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KASKATTAMA WELL 1 -

- Microfacies, stratigraphic and geochemical studies

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CONTENT

SUMMARY

The micropaleontological and geochemical studies concerning the Kaskattama bore I hole, yielded a number of results the summary of which is as follows

I - ENVIRONMENTS OF DEPOSITION -

The general characteristical features of the Kaskattama bore I sediments, seem to indicate a predominant shallow water environments of deposition These sediments were apparently deposited on a shelf allowing the settlement, now and then, of evaporitic minerals (gypsum and anhydrite)

- The Portage Chute, Caution Creek, Chasm Creek and Red Head Rapids Formations of the lower Kaskattama bore I sediments, mainly consists of rocks which point to irregular fluctuations between a normal marine environment (Trilobites, Crinoids, Pelecipods and Algae) and sublagoonal to lagoonal environments (high boron contents and occurrence of evaporites)

- The Middle part of Kaskattama bore I which includes the Port Nelson, Kaskattama, Attawapiskat, lower and middle Kenogami Formations, still indicates the presence of fluctuations which occurred, however, more frequently than those of the lower part of Kaskattama bore I

In that middle part, the Port Nelson and Kaskattama Formations show a general tendency towards reef development Moreover there occurred a number of marine oscillations indicating that these formations were deposited in sublagoonal to lagoonal environments. On the other hand, most of the Attawapiskat Formation points to its reefal development till its uppermost part, where, together with the lower Kenogami Formation, the sediments indicate a return to a logoonal environment The middle Kenogami Formation reminds the Wealdian of Europ and may represent a wedging facies of an evaporitic sequence

- The upper part of Kaskattama bore I is represented by the Abitibi Formation Only very few data could be gathered from this part and the results obtained suggest the deposition of Abitibi's sediments (excluding the interval of core 7) in a normal marine environment

II - BIOSTRATIGRAPHY -

The association of the different groups of microfossils (Conodonts, Ostracodes and Chitinozoa, Acritarchs, Scolecodonts and Spores) allow to establish the following biozones

- 11 biozones based on Conodonts
- 4 biozones based on Ostracodes
- 6 biozones based on palynoplanktons.

These biozones may suggest the following ages for the Kaskattama bore I sediments (in ascending order)

a/ The Ordovician, from 2900 to 2095', can be distinguished into

Middle Ordovician , from 2900' to 2709' and Upper Ordovician, from 2689' to 2095'

b/ The Silurian, from 2029' to 17(1'

c/ Silurian and/or Devonian, from 1761' to 1294'

e/ The lack or scarcity of microfossils did not allow a precise dating for the interval from 1294' to 925'

f/ The middle Devonian, from 925' to 93'

III - ORGANIC MATTER AND HYDROCARBONS POTENTIAL -

Geochemical analysis of organic matter and associated trace-elements as well as visual examination of microorganisms and diffuse organic matter lead to the following conclusions

Favourable factors

- Trace-element content, analysis of soluble organic extract and palynoplanctological determinations indicate that, except of the Middle Kenogami Formation, the bulk of organic matter is of marine origin

- The presence, in places, of a correlation between organic carbon (fine fraction of insoluble residue) and metals associated with marine organic matter, shows that for some levels, the redox potential has permitted a partial conservation of the organic matter of the sediments

According to these factors, the best sequences are found mainly within the Kaskattama and Port Nelson Formations while some other favourable levels exist here and there

- The composition of adsorbed gases suggests that the products which might be generated would be liquid hydrocarbons or, at least, gases with condensate

Unfavourable factors

- The total organic carbon content is generally rather low which is probably the consequence of an insufficient reducing environment

- The degree of coalification measured by the ratio C_R/C_T, as well as deducted from the opacity of Tasmanacea, shows that the organic matter has only undergone a slight maturation

Nevertheless, it must be said that these unfavourable factors are perhaps related to the near-shore situation of the well A more reducing environment could be found toward the center of the basin a higher maturity with increasing burrying

INTRODUCTION

The Kaskattama bore I is located near the mouth of Kaskattama River, in the Hudson Bay Lowlands (latitude 57°04' - longitude 90°104)

The purpose of this study was

- to establish the types of microfacies, to describe the lithology, to interpret environment of deposition and to recognize stratigraphic "markers",
- to determine chronostratigraphic boundaries,
- to give an estimation of the hydrocarbons potential

The main results obtained are represented in the 7, herein, including tables

In table 1, the types of microfacies are given as well as the boron content, the description of the interpreted environment and the distribution of microfossils

Table 2, represents the biostratigraphy established on the basis of Conodonts, Ostracodes and microplankton

Tables 3 to 6, give a detailed account of Conodonts-Ostracodes analysis (tables 3 and 4) and microplankton analysis (tables 5 and 6)

Table 7 shows the main results of geochemical analysis

PART I

Table I

1 - Lithology, Microfacies and tentative interpretation of depositional environment.

2 - Distribution of Microfossils.

1 - LITHOLOGY, MICROFACIES AND TENTATIVE INTERPRETATION OF DEPOSITIONAL ENVIRONMENT .

The lithology, microfacies and environments of deposition in connection to Kaskattama bore I sediments, have been studied by X rays, diffraction technics, microfacies technics and by geochemical analysis (boron content of the clay-fraction) The thin sections made in the cores, though not closely sampled, show the various microfacies of this bore. The 340 thin sections examined, were made in 107 cores representating 2941' of sediments

The formations herein described correspond to the A.C.C. log

A - ABITIBI RIVER FORMATION from 23' to 423' (cores 1 to 9)

This formation can be subdivided into the following members

1 - An upper member, from 23' to 153' (cores 1 to 4) which is characterized by microsparites and/or slightly dolomitic biomicrosparites with some intraclasts The fauna mainly contains Pelecypods (abundant in core 2), Crinoids, very rare Trilobite fragments (core 3) and abundant Pteropods (core 3).

2 - A lower member, from 153' to 423' (cores 5 to 9), consisting of limestones and dolomites which become chalky at the upper part. This member contains the following microfacies

a/ - cores 5 to 6 Micrites to biomicrites characterized by the occurrence of Pelecypods, Brachiopods and Crinoidal fragments, rare Pteropods and sporadically pyrite infilling

b/ - core 7 Brecciated limestone The cement of this breccia is micritic, the fossils are lacking and the intraclasts are dolomicrosparitic.

A locally restricted environment is pointed out by the boron content of this core.

c/ - cores 8 to 9 Mainly bedded micrite (dolomitized in core 8), with abundant little vughs of about 60 to 100 microns, apparently deposited in normal marine environment.

All the microfacies, except those of core 7, indicate a quiet marine environment of deposition (mud, thin bedding) and have been apparently deposited on a continental shelf (Pteropods and Trilobites associated with Pelecypods).

B - MIDDLE KENOGAMI FORMATION from 423' to 936' (cores 10 to 14)

The middle Kenogami Formation is mainly characterized by red and green shales, silts, with nodules and gypsum beds. The clay fraction includes illite and few chlorite This formation was apparently deposited in an environment with salinity lower or equal to that of an open sea This formation reminds the Wealdiar of Europ and may represent a wedging facies of an evaporitic sequence.

C - LOWER KENOGAMI FORMATION from 936' to 1076' (cores 15 and 16)

This formation consists of bedded dolomicrosparites (core 15), including anhydrite and gypsum, and rarely contains intraclasts or dolomicritic nodules.

The occurrence of sepiolite (magnesian argillaceous mineral) indicates chemical deposition in a quiet, warm and shallow water, apparently near a perireefoid area.

D - ATTAWAPISKAT FORMATION from 1076' to 1291' (cores 17 to 27)

The microfacies of this formation is as follows (in descending order)

1 - Micrites and/or intramicrites, in the uppermost part of this formation, sometimes dolomitized, including rare Pelecypods, Crinoids, Ostracodes fragments and very rare Amphipores.

2 - Microsparites slightly dolomitized, with bird-eyes facies (e.g. in core 18) and very rare microfossils such as Crinoids, Pelecypods and "Stromatactis" ?

3 - Gravelly microsparites with intraclasts (core 19 to 21). The characteristic fossils are Amphipores (occasionally abundant at the upper part of this interval) and Stromatopores appearing near the base of this interval, some rare Corals, Crinoids, Pelecypods, Gastropods and Ostracodes fragments also occur in this interval (cores 19-21).

4 - Toward the base of this formation (cores 22 to 27) there appear pellety micrites and pelbiomicrosparites ("facies grumeleux") with some intraclasts. The fossils consist of Stromatopores, rare Stroma tactis ?, tabulate Corals, Crinoids (occasionally abundant), Pelecypods, very rare Gastropods, Ostracodes, and Algal fragments (Solenopora).

The occurrence of Stromatopores, tabulate Corals and allied fauna at the base of Attawapiskat Formation suggest a reefal environment of deposition. However, the upper part of this formation seems to have been deposited in a sublagoonal environment as indicated by

. the great development of Amphipores,
the marked decrease of the Coral's frequency,
the occurrence of bird-eyes facies (core 18)

E - KASKATTAMA FORMATION from 1291' to 1884' (cores 28 to 49)

This formation consists mainly of calcareous sediments which become dolomitic at its both upper and lower parts. Illite has been found to be the principal mineral occurring in the clay contents of these rocks and sepiolite was found in core 34.

The fossils consist of Crinoids, Pelecypods, Gastropods and Trilobite fragments, rare carving organisms, fragments of Bryozoa, Favosites Stromatopores, dendritic Stromatopores, some Amphipores, rare solitary Corals and very rare Algae.

The following microfacies (in ascending order) has been recognized

1 - Slightly streaked, laminated ("rubané") micrites and dolomicrites apparently azoic and containing some anhydritic thin intercalations.

2 - Gravelly microsparites and intramicrosparites with abundant fossils.

3 - Pseudo-ooid micrites including very rare fossils

These types of microfacies are considered to belong to a sequence which in this formation recurs rythmically Each of these sequences seems to indicate irregular pulsations leading to a slight deepening of this area while still remaining in shallow quiet water environment.

Locally restricted conditions probably prevailed during the deposition of the upper and lower parts of this formation, indicating lagoonal environments or the proximity of reefal accumulations. However, the middle part of this formation was apparently deposited in normal marine environment (The low boron content of core 34 is related to the sepiolitic clay fraction)

F - PORT NELSON FORMATION from 1884' to 2191' (cores 49 to 63)

This formation is mainly dolomitic containing anhydrite throughout (sticks, nodules and very thin beds) and contains the following microfacies

1 - Streaked, laminated micrite ("rubanée") and algal dolomicrite (Spongiostromata)(cores 49-50) predominate at the top of this formation (cores 49 to 51) The fossils are very scattered and contain Pelecypods, Gastropoos, Crinoids and very rare Corals fragments (cores 50 - 51).

2 - Dolomicrosparites and gravelly dolomicrites with rare fossil fragments such as Thamnopora, Pelecypods, Ostracodes (cores 52 to 54).

3 - Irregular alternations of gravelly micrites and dolomicrosparites with dolomicrites to dolomicrosparites including distorded gravels and intraclasts (cores 55 to 63).

The fauna is represented by Pelecypods, Crinoids, Ostracodes, **very** rare Trilobite fragments, rare Bryozoa (Felopora), very rare Thamnopora, solitary Coral fragments, and rare silicified Porifera spicules.

It is to be noted that all the dolomites observed in this formation were found to be more or less porous and that the organic matter was mostly represented in the shales.

This formation which is essentially dolomitic seems to be have been deposited in a slightly restricted environment with some deposits of a more open sea environment

In these carbonates the clay content is composed of illite.

G - <u>RED HEAD RAPIDS FORMATION</u> from 2191' to 2371' (cores 63 to 72)

This formation may be subdivided as follows

1 - <u>An upper part</u> from 2191' to 2301' (cores 63 to 69) this part is composed by dolomicrosparites sometimes laminated, streaked ("rubané") often gravelly and dolomicrosparites with intraclasts. The gravels are distorded and stretched out while the intraclasts are elongated and lie parallel to the bedding plane.

2 - <u>A lower part</u> from 2301' to 2371' (cores 69 to 72) this part consists of gravelly and pelletoidal microsparites at its top and pellety or gravelly micrites at its base

The fossils are more abundant than those of the upper part and consists of crinoidal fragments, Pelecypods, Bryozoa, Gastropods, Trilobites, Ostracodes, Dasycladacean algae which occur abundantly in limestones at about 2317' depth.

Mainly dolomitic, this formation was apparently deposited mostly in localy restricted environment with some deposits of a more open sea environment. The clay content is illitic.

H - CHASM CREEK FORMATION from 2371' to 2601' (cores 73 to 85)

This formation is characterized by

interterbedded limestones and dolomites ,

chlorite which appears regularly in the clay fraction for the first time.

The microfacies of this formation are as follows (in descending order)

1 - From 2371' to 2394' Anhydritic in the upper part and Dolomitic with more or less abundant anhydrite in the lower part. Sometimes the dolomites contain gravels and ooids. The fossils are very rare and they consist of Pelecypod fragments.

2 - From 2394' to 2440' Gravelly and pellety micrites including patchy dolomicrosparites. The fossils are mainly Pelecypods and crinoidal fragments, Ostracodes and Porifera spicules.

Anhydrite is present but is very rare.

3 - From 2440' to 2601' Biomicrites with frequent fauna Pelecypods, Crinoids, Gastropods, Bryozoa, rare Corals, some Thamnopora, Trilobites, rare Tintinoids (2592') and sporadically abundant Dasycladacean algae (e.g. 2453' to 2456' and 2485' to 2496'). The latters may be considered as markers.

Anhydrite is very rare.

The depositional environment is less restricted than in Red Head Rapids Formation, and points to a rather normal marine environment at its base.

I - CAUTION CREEK FORMATION from 2601' to 2687' (cores 85 to 89)

The whole formation is composed of dolomicrosparites in which some intraclasts occur sporadically. Anhydrite is abundant (sticks, nodules and thin bands). Pelecypods, Gastropods and Ostracodes are found very rarely in this formation.

The sediments seem to indicate a lagoonal to sublagoonal environment of deposition. This is espacially so in core 86 where the boron content is particulary high.

J - PORTAGE CHUTE FORMATION from 2687' to 2912' (cores 89 to upper part of the core 104)

This formation is subdivided as follows

1 - From 2687' to 2900' (cores 89 to 103)

This interval consists of dolomitic and slightly dolomitic limestones with chlorite and illite in the clay fraction. The microfacies are composed of biomicrites, which are sometimes dolomitized. Few epigenic silica occurs in nodules or in shell fragments. Anhydrite is very rare.

The fauna is mainly composed of Crinoids (abundant), Pelecypods, Gastropods, Trilobites (sometimes abundant), Ostracodes, Corals (very rare) and algal fragments (Dasycladacae).

The upper part of this interval is believed to have been deposited in a more or less marine environment, while the lower part, belongs apparently either to a more locally restricted environment, or to a near shore environment.

2 - From 2900' to 2912' (upper part of the core 104)

Three main lithologic facies can be recognized in this lower part

a/ - silty and sandy shales (2902' and 2903') containing about 20 to 40 % sands Potassic feldspars are present but not abundant. The clay fraction includes illite, chlorite and kaolinite The occurrence of the latter mineral suggests the formation of laterite in a nearly emerged land.

b/ - argillaceous and siliceous limestones (2905'6" and 2907'6")

c/ - sandy shale **slightly** feldspatic (2908') and argillaceous sand (2910') with illite and chlorite.

The boron content in the all over mentioned facies is higher that of an environment characterizing a normal marine deposit, hence indicate restricted conditions of deposition

K - BASEMENT from 2912' to 2941' (Lower part of the core 104 to core 107)

The basement of Kaskattama bore I consists of granitic rocks, biotitic Oligoclase, Orthoclase-microcline granite showing sometimes metamorphic features, and basic segregations in which appears hornblende (Actinolite) and more basic feldspar (Andesine).

2 - DISTRIBUTION OF ISOLATED MICROFOSSILS

The distribution of microfossils in the Kaskattama core I is the following (in descending order)

1 - Abitibi Formation (cores 1 to 9)

In the upper part of this formation (cores 1 to 6) the Conodonts occur down to core 6, and then disappear in core 7 probably as a consequence of the locally restricted environment.

2 - Middle Kenogami Formation (cores 10 to 14)

The occurrence of rare Spores and Scolecodonts and the absence of Conodonts and Ostracodes, are the main characteristic features in this formation.

3 - Lower Kenogami Formation (cores 15 and 16)

This formation is characterized by the occurrence of large Ostracodes and the absence of palynoplanktonic fossils, Conodonts or any Ostracodes of normal size

4 - Attawapiskatt Formation (cores 17 to 27)

In Attawapiskatt Formation there are very few microfossils such as Chitinozoa, Acritarchs and Spores. The Conodonts are only found in one level 1172' (core 23).

5 - Kaskattama Formation (cores 28 to 49)

The distribution and frequency of microfossils allow to subdivide this formation into the following parts (in ascending order)

a/ - a lower part (cores 49 to 36)

. occurrence of Chitinozoa, Acritarchs and Scolecodonts (the Scolecodonts are frequent in cores 37 and 40) ,

. occurrence of Conodonts (abundant between cores 42 and 49) and of large Ostracodes which may indicate the irregular pulsations interpreted for this interval

b/ - a middle part (cores 35 to 32), characterized by very rare Acritarchs, Scolecodonts and Conodonts, and the relatively constant occurrence of large Ostracodes.

c/ - an upper part (cores 31 to 28)

. occurrence of Chitinozoa, Acritarchs and Scolecodonts (the Scolecodonts are frequent in cores 30 and 28) ,

occurrence of Conodonts in core 30 and large Ostracodes in cores 31 and 28.

6 - Port Nelson Formation (cores 49 to 63)

Microfossils frequency curve shows the possibility of two parts (in ascending order)

a/ - a lower part (cores 56 to 63)

Few to frequent Chitinozoa, many Acritarchs and Scolecodonts. The Conodonts are rare while the Ostracodes of "normal size" are abundant and the large Ostracodes are also present.

b/ - an upper part (cores 55 to 49)

There are few Acritarchs ("Tasmanacées") and very rare Scolecodonts in this upper part. We observed rythmical alternations between levels with many Conodonts and levels with few Conodonts. The large Ostracodes also occur in this part.

7 - Red Head Rapids Formation (cores 63 to 72)

Rythmical oscillations are observed in the occurrence of the Chitinozoa, Acritarchs, and Scolecodonts (Scolecodonts are abundant in core 65). The Conodonts are present in cores 71 and 72 (Remark a level with abundant Conodonts in core 71). Above core 71 Conodonts are less frequent Ostracodes are absent.

8 - Chasm Creek Formation . (cores 73 to 85)

Frequent to abundant Chitinozoa, Acritarchs, and Scolecodonts becoming fewer in the upper part of this formation.

The Conodonts frequency curve, (with its maximum corresponding to core 83), decreases from bottom to top of the formation An exceptional frequency of Conodonts is observed in core 76. We note a rather complete absence of large Ostracodes and the occurrence of relatively abundant phosphatic fragments.

9 - Caution Creek Formation (cores 85 to 89)

The Acritarchs are very rare, frequent occurrence of large Ostracodes and few Ostracodes of normal size.

10 - Portage Chute Formation . (cores 89 to 103)

A relatively high frequency of the Chitinozoa, Acritarchs and Scolecodonts is observed in this formation. There is a constant occurrence of Conodonts and a maximum frequency in the middle part of this formation (cores 93 to 97) while the large Ostracodes are absent. Occurrence of relatively abundant phosphatic fragments throughout this formation.

PART II Biostratigraphy

Tables 2 to 6

1 - Conodonts and Ostracodes

2 - Palynoplanktology

3 - Conclusions

1 - On the Conodonts and Ostracodes studies

INTRODUCTION -

This report deals with the results obtained from the examination of about

- 270 samples treated with monochloracetic or formic acid (sediment examined, too, before treatment)
- 15 samples washed with H_2O_2, and,
- 135 core fragments

A fairly good number of microfossils have been thus obtained (Conodonts, Ostracods, Tentaculita, phosphatic elements of organisms and others), and afforded the elaboration of a biostratigraphy and useful data for a further interpretation of the environment of deposition

BIOSTRATIGRAPHY -

The Conodonts appear to be the predominate extracted microfauna in this bore hole Indeed, they provided the main bio and chronostratigraphic data Less so important was the occurrence of Ostracoda

1 - / Ordovician /

a) Conodonts

Three bio-zones have been recognized within the Ordovician on the basis of the relatively frequent Conodonts These Corodonts indicate ages in close agreement with those suggested by the BANFF's geologists.

Conodont bio-zone "Ocl" (from 2908' to 2708')

This bio-zone corresponds to the Portage Chute Fm The occurring Conodonts indicate that the age of "Ocl" interval coevals a post-

Canadian age Indeed, the lack of Conodonts such as those belonging to the genus Chirognathus could confer to it a rather late Mohawkian age

The samples between 2702' and 2620 (Caution Creek Fm , "Edenian") did not react to the acid so that it was not possible to obtain Conodonts from this interv l (where, besides, they are most probably not represented)

Conodont bio-zone "Oc2" (2602' to 2448')

This bio-zone is equivalent to the lower and middle parts of the Chasm Creek Fm

The "Oc2" bio-zone is further subdivided into

"Oc2 a" (2602') which is characterized by the first appearance of probably uppermost Middle to Lower Upper Ordovician Conodonts

"Oc2 b" (2569'-2448') having an apparently Maysville age, assumed on the basis of

a Ambalodus - Amorphognathus group of Trenton to Richmond age (Arnheim)

b Cordylodus cf C robustus, known from the Wyoming and Manitoba's late Ordovician (Stony Mountains & Shamattawa Fms), and,

c Plegagnathus nelsoni and P dartoni known from the Stony Mountains, Shamattawa and Upper Bighorn Fms

Conodont bio-zone "Oc3" (2431' - 2257')

A sharp limit is characterized by the appearance of Conodonts, the age of which corresponds to the Upper part of the Chasm Creek Fm , and to the lower to middle parts of the Red Head Fm The Conodont association which contains forms from Rhipidognathus and Aphelognathus group, allow to correlate the interval between 2431' and 2343' with the Richmond of Kentucky and Indiana, while the overlying interval (up to 2257') may have the same age or an uppermost Ordovician age

b) Ostracodes

Though relatively rare in the Ordovician, the Ostracodes characterize the following bio-zone

Ostracode bio-zone "Oo1" (2646' - 2631')

which corresponds to the Caution Creek Fm and is defined by the occurrence of 2 indeterminate species

	Böhmen	Graptol Z n Ellis & Wood	Bezugsproben	Conodonten-Zonen	Conod Stufen	Co Bereiche Walliser 1962
Gedinne	eγ		Ockerige Kalke der Huing hauser Sch *M uniformis*	*woschmidti*	*steinhornensis*	VIII
	$e\beta_2$		*M transgrediens* *M bouceki*	*costein hornensis*		VII
				crispus	*crispus/ latialatus*	VI
			M ultimus	*latialatus*		
Ob Ludlow	$e\beta_1$		*M fritschi linearis*	*snajdri* Horiz *siluricus*	*Kockelella*	V
M Ludlow		36		*ploeckensis*		
Unt Ludlow		34/35	*M chimaera*	*crassa*		
		33 32	*M nilssoni*	*sagitta*		IV
Wenlock	eα	31	(*M testis*)	*patula*		
		26		*amorphognathoides*	*Apsidognathus*	III
Valent		25	(24) (23)	*celloni*		II
		16		Bereich I	Bereich I	I

Abb 10 Statigraphische und chronologische Daten

2 - / Ordovician/Silurian transition and Silurian /

The Ostracodes, though usually badly preserved, were used for bio-zonation within the Ordovician/Silurian passage and in the Silurian they were found to be more reliable than those rarely occurring in the underlying levels. On the other hand, the Conodonts are rather rare but afford a more or less precise dating on the basis of the European Stratigraphy (cf WALLISER, 1964, opposite fig 10 in "Conodonten des Silurs"). Generally the stratigraphical results obtained from the microfaunal studies, correspond with those obtained by the BANFF's geologists. It is to be noted that

(1) Our results are still not sufficiently precise in connection to the Ordovician/Silurian passage

(2) They indicate ages of some levels of Kaskattama Fm., and tend to include the Silurian/Devonian limit in an upper part of this formation (see "bio-zone $S_{c}6$", below)

A/ Ordovician/Silurian passage

- between 2034' and 2252' the scarcity of Conodonts and their bad state of preservation did not allow a precise age determination
- between 2160' and 2036' occurrence of rather abundant Ostracodes which, however, being badly preserved, cannot help for precise dating
- considering mainly the Conodonts, one may note (in ascending order), the occurrence of

a Specimens of doubtfull Silurian affinities between 2186 and 2101'

b Specimens with very probable Silurian affinities at 2093'

c Specimens of Silurian age starting from 2029'

B/ Ostracod bio-zone "O/Sol" (2160'-2036')

It seems possible to distinguish three units within this bio-zone. However one cannot be sure about their reliability since most of the occurring Ostracodes are in a fragmentary state (2160'-2155', 2109'-2092', 2036')

C/ Conodont bio-zones $S_{c}1$, $S_{c}2$ and $S_{c}3$ (2029' - 1739')

These bio-zones are based on the distribution of the Conodonts. Their specific identification being rather difficult, it should be kept in mind that these bio-zones and their datings are only provisionnaly established and tentatively suggested

Conodont bio-zone "S_{c1}" (2029' - 1936')

Mainly based on the occurrence of broken specimens related to "Spathognathodus pennatus/Pterospathodus amorphognathoides" group (of late Valentian to early Wenlock age)

Conodont bio-zone "S_{c2}" (1936'-1847')

The occurrence of Lonchodina walliseri associated with Ligonodina silurica, Ozarkodina aff edithae suggests an age probably equivalent to the "sagitta-zone *", corresponding to the passage Wenlock-Ludlow (the same dating may be extended to the interval between 1988' and 1936')

Conodont bio-zone "S_{c3}" (1845' - 1799')

This bio-zone is characterized by the dissapearance of some types of the "$S_{c}2$" bio-zone and by its intermediate position between the latter and the "$S_{c}4$" bio-zone One may suggest it as being eventually corresponding to the "crassa-zone"

D/ Conodont bio-zone "S_{c4}" (1795' - 1736')

On the basis of Kockelella variabilis and Lonchodina detorta, one may surely attribute to this bio-zone an "Upper Middle-Ludlow to Lower (?) Upper-Ludlow" age, corresponding to the European "siluricus-zone"

E/ Conodont bio-zone S_{c5}" (1617' - 1618')

A "Silurian/Devonian passage" age can be attributed to this S_{c5} bio-zone which corresponds to the "latialatus ?/crispus/eosteinhornensis zones" (e beta 2), on the basis of form related to Plectospathodus flexuosus, and Lonchodina detorta

F/ Conodont bio-zone S_{c6} (1349 - 1341')

In this bio-zone occurs Ozarkodina cf O typica denckmanni ("eosteinhornensis/woschmidti zone", Silurian-Devonian transition /Gedinnian) (Upper beta 2 - e gamma)

It is to be noted that the limit between Silurian to Devonian is not well defined on a world-wide basis (cf fig 10 of Walliser) thus leading to attribute either an Upper Silurian, or a basal Devonian age to both "S_{c5}" and "S_{c6}" bio-zones Moreover, the Attawapiskat and Kenogami Fms are considered to be of Silurian age in North-America, but their definite correlation with Europe is not yet established therefore, it is still questionable whether these formations are synchronous with the Silurian or with the basal Devonian

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* zone in the sense of German authors (cf fig 10)

G/ Ostracode levels S_{o2} and S/D_{o1}

Two levels at 1500' (S_{o2}) and at 1313' (S/D_{o1}) can be considered as markers due to the first appearance of some characteristic Ostracodes although badly preserved

3 - / Devonian /

a) Bio-zone D_{o1} (93' - 399')

In a previous note on Kaskattama bore I (cf R/ST n° 18879 issued 17/11/66), we attributed a" surely Emsian-Frasnian, probably Eifelian age for the interval between 102' to 399' (Conodonts Polygnathus linguiformis, Oneotodus ? K 351 , Styliolines) This dating is furthermore confirmed by this study and may be extended to include the interval 93' to 399 Moreover, these conclusions are corroborated by the presence of Semitextularia cf S thomasi (Foraminifera) at 93'-95' the type species is known from the European Eifelian, Givetiar and Upper Devonian, and, as far as we know, at least from the Frasnian of North America (Cerro Gordo Fm)

b) Remarks

The "per descensum" ? occurrence of indetermined Devonian species (2252' and 2271') and Upper Devonian species (containing Palmatolepis subrecta, 2273' and Palmatolepis sp ,2717') within the Ordovician of Kaskattama bore I, seems to indicate the actual or former occurrence of a lower Late-Devonian (to I one beta-gamma-to I delta) in the Kaskattama region

2 - On the Palynoplanktological studies

INTRODUCTION -

101 samples provided from Kaskattama bore 1 (cores n° 5 to n° 107) have been examined at about a mean-sample for each core The method used for this study was our usual chemical one (HCl, HF, HCl) The limestones and dolomites needed about 200 to 300 gr per sample

At least 3/4 of the residues were found to contain various palynoplanktonic microfossils These are mainly the following ,

- Chitinozoa (Cz)
- Acritarchs (Hy)
- Scolecodonts ("Denticulates" D)
- Spores (Sr), and,
- Primitive Algae

These associations have been used for stratigraphic (cf part II) as well as paleogeographic interpretations (cf part I, environment of deposition) Furthermore, an essay to evaluate the oil potential by the use of palynological technic (PA/C-H and MV) has been applied jointly with those of geochemical methods (cf part III)

REMARKS CONCERNING THE DIFFERENT GROUPS OF MICROORGANISMS -

1 - Chitinozoa

The Chitinozoa have been particularly looked for and were found to be represented in many levels between cores n° 24 and 103 Their greatest increase is observed between cores 76 and 103 (cf table 2) Moreover, their excellent state of preservation allowed precise identifications

From 56 types recognized, 31 were found to be new

2 - Acritarchs

This group was examined in the normal palynological slices and was found to be rather constantly distributed from cores 5 to 103 However, it may vary qualitatively and quantitatively, thus

- between core n° 28 and core n° 57, the occurring Acritarchs belong to the family TASMANACEA From core 59 to 60 and even to core 103, there is an increase in the type and family varieties From the whole material studied, 81 types were differenciated

- between core 5 and 27, the Acritarchs occur only sporadically and scarcely, then, between core 28 and 57 although constantly distributed, their amount vary greatly Between core 59 and 103 they are particularly well represented

The observed Acritarchs have usually a hyaline appearance and a faint yellow to clear brown colour They still show their membrane and fine processes However, they are often lacerated thus keeping from accurate identification an good photographing

3 - Scolecodonts

This group was up to now rarely used due to its scarcety and limited distributions However, the Scolecodonts are in this well the most abundant and diverse organic microfossils occurring between cores 28 and 103 51 types were recognized (excluding those which were found to be badly preserved)

4 - Spores

They are usually poor and occur only sporadically Moreover, their bad state of preservation allowed the recognition of only 11 types, the identification of which remains doubtful

5 - Algae

They are primitive algae, of which 4 main types can be recognized They occur almost throughout cores 77 to 103 One of these types seems to belong to the species Gloeocapsomorpha prisca

Almost all the above mentionned microfossils show some respond to the environnement of deposition, it seems that

a) the Chitinozoa are the most to be affected by marine ecology (depth, shore distance, salinity etc .) They are for instance the first to disappear under strong lagoonal conditions,

b) the Scolecodonts, less sensitive to these factors, may fairly well adapt themselves even to reef environments,

c) the Acritarchs develop different communities according to the various environmental types of deposition The Tasmanacea are the most important indicators of these environments

d) the Algae show particular life habitat (normal marine, or open shelf)

Despite these observations, a stratigraphical approach is attempted on the basis of palynoplanktological data The succeeding groups may witness for the biostratigraphic evolution

PALYNOSTRATIGRAPHY -

1 - Method used

First we tried to apply our usual method viz, that of the "maximum relative stratigraphical ranges" (cf VAN OYEN, 1964 *) For this purpose, we used our own terminology (S N P A , numerical types) In fact, most of these types were familiar to us and are well known Ordovician and Devonian microfossils

The various types in each sample have been thus recorded for each group A distribution chart has been prepared and each level has been determined according to the palynological units previously established for the Paleozoic (C R P , S N P A)

Thus, unit "C_Z" stands for Chitinozoa, "Hy" for Acritarchs, "D" for the Denticulates and "Sr" for Spores In this way, it appeared relatively easy to identify the Ordovician, Silurian and Devonian microfossils However, it was difficult to do the same in connection with the formerly established units In fact, these were based on studies concerning distant areas such as those of the Sahara The already admitted distributions appeared not always to fit with the present results

Therefore, though using another method, we only kept the general fundamental principles of the 1st one (VAN OYEN, op cit) Then, we tried to reach a more detailed and sharper zonation in order to obtain better reliable means of correlation for futur practical purposes (e g the stratigraphic correlations in the region of Hudson Bay)

Thus, a number of biozones have been established for each group of organic microfossils from Kaskattama bore I They were based on morphologically defined and numerically classified types These biozones are either delimited by types having stratigraphically restricted ranges, or by the overlapping ranges of at least two types (cf tables 5 and 6)

* F H VAN OYEN La Palynologie stratigraphique dans le cadre de la stratigraphie paléontologique Revue I F P - Vol XIX n° 2 - Février 1964

2 - Biozones and intervals

For each of the recognized groups, we selected the types of microfossils which are the most characteristic Being easily recognizable and/or of relatively restricted distribution, they are well-known in the palynological litterature, and were previously considered by us as stratigraphic "markers" in other regions Hence, according to their relative occurrences, we were able to establish six main biozones (cf table 6, concerning the fundamental types, and the biostratigraphical chart table 2, part PA) They are, from bottom upwards, as follows

Biozone I (Kaskattama 1, c 103 to c 90)

Mainly represented by Chitinozoa, they contain

- Sphaerochitina pilosa (C_z 189)
- Angochitina oklahomensis (C_z 304)
- Conochitina cretacea (C_z 317)

and - Conochitina micracantha micracantha (C_z 318)

This biozone, can be apparently subdivided into the following intervals

I A - (Kaskattama 1, c 103 to c 97)

Characterized by the occurrence of

- Chitinozoa

Lagenochitina tuifayersis (C_z 320)

- Acritarchs

Leiofusa aff pumilla (Hy 149)
and/or Verynachium sp (Hy 301)
Baltisphaeridium multipilosum (Hy 320)

- Scolecodonts

Paleoenonites armigirus (D 120)

I B - (Kaskattama 1, c 97 to c 90) ,

Mainly distinguished by the occurrence of

- Chitinozoa

Lagenochitina cf sphaerocephala (C_z 303)

and by the appearance of

Cyathochitina calix (C_z 35)
and Conochitina micracantha robusta (C_z 316)

- Acritarchs

	Veryhachium	sp	(Hy 113)
and/or	Veryhachium	sp	(Hy 183)
	Leiofusa	sp	(Hy 296)

Biozone II (Kaskattama 1, c 90 to c 79)

For the time being, this biozone is mainly characterized by the occurrence of

- Chitinozoa

Restricted types

Cyathochitina kuckersiana (C_z 184)
Hercochitina crickmayi (C_z 312)

appearance of

Ancyrochitina sp (C_z 324)

- Acritarchs

occurrence of

Leiofusa cf estrecha (Hy 11)
and/or Leiofusa filifera (Hy 14)

- Scolecodonts

overlapping ranges of

Eunicites denticulatus (D 5)
and Leodicites arquatus (D 23)

Biozone III (Kaskattama 1, c 79 to c 59)

Characterized, particularly, for the Chitinozoa by the restricted type Mirachitina quadrupedis (C_z 309) and by the overlapping ranges of Ancyrochitina ancyrea and Conochitina pachycephala (C_z 136)

It seems also possible to subdivide this biozone into the two following intervals

III A - (Kaskattame 1, c 79 to c 69)

Recognizable by the three following groups

- Chitinozoa

By the overlapping ranges of

Ancyrochitina ancyrea (C_Z 135) and
Conochitina micracantha capitata (C_Z 315)

- Acritarchs

By the overlapping ranges of

Polygonium sp (Hy 197) and/or
Veryhachium sp (Hy 318)
with Cymatiosphaera (?) sp (Hy 262) and/or Hy 321

- Scolecodonts

The occurrence of

Arabellites doutti (D 77) and/or
Oenonites crepitus var 1 (D 85)

III B - (Kaskattame 1, c 69 to c 59)

Characterized by the following selected microfossils

- Acritarchs

Overlapping ranges of

Navifusa sp (Hy 57) and/or
Polygonium sp (Hy 71)
with Hy 157

- Scolecodonts

Overlapping ranges of

D 15 - 215/D 97 - 193

BIOZONE IV - (Kaskattama 1, c 59 to C 43)

This biozone is mainly characterized by an Acritarchian "Guide fossil" viz , Leiofusa striatifera (Hy 89), which is a well known fossil Some other less characteristic types may also be associated such as Hy 139, Hy 175, Hy 235 and Hy 3_6

BIOZONE V - (Kaskattama 1, c 42 to c 24)

This biozone is delimited by the range of the Chitinozoa Sphaerochitina cf fenestrata (Cz 323) It is subdivided furthermore into the following intervals

V A - (Kaskattama 1, c 42 to c 28)

This interval contains Acritarch Hy 232, and the Scolecodont Nereidavus invisibilis var 3 (D 67)

V B - (c 27 to c 24) is a rather negative interval

BIOZONE VI - (Kaskattama 1, 925' to c 5)

Mainly characterized by the occurrence of Spores, this biozone is recognisable by the following

- Acritarchs

  Duvernaysphaer tessela (Hy 22) and/or

  Polyedrixium (?) octoaster (Hy 167)

- Spores

  Convolutispora aff crassa

3 - Chronostratigraphical interpretations

An attempt is made to correlate the previously defined "Pa Biozones" of Kaskattama 1, with the internationally established chronostratigraphy This attempt was reached at, on the one hand, on the basis of the known pal noplanktological litterature, and on the other hand, on the basis of our own experience on the Paleozoic

Thus, we may suggest the following ages for each of our biozones

Kaskatuama 1 Biozones	PA suggested Ages
VI	"Middle to upper Devonian"
Va IV	"Silurian"
III II	"Caradocian"
I	"Upper Llandeilian"

These interpretations refer mainly to north America, England, Baltic and the Sahara

4 - Remarks

a) On the stratigraphical methods used

When a local zonation is to be established, we usually start by identifying a number of various subdivisions As a first step, this process is called "The provisional primary subdivision" This is the case of what has been done for the zonation of Kaskatuama bore I Furthermore, in order to reach a more advanced and accurate subdivision, i e , a subdivision into units of practical value, it is fundamental to compare with at least two other bore holes having the same stratigraphic sequences

In this way, "the provisional primary subdivision" is compared with that of the third bore so as to avoid mis interpretation which may be due to any eventual unwedging of the various units studied So much so, aiming to avoid such misleading results, we tried the best we can, to select within each group, the types of microfossils which seem to be the best representatives of these units

Anyhow, it should be kept in mind that, owing to the fact that this study is based nothing but on a single bore hole, the herein suggested biozones should be considered as only provisional subdivisions.

b) Ranges of microfossils

The stratigraphic ranges of some types of the groups of Chitinozoa, Acritarchs and Scolecodonts as observed in Kaskattama bore I, do not correspond exactly with their formerly known ranges, e g , typical Devonian types are here observed in the Ordovician This may be either due to different stratigraphic range, or to some kind of 'displacement" of the microfossils Anyway, this means that one should be very careful when dealing with stratigraphic interpretations

c) On the environment of deposition

As mentioned earlier, the studied microfossils are more or less affected by the various environmental factors inasmuch as in this case, the environments of deposition indicate a rather unusual and varied facies, often changing in time and space

These facts may just add to the problems, which may be met with, in attempting any other stratigraphic correlations

3 - Conclusions

The chronostratigraphic conclusions based on the Ostracodes and Conodonts on the one hand, and palynoplanktological studies, on the other, seem to be both in agreement. Thus, rocks of "Middle Ordovician", "Upper Ordovician", Silurian-Devonian", and "Devonian" were successively dated. The following is a summary of the final results in connection with the chronostratigraphic boundaries adopted.

1 - Middle Ordovician - From 2900' to 2709'

Both methods attribute the upper boundary of the middle Ordovician at 2709'.

2 - Upper Ordovician - From 2689' to 2095'

An Upper Ordovician age was attributed for this interval by the 2 methods. The isolated microfauna seem to point to Silurian at 2186'. The Conodonts are rare between 2136 and 2029', and are generally not well known from litterature related to the Ordovician/Silurian passage. Therefore, it is the palynoplanktological Ord./Silur. boundary which is retained.

3 - From 2095' to 2029' -

Precise dating not yet established, although some good Silurian indications are given from 2076' mainly by Acritarchs.

4 - Silurian 2029' - 1781' -

Both methods lead to the same conclusion.

5 - Silurian and/or Devonian from 1761' to 1294'

The microfauna in this interval is composed of

A/ Conodonts which point to

a) [illegible] 2 age considered as Up. Ludlow to Gedinnian for the level 1617' (according to G. H. Walliser scale, cf. fig. 10).

b) Upper beta 2 to gamma (gamma corresponds to Givetian according to Wallisor op. cit.) t 1349'.

B/ Palynoplanktons of Silurian affinities

These results allow to attribute a Silurian and/or Devonian age to this 1761' to 1294' interval

6 - From 1294' to 925'-

This interval may be considered as "blind", since it only contains very rare fossils of no diagnostic value

7 - Middle Devonian - From 925' to 93'

This age attribution is only based on palynoplanktons

The upper boundary of the Devonian (93') is based on Conodonts a surely Emsian to Frasnian age, apparently Eifelian age, may be attributed Hence, the whole recognized Devonian seems to be "Middle Devonian"

It appears from these studies that the chronostratigraphy of the studied suquences as established by our methods (MD & PA) are in close agreement with that proposed by the BANFF's oil geologists. However, we tend, to assign a zone of transition "Silur /Devon " from 1617 to 1294' and a true Devonian at 925'

PART III Organic mätter and hydrocarbons potential

1 - Properties of the microscopically observable organic matter

2 - Geochemistry of trace elements and organic matter

3 - Maturity of the organic matter

3a - Palynological study of the degree of carbonization (MV)

33o - Geochemical measurement of degree of coalification

1 - Properties of the microscopically observable organic matter

Study on the "Organic medium" (PA/C - H)

It should be kept in mind that the aim of this palynological study is only to show the qualitative properties of the organic matter, and that it would be hazardous to draw any conclusion without taking into consideration, at least, the quantitative criteria

THE "ORGANIC MEDIUM" - DEFINITION

In palynology, the organic residues, obtained from sediments devoid of their mineral contents (by chemical attack) consist of organic microfossils (Chitinozoa, Acritarchs, Scolécodonts, Spores etc...) and of diffused organic matter The latter constitute the largest part of the residues (about 8 to 9/10 th) and is microscopically easily distinguishable.

It is a common use that we classify the organic matter into morphologically defined categories The main types are the

- "MOL", which stands for the "Lignine Organic Matter", the
- "MCT", for the tracheids, the
- "MOC", for the 'Colloidal Organic Matter", and the
- "MOV", for 'Vascular (or cellular) Organic Matter"

The organic elements of each microscopically examined sample are approximately evaluated both for microfossils and diffused organic matter content

Based on these data, as well as on many observations, and on the published oil genesis hypothesis (Tissot, Crejci-Graf) we emperically established, an "Organic units" system, which we applied for the Kaskattama bore I samples

From this system, we may deduce that

1 - The "I ' Units, defined by the predominance of lignine elements (MOL and/or MOL), reflect a phenomenon of considerable sedimentary feeding of continental origine. We attribute the "I' units to the "lignine Country" which can, theoretically and from a hydrocarbons viewpoints, become dry gas generators,

2 - The "III" units defined by the predominance of the "Fatty organic matter" (MOC and/or probably MOV), usually denote the proximity of a basin. These units are attributed to the "Fat Country' which is,

from a mother-rock viewpoint, rather good producer of humid gas or liquid hydrocarbons (becoming dry gaz in case of extreme maturity),

3 - The "II" units in which the previously mentioned organic matter categories may occur, reflect the presence of two different feeding sources. These "II" units were attributed to the "intermediate Country" which is, from an oil point of view , an interesting hinge zone. Indeed, if the occurring organic mixture already contains high amounts of MOC (limit considered from the II B), there would be chances to found mother and reservoir-rocks contiguously placed.

Remarks For each unit, the letter "A" indicates a tendency towards lignine-rich categories while the letter 'B" indicates a tendency towards the "fatty' categories

The symbols such as II_B - III_A, denote cases of double components mixing in ratios, which are at the limit of the two units.

RESULTS

The PA/C-H curve as represented in table 1 clearely shows the organic medium variations in Kaskattama bore I. The hatched part in the curve (II_B - III_B) particularely shows the "fat" tendency of the organic matter. Thus, the 'Fat country" appear to prevail all over the bore The "Fat Country' is composed of three main categories which seem to be responsible for this predominance viz, the MOC, the MOV and the primitive algae (to be related to MOC).

We think that it is useful to represent these differences in a separate manner in order to put emphasis on their relative importance, within the considered part.

The major organic sequences may be correlated with the lithologically defined formations as follows ,

Abitibi Fm.

Cores 5 and 6 = I = "Lignine Country"

Kenogami Fm.

Cores 9 to 17 = I - "Lignine Country"
(except cores 9 and 16)

Attawapiskat Fm

Cores 18 to 24 = I = 'Lignine Country"

Kaskattama Fm.

May be subdivided into

a) - Cores 28 to 39 = II/III = "Intermediate Country"/"Fat Country" alternatingly with MOC and MOV

The cores 34 and 35 are outstanding because the former is the unique to provide a sample belonging to the "Lignine country" in this sequence, whereas the latter is very rich in MOC

b) - Cores 40 and 49 = III = "Fat Country"

This is the only interval where the "Fat country", (caracterized by MOC), was determined in a continuous manner.

Fort Nelson Formation

Two intervals can be distinguished

a) - from cores 51 to 57 = III = "Fat Country" with MOC. This interval resembles that between cores 40 and 49 formerly mentioned.

b) - from cores 58 to 63 = III = "Fat country" but having various origin MOV, MOC and Algae.

Red Head Rapids Formation

Cores 64 to 72 II/II "Intermediate country/"Fat country", corresponding apparently to an alternating regime Upper part more "Fatty".

Chasm Creek Formation

Cores 75 to 85 = II/III = "Intermediate country"/"Fat country"

One can notice a considerable increase of primitive Algae (very rich in core 85) whereas in MOC they decrease Cores 80 and 81 mark an incursion of the "Lignine Country".

Caution Creek Fm

Cores 86 to 90 = II = "Intermediate Country" with primitive Algae MOC occurs in the last sequence.

Portage Chute Fm

Some levels (cores 91, 92, 103) can be individualized on the basis of the relative amounts of their components, the primitive Algae are here predominant Besides, cores 93 to 102 = II = "Intermediate Country" containing Algae

Therefore, it seems, on the basis of the results obtained from our analysis on the Kaskattama bore I material, that the following zones are the most important intervals (from the point of view of hydrocarbons) qualitatively considered These are in decreasing importance

1) Within Kaskattama Fm lower part (cores 40 to 49)
2) " Port Nelson Fm Upper part (cores 51 to 57)
3) " Read Head Rapids Fm Upper part (cores 63 to 67)

Indeed, these are the only zones containing colloidal organic matter (MOC) in a constant and good proportions In our actual knowledge this organic matter seems to be, by far, the most interesting component from hydrocarbons genesis viewpoint

The other zones, represented by the hatched parts in table 1, and comprized between our II_B and III_B units, though of lesser interest than the formers, are still be be taken into consideration in the optics of possible future investigations These zones, in fact contain MOV (probably cellulosic) and primitive Algae which can eventually give the MCC (Indeed some infra-red experiments indicate that similar transformations may occur) Therefore, should these zones be transformed elsewhere under favorable conditions, they would evolved probably into MOC zones, i e into equally valuable oil-prospecting intervals. The MOV material is, however, still not metamorphozed in Kaskattama core I sediments, the primitive Algae still showing their original structure

2 Geochemistry of trace-elements and organic matter

TRACE-ELEMENTS AND ORGANIC CARBON CONTENT OF THE FINE FRACTION OF SEDIMENTS

The ability of a sediment to preserve marine organic matter can be estimated by means of the trace-elements content Some metals, especially vanadium, nickel, molybdenum, copper, zinc and lead, which are concentrated in organisms by biological process and on organic matter by physico-chemical adsorption, are retained on the fine fraction of the deposits when sufficient reducing conditions prevail

The method consists in isolating the fine fraction (granulometry lower than five microns) of the insoluble residue following HCl treatment and determining trace-elements content by U V. spectrometry. All the values plotted on the log (plate 7) average at least two determinations

On the same fraction the organic carbon content is also measured The correlation between these results (trace-elements and organic carbon) is of great significance for the estimation of possibility for the sediment to preserve the marine organic matter

1) Abitibi River Formation

Moderate enrichments in molybdenum can been observed in cores # 7 and # 9 and copper in cores 3 and 7 but the highest concentrations in chalcophyl elements (Cu, Zn, Pb) appear in core # 9 The organic carbon (F F.) (1) is generally above 15 %

2) Middle Kenogami Formation

All the samples studied in these variegated silts and shales show very low concentrations in trace metals and organic carbon (F.F.) The depositional environment did not promote development nor conservation of organisms.

3) Lower Kenogami Formation

The presence of sepiolite in cores 15 and 16 brings out an environment of a shallow and warm sea where chemical precipitation can take place, probably in a lagoonal area Only one sample in the upper part of core 16 shows enrichments in copper and organic carbon (F F) and a moderate concentration in molybdenum

4) Attawapiskat Formation

In this reefoid formation the insoluble residue is practically non-existent The organic matter and its associated metals have not been preserved in that oxidizing facies (The slight concentration in lead might result from a diagenetic process)

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(1) F F = fine fraction (< 5 μ) of insoluble residue

5) Kaskattama Formation

The formation includes several levels showing enrichments in Ni, Mo, Cu and organic carbon (F F) The correlation between these elements and even, partly, with Zn and Pb is rather good, which involves, at least temporarily, the establishment of depositional conditions more favourable to the conservation of the marine organic matter

Nota The presence of sepiolite in two levels of core 34 explains the low concentrations in some metals and in boron

6) Port Nelson Formation

High organic carbon contents (F F.) are still present but the concentrations of Ni and Mo are much lower than in the preceeding formation One can only observe enrichments in copper and slight enrichments in lead The type of organic matter may be different from the one found in Kaskattama formation

7) Red Head Rapids Formation

An enrichment in copper, connected with a medium content in organic carbon must be noted in core 68 for which the depositional environment is less restricted than for the other samples taken in the formation. Core 67 shows enrichments in Zn and Pb (and slightly in Cu) but with a low organic carbon content (F.F.)

8) Chasm Creek Formation

Slight enrichments in nickel are observed in cores 75 and 78 which show also fairly high concentrations in copper in correlation with the organic carbon (F F) In the whole formation, vanadium content is slightly greater than in the preceeding formations but does not exceed the average usually found in such sediments

9) Caution Creek Formation

The only sample analysed indicates moderate enrichments in Ni, Mo and Pb

10) Portage Chute Formation

Upper part (cores 89 to 99) medium content in copper, zinc and organic carbon (F F) The enrichments in nickel (cores 95 and 97) without any correlation with Mo and Cu, are probably of detrital origin.

Lower part (cores 102 to 104) low concentrations in organic carbon and rather low in metals, especially molybdenum

11) In conclusion of the study of the fine fraction, it appears that the most favourable environments for the conservation of marine organic matter are located

a) Mainly in the Kaskattama formation as deducted from the existence of enrichments in Ni, Mo, Cu, Pb and organic carbon (F F) and a rather good correlation between these elements

b) In Port Nelson Formation and in some levels of Red Head Rapids, Chasm Creek, Caution Creek and the upper part of Portage Chute Formation according to organic carbon content and some enrichments in Cu Nevertheless, it must be pointed out that the molybdenum content is rather low even in the levels with notable concentrations of copper This may indicate that the organic matter is mainly of benthic rather than planctonic origin

c) In the lower parts of Abitibi and Lower Kenogami Formations (with the same remarks as above)

However, in spite of the type of facies, the concentrations are not very important for Ni and Mo and low for vanadium These results are probably the consequency of an insufficiently reducing environment

TRACE-ELEMENTS CONTENT OF THE TOTAL ROCK

Samples from cores 9, 16, 28, 31, 40, 46, 47, 53, 54, 60, 68, 75, 78 and 86 have been analysed for the trace-metals content of the total insoluble residue The results have been computed according to the percentage of insoluble residue to obtain the concentrations of Ni and Mo on the total rock

For all the samples analysed the values are very low (between 0 and 2 ppm) which confirm the lack of highly reducing conditions

ORGANIC MATTER

1 - Organic carbon content of the total rock

Twenty-eight samples, selected after the study of the fine fraction, have been analysed for their total organic carbon content The results are plotted on the log of table 7 In the carbonate facies the average carbon content is 0,17 %, which is a value relatively weak for such sediments The highest values are found in core 86 and mainly in the Kaskattama formation where they can reach 0,35 % (in a sepiolitic horizon of core 34)

2 - Soluble organic matter

Two successive extractions were made, the first one with ether and the second with the benzene-methanol (60-40) mixture. The results which are plotted on the log, and especially the ratio soluble organic matter/total organic matter, indicate that these soluble products are not the consequence of a migration but actually come from the original organic matter of the sediment.

Nota: in the sepiolitic part of core 34 the percentage of soluble extract is much higher than in the other facies but this particularity seems to be due to the properties of the clay fraction and very probably does not give a representative evaluation for this measurement in the whole section.

The composition of soluble organic matter after precipitation of asphaltenes is shown on the log. The ratio aromatic hydrocarbons/paraffinic hydrocarbons is generally lower than one, or slightly higher in core 68 (except for the very peculiar sepiolitic part of core 34).

3 - Adsorbed gases

On the same samples treated by organic solvants, a chromatographic analysis has been carried out for the gases desorbed from the rock by HCl treatment and heating. The percentages of light hydrocarbons (methane to pentane) are presented on the next table.

ADSORBED GASES

Cores	C_1	C_2	C_3	iC_4	nC_4	Butene 1	iC_5	nC_5
16	89,47	4,77	1,24	1,82	1,42	0,18	0,80	0,29
31	79,88	11,73	3,75	1,32	1,21	0,18	1,40	0,51
34 (1502'8")	83,80	9,04	2,86	1,44	0,99	0,03	1,52	0,32
34 (1509')	77,95	12,86	3,79	1,86	1,18		1,86	0,50
35	68,83	14,17	5,49	4,32	2,05		4,62	0,52
40	75,57	13,79	5,49	2,64	2,51	non identified		
47	71,25	11,98	6,02	3,52	2,61		3,58	1,03
53	81,11	8,11	3,42	2,03	1,65	0,13	3,04	0,51
68	86,88	7,97	2,51	0,96	0,64		0,84	0,19
78	76,48	11,92	4,44	2,49	1,57	0,05	2,55	0,49
86	83,40	9,09	3,08	1,42	0,99	0,34	1,19	0,48
99	80,48	10,73	3,56	1,48	1,37	0,07	1,73	0,57

The composition of the gases and especially the ratio methane/higher hydrocarbons, generally lower than 8, indicates that the products which might be generated would contain a fair proportion of liquid hydrocarbons

4 - In conclusion, these analyses have shown that the organic material is mainly of marine origin according to the constitution of its soluble fraction and might be able to generate liquid hydrocarbons (or gases with condensate)

Nevertheless, the percentages of organic matter appear too low, except in some levels, to characterize good source-rocks These low contents are probably the consequences of an insufficiently reducing environment which might become more favourable in a less near-shore area.

3 - Maturity of the organic matter

A - PALYNOLOGICAL STUDY OF THE DEGREE OF CARBONIZATION (MV)

1 - Definition and measurements properties

According to specialized literature (cf Gutjarr[x], Correia [xx]), the palynological material appears to be one of the greatest sensitive witness of "metamorphism" (s 1 temperature, pressure, contact,.) and reflects with high precision the degree of organic matter evolution associated to it

An attempt to evaluate the degree of carbonization of the organic microfossils was tried by physical methods Thus 'luminosity" measurements (expressed in µA) were made on some groups of microorganisms These measurements were usually made on smooth spores However, in Kaskattama bore I material where these spores are lacking, we used the Tasmanacea (Acritarchs) which display close similarity with the physical characteristics of the smooth Spores and behave the same way in respond to carbonization phenomenon

About ten measurements were taken for each sample , their arithmetical averages characterize the studied level

Based on the "carbon ratio" scale values, we distinguish 3 main groups which we named "immature", "mature" and "senile" The measurements made for the Kaskattama bore I can be considered as accurate since they were rather numerous and were made on a constant material (Tasmanacea) Therefore, the averages thus for obtained, should correspond fairly well with the degree of organic material evolution.

2 - Results

The great majority of the averages obtained are largely situated beyond 20 µA, which corresponds to the upper limit taken for the "mature" group. The mean averages of the bore hole remain around 30 µA, while some extreme values may reach up to 40 and even 45 µA. Therefore, the overall organic material represents an "immature" group

However, some sequences seem to belong, at least apparently, to a more evolved evolution (with averages lower than 20 µA) These are from up to down

a) Cores 41 to 47 only by intermittence.

---

[x] C C M GUTJAHR Carbonization measurements of Pollen grains and spores and their application Leidse Geol Medel V 38, pp 1-29, July 1966

[xx] M CORREIA Relations possibles entre l'etat de conservation des éléments figures de la matiere organique figuree (microfossiles palynoplanctologiques) et l'existence de gisements d'hydrocarbures Revue I.F P , V XXII, n° 9, sept 1967.

b) - Cores 63 to 68

c) - " 80 " ?3

d) - " 92 " 95

Owing to the fact that these 4 sequences are restricted to small dispersed intervals, we tried to explain this phenomenon. The effects of carbonization seem related, in the case of Kaskattama bore 1, to rather local factors. Thus

- The b) sequence is found in an anhydritic level. Besides, we always noted that anhydrite strongly affects the palynological material and consequently increase the degree (? apparent degree) of carbonization.

- In some way, the d) sequence may also be compared to the former case. Indeed, the d) sequence is precisely found near the "flowing water" (hypersaline) which probably affected the organic material round by.

- The state of preservation of the palynological material is not uniform within the c) sequence. This is probably due to some reworking which increased the measured degree of carbonization.

Moreover, the stratigraphic boundary which is at the top of the c) sequence may have been marked by an emersion which was probably responsible for the altered underlying material.

So far so, only the a) sequence which corresponds to the lower part of Kaskattama Formation with a relatively more calcareous facies, may probably represent some genuine value about the maturity of organic matter.

This is to be considered as just a tendency since the "mature" levels do not follow in a succeeding order (cores 41, 4?, 47).

B - GEOCHEMICAL MEASUREMENT OF DEGREE OF COALIFICATION

The degree of coalification is defined by the ratio residual carbon/total carbon (and noted C_R/C_T) of the insoluble organic matter (kerogen). The residual carbon (C_R) is the part of the total organic carbon which is not volatile upon pyrolysis at 900°C.

Originally, this measurement has permited a classification of coals according to their rank (carbon-ratio) and the technic is now applied to organic matter of sediments

It gives the best estimation of the degree of maturity and it presents the advantage of beeing representative of the bulk of the organic material contained in the sediment.

Twenty samples have been analysed to determine the degree of coalification The ratios C_R/C_T are plotted on the log (plate 7) and lead to the following conclusions

- the average value of 0,53 indicates an insufficient maturity of the organic matter,
- only two samples (in cores 67 and 82) come near a normal value,
- however these two relatively fair values (0,70 and 0,73) are found within a section where also exist very low ratios (core 68 0,47, core 78 0,49, core 99 0,49) which suggest that the increase of the ratio C_R/C_T for the samples form cores 67 and 82 is the consequence of local conditions The circulation of oxidizing fluids might have such a result and give to the sediments an apparent maturity In the case of a diagenetic process of maturation related with burying and geothermic heating the values of the ratio C_R/C_T show a moreregular increase with depth

Nevertheless, it must be said that the lack of maturity possibly might be the consequence of the low burying of the deposits and that better values might be found toward the center of the basin.

A N N E X E S

METALS CONTENT OF THE BASAL MEMBER OF KASKATTAMA WELL 1

At the request of A.C.C., two samples of the "basal sand member" and a sample of basement have been analysed for their metal content of the total rock.

The concentrations are very low

Metals - contents in ppm		V	Mo	Pb	Zn	Cu	Ni	Co
"Basal sand Mb"	2907'6"	35	10	8	4	4	25	30
	2910'	10	0	8	0	10	1	2
Basement	2917'	200	5	12	110	40	40	40

ANNEXE II

ANALYSE D'EAU

- Bulletin d'Analyse
- Diagramme de Schoeller

FICHE EAU: BULLETIN D'ANALYSE

SNPA CRP Sce Indices

Ste	nº analyse	pays	puits	labo	date analyse
1	1441	710			121b767

Organisme	A A C	Age geologique	ORDOVICIEN
Perimetre	Canada	Lithologie	
Puits	KASKATTAMA 1	Motif du test	
Mode de prelevement	FLOWING Date 1.12.66	Pertes m^3	
Unite des cotes	m feet X Z tr 30.0	Debit reel l	
Cotes extrêmes	de à 2777.0		
Type du test	decouvert perforations		
Cote absolue	2747.0		
Pression kg/cm^2			
Temperature °C	à		
Échantillon analyse			

Indices en forage	tr	p	Indices au prelevement	tr	p
gaz combustible			gaz combustible		
gaz non combustible			gaz non combustible		
H_2S			H_2S		
huile et/ou asphalte			huile et/ou asphalte		
aucuns / inconnus			aucuns X / inconnus		

Indice d échantillonnage %

Representativite: oui X | non | ... inconnue

Residu fixe, à 105°C g/l =		pH = 5.20	
Densite à 20°C =	1.3300	, in situ =	
ClNa (Cl x1,65), g/l =	477.39	, ppm =	358937
ClNa equivalent, mg/l =	451850	, ppm =	339737
ρ, ohms m2 m à 20°C, mesuree =		, calculee =	
ρ, in situ calculee =			
Viscosite, in situ estimee, cps =			

VALEURS et PROPRIÉTÉS de RÉACTION			
a) alcalins =	3.15	salinite primaire =	6.29
b) alcalino terreux =	46.98	salinite secondaire =	93.45
c) hydrogene =		salinite tertiaire =	
d) acides forts =	49.87	alcalinite primaire =	
e) acides faibles =		alcalinite secondaire =	.52
% ERREUR =	.26	rSO / (rSO₄ + rCl), % =	

IONS	Codes	mg/l	meq/l	R %
Na^+		7793.0	338.98	2.07
K^+		6875.0	175.82	1.07
Ca^{++}		122335.0	6104.54	37.30
Mg^{++}		19257.0	1584.16	9.68
H^+				
total +		156260.0	8203.50	50.13
OH^-				
CO_3^{--}				
CO_3H^-				
SO_4^{--}				
Cl^-		289325.0	8160.80	49.87
total −		289325.0	8160.80	49.87
TOTAL ±		445585.0	16364.30	100.00

INDICES CARACTÉRISTIQUES			
(rNa+rK) / (rCa+rMg) =	.067	rNa / rK =	1.928
rNa / rCa =	.056	rMg / rCa =	.260
rNa / (rCa+rMg) =	.044	rCl / rNa =	24.075
rSO₄ / rCl =		rCl / rSO₄ =	
rCO₃H / rSO₄ =		rNa / rMg =	.214
$\sqrt{rSO_4\ rCa}$ =		rCl / (rNa+rK) =	15.852
kr =		μ =	12.0265
i e b =	.9369	saturation SO₄Ca, % =	
(rNa−rCl) / rSO₄ =		(rCl − rNa) / rMg =	4.94

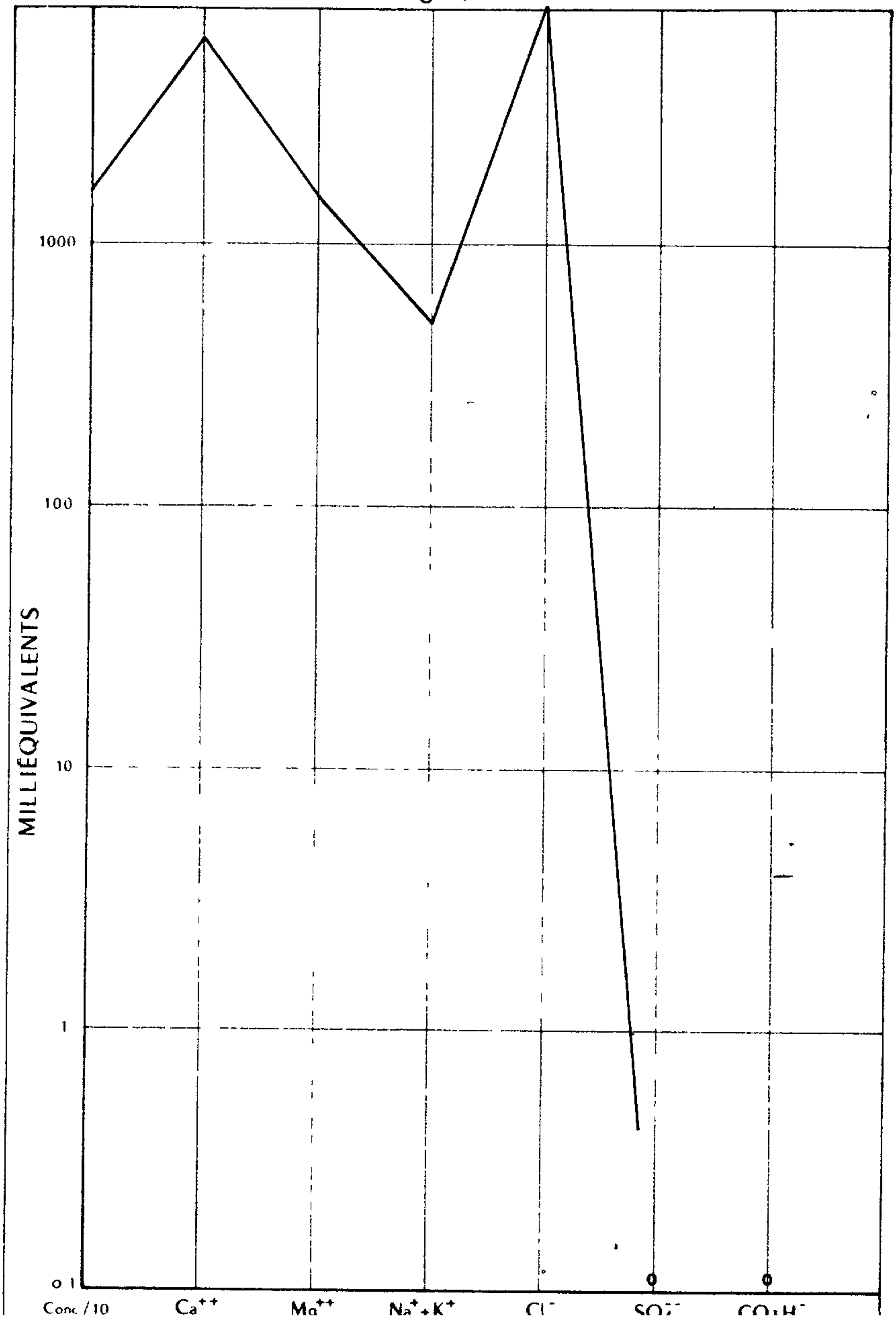
DOSAGES et RAPPORTS COMPLÉMENTAIRES, mg/l					
NH_4^+		I^-	20.00	NH_4 / Cl 10^3 =	
H_2S		Br^-	3742.	I / Cl 10^3 =	.691
S^{--}		Bore	230.00	Br / Cl 10^3 =	12.936
				Bore / Cl 10^3 =	.795

AUTRES DOSAGES mg/l									
Li	52,5	Fe_2O_3		Co	NÉANT	SO_3		NO_2	
Fe^{++}		Al_2O_3		Ni	NÉANT	S_2O_3		NO_3	
Fe^{+++}		Sr	2425,0	Zn	10,0	S total		SiO	
Al		Cu	NEANT	Mn		PO_4			
Ga				Rb	65				

OBSERVATIONS

ANALYSE D'EAU : *DIAGRAMME DE SCHŒLLER*

Puits KASKATTAMA 1 ~~Test N°~~ Flowing Etage Ordovicien N° d'analyse 1 - 1441



SNPA-CRP Sce INDICES N° A-025

(B)

S. N. P. A.

RESEARCH CENTRE - PAU

Report R/ST n°21.691

April 16, 1968

KASKATTAMA WELL 1 -

- Microfacies, stratigraphic and geochimical studies

P L A T E S

PLATE I

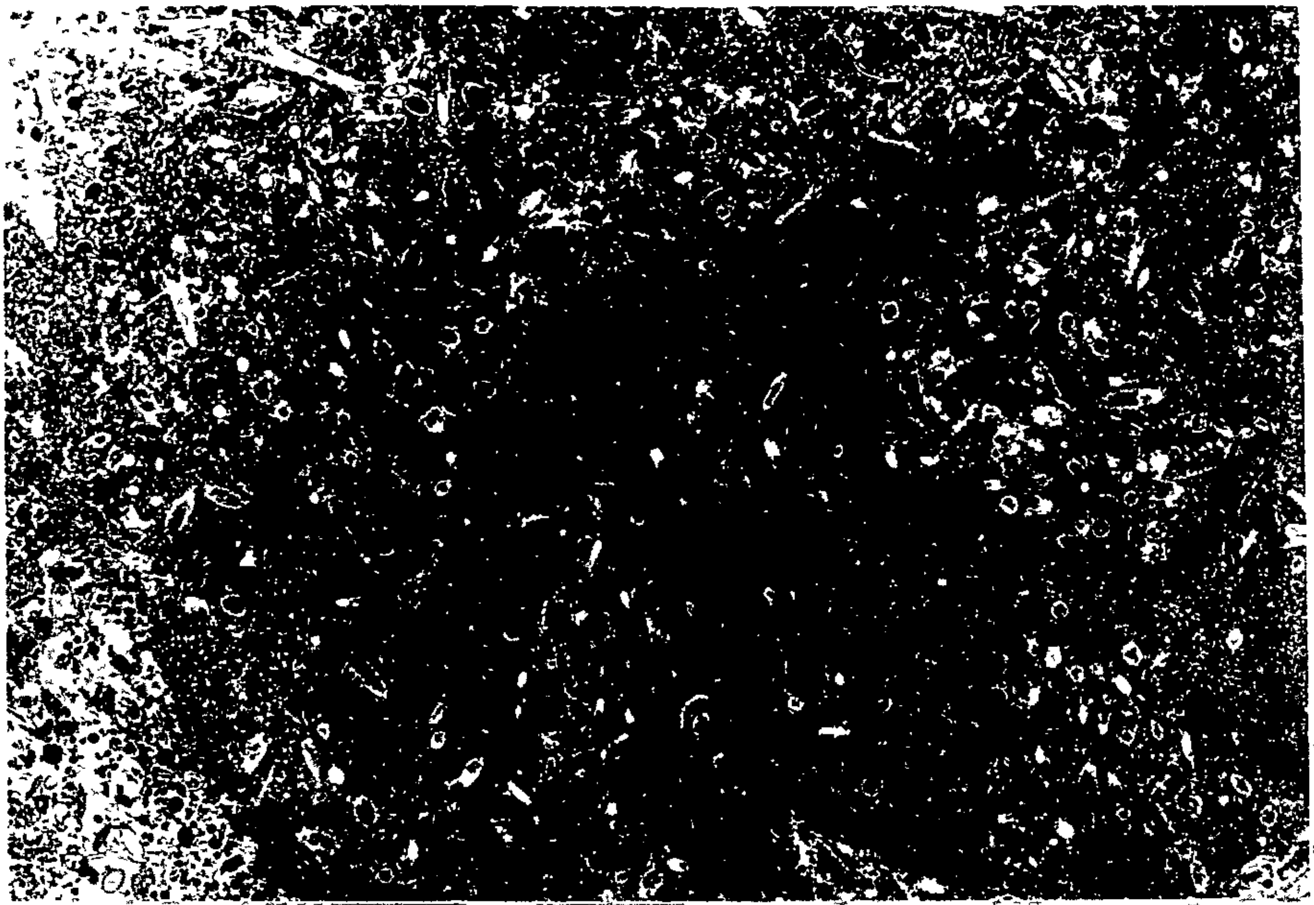
1 Kaskattama 1 - Core 3 (100') x 12

Biomicrosparites - The fauna mainly contains Pteropods

2 Kaskattama 1 - Core 16 (1065')

Dolomicrosparites including anhydrite.

PLATE 1



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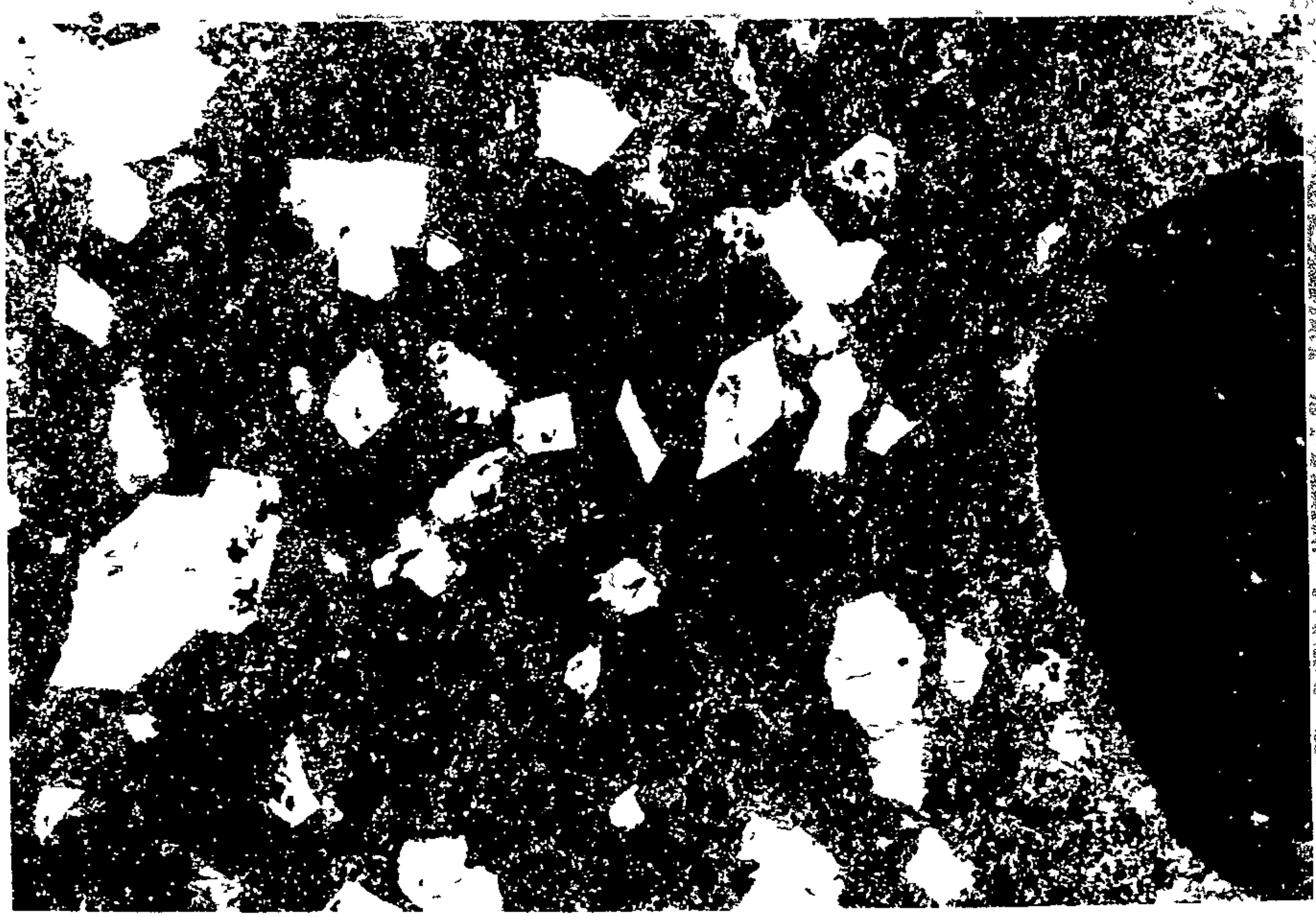


2

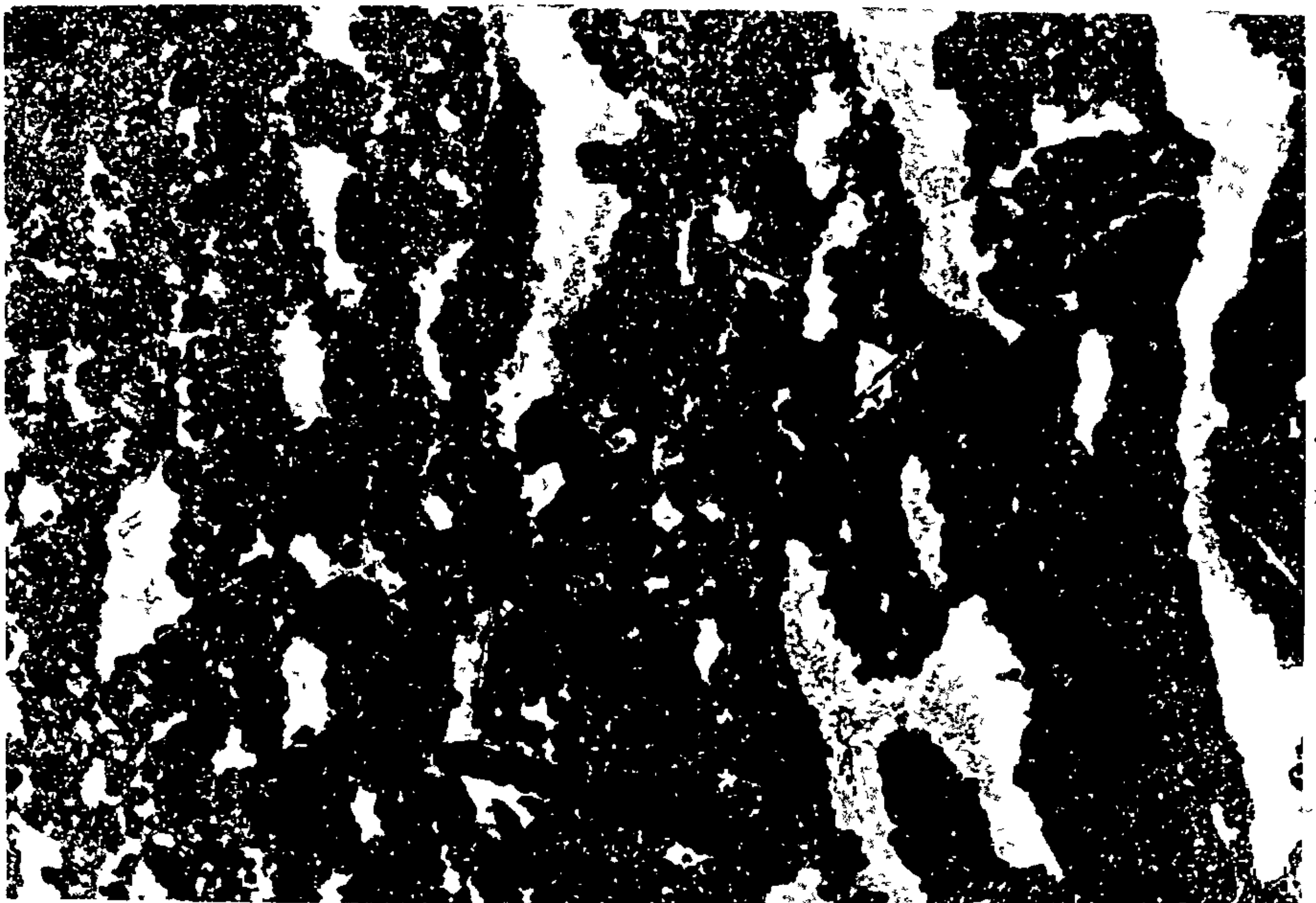
PLATE 2

1 Kaskattama 1 - Core 18 (1091') x 12

Microsparites slightly dolomitized with bird-eyes facies

2 Kaskattama 1 - core 19 (1111'4") x 12

Gravelly microsparites with intraclasts abundant Amphipora



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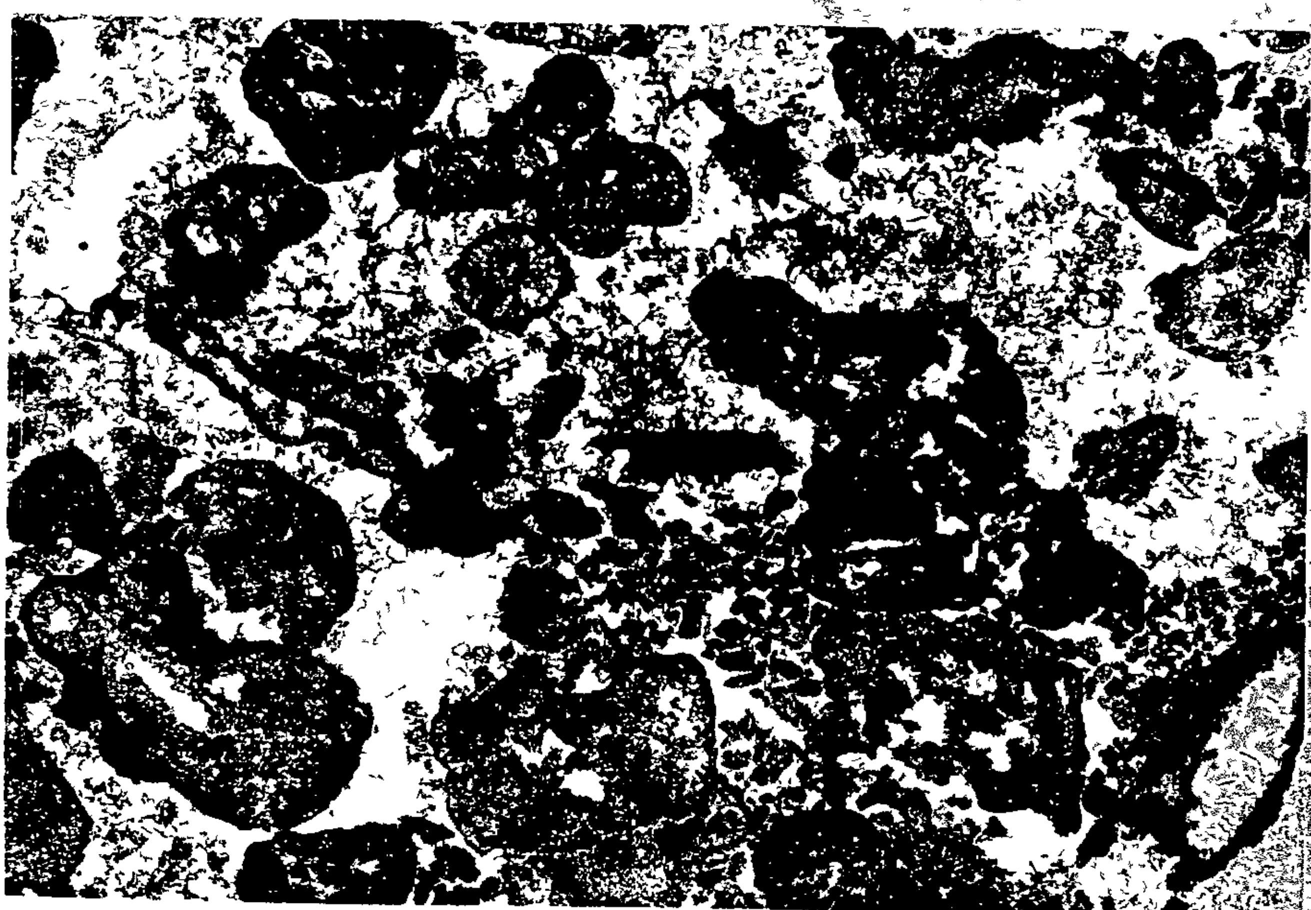


2

PLATE 3

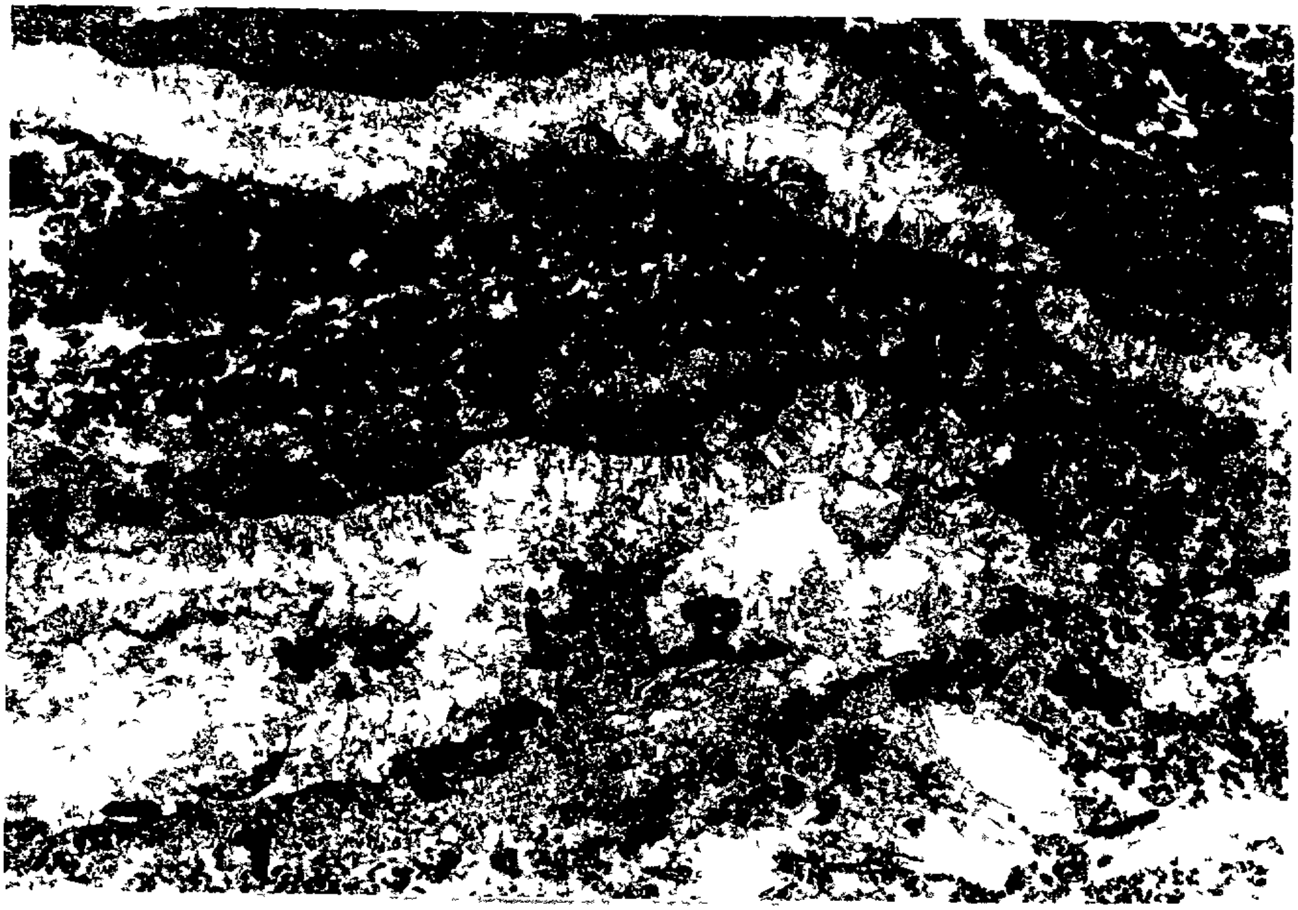
1 Kaskattama 1 - Core 25 (1195') x 12

Pel-biomicrosparites Stromatactis and rare Crinoidal fragments

2 Kaskattama 1 - Core 26 (1[illegible]')

Micrites including Stromatopores and algal fragments

PLATE 3



1

2

PLATE 4

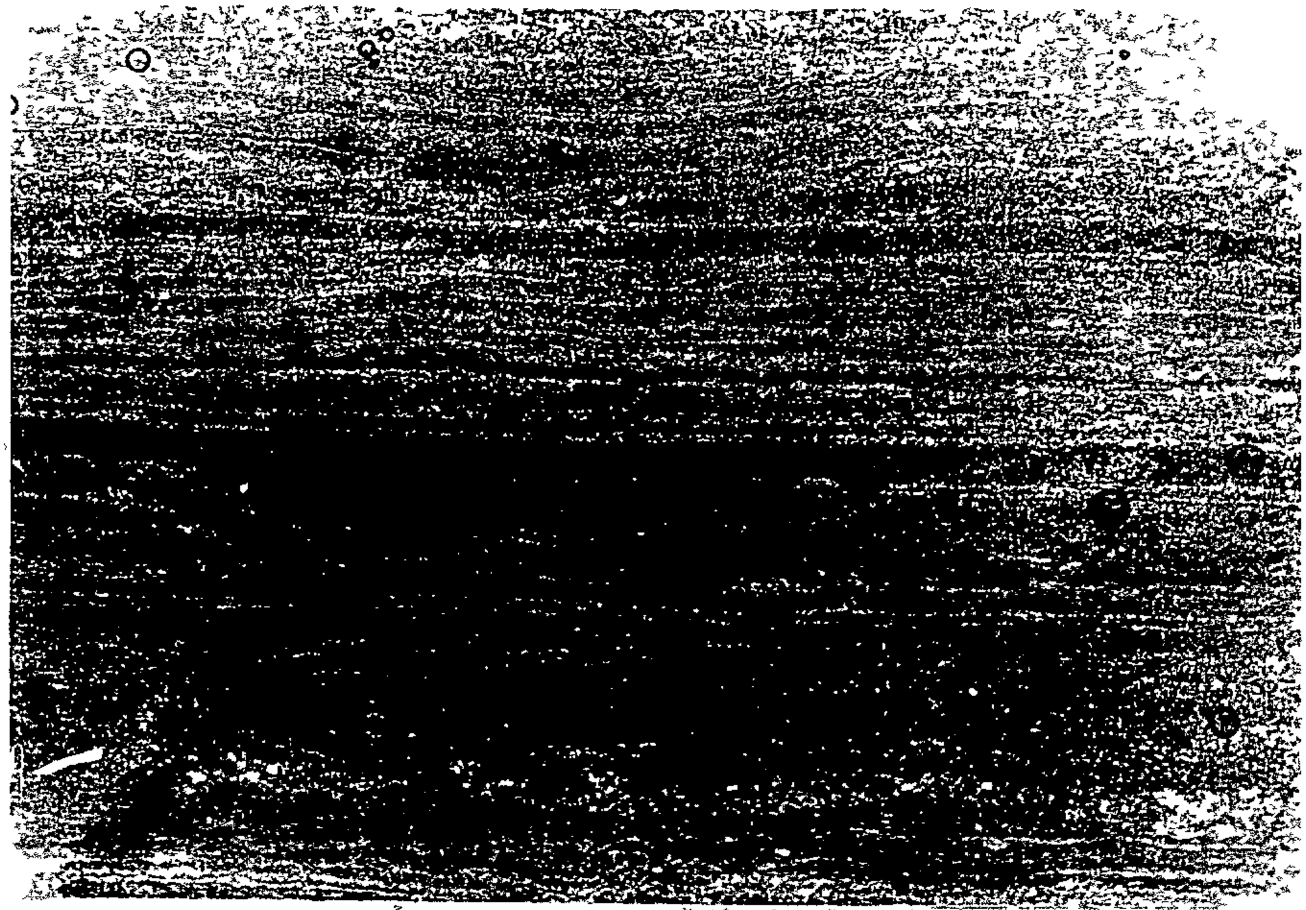
1 Kaskattama 1 - Core 35 (1552') x 12

Slightly, streaked laminated ("rubané") dolomicrosparites

2 Kaskattama 1 - core 38 (1668'6") x 12

Bio-intramicrosparites Corals, Crinoids, Pelecypods fragments

PLATE 4



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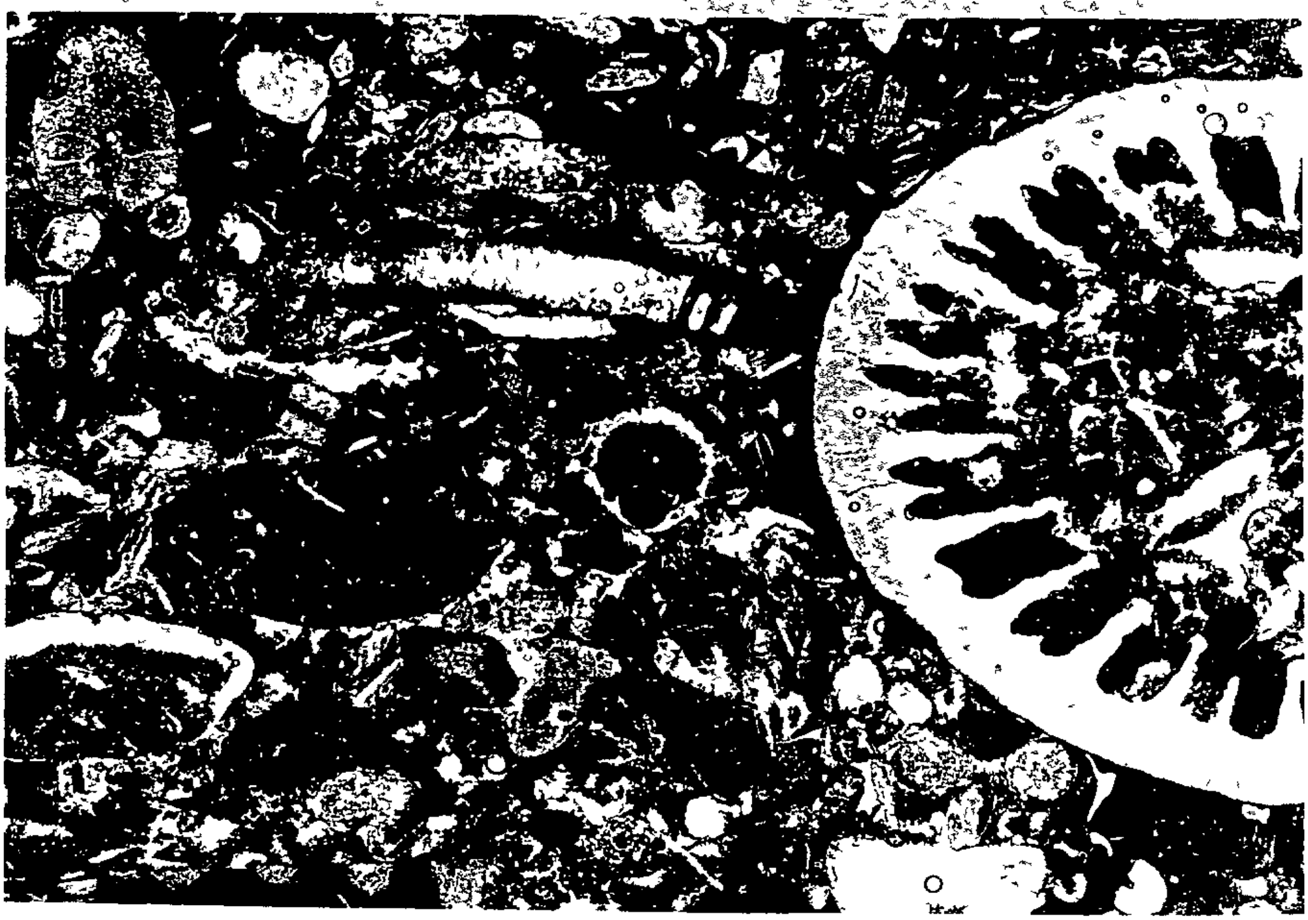


2

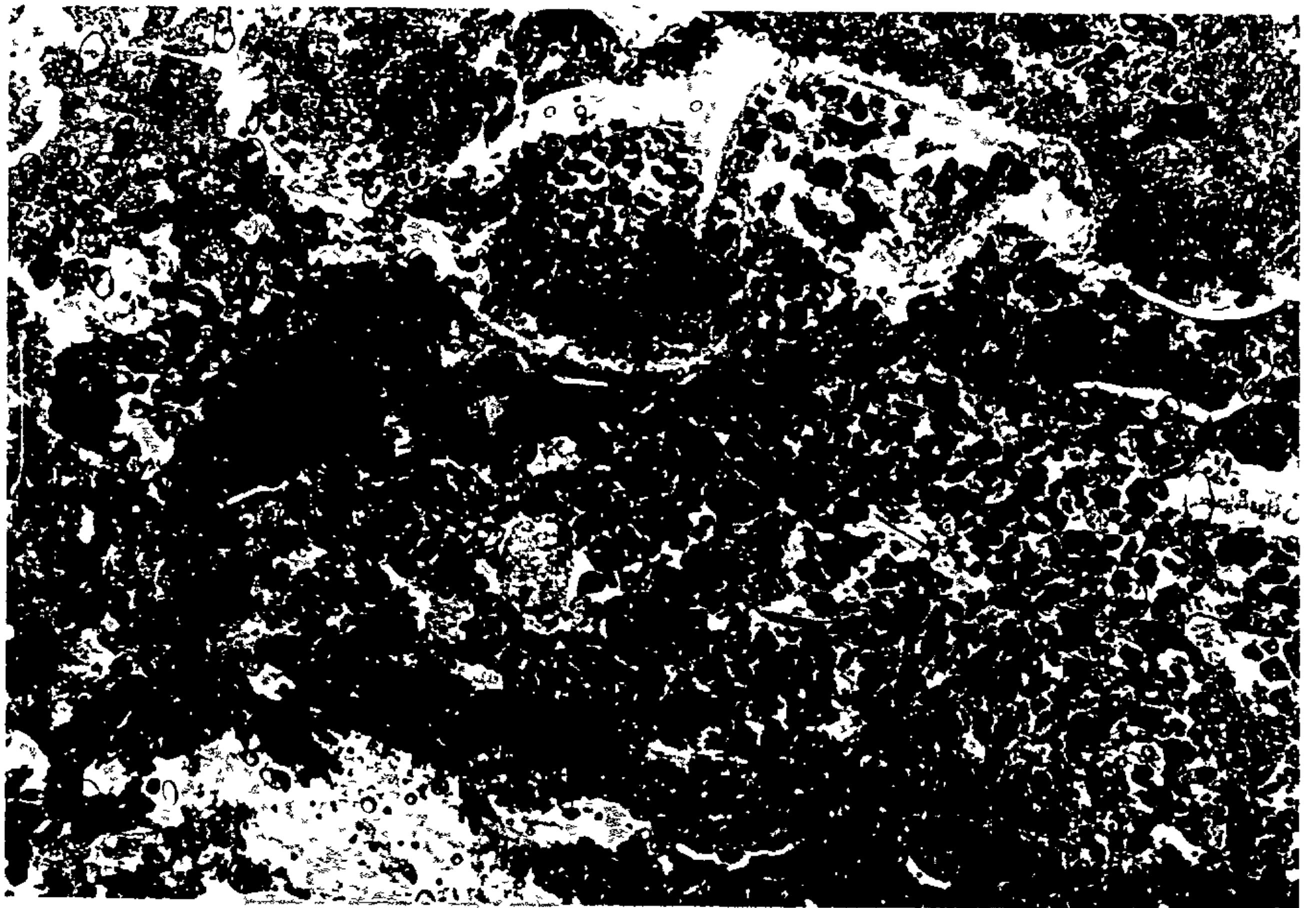
PLATE 5

1 Kaskattama 1 - core 33 (1452') x 12

Pseudo ooid micrite including very rare fossils Pelecypods

2 Kaskattama 1 - core 58 (2069'10') x 12

Dolomicrosparites including distorded gravels and intraclasts



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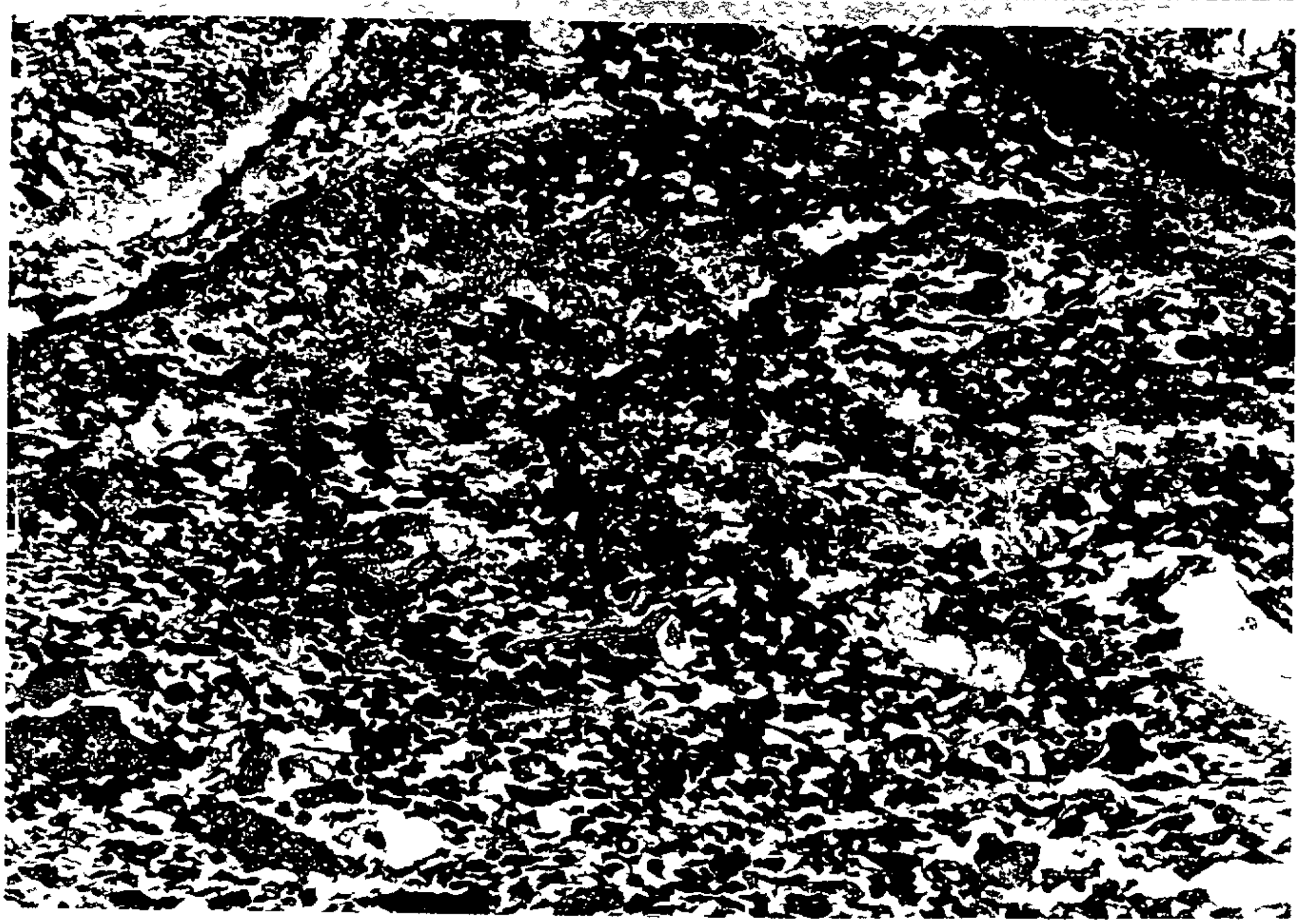


2

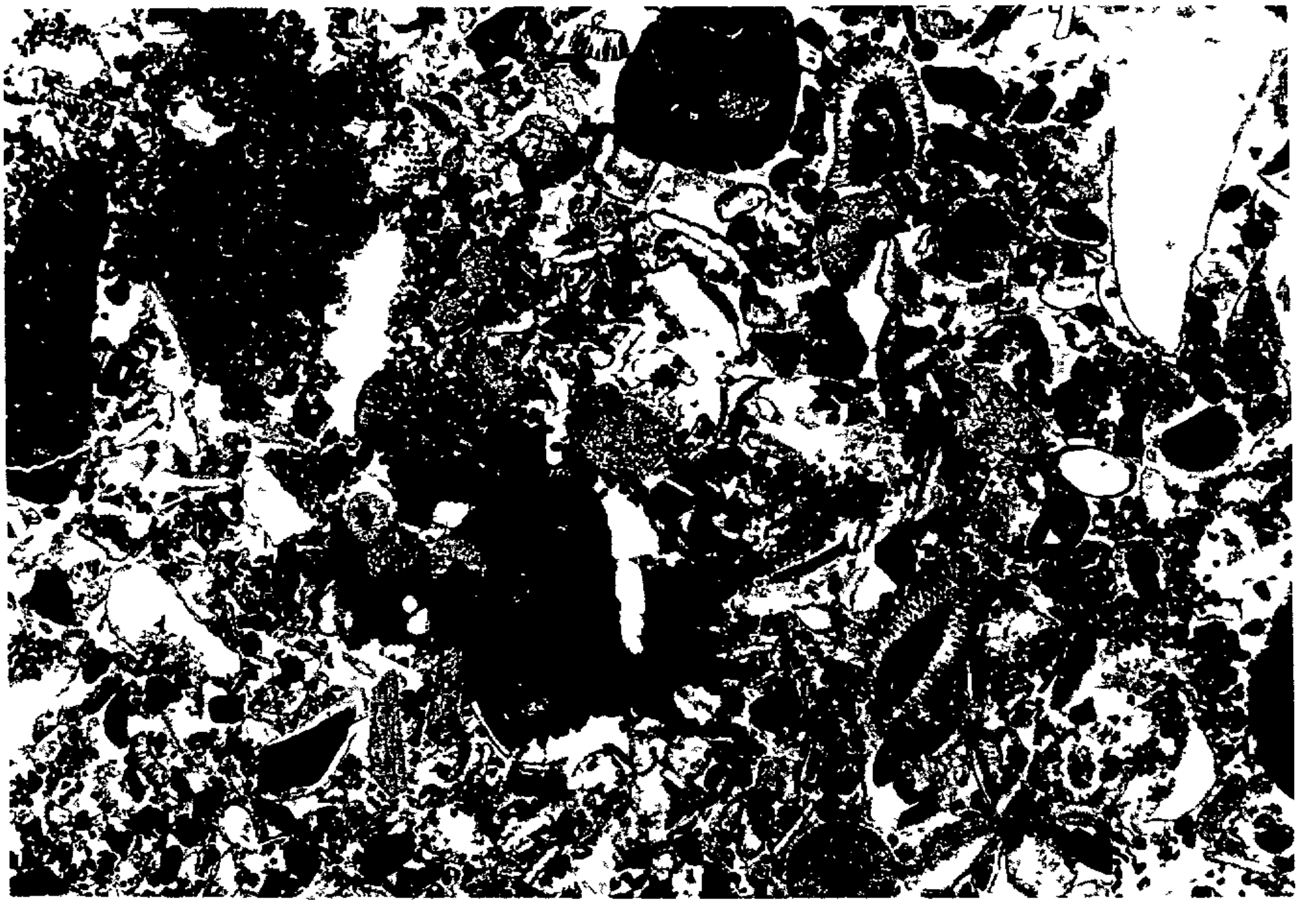
PLATE 6

1 Kaskattama 1 - core 70 (2317'10") x 12

Gravelly biomicrosparites with rare intraclasts
Abundant Crinoidal fragments, Pelecypods and Dasycladacean algae.

2 Kaskattama 1 - core 99 (2652') x 12

Biomicrite slightly dolomitized.
Abundant crinoidal fragments, Pelecypods, Trilobites and algae fragments.



1

2

PLATE 7

from left to right and from up to down

- Conodont bio-zone S_c6 , 1349'
- " " S_c5 , 1617'
- " " S_c4 , 1790'
- " " S_c2 , 1880'
- " " S_c1 , 2027'
- " " O_c3 , 2343-2351'
- Conodont zonule O_c2b, 2569'
- " " O_c2a, 2602'
- Conodont bio-zone O_c1 , 2748'

PLATE 7

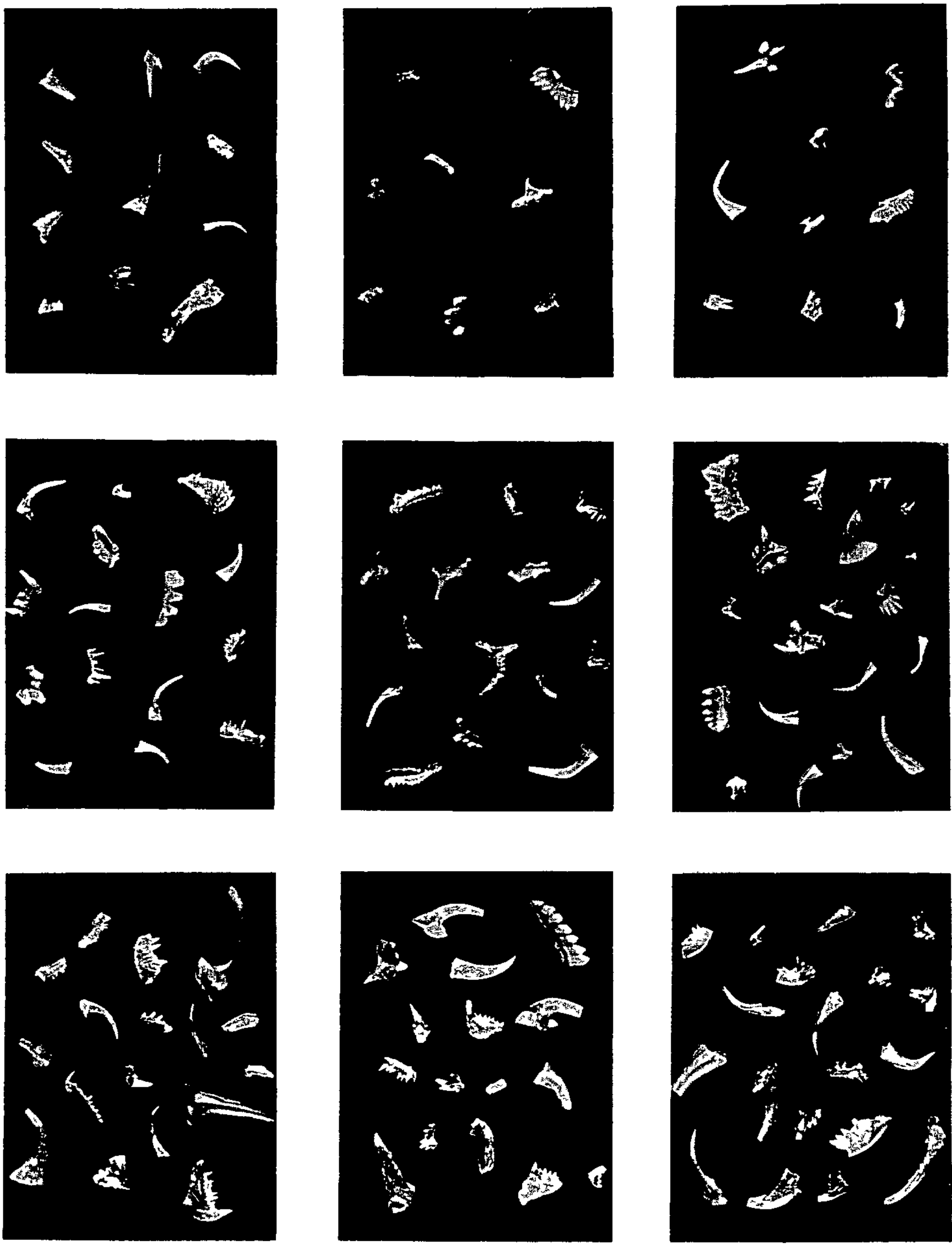


PLATE 8

CHITINOZOA

Fig.	S.N.P.A type	Species	Core	Sample
1	C_z 302	Cyathochitina stentor	83	2556' to 2575'
2	C_z 313	Cyathochitina hyalophrys	80	2496' to 2516'
3	C_z 226	Cyathochitina fistulosa	81	2516' to 2535'
4	C_z 194	Cyathochitina kuckersiana	81	2516' to 2535'
5	C_z 35	Cyathochitina calix	92	2729' to 2748'
6	C_z 304	Angochitina oklahomensis	95	2777' to 2795'
7	C_z 326	Hercochitina sp	81	2516' to 2535'
8	C_z 312	Hercochitina crickmayi	83	2556' to 2575'
9	C_z 327	Hercochitina sp.	102	2880' to 2886'
10	C_z 136	Conochitina pachycephala	80	2496' to 2516
11	C_z 309	Mirachitina quadrupedis	67	2257' to 2276'
12	C_z 316	Conochitina micracantha robusta	69	2295' to 2314'
13	C_z 315	Conochitina micracantha capitata	80	2496' to 2516'
14	C_z 318	Conochitina micracantha micracantha	99	2838' to 2857'
15	C_z 317	Conochitina cactacea	98	2819' to 2838'
16	C_z 135	Ancyrochitina ancyrea	42	1744' to 1761'
17	C_z 324	Ancyrochitina sp.	84	2575' to 2594'
18	C_z 303	Lagenochitina cf. sphaerochitina macrostoma	92	2729' to 2748'
19	C_z 320	Lagenochitina tarfayensis	102	2880' to 2886'
20	C_z 101 b	Lagenochitina sp	80	2496' to 2516'
21	C_z 323	Sphaerochitina cf. fenestrata	41	1714' to 1732'
22	C_z 139	Sphaerochitina pilosa	97	2800' to 2819'

Magnification · about 125 x

PLATE 8

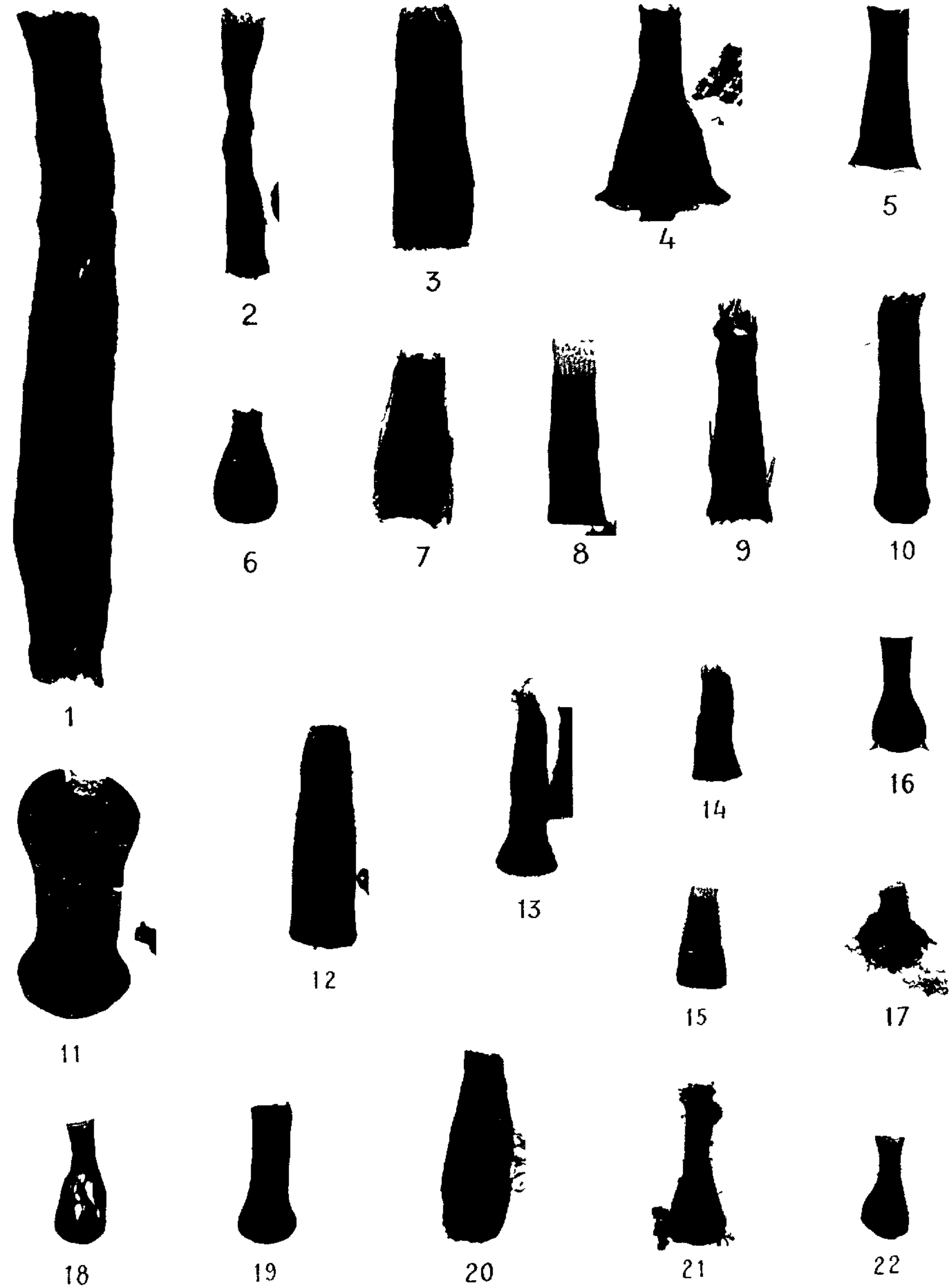


PLATE 9

ACRITARCHS AND ALGAE

Fig.	S.M.P.A. type	Species	Core	Sample
1	319	Polygonium sp.	82	2535-2554'
2	318	Veryhachium sp	77	2439-2458'
3	320	Baltisphaeridium multipilosum	100	2858-2877'
4	57	Navifusa sp	90	2689-2709'
5	215	Leiovalia similis	100	2858-2877'
6	296	Leiofusa	43	1761-1781'
7	151	Tasmanites sp.	60	2095-2125'
8	149	Leiofusa aff. pumilla	101	2877-2880'
9	157		62	2152-2182'
10	262	Cymatiosphaera (?) sp	39	1674-1694'
11		Primitive Algae	49	1879-1899'
12		"	91	2709-2729'
13		"	62	2152-2182'
14		"	89	2670-2689'

Magnification about 500 x

PLATE 9

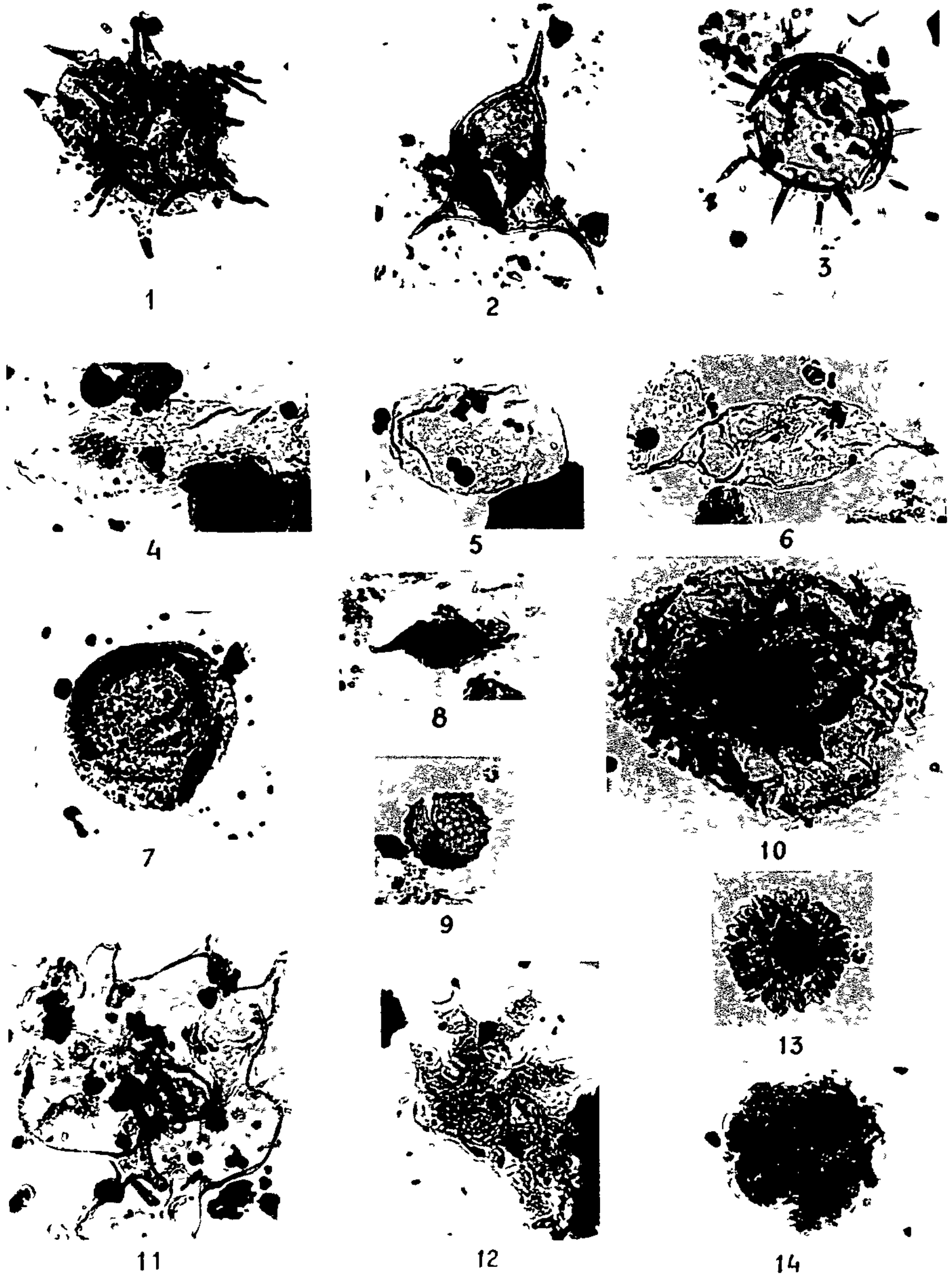


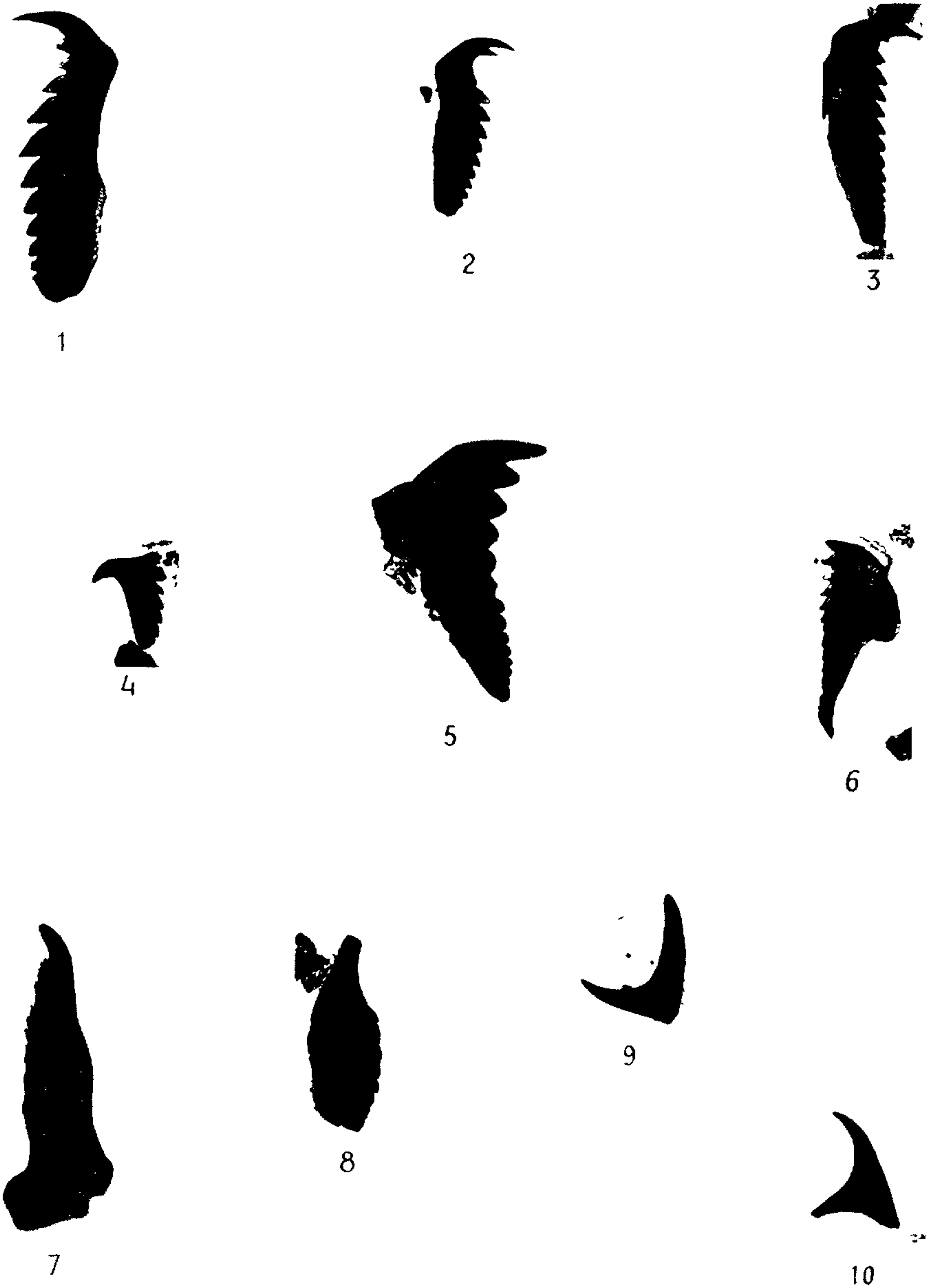
PLATE 10

SCOLECODONTS

Fig.	S.N.P.A. type	Species	Core	Samples
1	d 193	Oenonites sp.	67	2257' to 2276'
2	d 97	Lumbriconereites sp.	61	2125' to 2152'
3	d 85	Oenonites Crepitus var.1	79	2477' to 2496'
4	a 23	Leodicites arquatus	91	2709' to 2729'
5	d 120	Paleoenonites armigerus	102	2880' to 2885'
6	d 15	Ildraites sp.	61	2125' to 2152'
7	d 67	Nereidavus invisibilis var.3	30	1335' to 1354'
8	d 77	Arabellites doutti	72	2350' to 2369'
9	d 215	eunicites sp.	40	1694' to 1714'
10	d 5	Eunicites denticulatus	43	1761' to 1781'

Magnification : about 125 x

PLATE 10



CENTRE DE RECHERCHES - PAU
GROUPE STRATIGRAPHIE

TABLE 1

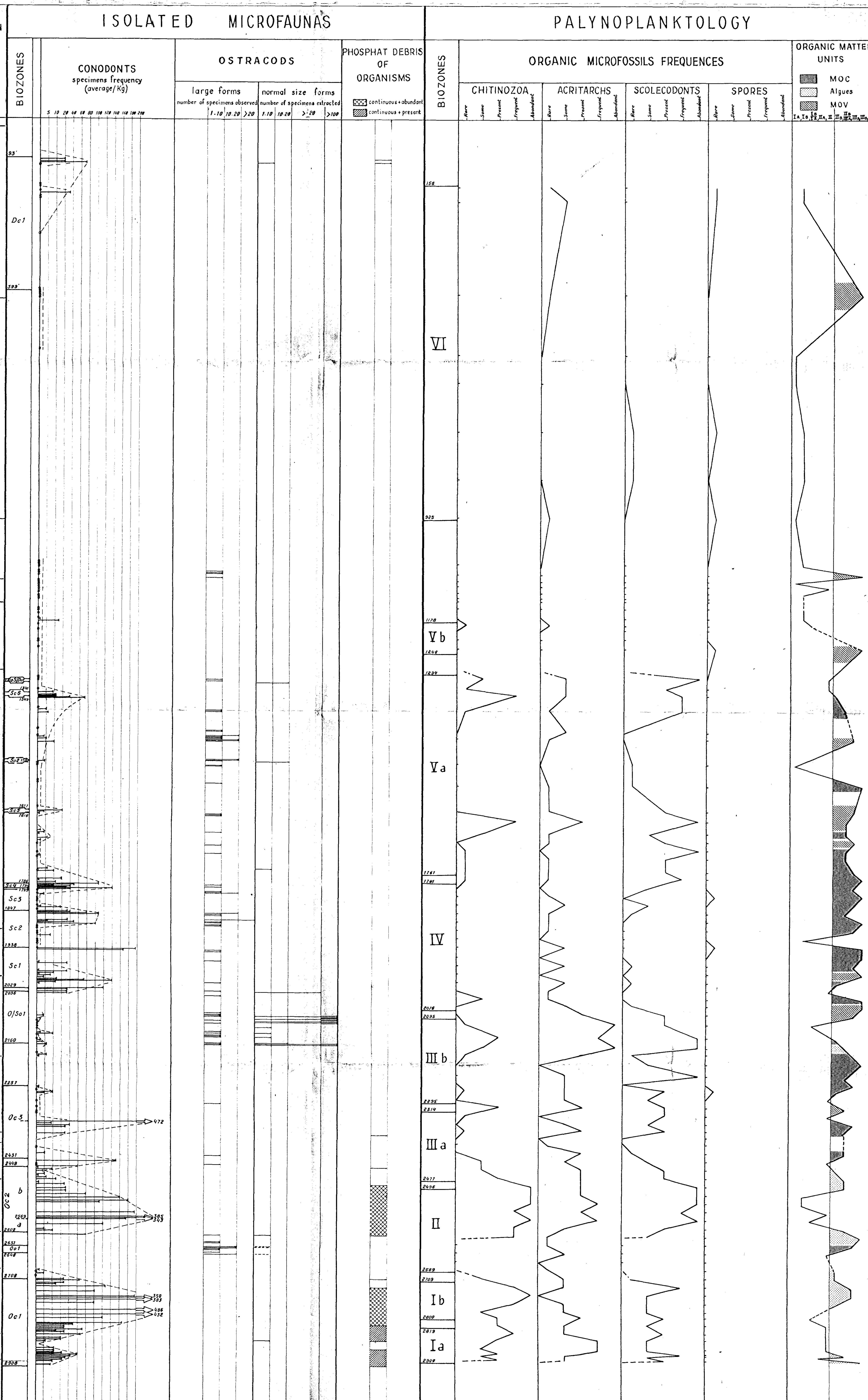
WELL : KASKATTAMA 1

TENTATIVE INTERPRETATION OF DEPOSITIONAL ENVIRONMENT AND DISTRIBUTION OF MICROFOSSILS

Note R/ST n° 21691

ARCH. CENT. FSE 2549

CORES / FORMATIONS	MICROFACIES	CLAY MINERALS AND BORON CONTENT	TENTATIVE INTERPRETATION OF DEPOSITIONAL ENVIRONMENT (Microfacies - clay minerals - boron content)
ABITIBI	- Microsparite with intraclasts (core 2) and gravels (core 3). The fauna is composed by : Pelecypods, Crinoids, fragments of Trilobites and abundant Pteropods (photo : plate 1 n° 1)		Mainly normal marine environment. (slightly restricted in core 7)
ABITIBI	- Cores 5 and 6 : Micrite to biomicrite. The fossils are : Pelecypods, Brachiopods, Crinoids and rare Pteropods. - Core 7 : Brecciated limestone = elements made of dolomicrosparite. - Cores 8 and 9 : Bedded micrite with numerous little vughs of 60 to 100µ.	- Clay fraction : illite with a little chlorite in places. - Nearly normal boron content except for core 7 (higher value —▸ slightly restricted environment).	
MIDDLE KENOGAMI	- Cores 10 to 14 : Red and green shale, silty, with nodules and banks of gypsum.	- Clay fraction : illite with a little chlorite in places. - Low to normal boron content.	Possible lateral facies of an evaporitic sequence ?
LOWER KENOGAMI	- Cores 15 - 16 : Bedded dolomicrosparite (with inclusions of evaporitic minerals (anhydite and gypsum). (Photo : plate 1 n° 2)	- Cores 15-16 : presence of sepiolite in the clay fraction. - Normal boron content.	Chemical sedimentation in quiet warm and shallow water.
ATTAWAPISKAT (1097–1132)	Micrite and intramicrite with Amphipora, Stromatactis, Crinoids - Core 18 : Bird eyes facies (Ph. pl. 2, n° 1). Microsparite with gravels and intraclasts : Amphipora, Stromatopores, rare corals, Pelecypods, Crinoids. (Photo : plate 2 n° 2)		Sub-lagoonal environment
ATTAWAPISKAT	- Pelletoidal micrite and microsparite with intraclasts : Stromatopores, tabulate Corals, Stromatactis, Pelecypods Crinoids. (Photo : plate 3 n° 1 and 2)	- Normal boron content for cores 18 - 23.	Reefoid environment
KASKATTAMA	- Formation composed of sequences which recur rythmically. The microfacies of each sequence is the following (in ascending order) : - Slightly streaked laminated ("rubané") micrites and dolomicrites. (Photo : plate 4 n° 1) - Gravelly biomicrosparites and bio-intramicrosparites. (Photo : plate 4 n° 2) - Pseudooid micrites. (Photo : plate 5 n° 1)	- Clay fraction : mainly illite with a little chlorite in core 38. - In some levels of core 34 (1493'-1496') sepiolite is nearly the only argilaceous mineral. - Normal boron content in the medium part of the formation. Higher values at the top (cores 28 and 31) and bottom (cores 46 - 47 - 48) indicate a slightly restricted environment.	Oscillations between sub-lagoonal and perireefoid environment.
NELSON	- Streaked laminated micrite and algal dolomicrite (Spongiostromata) 1939 - - - - Dolomicrosparite and dolomicrite with gravels. Very rare organisms : Thamnopora - Pelecypods Ostracods. 1999 - - -	- Clay fraction : illite. - Slightly restricted environment (light enrichments in boron)	Sub-lagoonal environment
PORT	- Irregular alternations of : Micrite with gravels and dolomitized microsparite with dolomicrite or dolomicrosparite including distorded gravels. (Photo : plate 5 n° 2) Fauna representated by : Pelecypods, Crinoids, rare Trilobites fragments, rare Thamnopora and Corals fragments.		Very slightly restricted environment.
RED HEAD RAPIDS	- Dolomicrite sometimes laminated streaked and dolomicrosparite with gravels and intraclasts. The organisms are rare : Pelecypods, Crinoids, Ostracods. Presence of fluorite sometimes abundant around 2274'. 2301 - - - - Pelmicrosparite with gravels : Pelecypods, Crinoids, Bryozoa, Trilobites, Ostracods. Occurence of limestone with abundant algae toward 2317'. (Photo : plate 6 n° 1)	- Clay fraction : illite with a little chlorite in core 63. - Mostly high boron content (restricted environment) with a lower value in core 68.	Sub-lagoonal environment with some less restricted levels.
CHASM CREEK	Dense anhydrite and dolomicrosparite with anhydrite 2394 - Pelletoidal micrite with gravels - Very rare organisms. 2440 - - - - Biomicrite with frequent organisms : Pelecypods, Crinoids, Bryozoa, Corals, rare Thamnopora, Trilobites - Abundant algae.	- Clay fraction : illite in core 75, illite and chlorite below. - Boron content indicates a slightly restricted environment at the top (cores 75-78) becoming normal marine in the lower part of the formation.	Lagoonal environment Sub-lagoonal environment Normal marine environment
CAUTION CREEK	- Dolomicrosparite with very rare intraclasts. Abundant anhydrite.	- Core 86 : illite and chlorite with high boron content (restricted environment).	Lagoonal to sub-lagoonal environment
PORTAGE CHUTE	- Biomicrosparite sometimes dolomitized : Crinoids (abundant), Pelecypods, Trilobites, Ostracods, rare Corals fragments ; algae fragments. (Photo : plate 6 n° 2)	- Clay fraction : chlorite and illite. - Normal marine conditions as pointed out by the boron content.	Normal marine environment
PORTAGE CHUTE		- Clay fraction : chlorite and illite. Enrichments in boron in core 99 and the lower part of core 103.	Slightly restricted environment
		- Upper part of core 104 : kaolinite chlorite and illite at the top, chlorite and illite from 2905' to the basement. Boron content indicates slightly restricted conditions of deposition.	



CENTRE DE RECHERCHES - PAU
GROUPE STRATIGRAPHIE

TABLE 2

WELL : KASKATTAMA 1

BIOSTRATIGRAPHY

LEGENDE

D 15.215 / D 91.193 — Biozone defined by overlap

Note R/ST n° 21691

ARCH. CENT. FSE 2549

CENTRE DE RECHERCHES - PAU
GROUPE STRATIGRAPHIE

TABLE 3

KASKATTAMA 1

BIO-ZONATION BY CONODONTS

ANALYTIC TABLE

NOTE R/ST N° 21.631

N° 4780

TABLE 4

CENTRE DE RECHERCHES - PAU
GROUPE STRATIGRAPHIE

KASKATTAMA 1

CONODONTS FREQUENCY-OSTRACODS & VARIOUS ORGANISMS DISTRIBUTION

NOTE R/ST N° 21691

ARC. CENT. FSE 2549

TABLE 5

CENTRE DE RECHERCHES - PAU
GROUPE STRATIGRAPHIE

WELL: KASKATTAMA 1

QUALITATIVE RANGE
of CHITINOZOA
ACRITARCHS
SCOLECODONTS
and SPORES

Note R/ST n° 21691

LEGENDE

× : "Normal" occurence

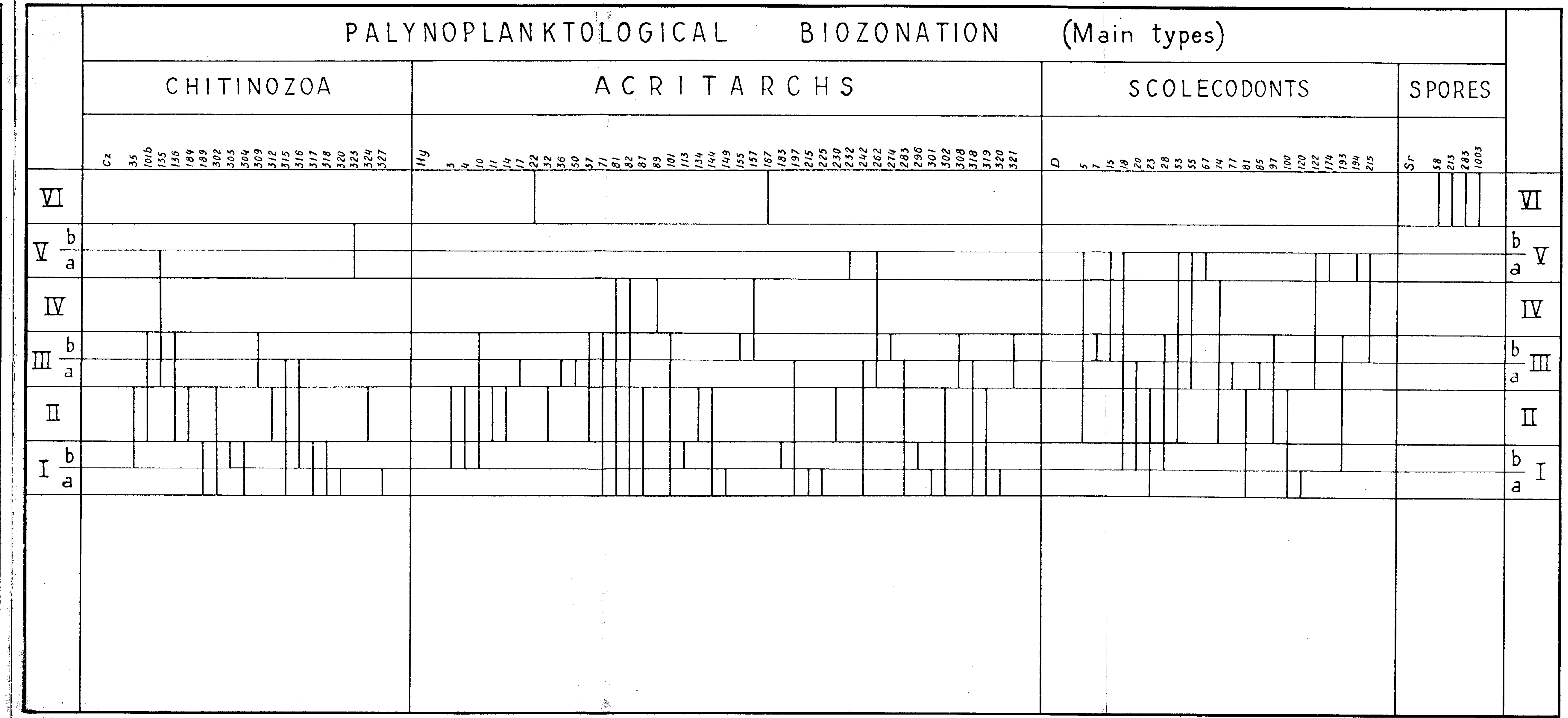
⊗ : Occurence probably due to infiltrations

CENTRE DE RECHERCHES - PAU
GROUPE STRATIGRAPHIE

TABLE 6

WELL: KASKATTAMA 1

PALYNOPLANKTOLOGICAL BIOZONATION
(Main types)



Note R/ST n° 21691

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TABLE 7

WELL : KASKATTAMA 1

GEOCHEMICAL ANALYSIS

NOTE R/St. n°: 21.691