Ass. Petrol. Geol. 12, pp. 513-556.

RIVA, J. 1974. A revision of some Ordovician graptolites of Eastern North America. Palaeontology 17, pp. 1-40.

C. CLAY MINERALOGY

I. INTRODUCTION

Qualitative determination and semi-quantitative evaluation of clay minerals were carried out on 58 samples taken at 100 feet intervals between 100 and 5700 feet. The analyses were done on two fractions; the less than 2 microns fraction (fine fraction) and 2-16 microns fraction (coarse fraction).

The analyses were performed with a Philips diffractometer using a Hewlett Packard XY recorder. The characteristics and the settings of the system are the following:

X-Rays: Cu Kα, 44 KV, 32 mA
Slits: 1°, -.2 + Ni, 1°
Discri.: Att: 1, Ht 1560 (counter)
Treshold: 1.65V, channel 3V
Time Cst: .4
Gonio. speed: 2.4°/min.
Recorder: Y sensitivity: Pos. 2, potentio.: 4.31
X sensitivity: 4×10^3 (PW4620), 1 mV/cm.

The following clay mineral species were identified in this well: illite, an irregular illite-smectite, mixed-layer, chlorite, some smectite in the few topmost samples and traces of kaolinite in only one sample at the 2800 feet level.

II. DIAGENESIS

In general, these sediments do not seem to have been submitted to high thermal diagenesis. This conclusion is based on the presence in great amount of irregular illite-smectite mixed-layer minerals and by the presence in some samples of relatively low diagenesis index minerals such as smectite and kaolinite. Moreover, the illite crystallinity, in general, is fairly low.

None of the parameters, usually used to evaluate the thermal diagenesis degree (illite crystallinity, index minerals such as smectite, mixed-layer minerals and kaolinite) indicates an evolution with depth. Many factors such as the chemical composition of interstitial fluids, porosity, permeability and organic matter content of the sediments may prevent the "normal" evolution of clay minerals.

The analyses of the measured parameters lead to the following observations:

a) from the 2500 feet level down to 3500 feet, a gradual decrease in the illite crystallinity in the less than 2 microns fraction is observed. Between 3500 and 5000 feet, there is a plateau where the illite crystallinity index is veyr high; thereafter, the crystallinity seems to increase. The trend is not very clear however;

b) from the 3000 feet level, the relative proportion of the mixed-layer minerals increases gradually with a maximum at 3900 feet. From 4200 feet, the abundance of this mineralogical type becomes fairly stable.

These observations may be interpreted as being the results of one or a combination of the following processes:

1) variation of the nature or the physico-chemical properties of the inherited minerals. The deterioration of the illite crystallinity may be the result of a more efficient hydrolysis process at the source area or the result of the presence of a new source area. The variation in the nature of the detrital material in general is confirmed by the almost complete disappearance of chlorite in the fine fraction at 3500 and at 4000 feet for the coarse fraction. Moreover, the illite crystallinity is quite low in the 2-16 microns fraction between 4000 and 5500 feet;

2) presence in the smectitic layers of the mixed-layer minerals (I-S)

and in open illite of organic complexes which prevent them to evoluate towards better crystallized micaceous minerals. This is specially the case in the Macasty Formation;

3) no circulation of fluids with high K^+ and Al^{+++} activities in the low permeability carbonates of the Romaine and Mingan Formations.

It is fairly evident that these three factors were more or less important at different levels. As it was said before, the influence of organic matter was more important between the 3000 and 4000 feet.

Briefly, the diagenetic evolution degree was not high enough to obliterate the influence of the detrital minerals composition or the influence of the physico-chemical properties of the diagenetic environment. This is why, and also because of the presence at the top of the bore-hole of smectites and because of the low illite crystallinities in general, it is concluded that the diagenetic evolution is still favourable to oil or at least to wet gas production.

III. CLAY MINERALS DISTRIBUTION

Illite

Illite is the most abundant mineral and is found in all the studied formations. Its abundance decreases slightly towards the base of the well, specially from 3500 feet, while the mixed-layer minerals increase also slightly. As indicated by the 002/001 reflection intensities ratio, the composition of illite (Al/Mg), does not vary much from the top to the bottom of the bore-hole. However, between 3300 and 3900 feet, this mineral seems a little richer in aluminum.

Mixed-layer minerals

Some mixed-layer minerals of illite-smectite were identified in all the studied samples. As it was noted before, the Macasty Formation is underlined by an important increase of this mineralogical type. This is also the case for the Mingan and Romaine Formations, but in less important proportions.

Chlorite

The chlorite has an irregular distribution in this well. This mineral is more abundant and its presence is more continuous in the 2-16 microns fraction than it is in the fine fraction where it disappears almost completely from 3500 feet down to the bottom of the bore-hole. It is present in small quantities in very few samples coming from the Macasty, Mingan and Romaine Formations.

Smectites

Some smectites are observed between the 600 and 800 feet level in the fine fraction and only at 600 feet in the coarse fraction. In fact, these smectites are found only in the nodular limestones at the top of the Vaureal Formation.

Kaolinite

Some traces of this mineral are noted only at the 2800 feet level. This presence in such a small quantity does not seem to have any special signification.

Conclusions

The Macasty, Mingan and Romaine Formations are characterized by an increase in mixed-layer minerals content and by the disappearance of significant amounts of chlorite. This is probably mainly related to a decrease in the basin of detrital material due to a change in the weathering processes at the source area. The chlorite being coarser than the mixed-layer minerals, would lead to differential settling which might have concentrated the latter in a more distal environment.

The nodular limestone at the top of the Vaureal Formation is underlined by the presence of smectites. Two hypothesis are more probably to explain the presence of this mineral only in the lithologic type:

1) persistency of the smectite only in this facies, whereas this mineral was transformed into mixed-layer minerals and illite by diagenetic processes in other units;
2) presence at this level of special conditions favourable to the formation of smectite such as the presence of volcanic ashes in a marine environment.

More detailed studies are needed in mineralogy and chemistry and also in petrography to choose the good hypothesis.

II. ORGANIC DIAGENESIS
SOURCE ROCK POTENTIAL

A - REFLECTOMETRY

B - ORGANIC MATTER CARBONIZATION DEGREE (colour)

C - ORGANIC CHEMISTRY
- T.O.C.
- Cr/Ct

A. REFLECTOMETRY

I. ORGANIC MATTER PETROGRAPHY

The size of the observed organic elements goes from tens of microns to many hundreds of microns. The polished sections of organic matter fragments are grey and fairly homogeneous and look quite like vitrinite. The very peculiar shapes of these polished fragments, in filaments, rings or ovals more or less distorded are characteristic (see photographs Pl. R1). It is obvious that these forms represent cross-sections of different orientations of organisms having an elongated sack shape. On several of these organisms, it is possible to observe some striated ornementations.

These observations coupled with palynological identifications in transmitted light microscopy confirm that most of these organic elements are chitinozoans or fragments of chitinozoans.

A certain amount of spherical elements named Spherolites according to the definition of Alpern (1970-1971) (1, 2) were observed. These Spherolites are also homogeneously grey. In general, their reflectance (R.O.) values are slightly lower than that of the chitinozoans, but in certain cases, they have a center having an higher R.O. The exact nature of these Spherolites is not known with certainty, but they might be Leiospheres.

In general, finely dispersed organic matter is scarcely present. In two samples at 3600 and 3950 feet, it is fairly more abundant.

Pyrite in microspheres or crystals is present in variable amounts.

II. REFLECTOMETRY AND DIAGENETIC INTERPRETATION

The reflectance (R.O.) was measured on the chitinozoa and on the Spherolites. The values are about 0.5% at 1300 feet and increase slightly down to 3500 feet; from there, they increase more rapidly to reach 1% at 4000 feet. The standard deviation of the reflectance values for a sample is normal or slightly higher if compared to what it is observed on vitrinite of the same rank.

There does not seem to be any reference concerning the interpretation of reflectance measurements on chitinozoans. Alpern (1970) (1) notes that "the wall aspect (of chitinozoans) in all is the same as vitrinite".

The lack of reference data makes impossible any correlation between the reflectance values measured on chitinozoans and the vitrinite scale giving the hydrocarbon favourable or unfavourable zones. However, it must be noted that, in this bore-hole, the chitinozoans R.O. increases with depth just like vitrinite R.O. does when present. It is thus concluded that the evolution of this type of R.O. could also be related to thermal diagenesis.

Many oil shows have been reported in this well. It is interesting to note that these oil shows correspond to chitinozoan R.O. values of .5 to 1%. These values are more or less the same as those generally accepted as being the limit of the diagenetically favourable zone for oil when vitrinite is used (between .5 and 1.35%).

TABLE R1

REFLECTANCE VALUES

INRS No	Depth	R.O. Average	Standard deviation
9132 - 9140	1200 - 1400'	.54	.06
9144 - 9152	1500 - 1700'	.67	.07
8975	1900 - 2100'	.62	.13
5724	2300 - 2500'	.77	.14
9543	2700 - 2900'	.75	.10
6062	3150 - 3250'	.76	.20
6507	3500'	.67	.07
6511	3500 - 3700'	.84	.08
6525	3950'	.85	.10
8421	4300 - 4400'	1.04	.13

REFERENCES

ALPERN, B. 1970. Classification petrographique des constituants organiques fossiles des roches sédimentaires. In Rev. Inst. Franc. Pet. 1970.

ALPERN, B., DURAND, B., ESPITALIE, J. and TISSOT, B. 1971. Localisation, caractérisation et classification pétrographique des substances organiques sédimentaires fossiles. In Adv. in Org. Geochem.

B. ORGANIC MATTER CARBONIZATION DEGREE (colour)

I. ORGANIC MATTER ABUNDANCE

The amount of organic matter obtained by palynological preparation techniques is estimated to be normal for the Ellis Bay, Becscie and Vaureal Formations; an increase in organic matter content is noted at the base of the Vaureal Formation, in the Macasty Formation and in the lithofacies 4 of the Mingan Formation. The dolomites of the Romaine and Mingan Formations are poor in organic matter.

II. THE NATURE OF ORGANIC MATTER

The palynological residue is essentially made up of acritarchs, chitinozoans, fragments of graptolites and fine organic matter. In some places (550 and 2900'), accumulations of leiospheres are noted. Black fragments are abundant mainly in the Macasty Formation (3925').

III. EVOLUTION DEGREE OF THE ORGANIC MATTER

The evolution degree of organic matter in the N.A.C.P. well is estimated "slightly mature" in the upper part of the bore-hole (Ellis Bay Formation). In the Vaureal Formation, the acritarchs are slightly darker and the organic matter is thus considered to be "mature". The evolution degree keeps on increasing with depth, but at 4500 feet, the microfossils are still well preserved and would be in the mature zone. Further down this level, the organic matter is more advanced.

IV. CONCLUSION

The evolution degree of organic matter determined on its colour, leads to the conclusion that in the N.A.C.P. well area, the diagenetic evolution is favourable to the presence of liquid hydrocarbons for the sequence between the top of the well and the Mingan Formation. Further down, the maturation might be more in accordance with the presence of gazeous hydrocarbons.

C. ORGANIC GEOCHEMISTRY

I. INTRODUCTION

The total organic carbon (T.O.C.) and the carbon ratio (C.R.) determinations on insoluble residues permit to evaluate the source rock potential of a sequence and to establish its thermal diagenetic evolution degree.

An introduction to these techniques is found in the Saint Roch bore-hole study (ref. MRN-76 St-Roch). The T.O.C. content is an indicator of a potential source-rock. Many parameters such as the lithology, the nature of organic matter, the temperature and the pressure control the amount of organic matter. However, it is generally accepted that from a content of 1.60% and over of organic matter, the rock may be considered as a source-rock.

The carbon ratio is used as thermal evolution indicator. Again, the nature of the organic matter, the temperature and the time have a certain influence on this parameter (see Saint Roch report). The higher the C.R. values, the higher the thermal evolution degree; it is generally admitted that in the Palaeozoic series, values of .80 or less are compatible with the presence of liquid hydrocarbons. From .80 and more, only gazeous hydrocarbons might be expected (or even no hydrocarbon at all).

II. TOTAL ORGANIC CARBON (T.O.C.) AND INSOLUBLE RESIDUE (I.R.)

Total organic carbon and insoluble residue analyses were carried out on 111 samples. The carbon ratio (Cr/Ct) was determined on 20 of these samples. The results of these analyses are shown on figure 2 and in plate Pl. 2.

Concerning the source rock potential of the formations encountered in N.A.C.P. well, the data shown on figure 2 suggest the following conclusions:

1) the only sample coming from the Macasty Formation (3950') and also those coming from the 3400 - 3900 feet interval in the Vaureal Formation are the only ones showing a good source rock potential;
2) the samples coming from the Mingan Formation and from the 3200 - 3400 feet interval of the Vaureal Formation only have, according to Sourisse and Gauthier's diagram (1969) (fig. 2) an intermediate quality as source rock;
3) all the other lithostratigraphic units in this studied sequence do not have any source rock potential.

The source rock potential may also be assumed in the plate Pl. 2. In this figure, the intervals where the T.O.C. and I.R. curves cross cut, generally have a better source rock potential than those elsewhere in the sequence. However, it must be noted that very few samples were analysed in the Macasty Formation and consequently the data may not be very significant in this interval.

The increase in total organic carbon content (Pl. 2) between 3500 and 4000 feet is confirmed by the observation of the organic matter in reflected light microscopy.

New Associated Consolidated Paper
Anticosti No.1

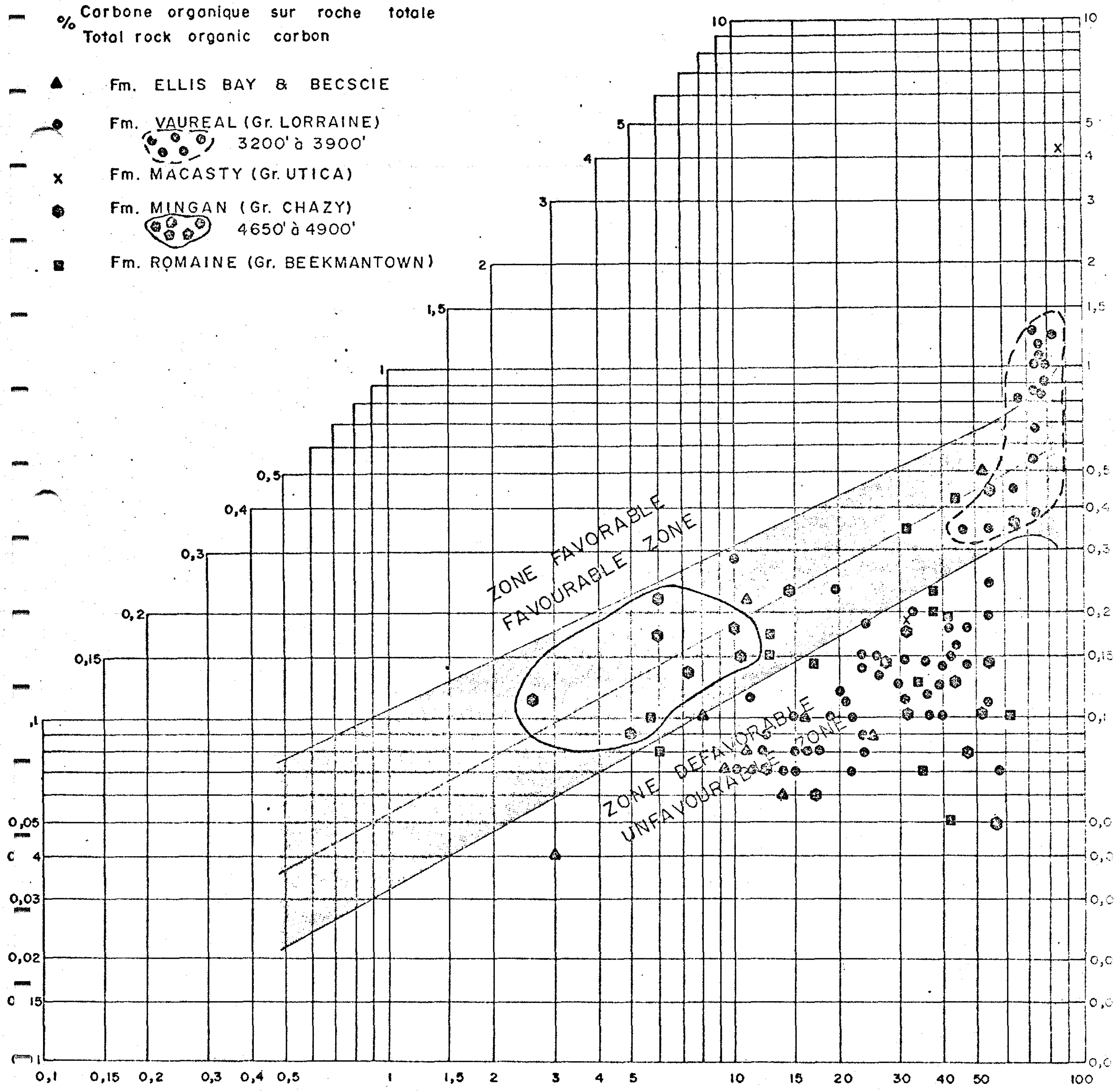


DIAGRAMME CARBONE ORGANIQUE / RESIDU INSOLUBLE
DIAGRAM OF ORGANIC CARBON / INSOLUBLE RESIDUE

Ref. Sourisse C. Gouthier J. 1969

III. CARBON RATIO - Cr/Ct

The evolution of this parameter (Cr/Ct) only reflects, in this sequence, the thermal diagenetic stage, the more aromatic substances of ligneous type being not yet present on the Earth surface (Ordovician-Lower Silurian). Moreover, the fossils (plants or animals) found in these formations indicate clearly the marine origin of the sediments.

The principal characteristics of the carbon ratio curve (see Pl. 2) are the following:

1) above 4000 feet, the Cr/Ct curve is more or less parallel with the reflectance (P.R.) curve;
2) below 4000 feet, the Cr/Ct values decrease abruptly and both curves then evoluate in opposite senses.

From these observations, the following conclusions can be drawn:

a) between 3500 and 4000 feet, the organic matter has been submitted to temperatures around 100°C (Le Tran, Connan and Van Der Weide 1973);
b) from 400 to 3500 feet, the carbon ratio seems to show a gradual evolution with depth, but because of the low density of sampling in this interval, any interpretation of the data must be done with caution ;
c) below 4000 feet, the abrupt decrease in carbon ratio values is impossible to explain at this point.

In conclusions, it is believed that the base of the Vaureal Formation, the Macasty Formation and also the Mingan Formation in part have a good source rock potential.

Taking into account the thermal time framework (Cornelius 1973), these potential source rock have probably reached a thermal diagenetic stage favourable to the formation of oil (100°C) in the Utica Group and probably also at the base of the Lorraine Group. However, we can not conclude on the diagenetic stage reached in the Chazy Group.

REFERENCES

SOURISSE, C. and GAUTHIER, J. 1969. Contribution à la géochimie du Carbone organique des roches sédimentaires. Rapport SNPA inédit.

LE TRAN, K., CONNAN, J. and VAN DER WEIDE, B. 1973. Problèmes relatifs à la formation d'hydrocarbures et d'hydrogène sulfuré dans le Bassin Sud-Ouest Aquitain. Adv. in Org. Geochem. Acte du 6e Congrès International de Géochimie Organique, 761-789.

CORNELIUS, C.D. 1973. Geothermal aspects of hydrocarbon exploration in the North Sea Area. Bergen Conf. on Petrol. Geol. of the North Sea, Oct. 1973.

III. RESERVOIR POTENTIAL EVALUATION
POROSITY
PERMEABILITY

RESERVOIR POTENTIAL EVALUATION

The porosity (∅) and permeability (K) determinations were carried out in order to evaluate the reservoir potential.

This evaluation must take into account the quantitative results of the permeability and porosity tests as well as the qualitative aspect of the microfacies analyses.

I. QUANTITATIVE EVALUATION (petrophysics)

Ten samples were tested. The raw values are shown in table Pl.

Sample no	Depth	Air permeability Millidarcys			% ∅	Density gm/cc	
		K max.	K 90°	Kv		Bulk	Grain
9688	5004	0.04			2.0		
9690	5019	0.11			3.2		
9695	5056	*1.54	*1.54	<0.01	3.9	2.58	2.69
9701	5203	*1.17	*0.08	<0.01	3.8	2.58	2.68
9707	5336	<0.01			1.3		
9708	5454	<0.01			4.1		
9712	5582	<0.01			1.1		
9714	5673	1.98			11.8		
9715	5685	<0.01			4.6		
9716	5775	0.04			7.6		

TABLE Pl. Conventional petrophysics determinations (small plugs) and whole core analysis on samples 9695 and 9701

* These permeability probably result of shale cleavage or parting and do not indicate the matrix permeability. A permeability of 0.1 to 0.2 MD might be assumed for this type of matrix.

The descriptions of these samples are summarized in the litholog found in appendix M1. The positions of these samples in the column are indicated by a special symbol (see last page of the litholog). These 10 samples were selected, after their petrographic descriptions, because their lithologies are the most favourable for a maximum Ø and K.

The values shown in table P1 are for samples coming mainly from the various facies of the Romaine Formation. However, the two samples from 5004 and 5019 feet were taken from a core,drilled in the sandstones at the base of the Mingan Formation.

II. POROSITY Ø

The porosity measurement is done by placing the sample in a sealed chamber where a partial vacuum is obtained. The calculation of the porosity consists in the determination of the sample volume and that of the gas released by the porous network. This permits the measurement of a maximum Ø.

However, it does not permit, as it is the case with the Hg test, to extrapolate the pore interconnections radius ($Pc = \delta\cos\Theta/\Gamma\mu$)[1] for a uniform capillary sytem (Monicard 1967) and to establish the height of the oil column which is needed for the migration of an oil droplet in a network of microfractures having the same size as the pore interconnections ($\Delta P = 2T/\Gamma\mu$). Moreover, the correlations between Ø and K ($K = \emptyset\Gamma^2/8$) are not possible to establish when the Ø values are obtained by the extraction of the gases.

Ø = porosity in %
Pc = capillary pressure in Hg tests (Kg/cm^2)
$\delta\cos\Theta$ = surface tension and contact angle, equivalent to 7.5 for Hg
$\Gamma\mu$ = pore radius in microns
K = permeability in millidarcys
T = interfacial tension water /oil ≃ 28 to 30 dynes/cm

---

[1] For the detailed equations, see Héroux 1975, p. 71

ΔP = pressure nedded to plish a droplet of oil through a pore interconnection of a Γ radius; in baryls (10^6 baryls = 1 bar).

The meaning of the measured Ø values is different according with the various lithologies. Thus, Ø of 2 to 3% in the sandstones at 5004 and 5019 feet indicate a very low reservoir potential. On the other hand, when values over 1% are detected in the carbonates, specially when K is over one millidarcy (MD), the reservoir quality is as good as those in exploitation (Langton and Chin 1968, p. 138). Keeping this in mind, it is noted that in table P1, there is only one value over one MD.

Briefly, there is only one dolomite sample at 5673 feet giving an interesting Ø (11.8%), which permits to believe that at this level, the presence of a reservoir is possible.

III. PERMEABILITY K

The K tests were carried out on small plugs and on the full core in the case of two samples (5056 and 5203). These tests (air) give an indication on the influence of the fractures (cleavages or partings) in the carbonates, when they are done on the whole core (Monicard 1967, p. 73). This influence of the fractures is suspected if the measurement heterogeneity of max. K, K 90, Kv and Ø are taken into account. Moreover, the sample at 5203 feet shows a grain density of 2.68 which is almost the same as a pure carbonate density (2.71 = calcite) which is confirmed by thin section study. Consequently, a K matrix is probably lower in these carbonates (tenths of MD). This hypothesis is confirmed by the presence of stylolites indicating that the primary Ø was considerably reducted.

IV. QUALITATIVE EVALUATION (microfacies)

Because the Ø values are not high enough to qualify the sandstones (5004 and 5019') and the nodular limestones (5056 and 5203') as reservoir facies or because the petrographic context (calcareous nodules-dolomitic mudstones) is not favourable for reservoir, the purpose of the following discussion is to establish the probabilities that the Romaine Formation could have acquired a reservoir potential by some other processes (pre-telogenetic, Choquette and Pray 1970).

As noted by these authors, the porosity may be created, modified or destroyed during the evolution of the carbonate deposit. The primary porosity was destroyed or at least considerably modified in the Romaine Formation as indicated by the presence of stylolites.

A secondary porosity was created (vugs) because the dolomitization reduces the volume, the density increasing with a constant mass. This dolomitization effect on the porosity may be non-existant if the process was of "Dorag type" (Badiozamani 1973). However, this process implies that the carbonates have lost an important portion of their porosity by an early cementation.

The high values of porosity 4 to 11% in the Romaine Formation result from a secondary porosity (vugs). Except for some microfractures which could have connected these vugs at 5673 feet (K = 1.98 MD), this porosity does not seem to be effective indicating a low reservoir potential for the samples studied. However, as the dolomites may have an heterogeneous porosity system (Link 1950, p. 291), it is important to consider the possibility of a tectonic fracture before disregarding the reservoir qualities of the formations on Anticosti Island. A structural study might permit to locate a secondary porosity (vugs) in a microfracture network (permeability).

REFERENCES

BADIOZAMANI, K. 1973. The Dorag dolomitization model application to the Middle Ordovician of Wisconsin. Jour. Sed. Petrology, vol. 43, no 4, pp. 965-984.

CHOQUETTE, P.W. and PRAY, L.C. 1970. Geologic nomenclature and classification of porosity in sedimentary carbonates. Bull. Am. Ass. Petrol. Geol., vol. 54, no 2, pp. 207-250.

HEROUX, Y. 1975. Stratigraphie de la Formation de Sayabec (Silurien) dans la Vallée de la Matapédia (Québec). Thèse de doctorat Univ. de Montréal, 136 p. (Version modifiée sous presse, Ministère des Richesses Naturelles du Québec).

LANGTON, J.R. and CHIN, G.E. 1968. Rainbow Member facies and related reservoir properties, Rainbow Lake, Alberta. Can. Petrol. Geol. vol. 16, no 1, pp. 104-143.

LINK, T.A. 1950. Theory of transgressive and regressive reef (Bioherm) development and origin of oil. Bull. Am. Ass. Petrol. Geol. vol. 34, no 2, pp. 263-294.

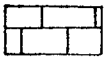
MONICARD, R. 1967. Cours de production, tome 1: caractéristiques des roches réservoirs, analyse des carottes. Ecole Nationale Supérieure du Pétrole et des Moteurs à Combusion Interne. Soc. des Editions Technip, 169 p.

APPENDIX M1

Detailed litholog
of the
New Associated Consolidated Paper Anticosti No 1
bore-hole

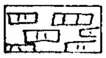
CARACTERES PETROGRAPHIQUES/PETROGRAPHIC CHARACTERISTICS

I ⊥	Calcareux - limy	*I ⊥*	Dolomitique - dolomitic
V	Vert - green	⬠	Fragment de roches anguleux Angular rock fragment
■	Bitumineux - bituminous	M	Marbre - marble
//	Strie de glissement Slickenside	T	Turbidite
○	Pelletoides - pellets	⊙	Ooides - Ooids
●	Lithoclasts-intraclasts	π	Feldspath - feldspar
Q	Quartz		



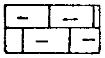
Calcaire; litage régulier
limestone; regular bedding

Calcaire; litage irrégulier
limestone; irregular bedding

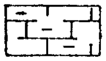


Calcaire nodulaire ou grumeleux
Nodular or lumpy limestone

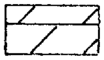
Conglomérat "intraformationnel" calcaire
"Intraformational" calcareous conglomerate



Calcaire argileux
Argillaceous limestone

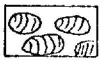


Marne et marne boueuse
Marl and muddy marl

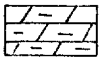


Dolomie
Dolomite

Calcaire pseudo bréchique
pseudo brecciated limestone



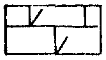
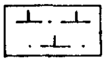
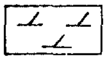
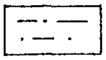
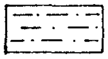
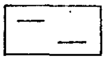
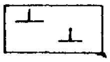
Conglomérat à fragments de Spongiostromate
Spongiostromata conglomerate



Dolomie argileuse
Argillaceous dolomite

Grès
Sandstone

Grès argileux
Argillaceous sandstone

	Calcaire dolomitique Dolomitic limestone
	Siltstone calcareux Limy siltstone
	Mudstone dolomitique Dolomitic mudstone
	Mudstone silteux Silty mudstone
	Siltstone Siltstone
	Claystone-mudstone Claystone-mudstone
	Claystone-mudstone calcareux Limy claystone-mudstone

B	Boundstone
G	Grainstone
M	Mudstone
P	Packstone
W	Wackestone
X	X-stone

STRUCTURES

Sédimentaires

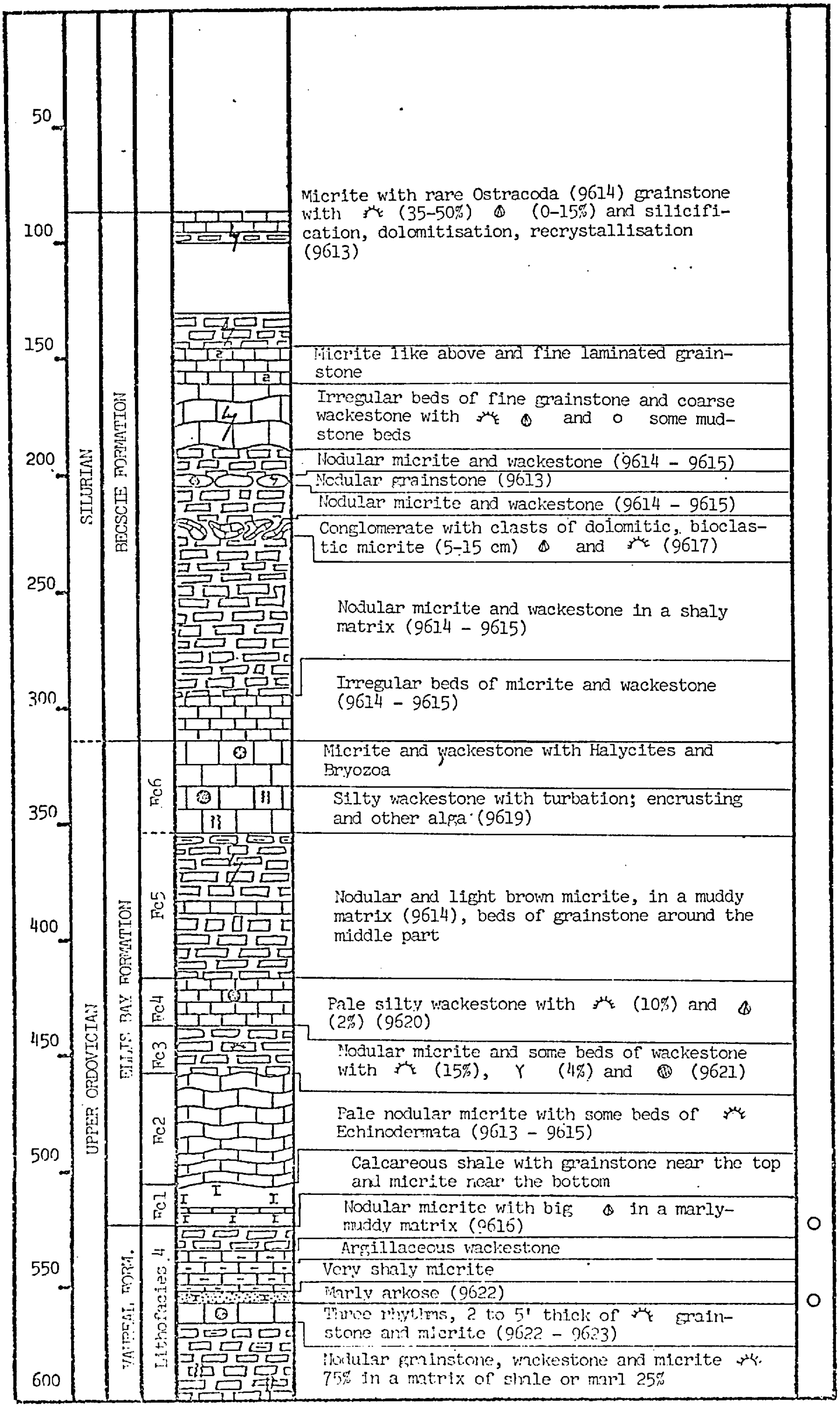
ƨ	Laminations parallèles Parallel laminations
⋋	Stratifications entrecroisées Cross-bedded stratifications
∫∫∫	Bioturbation - bioturbation
⬭	Nodules - nodules

Diagénétiques

ϟ	Stylolites - stylolite
⊛	Geodes - vugs

FOSSILES/FOSSILS

⊕	Coraux - coral
◍	Algues - algae
◬	Brachiopode - Brachiopoda
⁂	Echinodermes - Echinodermata
≋	Spongiostromate - Spongiostromata
⌓	Bird's eyes
⬯	Ostracode - Ostracoda
◎	Lingulide - Lingula
⌒	Trilobite - Trilobita
Y	Bryozoaire - Bryozoa
λ	Spicule -
@	Gastéropodes - Gasteropods
≈	Encroûtement organique Organic encrusting



Micrite with rare Ostracoda (9614) grainstone with (35-50%) (0-15%) and silicification, dolomitisation, recrystallisation (9613)

Micrite like above and fine laminated grainstone

Irregular beds of fine grainstone and coarse wackestone with and o some mudstone beds

Nodular micrite and wackestone (9614 - 9615)

Nodular grainstone (9613)

Nodular micrite and wackestone (9614 - 9615)

Conglomerate with clasts of dolomitic, bioclastic micrite (5-15 cm) and (9617)

Nodular micrite and wackestone in a shaly matrix (9614 - 9615)

Irregular beds of micrite and wackestone (9614 - 9615)

Micrite and wackestone with Halycites and Bryozoa

Silty wackestone with turbation; encrusting and other alga (9619)

Nodular and light brown micrite, in a muddy matrix (9614), beds of grainstone around the middle part

Pale silty wackestone with (10%) and (2%) (9620)

Nodular micrite and some beds of wackestone with (15%), Y (4%) and ⊛ (9621)

Pale nodular micrite with some beds of Echinodermata (9613 - 9615)

Calcareous shale with grainstone near the top and micrite near the bottom

Nodular micrite with big in a marly-muddy matrix (9616)

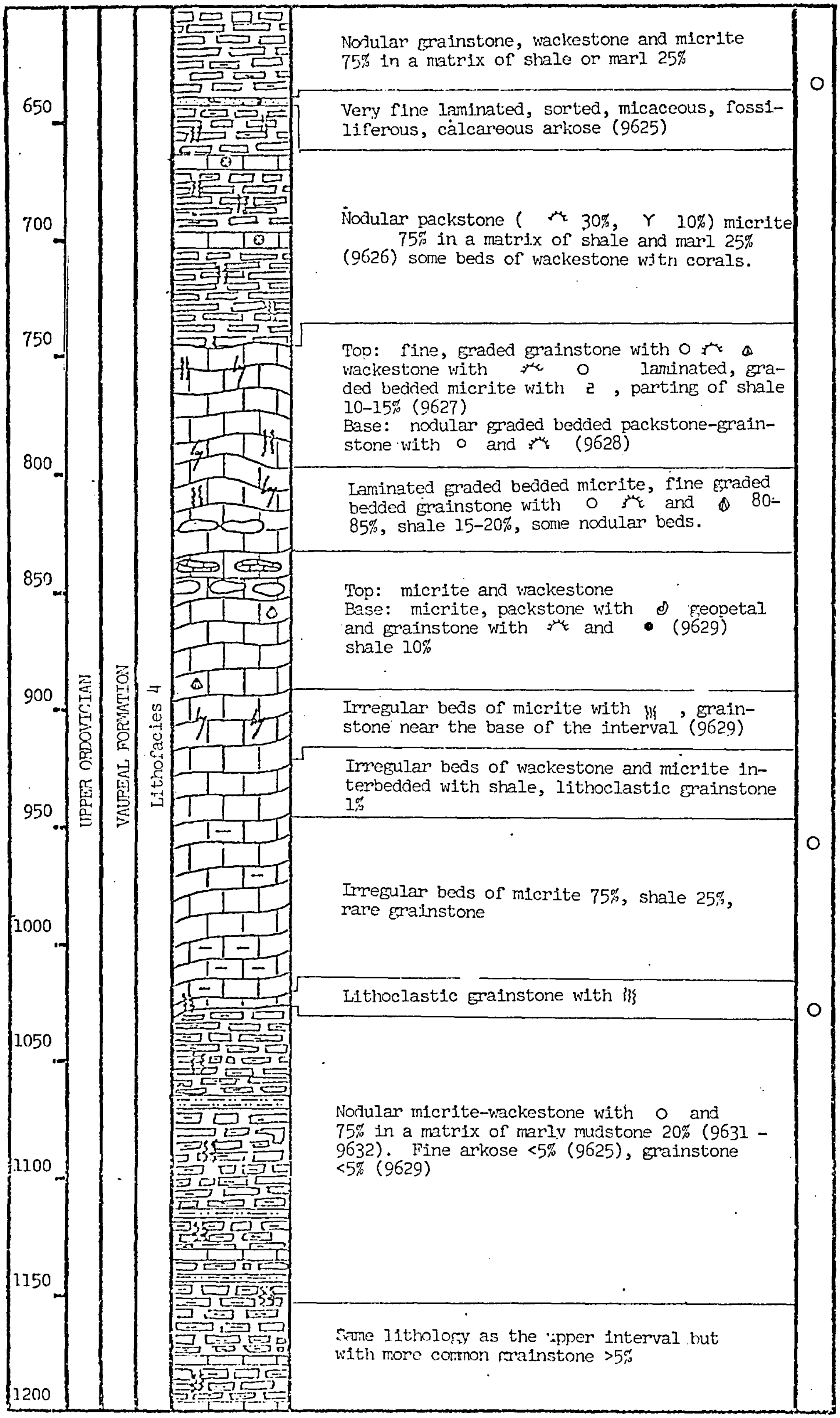
Argillaceous wackestone

Very shaly micrite

Marly arkose (9622)

Three rhythms, 2 to 5' thick of grainstone and micrite (9622 - 9623)

Nodular grainstone, wackestone and micrite 75% in a matrix of shale or marl 25%



Nodular grainstone, wackestone and micrite 75% in a matrix of shale or marl 25%

Very fine laminated, sorted, micaceous, fossiliferous, calcareous arkose (9625)

Nodular packstone (⌒ 30%, Y 10%) micrite 75% in a matrix of shale and marl 25% (9626) some beds of wackestone with corals.

Top: fine, graded grainstone with ○ ⌒ △ wackestone with ⌒ ○ laminated, graded bedded micrite with ƨ , parting of shale 10-15% (9627)
Base: nodular graded bedded packstone-grainstone with ○ and ⌒ (9628)

Laminated graded bedded micrite, fine graded bedded grainstone with ○ ⌒ and △ 80-85%, shale 15-20%, some nodular beds.

Top: micrite and wackestone
Base: micrite, packstone with ∂ geopetal and grainstone with ⌒ and ● (9629) shale 10%

Irregular beds of micrite with ≀≀ , grainstone near the base of the interval (9629)

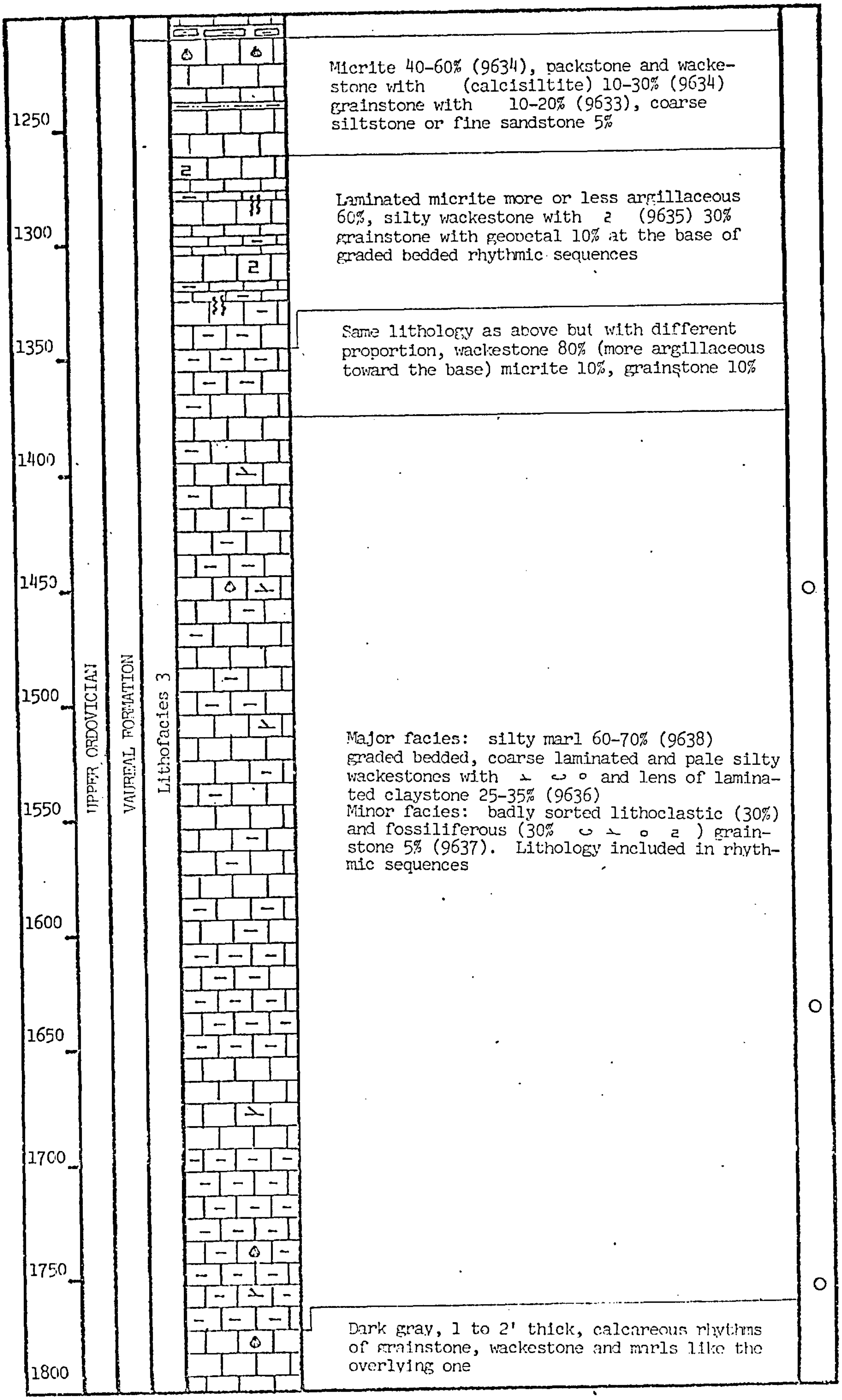
Irregular beds of wackestone and micrite interbedded with shale, lithoclastic grainstone 1%

Irregular beds of micrite 75%, shale 25%, rare grainstone

Lithoclastic grainstone with ≀≀

Nodular micrite-wackestone with ○ and 75% in a matrix of marly mudstone 20% (9631 - 9632). Fine arkose <5% (9625), grainstone <5% (9629)

Same lithology as the upper interval but with more common grainstone >5%



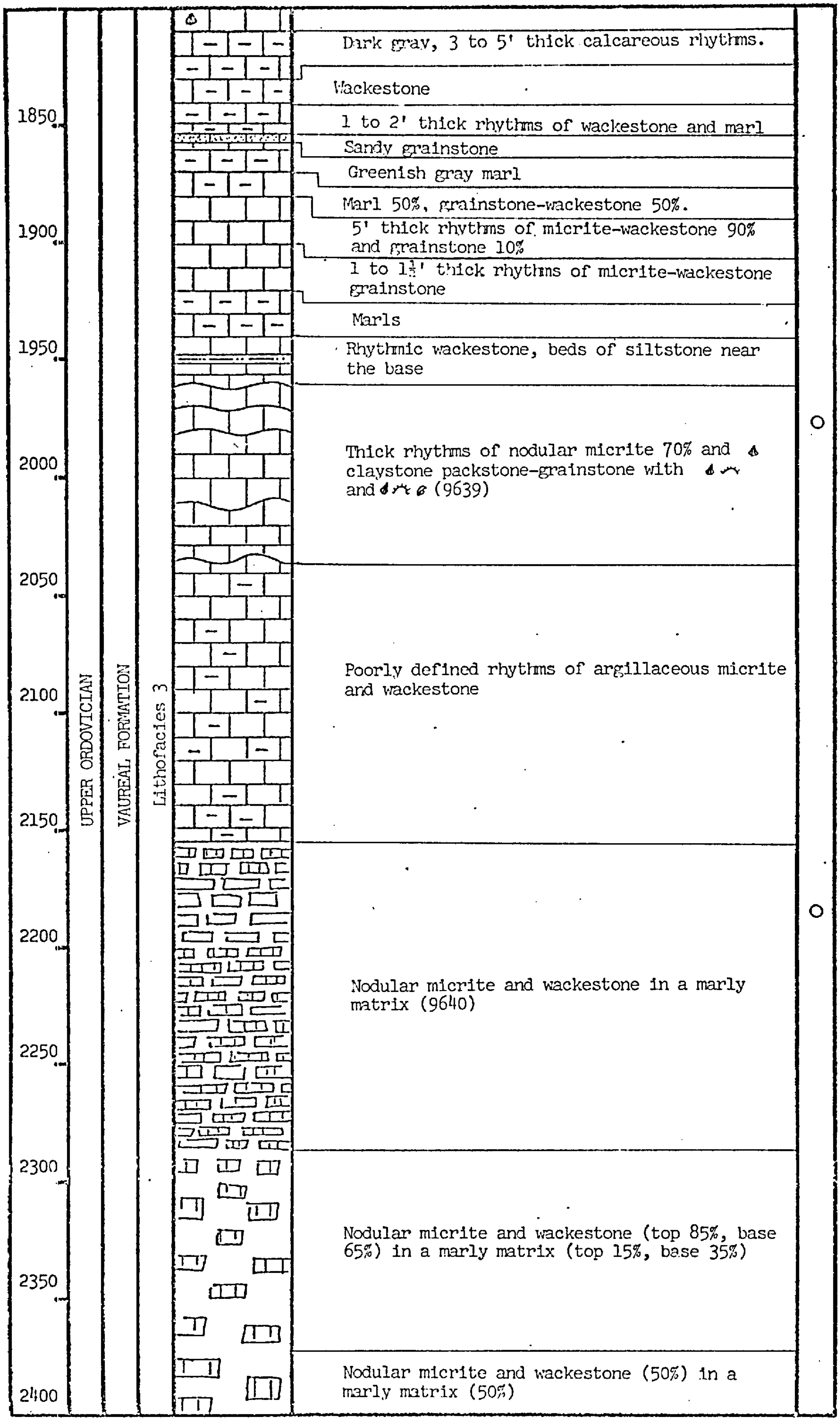
Micrite 40-60% (9634), packstone and wackestone with (calcisiltite) 10-30% (9634) grainstone with 10-20% (9633), coarse siltstone or fine sandstone 5%

Laminated micrite more or less argillaceous 60%, silty wackestone with 2 (9635) 30% grainstone with geopetal 10% at the base of graded bedded rhythmic sequences

Same lithology as above but with different proportion, wackestone 80% (more argillaceous toward the base) micrite 10%, grainstone 10%

Major facies: silty marl 60-70% (9638) graded bedded, coarse laminated and pale silty wackestones with ⅄ ◡ ○ and lens of laminated claystone 25-35% (9636)
Minor facies: badly sorted lithoclastic (30%) and fossiliferous (30% ◡ ⅄ ○ 2) grainstone 5% (9637). Lithology included in rhythmic sequences

Dark gray, 1 to 2' thick, calcareous rhythms of grainstone, wackestone and marls like the overlying one



Dark gray, 3 to 5' thick calcareous rhythms.

Wackestone

1 to 2' thick rhythms of wackestone and marl

Sandy grainstone

Greenish gray marl

Marl 50%, grainstone-wackestone 50%.

5' thick rhythms of micrite-wackestone 90% and grainstone 10%

1 to 1½' thick rhythms of micrite-wackestone grainstone

Marls

Rhythmic wackestone, beds of siltstone near the base

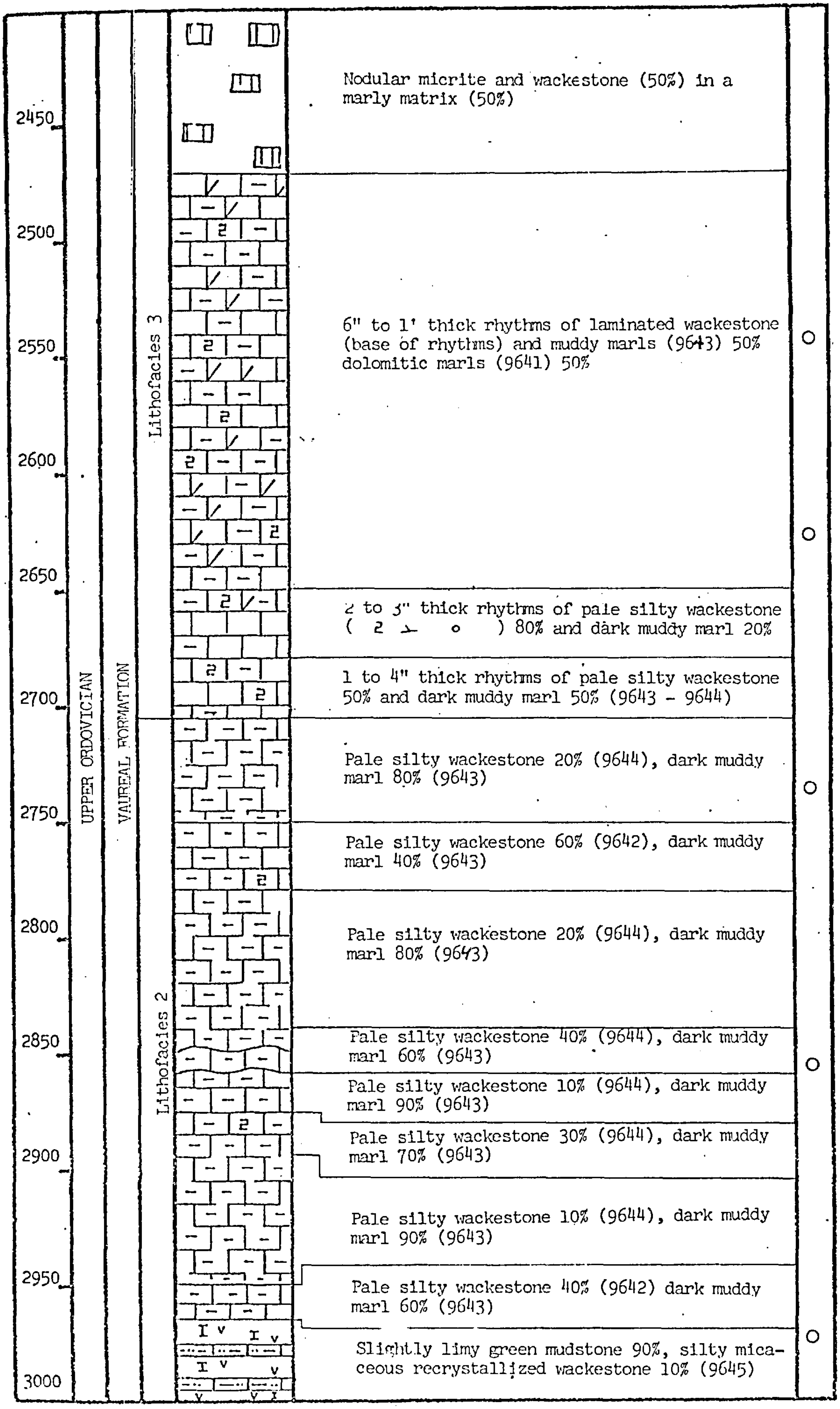
Thick rhythms of nodular micrite 70% and claystone packstone-grainstone with and (9639)

Poorly defined rhythms of argillaceous micrite and wackestone

Nodular micrite and wackestone in a marly matrix (9640)

Nodular micrite and wackestone (top 85%, base 65%) in a marly matrix (top 15%, base 35%)

Nodular micrite and wackestone (50%) in a marly matrix (50%)



Nodular micrite and wackestone (50%) in a marly matrix (50%)

6" to 1' thick rhythms of laminated wackestone (base of rhythms) and muddy marls (9643) 50% dolomitic marls (9641) 50%

2 to 3" thick rhythms of pale silty wackestone (2 ⊥ o) 80% and dark muddy marl 20%

1 to 4" thick rhythms of pale silty wackestone 50% and dark muddy marl 50% (9643 - 9644)

Pale silty wackestone 20% (9644), dark muddy marl 80% (9643)

Pale silty wackestone 60% (9642), dark muddy marl 40% (9643)

Pale silty wackestone 20% (9644), dark muddy marl 80% (9643)

Pale silty wackestone 40% (9644), dark muddy marl 60% (9643)

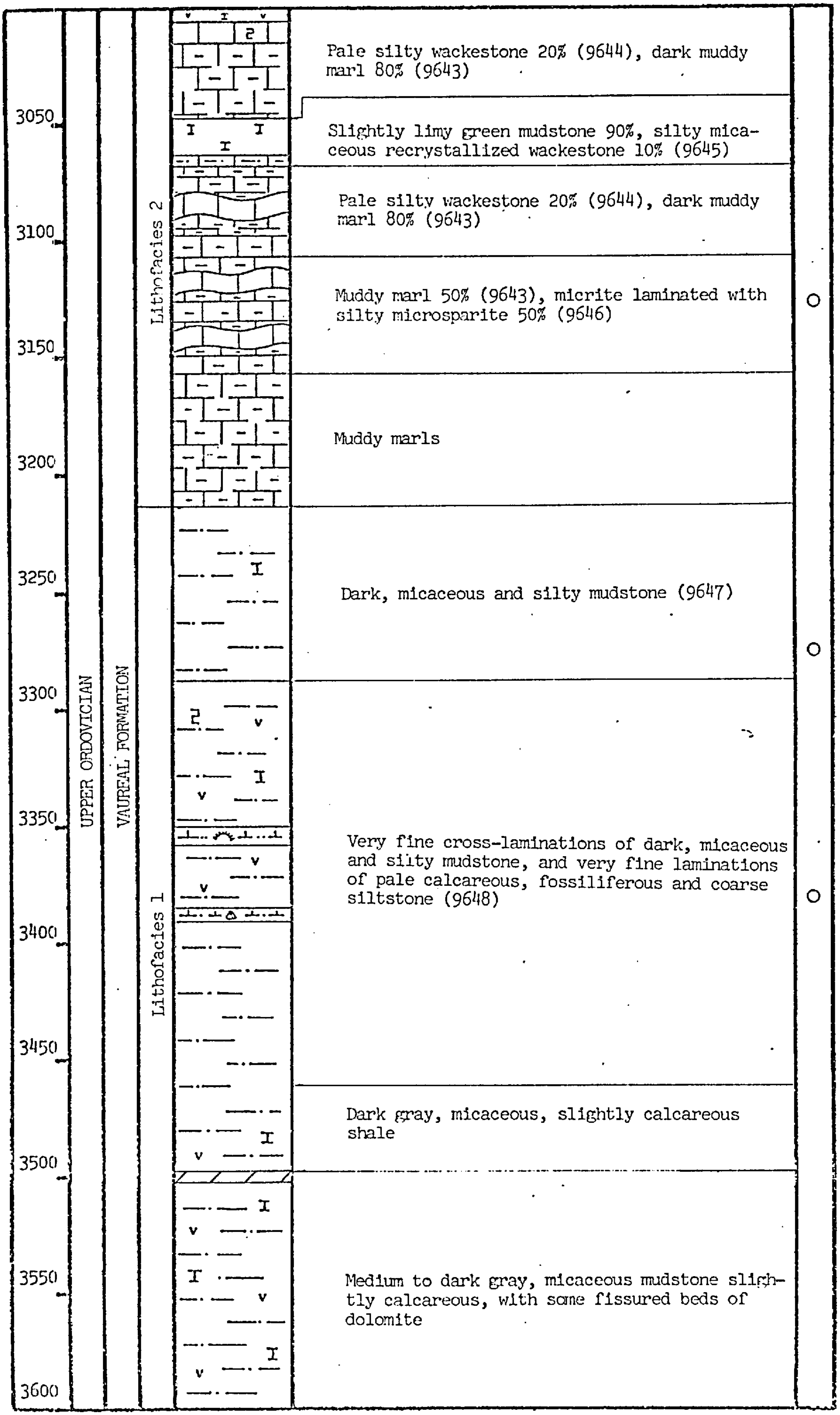
Pale silty wackestone 10% (9644), dark muddy marl 90% (9643)

Pale silty wackestone 30% (9644), dark muddy marl 70% (9643)

Pale silty wackestone 10% (9644), dark muddy marl 90% (9643)

Pale silty wackestone 40% (9642) dark muddy marl 60% (9643)

Slightly limy green mudstone 90%, silty micaceous recrystallized wackestone 10% (9645)



Pale silty wackestone 20% (9644), dark muddy marl 80% (9643)

Slightly limy green mudstone 90%, silty micaceous recrystallized wackestone 10% (9645)

Pale silty wackestone 20% (9644), dark muddy marl 80% (9643)

Muddy marl 50% (9643), micrite laminated with silty microsparite 50% (9646)

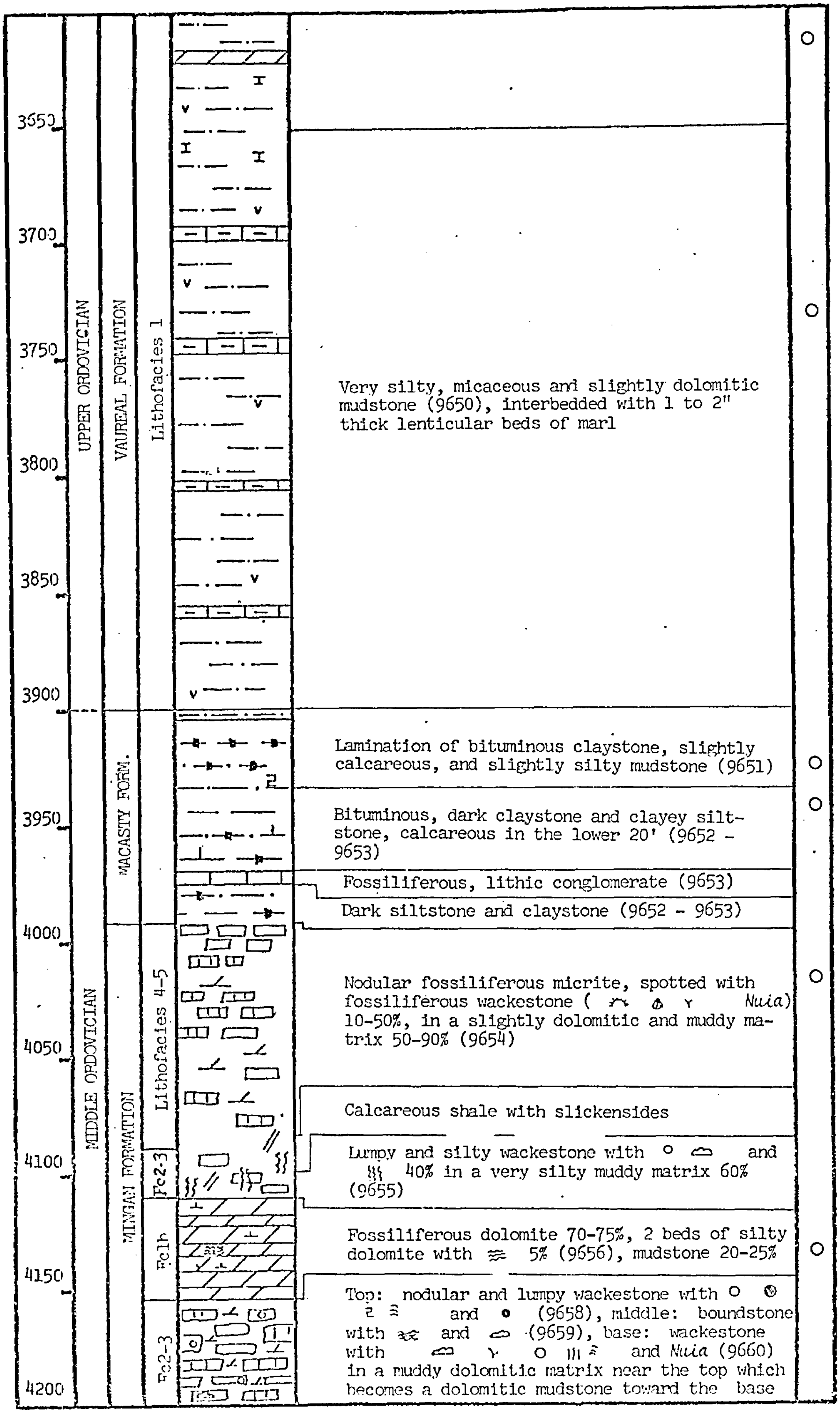
Muddy marls

Dark, micaceous and silty mudstone (9647)

Very fine cross-laminations of dark, micaceous and silty mudstone, and very fine laminations of pale calcareous, fossiliferous and coarse siltstone (9648)

Dark gray, micaceous, slightly calcareous shale

Medium to dark gray, micaceous mudstone slightly calcareous, with some fissured beds of dolomite



Very silty, micaceous and slightly dolomitic mudstone (9650), interbedded with 1 to 2" thick lenticular beds of marl

Lamination of bituminous claystone, slightly calcareous, and slightly silty mudstone (9651)

Bituminous, dark claystone and clayey siltstone, calcareous in the lower 20' (9652 - 9653)

Fossiliferous, lithic conglomerate (9653)

Dark siltstone and claystone (9652 - 9653)

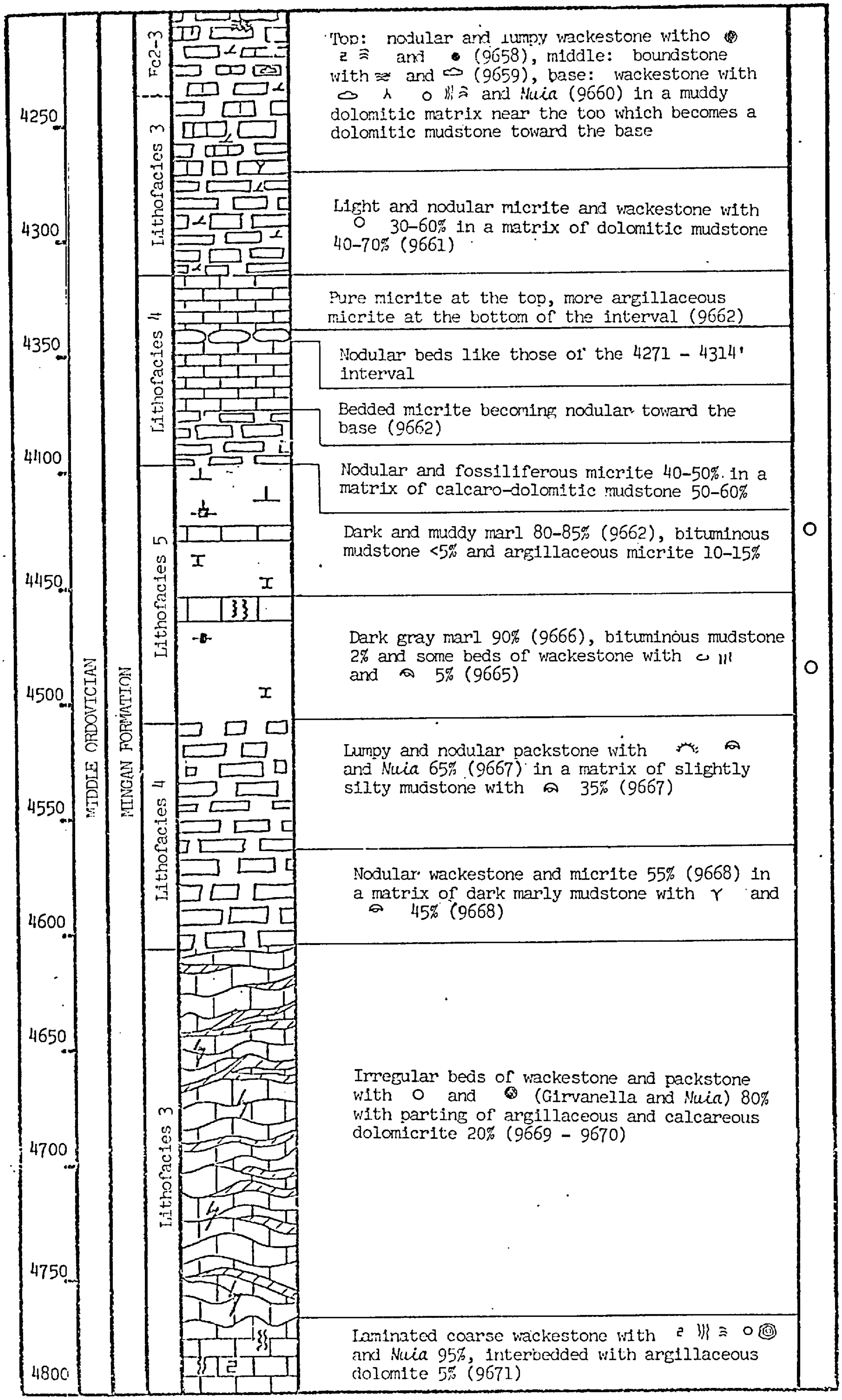
Nodular fossiliferous micrite, spotted with fossiliferous wackestone (*Nuia*) 10-50%, in a slightly dolomitic and muddy matrix 50-90% (9654)

Calcareous shale with slickensides

Lumpy and silty wackestone with ○ and 40% in a very silty muddy matrix 60% (9655)

Fossiliferous dolomite 70-75%, 2 beds of silty dolomite with ≋ 5% (9656), mudstone 20-25%

Top: nodular and lumpy wackestone with ○ and ● (9658), middle: boundstone with and (9659), base: wackestone with ○ and *Nuia* (9660) in a muddy dolomitic matrix near the top which becomes a dolomitic mudstone toward the base



Top: nodular and lumpy wackestone with ⊛ ≀ ≋ and • (9658), middle: boundstone with ≈ and ⌓ (9659), base: wackestone with ⌓ ⅄ ○ ≀≀ ≋ and *Nuia* (9660) in a muddy dolomitic matrix near the top which becomes a dolomitic mudstone toward the base

Light and nodular micrite and wackestone with ○ 30-60% in a matrix of dolomitic mudstone 40-70% (9661)

Pure micrite at the top, more argillaceous micrite at the bottom of the interval (9662)

Nodular beds like those of the 4271 - 4314' interval

Bedded micrite becoming nodular toward the base (9662)

Nodular and fossiliferous micrite 40-50% in a matrix of calcaro-dolomitic mudstone 50-60%

Dark and muddy marl 80-85% (9662), bituminous mudstone <5% and argillaceous micrite 10-15%

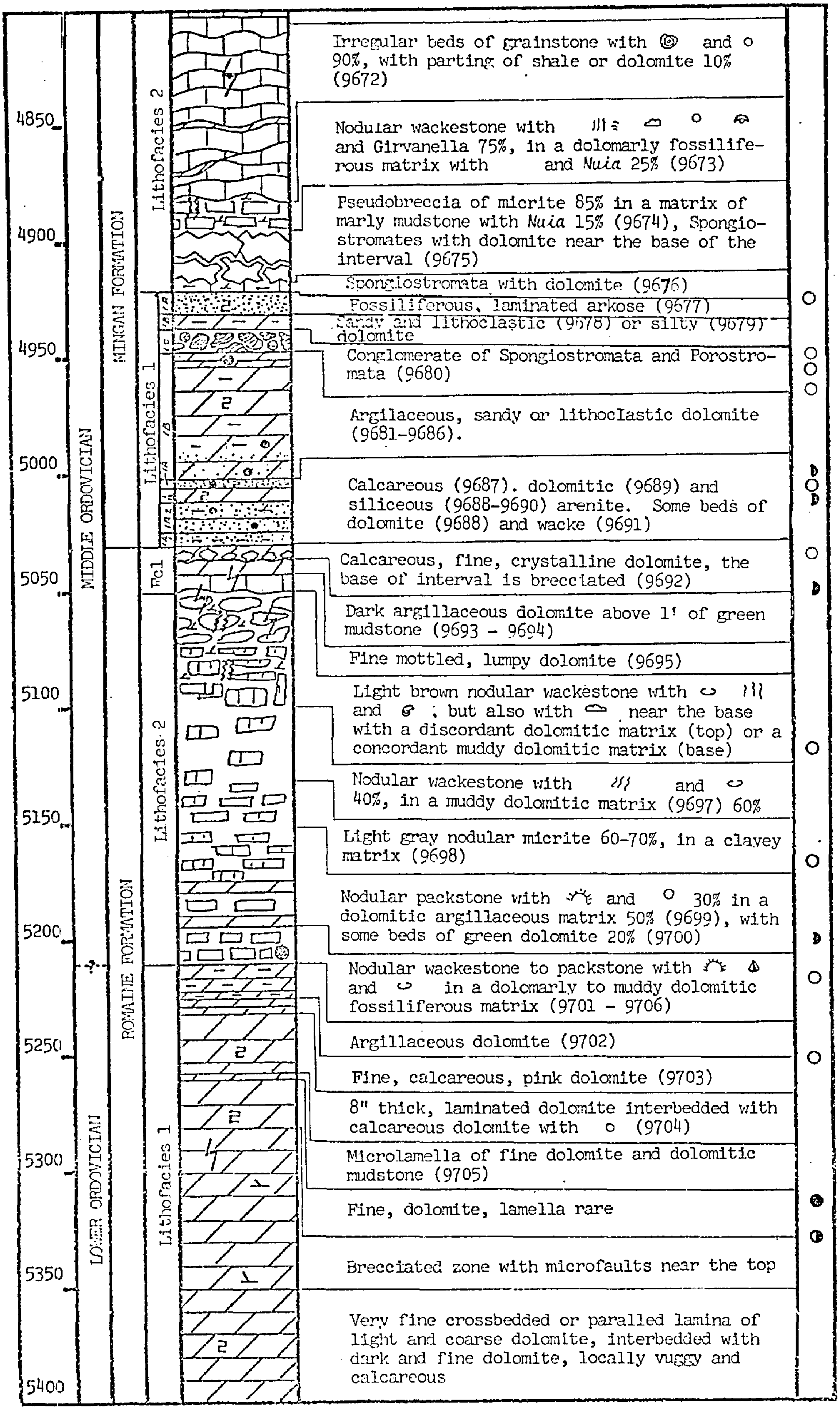
Dark gray marl 90% (9666), bituminous mudstone 2% and some beds of wackestone with ⌓ ııı and ⌓ 5% (9665)

Lumpy and nodular packstone with ⌒ ⌓ and *Nuia* 65% (9667) in a matrix of slightly silty mudstone with ⌓ 35% (9667)

Nodular wackestone and micrite 55% (9668) in a matrix of dark marly mudstone with Y and ⌓ 45% (9668)

Irregular beds of wackestone and packstone with ○ and ⊛ (Girvanella and *Nuia*) 80% with parting of argillaceous and calcareous dolomicrite 20% (9669 - 9670)

Laminated coarse wackestone with ≀ ≀≀ ≋ ○ ◎ and *Nuia* 95%, interbedded with argillaceous dolomite 5% (9671)



Irregular beds of grainstone with ◎ and ○ 90%, with parting of shale or dolomite 10% (9672)

Nodular wackestone with ○ and Girvanella 75%, in a dolomarly fossiliferous matrix with and *Nuia* 25% (9673)

Pseudobreccia of micrite 85% in a matrix of marly mudstone with *Nuia* 15% (9674), Spongiostromates with dolomite near the base of the interval (9675)

Spongiostromata with dolomite (9676)

Fossiliferous, laminated arkose (9677)

Sandy and lithoclastic (9678) or silty (9679) dolomite

Conglomerate of Spongiostromata and Porostromata (9680)

Argilaceous, sandy or lithoclastic dolomite (9681-9686).

Calcareous (9687). dolomitic (9689) and siliceous (9688-9690) arenite. Some beds of dolomite (9688) and wacke (9691)

Calcareous, fine, crystalline dolomite, the base of interval is brecciated (9692)

Dark argillaceous dolomite above 1' of green mudstone (9693 - 9694)

Fine mottled, lumpy dolomite (9695)

Light brown nodular wackestone with and ; but also with near the base with a discordant dolomitic matrix (top) or a concordant muddy dolomitic matrix (base)

Nodular wackestone with and 40%, in a muddy dolomitic matrix (9697) 60%

Light gray nodular micrite 60-70%, in a clayey matrix (9698)

Nodular packstone with and ○ 30% in a dolomitic argillaceous matrix 50% (9699), with some beds of green dolomite 20% (9700)

Nodular wackestone to packstone with and in a dolomarly to muddy dolomitic fossiliferous matrix (9701 - 9706)

Argillaceous dolomite (9702)

Fine, calcareous, pink dolomite (9703)

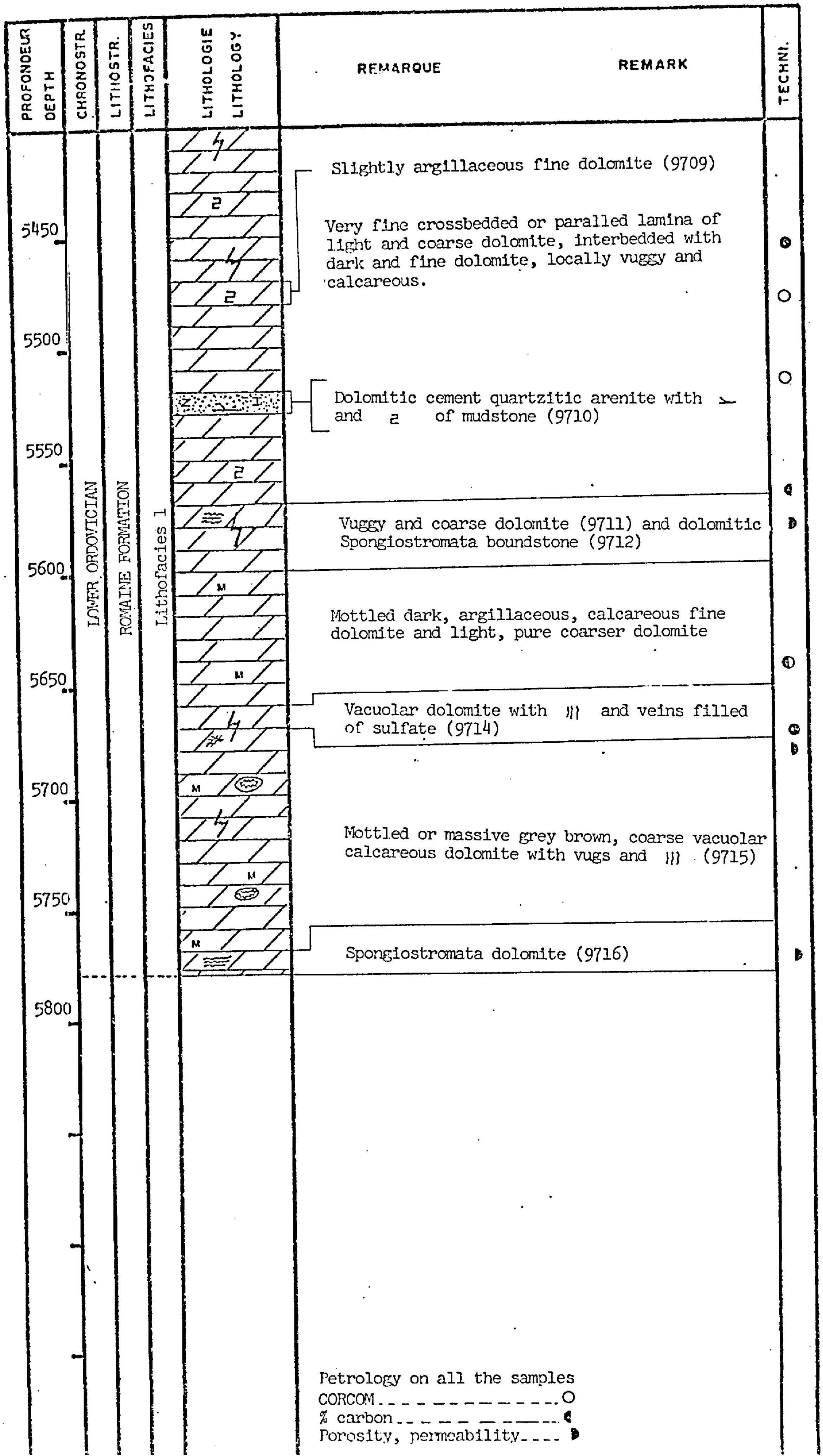
8" thick, laminated dolomite interbedded with calcareous dolomite with ○ (9704)

Microlamella of fine dolomite and dolomitic mudstone (9705)

Fine, dolomite, lamella rare

Brecciated zone with microfaults near the top

Very fine crossbedded or paralled lamina of light and coarse dolomite, interbedded with dark and fine dolomite, locally vuggy and calcareous



Slightly argillaceous fine dolomite (9709)

Very fine crossbedded or paralled lamina of light and coarse dolomite, interbedded with dark and fine dolomite, locally vuggy and calcareous.

Dolomitic cement quartzitic arenite with ⌣ and 2 of mudstone (9710)

Vuggy and coarse dolomite (9711) and dolomitic Spongiostromata boundstone (9712)

Mottled dark, argillaceous, calcareous fine dolomite and light, pure coarser dolomite

Vacuolar dolomite with ≀≀≀ and veins filled of sulfate (9714)

Mottled or massive grey brown, coarse vacuolar calcareous dolomite with vugs and ≀≀≀ (9715)

Spongiostromata dolomite (9716)

Petrology on all the samples
CORCOM .... ○
% carbon .... ◖
Porosity, permeability ..... ◗

APPENDICE 2

LISTE DES ECHANTILLONS ETUDIES

APPENDIX 2

LIST OF SAMPLES STUDIED

SAMPLES STUDIED FOR

C - Clay minerals
R - Reflectometry
P - Palynology
T.O.C. - Total organic carbon
Cr/Ct - carbon ratio

INRS No	Depth	C	R	P	T.O.C.	Cr/Ct
8424	100'	X		X	X	
8426	150'			X	X	
8428	200'	X		X	X	
8430	250'			X	X	
8432	300'	X		X	X	
8434	350'			X	X	
8436	400'	X		X	X	X
8438	450'			X	X	
8440	500'	X		X	X	
8442	550'			X	X	
8444	600'	X		X	X	
8446	650'			X	X	
8448	700'	X		X	X	
8450	750'			X	X	
8452	800'	X		X	X	
8454	850'			X	X	
8456	900'	X		X	X	
8458	950'			X	X	X
8460	1000'	X		X	X	
8462	1050'			X	X	
8464	1100'	X		X	X	
8466	1150'			X	X	
9432	1200'	X		X	X	
9434	1250'			X	X	
9136	1300'	X	X	X	X	
9138	1350'			X	X	
9140	1400'	X		X	X	X

INRS No	Depth	C	R	P	T.O.C.	Cr/Ct
9142	1450'			X	X	
9144	1500'	X		X	X	
9146	1550'			X	X	
9148	1600'	X	X	X	X	
9150	1650'			X	X	
9152	1700'	X		X	X	
9154	1750'			X	X	
8467	1800'	X		X	X	
8469	1850'			X	X	
8471	1900'	X		X	X	
8473	1950'			X	X	
8475	2000'	X	X	X	X	
8477	2050'			X	X	
8479	2100'	X		X	X	
8481	2150'			X	X	
8483	2200'	X		X	X	X
8485	2250'			X	X	
8487	2300'	X		X	X	
5722	2349'				X	
5724	2400'	X	X	X	X	
5726	2450'			X	X	
5728	2500'	X		X	X	
9541	2600'	X		X	X	
9542	2700'	X		X	X	X
9543	2800'	X	X	X	X	
6048	2850'			X	X	
6050	2900'	X		X	X	X
6052	2950'			X	X	
6056	3000'	X		X	X	
6057	3050'			X	X	
6058	3100'	X		X	X	
6060	3150'			X	X	
6062	3200'	X	X	X	X	
6064	3250'			X	X	X

INRS No	Depth	C	R	P	T.O.C.	Cr/Ct
6066	3300'	X		X	X	
6068	3350'			X	X	
6070	3400'	X		X	X	X
6505	3450'			X	X	
6507	3500'	X	X	X	X	
6509	3550'			X	X	
6511	3600'	X		X	X	
6513	3650'			X	X	
6515	3700'	X	X	X	X	
6517	3750'			X	X	
6519	3800'	X		X	X	
6521	3850'			X	X	
6523	3900'	X		X	X	
6525	3950'	X	X	X	X	X
6527	4000'	X		X	X	
8414	4050'			X	X	
8415	4100'	X		X	X	
8416	4150'			X	X	X
8417	4200'	X		X	X	
8418	4250'				X	
8419	4300'	X		X	X	
8420	4350'				X	
8421	4400'	X	X	X	X	
8422	4450'			X	X	
8423	4500'	X		X	X	X
9545	4550'				X	
9546	4600'	X		X	X	X
9547	4650'				X	
9548	4700'	X		X	X	
9549	4750'				X	
9550	4800'	X		X	X	
9551	4850'	X		X	X	
9552	4900'	X		X	X	

INRS No	Depth	C	R	P	C.O.T.	Cr/Ct
9553	4950'				X	
9554	5000'	X		X	X	
9556	5050'				X	
9557	5100'	X		X	X	X
9558	5150'				X	
9559	5200'	X		X	X	
9560	5250'				X	X
9561	5300'	X		X	X	
9562	5350'				X	
9563	5400'	X		X	X	
9564	5450'				X	
9565	5500'	X		X	X	X
9566	5550'				X	
9567	5600'	X		X	X	
9568	5650'				X	
9569	5700'	X		X	X	
9570	5750'				X	X

STUDIED SAMPLES IN PETROGRAPHY

Porosity and permeability tests were carried out on samples with an * and CORCOM analyses or samples with (o).

INRS No	Depth	INRS No	Depth
9613	96'	9640^{o}	2186'
9614	131'	9641^{o}	2548'
9615	187'	9642^{o}	2630'
9616^{o}	522'	9643^{o}	2737'
9617	230'	9644^{o}	2853'
9618	336'	9645^{o}	2974'
9619	353'	9646^{o}	3130'
9620	430'	9647^{o}	3281'
9621	452'	9648^{o}	3384'
9622^{o}	556'	9649^{o}	3618'
9623	560'	9650^{o}	3738'
9624	568'	9651^{o}	3927'
9625^{o}	638'	9652^{o}	3944'
9626	673'	9653	3973'
9627	751'	9654^{o}	4018'
9628	781'	9655	4097'
9629	876'	9656^{o}	4137'
9630^{o}	956'	9657	4140'
9631^{o}	1030'	9658	4161'
9632	1156'	9659	4219'
9633	1211'	9660	4250'
9634	1247'	9661	4306'
9635	1306'	9662	4338'
9636^{o}	1452'	9663	4385'
9637^{o}	1639'	9664^{o}	4434'
9638^{o}	1753'	9665	4461'
9639^{o}	1980'	9666^{o}	4492'

INRS No	Depth
9667	4542'
9668	4585'
9669	4656'
9670	4738'
9671	4780'
9672	4844'
9673	4889'
9674	4909'
9675	4915'
9676	4918'
9677	4921'
9678	4930'
9679°	4931'
9680	4947'
9681°	4950'
9682	4953'
9683°	4959'
9684°	4969'
9685	4992'
9686	4994'
9687	5003'
*9688	5004'
9689°	5013'
*9690	5019'
9691	5029'
9692	5034'
9693	5039'
9694°	5043'
*9695	5056'
9696	5073'
9697°	5123'
9698	5143'

INRS No	Depth
9699	5166'
9700°	5179'
*9701	5203'
9702°	5919'
9703	5230'
9704	5252'
9705°	5258'
9706	5298'
*9707°	5336'
*9708	5454'
9709°	5485'
9710°	5521'
9711	5581'
*9712	5582'
9713°	5647'
*9714	5673'
*9715	5685'
*9716	5775'