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Micropalaeontology and petrography of Middle and Upper Jurassic samples from Jameson Land and Milne Land, East Greenland

D.J.Batten, J.T.Berry, J.W.Church and L.A.Riley

1974

INTRODUCTION

As part of a larger study on the Jurassic of northwest Europe, 74 outcrop samples from East Greenland have been analysed by members of the staff of Robertson Research International Ltd. The results of the micropalaeontological and petrographical aspects of this work are presented here. The samples were selected from the collection of the Greenland Geological Survey by Professor T. Birkelund as being the most suitable for this kind of study. They were collected from Middle and Upper Jurassic outcrops in Jameson Land and Milne Land during the period 1968 - 71. The sampling localities are shown on fig. 1 and their approximate stratigraphic positions on fig. 2. Twenty-eight of the samples are from three sections in North Jameson Land. The remainder, many of which have been dated on ammonite evidence by the Greenland Geological Survey (Professor Birkelund, pers. comm.), are from scattered outcrops in North and South Jameson Land and in Milne Land (fig. 2).

Although the results of our study are of a preliminary nature, it is hoped that they will provide a useful basis for future micropalaeontological studies on East Greenland material. We have aimed at determinations of ages and depositional environments. A detailed taxonomic study of the fossils recovered was not attempted; only forms attributable to previously described taxa are listed on the tables (figs 3 - 5). A number of new dinoflagellate cyst species have been excluded pending further study.

None of the samples processed for microfaunas yielded ostracodes, and the foraminifera recovered are almost entirely attributable to species of the agglutinating genus *Haplophragmoides*. Most of the miospore assemblages are dominated by pollen of probable gymnospermous origin. Although these assemblages are considerably more diverse than the faunas, they are consistently comprised of relatively long-ranging taxa and hence of limited value for closely defined age determinations. The dinoflagellate cysts, while being less common than the miospores, have proved to be more useful in this respect because several of the species recorded have short stratigraphic ranges. None of the groups has, however, been considered in isolation; our suggestions regarding both ages and depositional environments have been inferred from all available data.

We thank the Director of the Geological Survey of Greenland for allowing us access to the samples and the Directors of Robertson Research International Ltd. for permission to publish. We are indebted to both Mr. G. Henderson and Professor T. Birkelund of the Greenland Survey for providing maps, reference stratigraphic data, unpublished data and other useful information. Palaeontological and petrographical slide preparations are now housed in the Survey collection. Within the Robertson Research organisation we wish to acknowledge the assistance of colleagues and those who have helped in sample preparation, draughting and typing. D.J.Batten is responsible for the miospore analyses, J.T.Berry for the petrography, J.W.Church for the microfaunal identifications and L.A.Riley for the sections on microplankton.

PREVIOUS WORK

Numerous articles have been published on the Jurassic rocks of Jameson Land and Milne Land. Useful summaries of previous work have been presented by Rosenkrantz (1934) and Donovan (1957) and more recently by Håkansson et al. (1971) and Surlyk et al. (1973). By contrast, little has appeared on the micropalaeontology of these rocks. The only paper is by Sarjeant (1972) in which he describes and illustrates microplankton from two horizons in the Upper Vardekløft Formation of central Jameson Land; a supplement by M.D.Muir on the miospores associated with these microplankton assemblages is included.

METHODS

The microfossils were extracted from rock samples using standard palaeontological techniques. Samples weighing approximately 500 gms were processed for microfaunas. The relative abundances of the faunal elements indicated on figs 3 - 5 are based on an examination of all the residue from these preparations. The assemblages of organic-walled microplankton (dinoflagellate cysts and acritarchs) and miospores were obtained by processing approximately 10 gms of rock. Relative abundances of these forms (figs 3 - 5) were determined from the examination of a single slide preparation using circular cover slips of 22 mm diameter.

Petrographic analyses were conducted on thin sections taken from both carbonate and clastic rocks (fig. 6). Porosity and permeability determinations were made on one inch diameter plugs orientated parallel to the observed bedding. The cores were taken using thin-walled impregnated diamond drills. The ends of each core were broken to expose untouched matrices of sample. The pieces were dried in an oven at a temperature of 105°C for approximately 24 hours and subsequently allowed to cool in a desiccator. The permeability, expressed in units of millidarcy (md, fig. 6), was measured using low moisture content nitrogen gas passing through the samples in a Fancher-type cell. Gas flow parameters were determined by employing a mercury manometer and a soap bubble flowmeter. The sample diameter was measured with a vernier caliper and the average length calculated from the diameter and bulk volume. The porosity was determined by an air compression pycnometer using helium to measure grain volume, and by a mercury displacement technique to measure bulk volume. The difference between these two values is expressed as a percentage of the bulk volume to give the porosity value (fig. 6).

The thin sections and plugs were not always taken from the same piece of sample. Differences in the visual and measured porosities on fig. 6 may be explained for this reason, and because some samples may have micron-sized porosity in clay minerals which is not visible under the microscope. The samples analysed are arranged on the figure in stratigraphic order within each section or area. It is necessary, however, to refer to figs 2 and 3 in order to find the stratigraphic position of the samples.

TERMINOLOGY

Certain terms which have been used on figs 3 - 5 require definition or comment.

Under the heading "Sample Investigation" we have, for convenience, distinguished between preparations for micropalaeontology, meaning for foraminifera, and for palynology, meaning for acid insoluble organic-walled microfossils. The term "micropalaeontology" is, however, normally used to include palynology, and it is in this wider sense that we use the word in the text.

Microfossils believed to be of little stratigraphic value have been grouped into broad taxonomic or morphologic units, e.g. *Haplophragmoides* spp. and acanthomorph acritarchs. The latter grouping has been employed for forms attributable to the subgroup Acanthomorphitae Downie, Evitt and Sarjeant 1963 of the group Acritarcha Evitt 1963. Forms referred to the genus *Tasmanites* and related genera are listed as "Tasmanitids". "Microforaminifera" denotes chitinous internal linings of the tests of small foraminifera or, in some instances perhaps, larval stages of foraminifera. "*Spherinollenites* group" includes forms referable to the species of the genus described by Couper (1958) and to *Exesipollenites tumulus* Balme 1957. All specimens with the characters of *Classopollis* were referred to the "*Classopollis torosus* group" although species other than *C. torosus* (Reissinger) Balme 1957 are probably present. Pollen grains of uncertain affinity but bearing some resemblance to Classopollis have been recorded as "Circumpolles group". Spores with the characters of Ischyosporites have been included with those referable to Klukisporites in the "Klukisporites group". All smooth-walled basically triangular trilete spores were recorded as Deltoidospora spp. Forms which could perhaps have been placed in Monosulcites were included in Cycadopites.

THE JAMESON LAND SAMPLES

Vardekløft Formation

(a) Sortehat Member

The Sortehat Member of the Vardekløft Formation consists of shales with concretionary layers and ironstones in its lower part. The upper part becomes more silty, the amount of ironstone decreases and lenses or layers of fine sand which are partially concretionary appear (Surlyk et al. 1973, pp. 32 - 33).

The microfaunas recorded from this member comprise only a few agglutinating foraminifera including Haplophragmium subaecuale and species of Haplophragmoides (fig. 4).

All 11 samples from the member were processed for the microscopic examination of their organic contents. The seven Pingeldal (North Jameson Land) samples yielded assemblages of carbonised pteridophyte spores and pollen of gymnospermous affinity, but no microplankton. The miospores are brownish-black to black in colour and show some structural break-down. Many are so degraded that they are barely recognisable as miospores. Thus some taxa were not counted because of frequent difficulties with accurate identification and a large number of forms were listed as indeterminate (fig. 3). Two of the South Jameson Land Sortehat miospore assemblages (137226 and 137206, fig. 4) are equally impoverished and poorly preserved, but a few microplankton are present in one of these (137226). The remaining two samples from South Jameson Land yielded somewhat better preserved, uncarbonised assemblages comprising numerous miospores and a few microplankton. Gymnospermous pollen grains are more abundant than "fern" spores, forms referable to the Spheripollenites group being particularly common in both samples. The occurrence of the pollen Tsugaepollenites trilobatus in the lower of the two samples (144229) and of T. dampieri in both, and in one of the Pingeldal samples, suggests that the palynofloras are not older than late Toarcian. The presence of the dinoflagellate cyst Nannoceratopsis gracilis in 144229 indicates that this sample is not younger than earliest Bathonian. We suggest, therefore, that the material we have examined from the Sortehat Member might be of Bajocian age.

Only one sample (137343) from this member, presumably from a thin sandstone, was examined petrographically (fig. 6). It is similar in composition to the sandstones of the Pelion Member (see below).

(b) Pelion Member

The Pelion Member consists of sandstones, usually micaceous, with intercalations of silty shales. There are also some thin conglomeratic horizons (Surlyk et al. 1973, p. 36). All but three (namely 100721, 144125 and 137343) of the samples examined petrographically from the Vardekløft Formation are from this member (fig. 6). Although they are predominantly fine to very fine grained sandstones, they are also locally medium grained in North Jameson Land. Quartz is the most common detrital mineral and occurs with small amounts of feldspar and mica. Most of the sandstones analysed have a well-developed carbonate cement and contain no visible porosity. The detritals are subangular to subrounded and display poor to good sorting.

Because of the coarse nature of the samples from this member, none was selected for processing for microfaunas and only one was picked for palynological examination (144111, from South Jameson Land, fig. 4). Although smooth-walled "fern" spores are common, the plant microfossil assemblage recovered is dominated by pollen of probable gymnospermous origin, bisaccate pollen and forms referable to the Spheripollenites group being particularly common. None of the taxa recorded closely defines the age of the sample, but the overall aspect of the assemblage is typical of many Middle Jurassic assemblages from Northwest Europe.

(c) Fossilbjerget Member

This member comprises silty micaceous shales with subordinate sandstone horizons (Surlyk et al. 1973, pp 37-38). The two samples from the member that were petrographically examined (100721 and 144125) are probably from thin sandstone bodies. Although the latter sample contains a considerable amount of clay, they are both petrographically similar to the sands analysed from the Pelion Member.

A few agglutinating foraminifera and one specimen of a calcareous benthonic form, recorded as Dentalina sp., were the only specimens recovered from the four samples processed for microfaunas.

One of the samples processed for palynomorphs from this member (144202) proved to be palynologically barren, and one other (137326) yielded only a few miospores. The remainder yielded palynomorph assemblages which are again dominated by pollen of probable gymnospermous affinity, bisaccate pollen grains, Cerebropollenites mesozoicus, and forms referable to the Spheripollenites group being particularly common. Tsugaepollenites dampieri is common in the Fossilbjerget section and is consistently recorded elsewhere throughout the member. Other forms usually present include Cycadopites spp., Perinopollenites elatoides, Araucariacites australis, species of Inaperturopollenites, Classopollis and Lycopodiumsporites, Osmundacidites wellmanii and smooth-walled trilete "fern" spores. The general aspect of the total miospore assemblage is typical of many assemblages from the Middle Jurassic of Northwest Europe.

Associated with these miospores are microplankton, represented by moderately abundant dinoflagellate cysts, infrequent acanthomorph acritarchs and rare microforaminifera and tasmanitids. Although numerically subordinate to the miospores, the dinoflagellate cysts are stratigraphically more valuable. The cyst assemblage of the highest sample (137329) of the member in the Olympelv section is dominated by forms attributable to Nannoceratopsis. A number of the specimens recorded are similar to N. gracilis, a characteristic middle Liassic - lowermost Bathonian form. A detailed study of the specimens is required to assess both their relationship with N. gracilis and their stratigraphic significance. With the exception of this sample, the dinoflagellate cysts recovered from this member not only confirm the Bathonian - Callovian ages previously assigned to it, but also permit the following refinements to be tentatively suggested.

1. Olympelv section (fig. 3). The occurrence of Ctenidodinium sp. in 137500 and of C. pachydermum, Scriniodinium cf. crystallinum and Gonyaulacysta cladophora in 137499 implies that these samples might be of Bathonian age. The association is similar to that described by Gocht (1970) from the German Bathonian. On the other hand, the occurrence of species of Adnatosphaeridium in 137237 is more indicative of a Callovian or younger age. It is possible, therefore, that the Bathonian - Callovian boundary lies somewhere between the horizons from which samples 137500 and 137327 were taken.

2. Fossilbjerget section (fig. 3). The occurrence of Valensiella sp. and Chytroeisphaeridia digitata in 137376 and of Ctenidodinium ornatum, Gonyaulacysta aff. jurassica and Meiourogonyaulax strongylos in 137370 indicate a Bathonian age for these samples. The presence of Hanaea, Adnatosphaeridium and Netrelytron aff. stegastum is more indicative of a Callovian age for 137377 and 137378. The Bathonian - Callovian boundary may, therefore, lie between 137376 and 137377.

3. South Jameson Land (fig. 4). Although the evidence is not entirely convincing, the palynomorph assemblage recovered from sample 137053 suggests an early Callovian age.

Olympen Formation

The Olympen Formation consists of sandstones, with some horizons of siltstone and silty shale (Surlyk et al. 1973, pp. 40 - 41) of middle - late Jurassic age. Petrographically the sandstones are similar to the Middle Jurassic sandstones mentioned above in that they contain both feldspar and mica in addition to quartz (fig. 6). Very fine to fine grained poorly to moderately sorted sands are dominant. Clay matrix is present and tends to be heavily iron-stained.

The only microfauna recovered from this formation consists of a *Haplophragmoides* assemblage from sample 137315 (fig. 3). The samples prepared for palynological examination yielded assemblages dominated by gymnospermous pollen but showing little diversity. Dinoflagellate cysts are infrequent and poorly preserved. The cysts recovered from sample 137311, in particular the association of *Gonyaulacysta cladophora*, *G. scarburghensis* and *Scriniodinium galeritum*, support an early Oxfordian age determination for the sample.

Hareelv Formation

The Hareelv Formation of South Jameson Land is composed of shales with large irregular lenses and layers of sandstone (Surlyk et al. 1973, pp. 44-47). Quartz is dominant in the only sample petrographically analysed; there are small amounts of feldspar and mica and a carbonate cement. It is similar in composition to the Raukelv samples examined.

Moderate to rich assemblages of agglutinating foraminifera, again dominated by *Haplophragmoides* spp., occur in the samples from this formation. The occurrence of *H. infracalloviensis* in sample 144133 (fig. 4) is significant in that it may suggest an early Kimmeridgian age. The taxon also occurs in sample 137463 from Milne Land which has been dated as Kimmeridgian on other evidence.

The stratigraphically highest sample palynologically analysed from the Hareelv Formation (144183, fig. 4) is characterised by a very small assemblage of indeterminate carbonised miospores. The lower samples yielded uncarbonised but still somewhat poorly preserved assemblages of miospores and microplankton. Although the assemblages are again characterised by an abundance of gymnospermous pollen, pteridophyte spores are rather more common and some assemblages (e.g. 144128 and 144133) show greater diversity than elsewhere. Dinoflagellate cysts are moderately abundant, with Gonyaulacysta cladophora and Adnatosphaeridium aemulum being locally common. The cysts recovered from samples 144114, 144115 and 144128 support an Oxfordian age determination for this material. The assemblages from the remaining samples are too poorly preserved and restricted to be of any stratigraphic value.

Raukelv Formation

The Raukelv Formation consists of cyclically alternating sandstones and shaley siltstones (Surlyk et al. 1973, pp. 49 - 53). All three samples investigated petrographically are composed of very fine to very coarse sand grains. Quartz is dominant and there are minor amounts of feldspar and mica. In the two samples without visual porosity there is a carbonate cement.

The only sample analysed for a microfauna (144154, from the Salix Dal Member; fig. 4) yielded rare specimens of Haplophragmoides spp. This sample was also prepared for palynological examination. A very small assemblage of poorly preserved carbonised miospores, most of which were not positively identified, was recovered.

THE MILNE LAND SAMPLES

The sandstones petrographically examined from Milne Land are similar to the Upper Jurassic samples from Jameson Land (Hareelv and Raukelv Formations) in that quartz is dominant, feldspar and mica are present in small quantities and carbonate cement is usually abundant. Glauconite has been noted in one of the sandstones and one of the siltstones. Two of the samples examined (137522 and 137457) are sandy limestones containing bivalves and indeterminate skeletal debris.

All nine samples processed for microfaunas and palynomorphs are from the Upper Jurassic 'shale and glauconite series'. Of the four examined for microfaunas, samples 137545 and 137450 proved to be barren, 137842 yielded Haplophragmoides sp. and 137463 produced moderate numbers of agglutinating foraminifera dominated by species of Haplophragmoides and including H. infracalloviensis (fig. 5).

The palynomorph assemblages examined contain large numbers of bisaccate and other pollen types, but "fern" spores are common in some; a few spores of probable bryophytic affinity (Stereisporites and Foraminisporis) were also recorded. Dinoflagellate cysts, acanthomorph acritarchs and tasmanitids occur generally in low numbers. It is not possible to use the palynofloras to refine the age determinations suggested on other evidence. The presence of Pareodinia nuda in sample 137426 does, however, suggest that this sample is from a post-Aulacostephanus eudoxus rather than a pre-A. eudoxus Zone. Of particular interest is the Middle Volgian occurrence of Ctenidodinium panneum; this distinctive form has hitherto only been recorded from the Upper Kimmeridgian - Portlandian of the Anglo-Paris Basin.

DEPOSITIONAL ENVIRONMENTS

The development of assemblages composed predominantly of species of the agglutinating foraminifera Haplophragmoides is almost certainly due to depositional factors. The lack of calcareous benthonic foraminifera could be due to post-depositional solution, but this is unlikely. The fact that some of the species are large and fine grained, H. infracallov-iensis for example, favours deposition in an outer sublittoral - bathyal environment. The nature of the sediments and the regional geology suggest, however, a shallow inner sublittoral environment. It is possible, therefore, that this microfaunal assemblage indicates either open marine influence in a shallow area or cold water conditions.

At best, the palynofloras recovered are only in a fair state of preservation; most are poorly preserved and in several instances highly carbonised. The general aspect of the assemblages, the relatively high ratios of miospores:dinoflagellate cysts and acanthomorph acritarchs: dinoflagellate cysts, and the usual abundance of microscopic plant debris do suggest, however, that most of the palynomorphs were deposited in shallow water near-shore marine (inner sublittoral) conditions. The results of the petrographic study indicate that the sands are also near-shore accumulations. The degree of carbonisation of the palynomorphs is more likely to be related to temperature increases associated with depth of burial than to proximity of regional metamorphism.

RESERVOIR POTENTIAL

Many of the sandstones, notably those from the Pelion Member, contain a clay matrix or a carbonate cement; consequently the reservoir properties are relatively poor. However, a few of the samples are both porous and permeable (fig. 6). It is possible, therefore, that reasonable reservoirs could be present in East Greenland, provided that the sands are thick enough. The available data suggest that the best potential reservoirs are in the Upper Jurassic, i.e. in the Raukelv and Olympen Formations of Jameson Land and perhaps in the Charcot Bugt Sandstone of Milne Land.

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APPENDIX - Authors of identified species

FORAMINIFERA

Ammobaculites agglutinans (D'ORBIGNY)

Ammobaculites cf. coprolithiformis (SCHWAGER)

Haplophragmoides infracalloviensis DAIN

Haplophragmoides subaequale (ROEMER)

Proteonina difflugiformis (BRADY)

MICROPLANKTON

aff. Acanthaulax spinosissima (DEFLANDRE)

Adnatosphaeridium aemulum (DEFLANDRE)

Adnatosphaeridium caulleryi (DEFLANDRE)

Chytroeisphaeridia chytroeides (SARJEANT)

Chytroeisphaeridia dictydia SARJEANT

Chytroeisphaeridia digitata SARJEANT

Chytroeisphaeridia pococki SARJEANT

Ctenidodinium ornatum (EISENACK)

Ctenidodinium pachydermum (DEFLANDRE)

Ctenidodinium panneum (NORRIS)

Dictyopyxidia areolata (COOKSON & EISENACK)

Endoscrinium oxfordianum (SARJEANT)

aff. Fromea elongata BEJU

Gonyaulacysta ambigua (DEFLANDRE)

Gonyaulacysta cladophora (DEFLANDRE)

Gonyaulacysta eisenacki (DEFLANDRE)

* Gonyaulacysta eisenacki oligodentata (COOKSON & EISENACK)

Gonyaulacysta jurassica (DEFLANDRE)

Gonyaulacysta aff. *jurassica sensu* SARJEANT

Gonyaulacysta cf. *mamillifera sensu* GITMEZ

Gonyaulacysta nuciformis (DEFLANDRE)

Gonyaulacysta scarburghensis SARJEANT

Hystrichogonyaulax cf. *nealei* SARJEANT

Hystrichosphaeridium costatum DAVEY & WILLIAMS

Komewuia glabra COOKSON & EISENACK

Leiofusa jurassica COOKSON & EISENACK

Leptodinium cf. *subtile* KLEMENT

Meiourogonyaulax staffinensis GITMEZ

Meiourogonyaulax strongylos SARJEANT

Nannoceratopsis gracilis ALBERTI

Nannoceratopsis pellucida DEFLANDRE

Netrelytron stegastum SARJEANT

Organism A. GITMEZ

Pareodinia ceratophora DEFLANDRE

Pareodinia nuda (DOWNIE)

Pareodinia aff. *prolongata* SARJEANT

Scriniodinium cf. *crystallinum* (DEFLANDRE)

Scriniodinium galeritum (DEFLANDRE)

Scriniodinium subvallare SARJEANT

Sirmiodinium grossi ALBERTI

Systematophora orbifera KLEMENT

Tenua pilosa (EHRENBERG)

MIOSPORES

Araucariacites australis COOKSON

Baculatisporites comaumensis (COOKSON)

Cerebropollenites mesozoicus (COUPER)

* *Classopollis torosus* (REISSINGER)

Concavisporites jurienensis BALME

Coronatispora valdensis (COUPER)

Cycadopites nitidus (BALME)

Cycadopites cf. *subgranulosus* (COUPER)

* *Densoisporites velatus* WEYLAND & KRIEGER EMEND. KRASNOVA

Duplexisporites problematicus (COUPER)

Eucommiidites troedssonii ERDTMAN

Foveosporites canalis BALME

Gleicheniidites apilobatus BRENNER

Gleicheniidites senonicus ROSS

Granulatisporites cf. *subgranulosus* (COUPER)

Inaperturopollenites turbatus BALME

Leptolepidites cf. *equatibossus* (COUPER)

Lycopodiacidites rugulatus (COUPER)

Lycopodiumsporites austroclavatidites (COOKSON)

Lycopodiumsporites clavatoides COUPER

Lycopodiumsporites reticulumsporites (ROUSE)

Marattisporites scabratus COUPER

Neoraistrickia truncata (COOKSON)

Osmundacidites wellmanii COUPER

Parvisaccites enigmatus COUPER

Perinopollenites elatoides COUPER

Reticulisporites semireticulatus (BURGER)

Sestrosporites pseudoalveolatus (COUPER)

* *Spheripollenites subgranulatus* COUPER

Staplinisporites caminus (BALME)

Stereisporites antiquasporites (WILSON & WEBSTER)

* *Stereisporites stereoides* (POTONIÉ & VENITZ)

Todisporites minor COUPER

Tsugaepollenites dampieri (BALME)

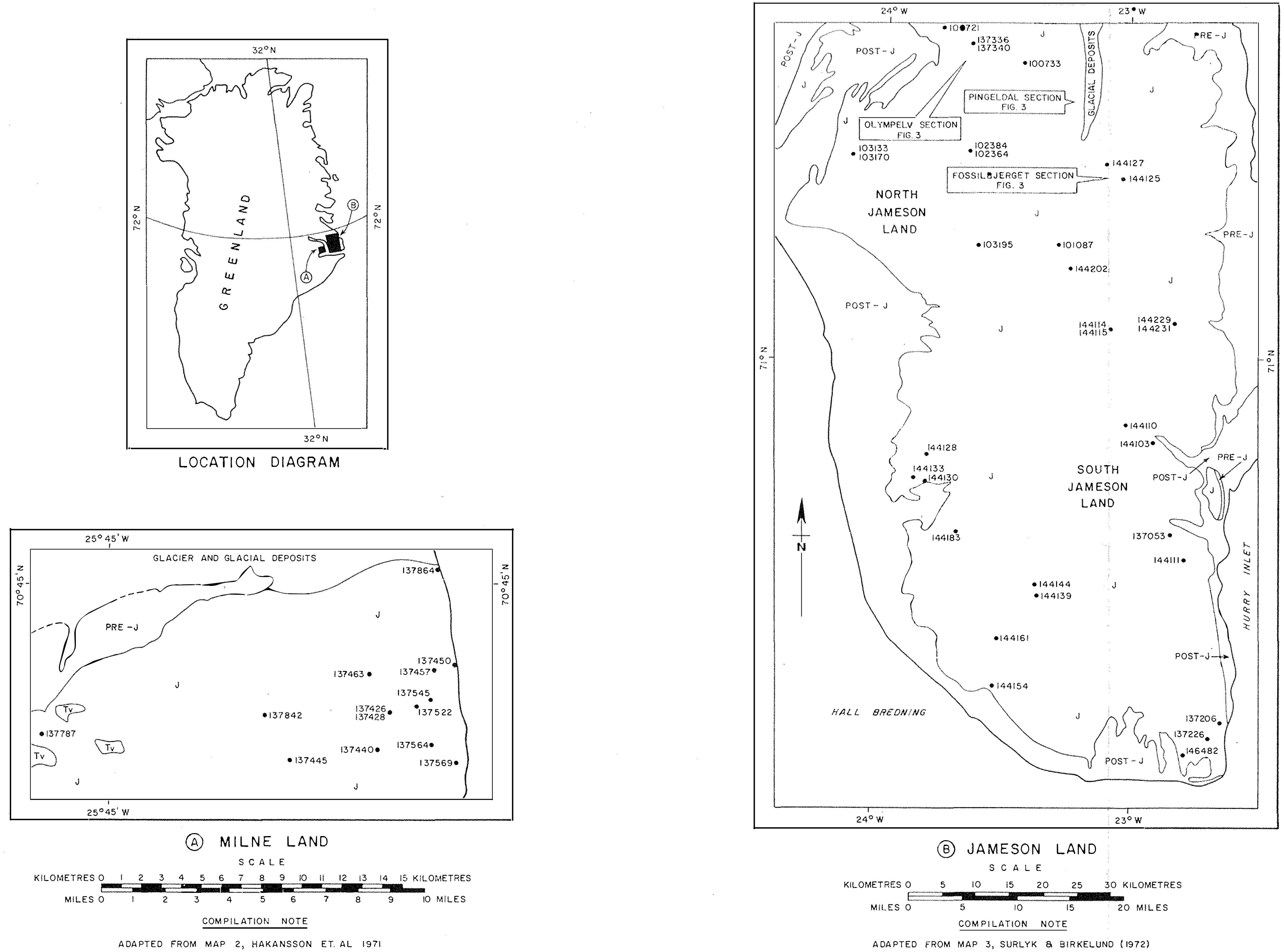
Tsugaepollenites segmentatus (BALME)

Tsugaepollenites trilobatus (BALME)

Undulatisporites cf. major DANZÉ & LAVEINE

Uvaesporites argenteaeformis (BOLKHOVITINA)

Vitreisporites pallidus (REISSINGER)



LEGEND

Plateau basalts	Tv	Jurassic	J
Post-Jurassic sediments	POST-J	Pre-Jurassic rocks	PRE-J

Sample locality ●

FIGURE 1

MAPS SHOWING SAMPLE LOCALITIES IN JAMESON LAND AND MILNE LAND

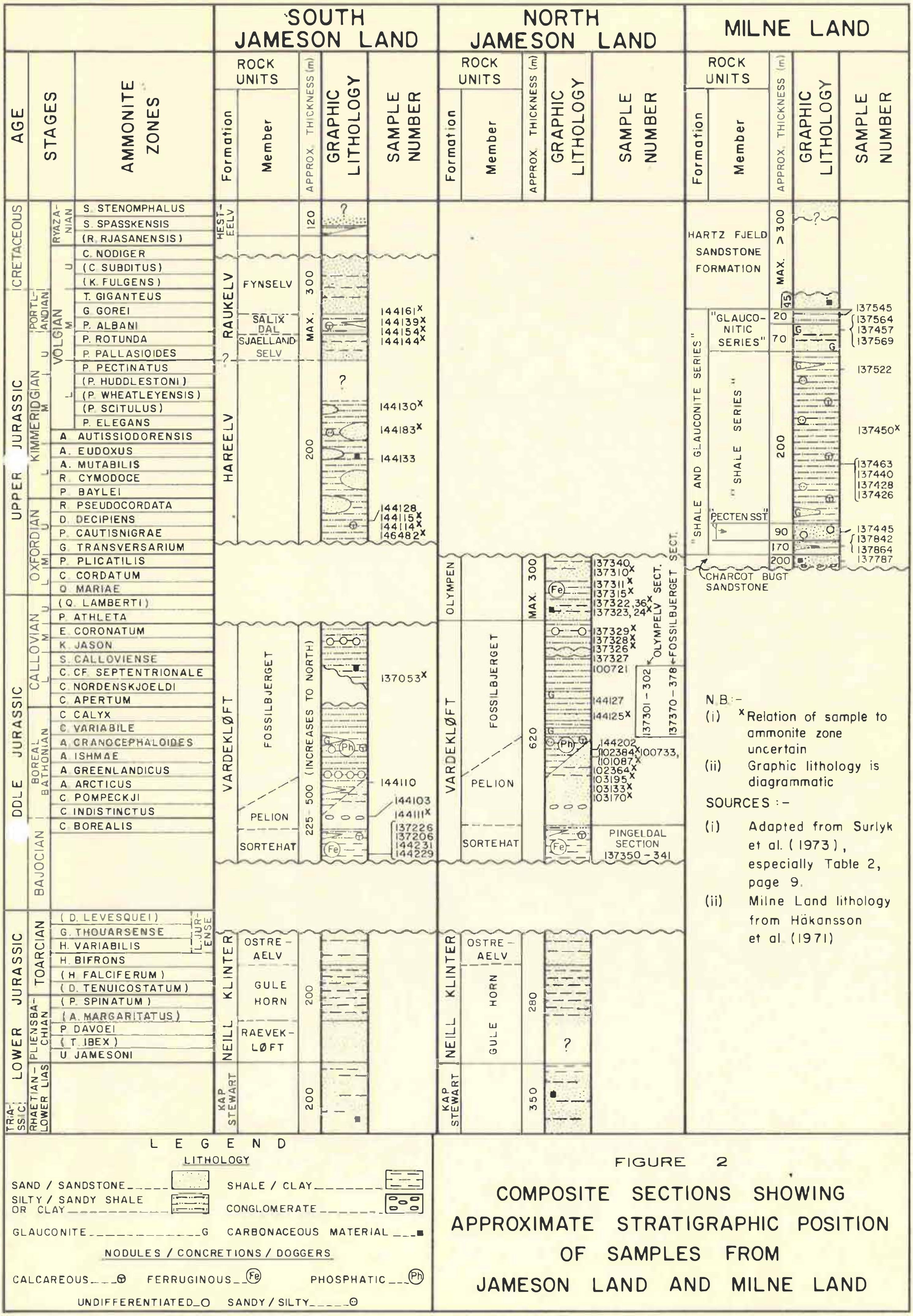
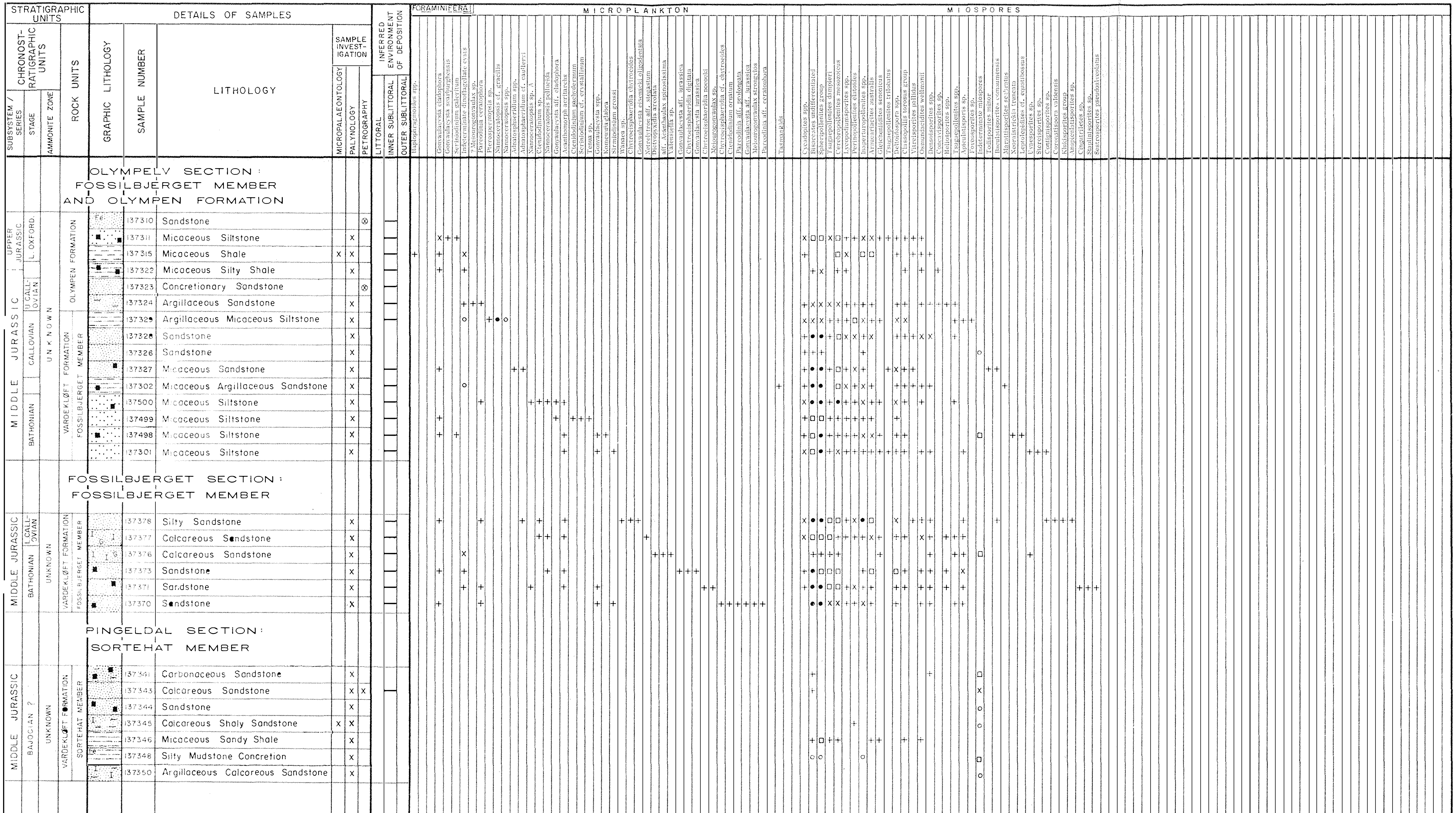


FIGURE 2

COMPOSITE SECTIONS SHOWING APPROXIMATE STRATIGRAPHIC POSITION OF SAMPLES FROM JAMESON LAND AND MILNE LAND



L E G E N D

LITHOLOGICAL ABBREVIATIONS AND SYMBOLS

Glauconite .... G
Iron / Ironstone .... Fe
Carbonaceous material .... ■
Nodules or Concretions .... o

STUDY OF SAMPLES

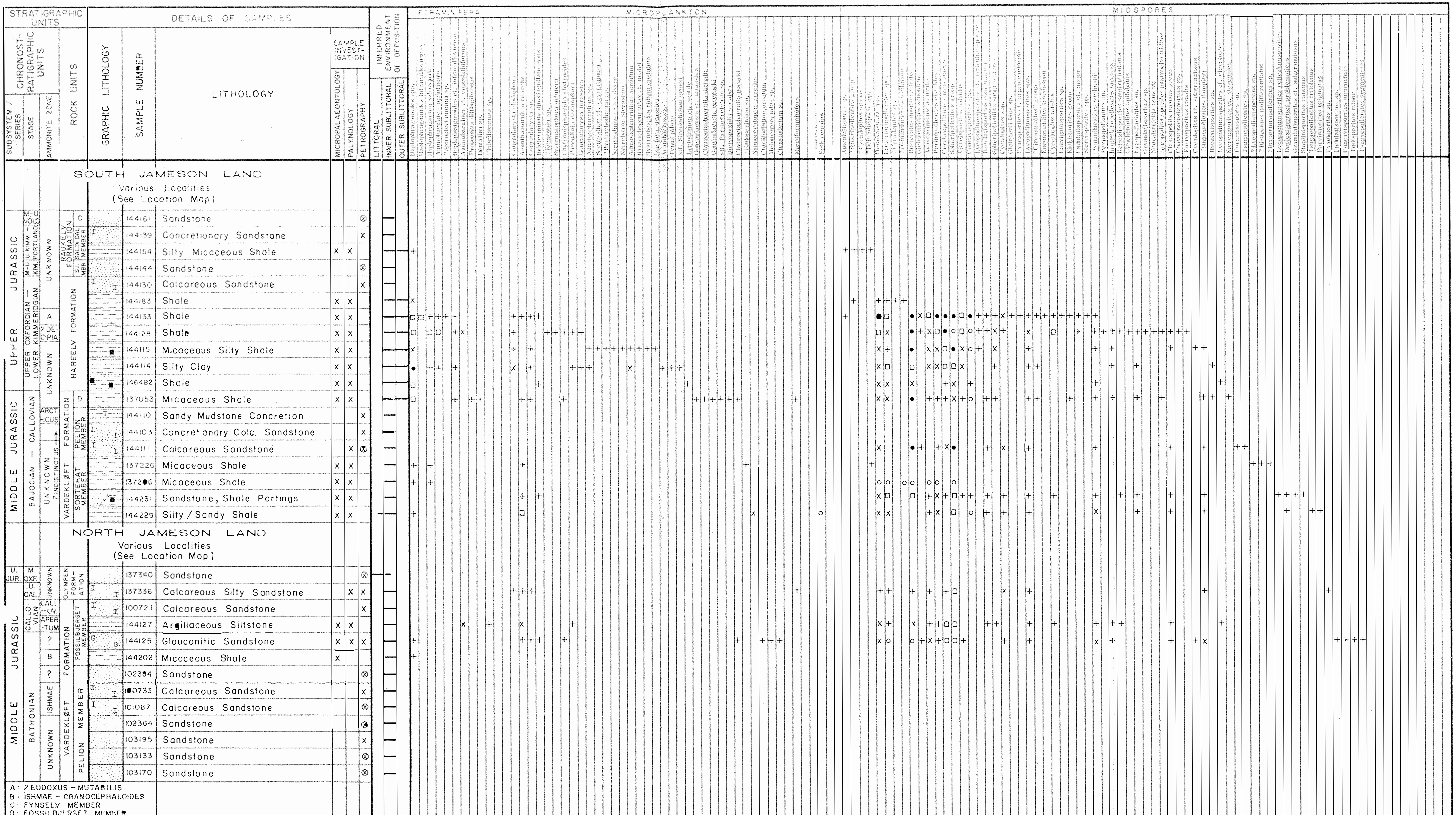
Sample examined x
Porosity / Permeability analysis (For details see Figure 6) .... ⊗

ABUNDANCES

1 - 5 .... +
6 - 20 x
21 - 50 .... □
> 50 .... ●
Present but not counted .... o

FIGURE 3

STRATIGRAPHIC CHART OF MIDDLE TO UPPER JURASSIC SAMPLES FROM THREE SECTIONS IN NORTH JAMESON LAND



L E G E N D

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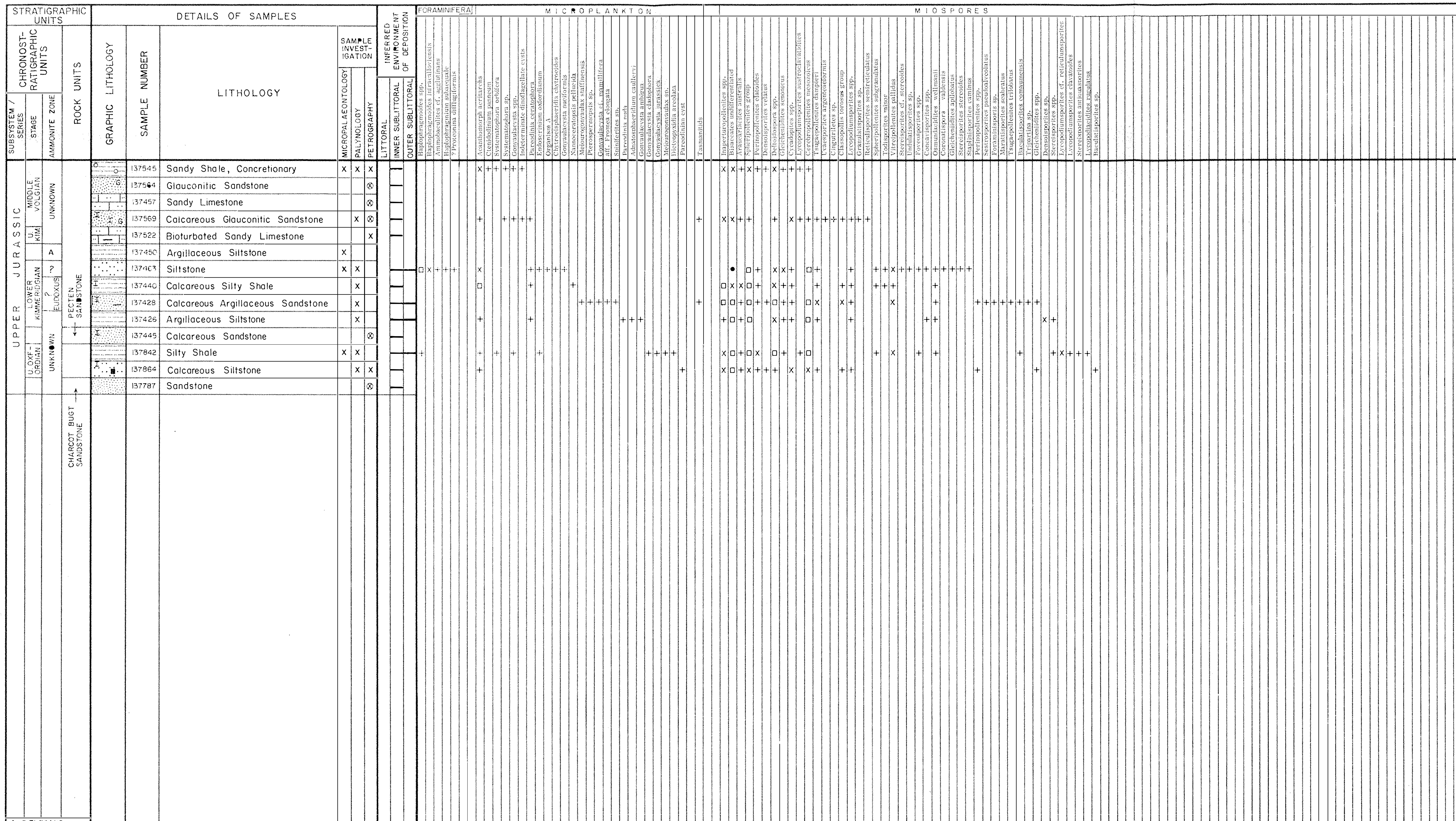
> 50 .... ●
Present but not counted .... o

FIGURE 4

STRATIGRAPHIC CHART OF MIDDLE AND UPPER JURASSIC SAMPLES FROM SCATTERED LOCALITIES IN JAMESON LAND



LEGEND

LITHOLOGICAL ABBREVIATIONS AND SYMBOLS

Glauconite	G
Iron / Ironstone	Fe
Carbonaceous material	■
Nodules or Concretions	o

STUDY OF SAMPLES

Sample examined	x
Porosity / Permeability analysis (For details see Figure 6)	⊗

ABUNDANCES

1 - 5	+
6 - 20	x
21 - 50	□
> 50	●
Present but not counted	o

FIGURE 5

STRATIGRAPHIC CHART OF UPPER JURASSIC SAMPLES FROM VARIOUS LOCALITIES IN MILNE LAND

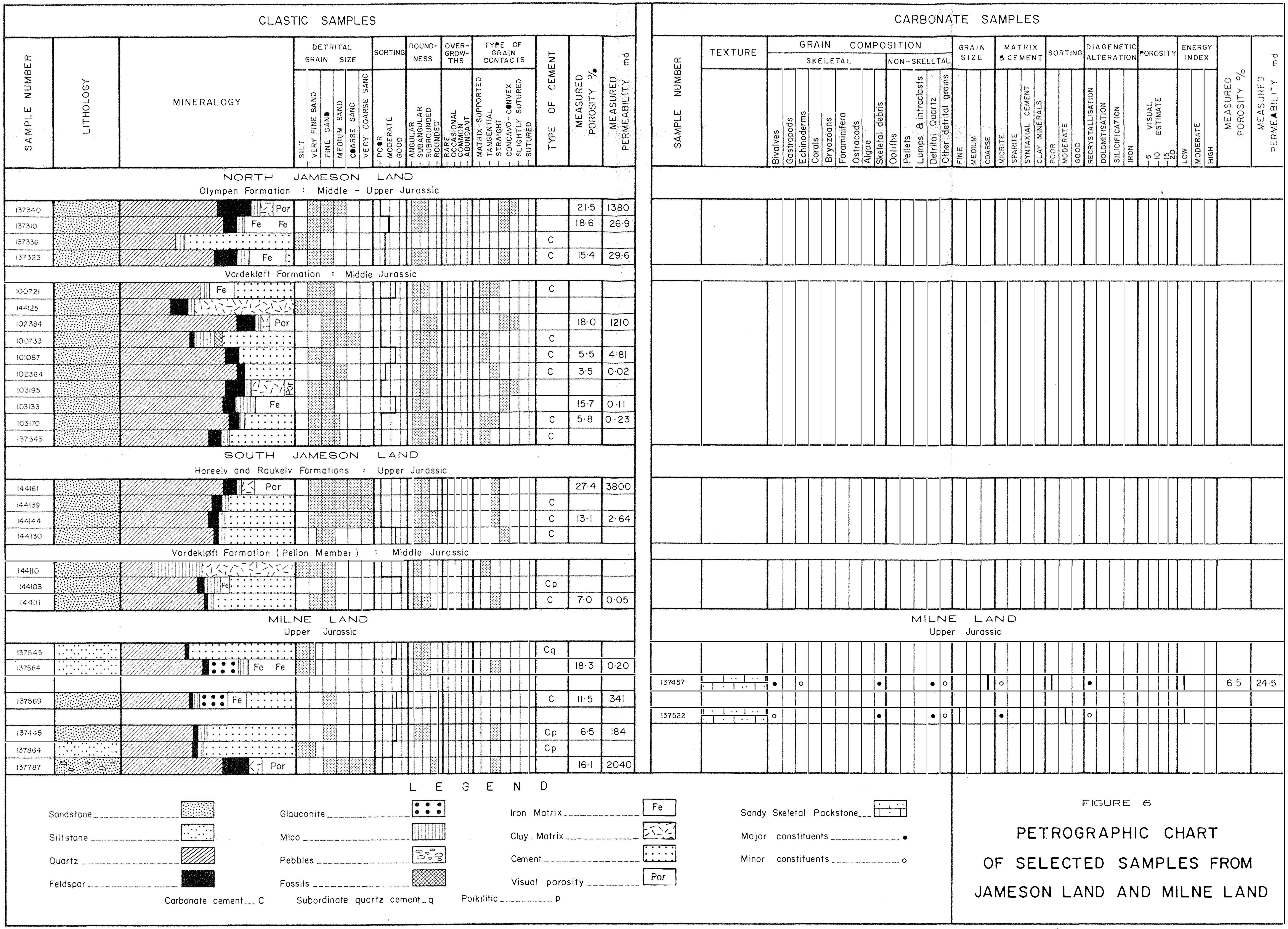


FIGURE 6

PETROGRAPHIC CHART OF SELECTED SAMPLES FROM JAMESON LAND AND MILNE LAND