GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

BULLETIN 259

UPPER JURASSIC–LOWER CRETACEOUS DINOFLAGELLATE ASSEMBLAGES FROM ARCTIC CANADA

W.W. Brideaux and M.J. Fisher

1976

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

UPPER JURASSIC–LOWER CRETACEOUS DINOFLAGELLATE ASSEMBLAGES FROM ARCTIC CANADA

Critical readers

J. A. Jeletzky
D. W. Morrow

Technical Editor

E. J. W. Irish

GEOLOGICAL SURVEY
BULLETIN 259

UPPER JURASSIC–LOWER CRETACEOUS DINOFLAGELLATE ASSEMBLAGES FROM ARCTIC CANADA

W.W. Brideaux and M.J. Fisher

Available by mail from

Printing and Publishing
Supply and Services Canada,
Ottawa, Canada K1A 0S9,

from the Geological Survey of Canada
601 Booth St., Ottawa, K1A 0E8

and at Canadian Government Bookstores:

HALIFAX
1683 Barrington Street

MONTREAL
640 St. Catherine Street West

OTTAWA
171 Slater Street

TORONTO
221 Yonge Street

WINNIPEG
393 Portage Avenue

VANCOUVER
800 Granville Street

or through your bookseller

Catalogue No. M42-259

Price: Canada: $6.00
Other countries: $7.20

Price subject to change without notice

PREFACE

This report describes a new Upper Jurassic-lowermost Cretaceous dinoflagellate assemblage from northern Canada and relates it to previously described miospore and microplankton assemblages and macrofossil zonal schemes. The assemblage, termed the *borealis* assemblage, has been recognized in fifteen surface and subsurface sections on the northern Canadian mainland and in the Canadian Arctic Archipelago.

Such detailed paleontological studies are basic to the provision of precise dating and correlation of the rocks that make up the geological framework of Canada. They are of immediate value for surface and subsurface stratigraphy and ultimately contribute toward the estimation of potential abundance and probable distribution of energy resources available to Canada.

D. J. McLaren,
Director General,
Geological Survey of Canada.

Ottawa, March 8, 1976

CONTENTS

Illustrations

Page

ABSTRACT

This paper describes the taxonomy, biostratigraphy and geographic occurrence within the Canadian Boreal Region of an Upper Jurassic-lowermost Cretaceous (Oxfordian-Berriasian) dinoflagellate cyst assemblage. This association, termed the *borealis* assemblage, is intermediate in age between assemblages described from older Jurassic rocks and those present in the upper Lower Cretaceous (Neocomian) in these regions.

Data have been obtained from three surface and four subsurface sections from the northern Interior Plains-Richardson Mountains regions and from four seismic shot-point locations and seven subsurface sections in the Arctic Islands (Sverdrup Basin).

Five new dinoflagellate cyst taxa are described: *Psaligonyaulax dualis*, *Pareodinia capillosa*, *Pareodinia borealis*, *Hologinella spinosigibberosa*, and *Lanterna saturnalis*. One other species, *Gonyaulacysta* sp. cf. *G. cladophora* (Deflandre) Dodekova, also is associated with the *borealis* assemblage. The ranges of the new taxa have been determined by comparison with published macrofaunal zonal schemes and from published ranges of selected spore, pollen and dinoflagellate taxa.

RÉSUMÉ

La présente étude décrit la taxonomie, la biostratigraphie et la répartition géographique, à l'intérieur de la région boréale du Canada, d'un assemblage de kystes de dinoflagellés datant du Jurassique supérieur et du Crétacé inférieur (Oxfordien-Berriasien). Cette association, qualifiée d'assemblage *borealis*, est d'âge intermédiaire entre les assemblages décrits à partir des roches plus vieilles du Jurassique et ceux des roches de la fin du Crétacé inférieur (Néocomien) dans cette région.

Les données proviennent de trois coupes de surface et de quatre coupes du sous-sol de régions du nord des plaines Intérieures et des chaînons Richardson, ainsi que de quatre points de tir sismique et de sept coupes du sous-sol de l'archipel Arctique (bassin Sverdrup).

Les auteurs décrivent cinq nouveaux taxons de kystes de dinoflagellés: *Psaligonyaulax dualis*, *Pareodinia capillosa*, *Pareodinia borealis*, *Hologinella spinosigibberosa* et *Lanterna saturnalis*. Une autre espèce, *Gonyaulacysta* sp. cf. *G. cladophora* (Deflandre) Dodekova, est également associée à l'assemblage *borealis*. Les gammes des nouveaux taxons ont été déterminées à la suite de comparaisons avec des schémas de zones macro-fauniques et à partir des gammes de taxons de spores, de pollens et de dinoflagellés déjà publiés.

UPPER JURASSIC - LOWER CRETACEOUS DINOFLAGELLATE ASSEMBLAGES FROM ARCTIC CANADA

INTRODUCTION

Dinoflagellate cyst assemblages of Jurassic and Early Cretaceous ages are known to be widespread in the Canadian Arctic Archipelago and in the Mackenzie Delta region of the northern Canadian mainland, but there is very little published information (Brideaux, 1975). The literature comprises two papers. Pocock (1972) treats acritarch and dinoflagellate cysts from the Awingak and Deer Bay Formations on Amund Ringnes Island. Johnson and Hills (1973) describe dinoflagellate and acritarch assemblages from Lower to lower Upper Jurassic strata of the Savik Formation and its lithologic equivalents on Axel Heiberg and Ellesmere Islands.

In this paper the writers describe an assemblage of dinoflagellate cysts that has been found in Upper Jurassic to basal Cretaceous (Oxfordian to Berriasian) strata throughout the Mackenzie Delta and the central and western Canadian Arctic Archipelago. The distinctive morphology and widespread occurrence of the species in this assemblage, named herein the *Pareodinia borealis* assemblage or, more simply, the *borealis* assemblage, make them of value to palynostratigraphy for defining the position of the Jurassic-Cretaceous boundary and determining the occurrence of Upper Jurassic and basal Cretaceous strata in marine sections. It will be demonstrated that the known basal occurrence of elements of the *borealis* assemblage is geologically contemporaneous or, perhaps, a little younger than the upper geologic occurrence of assemblages described by Johnson and Hills (1973). This contribution, therefore, contains the first comprehensive published information on uppermost Jurassic dinoflagellate cyst assemblages from northern Canada.

CURATION OF MATERIALS

All samples from outcrops and wells used in this investigation and stored at the Institute of Sedimentary and Petroleum Geology have been assigned Geological Survey of Canada location numbers (C-numbers). Palynologic slides prepared by the Institute of Sedimentary and Petroleum Geology and slides prepared by other organizations that do not contain holotypes or figured specimens are stored in the collection of the Institute, 3303 - 33rd Street N.W., Calgary, Alberta, Canada T2L 2A7. Slides containing holotypes or figured specimens are stored in the collections of the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8. Other palynologic slides (marked with *) are stored in the collections of Robertson Research (North America) Limited, 501 Cleveland Crescent S.E., Calgary, Alberta, Canada T2G 4R8.

Manuscript received: December 16, 1974
Authors' addresses:
W.W. Brideaux: Institute of Sedimentary and Petroleum Geology
3303 - 33rd Street N.W.
Calgary, Alberta T2L 2A7
M.J. Fisher: Robertson Research International Limited
"Ty'n-Y-Coed"
Llanrhos, Llandudno
LL 30 1SA
North Wales, U.K.

ACKNOWLEDGMENTS

The writers are pleased to thank the Directors of Robertson Research (NA) Ltd., Diego Henao of Panarctic Oils Limited, Aquitaine Company of Canada, and Atlantic Richfield Canada for their kind assistance in providing samples or other pertinent information. Discussions, regarding the morphology and taxonomy of the described assemblages, with E. J. Kidson (Amoco Production Company Research Center, Tulsa, Oklahoma) and with J. K. Lentin, Calgary, and W. A. S. Sarjeant of the University of Saskatchewan, Saskatoon, Saskatchewan, were greatly appreciated.

Thanks are due, also, to D. W. Morrow and J. A. Jeletzky, both of the Geological Survey of Canada, for reviewing the original manuscript and providing constructive suggestions for its improvement.

LOCATION AND STRATIGRAPHY OF SAMPLED SECTIONS

The *borealis* assemblage has been encountered in a number of surface exposures and subsurface sections on the mainland, in the Mackenzie Delta region (Fig. 1), and in the Canadian Arctic Archipelago (Fig. 2). Control sections in the Delta region include surface exposures and cored material and ditch cuttings from subsurface sections. In the archipelago, surface control is lacking. Subsurface sections, with the exception of air-drilled cores from several seismic shot-point holes, are represented only by ditch cuttings. Consequently, the age of rocks containing the *borealis* assemblage in the Delta region can be determined from faunal evidence and relevant palynologic data. In the Arctic Islands, almost all of the age determinations are based on palynology; faunal evidence plays a secondary role. Relevant information on the lithostratigraphy and age of the sampled strata is presented in the following pages.

MACKENZIE DELTA-RICHARDSON MOUNTAINS REGIONS

Information from three surface sections in the Delta region, located in the northern part of the

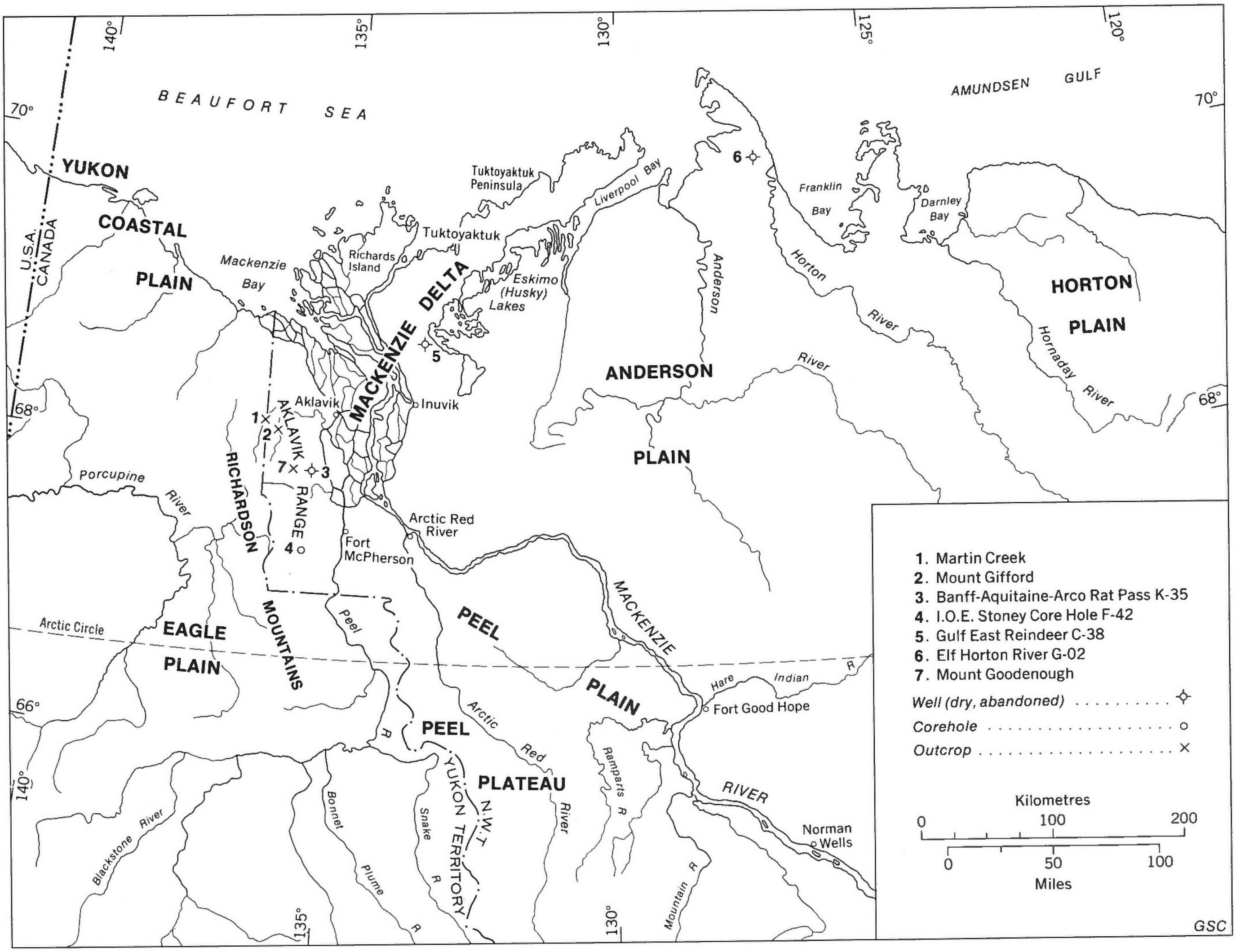


FIGURE 1. Location of sampled sections, northern Interior Plains and Richardson Mountains regions, District of Mackenzie

Aklavik Range near or on the eastern slope in the Richardson Mountains, is used in this investigation. The section at Martin Creek (NTS 107B; Lat. 68°12'N, Long. 135°37'W) contains an almost complete sequence of Upper Jurassic and basal Lower Cretaceous rocks. The section on the eastern slope of Mount Gifford (NTS 107B; Lat. 68°08'N, Long. 135°27.5'W) exposes the Jurassic-Cretaceous boundary (Jeletzky, 1958). A section sampled at Mount Goodenough (NTS 106M; Lat. 67°56'N, Long. 135°25'W) consists of Upper Berriasian strata unconformably overlain by upper Hauterivian to Aptian strata (not described in detail herein; Brideaux, unpublished data).

Subsurface sections are located in the following wells and structure test hole:

Banff-Aquitaine-Arco Rat Pass K-35 well (NTS 106M; Lat. 67°54'43"N, Long. 135°21'57"W)

Elf Horton River G-02 well (NTS 97C; Lat. 69° 51'23"N, Long. 127°15'57"W)

Gulf East Reindeer C-38 well (NTS 107B; Lat. 68°47'10"N, Long. 133°39'15"W)

IOE Stoney Core Hole F-42 structure corehole (NTS 106M; Lat. 67°21'23"N, Long. 135°38'43"W)

Subsurface sections penetrated by these wells and by the corehole include lithologic units, which often are unnamed, but may be lateral subsurface equivalents of surface exposures, and which carry elements of the *borealis* assemblage.

Martin Creek

Well-exposed sections of Jurassic and Lower Cretaceous rocks occur along both the north and south banks of Martin Creek, and on its main tributaries, near the confluence of the creek with Willow River. The samples used in this investigation were collected from three sections on the south bank of the creek, and are referred to a composite section constructed in Figure 3.

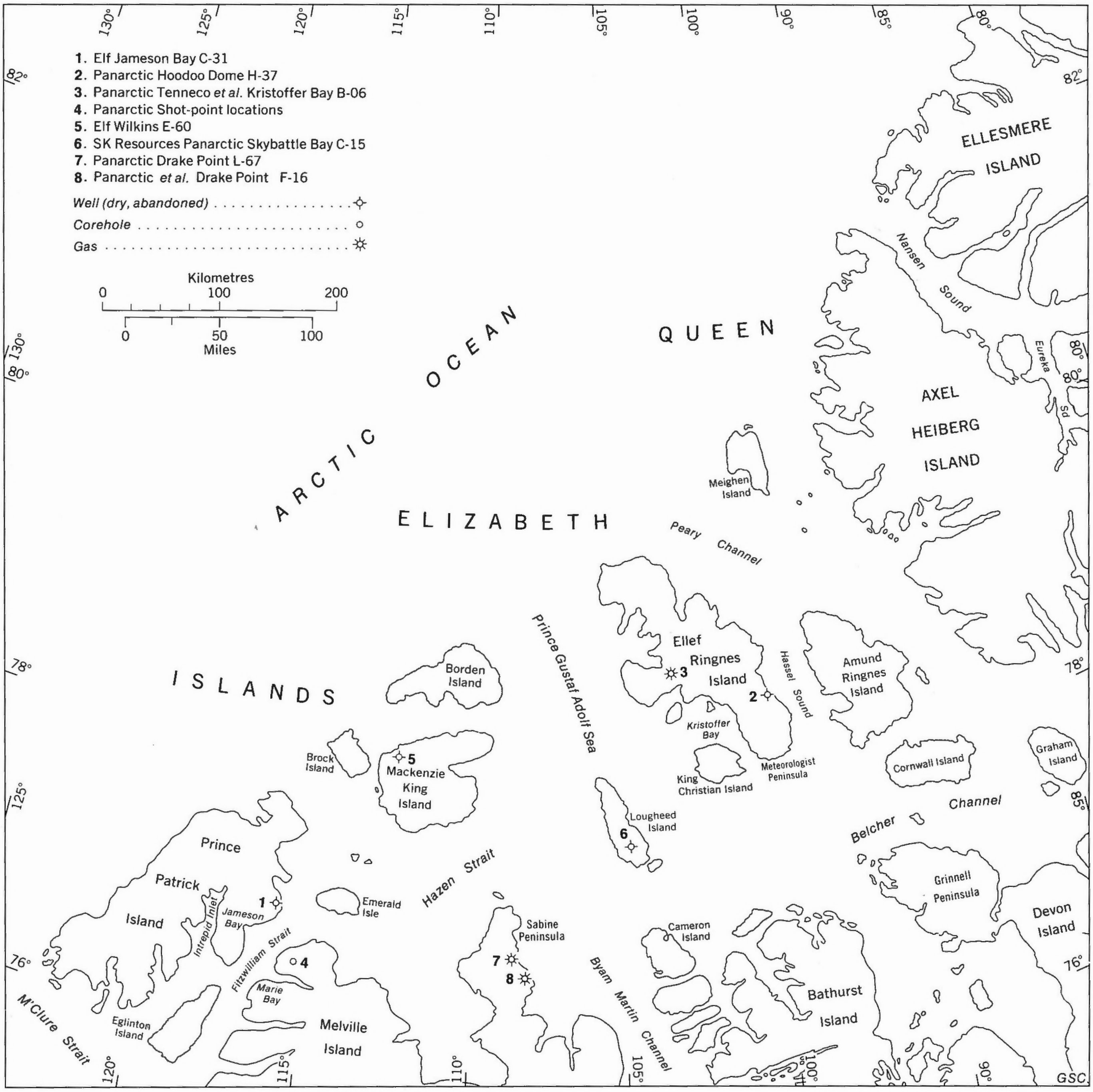


FIGURE 2. Location of sampled sections, western and central Canadian Arctic Archipelago, District of Franklin

The samples come from the Husky Formation and the base of the Buff sandstone unit of the Lower sandstone division (Jeletzky, 1958, 1960, 1967, 1972, pers. com., 1974). Within the Husky Formation, the following members and composite thicknesses were recognized: Lower member, 542 feet (165 m); Arenaceous member, 60 feet (18 m); Red-weathering shale member, 82 feet (25 m); and Upper member, 98 feet (30 m). The total thickness of rocks recognized and assigned to the Husky Formation at this location on Martin Creek is thus 782 feet (238 m). Only the basal 7 feet (2 m) of the Buff sandstone unit were investigated by the writers for the purposes of this paper, although at least 220 feet (67 m) of this unit, 70 feet (21 m) of the Bluish grey shale unit and 110 feet (34 m) of the White sandstone unit were measured and sampled at this locality by the senior author.

The basal 130 feet (40 m) of the composite section of the Husky Formation can be assigned with confidence to the *Buchia concentrica* sensu lato zone

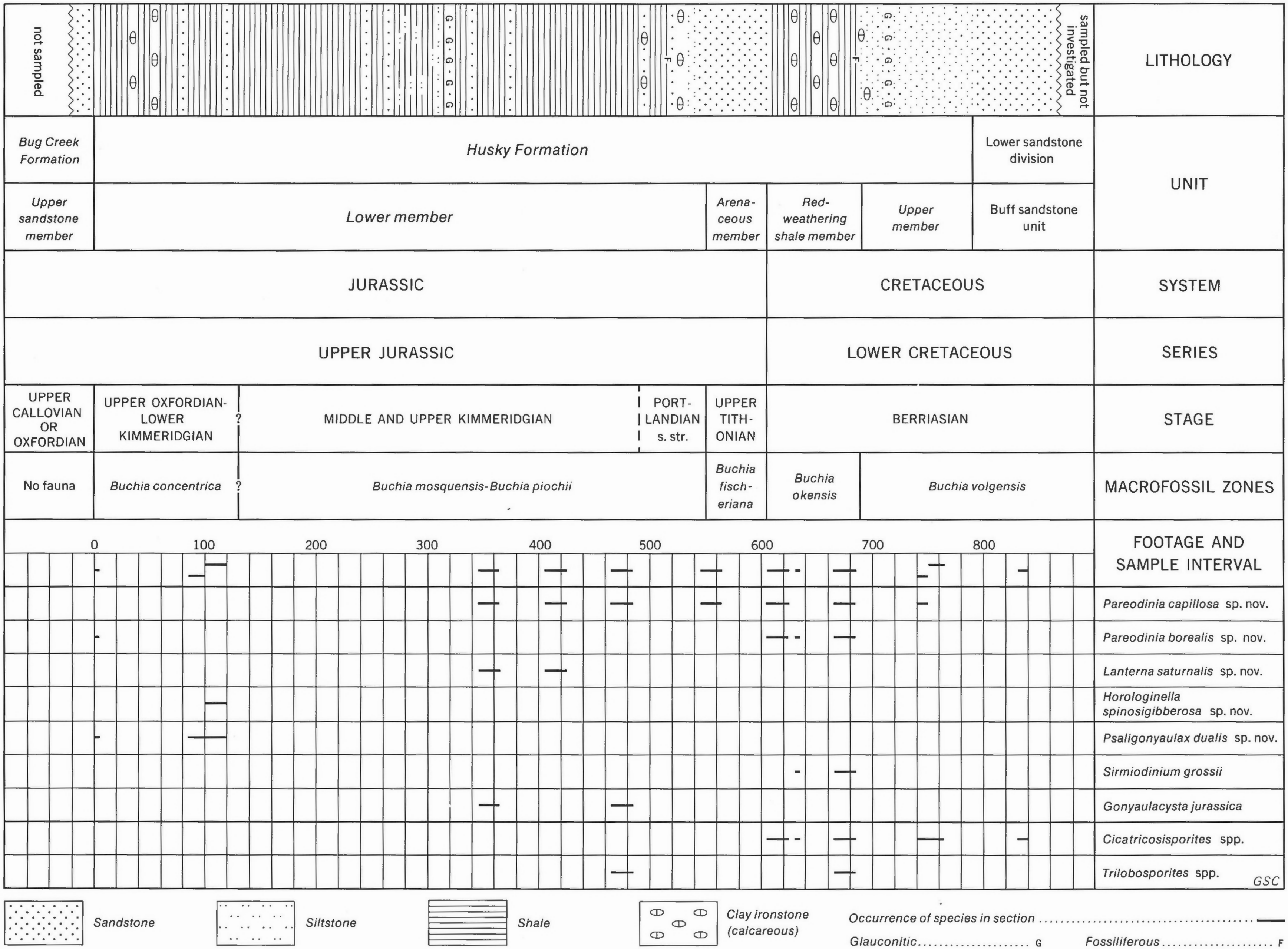


FIGURE 3. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the surface section along Martin Creek, Aklavik Range, District of Mackenzie

(Jeletzky, 1967, p. 17, 36) of Late Oxfordian to Early Kimmeridgian age. The remaining 412 feet (126 m) of the Lower member of the Husky Formation fall within the *Buchia mosquensis* sensu lato and *Buchia piochii* sensu lato zones (Jeletzky, 1967, p. 34, 35) of Middle Kimmeridgian to Portlandian age *sensu stricto* (*sensu* Jeletzky, 1967, 1967; *see* also Fig. 3, and discussion in a later part of this paper). The Arenaceous member is of Late Tithonian age (*Buchia fischeriana* sensu lato zone of Jeletzky, 1967, p. 34) and the Red-weathering shale member and Upper member are of Early and, in part, Late Berriasian age (Jeletzky, 1958, p. 6; 1967, p. 33, 34).

The basal beds of the Buff sandstone unit are of Late Berriasian age, and the upper beds of this unit are at least as young as Early Valanginian (Jeletzky, 1960, p. 7; 1961, p. 6, 11, 12; 1972).

These ages are valid for rock units in the immediate area around Martin Creek and Mount Gifford, but should not be construed as necessarily valid for lateral lithological equivalents in the various subsurface sections mentioned below.

A list of the samples investigated from the composite Martin Creek section follows. Footages given are composite footages, with the top of the Bug Creek Formation taken as datum.

Husky Formation

Lower member: *Buchia concentrica* sensu lato zone.

C-29106	0-5 ft	(0-1.5 m)
C-29112	83-100 ft	(26-30 m)
C-29113	100-120 ft	(30-37 m)

Lower member: *Buchia mosquensis* sensu lato and *B. piochii* sensu lato zones.

C-29127	342-362 ft	(104-110 m)
C-29130	402-422 ft	(123-129 m)
C-29133	464-484 ft	(140-146 m)

Arenaceous member: *Buchia fischeriana* sensu lato zone (in part).

C-29138	544-564 ft	(163-169 m)

Red-weathering shale member: *Buchia okensis* zone.

C-29141	604-624 ft	(184-191 m)
C-29145	636-638 ft	(193.9-194.5 m)
C-29144	644-684 ft	(202-208 m)

Upper member: *Buchia* n. sp. aff. *volgensis* zone.

C-29149	744-753 ft	(227-229 m)
C-29150	752-764 ft	(229-233 m)

Lower sandstone division

Buff sandstone unit: *Buchia* n. sp. aff. *volgensis* zone.

C-29155	830-837 ft	(253-255 m)

Mount Gifford

Well-exposed sections of the Husky Formation occur in the numerous steep-sided banks of streams which dissect the eastern slope of Mount Gifford. A total of 80 feet (24 m) of section was collected on the north bank of one of these southeast-flowing streams, approximately 1,800 feet (549 m) south of the summit of Mount Gifford.

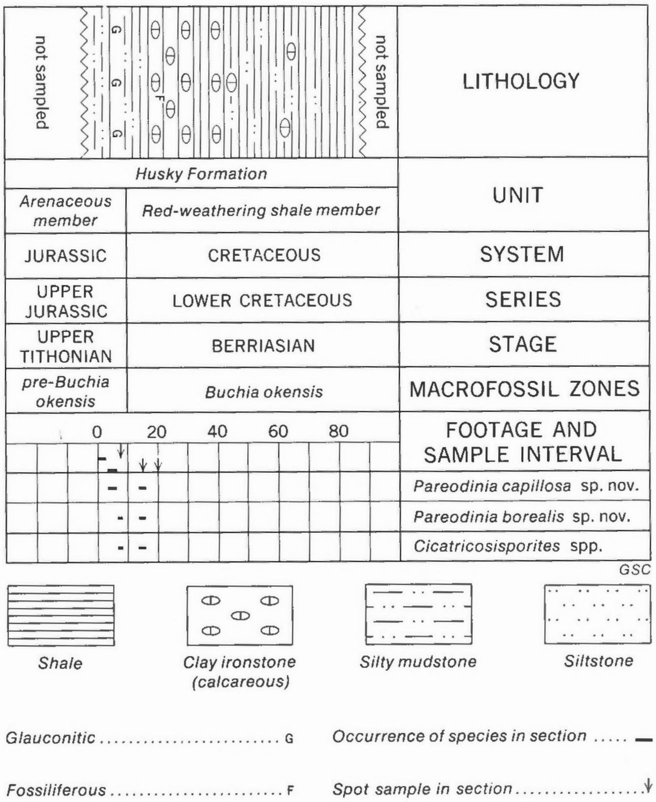


FIGURE 4. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the surface section on Mount Gifford, Aklavik Range, District of Mackenzie

The basal 10 feet (3 m) of the section (Fig. 4) are assigned to the Arenaceous member of the Husky Formation; the overlying 70 feet (21 m) belong to the Red-weathering shale member. Jeletzky (1958, 1960, 1961) refers the Arenaceous member to the Upper Tithonian and the Red-weathering shale member to the Lower Berriasian. The contact between the two members is gradational and is placed at the top of a bed, 6 inches (0.15 m) thick, of dark green, glauconitic, sandy siltstone which occurs at the top of the Arenaceous member.

The samples investigated from this section are listed below; the base of the measured section is taken as datum.

Husky Formation

Arenaceous member: Upper Tithonian, pre-*Buchia okensis* zone.

C-19759	0-3 ft	(0-1 m)

C-19760	3-8 ft	(1-2.4 m)
C-19761	8-8.5 ft	(2.4-2.6 m)

Red-weathering shale member: *Buchia okensis* zone.

C-19762	15 ft	(4.6 m)
C-19763	20 ft	(6.1 m)

Banff-Aquitaine-Arco Rat Pass K-35 well

The Banff-Aquitaine-Arco Rat Pass K-35 well (Rat Pass K-35) was drilled in 1970, and is located about six miles (9.6 km) southeast of the summit of Mount Goodenough, just south of Goodenough Creek. The well was drilled to a total depth of 6,004 feet (1830 m) and penetrated 1,920 feet (585 m) of strata that are assigned a Late Jurassic-Early Cretaceous age (Brideaux *in* Barnes *et al.*, 1974; D. W. Myhr, pers. com., 1974; unpubl. information) before reaching rocks of pre-Mesozoic age (Fig. 5).

Sample quality is poor from the top to a depth of about 460 feet (140 m) (D. W. Myhr, pers. com., 1974) and the age of these rocks based on palynology is somewhat problematical. However, a few productive samples from between the depths of 70 and 460 feet (21-140 m) yield palynologic evidence for an Aptian-Albian age (Brideaux *in* Barnes *et al.*, 1974, p. 6 and Fig. 4) and suggest that the strata penetrated are possible time and lithologic equivalents of parts of the surface Albian Shale-siltstone and Upper sandstone divisions of Jeletzky (1958 and later). Strata between the depths of 460 and 1,100 feet (140-335 m) probably, in part, are lithological equivalents of the Upper sandstone division and the Upper member of the Upper shale-siltstone division (Jeletzky, 1958 and later). Strata between the depths of 1,100 and 1,690 feet (335-515 m) are assigned to the Upper shale-siltstone division, and mainly to the Lower member (D. W. Myhr, pers. com., 1974; authors' determinations). Strata penetrated between 1,690 and 1,890 feet (515-576 m) comprise an unnamed shale unit, and between 1,890 and 1,920 feet (576-585 m) an unnamed basal sandstone unit. The shale unit may be a subsurface lithological equivalent of some part of the Husky Formation. Surface exposures on the Mount Goodenough escarpment described by Jeletzky (1958, 1960) and collected by one of us (W.W.B.) parallel the lithologic succession in the Rat Pass K-35 well above the depth of 1,690 feet (515 m) despite the surface expression of considerable faulting in the area (Jeletzky, 1960, Fig. 2). Palynologic evidence from sidewall cores and cuttings samples from the Rat Pass K-35 well in the interval between the depths of 1,690 and 1,920 feet (515-585 m) indicates the presence of a marked unconformity at 1,690 feet (515 m), and suggests that Hauterivian rocks of the Upper shale-siltstone division equivalents rest on strata

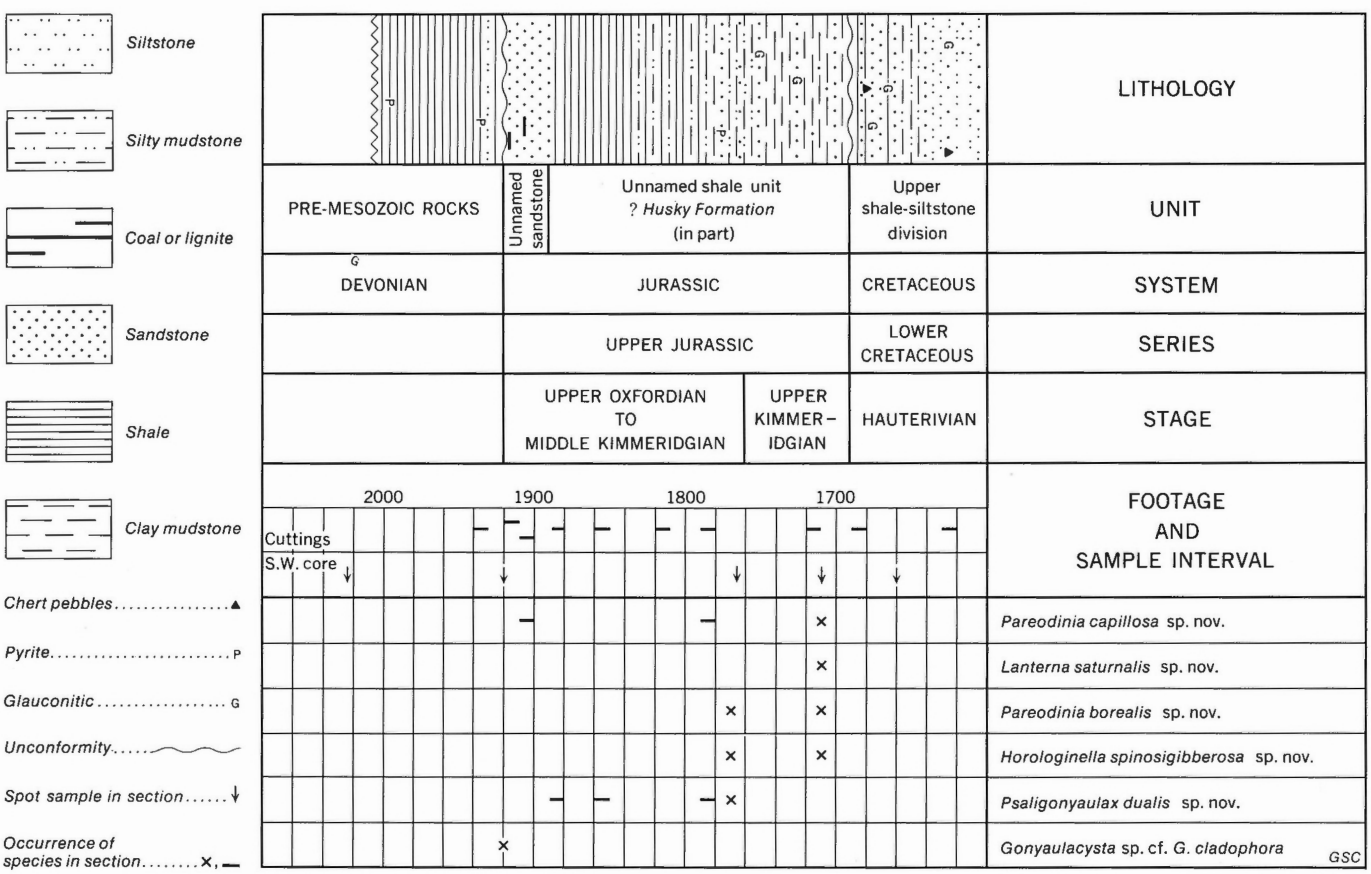


FIGURE 5. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the Banff-Aquitaine-Arco Rat Pass K-35 well, Aklavik Range, District of Mackenzie

which may be as old as Kimmeridgian or Portlandian *sensu* Jeletzky, and certainly no younger than basal Berriasian. These strata rest in turn, unconformably on strata of pre-Mesozoic age. Discussion of the palynologic evidence is presented in a later part of this paper. In the surface exposures at Mount Goodenough, rocks of the lower member of the Upper shale-siltstone division rest unconformably on rocks of the Upper member of the Husky Formation, and the unconformity is marked by a persistent chert-pebble conglomerate (Jeletzky, 1958; pers. com., 1972; Brideaux, unpubl.). Hence the basal Mesozoic part of the subsurface succession, in this well, does not appear comparable to the basal part of the nearby surface succession.

Brideaux (*in* Barnes *et al.*, 1974, p. 6 and Fig. 4) outlines a preliminary biostratigraphic subdivision of the well, and gives the following ages for stated depths, based on palynology:

70-1,090 ft (21-332 m) depth: Albian.
1,090-1,180 ft (332-360 m) depth: Aptian?-Albian.
1,180-1,360 ft (360-415 m) depth: Barremian-?Aptian.
1,360-1,530 ft (415-466 m) depth: Neocomian, probably Hauterivian.
1,530-1,690 ft (466-515 m) depth: Neocomian, probably pre-Hauterivian.
1,690-1,920 ft (515-585 m) depth: Neocomian, pre-Hauterivian.

New information and work in progress indicate that some of these age determinations must be revised. The discussion above for the interval between the depths of 1,690 and 1,920 feet (515-585 m) and the palynologic evidence for the revision are presented in this paper in a later section.

The following sample intervals were used in this study from the Rat Pass K-35 well:

Ditch cuttings

C-12625	1,620-1,630 ft	(494-497 m)
C-12627	1,680-1,690 ft	(512-515 m)
C-12629	1,710-1,720 ft	(521-524 m)
C-12631	1,780-1,790 ft	(543-546 m)
C-12632	1,810-1,820 ft	(552-555 m)
C-12633	1,850-1,860 ft	(564-567 m)
C-12634	1,880-1,890 ft	(573-576 m)
C-12636	1,900-1,910 ft	(579-582 m)
C-12637	1,910-1,920 ft	(582-585 m)
C-12638	1,930-1,940 ft	(589-591 m)

Sidewall cores

C-12624	1,600 ft	(487.6 m)
C-12626	1,660 ft	(506.0 m)
C-12628	1,710 ft	(521.2 m)
C-12630	1,765 ft	(538.0 m)
C-12635	1,920 ft	(585.2 m)
C-12639	2,025 ft	(617.2 m)

IOE Stoney Core Hole F-42

IOE Stoney Core Hole F-42 (Fig. 6) is a conventionally cored structure test hole drilled in 1967

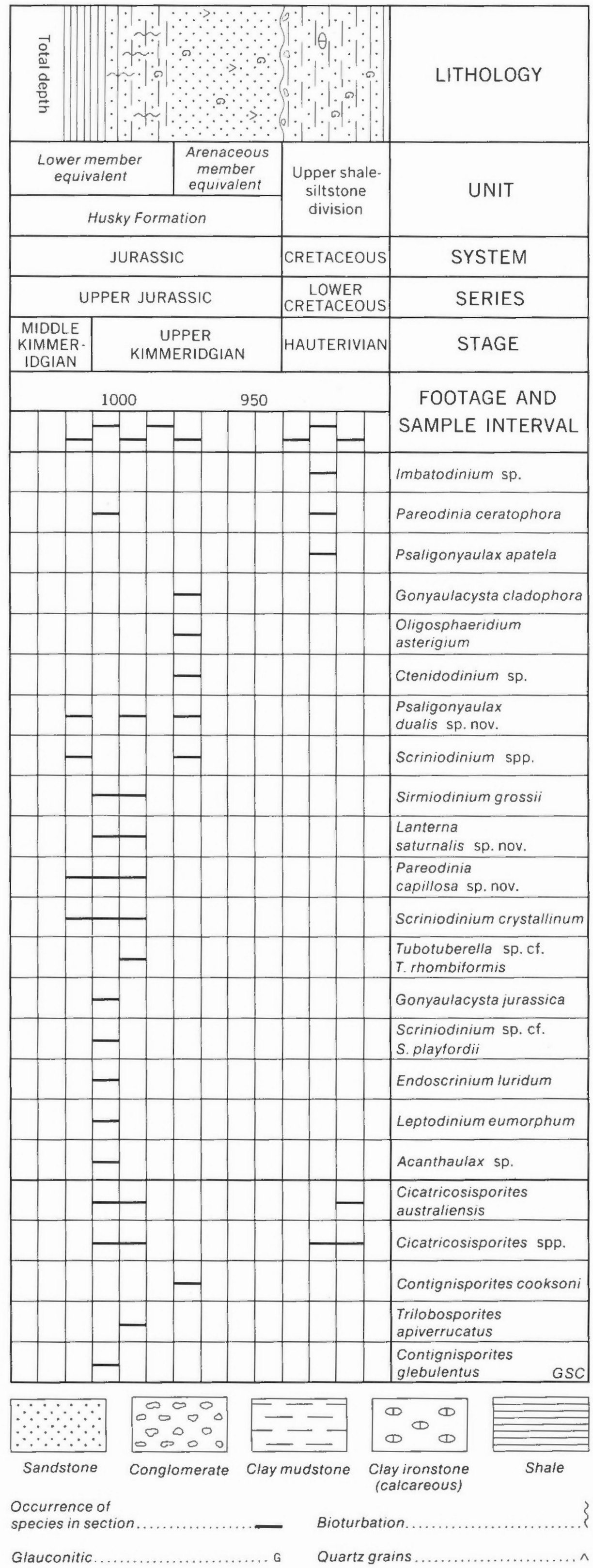


FIGURE 6. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the IOE Stoney Core Hole F-42, Stoney Creek, District of Mackenzie

at a location some eighteen miles (28.9 km) west-southwest of Fort McPherson, District of Mackenzie, near the Yukon Territory border. The well was spudded in rocks belonging to the Albian shale-siltstone division of Jeletzky (1960) and penetrated rocks belonging to the Albian shale siltstone division, the Upper sandstone division, and Upper shale-siltstone divisions, and subsurface lithological equivalents of the Arenaceous member and Lower members of the Husky Formation (Jeletzky, 1960, 1967; D. W. Myhr, pers. com., 1974; D. K. Norris, pers. com., 1974). The well reached a total depth of 1,020 feet (311 m).

The part of the well of greatest interest for this investigation comprises the basal 80 feet (24.3 m) of the section. Strata assigned to subsurface equivalents of the Arenaceous member occur in the interval between 940 and 980 feet (287-298 m). A basal unit of interbedded sandstone and mudstone grading to shale, considered to be an equivalent of the Lower member, occurs in the interval between 980 and 1,020 feet (298-311 m).

Jeletzky (*in* Norford *et al.*, 1971, p. 4) recognizes rocks of Albian age at a depth of 209 feet (64 m), and rocks of Hauterivian to Aptian age at depths of 420 and 560 feet (128 and 171 m), based on macrofossils. Chamney (*in* Norford *et al.*, 1971, p. 2, 3) gives a Barremian age for rocks between the depths of 725 and 730 feet (221-223 m), a Barremian-Hauterivian age for rocks between 900 and 910 feet (274-277 m), and a Neocomian age for rocks between 1,010 and 1,020 feet (308-311 m), based on microfauna.

Brideaux (*in* Norford *et al.*, 1971, p. 5-7) assigned ages ranging from Jurassic-Cretaceous to Early Cretaceous to selected samples. A more detailed study of the dinoflagellate assemblages in core samples from this corehole (Brideaux, unpublished) suggests that the following ages may be assigned to rocks at stated depths: 20 to 400 feet (6-122 m), Albian; 400 to ?680 feet (122-?207 m), Aptian; ?680 to 835 feet (?207-255 m), Barremian; 835 to 940 feet (207-287 m), Hauterivian; and 940 to 1,020 feet (287-311 m), Late Jurassic (*see* Fig. 6 and discussion in section on Biostratigraphy).

Samples investigated for this paper from the corehole are listed below:

C-10728	835-840 ft	(254.5-256.0 m)
C-10729	845-850 ft	(257.6-259.1 m)
C-10730	855-860 ft	(260.6-262 m)
C-10732	875-880 ft	(266.7-268 m)
C-10733	890-900 ft	(271-274 m)
C-4344	900-910 ft	(274-277 m)
C-10734	910-920 ft	(277-280 m)
C-30190	920-930 ft	(280-283 m)
C-30191	930-940 ft	(283-286 m)
C-30192	970-980 ft	(296-299 m)
C-30193	980-990 ft	(299-302 m)
C-10735 & C-30194	990-1,000 ft	(302-305 m)
C-10736 & C-30195	1,000-1,010 ft	(305-308 m)
C-4345 & C-30196	1,010-1,020 ft	(308-311 m)

Elf Horton River G-02 well

The Elf Horton River G-02 well, completed early in 1970, was drilled to a total depth of 8,130 feet (2478 m). The well is located a few miles southwest of the mouth of the Horton River on Franklin Bay in northern Anderson Plain (Fig. 1). The well was spudded in Lower Cretaceous strata and penetrated 1,820 feet (555 m) of Lower Cretaceous and, in part, Upper Jurassic rocks (Yorath *et al.*, in press) assigned to the Horton River and Langton Bay Formations (Fig. 7). Yorath *et al.* (in press) give the following thicknesses for these lithologic units in the well: Horton River Formation, 770 feet (235 m); Langton Bay Formation, 1,050 feet (320 m), the upper 400 feet (122 m) of which are assigned to the Crossley Lakes Member, and the lower 650 feet (198 m) to the Gilmore Lake Member.

Brideaux and McIntyre (in press) and Yorath *et al.* (in press) discuss the ages of these formations and members in outcrop sections along the Horton River. The Horton River Formation is of Middle Albian age, the Crossley Lakes Member of Aptian to Middle Albian age, and the Gilmore Lake Member of Aptian age. Brideaux (GSC Paleontology Report No. WWB-1-1972) assigned the interval, between the depths of 1,100 and 1,530 feet (335-466 m) in the Elf Horton River G-02 well (basal Crossley Lakes Member and upper Gilmore Lake Member), an Aptian-Early(?) Albian age based on palynology, and the interval between 1,530 and 1,820 feet (466-555 m) (lower part of the Gilmore Lake Member), a Berriasian to Valanginian age (*see* also Yorath *et al.*, in press). The age of the rocks below the marked hiatus at a depth of 1,530 feet (466 m) (Yorath *et al.*, in press) must be considered older, based on new information generated by study of the dinoflagellate assemblages (Brideaux, unpubl. information; this paper). The rocks contained in the interval between the depths of 1,530 and 1,820 feet (466-555 m) are no younger than Berriasian and may be as old as Late? Oxfordian-Kimmeridgian. Further discussion of the age of this interval is presented in another section of this paper.

The following ditch cutting sample intervals were used in this investigation:

Langton Bay Formation

Crossley Lakes Member

C-12520	1,100-1,200 ft	(335-366 m)

Gilmore Lake Member

C-12521	1,180-1,200 ft	(360-366 m)
C-12522	1,200-1,220 ft	(366-372 m)
C-12523	1,290-1,300 ft	(393-396 m)
C-12524	1,380-1,390 ft	(421-424 m)
C-12525	1,430-1,450 ft	(436-442 m)
C-12526	1,530-1,540 ft	(466-469 m)
C-12527	1,550-1,560 ft	(472-475 m)
C-12528	1,600-1,630 ft	(488-497 m)
C-12529	1,650-1,670 ft	(503-509 m)
C-12530	1,680-1,700 ft	(512-518 m)
C-12531	1,760-1,770 ft	(536-539 m)
C-12532	1,800-1,810 ft	(549-552 m)

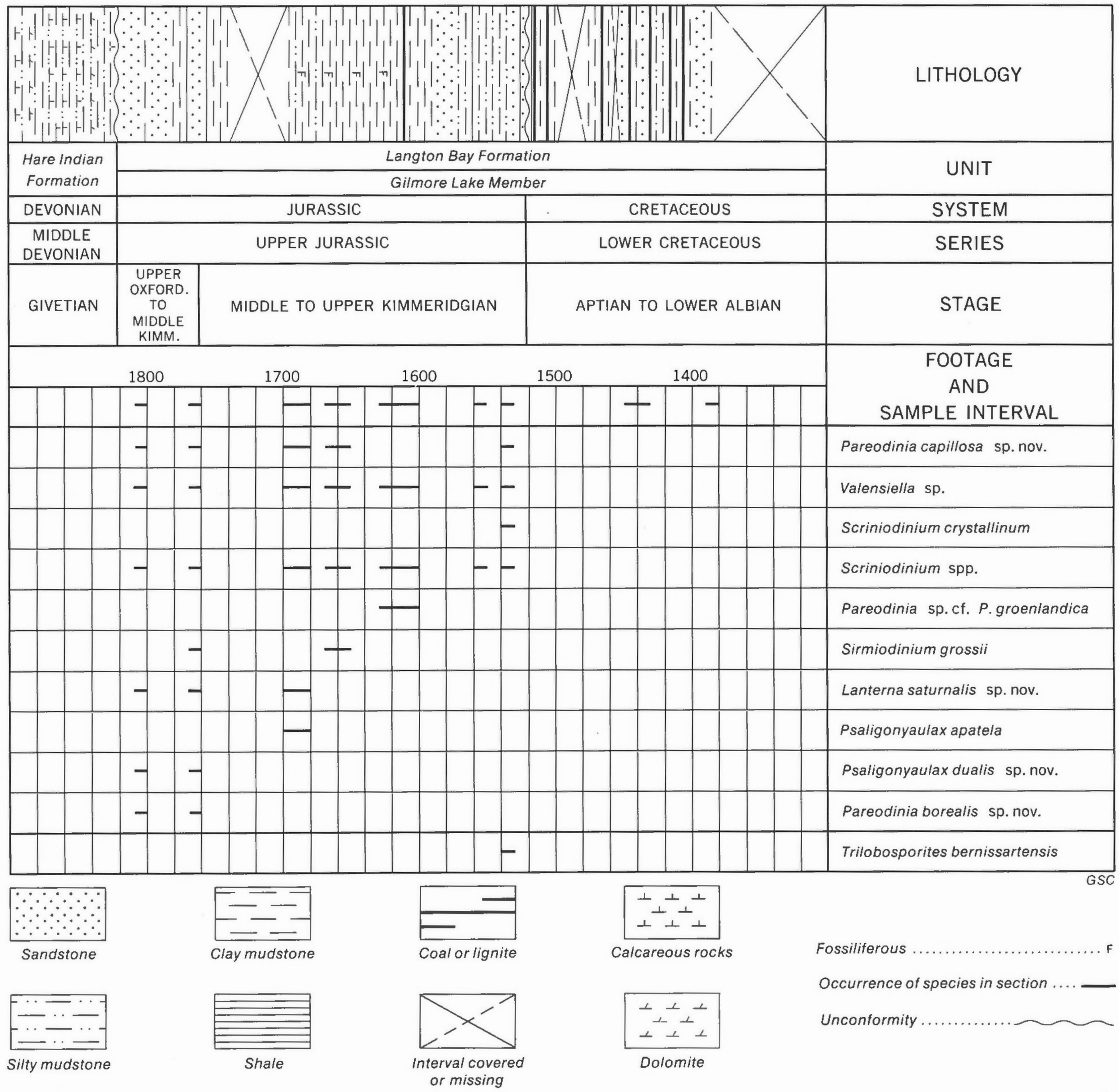


FIGURE 7. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the Elf Horton River G-02 well, northern Anderson Plain, District of Mackenzie

Gulf East Reindeer C-38 well

The Gulf East Reindeer C-38 well was completed in 1970 and reached a total depth of 8,506 feet (2593 m) (Gulf Oil Canada Ltd., 1970). The well is located about 30 miles (48.2 km) north of Inuvik, District of Mackenzie, and just southwest of the Eskimo (Husky) Lakes. The well was spudded in strata of Tertiary age and penetrated 4,200 feet (1280 m) of Tertiary and upper Mesozoic strata before reaching rocks of pre-Mesozoic age (Chamney, 1973). Strata assigned to the Husky Formation, or its subsurface lithologic equivalent in this well, occur between the depths of 3,910 and 4,200 feet (1192-1280 m) (D. W. Myhr, pers. com., 1974). The samples investigated in this well come from Core No. 1 taken from the interval between the depths of 3,922 and 3,951 feet (1195-1204 m). The lithology of the core comprises dark grey to brown, micromicaceous, occasionally carbonaceous, shale with thin interbeds of light grey, fine-grained, calcareous to argillaceous sandstone. The sandstone is locally crossbedded and shows evidence of bioturbation (D. W. Myhr, pers. com., 1974).

Palynologic residues were examined from the following footages in the core:

*	3,922-3,927 ft	(1195-1197 m)
*	3,923 ft	(1196 m)
*	3,937-3,941 ft	(1200-1201 m)

*	3,939 ft	(1200.6 m)
*	3,942 ft	(1201.5 m)
*	3,949 ft	(1203.7 m)
*	3,951 ft	(1204.2 m)

CANADIAN ARCTIC ARCHIPELAGO (SVERDRUP BASIN)

The *borealis* assemblage occurs also in a number of subsurface sections in the Canadian Arctic (Fig. 2), mainly in ditch cuttings, but also in core samples from several seismic shot-points. Suitable control samples from surface exposures were not available from the Arctic regions during the course of this investigation.

Diverse palynological assemblages, essentially similar to those described from sections in the Mackenzie Delta (this paper; unpubl. information), have been recorded in three wells:

Elf Jameson Bay C-31 (NTS 89B; Lat. 76°40'12"N, Long. 116°43'45"W; southeastern Prince Patrick Island);

Panarctic Hoodoo Dome H-37 (NTS 69E; Lat. 78°06'27"N, Long. 99°45'48"W; southeastern Ellef Ringnes Island);

Panarctic Tenneco *et al.* Kristoffer Bay B-06 (NTS 69F; Lat. 78°15'01"N, Long. 102°32'25"W; southern Ellef Ringnes Island).

In addition, these assemblages are represented also by relatively impoverished associations in the following wells:

Elf Wilkins E-60 (NTS 79C; Lat. 77°59'19"N, Long. 111°21'45"W; northern Mackenzie King Island).

Sun King Resources Panarctic Skybattle Bay C-15 (NTS 79D; Lat. 77°14'12"N, Long. 105°05'57"W; southwestern Lougheed Island).

Panarctic Drake Point L-67 (NTS 79B; Lat. 76° 26'37"N, Long. 108°55'23"W; Sabine Peninsula, northeastern Melville Island).

Panarctic *et al.* Drake Point F-16 (NTS 79B; Lat. 76°25'17"N, Long. 108°36'15"W; Sabine Peninsula, northeastern Melville Island).

Finally, core samples obtained by air-drill were made available for this study by Panarctic Oils Limited from Seismic Line 2, shot-points 15, 16, 17 and 18, located (Fig. 11b) on northwestern Melville Island, north of Marie Heights (NTS 89A; Lat. 76°21' to 76°23'N; Long. 115°13' to 115°15'W).

Elf Jameson Bay C-31 well

The Elf Jameson Bay C-31 well, drilled in 1971 to a total depth of 8,327 feet (2538 m), is located on southeastern Prince Patrick Island near Jameson Bay on Fitzwilliam Strait. The well was spudded in an alternating succession of sandstone, shale and siltstone of the middle member of the Mould Bay Formation (Fig. 8) and penetrated 5,270 feet (1606 m) of Mesozoic strata before reaching rocks of Paleozoic age. The middle member of the Mould Bay Formation is underlain at a depth of about 500 feet (152 m) by the lower member, comprising grey-brown shale grading into dark grey shale below 700 feet (213 m). The shale persists to a depth of 930 feet (283 m), where it grades into coarse-grained white sandstone with thin coaly and silty interbeds, assigned to the upper member of the Wilkie Point Formation. This lithology persists to a depth of 1,450 feet (442 m).

The section penetrated in the Elf Jameson Bay C-31 well is correlative with the outcrop succession described in the vicinity by Tozer and Thorsteinsson (1964, p. 130-132, 138-141) based on outcrops between Intrepid Inlet and Fitzwilliam Strait. Here the Wilkie Point Formation is about 560 feet (171 m) thick and composed of grey to reddish brown to white sandstone. A composite section of the overlying Mould Bay Formation in this region (Tozer and Thorsteinsson, 1964) indicates that three members can be distinguished: a lower shale member; a middle sandy member; and an upper shale member. Tozer and Thorsteinsson (1964) give a total thickness for the Mould Bay in this region of at least 400 feet (122 m), the middle member being about 160 feet (49 m), and the lower member at least 150 feet (46 m) thick. Thus the total thickness of the two lower members of Mould Bay Formation in outcrop is apparently about one-third the thickness of those members encountered in the Elf Jameson Bay subsurface section. The total thickness of strata penetrated by the Elf Jameson Bay well and assigned to the Wilkie Point Formation also is considerably greater.

In outcrop, the basal beds of the Wilkie Point Formation are of early Bajocian age. The upper beds are of Late Bathonian age (Frebold *in* Tozer and Thorsteinsson, 1964, p. 131, 132). Macrofaunas indicating a Late Tithonian age were identified 100 feet (30 m) above the base of the Mould Bay Formation in the lower member as well as in the middle member in this area (Jeletzky *in* Tozer and Thorsteinsson, 1964, p. 140). Palynologic evidence from samples from the Elf Jameson Bay C-31 well indicates that the age of the strata penetrated between the depths of 100 and 690 feet is Early Cretaceous (Berriasian or? Valanginian) at the top of the interval to as old as early Late Jurassic (Oxfordian) at the base. A discussion of this data is presented in a later section.

A list of the cuttings samples from the well used in this investigation follows.

Mould Bay Formation

Middle member

*	110-170 ft	(34-52 m)
*	200-290 ft	(61-88 m)
C-30208	300-310 ft	(91-94 m)
*	350 ft	(107 m)
C-30208	360 ft	(110 m)
*	320-380 ft	(98-116 m)
*	400-420 ft	(122-128 m)
C-30208	410-470 ft	(125-143 m)
*	400-490 ft	(122-149 m)
*	430-450 ft	(131-137 m)

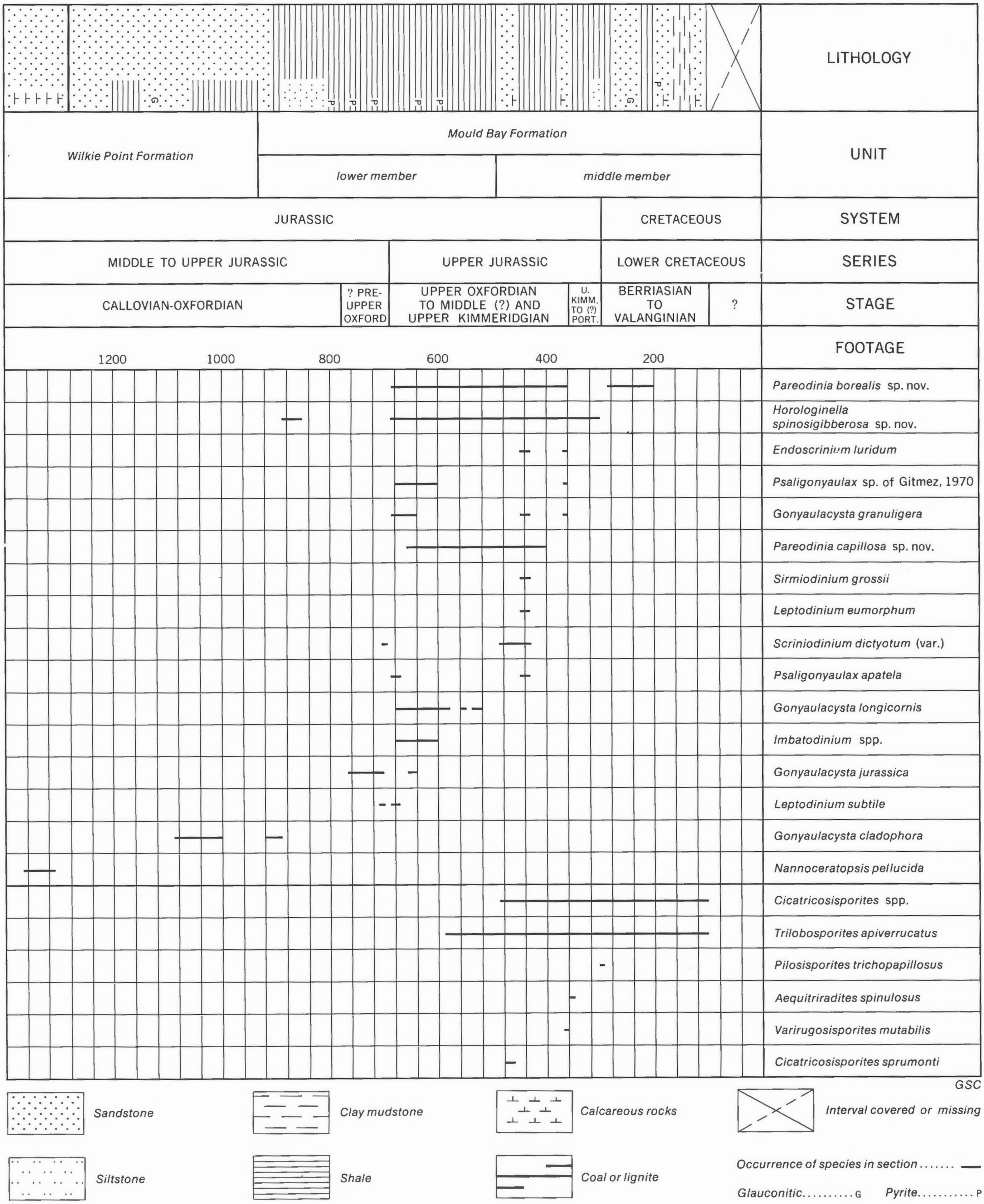


FIGURE 8. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the Elf Jameson Bay C-31 well, southeastern Prince Patrick Island, District of Franklin

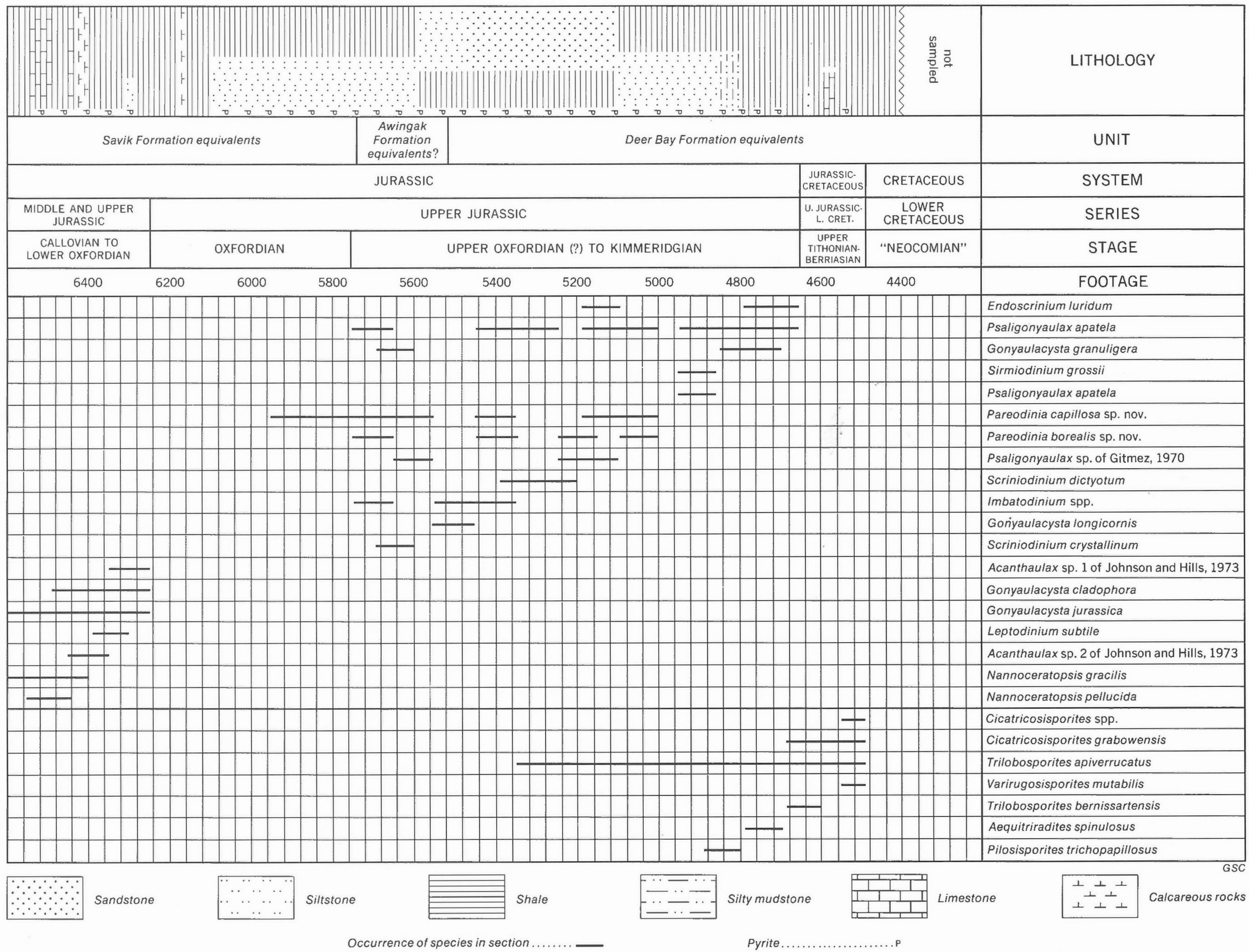


FIGURE 9. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the Panarctic Hoodoo Dome H-37 well, southeastern Ellef Ringnes Island, District of Franklin

*	460-480 ft	(140-146 m)
*	490-510 ft	(149-155 m)

Lower member

*	500-530 ft	(152-162 m)
*	500-580 ft	(152-177 m)
*	520-540 ft	(159-165 m)
*	550-560 ft	(168-171 m)
*	560-590 ft	(171-180 m)
*	580-600 ft	(177-183 m)
*	600-680 ft	(183-207 m)
*	610-630 ft	(186-192 m)
*	640-660 ft	(195-201 m)
*	670-690 ft	(204-210 m)
*	850-950 ft	(259-290 m)

Wilkie Point Formation

*	950-980 ft	(290-299 m)
*	1,000-1,090 ft	(305-332 m)
*	1,010-1,070 ft	(308-326 m)
*	1,100-1,190 ft	(335-363 m)
*	1,200-1,280 ft	(366-390 m)
*	1,310-1,370 ft	(399-418 m)

Panarctic Hoodoo Dome H-37 well

The Panarctic Hoodoo Dome H-37 well was drilled in 1970 to a total depth of 11,072 feet (3375 m). The well site is on the southeastern part of Ellef Ringnes Island, on the eastern side of Meteorologist Peninsula, and is drilled on the Hoodoo Dome structure (Stott, 1969, p. 35). The well spudded in the Christopher Formation and penetrated strata assigned to the Christopher and Isachsen Formations before encountering strata assigned to the Deer Bay Formation or its subsurface lithologic equivalents at the 3,700-foot (1128 m) depth [Robertson Research (N.A.) Ltd., Exploration Report No. 50, 1973]. The well then penetrated unnamed formations of Early Cretaceous and Jurassic age (Fig. 9), before bottoming in the Upper Triassic Heiberg Formation.

Strata in the interval between the depths of 4,400 and 6,500 feet (1341-1981 m) were examined for diagnostic palynofloras in connection with this investigation. The lithology of the interval between 4,400 and 4,700 feet (1341-1433 m) is composed predominantly of grey or brown, micaceous, strongly calcareous shale, interrupted by an argillaceous limestone unit in the interval between 4,550 and 4,580 feet (1387-1396 m). Below the 4,700-foot (1341 m) depth, the shale becomes more pyritic and increasingly silty. The shale grades into grey siltstone with shaly interbeds below the 5,050-foot (1539 m) depth, which in turn grades into fine-grained sandstone below the 5,100-foot (1554 m) depth. Sandstone, with some shale, comprises the lithology in the interval between 5,100 and 5,450 feet (1554-1661 m). Between 5,450 and 5,600 feet (1661-1707 m), the lithology consists of grey siltstone and brown shale. Below 5,600 feet and continuing to 6,500 feet (1707-1981 m), dark grey, in places silty, shale predominates, with some brownish grey, limy beds below 6,400 feet (1951 m) (Panarctic Oils Limited, 1970).

Strata penetrated in the well between the depths of 4,400 and 5,520 feet (1341-1682 m) are assigned to subsurface equivalents of the Deer Bay Formation. The part of the siltstone and shale succession between 5,520 and 5,740 feet (1682-1750 m) is referred doubtfully to subsurface equivalents of the Awingak Formation. The shale below 5,740 feet (1750 m), and including the shale and limy beds below 6,400 feet (1951 m), are assigned tentatively to subsurface equivalents of the Savik Formation [Robertson Research (N.A.) Ltd., Exploration Report No. 50, 1973].

The age of the strata in this interval, based on palynologic evidence, is considered to be Early Cretaceous, probably early Neocomian at the top of the interval, and as old as Late Callovian or Oxfordian at the base. The palynologic data from this well and their bearing on the age of the *borealis* assemblage are discussed in a later section.

A list of the cuttings samples from the well used in this investigation follows.

Deer Bay Formation equivalent

*	4,460-4,550 ft	(1359-1387 m)
*	4,500-4,590 ft	(1372-1399 m)
*	4,560-4,650 ft	(1390-1417 m)
*	4,600-4,690 ft	(1402-1430 m)
*	4,660-4,750 ft	(1420-1448 m)
*	4,700-4,790 ft	(1433-1460 m)
*	4,760-4,850 ft	(1451-1478 m)
*	4,800-4,890 ft	(1463-1490 m)
*	4,860-4,950 ft	(1481-1509 m)
*	4,900-4,990 ft	(1494-1521 m)
*	4,960-5,050 ft	(1512-1539 m)
*	5,000-5,090 ft	(1524-1551 m)
*	5,050-5,150 ft	(1539-1570 m)
*	5,100-5,190 ft	(1554-1582 m)
*	5,150-5,250 ft	(1570-1600 m)
*	5,200-5,290 ft	(1585-1612 m)
*	5,250-5,350 ft	(1600-1631 m)
*	5,300-5,390 ft	(1615-1643 m)
*	5,350-5,450 ft	(1631-1661 m)
*	5,400-5,490 ft	(1646-1673 m)
*	5,460-5,550 ft	(1664-1692 m)
*	5,500-5,590 ft	(1676-1704 m)

Awingak Formation equivalent

*	5,560-5,650 ft	(1695-1722 m)
*	5,600-5,690 ft	(1707-1734 m)
*	5,660-5,750 ft	(1725-1753 m)
*	5,700-5,790 ft	(1737-1765 m)

Savik Formation equivalent

*	5,760-5,850 ft	(1756-1783 m)
*	5,800-5,890 ft	(1768-1795 m)
*	5,860-5,950 ft	(1786-1814 m)
*	5,900-5,990 ft	(1798-1826 m)
*	5,960-6,050 ft	(1817-1844 m)
*	6,000-6,090 ft	(1829-1856 m)
*	6,060-6,150 ft	(1847-1875 m)
*	6,100-6,190 ft	(1859-1887 m)
*	6,160-6,250 ft	(1878-1905 m)
*	6,200-6,290 ft	(1890-1917 m)
*	6,260-6,350 ft	(1908-1935 m)

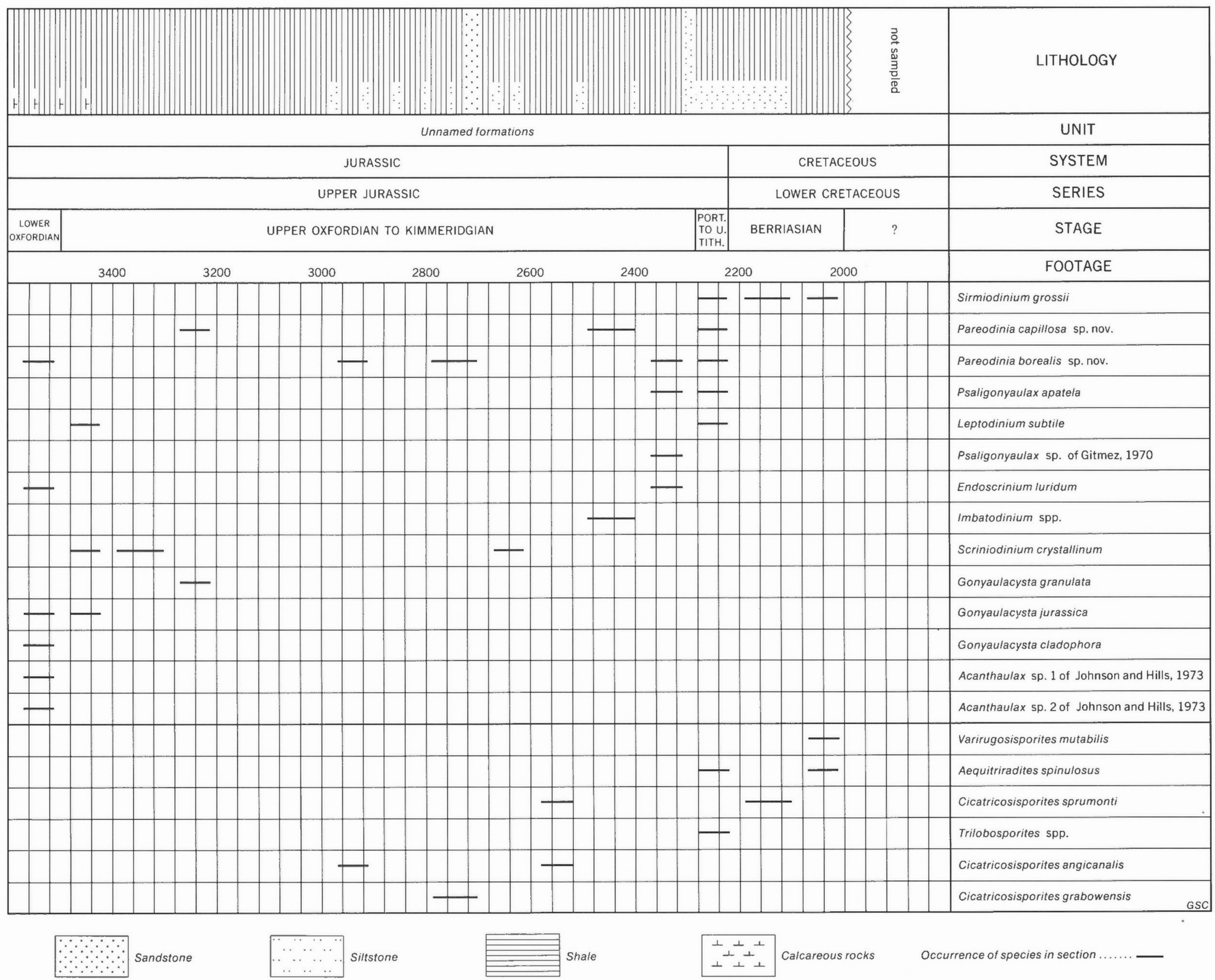


FIGURE 10. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in the Panarctic Tenneco *et al.* Kristoffer Bay B-06 well, southern Ellef Ringnes Island, District of Franklin

*	6,300-6,390 ft	(1920-1948 m)
*	6,360-6,450 ft	(1939-1966 m)
*	6,400-6,490 ft	(1951-1978 m)
*	6,460-6,550 ft	(1969-1996 m)
*	6,500-6,590 ft	(1981-2009 m)

Panarctic Tenneco *et al.* Kristoffer Bay B-06 well

The Panarctic Tenneco *et al.* Kristoffer Bay B-06 well, completed in 1972, was drilled on the Dome Bay Anticline structure (Stott, 1969, p. 33) to a total depth of 12,877 feet (3925 m) and is a suspended gas well. The well site is on the southern coast of Ellef Ringnes Island on Kristoffer Bay. The well was spudded in the Isachsen Formation of Early Cretaceous age (Panarctic Oils Limited, 1972) and, at 1,250 feet (381 m), encountered predominantly shale. The shale (Fig. 10) persists to 4,660 feet (1420 m) before grading into a fine- to medium-grained sandstone. The shale below 2,000 feet (610 m) depth is grey, micromicaceous and, in places, silty. A fine-grained, glauconitic sandstone occurs between the depths of 2,300 and 2,320 feet (701-707 m), and a sandy shale between 2,710 and 2,730 feet (826-832 m). Beds of calcareous shale or argillaceous limestone occur in the interval between the depths of 3,450 and 3,600 feet (1052-1097 m). The strata in these intervals are assigned to unnamed formations. The samples used in this investigation come from the interval between 2,000 and 3,600 feet (610-1097 m) and consist of ditch cuttings. Based on palynologic evidence, the age of the strata in this sampled interval is Berriasian at the top and Oxfordian at the base. A list of the cuttings samples from this well used in this investigation follows.

*	2,010-2,070 ft	(613-631 m)
*	2,100-2,190 ft	(640-668 m)
*	2,220-2,280 ft	(677-695 m)
*	2,310-2,370 ft	(704-722 m)
*	2,400-2,490 ft	(732-759 m)
*	2,520-2,580 ft	(768-786 m)
*	2,610-2,670 ft	(796-814 m)
*	2,700-2,790 ft	(823-850 m)
*	2,820-2,880 ft	(860-878 m)
*	2,910-2,970 ft	(887-905 m)
*	3,000-3,090 ft	(914-942 m)
*	3,120-3,180 ft	(951-969 m)
*	3,210-3,270 ft	(978-997 m)
*	3,300-3,390 ft	(1006-1033 m)
*	3,420-3,480 ft	(1042-1061 m)
*	3,510-3,570 ft	(1070-1088 m)

Other wells

Ditch cuttings samples were examined from the Elf Wilkins E-60 well in the interval between 60 and 500 feet (18-152 m). The strata are composed of dark grey, micromicaceous shale and probably are subsurface equivalents of the Mould Bay Formation.

Cuttings were examined from a sample taken between the depths of 4,720 and 4,780 feet (1439-1457 m) in the Sun KR Skybattle Bay C-15 well. The strata are composed of black, grey, and dark brown silty shale assigned to an unnamed formation.

Cuttings samples were examined from the interval between 2,390 and 3,200 feet (728-975 m) from the Panarctic Drake Point L-67 well. The strata in this interval are assigned to subsurface equivalents of the Deer Bay Formation.

Samples were taken of cuttings from the interval between 3,000 and 3,150 feet (914-960 m) in the Panarctic Tenneco *et al.* Drake Point F-16 well (a suspended gas well). The lithology at the top of the interval comprises black shale which grades abruptly into more arenaceous strata composed of glauconitic and pyritic sandstone with subordinate dark grey, silty shale. These strata are assigned to an unnamed formation.

The sample intervals investigated for this paper are listed below by wells.

Elf Wilkins E-60

*	60-100 ft	(18-30 m)
*	310-400 ft	(94-122 m)
*	410-500 ft	(125-152 m)

Sun KR Skybattle C-15

*	4,720-4,780 ft	(1439-1457 m)

Panarctic Drake Point L-67

C-12246	2,390 ft	(728 m)
C-12247	2,500 ft	(762 m)
C-12249	2,710 ft	(826 m)
C-12250	2,800 ft	(853 m)
C-12251	2,900 ft	(884 m)
C-12252	3,020 ft	(920 m)
*	3,120-3,150 ft	(951-960 m)
C-12254	3,200 ft	(975 m)

Panarctic Tenneco *et al.* Drake Point F-16

*	3,000-3,060 ft	(914-933 m)
*	3,090 ft	(942 m)
*	3,120 ft	(951 m)
*	3,150 ft	(960 m)

Shot-point samples - northwestern Melville Island

Panarctic Oils Ltd. kindly made available core samples (air-drilled) from seismic shot-points for this investigation. The samples come from shot-points 15 to 18 of Line 2. This line trends east of north, intersecting Paleozoic rocks near its southern end on Marie Bay, and Mesozoic rocks in its middle and northern parts (Fig. 11a, b).

The strata in this region dip to the north at a very small angle (D. Henao, pers. com., 1974; Tozer and Thorsteinsson, 1964). The assumed contact (Fig. 11b) between the Mould Bay Formation and the underlying Wilkie Point Formation lies about 0.25 mile (0.4 km) south of the location of shot-point 15, and the contact of the Mould Bay Formation with the overlying Isachsen Formation lies about 2.5 miles (4 km) north of the location of shot-point 18. Tozer and Thorsteinsson (1964, p. 141) estimate that 100 feet (30 m) of the lower shale member and 350 feet

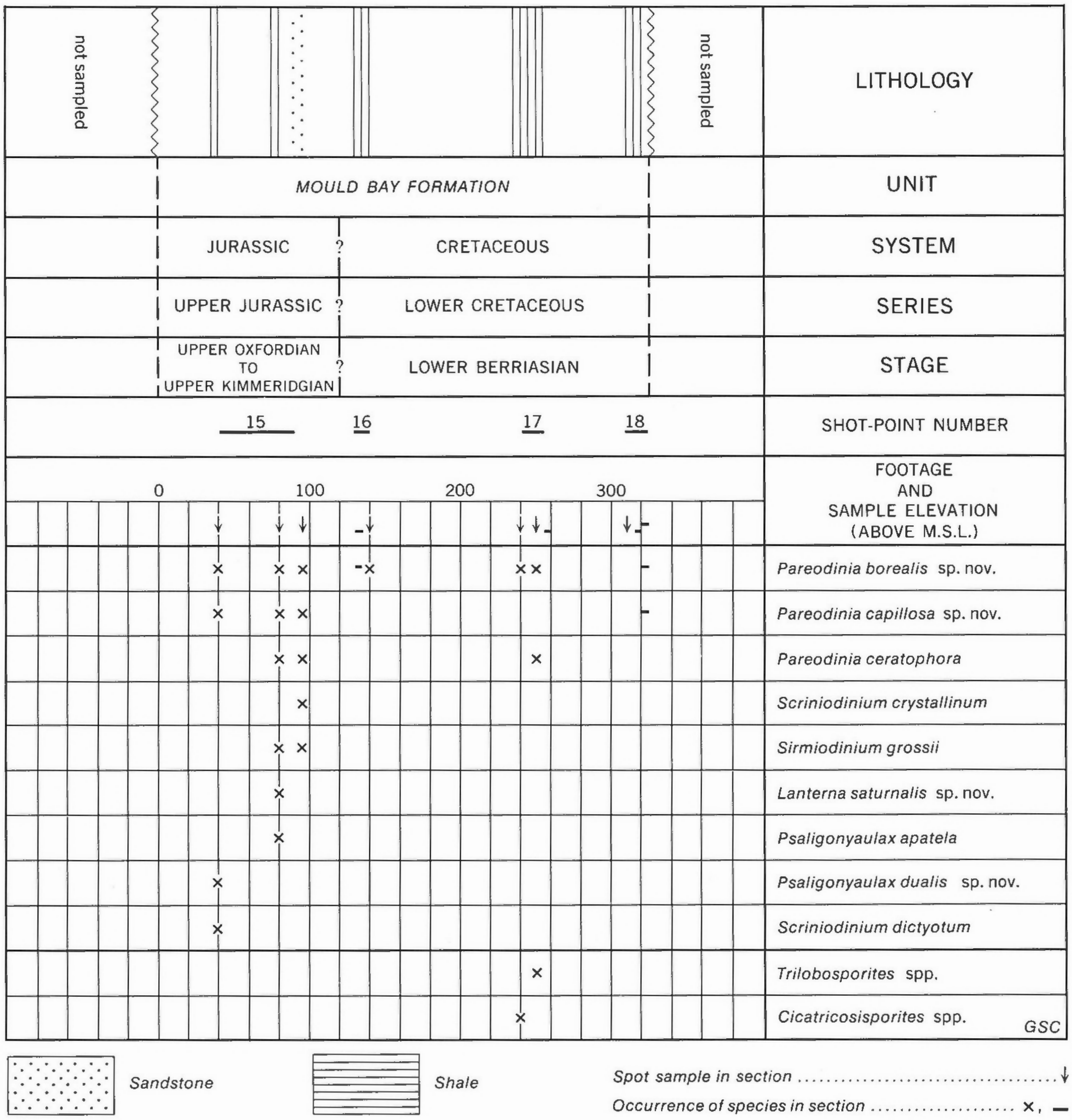


FIGURE 11a. Generalized lithologic column, biostratigraphy and occurrence of selected spore, pollen and dinoflagellate species in shot-points 15, 16, 17 and 18, of Panarctic Oils Limited seismic line 2, northwestern Melville Island, District of Franklin

(107 m) of the upper sandy member of Mould Bay Formation are present in this outcrop belt. Estimates of the average dip, as deduced from outcrop patterns and topographic expression, indicate that all samples come from the Mould Bay Formation. It is not possible to calculate with certainty the absolute stratigraphic position of the samples. However, it is certain that the samples, beginning at the base of shot-point 15 and ending with the topmost sample of shot-point 18, are in ascending stratigraphic order. The samples consist of dark grey shale with the exception of that from GSC locality C-34778 between 88 and 90 feet (26.8-27.4 m) above mean sea level in shot-point 15, which is a fine-grained sandstone.

Jeletzky (*in* Tozer and Thorsteinsson, 1964) gives an age for the lower two members of the Mould Bay Formation of Portlandian sensu stricto to Late Tithonian. The upper shale member (not present in this composite section) is as young as Valanginian in age. Macrofossil localities in the immediate vicinity of the shot-points do not yield diagnostic macrofossils but, elsewhere in the region, ample evidence is cited to support these age determinations. The evidence from palynologic analyses of these samples is consistent with these conclusions. It seems possible also to refine the age determinations for this particular composite section based on evidence from the dinoflagellate assemblages.

A summary of the intervals from the shot-point samples follows. The actual depth in the shot-point is given in the left column, and the actual elevation from Mean Sea Level (MSL) is given in the right column. The samples are plotted in Figure 11a in descending order of height above MSL. Data on altitude

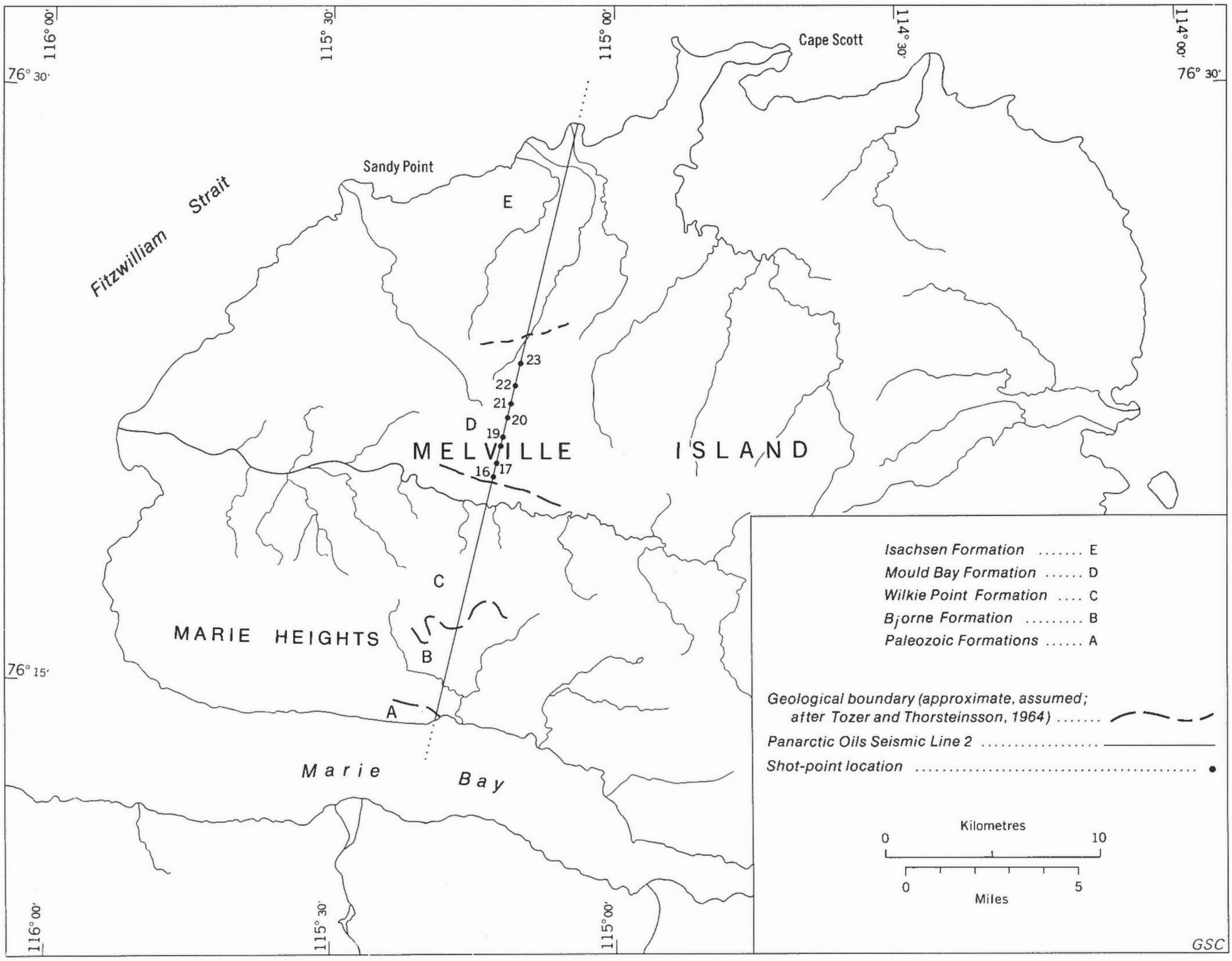


FIGURE 11b. Location of shot-points spudded in the Mould Bay Formation, on Panarctic Oils Limited seismic line 2, northwestern Melville Island, District of Franklin (NTS 89A)

are based on National Topographic Series Map 89A (Emerald Island).

<u>Shot-point 15</u> [Elevation 140 ft (43 m) above MSL]

C-34778 50-52 ft (15.2-15.8 m); 88-90 ft (26.8-27.4 m)
C-34778 60 ft (18 m); 80 ft (24 m)
C-34778 100 ft (30 m); 40 ft (12 m)

<u>Shot-point 16</u> [Elevation 200 ft (61 m) above MSL]

C-34779 50-55 ft (15.2-16.8 m); 130-135 ft (39.6-41.1 m)
C-34779 60 ft (18 m); 140 ft (43 m)

<u>Shot-point 17</u> [Elevation 300 ft (91 m) above MSL]

C-34780 42-47 ft (12.8-14.3 m); 253-258 ft (77.1-78.6 m)
C-34780 52.5 ft (16 m); 248.5 ft (76 m)
C-34780 60 ft (18 m); 240 ft (73 m)

<u>Shot-point 18</u> [Elevation 360 ft (110 m) above MSL]

C-34781 35-40 ft (10.7-12.2 m); 320-325 ft (97.8-99.3 m)
C-34781 40-45 ft (12.2-13.7 m); 315-320 ft (96.3-97.8 m)
C-34781 50 ft (15 m); 310 ft (95.0 m)

The ascent in height above mean sea level from the basal sample of shot-point 15 to the topmost sample of shot-point 18 is 325 feet (99.3 m), so that even with a very small dip it is likely that over 400 feet (122 m) of the Mould Bay Formation are represented in this composite section. It is possible that the thickness of 450 feet (137 m) for this formation estimated by Tozer and Thorsteinsson (1964) may be low by as much as 100 feet (30 m).

SYSTEMATICS

Genus *Gonyaulacysta* Deflandre ex Norris and Sarjeant emend. Sarjeant

1964 *Gonyaulacysta* Deflandre, p. 5 (*nom. nud.*)
1965 *Gonyaulacysta* Deflandre ex Norris and Sarjeant, p. 65.
1966 *Gonyaulacysta* Deflandre ex Norris and Sarjeant emend. Sarjeant, p. 111.
1969 *Gonyaulacysta* Deflandre ex Norris and Sarjeant emend. Sarjeant *in* Davey *et al.*, p. 7.

Gonyaulacysta sp. cf. *G. cladophora* (Deflandre) Dodekova

Plate 1, figures 1-3, 7

cf. 1938 *Gonyaulax cladophora* Deflandre, p. 173, Pl. 7, figs. 1-5, Text-figs. 5, 6.

cf. 1967 *Gonyaulacysta cladophora* (Deflandre) Dodekova, p. 17, Pl. 2, figs. 2-8.

Description. Most specimens recovered are extremely fractured or torn. The description that follows is a composite based on the few available specimens. The cyst is polygonal with the length greater than the width; the maximum width occurs at the latitude of the cingulum. A short, rounded apical horn was observed on one specimen; antapical horns are absent.

The cyst wall is two-layered. The periphragm forms the reflected sutural ridges, crests and spinose ornament. The endophragm is approximately 1.0μ thick in optical section. The surface of the endophragm is smooth or scabrate.

Reflected tabulation is outlined by the sutural crests and ridges. The broken condition of the material precludes a complete analysis, but the reflected tabulation pattern is probably: 4', 6", 6c, 5'''-?6''', ?1p, 1"". The cingulum was observed to be displaced about one cingulum width (6-8μ) on several specimens. A sulcus is present but was not observed clearly.

Reflected plates are outlined by low, narrow sutural ridges prolonged into thin sutural crests bearing rows of closely set, pilate to bifid, more rarely bifurcated, spinose processes. The sutural ridges are 1-2μ high and about 1-2μ wide; the sutural crests are raised approximately 3μ above the ridges. The spinose processes are 3-9μ high, typically 4-5μ high, except in gonal position and along the cingulum, where they may reach 15-20μ in length.

The archeopyle is precingular in position, and formed probably by the loss of reflected plate, 3", but neither the opening, nor the operculum, was observed clearly in the available material.

Dimensions. (5 specimens, 3 measured) Length, 103-145μ; width, 90-122μ.

Comparison. The damaged condition of the specimens (cf. Deflandre, 1938, p. 173 and Sarjeant, 1961, p. 94) precludes a direct identification as *G. cladophora* (Deflandre) Dodekova, although the specimens available compare favourably in dimensions and morphology with that species.

Occurrence. Banff-Aquitaine-Arco Rat Pass K-35 well: unnamed sandstone, sidewall core, 1,920-foot (585 m) depth (Upper Oxfordian to Middle Kimmeridgian).

Previous occurrence. Closely comparable forms (as *Gonyaulacysta cladophora*) recorded from strata of Bajocian to Kimmeridgian age (Deflandre, 1938; Valensi, 1953; Klement, 1960; Sarjeant, 1961; Dodekova, 1967; other authors).

Genus *Psaligonyaulax* Sarjeant 1966

1966 *Psaligonyaulax* Sarjeant, p. 136.

Psaligonyaulax dualis sp. nov.

Plate 1, figures 4-6, 8-12; Plate 2, figures 1, 2

Holotype. GSC 34154; Slide P810-13B, 25.4 x 123.5, Langton Bay Formation, Gilmore Lake Member; cuttings sample from between depths of 1,800-1,810 feet (549-552 m), Elf Horton River G-02 well; GSC loc. C-12532; Upper Oxfordian-Middle Kimmeridgian.

Dimensions. Periblast length 125μ, width 95μ; endoblast length 74μ.

Diagnosis. Periblast elongate, typically twice as long as broad, with slightly tapering apical horn; endoblast rhomboid with a short apical prominence and rounded antapex. Antapical breach typically present in the periblast, rarely closed by a moderately bulging antapical prominence. Periblast and endoblast in close contact only at latitude of cingulum, resulting in formation of distinct apical and antapical pericoels. Surface of periphragm and endophragm smooth or, rarely, scabrate. Archeopyle in each layer formed by loss of third reflected precingular plate; opercula separate and detached, elongate. Periblast forms sutural crests which outline a reflected tabulation of 1pr, 4' 6", 6c, 5'''-?6''', 1p, 1""; crests variable, entire to denticulate, rarely spiny. Cingulum displaced up to two cingular widths, distinct; reflected sulcal tabulation absent but sulcal region distinct.

Description. The periblast is elongate, the length from one and one-half to two and one-half times the width. Maximum width of the periblast occurs at the latitude of the cingulum. The periblast is prolonged apically into a slightly tapered and slender horn, which is capped by a small pre-apical reflected plate. The apical horn represents from one-fifth to one-third, typically one-fourth of the total periblast length. Antapically the periblast exhibits a quadrangular opening at the position of the reflected antapical plate. A few specimens (Pl. 1, fig. 12) bear a moderately bulging antapical prominence and the opening is absent. The commonly occurring antapical breach is thus interpreted as resulting from the ?mechanical loss of this antapical prominence.

The endoblast is somewhat rhomboidal in general shape. The epithecal part is generally triangular and bears a short, rounded apical prominence, 3-9μ in length. The hypothecal part is more hemispherical and is rounded antapically.

The periblast and endoblast are in close contact only at the latitude of the cingulum; consequently, extensive apical and antapical pericoels result. The apical prominence of the endoblast extends into the apical pericoel. The antapical pericoel is generally open to the exterior. The surfaces of the periphragm and endophragm are smooth or, more rarely, scabrate. Folded portions of the periblast are projected to form the sutural crests.

The archeopyle is precingular in position on the periblast and endoblast and in both cases is formed by loss of reflected plate 3". The opercula are separate and usually detached, but may remain in place, especially in the case of the endoperculum. Opercula are commonly found in the pericoel and less commonly in the endocoel. Opercula are distinctly longer than broad, rounded anteriorly and flattened posteriorly.

The sutural crests are 3-4μ high and may be entire, variably denticulate or, more rarely, bear spinose ornament. The denticulate processes are connected basally and are 1-2μ high; the spiny elements may reach 4μ in height and generally are discrete but densely spaced along the crests. The sutural crests outline a reflected tabulation pattern of 1pr, 4', 6", 6c, 5'''-?6''', 1p, 1"". All reflected plates of the apical series, but especially 1', are elongated and terminated anteriorly by the reflected pre-apical plate. Reflected plates of the precingular series and plate 3'''-5''' of the postcingular series also are elongate. Reflected plates 2''' and 6''' are smaller and more equidimensional. Plate 1''' may not be distinct, merging with the sulcal region; where 1''' is distinct, it is very small and triangular. Reflected intercalary plates were not observed.

The sutural crests outline a cingulum and six reflected cingular plates. The cingulum is about 7-9μ wide and its ventral terminations are displaced from one and one-half to two cingular widths. The sulcus is poorly defined by the periphery of the other reflected plates and is without distinct reflected sulcal tabulation. The sulcus widens posteriorly to meet the antapical breach, and narrows anteriorly where it is terminated by reflected apical plate 1'. There is no distinct boundary between the anterior termination of the sulcus and the posterior termination of plate 1'. The anterior portion of the sulcus begins where the sutural crests outlining reflected plate 1' end abruptly.

Dimensions. (25 specimens) Periblast length, 93-135μ; apical horn, 20-33μ; endoblast length, 63-100μ; endoblast horn, 3-9μ; periblast width, 40-83μ.

Comparison. *Psaligonyaulax dualis* sp. nov. differs from previously published species of the genus in the following ways: from *P. deflandrei* Sarjeant (1966, p. 137) by its larger size, more prominent apical horn, rhombic endoblast, and details of tabulation; from *P. apatela* (Cookson and Eisenack) Sarjeant (1969, p. 15) in overall shape, greater overall length and length of apical horn, type of sutural crests, shape of the endophragm, and details of tabulation; and from *P. simplicia* (Cookson and Eisenack) Sarjeant (1969, p. 15) in shape, form of sutures, details of tabulation, and other features.

Psaligonyaulax dualis sp. nov. bears a superficial similarity to *Gonyaulacysta jurassica* (Deflandre) Norris and Sarjeant (1965, p. 65), but differs in at least four features. The size of the periblast and endoblast is generally larger, the smaller specimens of *P. dualis* overlapping only with the largest specimens of *G. jurassica; P. dualis* sp. nov. has well-developed apical and antapical pericoels; specimens with a pronounced apical pericoel assigned to *G. jurassica* by Sarjeant (1972, p. 10, 11, Pl. 1, figs. 2, 4) differ in that the pericoel is formed by broadening of the apical horn at its base. *Psaligonyaulax dualis* sp. nov. has a consistently well-developed antapical breach in the periblast, and more rarely, an antapical bulge. Finally, the endoblast of *P. dualis* sp. nov. exhibits a consistently rhombic outline.

Several authors have illustrated specimens assigned to *Gonyaulacysta jurassica* subsp. *longicornis* Lentin and Williams, 1973 (p. 62), which appear closely comparable to *Psaligonyaulax dualis* sp. nov. based on examination of the figures. These are listed below:

Klement, 1960, p. 28, Pl. 2, figs. 6-8 (Middle Malm Alpha - Oxfordian; Germany).

Sarjeant, 1962, p. 258, Pl. 1, fig. 3 (Upper Oxfordian; Dorset, England).

Gitmez, 1970, p. 260, Pl. 5, fig. 11 (Lower Kimmeridgian; Le Havre, France).

Most of this material is slightly smaller in size or overlaps the lower size range of *P. dualis* sp. nov., although Gitmez (1970, p. 261) quotes a size range for her material of 75-145μ. The specimens illustrated compare in shape and construction but the antapical breach cannot always be observed clearly (Sarjeant, 1962; Gitmez, 1970).

Other illustrated specimens show some similarity to *P. dualis* sp. nov., but the published figures do not show clearly some of the diagnostic features. These specimens include:

Gonyaulacysta jurassica (Deflandre) Norris and Sarjeant; Gorka, 1965, p. 298, Pl. 1, figs. 4a, 4b (Oxfordian; Poland).

Gonyaulacysta jurassica subsp. *longicornis* Lentin and Williams; Vozzhennikova, 1967, p. 85, Pl. 19, fig. 5 (Upper Volgian; Russia).

Original material would have to be examined in each case before synonymy could be established.

Occurrence.

Martin Creek: Husky Formation, Lower member, 0-120 ft (0-37 m), composite section, *Buchia concentrica* sensu lato zone (Upper Oxfordian-Lower Kimmeridgian).

Banff-Aquitaine-Arco Rat Pass well: unnamed shale unit, sidewall core, 1,765-foot (538 m) depth; unnamed shale unit, cuttings, 1,780- to 1,890-foot (543-576 m) depth (Upper Oxfordian to Middle Kimmeridgian).

IOE Stoney Core Hole F-42: Husky Formation, Arenaceous member equivalent, conventional core, 970 to 980 feet (296-299 m); Husky Formation, Lower member equivalent, conventional core, 990 to

1,000 feet and 1,010 to 1,020 feet (302-305 m and 308-311 m) (Upper Oxfordian to Upper Kimmeridgian).

Elf Horton River G-02 well: Langton Bay Formation, Gilmore Lake Member, cuttings, 1,750- to 1,810-foot (533-552 m) depth (Upper Oxfordian-Middle Kimmeridgian).

Panarctic Drake Point L-67 well: unnamed formation, cuttings, 3,000- to 3,090-foot (914-942 m) depth (highest occurrence, Middle Kimmeridgian).

Panarctic Oils Ltd. Line 2, shot-point 15: Mould Bay Formation, lower shale member, 40 feet (12.2 m) above MSL [Upper Oxfordian to Middle, possibly (?)Upper Kimmeridgian].

Previous occurrence. Comparable forms (*see* discussion under comparison) recorded by Klement (1960), Sarjeant (1962) and Gitmez (1970) from strata of Oxfordian to Early Kimmeridgian age; more doubtful records in Gorka (1965) and Vozzhennikova (1967) from strata of Oxfordian and Late Volgian age, respectively.

Genus *Pareodinia* Deflandre emend. Gocht

1947 *Pareodinia* Deflandre, p. 4.
1970 *Pareodinia* Deflandre emend. Gocht, p. 153.

Pareodinia capillosa sp. nov.

Plate 2, figures 3-10; Plate 3, figures 1, 2, 5

Holotype. GSC 34155; Slide P810-7B, 12.7 x 123.7, Langton Bay Formation, Gilmore Lake Member; cuttings sample from between depths of 1,530 and 1,540 feet (466-469 m), Elf Horton River G-02 well; GSC loc. C-12526; Middle or Upper Kimmeridgian.

Dimensions. Overall length, 112μ; overall width, 53μ.

Diagnosis. Periblast with tripartite outline; maximum width at cingulum; prolonged tapering apical horn, subcircular central portion; and moderately prominent antapical prominence (bulge). Periphragm and endophragm closely appressed; periphragm bearing a dense cover of solid, hairlike processes and lineations of processes or faint, low ridges marking outlines of reflected tabulation. Archeopyle intercalary outline often indistinct, formed by loss of two large polygonal reflected intercalary plates; operculum simple, often loosely in place. Reflected tabulation scheme, ?4', 2a, 6", 6c, 5'''-?6''', 1p, 1"". Cingulum distinct, reflected cingular plates transversely elongate and polygonal; sulcal region rarely distinct, wide anteriorly, narrowing posteriorly; details lacking.

Description. The cyst is elongate, the length generally twice the maximum width, the latter occurring at the latitude of the cingulum. The epitract is distinctly longer than the hypotract; the main portion of the epitract length is formed of the stout, tapering apical horn. The hypotract is prolonged antapically into an antapical prominence, giving the cyst a tripartite outline. The periblast and endoblast are closely appressed. The periphragm is very thin, about 0.5μ thick in optical section, and clearly visible only where gonal parts of the sutures project at the periphery. The endophragm is slightly thicker, about 1.0μ thick in optical section. The surface of the periphragm bears a dense cover of slender, tapering hairlike processes, 2-4μ but typically 3μ long. The processes are more easily seen on the periphery and at the antapices of specimens, but well-preserved specimens confirm a general process cover.

The archeopyle is formed by the loss of two large and polygonal reflected intercalary plates (Type 2I of Evitt, 1967). The outline of the archeopyle is often indistinct. This is especially so when the simple operculum remains in place, and the opening is defined only by the faint principal archeopyle sutures.

Lineate rows of processes or faint low ridges on the periphragm outline a reflected tabulation pattern determined as: ?4', 2a, 6", 6c, 5'''-6''', 1p, 1"". This tabulation scheme is only partially visible on any given specimen and the scheme is based on a composite study of all material available. Details of the hypotractal and cingular tabulation are generally better preserved than those of the epitract. The sutures outlining the reflected apical plate series are especially poorly developed but, apparently, there are four reflected apical plates.

The cingulum is variably represented, even on a given specimen. Very faint low ridges, or lineations of processes, outline six reflected cingular plates. The reflected plates are transversely elongate, polygonal and up to 6μ in maximum longitudinal dimension. The ventral terminations of the cingulum have been observed only imperfectly on a few specimens; there is only a slight displacement of these terminations. On such specimens, the sulcal region is faintly visible, but no details of reflected sulcal tabulation are discernible. The sulcus is widest anteriorly and narrows posteriorly.

Dimensions. (32 measured specimens) Overall length, 87-135μ; maximum overall width, 40-65μ.

Comparison. The shape and size of the periblast, the dense cover of hairlike processes and the presence of reflected tabulation distinguish *Pareodinia capillosa* sp. nov. from other published species assigned to *Pareodinia*.

Occurrence.

Martin Creek: Husky Formation, Lower, Arenaceous, Red-weathering shale and Upper members, 342-752 ft (104-299 m), composite section, *Buchia mosquensis* sensu lato to *Buchia* n. sp. aff. *volgensis* zone (Middle Kimmeridgian to Berriasian).

Mount Gifford: Husky Formation, Arenaceous member, 3.0 to 8.5 feet (0.9-2.5 m), pre-*Buchia okensis* zone (Upper Tithonian).

Banff-Aquitaine-Arco Rat Pass K-35 well: unnamed shale unit, sidewall core, 1,710-foot (521 m) depth (Upper Kimmeridgian); unnamed shale unit, cuttings, 1,780- to 1,790-foot (543-546 m) depth; unnamed sandstone unit, cuttings, 1,900- to 1,910-foot (579-582 m) depth (Upper Oxfordian-Middle Kimmeridgian).

IOE Stony Core Hole F-42: Husky Formation, Lower member equivalent, conventional core, 990- to 1,020-foot (302-311 m) depth (Upper Oxfordian to Upper Kimmeridgian).

Elf Horton River G-02 well: Langton Bay Formation, Gilmore Lake Member, cuttings, 1,530- to 1,810-foot (466-552 m) depth (highest occurrence, Middle to Upper Kimmeridgian).

Panarctic Oils Ltd., Line 2, shot-point 15, Mould Bay Formation, lower shale member, 40 to 90 feet (12-27 m) above MSL (Upper Oxfordian-Upper Kimmeridgian); shot-point 18, Mould Bay Formation, Middle member, 320 to 325 feet (97.5-99.1 m) above MSL (Berriasian).

Elf Jameson Bay C-31 well: Mould Bay Formation, Lower and Middle members, cuttings, 400- to 660-foot (122-183 m) depth (highest occurrence, Upper Oxfordian to Upper Kimmeridgian).

Panarctic Hoodoo Dome H-37 well: unnamed formations, probably subsurface equivalents of the Deer Bay, Awingak and Savik Formations, cuttings, 5,000- to 5,950-foot (1524-1814 m) depth [highest occurrence, Upper(?) Oxfordian to Kimmeridgian].

Panarctic Tenneco *et al.* Kristoffer Bay B-06 well: unnamed formation, cuttings, 2,200- to 2,490-foot (671-759 m) and 3,210- to 3,270-foot (978-997 m) depths (highest occurrence, Upper Tithonian).

Pareodinia borealis sp. nov.

Plate 3, figures 3, 4, 6-9; Plate 4, figures 1-8

Holotype. GSC 34156; ARCO Slide 10616A-2, 30.2 x 125.7, unnamed shale unit; sidewall core at 1,710-foot (521 m) depth, Banff-Aquitaine-Arco Rat Pass K-35 well; GSC loc. C-12678; Upper Kimmeridgian.

Dimensions. Overall length, 70μ; overall width, 43μ.

Discussion. No one specimen shows clearly all features of the species. Although the holotype specimen chosen is partly obscured at the apex by a fragment of debris, it does exhibit a two-layered wall, some of the reflected tabulation and the typical shape of the species.

Diagnosis. Cyst length greater than maximum width; apex prolonged into a short, stout, tapering apical horn; antapex rounded. Periphragm and endophragm closely appressed. Periphragm surface smooth or scabrate, bearing low, narrow sutures that outline a reflected tabulation scheme, imperfectly determined as ?4', 2a, 6'', 6c, 5'''-?6''', 1'''', ?1p. Archeopyle intercalary, probably formed by the loss of two polygonal reflected intercalary plates; operculum apparently simple. Cingulum outlined by low sutures; six cingular reflected plates, transversely elongated and polygonal. Sulcus not observed.

Description. The length of the cyst is from one and one-half to two times the width; the maximum width occurs at the latitude of the cingulum. The outline of the cyst is somewhat droplet-shaped, with a short, stout and tapering apical horn and rounded antapex. The periphragm is membranous, about 0.25 to 0.5μ thick in optical section, and forms the low, narrow sutures which are most evident where the gonal portions of the sutures project slightly at the periphery. The endophragm is closely appressed to the periphragm and is about 1μ thick in optical section and, therefore, slightly thicker than the periphragm. The surface of the periphragm is smooth or scabrate; the surface of the endophragm is smooth. The periphragm occasionally bears a fine, discontinuous, membranous patchwork, which may represent remnants of a kalyptra (cf. Gocht, 1970).

The archeopyle is intercalary in position. The archeopyle and operculum are not well represented on available material, but several specimens appear to possess a Type 2I archeopyle (Evitt, 1967), formed by the loss of two reflected intercalary plates, as evidenced by the outline of the principal archeopyle sutures. The simple operculum may be observed indistinctly in place in several specimens.

The sutural ridges of the periphragm outline a reflected tabulation, imperfectly developed on any one specimen, which corresponds to the scheme ?4', 2a, 6'', 6c, 5'''-?6''', 1p, 1''''. The reflected apical plate series is the least readily discernible.

The cingulum consists of six reflected plates, transversely elongate and polygonal in shape. The ventral terminations of the cingulum are not clearly exhibited on material available, but the cingulum appears offset about one-half to one cingulum width (from 4-8μ). The sulcus was not clearly observed.

Dimensions. (47 specimens) Overall length, 53-95μ; overall width, 36-61μ.

Comparison. *Pareodinia borealis* sp. nov. is distinguished from *Pareodinia capillosa* sp. nov. by its shape and smooth periphragm, and by its generally smaller size range. *Pareodinia borealis* is comparable in size, range and shape to *Pareodinia ceratophora* (Deflandre) emend. Gocht (1970), but differs in possessing a defined, distinct to indistinct reflected tabulation pattern. Parts of the reflected cingulum are sometimes visible on *P. ceratophora* (*see*, for example, Gocht, 1970, Pl. 35, fig. 5), but extensive reflected tabulation exhibited by *P. borealis* sp. nov. has never been reported (Deflandre, 1947; Valensi, 1953; Gocht, 1970). The periphragm surface of *P. borealis* sp. nov. is smooth or scabrate, whereas that of *P. ceratophora* is often finely granulate. Finally, *P. borealis* sp. nov. is distinctly two-layered in construction, whereas *P. ceratophora* appears to possess an autophragm.

Warren (1967, p. 264, Pl. 25, fig. 3 only) describes a species from rocks of Late Tithonian to Valanginian age in the west side of the Sacramento Valley, California, which he calls "Pareodinia albertii" that appears to be conspecific in part with *P. borealis* sp. nov. In the opinion of the writers, the other specimen figured by Warren (1967, Pl. 25, fig. 6) does not belong in the same taxon and, furthermore, comes from an unspecified locality (Warren, 1967, p. 269).

Pareodinia sp. of Singh (1971, p. 314, Pl. 48, figs. 3-7) also is probably conspecific with *P. borealis* sp. nov. It possesses comparable tabulation (as determined from the photographs of Singh, 1971, Pl. 48, figs. 3-7) and a two-layered wall with a smooth periphragm surface. Singh (op. cit.) bases his description on a single specimen, and the writers feel that there is a strong possibility that it is derived from older strata.

Occurrence.

Martin Creek: Husky Formation, Lower, Arenaceous, Red-weathering and Upper members, 0 to 684 feet (0-208 m), composite section, *Buchia concentrica* sensu lato to *Buchia okensis* zones (Upper Oxfordian to Lower Berriasian).

Mount Gifford: Husky Formation, Arenaceous member, 8 to 10 feet (2.4-3.0 m), pre-*Buchia okensis* zone (Upper Tithonian).

Banff-Aquitaine-Arco Rat Pass K-35 well: unnamed shale unit, sidewall core, from between depths of 1,710 feet and 1,765 feet (521-538 m) (Upper Oxfordian-Kimmeridgian).

Elf Horton River G-02 well: Langton Bay Formation, Gilmore Lake Member, cuttings, 1,750- to 1,810-foot (533-552 m) depth (Upper Oxfordian-Middle Kimmeridgian).

Gulf East Reindeer C-38 well: Husky Formation, conventional core, 3,949- to 3,951-foot (1203.7-1204.2 m) depth (Berriasian).

Panarctic Oils Ltd. Line 2, shot-point 18, Mould Bay Formation, middle member, 320 to 325 feet (97.5-99.1 m) above MSL (Berriasian); shot-point 17, Mould Bay Formation, middle member, 248.5 to 253 feet (75.7-77.1 m) above MSL (Berriasian); shot-point 16, Mould Bay Formation, lower shale member, 140 feet (42 m) above MSL (Berriasian? or Upper Tithonian); shot-point 15, Mould Bay Formation, lower shale member, 40 to 90 feet (12-27 m) above MSL (Upper Oxfordian to Upper Kimmeridgian).

Elf Jameson Bay C-31 well: Mould Bay Formation, Lower and Middle members, cuttings, 200- to 690-foot (61-210 m) and 1,300- to 1,390-foot (396-424 m) depths, Wilkie Point Formation (highest occurrence, Berriasian).

Panarctic Hoodoo Dome H-37 well: unnamed formations, probably subsurface equivalents of the Deer Bay, Awingak and Savik Formations, cuttings, 5,000- to 5,950-foot (1524-1814 m) depth (highest occurrence, Upper Oxfordian-Kimmeridgian).

Panarctic Tenneco *et al.* Kristoffer Bay B-06 well: unnamed formation, cuttings, 2,220- to 3,570-foot (677-1088 m) depth (highest occurrence, Upper Tithonian).

Elf Wilkins E-60 well: Mould Bay Formation, cuttings, 410- to 500-foot (125-152 m) depth (highest occurrence, Kimmeridgian).

Sun KR Sky Battle Bay F-15 well: unnamed formation, cuttings, 4,720- to 4,780-foot (1439-1457 m) depth (Middle to Upper Kimmeridgian).

Panarctic Tenneco *et al.* Drake Point F-16 well: unnamed formation, cuttings, 3,000- to 3,060-foot (914-933 m) depth (highest occurrence, Kimmeridgian).

Panarctic Drake Point L-67 well: unnamed formation, cuttings, 3,020- to 3,200-foot (920-975 m) depth (highest occurrence, Middle Kimmeridgian).

Genus *Horologinella* Cookson and Eisenack

1962 *Horologinella* Cookson and Eisenack, p. 271.

Horologinella spinosigibberosa sp. nov.

Plate 4, figure 9; Plate 5, figures 1-16

Holotype. GSC 34157, ARCO Slide 10616A-2, 27.4 x 123.9; unnamed shale unit; sidewall core, at 1,710-foot (521 m) depth; Banff-Aquitaine-Arco Rat Pass K-35 well; GSC loc. C-12628; Upper Kimmeridgian.

Dimensions. Autoblast length, 53μ; minimum autoblast width, 34μ.

Diagnosis. Autoblast longer than broad; hourglass-shaped; dorso-ventrally compressed. Autophragm bearing apiculate to vermiculate sculpture in more or less continuous bands, or in clusters interpreted as representing reflected plates. Archeopyle apical, formed by the loss of ?four reflected apical plates; operculum simple. Reflected tabulation scheme proposed as ?4', 5''-?6'', 0c, 5''', ?0''''. Medial, transverse, and medial longitudinal areas lacking processes and interpreted as a reflected cingulum and sulcus, respectively.

Description. The autoblast is longer than broad, dorso-ventrally compressed, and has an outline that is slightly to markedly hourglass-shaped. The maximum width of the autoblast occurs at the apices and the minimum width occurs at the latitude of the reflected cingulum. The apex is either nearly flat or medially slightly invaginated. The antapex is broadly rounded, to nearly flat in outline. An occasional specimen may show a slightly invaginated antapical outline similar to the apex. There are no apical or antapical horns or prominences.

The wall of the cyst cannot be differentiated into a periphragm and endophragm layer and is termed an autophragm. The thickness of the autophragm in optical section is about 1.0μ. The surface of the autophragm bears solid, variably shaped, vermiculate to apiculate sculptural elements. The apiculate processes are 0.5 to 1.0μ high, and are conical, baculate or occasionally pilate. A mixture of these process types may occur on any given specimen. The vermiculate processes are sinuous, arcuate or irregular in course, occasionally anastomosing in an irregular meshwork, and are low, 0.5 to 1.0μ in height, and narrow, from 0.25 to 0.5 in width. The distribution of these processes is discussed in connection with reflected tabulation patterns and the presence of what is interpreted as a cingulum and sulcus.

An apical opening is present on many specimens and is interpreted as an apical archeopyle, as evidenced by its angular outline. The archeopyle is located symmetrically with respect to a vertical median line. The operculum is simple and bears vermiculate to apiculate sculpture; although there is no indication of tabulation, analysis of the archeopyle outline suggests that the operculum is formed of four apical reflected plates. The operculum is attached or free; isolated opercula have been observed.

The structure and sculpture of the autoblast offer evidence for the proposed reflected tabulation scheme: ?4', 5"-?6", 0c, 5''', ?0"". Dorsal epitractal processes are generally present as a continuous band. However, the angular edge of the archeopyle opening and the two ventral epitractal sculpture clusters, separated by the medial longitudinal process-free region, suggest that at least five, and possibly six reflected precingular plates are represented. On some specimens, an occasional accessory archeopyle suture running from the archeopyle opening, and the rare presence of a low irregular ridge dividing the dorsal process band, lend further support to this interpretation. Similarly, two ventral hypotractal process clusters and a dorsal hypotractal band of processes suggest that at least five reflected post-cingular plates may be represented. The antapex is free of processes; therefore, interpretation of reflected antapical tabulation is not possible.

A medial process-free region running transversely about the autoblast, and including the zone of minimum width, is interpreted as a reflected cingular region. This process-free band is quite broad, from 16 to 18μ wide dorsally but narrowing to 8 to 10μ wide ventrally. The narrowest part of this cingular area occurs ventrally to the left side of a vertical median line. The cingular region thus appears slightly laevo-rotary.

A similar longitudinal process-free area is interpreted as a reflected sulcal region. The sulcus runs from directly below that portion of the archeopyle adjacent to the median-line to the antapex, where it broadens to include the whole of the ventral antapical area, and where it is terminated at the periphery of the dorsal hypotractal process band. The width of the sulcus at the latitude of the two ventral process clusters is 4 to 8μ.

The features described above are shown with varying clarity on available specimens. The archeopyle commonly is present, but often poorly exhibited. The dorsal process bands and ventral process clusters are not always clearly developed. The reflected tabulation scheme proposed above is necessarily the result of an analysis of features on many specimens.

Dimensions. (19 specimens, 15 measurable) Autoblast length, 30-55μ; maximum autoblast width, 37-40μ; minimum autoblast width, 20-35μ.

Description. Horologinella spinosigibberosa sp. nov. is the first species assigned to that genus to be described from rocks older than Aptian-Albian age (Cookson and Eisenack, 1962). Other species assigned to this genus have been described from rocks of Late Cretaceous, Paleocene and Eocene ages (Cookson and Eisenack, 1962; Cookson, 1965; Wilson, 1967).

The presence of reflected tabulation is indicated clearly on the type species of *Horologinella, H. lineata* Cookson and Eisenack, 1962, by markings interpreted as suture lines. An analysis of figured specimens from published photographs (Cookson and Eisenack, 1962, Pl. 37, figs. 1-3) suggests that the reflected tabulation scheme is approximated by: ?4', 5"-?6", 0c, 6''', ?1p, ?1"". The details of the reflected apical plate series and the presence of reflected plates 6", 1p and 1"" are difficult to confirm. Medial transverse and longitudinal regions are clearly representative of a reflected cingulum and sulcus, respectively. The reflected tabulation scheme and interpreted presence of cingulum and sulcus on *H. spinosigibberosa* sp. nov., therefore, accord closely with the type species.

Six other species have been assigned, three doubtfully, to the genus *Horologinella* by Cookson and Eisenack (1962) and Cookson (1965). *Horologinella incurvata* Cookson and Eisenack (1962, p. 272, Pl. 37, fig. 5), *H. apiculata* Cookson and Eisenack (1962, p. 272, Pl. 37, fig. 4) and *H.? obliqua* Cookson and Eisenack (1962, p. 272, Pl. 37, fig. 10) exhibit a more or less symmetrical outline about a vertical medial line, an hourglass shape, and dorso-ventral compression, but do not possess the angular archeopyle and reflected tabulation characteristic of the type species, *H. lineata*, and the species described herein, *H. spinosigibberosa* sp. nov. *Horologinella apiculata* shows an opening, "apical" in position, and symmetrically placed with respect to a vertical median line, but without indication of a relation to reflected tabulation. *Palaeostomocystis sinuosa* Cookson and Eisenack (1960, p. 258; Pl. 38, figs. 16, 17) is of similar construction, and differs only in the presence of medial latitudinal prominences.

Horologinella? obliqua Cookson and Eisenack (1962, p. 273, Pl. 37, fig. 9) and *H.? spinosa* Cookson (1965, p. 89, Pl. 10, figs. 10-12, Pl. 11, fig. 10), by contrast, possess an asymmetrical outline about a vertical median line and an asymmetrically placed "apical" opening that appears to bear no relation to possible reflected tabulation. *Horologinella? obliqua*, in particular, bears a remarkable similarity to the inner body enclosed in the membranous outer layer of *Halophoridia xena* Cookson and Eisenack (1962, p. 271, Pl. 37, figs. 6-8).

It seems, therefore, that three unrelated groups of species are united in the form genus, *Horologinella*, and that future investigations of these taxa will lead to restriction of *Horologinella* to tabulated, more or less symmetrical forms with distinct, angular apical archeopyles situated symmetrically about a vertical median line. It appears also that *H.? obliqua* might be better accommodated in *Haplophoridia* rather than doubtfully in *Horologinella*. The form described as *Horologinella* sp. indet. by Cookson and Eisenack (1962, p. 273, Pl. 37, fig. 15) may belong to yet a different category. It is not the purpose of this paper, however, to pursue these observations and to propose new taxa and new combinations.

Occurrence.

Martin Creek: Husky Formation, Lower member, composite section, 100 to 120 feet (30-37 m), *Buchia concentrica* sensu lato zone (Upper Oxfordian to Lower Kimmeridgian).

Banff-Aquitaine-Arco Rat Pass K-35 well: unnamed shale unit, sidewall core, at 1,710 feet (521 m) and 1,765 feet (538 m) (Upper Oxfordian-Upper Kimmeridgian).

Elf Jameson Bay C-31 well: Mould Bay Formation, Lower and Middle members, cuttings, 300- to 690-foot (91-210 m) and 850- to 890-foot (259-271 m) depths [highest occurrence, Upper Kimmeridgian to (?)Portlandian].

Genus *Lanterna* Dodekova

1969 *Lanterna* Dodekova, p. 16

Lanterna saturnalis sp. nov.

Plate 6, figures 1-10; Plate 7, figures 1-13

Holotype. GSC 34158, Slide P810-11A, 16.3 x 117.2; Langton Bay Formation, Gilmore Lake Member, cuttings sample at 1,680 to 1,700 feet (512-518 m) depth; Elf Horton River G-02 well, GSC loc. C-12530; Middle to Upper Kimmeridgian.

Dimensions. Overall length, 80μ; overall width, 70μ.

Diagnosis. Cyst length slightly greater than width; outline roughly truncated biconical. Periphragm and endophragm closely appressed throughout; periphragm produced into a densely spaced intratabular sculpture of varying process types, generally anastomosing basally and forming an irregular meshwork, but occasionally discrete. Archeopyle apical, formed by the loss of the reflected apical plate series in both wall layers; operculum simple, composed of both wall layers, occasionally partly attached, but generally detached. Reflected tabulation scheme determined as 4', 6", 0c, ?6''', ?1p, ?1"". Reflected cingulum outlined by parallel rows of processes of greater length than the intratabular processes; cingulum offset from one-half to three-quarters of the cingulum width. Sulcus generally indistinct; where discernible, following a relatively straight course from the antapex and reaching onto the epitract, terminating at the posterior edge of reflected plate 1'.

Description. The length of the cyst is slightly greater than the maximum width. The maximum width occurs at the latitude of the reflected cingulum, the cyst tapering and rounded at the apices to give a truncated biconical outline. The cyst outline probably explains the preferred apical-antapical orientation of most specimens.

The periblast and endoblast are closely appressed and in contact throughout. The periphragm is thin, about 1.0μ thick in optical section and is produced into a dense cover of processes: the processes are intratabular and occasionally distinctly peritabular in position. They anastomose basally to form an irregular, perfect to imperfect reticulum or, less commonly, irregularly converging arcuate patterns. Occasionally, the processes are discrete and more widely spaced. The processes also may form irregular peritabular ridges by anastomosing basally and indistinctly or, rarely, distinctly, outlining reflected tabulation in part. Individual sculpture elements include simple, tapering spines, bifid or bifurcating processes, and flattened, irregularly foliate processes, 6-8μ in length, but longer, 7-12μ, at the antapex and along the reflected cingular ledges. The endophragm is thin, less than 1.0μ thick in optical section, and smooth.

The archeopyle is apical and formed by the loss of four reflected apical plates in both layers. The operculum is simple, formed of both wall layers, and on some specimens remains partly attached. Isolated opercula have not been recognized.

The outline of the archeopyle, the shape of the partly attached operculum and the presence of secondary archeopyle sutures indicate that the reflected epitractal tabulation comprises four apical reflected plates and six pre-cingular reflected plates. The reflected tabulation of the hypotract is less distinct. Arrangement of the processes and the occasional presence of peritabular ridges suggest, but do not confirm, a reflected hypotractal tabulation of 6", 1p, 1"".

The reflected cingulum is defined by parallel rows of processes joined basally to form cingular ridges. The process elements are similar to those arising from intratabular and peritabular areas, except that they are slightly longer. The width of the reflected cingulum is about 5.0μ on specimens suitably oriented for measurement and the ventral terminations of the reflected cingulum are offset from one-half to three-quarters of the cingulum width.

The reflected sulcus is indistinctly outlined on a few specimens by a broad lineation formed of the anastomosing bases of the hypotractal processes. The sulcus is set on the median line joining apex and antapex and terminates at the base of the reflected apical plate 1'. On specimens preserved in apical orientation, the position of the sulcus is indicated in outline by an absence of cingular processes. This indentation corresponds, in several suitably oriented specimens, with the part of the rim of the primary archeopyle suture marking the posterior margin of reflected plate 1'.

Dimensions. (42 measured specimens) Cyst length, 70-80μ; cyst width, 57-82μ.

Discussion. The mode of the apical archeopyle, the reflected tabulation scheme and the absence of an offset sulcal notch suggest that this species exhibits basically a gonyaulacacean organization.

Comparison. *Lanterna saturnalis* sp. nov. most closely resembles *Lanterna sportula* Dodekova (1969, p. 18, Pl. 3, figs. 4, 7, 10, 11), of previously described species of the genus. The two species are of similar size and general construction, but *Lanterna saturnalis* sp. nov. differs in having an imperfect to perfect reticulum formed by the anastomosing bases of processes compared with the rugulate to rugulo-reticulate pattern exhibited by *L. sportula*. *Lanterna saturnalis* sp. nov. also exhibits a truncated biconical outline and possesses distinctly longer processes at the antapex and along the cingular sutures. *Lanterna sportula* is more equidimensional.

Baltisphaeridium pattei (Valensi) Sarjeant, 1960, as illustrated in Valensi (1948, 1953) exhibits a similar morphology to the four described species of *Lanterna*. Klement (1960) illustrates material assigned to that species (as *Hystrichosphaeridium pattei* Valensi; Klement, 1960, p. 56, Pl. 7, figs. 6-8) which shows an apical archeopyle. The species *pattei* is slightly smaller and its processes are shorter than described species of *Lanterna*. The species appears to belong in the genus *Lanterna*, and is transferred herein:

Lanterna pattei (=*Hystrichosphaeridium pattei* Valensi, 1948, p. 539, fig. 1) comb. nov., *?auct. non H. pattei* Valensi; Downie, 1957, p. 425, Pl. 20, fig. 10, Text-fig. 4c). Valensi (1948) records the species from Bathonian rocks of France and Klement (1960) reports the species from rocks of the lower and middle Malm (Oxfordian-Kimmeridgian) of southwestern Germany.

Lanterna pattei (Valensi) comb. nov. is not unlike *L. bulgarica* Dodekova in morphology and construction, but comparison of original material would be needed before synonymy could be established.

Occurrence.

Martin Creek: Husky Formation, Lower member, 342 to 484 feet (103-145 m), composite section, *Buchia mosquensis* sensu lato and (in part) *Buchia piochii* sensu lato zones (Middle to Upper Kimmeridgian).

Banff-Aquitaine-Arco Rat Pass K-35 well: unnamed shale unit, sidewall cores, 1,710- and 1,765-foot (521 and 538 m) depths [Upper Oxfordian(?) to Kimmeridgian].

Elf Horton River G-02 well: Langton Bay Formation, Gilmore Lake Member, cuttings, 1,680- to 1,810-foot (512-552 m) depth (highest occurrence, Upper Oxfordian-Upper Kimmeridgian).

Panarctic Oils Ltd. Line 2, shot-point 15: Mould Bay Formation, lower shale member, 80 feet (24 m) above MSL (Upper Kimmeridgian).

BIOSTRATIGRAPHY

MACROFOSSIL ZONAL SCHEMES AND THE JURASSIC-CRETACEOUS BOUNDARY

The biostratigraphy of mid- to upper Upper Jurassic and lowermost Cretaceous strata in the Canadian Arctic Archipelago and northern Interior Plains is complicated by several considerations, some of which are inherent in any biostratigraphic study of this part of the geologic column, and some of which are peculiar to the particular geographic region covered in this investigation.

Of the former category, the differing biostratigraphic schemes utilizing ammonites and pelecypod faunas that have been applied to strata assigned to Upper Jurassic and lowermost Cretaceous Stages, inclusive of Kimmeridgian to Berriasian, present the greatest problem. Biostratigraphic work, especially establishment of ranges of new taxa, is made more difficult because of the need to reconcile the several northwestern European schemes (Arkell, 1956; Ager, 1963; Cope *et al.*, 1964; and others) with those of the Tethyan region (Arkell, 1956; Enay, 1964; Ager, 1964; and others) and those of the Russian Platform and other parts of the boreal realm (Michailov, 1964; Sasonov, 1964; and others). An allied problem is the unsatisfactory definition of the Jurassic-Cretaceous System boundary. The so-called Purbeckian of England is a brackish-water to nonmarine facies, unsuitable for an international standard (Sylvester-Bradley, 1964; Wiedmann, 1968). The Portlandian Stage thus terminates with strata that cannot be correlated satisfactorily with uppermost Jurassic strata in other regions. Recent work by Casey (1973) on the Spilsby Sandstone of eastern England may help in the correlation of northwestern European stages with those of the Russian Platform at the Jurassic-Cretaceous boundary. In the region of the Russian Platform, there is evidence that the Ryazanian Stage does not represent all of the Berriasian Stage of Europe, and that the uppermost part of the boreal Jurassic succession is not represented by the Upper Volgian substage of the type area (Jeletzky, 1973). Finally, there is the question of whether the Berriasian is a stage, or is to be regarded as part of the Valanginian Stage (the so-called Infravalanginian, or Lower Valanginian of some authors), and whether, if it is considered a stage, it represents not the basal Cretaceous Stage, but the uppermost Jurassic Stage or a part thereof. Wiedmann (1968), Donze (1964), Busnardo, Le Hégarat and Magné (1965) and Jeletzky (1973), among others, discuss this matter at some length.

Of complications peculiar to biostratigraphic studies of the Jurassic-Cretaceous boundary in northern Canada, the scarcity of ammonite faunas makes external correlation of the uppermost Jurassic-lowermost Cretaceous of the Canadian Arctic with other regions most difficult. Correlation within the region is based mainly on pelecypods, other macrofossil faunal groups being of little practical use in this regard (Jeletzky, 1973). Therefore, zonal schemes proposed for Upper Jurassic and basal Lower Cretaceous strata of the Arctic Archipelago and northern Interior Plains (Frebold, 1961, 1964; Jeletzky, 1958, 1960, 1961, 1964, 1966, 1967, 1971, 1973) have not been refined yet to the level of those proposed for regions more extensively investigated. The recent syntheses of information published by Jeletzky (1967, 1971, 1973) have done much to clarify interrelationships of Canadian Arctic zonal schemes with other established schemes. It is still necessary, however, to borrow from other schemes from time to time in order to relate ranges of newly described taxa to international nomenclature.

The scarcity of lithologic marker horizons which approximate the position of the Jurassic-Cretaceous boundary in the Canadian Arctic also frequently complicates biostratigraphic work. The Jurassic-

ENGLAND/NORTHWESTERN EUROPE

Arkell (1956), Ziegler (1962), Cope (1967), Jeletzky (1973). Arkell's (1956) zonation of the Middle Kimmeridgian is to the left, Cope's (1967) zonation to the right.

SERIES	STAGE/ SUBSTAGE		ZONES	
LOWER CRETACEOUS	BERRIASIAN		PURBECK-WEALDEN (FACIES)	
UPPER JURASSIC			PURBECK-WEALDEN (FACIES)	
UPPER JURASSIC	PORTLANDIAN		*Titanites giganteus*	
UPPER JURASSIC	PORTLANDIAN		*Crendonites (Glaucolithites) gorei*	
UPPER JURASSIC	PORTLANDIAN		*Zaraiskites (Progalbanites) albani*	
UPPER JURASSIC	KIMMERIDGIAN	UPPER	*Pavlovia pallasioides*	
UPPER JURASSIC	KIMMERIDGIAN	UPPER	*Pavlovia rotunda*	
UPPER JURASSIC	KIMMERIDGIAN	UPPER	*Pectinatites pectinatus*	
UPPER JURASSIC	KIMMERIDGIAN	MIDDLE	*Subplanites wheatleyensis*	*Pectinatites hudlestoni*
UPPER JURASSIC	KIMMERIDGIAN	MIDDLE	*Subplanites grandis*	*Pectinatites wheatleyensis*
UPPER JURASSIC	KIMMERIDGIAN	MIDDLE	*Subplanites* spp. (? *vimineus*)	*Pectinatites scitulus*
UPPER JURASSIC	KIMMERIDGIAN	MIDDLE	*Gravesia gigas*	*Pectinatites elegans*
UPPER JURASSIC	KIMMERIDGIAN	MIDDLE	*Gravesia gravesiana*	*Pectinatites elegans*
UPPER JURASSIC	KIMMERIDGIAN	LOWER	*Aulacostephanus autissiodorensis*	
UPPER JURASSIC	KIMMERIDGIAN	LOWER	*Aulacostephanus pseudomutabilis*	
UPPER JURASSIC	KIMMERIDGIAN	LOWER	*Aulacostephanus mutabilis*	
UPPER JURASSIC	KIMMERIDGIAN	LOWER	*Aulacostephanus cymodoce*	
UPPER JURASSIC	KIMMERIDGIAN	LOWER	*Pictonia baylei*	
UPPER JURASSIC	OXFORDIAN			

SOUTHWESTERN EUROPE (TETHYAN)

Based mainly on Donze and Enay (1961), and Enay 1964). Additional information from Arkell (1956), Jeletzky (1973) and others.

STAGE/ SUBSTAGE		ZONES: ALPINE	ZONES: SUBALPINE
BERRIASIAN		*Berriasella boissieri*	*Berriasella boissieri*
BERRIASIAN		*Berriasella grandis*	*Berriasella grandis*
TITHONIAN	UPPER	*Virgatosphinctes transitorius*	*Berriasella chaperi*
TITHONIAN	UPPER	*Virgatosphinctes transitorius*	*Berriasella delphinensis*
TITHONIAN	LOWER	*Pseudovirgatites scruposus* ?	*Anavirgatites palmatus*
TITHONIAN	LOWER	*Pseudovirgatites scruposus* ?	*Lithacoceras ciliata*
TITHONIAN	LOWER	*Pseudovirgatites scruposus* ?	*Subplanites vimineus*
TITHONIAN	LOWER	*Semiformiceras semiforme*	*Subplanites contiguus*
TITHONIAN	LOWER	*Semiformiceras semiforme*	*Glochyceras lithographicum*
KIMMERIDGIAN	LOWER	*Hybonoticeras beckeri*	*Virgataxioceras setatum/subeumela*
KIMMERIDGIAN	LOWER	*Aulacostephanus pseudomutabilis*	*Aulacostephanus pseudomutabilis*
KIMMERIDGIAN	LOWER	*Streblites tenuilobatus*	*Streblites tenuilobatus*
OXFORDIAN			

GSC

FIGURE 12. Comparison and correlation of stage and zonal nomenclature from selected regions with those used in the Canadian Boreal Region (with sources for correlation data given)

RUSSIAN PLATFORM Sasonov (1961, 1964), Michailov (1964), Jeletzky (1965, 1966, 1967, 1971, 1973)			CANADIAN BOREAL REGION Frebold (1961, 1964), Jeletzky (1965, 1966, 1967, 1971, 1973)			
					CANADIAN ARCTIC ARCHIPELAGO	RICHARDSON MOUNTAINS-PEEL PLATEAU
STAGE	SUB-STAGE	ZONES/SUBZONES	STAGE	SUB-STAGE	ZONES	ZONES
RYAZANIAN		*Surites spasskensis*	BERRIASIAN	UPPER	Diagnostic fossils unknown Strata appear to be present	*Buchia* n. sp. aff. *volgensis* and *Tollia* cf. *payeri*
		Berriasella rjasanensis				
				LOWER	*Buchia okensis* and *Craspedites* aff. *suprasubditus*	*Buchia okensis* and *Craspedites* aff. *suprasubditus*
VOLGIAN	UPPER	*Craspedites nodiger*	TITHONIAN	UPPER	*Praetollia antiqua* and *Buchia terebratuloides* sensu lato	*Buchia* n. sp. aff. *okensis* *Buchia terebratuloides* sensu lato
		Craspedites subditus			*Buchia unschensis* and *Craspedites canadensis*	*B. unschensis* and *C. canadensis* (undivided)
		Craspedites okensis/Kachpurites fulgens			*Buchia fischeriana/B. richardsonensis*	*Buchia fischeriana/B. richardsonensis*
	UPPER LOWER	*Epivirgatites nikitini*	PORTLANDIAN		*Buchia piochii*	*Buchia piochii*
		Virgatites rosanovi				
		Virgatites virgatus			*Buchia mosquensis*	*Buchia mosquensis*
	LOWER LOWER	*Zaraiskites scythicus*: *Dorsoplanites panderi*	KIMMERIDGIAN	MIDDLE AND UPPER		
		Zaraiskites scythicus: *Pavlovia pavlovi*				
		Subplanites pseudoscythicus				
		Subplanites sokolovi				
		Subplanites klimovi				
		Gravesia gravesiana				
KIMMERIDGIAN	LOWER	*Virgataxioceras fallax*		LOWER	*Amoeboceras* sp. *Buchia concentrica* sensu lato	*Buchia concentrica* sensu lato
		Aulacostephanus pseudomutabilis				
		Ilovaiskiceras stephanoides/ *Amoeboceras kitchini*				
OXFORDIAN			OXFORDIAN	UPPER		
				LOWER	*Cardioceras* aff. *mirum*	*Cardioceras* ex gr. *cordatum*

GSC

FIGURE 12. Continued

Cretaceous boundary in the Arctic Archipelago, for example, falls within relatively homogeneous lithologic units (Chamney, 1971; Jeletzky, 1973). In the Richardson Mountains-Peel Plateau regions west of the Mackenzie Delta, the Jurassic-Cretaceous boundary is defined by the base of the lowermost Cretaceous *Buchia okensis* zone and the top of the uppermost Jurassic *Buchia unschensis* and *Buchia* n. sp. aff. *okensis* zones (Jeletzky, 1967, 1971, 1973). This macrofaunal change occurs just above uppermost glauconitic beds of the Arenaceous member and within basal beds of the Red-weathering shale member of the Husky Formation. However, this lithologic marker horizon may be absent or unrecognizable because of facies changes outside the type localities.

To provide a framework for defining the ranges of new dinoflagellate taxa described in this paper, the authors have constructed a summary (Fig. 12) of the pertinent macrofossil zonal schemes for various regions, based on reviews of representative literature and the compilations of Jeletzky (1965, 1971, 1973). Based on information presented in Jeletzky (1973) and Le Hégarat and Remane (1968), the present writers consider the Berriasian as the lowest Cretaceous Stage. The Portlandian and the lower two of the four *Berriasiella* zones shown in Figure 13 are considered to be approximately equivalent to the Upper Tithonian; that is, the Upper Tithonian begins at the base of the *Zaraiskites albani* zone. Following Enay (1964), the Lower Tithonian is taken to commence at the base of the *Hybonoticeras beckeri* zone [=*Aulacostephanus autissiodorensis* zone of Zeigler (1962) mentioned *in* Cope *et al.* (1964)]. Hence the Lower Tithonian encompasses the Middle and Upper Kimmeridgian of the English succession, beginning with the *Gravesia gravesiana* zone and ending with the *Pectinatites pectinatus* zone of Cope (1967) and Arkell (1956). The interregional occurrence of several species of *Gravesia*, in the Tethyan (southeastern France) and the Boreal Realms (England, northeastern France, and European Russia), permits the recognition of the lower boundary of the Tithonian in these areas. This use of the Kimmeridgian Stage thus differs from that of some authors (e.g., Ager, 1963). It should be remembered, however, that, throughout following discussions, general or partial equivalence rather than direct correlation is implied in this use of international stage names. The Canadian Arctic macrofossil zones established by Jeletzky (1965, 1967, 1971, 1973) remain the only representative ones for the northern Interior Plains and Arctic Archipelago.

Finally, Figure 13 shows the known ranges of dinoflagellates used extensively in the following discussion to correlate subsurface sections with international stages and to supplement the macrofossil zonations in surface sections. These ranges are compiled from a survey of the literature and from such compilations as are available at the time of writing (Riley and Sarjeant, 1972). The ranges of new taxa published in this paper are given also in Figure 13, together with the nomenclature of international stages and substages followed in this paper.

BIOSTRATIGRAPHY OF THE *borealis* ASSEMBLAGE

Surface exposures and shot-point samples - northern mainland and Arctic Islands

The composite section on Martin Creek provides a surface reference column which is supplemented by information from the Mount Gifford locality, the Panarctic Oils Ltd. air-drilled, seismic shot-point core samples from Melville Island, and the Mount Goodenough locality (not described in this paper).

The uppermost occurrence of the *borealis* assemblage is in Berriasian strata at Martin Creek (Fig. 3). *Pareodinia capillosa* sp. nov. becomes extinct in the Upper member of the Husky Formation, and *P. borealis* sp. nov. in the Red-weathering shale member. Their uppermost occurrences are in strata assigned to the *Buchia okensis* zone (Jeletzky, 1958, 1967, 1971).

Lanterna saturnalis sp. nov. is the next species, in descending order, recorded in the section, occurring in strata of the Lower member of the Husky Formation assigned to the *Buchia piochii* sensu lato and *Buchia mosquensis* sensu lato zones. Jeletzky (1967, and earlier) states that these zones comprise strata of Middle Kimmeridgian to Portlandian sensu stricto age.

Lastly, the uppermost occurrences of *Horologinella spinosigibberosa* sp. nov. and *Psaligonyaulax dualis* sp. nov. are in strata assigned to the *Buchia concentrica* sensu lato zone (Jeletzky, 1967 and earlier) of Late Oxfordian to Early Kimmeridgian age.

Specimens unquestionably attributable to *Gonyaulacysta jurassica* (Deflandre) Norris and Sarjeant, 1965, do not occur above the top of the Lower member of the Husky Formation, in the *Buchia piochii-Buchia mosquensis* sensu lato zones. Riley and Sarjeant (1972) cite the range for *G. jurassica* as Bathonian to Upper Kimmeridgian (*Pectinatus* zone of Arkell, 1956; Cope, 1967). Species of *Cicatricosisporites* first occur in the Red-weathering shale member, Husky Formation (*Buchia okensis* zone) and species of *Trilobosporites* are first recorded in the upper beds assigned to the *Buchia piochii-Buchia mosquensis* sensu lato zones, coincident with the uppermost occurrence of *G. jurassica*. Norris (1969) established that the genus *Trilobosporites* does not persist below the Middle Kimmeridgian of England (i.e., above the top of the *beckerii* zone = *Gravesia* zones and higher = zones above the *autissiodorensis* zone; Arkell, 1956; Cope, 1967; Jeletzky, 1965).

This palynologic evidence suggests that strata up to the 484-foot (148 m) level in the composite section are no younger in age than Middle or Late Kimmeridgian. Therefore, at Martin Creek, *P. capillosa* ranges downward into strata as old as Middle Kimmeridgian and *Lanterna saturnalis* occurs in rocks of Middle and Late Kimmeridgian age. *Psaligonyaulax dualis* and *Horologinella spinosigibberosa* occur in strata of Late Oxfordian to Early Kimmeridgian age

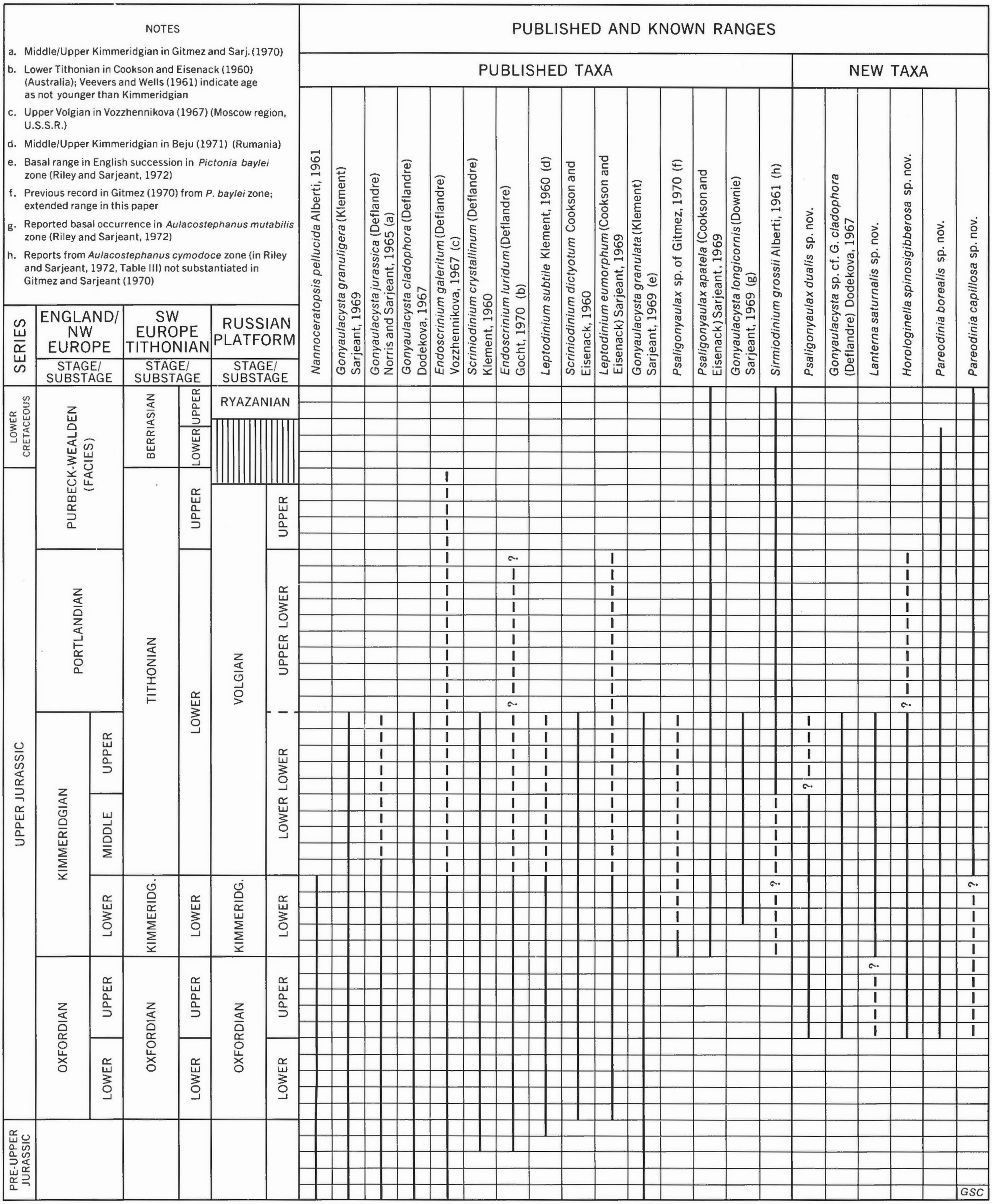


FIGURE 13. Published ranges of key dinoflagellate cyst species used for purposes of correlation in this paper, and determined ranges of newly proposed taxa (with notes on the ranges of selected species)

and *P. borealis* ranges downward into strata as old as Late Oxfordian (*Buchia concentrica* sensu lato zone of Jeletzky, 1967).

At the Mount Gifford locality (Fig. 4), basal beds of the Red-weathering shale member and uppermost beds of the Arenaceous member (Husky Formation) carry *Pareodinia borealis, P. capillosa* and the spore genus *Cicatricosisporites*. These beds are assigned Late Tithonian (pre-*Buchia okensis* zone) and Berriasian ages (*Buchia okensis* zone) by Jeletzky (1967).

The shot-point core samples from northwestern Melville Island (Fig. 11a) show a succession of species similar to that encountered at Martin Creek. *Pareodinia borealis* and *P. capillosa* are the last species of the *borealis* assemblage to occur, being recorded in the topmost sample of shot-point 18 [320 ft (97.5 m) above MSL]. Both of these species range downward to the basal sample in shot-point 15 at 40 feet (12.2 m) above MSL. *Lanterna saturnalis* occurs only in shot-point 15 at 80 feet (24 m) above MSL and *Psaligonyaulax dualis* occurs only in the basal sample of shot-point 15 at 40 feet (12.2 m) above MSL. At, or close to, the level of occurrence of *L. saturnalis*, other dinoflagellate species also occur, including *Pareodinia ceratophora* Deflandre, 1947, *Sirmiodinium grossii* Alberti, 1961, *Psaligonyaulax apatela* (Cookson and Eisenack) Sarjeant, 1969, and *Scriniodinium crystallinum* (Deflandre) Klement, 1960. *Scriniodinium dictyotum* Cookson and Eisenack, 1960, occurs together with *Psaligonyaulax dualis*. Species of *Trilobosporites* and *Cicatricosisporites* occur only in samples from shot-point 16 in the interval between 130 and 140 feet (39.6-42.6 m) above MSL. Samples below this level are dominated by bisaccate pollen and dinoflagellates, with a sharply reduced pteridophyte spore content. Thus the distribution of these genera is probably influenced by the depositional environment and distance from a source of continental material.

Analysis of this distribution of dinoflagellate species suggests the following interpretation. The association of species present in samples from shot-points 16, 17 and 18 indicate that the age of these strata is basal Cretaceous, Early Berriasian. From evidence obtained along Martin Creek and on Mount Gifford, and from known ranges of dinoflagellate species, the age of the strata in shot-point 15 is no younger than Late Kimmeridgian at the top, and may be as old as Late Oxfordian at the base. The age of the upper 50 feet (15 m) of the shot-point is Late Kimmeridgian, based on the dinoflagellate assemblage. The sample at 40 feet (12.2 m) above MSL is of Late Oxfordian to Middle, possibly(?) Late, Kimmeridgian age. The Jurassic-Cretaceous boundary falls, therefore, more than 90 feet (27 m) above MSL and less than 240 feet (73 m) above MSL. Unfortunately, spore-pollen and dinoflagellate assemblages within the interval between 90 and 240 feet (27-73 m) above MSL are not diagnostic.

The conclusion that the *borealis* assemblage does not range upward into strata younger than Berriasian in age is supported by the following observations. Upper Berriasian, Upper Hauterivian and Barremian strata sampled at Mount Goodenough (Brideaux, unpubl. data), and Upper Berriasian and Valanginian strata (J. A. Jeletzky, pers. com., 1974) of the Lower sandstone division sampled at Martin Creek (Brideaux, unpubl. data) do not contain elements of the *borealis* assemblage. Also, the *borealis* assemblage has not been found in rocks assigned a post-Berriasian age in sidewall cores and cuttings from the Banff-Aquitaine-Arco Rat Pass K-35 well or in core samples from the IOE Stoney Core Hole F-42. The *borealis* assemblage does not occur in samples of Early Cretaceous, post-Berriasian age, from surface exposures from the Arctic Islands (Brideaux, unpubl. data, based on samples made available by W. S. Hopkins, Jr.). Therefore, the authors conclude that elements of the *borealis* assemblage do not occur in rocks younger than Berriasian in age (*Buchia okensis-Buchia* n. sp. aff. *volgensis* zones of Jeletzky, 1967, and earlier). The lower limit of the range of the *borealis* assemblage, from evidence discussed above, extends at least into strata of Late Oxfordian age. Samples from older Jurassic rocks of the Bug Creek Formation on Martin Creek were not processed for this investigation, and control from this source is not available. A further discussion of the lower limit of the range of the *borealis* assemblage will be undertaken in connection with analysis of data from the Arctic Island wells in a later part of this paper.

Subsurface well sections - Mackenzie Delta-Richardson Mountains regions

In the Rat Pass K-35 well (Fig. 5), the sidewall core from the 1,710-foot (527 m) depth contains *Pareodinia capillosa, P. borealis, Lanterna saturnalis, Horologinella spinosigibberosa* of the *borealis* assemblage and, in addition, *Lunatadinium dissolutum* Brideaux and McIntyre, 1973, *Sirmiodinium grossii* and *Psaligonyaulax apatela*. The sidewall core from the 1,765-foot (538 m) depth contains *P. borealis* and *Psaligonyaulax dualis*. Both samples contain an undifferentiated Upper Jurassic-Lower Cretaceous spore and pollen assemblage (Brideaux *in* Barnes *et al.*, 1974). Based on the evidence presented in the foregoing discussion, the age of the strata, represented by the sidewall core from the 1,710-foot (521 m) depth and strata above 1,765 feet (538 m), is Late Kimmeridgian. The presence of *Psaligonyaulax dualis* in the sidewall core from the 1,765-foot (538 m) depth and of *Gonyaulacysta* sp. cf. *G. cladophora* in the sidewall core from 1,920 feet (585 m) indicates that the age of the strata between 1,765 feet and 1,920 feet (538 and 585 m) is not younger than Middle Kimmeridgian and may be as old as Late Oxfordian. Based on this analysis, the range of *Horologinella spinosigibberosa* sp. nov. should be extended upward into the Upper Kimmeridgian.

In the IOE Stoney Core Hole F-42, strata between the depths of 930 and 970 feet (280-296 m) proved barren of diagnostic spore, pollen and dinoflagellate species. The age of this interval is thus not directly determinable. But because the lithology of this interval corresponds to that of the Arenaceous member of the Husky Formation of the surface sequence (Jeletzky, 1967, p. 127, Sec. 115) to some extent, and because a marked unconformity occurs at the 940-foot (283 m) depth, the age of this interval is most likely Late Jurassic, perhaps Portlandian or Late Tithonian (cf. Jeletzky, 1967, p. 33, 34; *see* discussion of the Martin Creek section and Fig. 3).

The sample from the depth between 970 and 980 feet (296-299 m) yielded undescribed species of *Scriniodinium* along with *Gonyaulacysta cladophora*, *Psaligonyaulax dualis* and *Contignisporites cooksoni* (Balme) Dettmann, 1963. Diagnostic species were not observed in the sample between 980 and 990 feet (299-302 m). Between 990 and 1,000 feet (302-305 m), *Psaligonyaulax dualis*, *Heterosphaeridium? saturnalis* and *Pareodinia capillosa* of the *borealis* assemblage are associated with *Sirmiodinium grossii*, *Scriniodinium crystallinum*, *Tubotuberella* sp. cf. *T. rhombiformis* Vozzhennikova, 1967 and the spore species, *Trilobosporites apiverrucatus* Couper, 1958.

Between depths of 1,000 and 1,010 feet (305-308 m), this dinoflagellate association persists (excepting *Psaligonyaulax dualis* and *Tubotuberella* sp. cf. *T. rhombiformis*) and includes, in addition, *Gonyaulacysta jurassica*, *Scriniodinium* sp. cf. *S. playfordii*, *Endoscrinium luridum* (Deflandre) Sarjeant, 1969, *Leptodinium eumorphum* (Cookson and Eisenack) Sarjeant, 1969 and *Acanthaulax* sp. The spore assemblage includes species of *Cicatricosisporites* (*C. australiensis*; *C. brevilaesuratus* Couper, 1958; and *C. angicanalis* Döring, 1965) and *Contignisporites glebulentus* Dettmann, 1963.

In the basal sample between 1,010 and 1,020 feet (308-311 m), only *Pareodinia capillosa*, *Psaligonyaulax dualis* and *Scriniodinium crystallinum* persist, and they are associated with a small assemblage of Upper Jurassic-Lower Cretaceous spore and gymnosperm pollen species.

Thus, the age of the interval between 970 and 1,010 feet (286-308 m), based on the dinoflagellate assemblages (*see* Fig. 13), is Late Kimmeridgian. The occurrence of the genus *Cicatricosisporites* throughout this interval supports this determination. Hughes and Moody-Stuart (1966) note that *Cicatricosisporites* in England occurs first at the top of the Kimmeridge Clay. Norris (1969) has recorded *Cicatricosisporites australiensis* and *C. brevilaesuratus* from Upper Kimmeridgian and Portlandian (=upper Lower and Upper Tithonian) and younger strata. Dettmann and Playford (1968) state that the genus first occurs in Australia in strata directly overlying rocks no younger in age than Kimmeridgian.

The age of the basal sample between 1,010 and 1,020 feet (308-311 m) is probably no older than Middle Kimmeridgian. This determination is based on the overlap of the confirmed basal range of *Pareodinia capillosa* and the upper confirmed range of *Psaligonyaulax dualis*.

In the Elf Horton River G-02 well (Fig. 7), the sample between depths of 1,530 and 1,540 feet (466-469 m) contains *Pareodinia capillosa* in association with *Scriniodinium crystallinum*, *Scriniodinium* spp., *Valensiella* sp. (undescribed), *Trilobosporites bernissartensis* Delcourt and Sprumont, 1955, and a caved assemblage including *Oligosphaeridium* spp., *Tenua hystrix* Eisenack, 1958, *Tenua* sp. A of Brideaux and McIntyre, in press, and *Appendicisporites* sp. from uphole strata of Aptian-Albian age (Brideaux, unpubl., and *in* Yorath *et al.*, in press). The age of this sample, based on the presence of *Pareodinia capillosa*, *Valensiella* sp., *Scriniodinium crystallinum* and *Trilobosporites bernissartensis* is no younger than Late Kimmeridgian. *Lanterna saturnalis* first occurs between 1,680 and 1,700 feet (512-518 m) and *Psaligonyaulax dualis* and *Pareodinia borealis* between 1,760 and 1,770 feet (536-539 m). Based on the foregoing discussions, the strata penetrated in the interval between 1,540 and 1,750 feet (469-536 m) are assigned a Middle to Late Kimmeridgian age, and the age of strata in the interval between 1,760 and 1,810 feet (536-552 m) are considered to be Late Oxfordian to Middle Kimmeridgian.

The conventional core from the Gulf East Reindeer C-38 well for the interval between 3,922 and 3,951 feet (1195-1197 m) contains a rich spore assemblage that includes *Cicatricosisporites australiensis* (Cookson) Potonié, 1956, *C. hallei* Delcourt and Sprumont, 1955, *C. grabowensis* Döring, 1965, *Trilobosporites apiverrucatus* Couper, 1958, *T. bernissartensis*, *Trilobosporites* spp., *Pilosisporites trichopapillosus* (Thiergart) Delcourt and Sprumont, 1955, *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann, 1961, and *Appendicisporites* sp. (=*Cicatricosisporites sprumontii* Döring, 1965). The core for the interval between 3,922 and 3,927 feet (1195-1197 m) contains *Pareodinia ceratophora*, *Canningia "adnata"* of Warren (1967) and *Imbatodinium* sp. (undescribed). *Pareodinia borealis* appears in the core for the interval between 3,949 and 3,951 feet (1203.7-1204.2 m). Based on evidence presented in this paper and the associated spore assemblage, the age of this cored interval is Berriasian, Early Berriasian in the interval between 3,949 and 3,951 feet (1203.7-1204.2 m).

Subsurface well sections - Arctic Islands

As noted earlier in this paper, analyses of the ranges of constituents of the *borealis* assemblage in Arctic Archipelago wells must, of necessity, be based mainly on palynologic data derived from associated spore-pollen and dinoflagellate assemblages. Pertinent palynofloral successions, transgressing the Jurassic-Cretaceous boundary, have been described from Europe and England by, among others, Couper (1958), Döring (1965, 1966), Burger (1966) and Norris (1969, 1970), and from North America by Pocock (1962, 1964, 1967), Warren (1967), and Habib and Warren (1973). Pocock (1972) and Johnson and Hills (1973) have described spore-pollen and dinoflagellate associations from Jurassic strata of the Canadian Arctic. Although some of the microplankton species referred to or described herein have not been recorded previously, the spore and pollen associations in the Arctic are essentially similar to those from equivalent strata in Europe. Therefore, it has been possible to correlate the Arctic palynofloral successions with those of Europe, despite limitations imposed by the inherent danger of caved contaminants of cuttings samples from well sections.

The assemblages recorded from the Elf Jameson Bay C-31 well (Fig. 8) are essentially similar to those recorded from the Mackenzie Delta (Brideaux and Fisher, unpubl. data), but are rather more diverse than is typical for palynofloras from the Sverdrup Basin. The Jameson Bay C-31 well spudded in the middle member of the Mould Bay Formation and, therefore, the uppermost strata encountered are very close to the Jurassic-Cretaceous boundary. Consequently, there is probably little caving of Cretaceous material in the cuttings samples examined for this investigation.

The palynofloras from the composite samples from the 110- to 170-foot (34-52 m) and 200- to 290-foot (61-88 m) depths were composed predominantly of spores and pollen indicating an undifferentiated Berriasian-Valanginian age for these intervals. However, the occurrence of *Pareodinia borealis* in the sample from the 200- to 290-foot (61-88 m) depth in association with this spore-pollen assemblage indicates that this interval is of Berriasian age. Below 300 feet (91 m), microplankton assemblages are more diversified. *Horologinella spinosigibberosa* occurs between 300 and 310 feet (91-94 m), and again at 360 feet (110 m) in association with *Psaligonyaulax* sp. of Gitmez, 1970, *Gonyaulacysta granuligera* (Klement) Sarjeant, 1969, and *Endoscrinium luridum* (Deflandre) Gocht, 1970. The associated spore and pollen assemblage in the interval between 300 and 360 feet (91-110 m) includes: between 300 and 310 feet (91-93 m), *Pilosisporites trichopapillosus, Trilobosporites apiverrucatus, Retitriletes parvimurus* Döring, 1965, and *Maculatisporites microverrucatus* Döring, 1965; at 350 feet (107 m), *Aequitriradites spinulosus, Trilobosporites obsitus* Norris, 1969, *Cicatricosisporites abacus* Burger, 1966 and *Retriletes parvimurus*; and at 360 feet (110 m), *Trilobosporites apiverrucatus, T. tenuiparietalis* Döring, 1965, *Tuberositriletes montuosus* Döring, 1964, *Maculatisporites microverrucatus, Cicatricosisporites australiensis,* and *Varirugosisporites mutabilis* Döring, 1964. Although *Cicatricosisporites* persists to the 490-foot (149 m) depth and *Trilobosporites apiverrucatus* persists to the 590-foot (180 m) depth, only rare occurrences of diagnostic Cretaceous species were noted below the 400-foot (122 m) depth, where *Pareodinia capillosa* was first recorded.

Microplankton assemblages are diverse in the sample from between depths of 430 and 450 feet (131-137 m). *Sirmiodinium grossii* Alberti, 1961, *Scriniodinium dictyotum* (variety), *Leptodinium eumorphum* (Cookson and Eisenack) Sarjeant, 1969, *Endoscrinium luridum* and *Psaligonyaulax apatela* (Cookson and Eisenack) Sarjeant, 1969 are associated with *Pareodinia borealis, P. capillosa* and *Horologinella spinosigibberosa* of the *borealis* assemblage. *Gonyaulacysta granuligera* occurs also with this assemblage and reappears lower in the section along with *Gonyaulacysta longicornis* Downie, 1957 which was recorded for the first time at the 520- to 540-foot (159-165 m) depth. *Gonyaulacysta jurassica* was first recorded at the 640- to 660-foot (195-201 m) depth and *Leptodinium subtile* Klement, 1960 between 670 and 710 feet (203 and 215 m) in the section.

The following species do not occur in cuttings samples below 690 feet (210 m): *Pareodinia borealis, Pareodinia capillosa, Psaligonyaulax apatela, Psaligonyaulax* sp. of Gitmez, 1970, *Gonyaulacysta granuligera, G. longicornis,* and *Imbatodinium* spp. The single occurrence of *Horologinella spinosigibberosa* recorded below this depth at from 850 to 890 feet (259-290 m) is attributable to caving. None of the diagnostic Late Jurassic dinoflagellate species persists into strata assigned to the subsurface equivalents of the Wilkie Point Formation.

The record of *Horologinella spinosigibberosa* from the 300- to 310-foot (91-94 m) depth, based on evidence from Mackenzie Delta assemblages, indicates the presence of Upper Jurassic strata. *Horologinella spinosigibberosa,* in the delta region, is known only from Upper Oxfordian and Kimmeridgian strata. Taken together with the spore-pollen association of general Late Tithonian to Berriasian age, recorded in the interval between 300 and 360 feet (91-107 m), the age of the strata penetrated in this interval is probably Late Jurassic, Late Kimmeridgian in age, but possibly may be as young as Portlandian (=late Early Tithonian) at the 300- to 310-foot (91-94 m) depth. The appearance of the dinoflagellate assemblage at 360 feet (110 m) indicates that the well has penetrated strata no younger than Middle to Late Kimmeridgian. Although the persistence of the spore-pollen assemblage to this level probably is attributable in part to caving, species of *Trilobosporites* are known to occur in strata of Middle Kimmeridgian age. Elements of this spore-pollen assemblage are rare below the 400-foot (122 m) depth. The microplankton assemblage at the 430- to 450-foot (131-137 m) depth indicates that the interval is no younger than Late Kimmeridgian in age, and may be as old as Late Oxfordian (Riley and Sarjeant, 1972). The disappearance below 690 feet (210 m) of the microplankton assemblage prevalent between 360 and 690 feet (110-210 m) suggests that strata below that depth are older than Late Oxfordian to Early Kimmeridgian. These conclusions, based on palynologic evidence, are consistent with age determinations on surface exposures of equivalent lithologic units in the vicinity of the well. Elements of the *borealis* assemblage in this well, therefore, occur in strata of Late Oxfordian to Berriasian age.

A discussion of the palynofloral associations from the Panarctic Hoodoo Dome H-37 well is difficult because of the relatively impoverished assemblages and the great amount of caved contamination present in the interval between 4,400 and 6,500 feet (1341-1981 m) studied for this investigation. Spore and pollen assemblages of a general Neocomian age above the 4,400-foot (1341 m) depth are replaced in the interval between 4,490 and 4,560 feet (1369-1390 m) by an assemblage of later Tithonian or Berriasian age including: *Maculatisporites maculatus, Varirugosisporites mutabilis, Retitriletes parvimurus, Trilobosporites bernissartensis* and *Trilobosporites* form sp. A of Döring, 1965. In the underlying interval between 4,650 and 4,850 feet (1417-1478 m), the appearance of a dinoflagellate assemblage which includes *Endoscrinium luridum, Psaligonyaulax apatela* and *Gonyaulacysta granuligera* indicates that the well has penetrated strata of Late Jurassic age, no younger than Late Kimmeridgian. *Sirmiodinium grossii* occurs between depths of 4,860 and 4,950 feet (1481-1509 m) associated with *Psaligonyaulax apatela.*

Elements of the *borealis* assemblage, represented by *Pareodinia borealis* and *P. capillosa,* are recorded first in the section between the depths of 5,000 and 5,090 feet (1524-1551 m) and persist downhole to 5,750 feet (1753 m) and 5,900 feet (1798 m), respectively. They are associated with the first occurrences in the well of the following species at the following depths: *Psaligonyaulax* sp. of Gitmez, 1970 between 5,150 and 5,250 feet (1570-1600 m), *Scriniodinium dictyotum* Cookson and Eisenack, 1960 between 5,200 and 5,290 feet (1585-1612 m), *Gonyaulacysta longicornis* between 5,460 and 5,550 feet (1664-1692 m), and *Scriniodinium crystallinum* between 5,600 and 5,690 feet (1707-1734 m). These species, with the exception of *Pareodinia capillosa*, do not persist below the 5,750-foot (1753 m) depth.

The underlying microplankton assemblages include the following species which first occur in the well between 6,260 and 6,460 feet (1908-1969 m): *Acanthaulax* sp. 1 and *Acanthaulax* sp. 2 of Johnson and Hills, 1973, *Gonyaulacysta cladophora* and *G. jurassica, Leptodinium subtile* Klement, 1960, *Nannoceratopsis gracilis* Alberti, 1961 and *N. pellucida* Deflandre, 1938.

The assemblage associated with *Pareodinia borealis* and *P. capillosa* indicates that the strata in that interval are of a general Late Oxfordian(?) to Late Kimmeridgian age. The underlying assemblage between the depths of 6,260 and 6,460 feet (1908-1969 m) indicates an age for these strata of Callovian-Early Oxfordian. Thus, elements of the *borealis* assemblage in the Panarctic Hoodoo Dome H-37 well occur in strata of Late Jurassic age, probably Late Oxfordian(?) to Late Kimmeridgian.

The palynofloras encountered in the interval between 2,010 and 2,220 feet (613-677 m) in the Panarctic Tenneco *et al.* Kristoffer Bay B-06 well indicate that the age of these strata is Early Cretaceous, probably Berriasian. A typical assemblage, recorded in a sample from between 2,010 and 2,070 feet (613-631 m) includes *Sirmiodinium grossii, Aequitriradites spinulosus, Varirugosisporites mutabilis* and *Cicatricosisporites* spp. In a sample from between 2,100 and 2,190 feet (640-668 m), *S. grossii* again occurs in association with *Cicatricosisporites australiensis* and *C. sprumontii* (=*Appendicisporites* sp.). Below 2,220 feet (677 m), however, the assemblages include typical Upper Jurassic microplankton species. These include: at the 2,220- to 2,280-foot (677-695 m) depth, *Pareodinia borealis, P. capillosa, S. grossii, Psaligonyaulax apatela* and *Leptodinium subtile*; at the 2,310- to 2,370-foot (704-722 m) depth, *Pareodinia borealis, Psaligonyaulax apatela, Psaligonyaulax* sp. of Gitmez, 1970, and *Endoscrinium luridum*; and at the 2,400- to 2,490-foot (732-759 m) depth, *Pareodinia capillosa* and *Imbatodinium* spp.

The microplankton assemblages become less diverse in the underlying strata. *Scriniodinium crystallinum* was recorded in a sample from between 2,610 and 2,670 feet (796-814 m). *Gonyaulacysta jurassica* occurs at the 3,420- to 3,480-foot (1042-1061 m) depth and also in a sample from between 3,510 and 3,570 feet (1070-1088 m), where it is associated with *Acanthaulax* sp. 1 and sp. 2 of Hills and Johnson, 1973, and *Gonyaulacysta cladophora*. *Pareodinia capillosa* and *P. borealis* persist to the 3,270-foot (997 m) and 3,570-foot (1088 m) depths, respectively, but are most abundant in the interval between 2,220 and 2,490 feet (677-759 m). These two species are the only representatives of the *borealis* assemblage in this well.

The microplankton assemblage in the interval between the depths of 2,220 and 2,280 feet (677-695 m) is indicative of a Late Jurassic, Late Tithonian (=Portlandian and Late Tithonian) age. The assemblage from strata between 2,310 and 2,370 feet (704-722 m) is of an age no younger than Late Kimmeridgian. Therefore, the typical development of the *borealis* assemblage, represented by *Pareodinia borealis* and *P. capillosa*, occurs in this well in strata of Kimmeridgian to Late Tithonian age (=Kimmeridgian, Portlandian and higher Jurassic zones; *see* Figs. 12, 13). These two species persist into strata as old as Early Oxfordian in age between depths of 3,270 and 3,570 feet (978-1088 m), but the possibility of contamination by caving precludes accepting this as evidence that elements of the *borealis* assemblage range downward into strata older than Late Oxfordian.

Elements of the *borealis* assemblage occur also in parts of sections penetrated by four other wells in the Arctic Archipelago. In the Elf Wilkins E-60 well, *Pareodinia capillosa* was recorded in the section between depths of 310 and 400 feet (94-122 m) in association with *Scriniodinium dictyotum* variety, *Gonyaulacysta longicornis, Psaligonyaulax* sp. of Gitmez, 1970 and *Tubotuberella* sp. A single specimen of *Pareodinia borealis* was recorded in the immediately underlying sample at the 410- to 500-foot (125-152 m) depth. The microplankton assemblages indicate that the age of the strata penetrated between 310 and 500 feet (94-152 m) is Kimmeridgian.

A single sample from Sun KR Skybattle Bay C-15 well from between depths of 4,720 and 4,780 feet (1439-1457 m) contains rare specimens of *Pareodinia borealis* associated with *Psaligonyaulax apatela, Scriniodinium dictyotum, Trilobosporites apiverrucatus* and *Cicatricosisporites* spp. The sample is probably of Middle to Late Kimmeridgian age.

Samples from the Panarctic Drake Point L-67 well from between depths of 2,390 and 3,200 feet (728-975 m) were examined. The *borealis* assemblage, represented only by *Pareodinia borealis*, appears at the 3,020-foot (920 m) depth and persists to the 3,200-foot (975 m) depth. The species is associated with *Gonyaulacysta cladophora, G. jurassica* and *Acanthaulax* sp. at the 3,020-foot (920 m) depth. The age of this interval is probably no younger than Kimmeridgian and may be as old as Oxfordian. *Pareodinia borealis* occurs in association with *Gonyaulacysta longicornis* between 3,120 and 3,150 feet (951-960 m). *Pareodinia borealis*, therefore, occurs in strata of possible Early Oxfordian to Middle Kimmeridgian age in this well.

Three samples were examined from the Panarctic Tenneco *et al.* Drake Point F-16 well in the interval between 3,000 and 3,150 feet (914-960 m). *Pareodinia borealis* occurs throughout this interval and *Psaligonyaulax dualis* occurs at the 3,000- to 3,060-foot (914-933 m) and 3,090-foot (942 m) depths. Elements of the *borealis* assemblage are not found in this well above the 3,000-foot (914 m) depth (Fisher, unpubl. data). The range of *Psaligonyaulax dualis*, determined from information reported in this paper, is Upper Oxfordian to Kimmeridgian. The species of the *borealis* assemblage are associated with: at the 3,000- to 3,060-foot (914-933 m) depth, *Gonyaulacysta jurassica, Endoscrinium galeritum* and *Scriniodinium dictyotum*; at 3,090 feet (942 m), *Gonyaulacysta jurassica, G.* sp. cf. *G. granulata* (Klement) Sarjeant, 1969, and *Leptodinium* sp. cf. *L. clathratum* (Cookson and Eisenack) Sarjeant, 1969; and at the 3,120- to 3,150-foot (951-960 m) depth, *Gonyaulacysta cladophora, G. jurassica,* and *Nannoceratopsis pellucida.* These associated assemblages confirm the age of the strata penetrated in this interval as being no younger than Kimmeridgian and at least as old as Oxfordian. Although cuttings samples do not provide unequivocal proof of basal ranges of species in well sections, it is possible that the range of *Pareodinia borealis* must be extended downwards from Upper to Lower Oxfordian, based on evidence from the Drake Point F-16 well.

The evidence from the subsurface sections examined from the Canadian Arctic Archipelago confirms the conclusion based on evidence from the Mackenzie Delta surface and subsurface sections that the upper range limit of the *borealis* assemblage is Berriasian. Evidence gathered from data on the Drake Point F-16 and Drake Point L-67 wells on northeastern Melville Island suggests that the lower range limit of *Pareodinia borealis* should be extended to Lower Oxfordian.

CONCLUDING REMARKS

Species of the *borealis* assemblage are known to occur throughout the Canadian Arctic from Ellef Ringnes Island to Prince Patrick Island in the Archipelago, and from the Anderson Plain and eastern slopes of the Richardson Mountains between Latitudes 67°15'N and 68°30'N in the Mackenzie Delta region.

A few occurrences of species which may be conspecific with several of those comprising the *borealis* assemblage have been reported elsewhere in North America and England and western Europe. Warren (1967) describes Pareodinia "alberti", a species which is, in part, conspecific with *Pareodinia borealis* sp. nov., and which occurs on the west side of the Sacramento Valley, California, U.S.A. in Upper Tithonian to Valanginian strata. Several authors (Klement, 1960; Sarjeant, 1962; Gitmez, 1970) figure specimens from Oxfordian to Lower Kimmeridgian strata of England and western Europe that are comparable to *Psaligonyaulax dualis* sp. nov. The species described from the Banff-Aquitaine-Arco Rat Pass K-35 well as *Gonyaulacysta* sp. cf. *G. cladophora* (Deflandre) Dodekova is comparable to the species *Gonyaulacysta cladophora*, reported from Bajocian to Kimmeridgian strata of England and the continent by various authors.

Three other species of the *borealis* assemblage, *Pareodinia capillosa* sp. nov., *Lanterna saturnalis* sp. nov., and *Hologinella spinosigibberosa* sp. nov., are known only from Upper Jurassic to basal Cretaceous strata from the Canadian Arctic.

Pareodinia borealis and *P. capillosa* are geographically widespread, occurring throughout the Arctic Islands and northern mainland localities (Table 1). These two species are also the longest ranging, occurring in Upper Oxfordian to Lower Berriasian, but not in Upper Berriasian, strata. *Pareodinia borealis* may range into Lower Oxfordian strata on northwestern Melville Island.

The remaining four species of the *borealis* assemblage have more restricted ranges and are more restricted in geographic distribution. *Psaligonyaulax dualis* has been found in Upper Oxfordian to Middle Kimmeridgian strata of the eastern slopes of the Richardson Mountains, the Anderson Plain, and on Melville Island in the Archipelago. *Lanterna saturnalis* has a geographic distribution similar to *Psaligonyaulax dualis*, but is confined to Kimmeridgian strata. *Horologinella spinosigibberosa* has been recorded from Upper Oxfordian to Upper Kimmeridgian strata at two localities in the Mackenzie Delta region and on Prince Patrick Island in the Archipelago. The ranges of these two species have been determined, from palynologic evidence, to have an upper limit of Upper Kimmeridgian, equivalent to lower parts of the *Buchia mosquensis* sensu lato zone of Jeletzky (1967). Strata at Martin Creek carrying these two species cannot be so divided on the basis of macrofossil zones and are assigned (*see* Fig. 3) to the undifferentiated *Buchia mosquensis-Buchia piochii* sensu lato zones; these are defined by Jeletzky (1967) to comprise Middle Kimmeridgian to Portlandian sensu stricto strata. Later work may show that the ranges of these two species must be extended upward to the Portlandian sensu stricto. Finally, *Gonyaulacysta* sp. cf. *G. cladophora* shows the most restricted geographic distribution, occurring only in Upper Oxfordian to Lower and(?) Middle Kimmeridgian strata penetrated by the Rat Pass K-35 well on the eastern slopes of the Richardson Mountains.

Many other species of spores, pollen, dinoflagellate cysts and acritarchs are associated with described species of the *borealis* assemblage. A number of these are new species and a few of them undoubtedly will be added to the *borealis* assemblage. Description of these species must await later publications. This investigation has established that a distinctive dinoflagellate assemblage, intermediate in age between typical Lower Cretaceous assemblages and upper Lower to lower Upper Jurassic assemblages, as described by Johnson and Hills (1973) and Pocock (1972), exists in the Canadian Arctic. The assemblage is, for the most part, endemic to the Arctic region, with only limited distribution in more southern latitudes.

REFERENCES

Ager, D. V.
1963: Jurassic stages; Nature, v. 198, p. 1045-1046.

1964: The British Mesozoic Committee; Nature, v. 199, p. 1059.

Alberti, G.
1961: Zur Kenntnis mesozoischer und alttertiärer Dinoflagellaten und Hystrichosphaerideen von Nord - und Mitteldeutschland sowie einigen anderen europäischen Gebieten; Palaeontographica, Abt. A, v. 116, p. 1-58.

Arkell, W. J.
1956: Jurassic Geology of the World; Oliver and Boyd Ltd., Edinburg and London.

Barnes, C. R., Brideaux, W. W., Chamney, T. P., Clowser, D. R., Dunay, R. E., Fisher, M. J., Fritz, W. H., Hopkins, William S., Jr., Jeletzky, J. A., McGregor, D. C., Norford, B. S., Norris, A. W., Pedder, A. E. H., Rauwerda, P. J., Sherrington, P. F., Sliter, W. V., Tozer, E. T., Uyeno, T. T., and Waterhouse, J. B.
1974: Biostratigraphic determinations of fossils from the subsurface of the Northwest and Yukon Territories; Geol. Surv. Can., Paper 74-11.

Beju, D.
1971: Jurassic microplankton from the Carpathian Foreland of Roumania; Instit. Geol. Publ. Hung., Ann., v. 42, p. 275-317.

Brideaux, W. W.
1972: Report on the palynologic analysis of thirteen samples of cuttings from Elf Horton River G-02 well (NTS 97C); Geol. Surv. Can., Paleontol. Rept. No. WWB-1-1972 (unpubl.).

1975: Status of Mesozoic and Tertiary dinoflagellate studies in the Canadian Arctic; Am. Assoc. Stratigr. Palynol., Contributions Series, no. 4, p. 15-28.

Brideaux, W. W. and McIntyre, D. J.
1973: *Lunatadinium dissolutum* gen. et sp. nov., a dinoflagellate cyst from Lower Cretaceous rocks, Yukon Territory and northern District of Mackenzie; Bull. Can. Petrol. Geol., v. 21, p. 395-402.

in press: Spores, pollen, dinoflagellates and acritarchs from Lower Cretaceous rocks on Horton River, District of Mackenzie, Canada; Geol. Surv. Can., Bull. 252.

Burger, D.
1966: Palynology of uppermost Jurassic and lowermost Cretaceous strata in the eastern Netherlands; Leidse Geol. Meded., v. 35, p. 211-276.

Busnardo, R., Le Hégarat, G., and Magné, J.
1965: Le Stratotype du Berriasian; Fr., Bur. Rech. Géol., Minières, Mém. 34, p. 5-33.

Casey, R. A.
1973: The ammonite succession at the Jurassic-Cretaceous boundary in eastern England *in* The Boreal Lower Cretaceous, Casey, R., and Rawson, P. F. (eds.); Geol. J., Spec. Issue 5, p. 193-266.

Chamney, T. P.
1971: New species of foraminifera, Cretaceous-Jurassic boundary, Arctic America *in* Contributions to Canadian paleontology; Geol. Surv. Can., Bull. 192, p. 95-113.

1973: Tuktoyaktuk Peninsula Tertiary and Mesozoic biostratigraphy correlations; Geol. Surv. Can., Paper 73-1B, p. 171-178.

Clowser, D. R., Fisher, M. J., Bujak, J. P., Dunay, R. E., Rauwerda, P. J., and Sherrington, P. F.
1973: The biostratigraphy of the Panarctic Hoodoo Dome H-37 well, Ellef Ringnes Island, District of Franklin; Robertson Research (North America) Limited, Exploration Rept. No. 50, p. 1-21.

Cookson, I. C.
1965: Microplankton from the Paleocene Pebble Point Formation, southwestern Victoria; Part 1; Roy. Soc. Victoria, Proc., v. 78, pt. 2, p. 137-141.

Cookson, I. C. and Dettmann, M. E.
1961: Re-appraisal of the Mesozoic microspore genus *Aequitriaradites*; Palaeontology, v. 4, p. 425-427.

Cookson, I. C. and Eisenack, A.
1960: Upper Mesozoic microplankton from Australia and New Guinea; Palaeontology, v. 2, p. 243-261.

1962: Additional microplankton from Australian Cretaceous sediments; Micropaleontology, v. 8, p. 485-507.

Cope, J. C. W.
1967: The palaeontology and stratigraphy of the lower part of the Upper Kimmeridge Clay of Dorset; Bull. Brit. Mus. Nat. Hist. (Geol.), v. 15, p. 1-78.

Cope, J. C. W., Sarjeant, W. A. S., Spalding, D. A. E., and Zeiss, A.
1964: The Kimmeridgian-Portlandian boundary; Colloque du Jurassique, Luxembourg, 1962, Comptes Rendus et Mémoires, p. 933-936.

Couper, R. A.
1958: British Mesozoic microspores and pollen grains, a systematic and stratigraphic study; Palaeontographica, Abt. B, Bd. 103, p. 75-179.

Davey, R. J., Downie, C., Sarjeant, W. A. S., and Williams, G. L.
1969: Appendix to "Studies on Mesozoic and Cainozoic dinoflagellate cysts"; Bull. Brit. Mus. Nat. Hist. (Geol.), Appendix to Supplement 3, p. 1-24.

Deflandre, G.
1938: Microplancton des mers jurassique conservé dans les marnes de Viller-sur-Mers (Calvados). Etude limnaire et considérations générales; Stat. Zool. Wimereux, Trav., v. 13, p. 147-200.

1947: Sur quelques microorganismes planctoniques des silex jurassiques; Inst. Oceanogr., Monaco, Bull. 921, p. 1-10.

1964: Quelques observations sur la systematique de la nomenclature des Dinoflagellés fossiles; Multicopie Ecôle Pratique des Hautes Etudes, p. 1-8.

Delcourt, A. F. and Sprumont, G.
1955: Les spores et grains de pollen du Wealdien du Hainaut; Soc. Geol. Belgique, Mém., n.s., v. 4, no. 5, p. 1-73.

Dettmann, M. E.
1963: Upper Mesozoic microfloras from south-eastern Australia; Roy. Soc. Victoria, Proc., v. 77, p. 1-148.

Dettmann, M. R. and Playford, G.
1968: Taxonomy of some Cretaceous spores and pollen grains from eastern Australia; Roy. Soc. Victoria, Proc., v. 81, no. 2, p. 69-94.

Dodekova, L.
1967: Les dinoflagellés et acritarches de l'Oxfordien-Kimeridgien de la Bulgarie du Nord-Est; Ann. Univ. Sofia, Fac. Géol. Geogr., v. 60, Livre 1, Géol., 1965-1966, p. 9-30.

1969: Dinoflagellés et acritarches du Tithonique aux environs de Pleven, Bulgarie Central du Nord; Bulgarian Acad. Sci., Committee Geol., Bull. Geol. Inst., Ser. Paleontol., v. 18, p. 13-24.

Donze, P.
1964: Les formations de la limite Jurassique-Crétacé dans le sud-est de la France: Colloque de Jurassique, Luxembourg, 1962, Comptes Rendus et Mémoires, p. 531-538.

Donze, P. and Enay, R.
1961: Les Céphalopodes du Tithonique inférieur de la Croix de Saint-Concors près Chambéry (Savoie); Trav. Lab. Géol. Lyon, n.s., no. 7.

Döring, H.
1964: Neue Sporengattungen und -arten aus dem Jura-Kreide-Grenzbereich Norddeutschlands; Monatsber. Deut. Akad. Wiss., Berlin, v. 6, p. 37-45.

1965: Die Sporenpaläontologische Gliederung des Wealden in Westmecklenburg (Structur Werle); Geologie Beih., v. 47, p. 1-118.

Downie, C.
1957: Microplankton from the Kimeridge Clay; Geol. Soc. London, Quart. J., v. 112, p. 413-434.

Eisenack, A.
1958: Microplankton aus dem norddeutschen Apt nebst einigen Bermerkungen über fossile Dinoflagellaten; Neues Jahrb. Geol. Paläontol., Abh., v. 106, p. 383-422.

Enay, R.
1964: L'étage Tithonique; Colloque de Jurassique, Luxembourg, 1962, Comptes Rendus et Mémoires, p. 355-379.

Evitt, W. R.
1967: Dinoflagellate studies. II. The archeopyle; Stanford Univ. Publ., Geol. Sci., v. 10, p. 1-83.

Frebold, H.
1961: The Jurassic Faunas of the Canadian Arctic, Middle and Upper Jurassic Ammonites; Geol. Surv. Can., Bull. 74.

1964: Outline of the Jurassic system in Canada; Colloque du Jurassique, Luxembourg 1962, Comptes Rendus et Mémoires, p. 479-483.

Gitmez, G. U.
1970: Dinoflagellate cysts and acritarchs from the basal Kimmeridgian (Upper Jurassic) of England, Scotland and France; Bull. Brit. Mus. Nat. Hist. (Geol.), v. 18, p. 231-331.

Gitmez, G. U. and Sarjeant, W. A. S.
1972: Dinoflagellate cysts and acritarchs from the Kimmeridgian (Upper Jurassic) of England, Scotland and France; Bull. Brit. Mus. Nat. Hist. (Geol.), v. 21, p. 171-257.

Gocht, H.
1970: Dinoflagellaten-Zystem aus dem Bathonium des Erdölfeldes Aldorf (NW-Deutschland); Palaeontographica, Abt. B, v. 129, p. 125-165.

Gorka, H.
1965: Les microfossiles du Jurassique supérieur de Magnuszew (Pologne); Acta Palaeontol. Pol., v. 10, p. 291-327.

Gulf Oil Canada Limited
1970: Well history report. Gulf East Reindeer C-38; p. 1-10.

Habib, D. and Warren, J. S.
1973: Dinoflagellates near the Cretaceous Jurassic boundary; Nature, v. 241, p. 217-218.

Hughes, N. F. and Moody-Stuart, J. C.
1966: Descriptions of schizaeaceous spores taken from Early Cretaceous macrofossils; Palaeontology, v. 9, p. 274-289.

Jeletzky, J. A.
1958: Uppermost Jurassic and Cretaceous rocks of Aklavik Range, northeastern Richardson Mountains, Northwest Territories; Geol. Surv. Can., Paper 58-2.

1960: Uppermost Jurassic and Cretaceous rocks, east flank of Richardson Mountains between Stony Creek and Donna River, Northwest Territories; Geol. Surv. Can., Paper 59-14.

1961: Upper Jurassic and Lower Cretaceous rocks, west flank of Richardson Mountains between headwaters of Blow River and Bell River, 116P and 117A (parts of); Geol. Surv. Can., Paper 61-9.

1964: Illustrations of Canadian fossils. Lower Cretaceous marine index fossils of the sedimentary basins of Western and Arctic Canada; Geol. Surv. Can., Paper 64-11.

Jeletzky, J. A.
1965: Late Upper Jurassic and early Lower Cretaceous fossil zones of the Canadian Western Cordillera, British Columbia; Geol. Surv. Can., Bull. 103.

1966: Upper Volgian (latest Jurassic) ammonites and buchias of Arctic Canada; Geol. Surv. Can., Bull. 128.

1967: Jurassic and (?) Triassic rocks of the eastern slope of the Richardson Mountains, northwestern District of Mackenzie; Geol. Surv. Can., Paper 66-50.

1971: Biochronology of Jurassic-Cretaceous transition beds in Canada; Geol. Surv. Can., Paper 71-16.

1972: Stratigraphy, facies and palaeogeography of Mesozoic and Tertiary rocks of northern Yukon and northwest Mackenzie District, N.W.T. [NTS 107B, 106M, 117A, 116-O (N 1/2), 116I, 116H, 116J, 116K (E 1/2)]; Geol. Surv. Can., Open File 82.

1973: Biochronology of the marine boreal latest Jurassic, Berriasian and Valanginian in Canada *in* The Boreal Lower Cretaceous, Casey, R., and Rawson, P. F. (eds.); Geol. J., Spec. Issue 5, p. 41-80.

Johnson, C. D. and Hills, L. V.
1973: Microplankton zones of the Savik Formation (Jurassic), Axel Heiberg and Ellesmere Islands, District of Franklin; Bull. Can. Petrol. Geol., v. 21, p. 178-218.

Klement, K.
1960: Dinoflagellaten und Hystrichosphaerideen aus dem Unteren und Mittleren Malm Sudwestdeutschlands; Palaeontographica, Abt. A, v. 114, p. 1-37.

Le Hégarat, G. and Remane, J.
1968: Tithonique supérieur et Berriasien de la bordure cévenole. Corrélation des Ammonites et des Calpionelles; Geobios, v. 1, p. 7-70.

Lentin, J. K. and Williams, G. L.
1973: Fossil dinoflagellates: index to genera and species; Geol. Surv. Can., Paper 73-42.

Michailov, N. P.
1964: Zonal sequence of the Lower Volgian stage and its equivalents; Colloque du Jurassique, Luxembourg 1962, Comptes Rendus et Mémoires, p. 381-390.

Norford, B. S., Barss, M. S., Brideaux, W. W., Chamney, T. P., Fritz, W. H., Hopkins, William S., Jr., Jeletzky, J. A., Pedder, A. E. H., and Uyeno, T. T.
1971: Biostratigraphic determinations of fossils from the subsurface of the Yukon Territory and the District of Mackenzie; Geol. Surv. Can., Paper 71-15.

Norris, G.
1969: Miospores from the Purbeck Beds and marine Upper Jurassic of southern England; Palaeontology; v. 12, p. 574-620.

1970: Palynology of the Jurassic-Cretaceous boundary in Southern England; Geoscience and Man, v. 1, p. 57-65.

Norris, G. and Sarjeant, W. A. S.
1965: A descriptive index of genera of fossil Dinophyceae and Acritarcha; N.Z., Geol. Surv., Paleontol. Bull. 40, p. 1-72.

Panarctic Oils Limited
1970: Completion report. Panarctic Hoodoo Dome H-37; p. 1-74.

1972: Well history report. Panarctic Tenneco *et al.* Kristoffer Bay B-06; p. 1-53.

Pocock, S. A. J.
1962: Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the western Canada plains; Palaeontographica, Abt. B., v. 111, p. 1-95.

1964: Pollen and spores of the Chlamydospermidae and Schizaceae from Upper Mannville strata of the Saskatoon area of Saskatchewan; Grana Palynologica, v. 5, no. 2, p. 129-209.

1967: The Jurassic-Cretaceous boundary in Northern Canada; Rev. Palaeobotan. Palynol., v. 5, p. 129-136.

1972: Palynology of the Jurassic sediments of western Canada. Part 2. Marine species; Palaeontographica, Abt. B, v. 137, p. 85-153.

Potonié, R.
1956: Synopsis der Gattungen der Sporae dispersae, I. Teil: Sporites; Beih. Geol. Jahrb., Heft 23.

Riley, L. A. and Sarjeant, W. A. S.
1972: Survey of the stratigraphical division of dinoflagellates, acritarchs and tasmanitids in the Jurassic; Geophytology, v. 2, p. 1-40.

Sarjeant, W. A. S.
1960: New hystrichospheres from the Upper Jurassic of Dorset; Geol. Mag., v. 96, p. 137-144.

1961: Microplankton from the Kellaways Rock and Oxford Clay of Yorkshire; Palaeontology, v. 4, p. 90-118.

1962: Upper Jurassic microplankton from Dorset, England; Micropaleontology, v. 8, p. 255-268.

Sarjeant, W. A. S.
1966: Dinoflagellate cysts with Gonyaulax-type tabulation *in* Studies on Mesozoic and Cainozoic dinoflagellate cysts; Bull. Brit. Mus. Nat. Hist. (Geol.), Supplement 3, p. 107-156.

1969: III. Taxonomic changes proposed by W. A. S. Sarjeant *in* Appendix to "Studies on Mesozoic and Cainozoic dinoflagellate cysts"; Bull. Brit. Mus. Nat. Hist. (Geol.), Appendix to Supplement 3, p. 7-15.

1972: Dinoflagellate cysts and acritarchs from the Upper Vardekløft Formation (Jurassic) of Jameson Land, East Greenland [with a supplement: Pollen grains and spores from the Upper Vardekløft Formation (Jurassic), Majeson Land, East Greenland by M. D. Muir]; Medd. om Grønland, v. 195, p. 1-69.

Sasonov, N. T.
1964: Stratigraphie des dépôts jurassiques de la Plate-forme Russe; Colloque du Jurassique, Luxembourg 1962, Comptes Rendus et Mémoires, p. 787-805.

Singh, C.
1971: Lower Cretaceous microfloras of the Peace River area, northwestern Alberta; Res. Council Alberta, Bull. 28, v. 2, p. 301-542.

Stott, D. F.
1969: Ellef Ringnes Island, Canadian Arctic Archipelago; Geol. Surv. Can., Paper 68-16.

Sylvester-Bradley, P. C.
1964: Type sections of Bathonian, Portlandian and Purbeckian Stages, and the problem of the Jurassic-Cretaceous boundary; Colloque du Jurassique, Luxembourg 1962, Comptes Rendus et Mémoires, p. 259-263.

Tozer, E. T. and Thorsteinsson, R.
1964: Western Queen Elizabeth Islands, Arctic Archipelago; Geol. Surv. Can., Mem. 332.

Valensi, L.
1948: Sur quelques micro-organismes planctoniques des silex du Jurassique moyen du Poitou et de Normandie; Soc. Géol. Fr., Bull., ser. 5, v. 18, p. 537-550.

1953: Microfossilés de silex du Jurassique moyen. Remarques pétrographiques; Soc. Géol. Fr., Mém. 68, p. 1-100.

Veevers, J. J. and Wells, A. T.
1961: The Geology of the Canning Basin, West Australia; Austral., Bur. Miner. Resour., Geol. Geophys., Bull. 60.

Vozzhennikova, T. F.
1967: Iskopaemye peridinei yurskikh, melovykh i paleogenovykh otlozheniy SSSR; Akad. Nauk SSSR, Sib. Otd., Inst. Geol. Geofiz., Tr. (Fossil peridinians of the Jurassic, Cretaceous and Paleogene deposits of the U.S.S.R.).

Warren, J. S.
1967: Dinoflagellates and acritarchs from the Upper Jurassic and Lower Cretaceous rocks on the west side of the Sacramento Valley, California; Ph.D. Dissert., Stanford University, Palo Alto, California (unpubl.).

Wiedmann, J.
1968: Das Problem stratigraphischer Grenziehung und die Jura/Kreide Grenze; Ecologae geol. Hel., v. 61, p. 321-386, Tr. (The problem of stratigraphic delimitations and the Jurassic/ Cretaceous boundary).

Wilson, G. J.
1967: Microplankton from the Garden Cove Formation, Campbell Island; N.Z.J. Bot., v. 5, p. 223-240.

Yorath, C. J., Balkwill, H. R., and Klassen, R. W.
in press: Franklin Bay (97C) and Malloch Hill (97F) map-areas, District of Mackenzie; Geol. Surv. Can., Paper 74-36.

Ziegler, B.
1962: Die Ammoniten-Gattung *Aulacostephanus* im Oberjura (Taxonomie, Stratigraphie, Biologie); Palaeontographica, Abt. A, v. 119, p. 1-172.

PLATE LEGENDS

In the explanation of figures, the species name is followed by the GSC (I.S.P.G.) locality number, the slide number, the stage co-ordinates for Reichert Zetopan Microscope No. 56 395 at the Institute of Sedimentary and Petroleum Geology, Calgary, Canada, an explanation of the focus level and orientation, if needed, the GSC Type Number, and the magnifications. IC refers to Interference Contrast; other figures are photographed in brightfield.

PLATE 1

Figures 1-3, 7. *Gonyaulacysta* sp. cf. *G. cladophora* (Deflandre) Dodekova.

1. C-12635, ARCO Slide 10618A-2, 11.4 x 115.8; IC, lo-focus on dorsal surface and apical horn; GSC 42356. x325.

2, 3. C-12635, ARCO Slide 10618A-2, 16.8 x 129.7; IC, (2) lo-focus on sutural spines, (3) hi-focus on dorsal surface; GSC 42357. x325.

7. C-12635, ARCO Slide 10618A-1, 15.7 x 124.2; IC, lo-focus on dorsal surface; GSC 42358. x325.

Figures 4-6, 8-12. *Psaligonyaulax dualis* sp. nov.

4, 5. Holotype: C-12532, Slide P810-13B, 25.4 x 123.5; (4) lo-focus on dorsal surface and periarcheopyle, (5) hi-focus on ventral surface and endarcheopyle; GSC 34154. x325.

6,10. C-12531, Slide P810-12A, 24.6 x 119.0; (6) hi-focus on dorsal surface, (10) lo-focus on ventral surface; GSC 42359. x500.

8. C-12532, Slide P810-13A, 43.7 x 134.4; IC, apical part of the endoblast; GSC 42360. x1250.

9. C-12532, Slide P810-13A, 30.0 x 121.6; IC, hi-focus on ventral surface and antapical breach; GSC 42361. x325.

11. C-29106, Slide 912-1C, 37.5 x 127.8; mid-focus on peri- and endarcheopyles; GSC 42362. x500.

12. C-12636, Slide P784-41C, 18.5 x 129.1; IC, hi-focus on antapical part of cyst possessing an antapical extension in the normal position of the antapical breach; GSC 42363. x1250.

PLATE 1

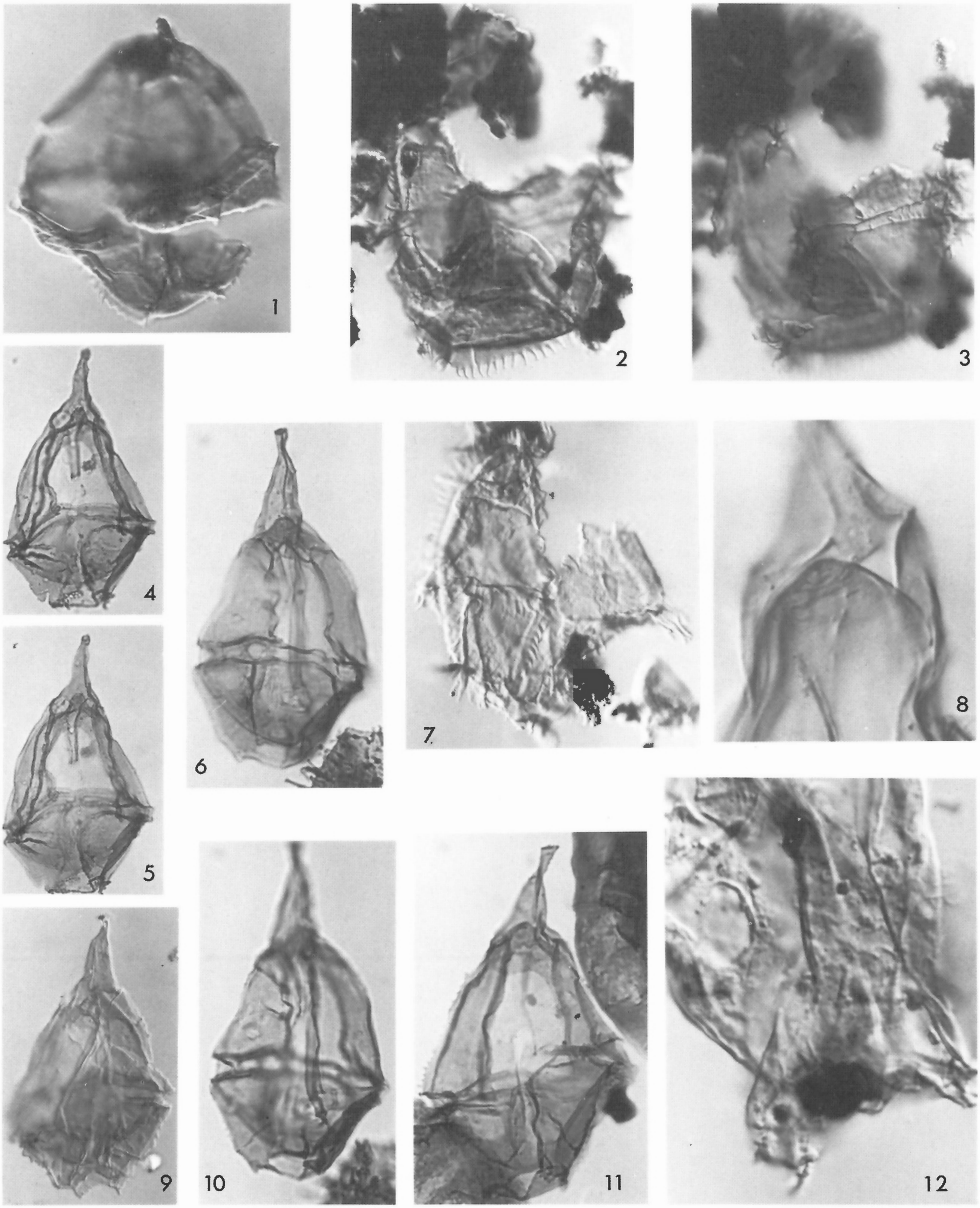


PLATE 2

Figures 1, 2. *Psaligonyaulax dualis* sp. nov. C12630, ARCO Slide 10617A-2, 20.4 x 123.2; IC, (1) mid-focus, (2) lo-focus on dorsal surface; GSC 42364. x500.

Figures 3-10. *Pareodinia capillosa* sp. nov.

3. C-12526, Slide P810-7A, 40.4 x 121.2; IC, mid-focus on archeopyle, lateral view; GSC 42365. x500.

4. C-12531, Slide P810-12B, 34.1 x 116.8; IC, mid-focus on attached operculum; GSC 42366. x500.

5-7. Holotype: C-12526, Slide P810-7B, 12.7 x 123.7; IC, (5) hi-focus on hypotract, (6) lo-focus on hypotract and part of epitract, (7) lo-focus on epitract; GSC 34155. X900.

8. C-12530, Slide P810-11A, 30.3 x 117.9; IC, focus on attached operculum and principal archeopyle sutural trace; GSC 42367. x1250.

9. C-12628, ARCO Slide 10616A-2, 23.4 x 117.0; IC, focus on antapical fimbriate processes; GSC 42368. x500.

10. C-12529, Slide P810-10B, 39.1 x 125.3; IC, focus on faint principal archeopyle suture trace and general process cover; GSC 42369. x900.

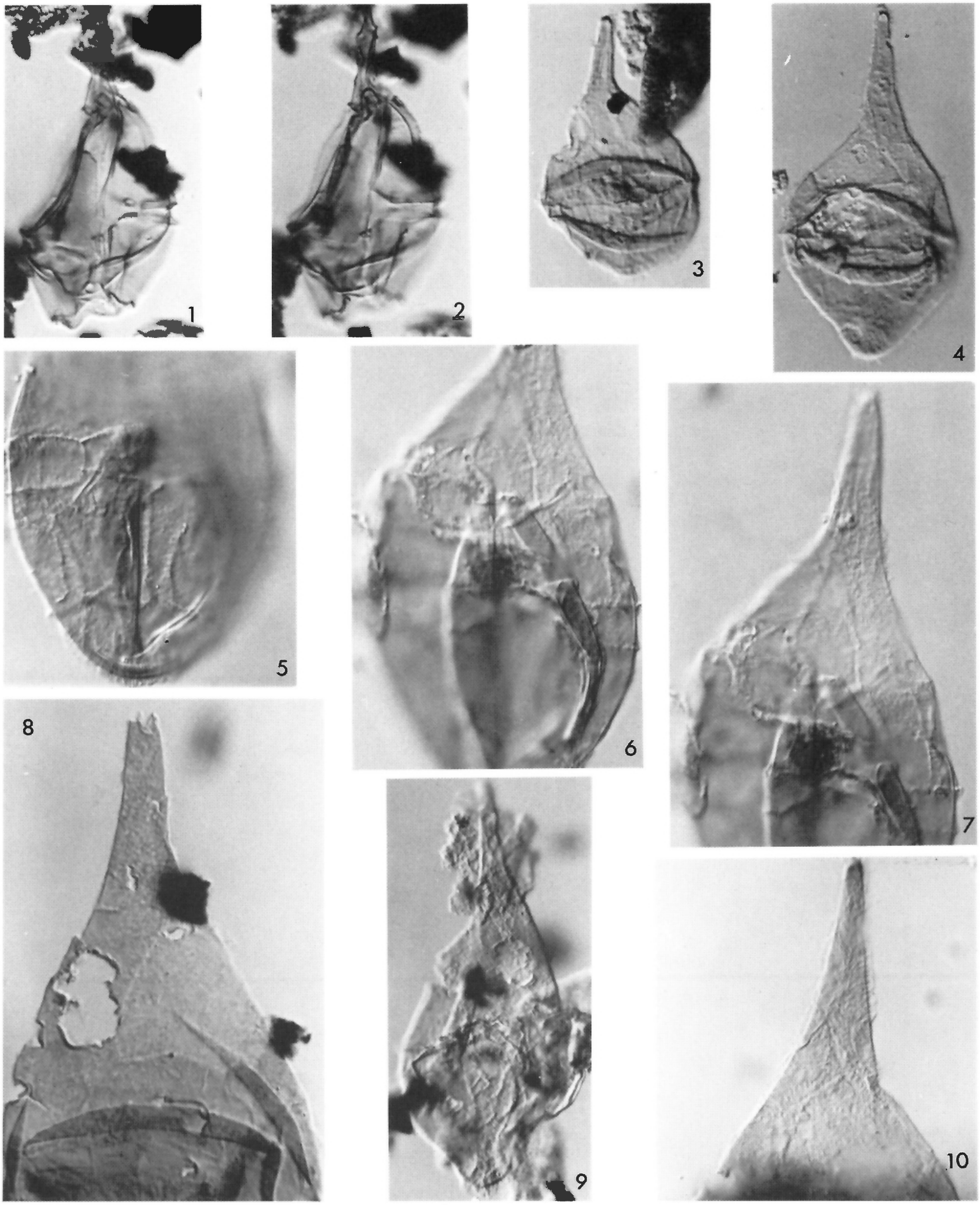

1
2
3
4
5
6
7
8
9
10

PLATE 3

Figures 1, 2, 5. *Pareodinia capillosa* sp. nov.

1. C-12628, ARCO Slide 10616A-2, 22.2 x 117.2; IC, mid-focus on process cover; GSC 42370. x800.

2, 5. C-12526, Slide P810-7A, 40.4 x 121.2; IC, lateral view (2) at mid-focus and (5) at lo-focus on hypotract; GSC 42365. x900. (Figured also in Pl. 2, fig. 3.)

Figures 3, 4, 6-9. *Pareodinia borealis* sp. nov.

3,6,8. Holotype: C-12628, ARCO Slide 10616A-2, 30.2 x 125.7; (3) IC, hi-focus on dorsal surface, (6) IC, lo-focus on ventral surface, (8) hi-focus on dorsal surface. GSC 34156. x1000.

4, 7. C-12630, ARCO Slide 10617A-1, 19.7 x 125.8; IC, (4) hi-focus on dorsal surface, (7) lo-focus, near optical section; GSC 42371. x900.

9. C-30208, Robertson Research Slide, Elf Jameson Bay (360 ft, 110 m), 28.2 x 123.0; IC, hi-focus on epitract; GSC 42372. x1000.

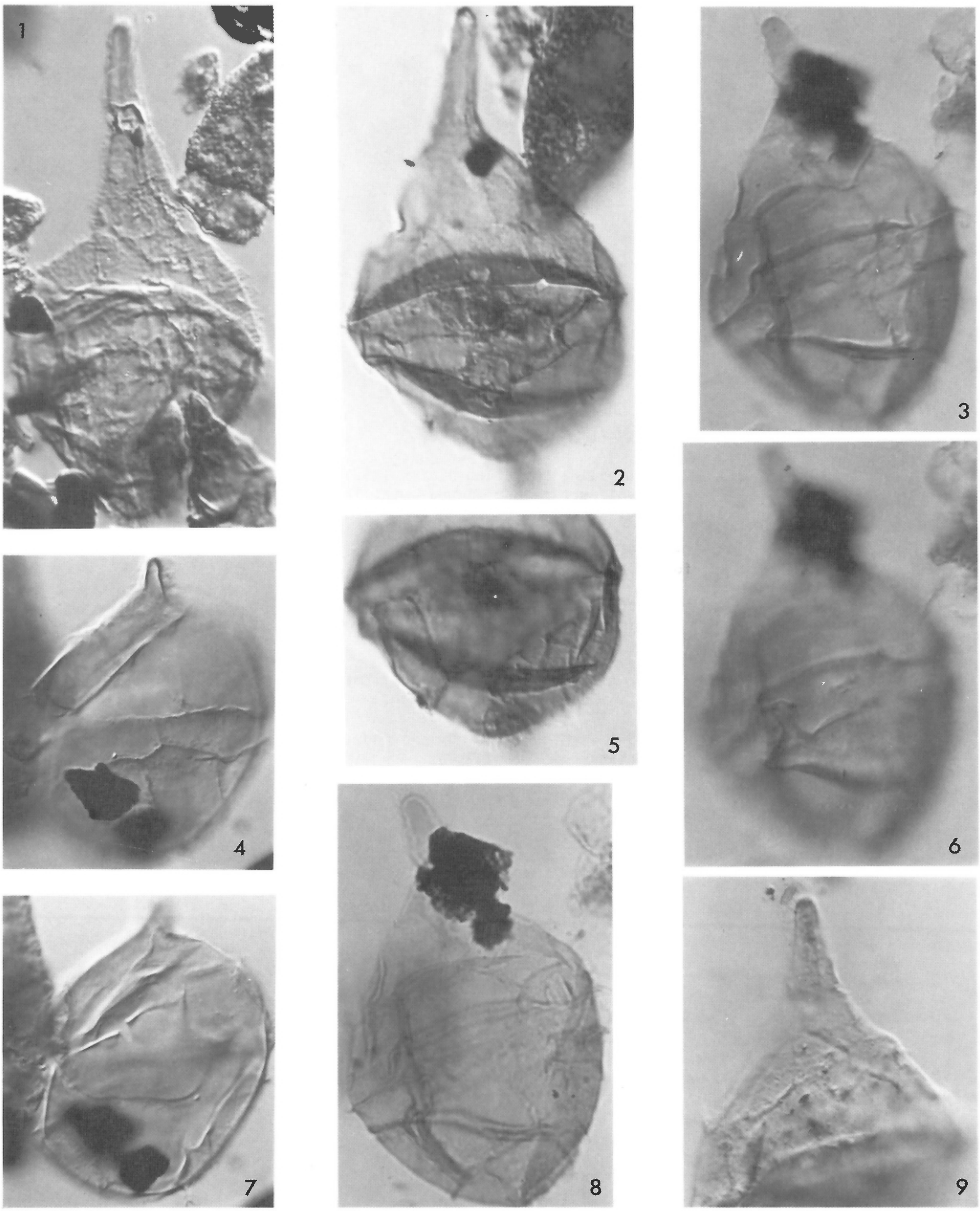

1
2
3
4
5
6
7
8
9

PLATE 4

Figures 1-8. *Pareodinia borealis* sp. nov.

1-3. C-12531, Slide P810-12B, 37.1 x 125.3; IC, (1, 2) hi-focus on dorsal surface and operculum, (3) lo-focus on ventral surface; GSC 42368. x900.

4. C-29106, Slide P912-1C, 14.6 x 126.3; IC, lateral view, mid-focus on archeopyle; GSC 42373. x900.

5, 6. C-12526, Slide P810-7A, 10.0 x 128.9; IC, (5) lateral view at hi-focus, (6) lo-focus on operculum; GSC 42374. x900.

7, 8. C-12628, ARCO Slide 10616A-2, 21.2 x 127.4; IC, (7) hi-focus, oblique left-lateral view, (8) the same at lo-focus, dorsal surface; GSC 42375. x900.

Figure 9. *Hologinella spinosigibberosa* sp. nov. C-30208, Robertson Research Slide Elf Jameson Bay (300-310 ft, 91-94 m), 50.1 x 131.3; IC, detail of antapical spine cover; GSC 42376. x1250.

PLATE 4

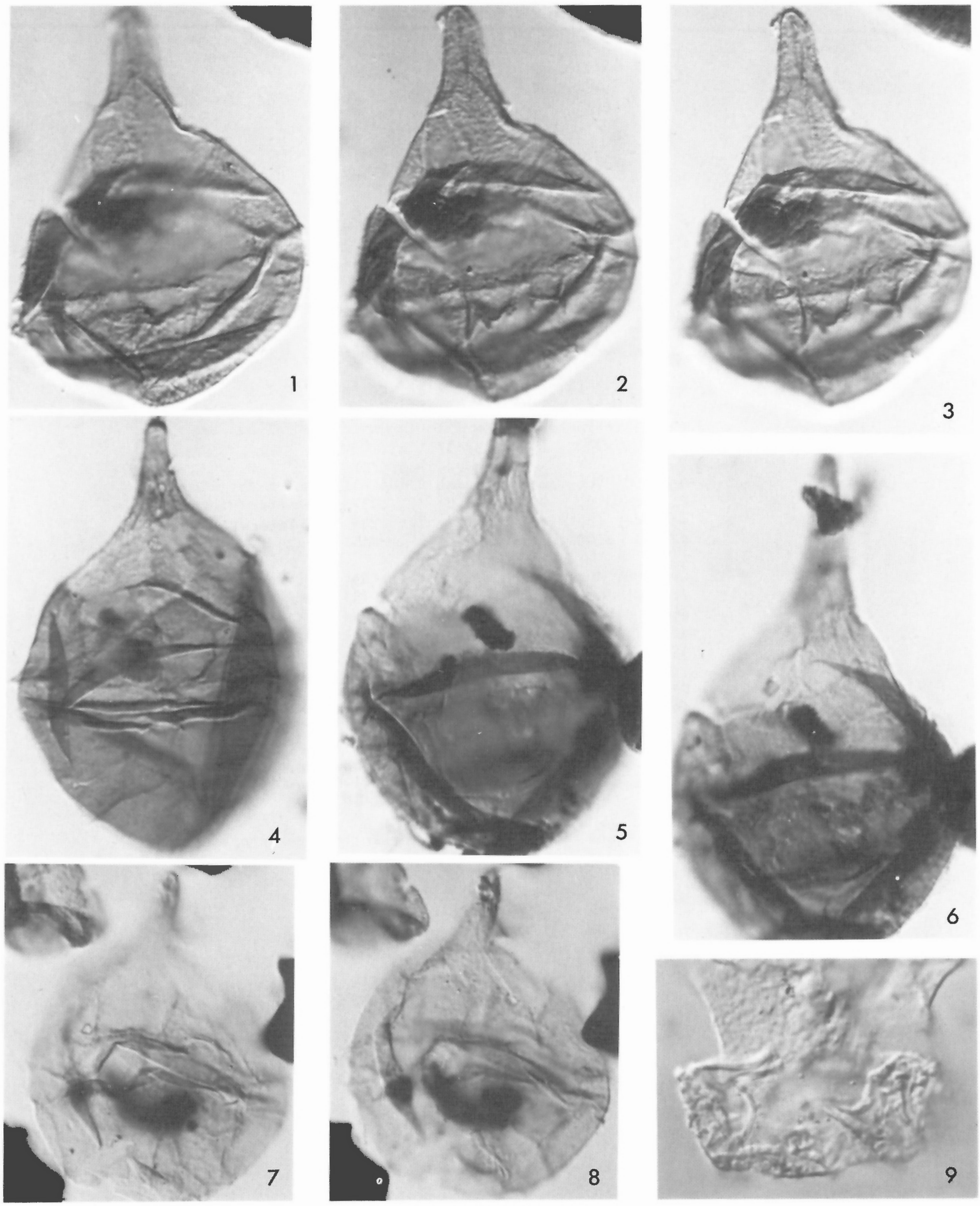


PLATE 5

Figures 1-16. *Horologinella spinosigibberosa* sp. nov.

1, 5-8. Holotype: C-12628, ARCO Slide 10616A-2, 27.4 x 123.9; IC, (1, 5) hi-focus, oblique dorsal view, (6) lower hi-focus, (7, 8) lo-focus and lower lo-focus on ventral surface; GSC 34157. x900.

2-4. C-30208, Robertson Research Slide Elf Jameson Bay (300-310 ft, 91-94 m), 50.1 x 131.3; IC, (2) hi-focus on ventral surface, (3) mid-focus, (4) lo-focus on dorsal surface; GSC 42376. x1000. (Figured also in Pl. 4, fig. 9).

9-12. C-30208, Robertson Research Slide Elf Jameson Bay (410-470 ft, 125-143 m), 28.0 x 120.9; IC, (9) hi-focus on ventral surface, (10) mid-focus on dorsal surface, (11) lo-focus, and (12) lower lo-focus on dorsal archeopyle opening; GSC 42377. x1250.

13. C-12630, ARCO Slide 10617A-1, 16.4 x 121.5; IC, hi-focus on dorsal surface; GSC 42378. x900.

14-16. C-12630, ARCO Slide 10617A-2, 15.8 x 120.4; IC, (14) hi-focus on dorsal surface, (15) mid-focus on archeopyle, (16) lo-focus on ventral surface; GSC 42379. x900.

Note: Specimen on Plate 5, figure 11 inadvertently figured upside-down.

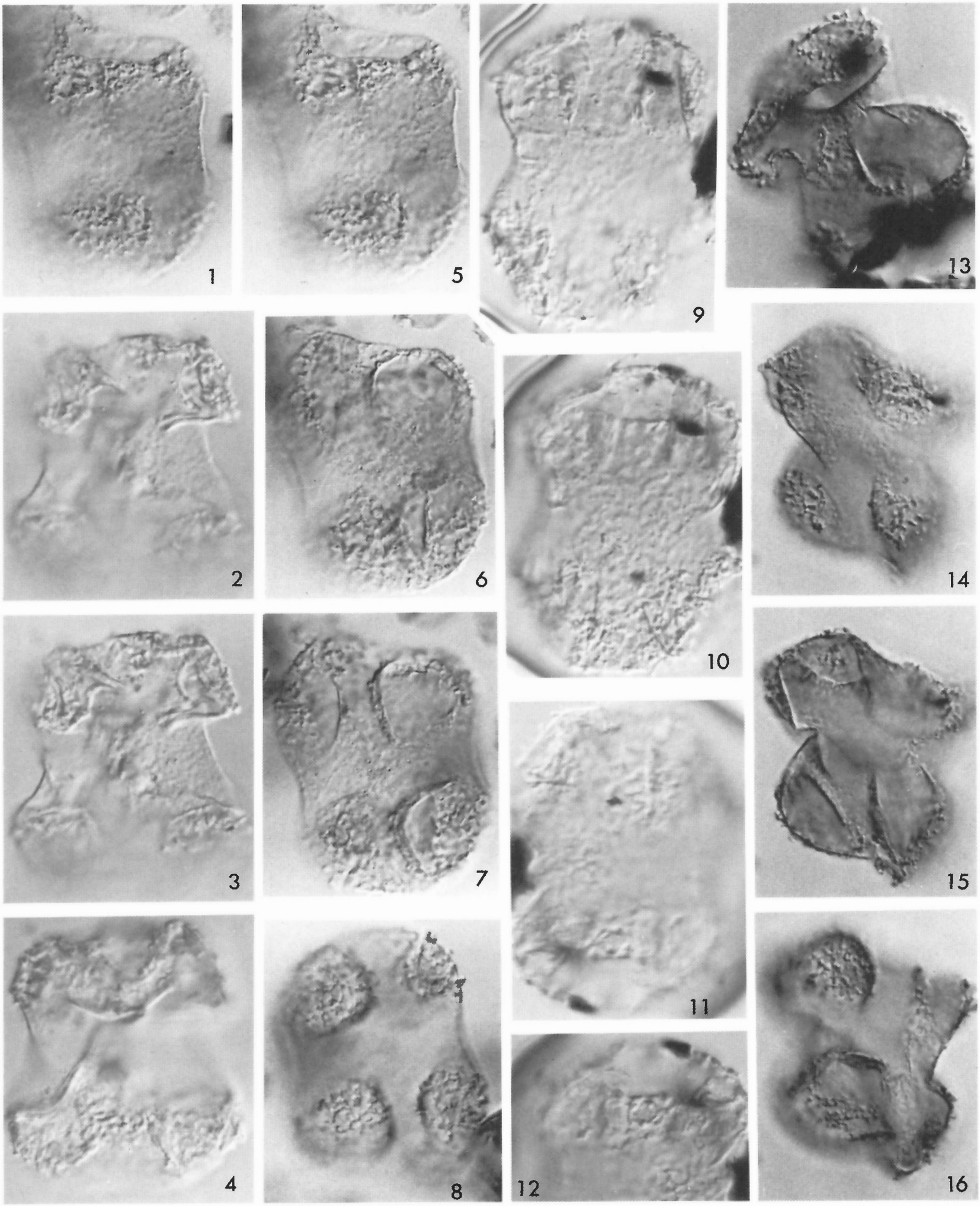
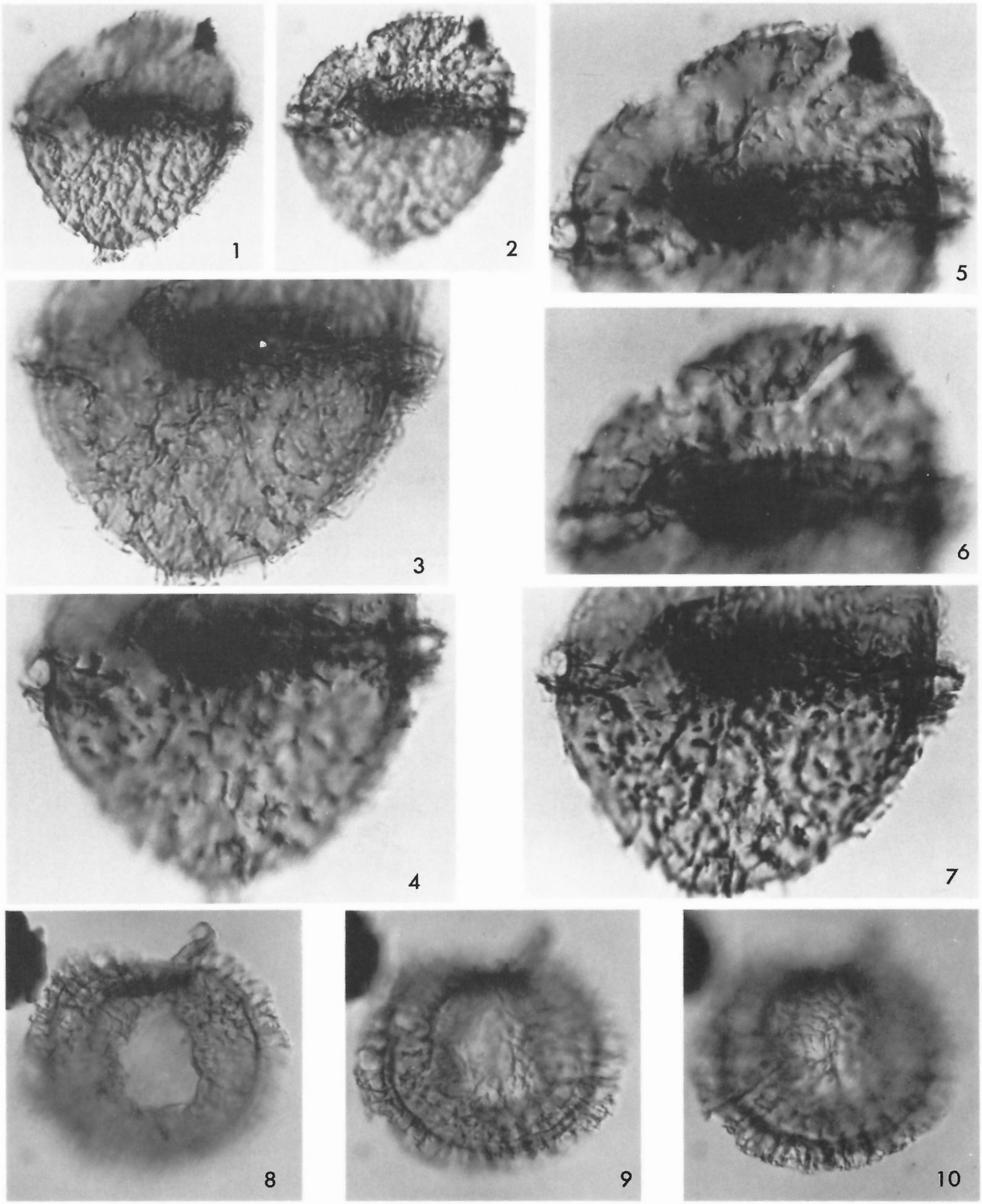


PLATE 6

Figures 1-10. *Lanterna saturnalis* sp. nov.

1-7. Holotype: C-12530, Slide P810-11A, 16.3 x 117.2; IC, (1, 2) hi- and lo-focus respectively on complete specimen, x500; (3, 4, 7), the hypotract, (3) hi-focus on ventral surface, (4, 7) lo-focus and lower lo-focus on dorsal surface respectively; (5, 6) the epitract, (5) hi-focus, ventral view of partly detached operculum, (6) lo-focus on operculum, dorsal view; GSC 34158. x900.

8-10. C-12531, Slide P810-12B, 26.4 x 131.5; IC, (8) hi-focus on apex and apical archeopyle, (9) mid-focus on cingular processes, (10) lo-focus on antapex and antapical reflected plate 1""; GSC 42380. x500.


1
2
5
3
6
4
7
8
9
10

<u>PLATE 7</u>

Figures 1-13. *Lanterna saturnalis* sp. nov.

1, 2. C-12532, Slide P810-13A, 24.3 x 121.8; IC, (1) oblique apical view at hi-focus, sulcus to SE, (2) oblique antapical view at lo-focus; GSC 42381. x500.

3, 4. C-12530, Slide P810-11B, 41.1 x 117.8; IC, (3) hi-focus, oblique antapical view, sulcus to N, (4) oblique apical view at lo-focus; GSC 42382. x500.

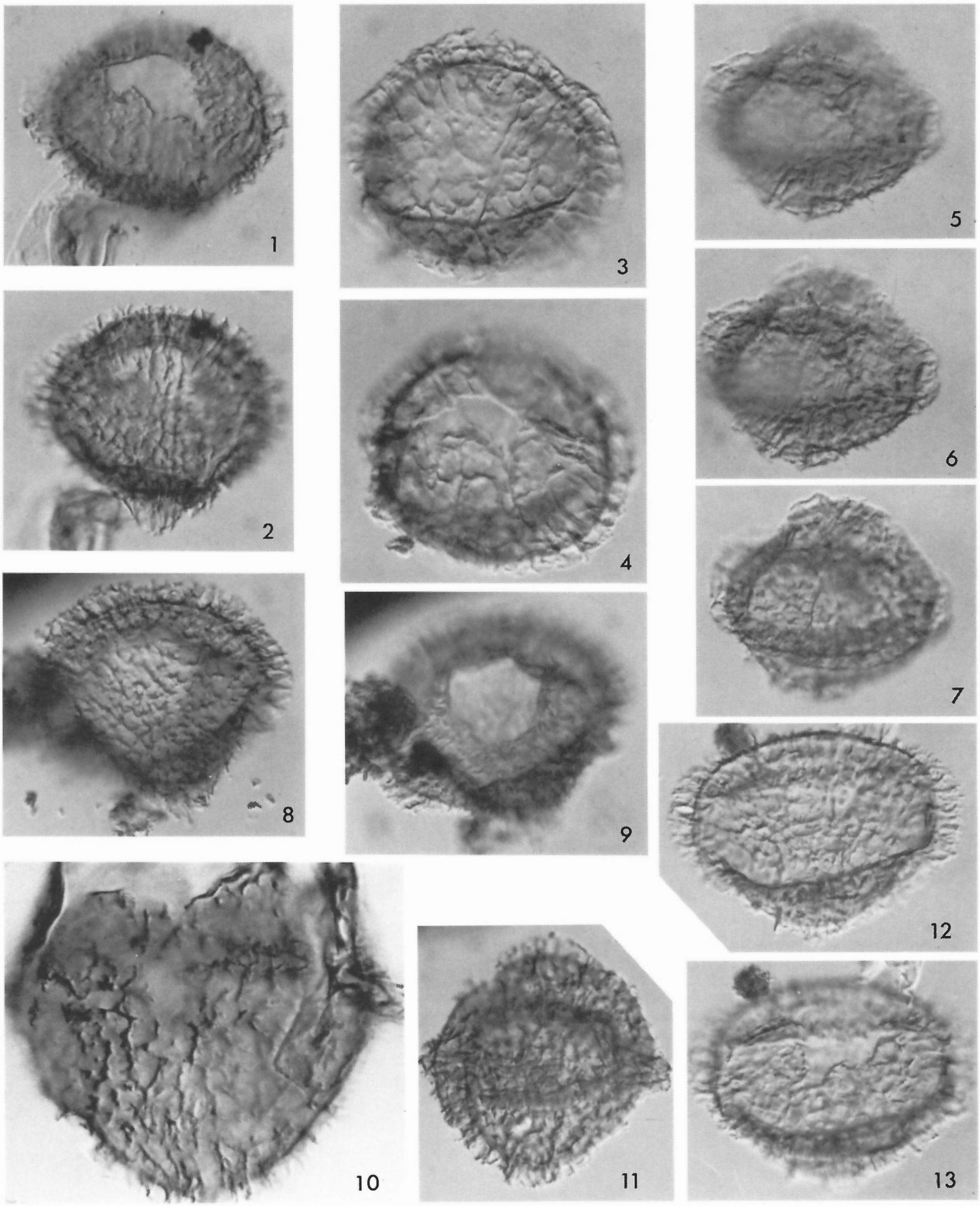
5-7. C-12531, Slide P810-12A, 24.2 x 131.4; IC, (5) hi-focus, oblique ventral view, (6) mid-focus, (7) lo-focus, oblique dorsal view of epitract; GSC 42383. x500.

8, 9. C-12532, Slide P810-13B, 3016 x 132.0; IC, (8) oblique ventral antapical view at hi-focus, (9) oblique dorsal apical view at lo-focus; GSC 42384. x500.

10. C-12530, Slide P810-11A, 07.6 x 128.6; IC, hi-focus on ventral surface; GSC 42385. x900.

11. C-12531, Slide P810-12B, 33.5 x 114.6; IC, mid-focus, operculum partly detached; GSC 42386. x500.

12, 13. C-12530, Slide P810-11B, 23.7 x 134.0; IC, (12) hi-focus, oblique ventral antapical view, (13) lo-focus, oblique apical view, archeopyle and sulcal notch in focus; GSC 42387. x500.


1
2
3
4
5
6
7
8
9
10
11
12
13