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ARCO-ANTICOSTI NO. 1 (M.R.N. NO.7
SEDIMENTOLOGICAL, MINERALOGICAL
BIO-STRATIGRAPHICAL, GEOCHEMICAL
ORGANIC AND MINERAL STUDY
DIAGENISIS AND PETROLEUM POTENTIAL

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ABSTRACT

Arco-Anticosti No.1, drilled on Anticosti Island (Province of Quebec), coordinates: latitude 49°23'18" north, longitude 63°31'29" west, reached the Precambrian basement at a depth of 12,582' (altitude: 12,359'). From the Middle to Lower Silurian to the Lower (?) Ordovician, the well traversed the Chicotte-Jupiter, Becscie, Vauréal and Macasty Formations, the Trenton Group, and the Mingan and Romaine Formations. From the study of microfacies it was not possible to distinguish the Gun River and Ellis Bay Formations, or the Chicotte from the Jupiter.

Six well defined palynologic zones have been recognized in the formations overlying the Macasty. Four levels of high energy appear: at the base of the Romaine, in the Mingan, at the top of the Vauréal, and to a lesser degree in the Chicotte-Jupiter. In general no reservoir zone was apparent from the examination of cuttings, but the localisation of zones of high energy is a first lead in the search fro a reservoir. In comparison with the reference sections, a thickening of the Romaine Formation and a change in facies of the Mingan was noted.

The sedimentation has the general character of sedimentation on a platform or in a shallow sea. According to the concentrations of boron, the sediments of the Trenton Group were deposited in a slightly confined sea. Apart from the Macasty, and even for the carbonate formations, the hydrocarbon potentials - in the strict sense the reserves of organic matter - are rather slight.

Reflectometry, analysis of organic matter by transmitted light, the nature, quantity, and composition of adsorbed gases, the crystallinity of illite, and clay mineralogy are all in accord: the best potential source rock is in the Macasty (equivalent to the Utica). It has been subject to a paleotemperature sufficient for it to have attained the diagenetic stage

of the potential zone of condensate gas (according to some methods) or the zone of high - G.O.R. oil for others. The upper formations would be, from 710', in the oil zone, the lower formations in the zone of dry or even very dry gas. From 10,000' the Romaine Formation belongs to the anchizone (confirmed by the presence of pyrophyllite). With a normal paleothermic gradient, there would be 8,000' to 10,000' of strata missing above the Chicotte-Jupiter.

SUMMARY OF STRATIGRAPHY ACCORDING TO THE LITERATURE

Formation Names	Lithologic descriptions	Thickness	Age
Chicotte Formation	Crinoidal limestone, white to brown, massive or thick bedded. Reefoid.	75'-100'	Late Llandoverian Early Wenlockian
	Sharp, undulating contact		
Jupiter Formation	Fine-grained argillaceous limestones, fossiliferous to barren, alternating with fossiliferous or non-fossilifeorus grey-green shales. The relative amounts of these rocks vary in all proportions. The base is defined by conglomeratic limestones and bioherms.	475'	Middle to late Late Landoverian
	Conformable contact.		
Gun River Formation	Very fossiliferous fine-grained limestones in thin to thick beds, and intervals of intraformational conglomerate, alternationg with sublithographic limestone, which are more and more argillaceous towards the top.		Early to middle Late Llandoverian
	Thin beds of limestone, semi-lithographic at the base, becoming coarse to fine grained limestone with intercalations of beds of conglomerate at the top.	250'	
	Sharp conformable contact.		
Becscie Formation	Dense to granular limestones at the base, becoming more argillaceous and nodular towards the top. The upper thirty (30) feet are green nodular shales.	265'	Early to middle Llandoverian
	Conformable contact.		
Ellis Bay Formation	Several units of limestone, nodular or sublithographic and of shale, which alternate in various proportions.	175'-315'	Middle Ashgillian to Early Llandoverian
	Conformable contact.		

Formation Names	Lithologic descriptions	Thickness	Age
Vauréal Formation	Fine to granular limestones in thin beds separated by argillaceous interbeds.		Late Ashgillian
	Grey shale interbedded with thin lenses of limestone.	1,200'	
Macasty Formation	Blach bituminous shales		Early Ashgillian Late Caradocian (Lorraine)
Trenton Group	Assemblage of very varied limestones, well bedded, very fossiliferous, with argillaceous interbeds.		Middle Caradocian
Mingan Formation	Fine-grained or sublithographic limestones, becoming more and more sandy and fossiliferous towards the base. The base of the formation is composed of conglomeratic sandstone and shales.		Llanvirnian Early Caradocian (Chazy)
	Disconformable contact.		
Romaine Formation	Thickly and evenly bedded dolomite, bituminous shales, and some limestone horizons. The base is sandy.	260'	Early Ordovician

See Bolton 1970, 1972; Clark 1972; Hofmann 1972; Twenhofel 1925, 1928; Waddington 1950.

Petrographic analysis

The petrographic analysis is a summary of observations and conclusions drawn from a study of 141 thin sections.

Among the series studied which range in age from the middle Silurian to the lower Ordovician, it is not possible to distinguish in the well, all the formations predicted in the literature (cf. summary above). Thus, due to the lack of distinctive criteria, we have combined the Chicotte and Jupiter Formations, and grouped together the Gun River/Becscie and Ellis Bay/Vauréal Formations under the respective names of Becscie and Vauréal.

The energy of the depositional environment of the formations is quantified (low, moderate, high, very high) by use of the following observations: 1. - presence of absence of mud (clay or carbonate) and arrangement of grains (Dunham 1962), 2. - granulometry of transported fragments, 3. - presence of diagnostic structural elements such as intraclasts of oolites.

Conclusions drawn from petrographic analysis

Chicotte and Jupiter Formations (200' - 2,160') (Plates 1-3).

In this mainly limestone formation a terrigenous fraction is always present. This fraction becomes more and more coarsely sandy downward in the lowest quarter of the formation. Above, it loses its importance relative to the limestones.

Fossil debris is well preserved. Recrystallization is in general slight and no porosity is observable.

The energy of the depositional environment of this formation is

for the most part moderately high. It varies in cyclical fashion through, minima (450' (c), 800' (T), 1,300' (c), 1,450' (T) and maxima (200' (c), 500' (c), 1,000' (c), 1,400' (T), 1,500' (c), which are associated with carbonates (c) or terrigenous material (T).

Becscie Formation (2,160' - 3,960') (Plate 3).

The Becscie Formation contains even more carbonate than the Chicotte-Jupiter Formation. It is however, more monotonous, and the limestones are argillaceous or sandy. The base and the top are characterized by a greater abundance of sandstone and shale.

Fossils are not common in these non-porous, clotted (or pelletoidal) limestones.

The energy of the environment of deposition of this formation is low, since all the lithologies encountered are very micritic.

Vauréal Formation (3,900' - 7,620') (Plate 4).

Four lithologic units are discernable in the Vauréal Formation. The two upper units are limy (1: 3,960' - 4,450'; 2: 4,450' - 5,220'), the third unit is silto-calcareous (5,220' - 6,620'), and the last is mainly silty (6,620' - 7,500').

Fossil remains, common in the uppermost unit, are rare elsewhere, even though recrystallization is slight.

A fairly significant optical porosity is observed in a small fraction (5%) of the cuttings of the silto-calcareous unit (5,200' - 5,600'). However, the pores are small (10-30μ).

The energy of the depositional environment is different for each lithologic unit of this formation. The energy of the depositional environ-

ment of the upper limestone unit is fairly high relative to that of the underlying limestone unit.

The energy of the depositional environment of the basal unit is low (shale and calcareous siltstone). The energy of the depositional environment of the intermediate unit (5,200' - 6,620') shows two maxima of moderate energy (5,460' - 5,600' and 6,120' - 6,360') and remains low on either side of these maxima. (The energy of the environment is interpreted as moderate to high because of the quantity of sand (15-22%) present in these zones).

Macasty Formation (7,600' - 8,170') (Plate 4).

The Macasty Formation is exclusively a very bituminous argillaceous siltstone.

No fossil remains are observable in the upper part of the formation. However, its lower part contains a very specific fauna composed entirely of large sponge spicules.

The energy of the depositional environment is low; and the abundance of organic matter indicates a negative oxydation-reduction potential.

Trenton Group (8,170' - 9,500') (Plates 4 - 6)

This group, which is more than 1,300' thick, consists mainly of limestone. According to the fabric and the fossil content, three lithologic units are identifiable in this interval; fossil-fragment wackestone-packstone (units 1 and 3, 8,170' - 8,600' and 9,240' - 9,500') bracketing slightly fossiliferous mudstone (unit 2).

An optical porosity of 2 to 15% is observed locally (8,850').

The energy of the depositional environment of this group is moderate to high for units 1 and 3 and low for unit 2. The presence of intraclasts

of blue-green algae (Girvanella) and fragments of red algae (Solenoporaceae) is also an indication of a shallow environment (euphotic zone).

Mingan Formation (9,500' - 10,000') (Plates 7 - 8).

The Mingan Formation is a sandy-dolomitic sequence. The textural and mineralogic maturity of the sandstones as well as the dolomite/limestone ratio diminish from the base upwards.

No significant optical porosity is observed.

The sediments of this formation were deposited in a turbulent (energetic) environment: the sands are well sorted, coarse, and rounded; the limestones are intraclastic. Further, the environment of deposition was shallow (euphotic zone: blue-green algae (Girvanella), numerous bryozoans and corals).

Romaine Formation (10,000' - 12,580') (Plates 9 - 11)

The Romaine Formation is a calcaro-dolomitic sequence, becoming more dolomitic towards the middle and the base (60 - 90% of the cuttings). The other lithofacies encountered are silicified shales (10 - 30% of the cuttings) in the upper three-quarters of the formation, and oolitic sandstones with siliceous cement (10 - 25%) in the basal part.

Fossil fragments are not abundant in this formation; fragments of molluscs and trilobites are the most common. The various molluscs (gastropods) encountered are at 11,800' depth.

The sediments of the Romaine Formation were deposited in an environment of variable energy. The abundance of coarse sandstone and oolitic grainstone confirms the high energy of the basal part. The sporadic presence of intraclastic limestone or dolomite, containing red algae (Solenoporacea at 10,900'), is also indicative of high energy.

These same observations suggest a very shallow environment, probably intertidal for a good part of the formation.

The base of the Romaine is the only part of the well where a worthwhile optical porosity is found. This intercrystalline porosity is restricted mainly to the dolomites. However, it rarely exceeds ten percent (10%).

The common presence of bryozoans in the limestones of this formation leads one to believe that its age is Middle Ordovician rather than Early Ordovician (Clark 1972, p.65).

DEPOSITIONAL ENVIRONMENTS

According to petrographic criteria, it is possible to propose several hypotheses concerning the environment of deposition. Some of these hypotheses however can be eliminated by a study of the regional context.

In this chapter various possible environments are suggested in relation to several models, and they may be used as a reference for a further more detailed regional study.

Jupiter-Chicotte Formation

1. - Echinoderm and bryozoan calcarenite-packstone.
   Brachiopods, a little lime mud.
   a) Intertidal, good circulation - (Laporte 1969, p. 105).
   b) Shelf-bank margin (Wilson 1969, p. 12).

2. - Mudstone with the same fossil debris.
   a) Intertidal to shallow subtidal, good circulation (Laporte 1969, p. 105).
   b) Restricted environment behind the bank (Wilson 1969, p. 13).
   c) Lagoonal environment behind the reefal barrier (Bathurst 1971, p. 171).

Becscie Formation

1. - Echinoderm, ostracode, pellet, and sponge-spicule mudstone-wackestone.
   Some terrigenous detritus.
   a) Open, shallow to deep subtidal environment.
      Terrigenous detritus possible (Laporte 1969, p. 105).
   b) Wide, shallow to fairly deep cratonic basin (Wilson 1969, p. 12).
   c) Basinal environment, distal from coast (Horowitz & Potter, 1971, p. 14, fig. 5).

Vauréal Formation

1. - Upper unit: echinoderm, brachiopod, and ostracod packstone-grainstone.
   a) Intertidal environment, high energy and good circulation (Laporte 1969, p. 105

b) Bank-margin environment (Horowitz & Potter 1971, p.14, fig.5)

2.- Three lower units: mudstone (Dunham 1962) and calcareous shale-siltstone, with ostracods and spicules.
   a) Shallow to deep subtidal environment (Laporte 1969, p.105)
   b) Bank-foot basin (Horowitz & Potter 1971, p.14, fig.5).

Macasty Formation

Bituminous siltstone with sponge spicules.
a) Subtidal environment, oxygen-poor, lagoonal.

Trenton Group

Limestone (mudstone-wackestone-packstone) with echinoderms, bryozoans, brachiopods, red algae, and blue-green algae.
a) Shallow marine environment, supra- to intertidal (lower quarter) to shallow subtidal, good circulation (Laporte, 1969, pp.104-109)
b) Bank environment, photic zone of a shallow sea (upper part and lower quarter of the group), and lagoonal environment (middle part of group) (Horowitz & Potter 1971, pp.13-18)
c) Proximal back-reef environment for the lower quarter of the group. More distal back-reef for the micritic middle part (Bathurst 1971, pp.102-104).

Mingan Formation

Well rounded, coarse sandstone; sandy dolomite; bryozoan, coral, echinoderm, and blue-green algae intraclastic limestone.
a) Supratidal-intertidal environment, high energy (Laporte 1969, pp.104-109).
b) Reef and proximal back-reef to beach environment (Bathurst 1971, pp.104, 171, 182), becoming supra-litoral towards the base.

Romaine Formation

Micrite, calcareous and dolomite, slightly fossiliferous at the top, becoming intraclastic, then more and more dolomitic, and finally sandy-dolomitic and oolitic at the base.

a) Environment intertidal (slightly dolomitic upper quarter) to supratidal (algal and dolomitic intraclastal zone) (Laporte 1964, pp.104-107).

b) Lagoonal to supratidal, "Sabkha"-type environment (Bathurst 1971, pp.205-212). Oolites probably formed in tidal channels of the tidal flat (Bathurst 1971, pp.134-135).

STUDY OF CLAY MINERALS AND CRYSTALLINITY OF ILLITE

Qualitative and semi-quantitative analyses of the minerals of the clay fraction, and determinations of the degree of diagenetic evolution of the micaceous minerals, were performed for the samples listed in Table I. This study was done by X-ray diffraction on the granulometric fraction finer than 2 microns.

The degree of diagenetic evolution is based on the index of crystallinity of illite. This index is the measured width at mid height of the illite peak corresponding to d = 10Å. The crystallinity indices of illite are absolute values expressed in mm or in $^{o}2\theta$, and are only comparable within the same laboratory or between laboratories where the instruments have been calibrated from the same standards.

The anchimetamorphic zone (fig. 2 and summary table), which is the zone of transition between diagenesis and epimetamorphism, is generally considered to be the economic threshold for hydrocarbons. In the present study, the crystallinity indices that define this zone are: 4mm for the limit diagenesis-anchimetamorphism; and 2.5mm for the limit anchimetamorphism-epimetamorphism.

In the following paragraphs a report is given on the mineralogic assemblages and the degree of diagenetic evolution that characterize each of the formations encountered in Arco-Anticosti No.1. The results of the study are summarized in figure 2 and in Plate 1.

Chicotte-Jupiter Formation (200' - 2,160')

Mineralogy: In this interval the clay fraction is composed of illite, chlorite, and mixed-layer minerals of the illite-smectite type. Illite is always the most abundant (45% to 75%); chlorite varies between 15% and 40%, and the mixed-layers between 5% and 25%. The abrupt diminution of mixed-layers in the lowest quarter of the formation corresponds with an interval of coarser grain and a more abundant detrital fraction.

Illite crystallinity: The indices of crystallinity vary between 3.2mm and 9.5 mm, the mean being 7.71 mm with a standard deviation of ± 1.62mm. The relatively high value of the indices together with their variability indicates a degree of diagenetic evolution not yet incompatible with the presence of hydrocarbons, at least as gas. The low index at the base of the formation corresponds with the higher proportion of detrital material, and we conclude that this low index reflects the freshness of the detritus.

Becscie Formation (2,160' - 3,960')

Mineralogy: This formation contains on the average 58% illite, 32% chlorite, and 10% irregular mixed-layers of the illite-smectite type. The top and the base of the interval are richer in chlorite than the middle part. Since these augmentations of chlorite correspond with augmentations of the terrigenous fraction, we conclude that the chlorites are of detrital origin. The mixed-layers diminish gradually towards the base of the formation.

Illite crystallinity: The indices of crystallinity vary between 5mm and 7mm, with a mean of 5.8mm and a standard deviation of .84mm. As in the preceding formation, the lower crystallinity indices are related to a greater abundance of detrital material, though the phenomenon is less marked in this case.

Vauréal Formation (3,960' - 7,620')

Clay mineralogy: Again illite dominates, making up 60% to 70%, on the average 63%, of the argillaceous fraction. The percentage of chlorite varies between 25% and 50%, with an average of 34%. There is an increase in chlorite from the top towards the base, which parallels an increase in the detrital fraction as in the preceding formations. Mixed-layers are absent, except in the interval 4,700' - 5,850'.

Illite crystallinity: The indices of crystallinity vary between 4.2mm and 5.5mm with a mean of 4.9mm and a standard deviation of .38mm. One may conclude that the effects of diagenesis are becoming more significant, the indices being no longer clearly related to lithology and their mean value continuing the downward trend begun in the preceding formations.

Macasty Formation (7,620' - 8,170')

Clay mineralogy: The content of illite varies between 60% and 70% in this formation. Chlorite forms 30% to 35% of the argillaceous fraction in the upper part of the formation, but only 10% at the base. The diminution of chlorite is accompanied by the appearance of 30% of mixed-layers of the illite-smectite type. The persistence of mixed-layers is probably due to the presence of organic molecules, which would have prevented the closing of the layers. The formation is in fact a bituminous siltstone.

Illite crystallinity: The rather low indices (5mm) at the top become higher (7.5mm) at the base of the formation. The poor crystallinity and the abundance of mixed-layers are evidently related to the same cause.

Trenton Group (8,170' - 9,500')

Clay mineralogy: In the upper two thirds of the interval the argillaceous fraction is composed of illite and chlorite in very varied proportions: 50% to 75% of illite and 25% to 50% of chlorite. In the lower third there is, besides the illite and chlorite, about 10% of mixed-layers of the illite-smectite type. The chlorites are more abundant in the middle of the interval, and here also the increase corresponds to a sequence richer in detrital particles.

Illite crystallinity: In the upper two thirds the crystallinity indices are roughly constant, at 4.5mm, the standard deviation being .21mm. In the lower third the mean of the indices increases to 6.0mm, with a standard

deviation of .75mm. This increase in the indices and the presence of mixed-layers in the lower third are probably due to the preservation or fossilization of the properties of the clay minerals. This would be caused by a slight or non-existent permeability preventing the "illitizing" fluids from accomplishing their task in accord with the increase in temperature. Calcareous rocks are very favourable to this kind of fossilization.

Mingan Formation (9,500' - 10,000')

From the point of view of mineralogy and illite crystallinity, this formation is identical to the lower third of the Trenton Group, and the same conclusions apply.

Romaine Formation (10,000' - 12,580')

Clay Mineralogy: The argillaceous fraction is composed on the average of 65% illite and 35% chlorite. Except in the first three hundred feet these proportions vary very little. At the 10,800' level the presence of 20% pyrophyllite was noted.

Illite crystallinity: The values of the crystallinity index vary between 3mm and 4.2mm with a mean of 3.8mm and a standard deviation of .67mm. The values of the index and their constancy, coupled with the presence of pyrophyllite, indicate that the diagenetic evolution has attained the anchizone of metamorphism.

Conclusions:

The diagenetic evolution of the clay minerals can be followed throughout the well. In the Chicotte-Jupiter and Becscie Formations, properties related to a detrital origin are still observed; the indices are relatively high and variable. Beginning with the Vauréal the effects

of detrital origin diminish, and the processes of diagenesis, mainly thermal, tend to render the qualities of the illitic minerals more uniform. The indices become smaller and less variable. Finally we pass the limit of the anchizone in the Romaine Formation. A few "anomalies" are noted in the Macasty, Trenton and Mingan. This kind of anomaly is common, but does not in the least mask the general trends.

TABLE I

Semi-Quantitative Determinations of
Clay Mineralogy and Illite Crystallinity

No. INRS	Depth (Beds)	Illite	Illite Cryst. (mm)	Chlorite	(%) Interstratified	Others
1747	200'	65%	7mm	15%	20	
1749	500'	60%	7.5	15%	25	
1750	560'	60%	8.0	15%	25	
1751	680'	55%	8.5	15%	30	
1752	710'	55%	8.0	15%	30	
1753	800'	55%	9.0	15%	30	
1754	840'	55%	8.5	15%	30	
1757	1,300'	60%	8.5	20%	20	
1759	1,370'	35%	9.5	40%	25	
1761	1,510'	50%	8.5	25%	25	
1763	1,700'	70%	3.5	30%	00	
1768	2,120'	65%	6.0	25%	10	
1770	2,200'	55%	7.0	25%	20	
1772	2,320'	45%	5.5	50%	05	
1774	2,500'	60%	7.0	25%	15	
1776	3,000'	70%	6.0	20%	10	
1777	3,300'	60%	5.0	30%	10	
1778	3,600'	60%	5.0	35%	05	
1779	3,800'	55%	6.0	35%	10	
1780	3,900'	60%	5.0	30%	10	
1783	4,100'	60%	5.0	35%	05	
1784	4,450'	70%	4.0	30%	00	
1786	4,600'	60%	5.0	35%	05	
1787	4,660'	60%	5.0	35%	05	
1789	5,000'	75%	4.5	20%	05	

No. INRS	Depth(Beds)	Illite	Illite Cryst.(mm)	Chlorite	Interstratified (%)	Others
1791	5240'	65%	5.0	25%	10	
1792	5280'	60%	5.5	30%	10	
1795	5800'	65%	5.0	35%	00	
1797	6200'	65%	5.0	35%	00	
1798	6300'	65%	5.0	35%	00	
1799	6400'	65%	5.0	35%	00	
1803	6800'	60%	5.5	40%	00	
1804	6900'	60%	5.0	40%	00	
1805	7000'	60%	4.5	40%	00	
1808	7500'	60%	4.5	40%	00	
1810	7600'	65%	5.0	35%	00	
1811	7650'	70%	5.0	30%	00	
1812	7800'	65%	5.0	35%	00	
1816	8200'	65%	4.5	30%	05	
1819	8350'	80%	4.9	20%	00	
1821	8440'	75%	4.9	25%	00	
1824	8760'	50%	4.5	50%	00	
1827	8900'	60%	4.5	40%	00	
1830	9050'	70%	5.0	30%	00	
1831	9100'	50%	6.5	40%	10	
1836	9350'	65%	5.0	30%	05	
1838	9450'	60%	6.5	30%	10	
1839	9500'	65%	6.0	25%	10	
1840	9550'	70%	5.0	20%	10	
1844	9750'	55%	5.0	40%	05	
1845	9800'	60%	5.5	35%	05	
1847	9900'	63%	5.0	25%	12	
1848	9950	63%	5.0	25%	12	
1849	10000'	60%	5.5	28%	12	
1850	10050'	65%	4.0	35%	00	
1851	10250'	75%	4.3	25%	00	

No. INRS	Depth(Beds)	Illite	Illite Cryst.(mm)	Chlorite	Interstratified (%)	Others
1852	10300'	85%	3.5	15%	00	
1853	10350'	60%	4.0	40%	00	
1854	10400'	65%	4.0	35%	00	
1858	10600'	75%	4.5	25%	00	
1861	10800'	55%	4.0	25%	00	20 Pyrophyllite
1864	11100'	80%	3.5	20%	00	
1870	11590'	65%	3.0	35%	00	
1872	11750'	70%	3.0	30%	00	
1875	11950'	-	-	-	-	
1877	12150.	70%	3.8	30%	00	
1879	12300'	60%	3.8	40%	00	
1880	12360'	60%	3.0	40%	00	
1882	12440'	65%	3.2	35%	00	

PALYNOSTRATIGRAPHY

a) Introduction

Fifty-five samples were processed by standard palynological techniques. With a few exceptions the fossiliferous samples were confined to the upper part of the succession (Chicotte, Jupiter, Becscie and Vauréal), and the sandstones, limestones and dolomites of the lower part were generally lacking significant numbers of acid resistant microfossils. Acritarchs, chitinozoa, scolecodonts and other palynomorphs were found and preservation of all groups is in most cases good, although some of the more delicate acritarchs have often suffered damage by corrosion. Identification of the chitinozoa and acritarchs at the generic level was generally possible, but specific identification was hindered by the fact that descriptions of some of the forms could not be found in the available literature. Virtually no work has been published concerning the palynology of the lower part of the Lower Palaeozoic of Eastern Canada; one of the few exceptions being a publication by J. Jansonius (1967), which mentions various Ordovician chitinozoa found in material from Anticosti Island. Identification of the contained scolecodonts was not possible in view of the general lack of published work concerning their taxonomy.

Qualitative data concerning the assemblages and stratigraphic ranges are shown on Plate 2, and photomicrographs illustrating the various forms found are shown on the accompanying plates. It should be pointed out however, that all of the samples were well cuttings and that some contamination of older samples by younger may well have occurred.

b) Summary of assemblages

Six "associations" may be recognized and these are based to a large extent on the vertical distribution of chitinozoa, which show significant general variations throughout the succession. To a certain extent recognition of the "association" may be supplemented by data obtained from acritarchs, but because these show considerable qualitative variations

from sample to sample general changes are less apparent. The variation of the contained scolecodonts is even more marked.

500' - 1,300' Association F

This association is characterized by the presence of chitinozoa, acritarchs and tetrad palynomorphs. Chitinozoa found include: *Ancyrochitina ancyrea*, *A. diabolo*, *Sphaerochitina sphaerocephala*, *Conochitina* sp., *Cyathochitina campanulaeformis*, *Cyathochitina* sp.

Acritarchs identified include *Baltisphaeridium visbyense*, *Baltisphaeridium* sp., *Multiplicisphaeridium* sp., *Veryhachium pharaonis*. Also present are "palynomorphs" similar to tetrad forms called "non-miospore" by Cramer (1972).

age: Llandovery

2,200' - 2,500' Association E

The chitinozoa found include: *Conochitina* sp., *C. micracantha*, *Cyathochitina campanulaeformis*, *Angochitina* cf. *A. longicolla*, *Desmochitina minor*, *Desmochitina dornbuschi*.

The assemblage of acritarchs comprises a number of forms including *Leiofusa* sp., *Leiofusa striatifera*, *Veryhachium* sp., *Goniosphaeridium polygonale*, *Michrystridium* sp., *Baltisphaeridium* cf. *B. ravum*, *Baltisphaeridium spiniferum*, *Baltisphaeridium hermosum*, *Peteinosphaeridium palmatum*.

age: Llandovery ?

2,800' - 3,900' Association D

This is characterized by the presence of the Chitinozoa *Hercochitina crickmayi, Cyathochitina kuckersiana, Rhabdochitina magna,? Parachitina* sp. *Cyathochitina agrestis.*

The assemblage of acritarchs is characterized by the appearance of *Veryhachium trispinosum*, and the presence of *Veryhachium* cf. *V. lairdi, Baltisphaeridium denticulatum, Baltisphaeridium lucidum, Multiplicisphaeridium* sp.

age: Llandovery? or Upper Ordovician?

3,490' - 4,450' Association C

There is a significant change in the assemblage of Chitinozoa. For example *Hercochitina crickmayi* disappears, but *Conochitina bulmani, Conochitina* cf. *C. edjelensis, Belonechitina* sp., *Ancyrochitina* sp., *Illichitina multiplex.* Acritarchs are represented by *Veryhachium trispinosum, Veryhachium* sp.A, *Evittia granulatispinosa, Michrystridium* sp.

age: Ashgill (?)

5,275' - 5,800' Association B

Many of the Chitinozoa found in Associations C and D disappear; this association is characterized by the appearance of *Cyathochitina calix.* The acritarchs found include *Polkilofusa spinata, Veryhachium trispinosum, Evittia granulatispinosa.*

age: Caradoc?

5,800' - 7,000' Association A

From the 5,800' level there is a sudden decrease in the number of chitinozoa, but acritarchs are common and include *Veryhachium trispinosum,? Cymathiosphaera* sp., *Baltisphaeridium* sp., *Multiplicisphaeridium ramusculosum Polkilofusa spinata.* Chitinozoa found include cf. *Desmochitina* sp., *Conochitina poumoti, Rhabdochitina* sp.

age: Caradoc?

From 7,000' onwards fossiliferous samples are rare and consequently any zonation is difficult. The main exception to this is between 8,800' and 9,250' where the following formswere found: *Conochitina cactacea, Desmochitina lecaniella, Cyathochitina* sp., *Hoegisphaera glabra, Hoegisphaera complanata, Desmochitina* cf. *D. densa, Calpichitina scabiosa.*

age: Mid-Ordovician

c) Stratigraphic conclusions:

With the aid of chitinozoa and acritarchs at least part of the Ordovician/Silurian succession on Anticosti Island may be sub-divided into micro-fossil zones. Much of the exposed succession on the island has been dated by macrofossils (graptolites, brachiopods, trilobites, etc.) and thus microfossil zones can in part be correlated with macro-fossil zones thereby providing a useful reference section. This will be of considerable value when dating borehole samples lacking macro-fossils from other parts of Eastern Canada. Unfortunately, some of the lithostratigraphic units readily apparent at exposures on the island are difficult to recognize from borehole cuttings (e.g. Ellis Bay and Gun River), thus making an exact correlation of macro- and microfossil zones in some instances impossible. This problem could be resolved however, by further work involving the study of outcrop samples or borehole cores already dated by macrofossils.

TRACE-ELEMENT GEOCHEMISTRY

1. Introduction

Trace-elements were determined on the fraction finer than two microns. The purpose of the analysis is to characterize the organic fraction as well as the environment of sedimentation. Taking the results for the well as a whole, there is no apparent association of organic carbon with the trace-elements. Incomplete decarbonatization could probably have masked such an association, if it existed. It will be seen, however, that in certain formations poor in carbonates, organic - carbon - trace-element associations are observable.

2. Boron

In general the quantity of boron varies between 150 and 250 ppm which is indicative of a marine environment of about normal salinity. Variations within these limits are generally related to variations in the illite content. However, at the base of the Macasty, as well as in the Trenton, at the base of the Mingan, and at the top of the Romaine Formation, the average concentrations of boron become greater. For instance, there are concentrations of 378 ppm and 355 ppm in the Trenton and of 441 ppm at the base of the Mingan. In these cases the increases are not related to the illite content, or to that of carbon. It is concluded that these horizons correspond to slightly hypersaline environments.

3. Organic matter

As stated above, there is no obvious relation between organic carbon and trace-elements for the section as a whole. However, in the Macasty Formation there is a Cu - Cr - Ni - Co association that seems to be related to carbon. This reflects an oxygen-poor environment and a sediment of sapropelic type.

4. Other associations

a) Association of Sr, Ga, V;
against Ca, Sr, loss on ignition, carbon, Mn (Mo, Co, Cu, Fe, to a lesser extent).
This association expresses the opposition between the elements related to carbonates and those related to fine terrigenous material.

b) Association of Ni, Mg, Cr, Zn, Mn, Fe, Co, (U and Ti to a lesser extent). These elements are principally related to chlorite.

c) Association of Al, Ti, B, Ca, V, (Si and Co), related to illitic minerals.

d) Association of Pb, Cu, (Ga, Zn, V, Co), especially well developed between 0 and 5,000', and which is generally related to sulphides. Probably this association corresponds to interbeds of shale in the carbonates, since an inverse relation is observed between these elements and those associated with carbonates, such as Sr and Ca.

NATURE AND EVOLUTION OF THE ORGANIC MATTER
BY MICROSCOPIC EXAMINATION WITH TRANSMITTED LIGHT

On the basis of the contained organic material, the formation investigated may be divided into 4 units.

a) 800' to 3,900'

This interval approximately corresponds to the Chicotte, Jupiter and Becscie Formations. The organic matter consists of acritarchs, generally well preserved, chitinozoa and scolecodonts. The preparations often contain amorphous organic material, either coagulated (sapropelic) or finely dispersed. Pyrite is present and the fossils often show the effects of pyrite corrosion. - Type 2-3 on the scale proposed by Correia.

b) 3,900' - 5,200'

The organic matter consists of the same elements as that described above. The state of preservation is slightly poorer, acritarchs, especially those belonging to the genus Veryhachium, are encrusted or severely corroded by pyrite. - Type 3 on the scale of Correia.

c) 5,400' - 7,000'

The state of preservation of fossils becomes worse, acritarchs are darker, more corroded and encrusted with pyrite; chitinozoa are often fissured and contain many holes. The preparations contain a high proportion of organic material, either coagulated (sapropelic) or dispersed. - Type 4 on the scale of Correia.

d) 7,800' - 10,500'

This interval is characterized by a reduction in the quality of the organic material. Most of the slides contain black organic debris

rather than any identifiable fossils. However, at certain horizons, rare black chitinozoa and scolecodonts occur, as do some rare brown acritarchs. Pyrite is always present.

- The evolution of the organic material in this interval is quite advanced; Type 5 on the scale of Correia.

N.B. In certain samples acritarchs encrusted with pyrite occur but they are otherwise relatively well preserved and similar to forms from the overlying units, suggesting a certain amount of contamination.

Conclusions

1. Corrosion of the organic material by pyrite is a characteristic phenomenon of the Arco-Anticosti material. This phenomenon is especially important in the Vauréal formation from 5,400' downsection (Photo of sample from 5,400', Pl. 4).

2. Four units have been defined on the basis of the contained organic material, the units being characterized by an increase in carbonisation with depth (Pl. 4).

3. The state of preservation of the organic material suggests in the upper part of the succession (800' - 5,200') a potential within the oil and condensate zones, in the middle part of the borehole a potential within the gas and condensate zones, and finally in the lower part of the succession a potential in the gas zone, although the evolution of the organic material is advanced to the stage where the potential is very low.

REFERENCE

CORREIA, M. 1969, Contribution à la recherche de zones favorables à la genèse du pétrole par l'observation microscopique de la matière organique figurée. Revue de l'Institut Français du Pétrole. Vol. 24, no.12, pp.1417-1454.

PETROGRAPHY AND REFLECTOMETRY OF ORGANIC MATTER

Technique

For the reflectometric study of Arco-Anticosti No.1, twenty-two polished sections were examined. Most of the sections were derived from palynologic residues (<200μ). Two sections were made directly from the crude cuttings (Macasty shales). Measurements of reflectance were made on fifteen polished sections, following the usual method employed by INRS-Pétrole (Cf. Brion report).

Content of organic matter

There is not much organic matter anywhere in the section (Cf. petrographic and chemical analyses). The richest interval is between 7,600' and 8,200' (Macasty Formation, equivalent to the Utica).

Petrography of organic matter (by reflected light)

The organic matter, which the organic geochemistry data indicate to be kerabitumen (or kerogen) (LOUIS M. 1967), appears in two forms:

- finely divided in agglomerations; this corresponds to the dispersed organic matter seen by transmitted light.
- in small lenses (2 to 30μ thick, 10 to 200μ long) of light grey colour and - in fine filaments (1 to 2μ thick, 10 to 60μ long).

The latter type, which is found in variable quantities in fourteen of the sections studied, is identified as bitumen (asphaltic pyrobitumen). There are several reasons for this identification:

1) the fact that coaly organic matter is not present in Cambro-Ordovician rocks (BOUREAU E. et al. 1973).

2) the morphology and aspect of the organic substance.

3) the optical properties of this substance.

It can be seen from examination of the crude cuttings that the lenses and filaments are disposed parallel to the bedding. This type of fabric is comparable to that observed in bituminous shales (BESEME P. 1972). Biological structured bitumens were not recognized in the large expanses; the material appears very homogeneous.

Measurements of reflectance and petrographic observations can only be carried out on sufficiently large lenses. Some areas or particles are anistropic in polarized light (single nicol). Most particles are anisotropic under crossed nicols; the extinction is often wavy or in halos. These optical properties are characteristic of bitumens (ROBERT 1973). Referred to the curve of JACOB (1966), which correlates the types of bitumen, their reflectances, and their richness in volatile matter, these bitumens appear to be epi- to meso-impsonits (Fig.6).

Woody fragments

Rare fragments of vegetal tissue were observed (by transmitted and by reflected light) in samples 1784 (4450'), 1792 (5280'), 1805 (7000'), 1834 (9250'), 1844 (9750'), and 1867 (11,350'). It is almost certain that these fragments are contaminations.

Pyrite

Pyrite is abundant. It is present in small polygranular spherules (10) or in dispersed crystals. It may represent up to 50% of the palynologic residue. In several samples (1813 (8000'), 1819 (8350'), 1827 (8900')) there are pyritized tubes. These are certainly pseudomorphs after spicules.

Reflectometry and diagenetic interpretation

Because of the rarity of sufficiently large areas of bitumens, few measurements of reflectance (Ro) were carried out. The histograms (Fig.5) show that the dispersion of the values of Ro in the same sample is fairly large (more than 1%). This may be due either to caving or to the anistropy of the organic matter.

The diagenetic interpretation of the Ro of bitumens remains delicate because of the lack of references. P. Robert (1973) states that the Ro of bitumens is about the same as that of vitrinite for values between 1 and 2%. However, for values higher than 2% the correlation is less certain.

The measurements of Ro on the sample from 1,800' will be treated with circumspection, since its isolation suggests the possibility of contamination. If it is assumed that the phenomenon of caving played a small or non-existent role and that anistropy alone is responsible for the spread in the measurements, the arithmetic means of the Ro's may be considered as representative. These vary from 1.61% at 8,000' to 2.69% at 12,600' (gradient = .26%/100' or .78%/100m). In this case the conclusion would be that the section between 8,000' and 12,600' is in a zone diagenetically favourable to the presence of wet to dry gas.

On the other hand, if it is assumed that caving played an important role, it becomes necessary to identify the population due to caving. Although there is no bimodalism, it may be considered, as a first approximation, that the minimum values of Ro represent the caving and that the maximum values of Ro characterize the particles in place. In this case only the maximum values would be characteristic of the degree of diagenesis. According to this hypothesis, the conclusions as to the diagenetic possibility of the occurence of hydrocarbons would

be more pessimistic. The section between 8000' and 9000' would be in a zone diagenetically favourable to gas. The section between 9500' and 12,600' would be diagenetically sterile (below the hydrocarbon deadline).

TABLE 2

Reflectance of Bitumens
(Arithmetic Means)

No. INRS	Depth (')	P.R. Bitumen % (oil immersion)
1763	1700	--
1764	1800	.56
1805	7000	--
1813	8000	1.82
1814	8100	1.61
1815	8150	1.88
1816	8200	1.91
1819	8350	2.25
1824	8760	1.78
1825	8800	2.10
1827	8900	--
1828	8950	1.99
1833	9200	1.78
1836	9350	2.08
1850	10050	--
1854	10400	--
1856	10500	2.55
1858	10600	1.72
1864	11120	--
1867	11350	2.15
1870	11590	--
1884	12600	2.69

ORGANIC GEOCHEMISTRY

Siluro-Ordovician rocks are not particularly rich in organic matter; and the size of the samples being not always sufficient, it was necessary to group them into composite samples as the only way of getting enough extracted gas for analysis.

Three scales for the measurement of organic carbon were used in this study: the organic carbon of the fraction below 2μ (cf. Pl.3), organic carbon measured on the insoluble residue but expressed relative to the total rock (cf. Fig.4 and Pl.5), and the organic carbon of the insoluble residue (cf. Pl.5), the last being a complementary measure, on the larger test samples, to confirm the impression of the general poverty of the section.

Total organic carbon and the organic carbon of the insoluble residue

All the measured values of total organic carbon (T.O.C.) are below average with the exception of that for the base of the Macasty. This is particularly well seen in Fig.4, a diagram borrowed from C. Sourisse and J. Gauthier*. Apart from the Macasty, from 12,600' to 710' the average T.O.C. is 0.16 - ± .06%. The variation of about 38% is relatively slight. The Macasty, with 3.32% T.O.C. possesses a very favourable organic reserve. It should be noted that the seven samples from the Trenton Group do not exceed 0.19%. The figures for organic carbon of the insoluble residue (O.C.I.R.) confirm the general poverty in organic matter, the best value barely attaining 3%. The organic carbon of the fine fraction is relatively monotonous from the Romaine Formation up to the Becscie Formation, rarely attaining 2% (of the fine

* SNPA. Unpublished report.

fraction), and "takes off" only slightly in the Macasty. This observation confirms the results of the petrographic analysis, which shows that the particles of organic matter are partly finely divided and partly greatly exceed the diameter of 2 microns.

It should be pointed out that the distribution of organic matter is not very sensitive to changes in facies, as is often the case. No clear enrichment in O.C.I.R. is noted in the facies very rich in carbonates. Neither is there any increase (less clear in the general case) with increase in terrigenous detritus. The richness of the Macasty in organic matter is all the more strongly affirmed by this. There was really a more abundant organic production independent of any law of covariation dependent on variations of facies.

Organic extracts and their constitution

It must first be noted that four extracts are suspected either of impregnation or of pollution. In comparison with the results as a whole they are in fact too rich and their "yield" is too high, for three extracts at least. The samples concerned are from 4660' - 5200', 10,300' - 10,550', and 10,750' - 10,900'.

If for the moment we exclude these doubtful cases, we see that the Macasty, with 466 ppm of extract soluble in chloroform, is more than three times richer than the average (calculated from 10 samples, excluding the four doubtful ones and the Macasty itself). The average is in fact 140 ± 80 ppm. This is a relatively low value for a series as a whole fairly rich in carbonate.

From top to bottom of the well there is a clear diminution in extracts: above 200 ppm in the Chicotte-Jupiter and Becscie, the extracts from the Trenton down are often less than 100 ppm. Correspondingly, the "yields" (organic extract over T.O.C.) diminish from more

Depth in ft.	Total Rock				Organic Extract Composition				
	Insoluble Residue (%)	Organic Carbon	Organic Extract	Yield (Organic extract per gram of organic carbon	Saturated (%)	Aromatic (%)	Resin (%)	Asphalt. (%)	Aromatic/ Saturated
710'- 1,450'	29.3	.15	.0251	16.7	32	16	1	51	.49
2,200'	51.3	.18	.0240	13.3	17	13.5	60.5	9	.80
4,660'- 5,200'	21.1	.13	.0488	37.4	43	15.	34.	8	.35
5,500'	36.1	.25	.1271	51.0	61.5	15.5	18.5	4.5	.25
7,600'	40.8	.27	.0258	10.7	41	12.5	42.5	4	.30
8,100'- 8,150'	65.5	3.32	.0466	14.0	24.5	13.5	40.	22	.56
8,760'- 8,900'	26.3	.15	.0103	6.9	-				
8,950'- 9,000'	-	-	-	-	-				
9,150'	30.0	.19	.0084	4.4	-				
8,300'- 9,450'	22.6	.14	.0150	10.7	-				
9,850'	34.4	.08	.0072	9.0	-				
9,900'	70.4	.09	.0082	9.1	-				
10,300'-10,550'	19.7	.22	.0362	16.5	55.5	15.5	20.5	8.5	.28
10,750'-10,900'	26.9	.21	.0589	28.0	58.5	11.5	19.5	10.5	.20
11,650'-12,210'	19.8	.09	.0101	11.2					
12,510'-12,600'	28.0	.07	.0061	8.7					

TABLE 3 - Organic Carbon and Organic Extracts

than 10% in the upper formations to less than 10% in the lower formations. This evolution can be perfectly well explained by an increase in temperature and a more advanced maturation of the organic matter.

The best yields and the highest extracts are found, in descending order, in the Chicotte-Jupiter and Becscie Formations and naturally in the Macasty, the poorest in the Mingan Formation and at the base of the Romaine.

The four suspect samples gave very abundant extracts (more than 1200 ppm from the Vauréal at 5500'), very high yields (51% from the same sample), very abundant total saturated hydrocarbons (65%), and low ratios of aromatics to saturateds (0.25). To explain these facts, we can use the hypothesis of impregnation or that of contamination. In the choice between these two hypotheses, the chromatographic study of the total saturated hydrocarbons supplies important data.

Chromatographic study of total saturated hydrocarbons

Only eight samples provided sufficient extract for the employment of chromatographic analysis. Among these eight, it must be remembered, are the four suspected of contamination. For the two samples from 2200' (Becscie) and 8100' - 8150' (Macasty), normal-paraffin parity has been attained. The iso- and cyclo-paraffins tend to be arranged in seires of homologues of iso- and ante iso-alcanes (cf. Pl.5). This corresponds to relatively mature organic matter.

The extract from 4660' - 5200' is, as already mentioned, suspect. Under the microscope the cuttings are seen to be on the whole very pure limestones (confirmed by DX analyses). For the 4660' sample no organic matter is visible except as traces, and it is the same for that from 5200'. It must be admitted that if the abundant extracts come from natural impregnations, these would not be visible under mi-

croscopic examination of the cuttings. The question of impregnation versus contamination therefore cannot be resolved by this means and remains unanswered.

The chromatogram of the extract from the two Macasty samples (8100' - 8150') also shows the tendancy towards parity of normal paraffins; the organic matter is mature. It could be a good source-rock, in a stage of evolution entirely favourable to the genesis of oil.

The organic matter might have experienced an advanced thermal evolution. This hypothesis must be abandoned. According to the literature, and notably the work of Connan (1973), the significant proportion of iso- and cyclo-alcanes revealed by the chromatograms is not compatible with a very high degree of maturity. It should be remembered that, according to the crystallinity of illite and the presence of pyrophyllite, the whole Romaine Formation is in the anchizone or at least at its upper limit. The advanced thermal evolution indicated by the clay mineralogy is in contradiction with the presence of iso- and cyclo-alcanes.

On the other hand, such chromatograms, poor in n-paraffin peaks, are met with in the case of impregnations or oils submitted to bacterial degradation (cf. Connan, 1973, Tissot, 1974). Here also the presence of iso- and cyclo-alcanes is contradictory. Such products of bacterial biodegradation, submitted to the temperatures of deep diagenesis, should normally also be impoverished in cyclo- and iso-alcanes.

The contradiction between the presence of these compounds and the indications drawn from the clay mineralogy disappears if we return to the hypothesis of pollution by drill-pipe grease or other industrial lubricants, of which the chromatograms are fairly similar to those of the two extracts mentioned above.

To remove the doubts, all the samples that furnished the suspect extracts were re-examined by natural light and especially - a much more selective and effective means for detecting impregnations, natural or artificial - by fluorescent light. As usual it was found that what is considered to be organic matter by transmitted light includes a high percentage of opaques, and at Arco-Anticosti pyrite especially (more than 50% of the organic matter defined by transmitted light). Examination of the cuttings by fluorescent light showed that the fluorescence is the same for the samples poor or rich (anomalous) in extracts. No impregnation, natural or artificial, could be detected. The problem of the representativeness of the extracts therefore remains unsolved.

Adsorbed gases

The amounts (ml of gas collected per kg of rock) and the yields (ml of gas collected per g of organic carbon) are fairly normal for a carbonate series. A clear increase of these two parameters with depth is noted. It is the Macasty Formation that liberates the greatest absolute quantities of gas; 447 ml/kg. With the exception of the sample from the Mingan Formation at 9850', the values for all the formations below the Macasty exceed 200 ml/kg. Correspondingly, the amount of methane increases with depth (cf. Pl.5 and Table 4), which is often correlated with an increase in temperature.

Finally, according to the ratios C_3/C_1 and C_2/C_1 and by reference to known basins, it can be seen according to Fig.7 that the sample 1760 (1450', Chicotte-Jupiter Formation) is from a thermal zone favourable to the genesis of liquid hydrocarbons. The Macasty (8150') should be in the zone of potential for condensate gas or oil of high G.O.R. All the other samples come from the zone of dry or even very dry gas (e.g. the sample from 12,210' of the Romaine Formation or that from 9900' of the Mingan).

Depth in feet	Organic Carbon (%)	Volume recuperated cc/kg.	Yield volume recuperated per gram of organic carbon. cc/g. C. Org.	Methane CH_4/total gas recuperated
710'- 1,450'	.15	39.4	26.3	63.3
4,660'- 5,200'	.13	97.3	74.9	60.4
8,100'- 8,150'	3.32	447	13.5	68.7
8,760'- 8,900') 8,950'- 9,000')	.15	306	204	87.7
9,300'- 9,450'	.14	291.3	208	93.5
9,850'	.08	96.3	107	95.8
10,300'-10,550'	.22	323.7	147	88.3
10,750'-10,900'	.21	275.5	132	88.9
11,650'-12,210'	.09	290	322	95.5
12,510'-12,600'	.07	203.6	209	92.7

TABLE 4. Adsorbed Gases

Depth in feet	Organic Carbon (%)	No. INRS
4,700'	1.45	1788
6,200'	.33	1797
7,600'	1.95	1810
7,650'	.70	1811
7,800'	.81	1812
8,000'	3.47	1813
8,300'	.60	1818
8,850'	.67	1826
9,100'	1.48	1831
9,200'	.67	1833
9,350'	.70	1836
9,550'	.12	1840
9,750'	.19	1844
10,450'	.78	1855
10,600'	.77	1858
10,700'	.97	1859
10,800'	2.64	1861
11,120'	1.43	1864

TABLE 5. Organic Carbon of the Insoluble Residue

The evolution of adsorbed gases, in their absolute amounts, their yields, and their compositions, confirms the major trends revealed by clay mineralogy and reflectometry.

Carbon ratio

Because of the poverty of organic matter, and in spite of the selection of the least poor samples, only 14 samples furnished information to the chromatograph, and amongst these fourteen only five did the "peaks" pass the experimental limit of 30mm - beyond which the results become reliable.

From 710' to 10,550' the progression is very clear. If it is assumed that the bulk of the organic matter submitted to analysis is not of continental origin, or at least of vegetal origin, as shown by the chromatograms and microscopic examination with transmitted light, by reflection, and by fluorescence, it must then be accepted that the value of .6% is the limit of the "thermal" zone for the generation of liquid hydrocarbons.

According, then, to the rare reliable data of the carbon ratio method, this limit lies between 5500' and 10,550'. It is not possible in view of the imprecision of the intermediate values to define the limit any better. It is to be noted, all the same, that there is agreement between the information from the carbon ratio method and that provided by the other techniques in illustrating the tendancy towards supermaturity towards the bottom of the well.

No. INRS	Depth in feet	Carbon Ratio
1752	710'	.359
1760	1,450'	.419
1770	2,200'	.333
1790	5,200'	.636*
1794	5,500'	.511
1814	8,100'	.959*
1824	8,760'	.773*
1832	9,150'	.821*
1835	9,300'	.870*
1841	9,600'	.728*
1846	9,850'	.501*
1852	10,300'	.909*
1857	10,550'	.677
1871	11,650'	.810*

The values followed by * have been calculated from peaks less than 30mm high. This means that the carbon contents were too low to permit meaningful results.

TABLE 6. Tentative Determinations of the Carbon Ratio.

Conclusions

The organic reserve, poor in the formations as a whole, is very favourable in the Macasty Formation.

Organic matter of continental or vegetal origin, according to the results of the techniques of microscopic examination, confirmed here by chromatography, plays a quite subordinate role.

The excessive and anomalous organic extracts from the Romaine Formation are to be attributed to contamination by industrial lubricants. Even following the hypothesis of bacterial biodegradation, the other criteria as a whole demonstrate that the iso- and cyclo-alcanes should have been transformed.

A paleotemperature sufficient for primary migration having been attained at 710', the anomalous extracts derived from 4660' - 5560' can be attributed to natural impregnations, although no microscopic criterion, whether by transmitted light, fluorescence, or reflection, confirms it. The composition of the gases places this level in the potential zones of high G.O.R. oil.

The stage of potential for condensate gas or high oil is attained at the level of the Macasty.

All the lower formations are in the potential zone of dry gas or even very dry gas.

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ORGANIC GEOCHEMISTRY

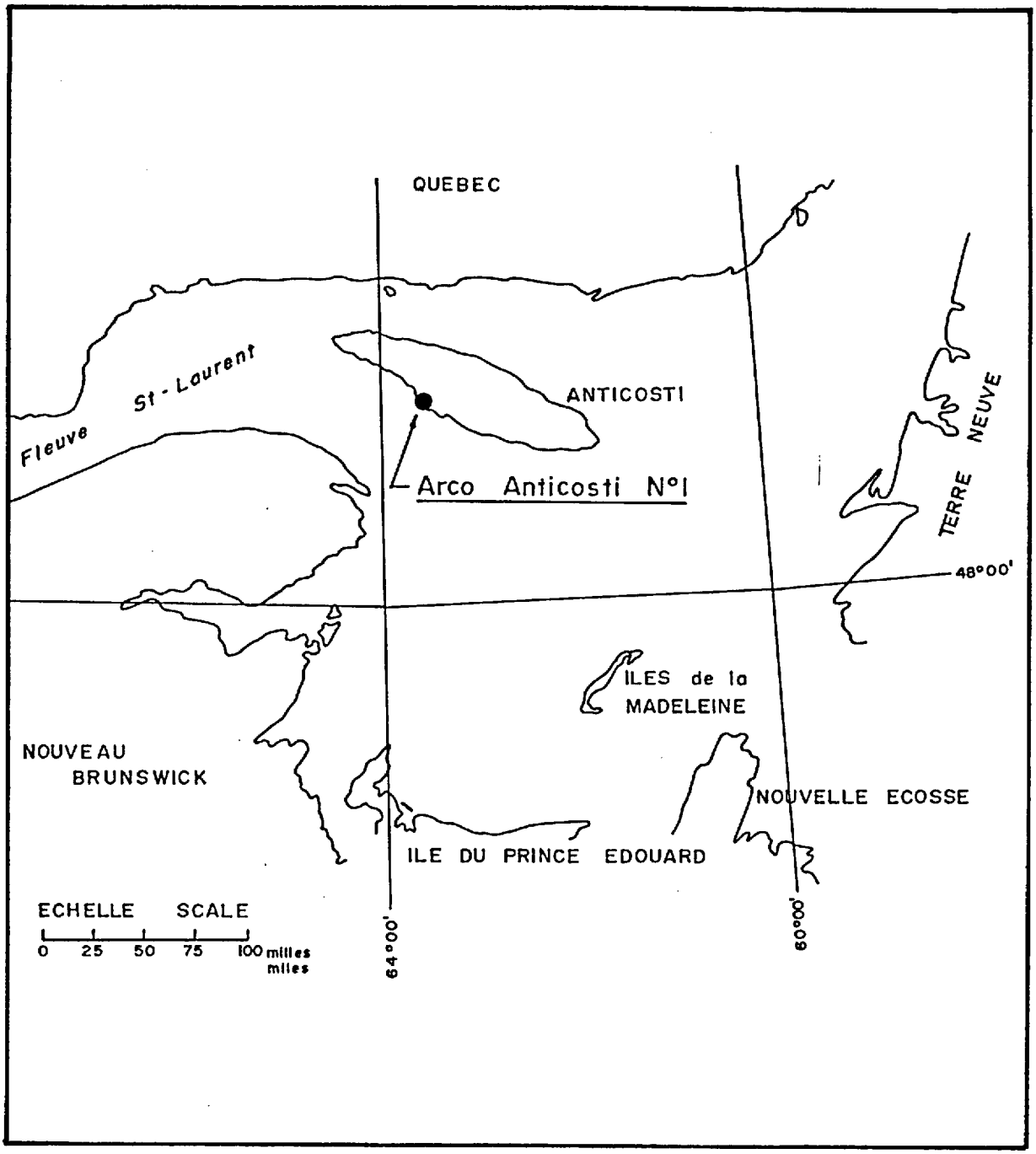
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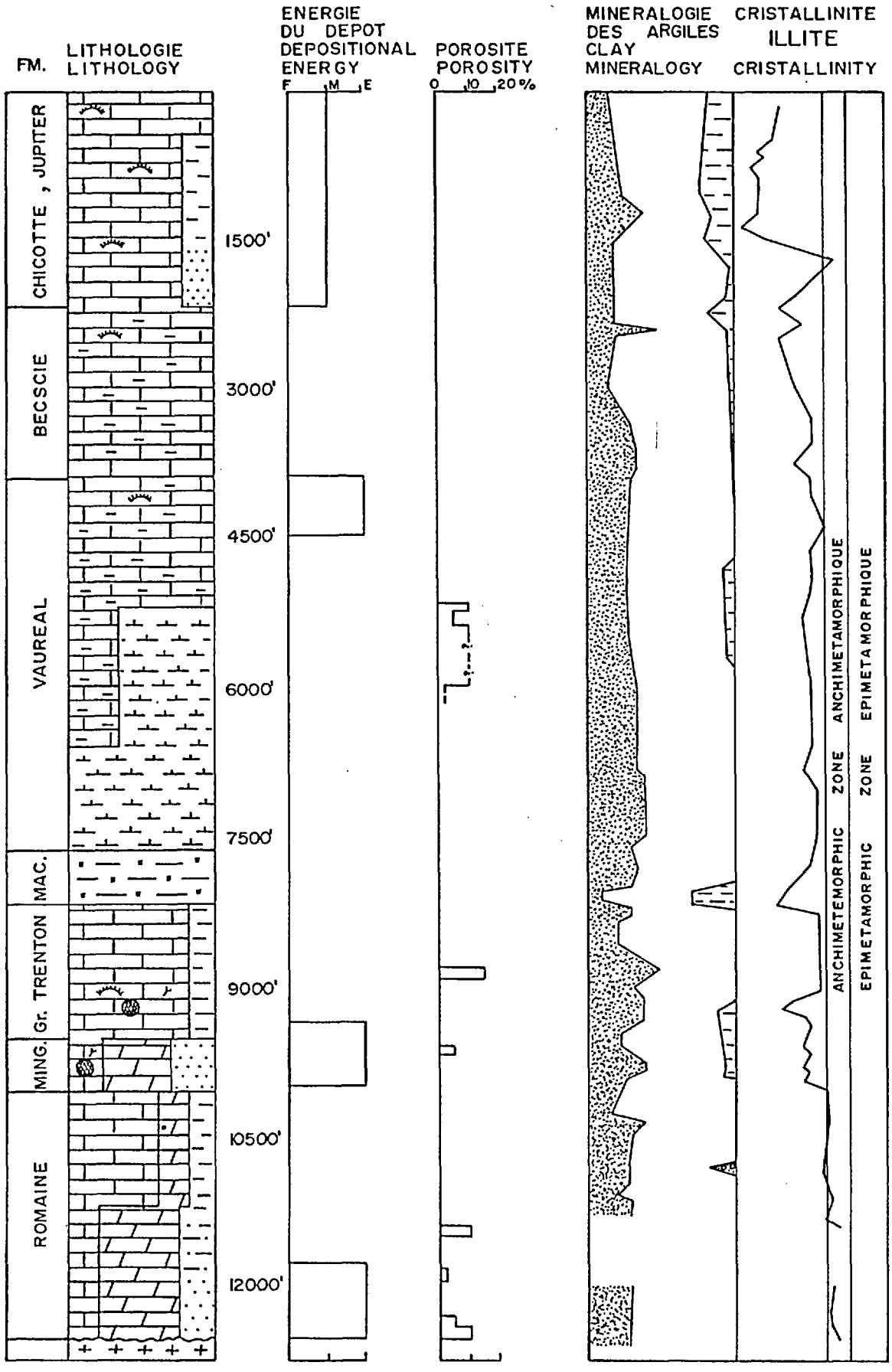
ARCO - ANTICOSTI N° I

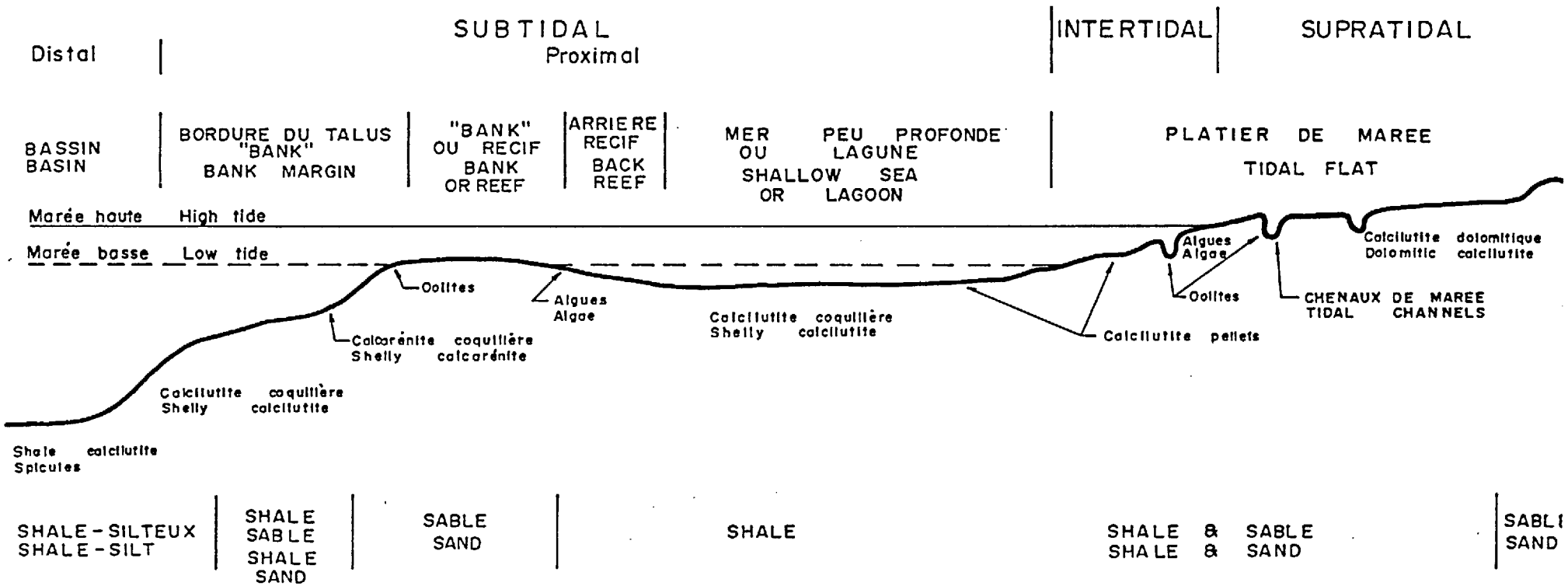
CARTE DE LOCALISATION

LOCATION MAP

Fig. 2

ARCO ANTICOSTI N° 1 M.R.N. N°7





SCHEMA D'ENVIRONNEMENTS MARINS PEU PROFONDS
DIAGRAM OF SHALLOW MARINE ENVIRONMENTS

Fig. 3

Services technologiques de pétrole
Petroleum technological services

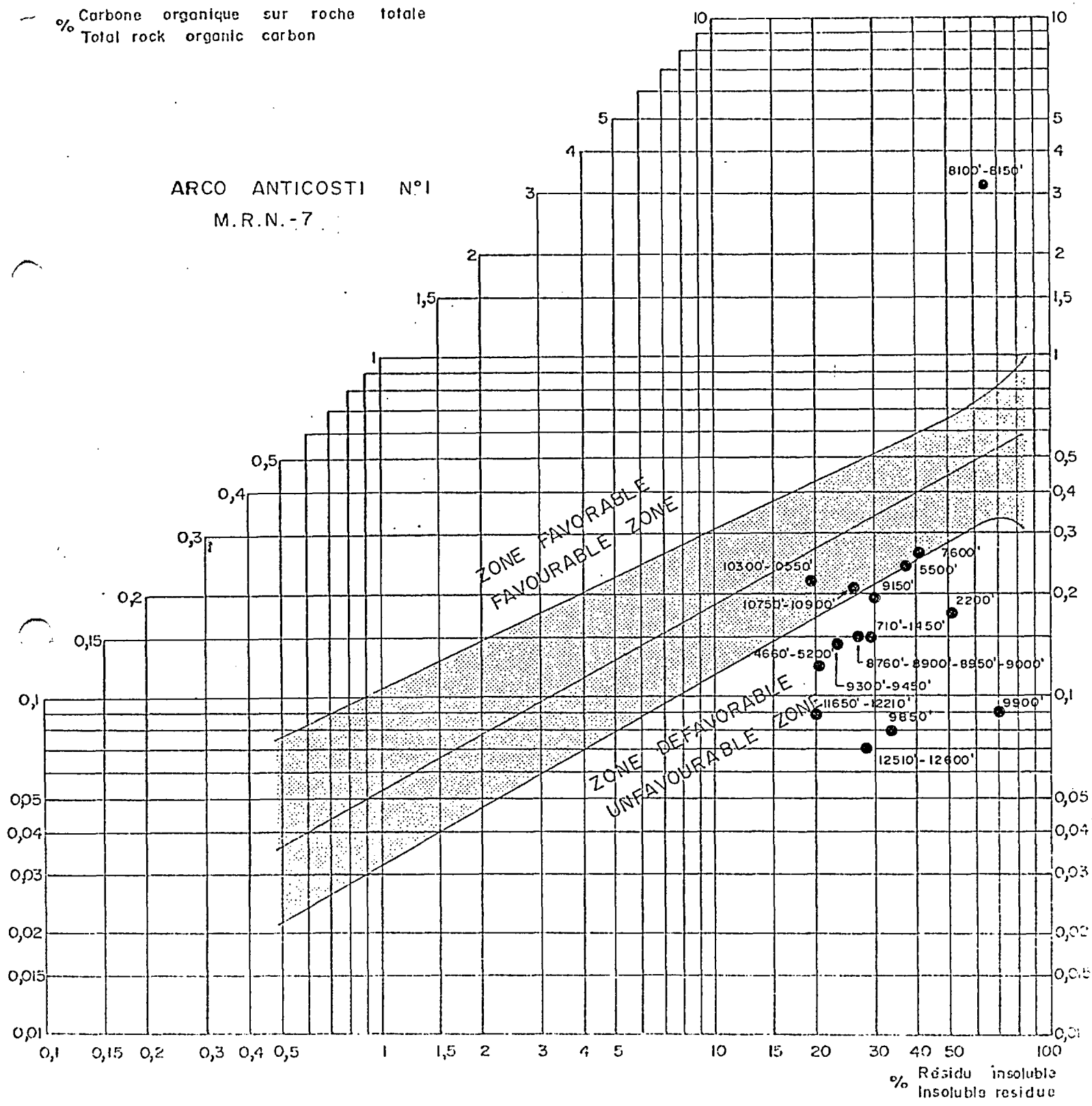
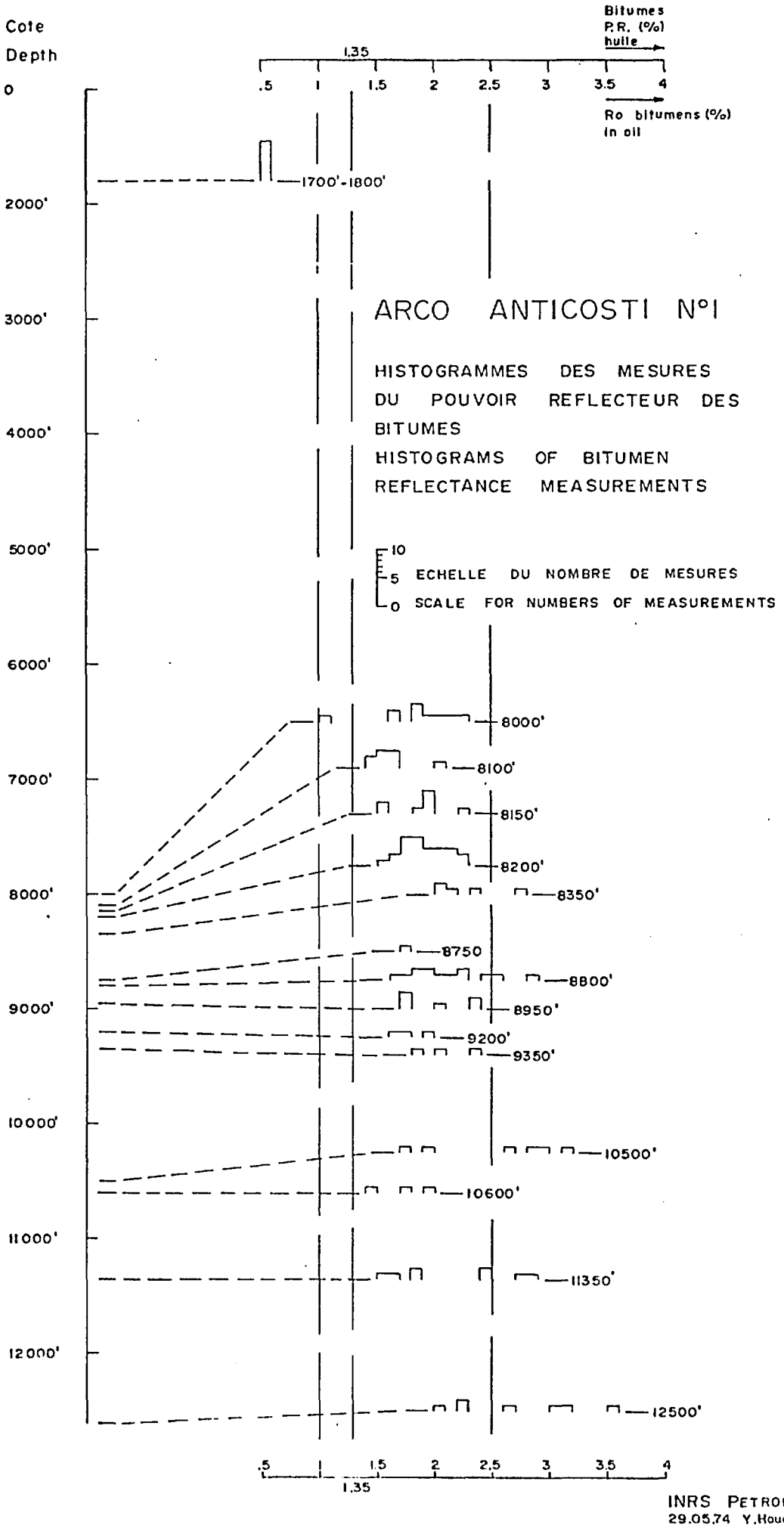


DIAGRAMME CARBONE ORGANIQUE / RESIDU INSOLUBLE
DIAGRAM OF ORGANIC CARBON / INSOLUBLE RESIDUE

Fig. 5



INRS PETROLE
29.05.74 Y.Houde

Fig. 6 Legend

The results of the average reflectance capacity for bitumens of Arco-Anticosti have been shown on the graph of Jacob (1967). As the percentages of volatile materials were not known, the results were plotted at the intersection of the Ro, in a consistent manner, and on the first curve of the graph of Jacob.

The progression from 1,800' to 12,600' is very distinct and shows well the general tendancy of the borehole to reach a super-mature zone in the Romaine Formation.

Fig.6

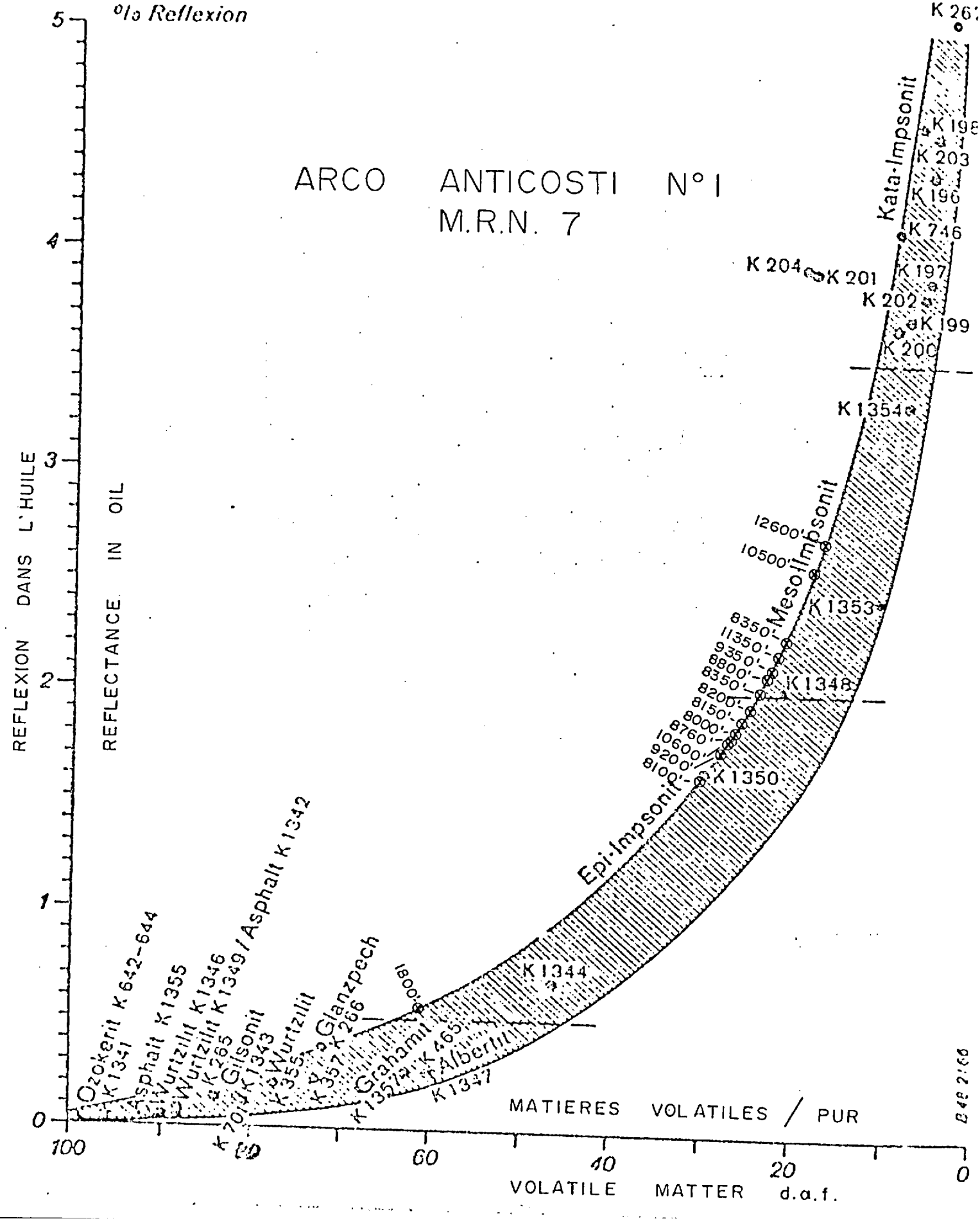

% Reflexion
ARCO ANTICOSTI N°1
M.R.N. 7
REFLEXION DANS L'HUILE
REFLECTANCE IN OIL
MATIERES VOLATILES / PUR
VOLATILE MATTER d.a.f.
Kata-Impsonit
Meso-Impsonit
Epi-Impsonit
K 261
K 198
K 203
K 196
K 746
K 204
K 201
K 197
K 202
K 199
K 200
K 1354
K 1353
K 1348
K 1350
K 1344
K 1347
12600'
10500'
8350'
11350'
9350'
8800'
8350'
8200'
8150'
8000'
8760'
10600'
9200'
8100'
Ozokerit K 642-644
K 1341
Asphalt K 1355
Wurtzilit K 1346
K 265
Wurtzilit K 1349 / Asphalt K 1342
Gilsonit
K 1343
K 701
Wurtzilit
K 355
Glanzpech
K 357
K 266
Grahamit
K 1357
K 465
Albertit
5
4
3
2
1
0
100
80
60
40
20
0

DIAGRAMME DES GAZ
ARCO-ANTICOSTI NO. 1
M.R.N. 7

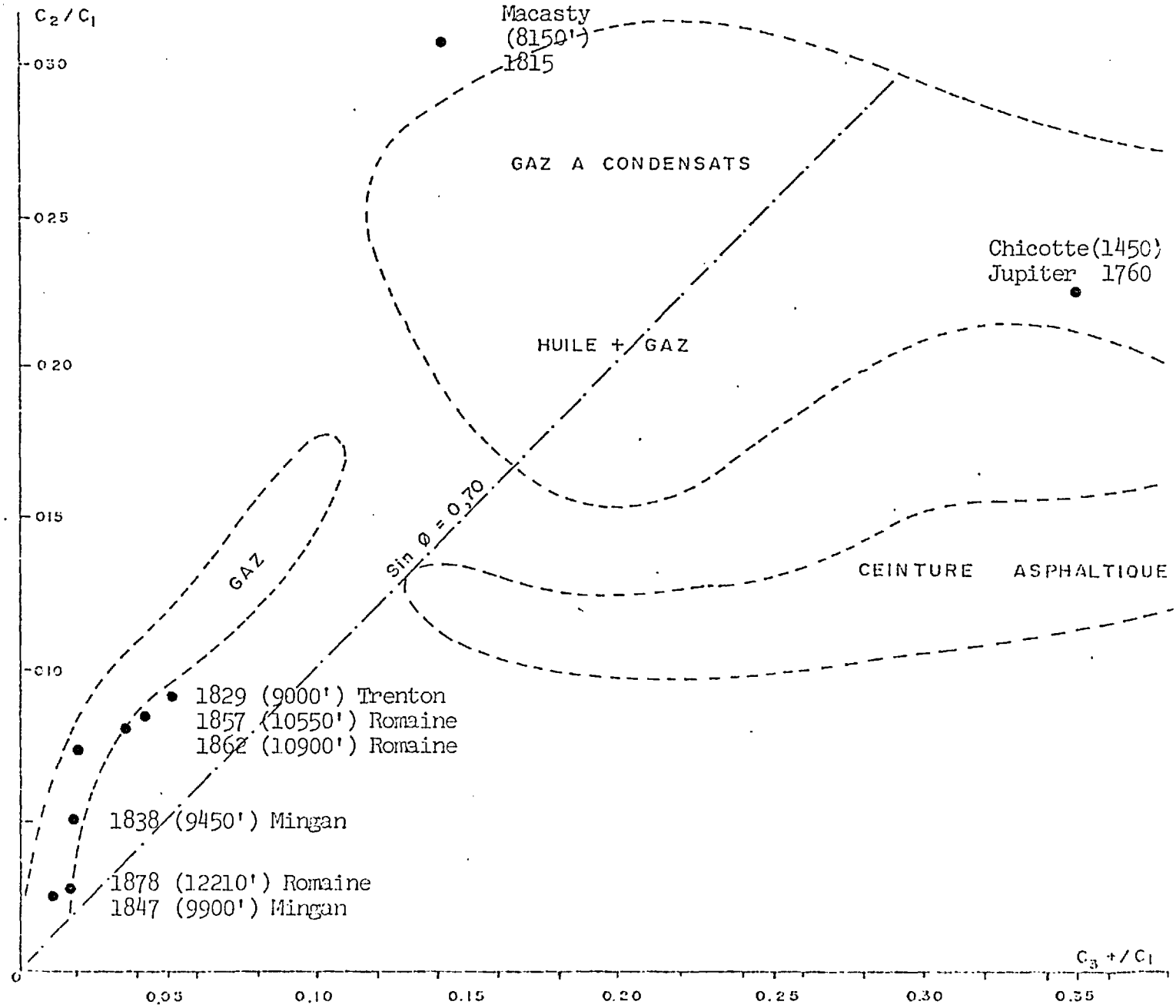


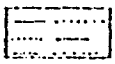
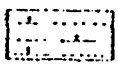
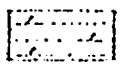
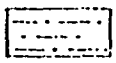
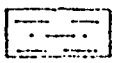
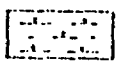
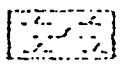
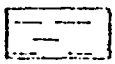
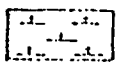
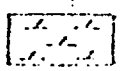
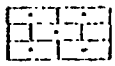
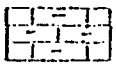
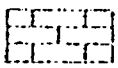
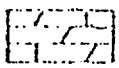
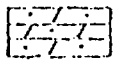
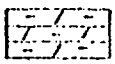
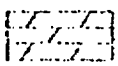
FIG. 7

KEY

ARCO-ANTICOSTI

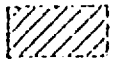
M.R.N. No.7

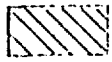
Lithology:

	Sandy	Silty	Argillaceous	Calcareous	Dolomitic
Sandstone					
Siltstone					
Shale					
Limestone					
Dolomite					

Echinoderm		Alga	
Brachiopod		Oolite	
Ostracod		Gasteropod	
Bryozoan		Bitumen	
Pellet		Siliceous-Cherty	
Intraclast		Feldspar	

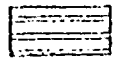
Grain Packing

Mudstone 

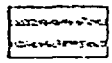
Wakestone 

Packstone 

Grainstone 

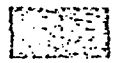
X-stone
(crystalline rock) 

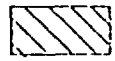
Allochems

Coral 

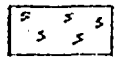
Echinoderm (crinoid) 

Brachiopod 

Bryozoan 

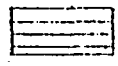
Ostracod 

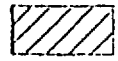
Oolite 

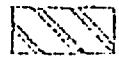
sponge, specules 

Pellet 

Intraclast 

Undetermined 

Trilobite 

Mollusca
(lamellibranch) 

Pores, crystallisation, dolomitisation

Pores ——— 0 - 15%

Recrystallisation _____ F - Low
M - Average
E - High
TE - Very high

Quartz - Detrital Fn

Fn - Feldspar - - -
Qtz Quartz _____

Organic Matter

Absent	N
Present	P
Common	C
Abundant	A

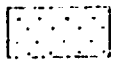
Energy Index

Low	F
Average	M
High	E
Very High	TE

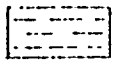
Oxido - Reduction

Oxidized environment	O
Reducing environment	R

Mineralogy (clay)

Chlorite 

Mica type Illite 

Interbedded 

Pyrophyllite 

X Ray D.

Calcite 

Dolomite 

Quartz 

Others 