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A palynological study of the Gustav Group from north-west James Ross Island, Antarctica

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A palynological study of the Gustav Group from north-west James Ross Island, Antarctica

James B. Riding

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Foreword

This report represents a study of the stratigraphical palynology of 32 samples from the Whisky Bay and Hidden Lake formations (Gustav Group) from the Brandy Bay area, north-west James Ross Island, Antarctic Peninsula.

Contents

Summary

The material from station DJ.1456/DJ.1504 at Brandy Bay is from the Lewis Hill and Brandy Bay members of the Whisky Bay Formation. The presence of *Ascodinium acrophorum* indicates a mid Vraconian (latest Albian) to early Cenomanian age for this succession. The occurrence of *Ascodinium* cf. *serratum,* and certain semi-quantitative data are strongly suggestive of the early Cenomanian.

The palynological associations from station DJ.1502 at Brandy Bay are similar to those observed from station DJ.1456/DJ.1504. The station DJ.1502 succession is entirely within the Lewis Hill Member. Key dinoflagellate cyst taxa are indicative of the Vraconian (latest Albian) to early Cenomanian interval. The consistent occurrences of *Ascodinium* cf. *serratum* strongly suggest the early Cenomanian, but this cannot be deemed to be unequivocal evidence of this substage. Semi-quantitative dinoflagellate cyst data also suggest the early Cenomanian.

Twelve samples from station DJ.1504 at Brandy Bay were studied. These are from the Lewis Hill and Brandy Bay members of the Whisky Bay Formation. The six Lewis Hill Member samples proved more palynologically-rich than the six samples from the overlying Brandy Bay Member. The assemblages from the Lewis Hill Member are similar to those from this unit at station DJ.1502, however, the occurrence of unequivocal *Ascodinium serratum* is indicative of the early Cenomanian. This study is the first definite palynological evidence for the Cenomanian Stage in the James Ross Basin. The material from the overlying Brandy Bay Member produced the key marker species *Isabelidinium acuminatum* and *Isabelidinium glabrum*, which is indicative of the early Turonian. This conclusion is consistent with previous palynological studies, but not strontium isotope stratigraphy that invoked a late Turonian age for the underlying uppermost Lewis Hill Member.

The Hidden Lake Formation of station DJ.1507 at Brandy Bay yielded dinoflagellate cysts such as *Conosphaeridium striatoconus* and *Spinidinium echinoideum* subsp. *rhombicum,* which indicate a Coniacian age. This finding is in accord with previous studies.

1 Introduction

Drs J. A. Crame and D. Pirrie collected an extensive suite of rock/sediment samples from the Cretaceous strata of north-west James Ross Island, Antarctica during the Austral summer of 2002. The majority of the samples are from the Gustav Group of the southern side of Brandy Bay. The aim of collecting from this key reference succession is to obtain material for strontium isotope stratigraphy and biostratigraphy. This report documents the stratigraphical palynology of 32 samples from the Whisky Bay and Hidden Lake formations. The samples are listed in Appendix 1. One of the key aims is to identify if Cenomanian sediments are present. Some macrofossils of Cenomanian aspect have been found in this region, but the presence of strata of this age has not been confirmed palynologically (Riding and Crame, 2003).

2 Palynology

In this section, the palynofloras are described in four sections, corresponding to each of the stations studied. Full listings of all the palynomorph taxa recognised, including quantitative data, are held on the respective BGS micropalaeontology/palynology data sheets, which have been archived. These data are also provided here as Tables 1 to 4.

2.1 STATION DJ.1456 (= DJ.1504 OF D. PIRRIE) (63° 50.636' 58° 00.998')

Five samples were collected during late January 2002 from DJ.1456. This location, which is also DJ.1504, is located on the south side of Brandy Bay, north-west James Ross Island (Pirrie, 2002. fig. 3). This succession is entirely within the Lewis Hill and Brandy Bay members of the Whisky Bay Formation. This succession is of late Albian to late Turonian age according to Riding and Crame (2003).

The five samples produced variably productive palynofloras (Table 1); preservation is normally fair. Samples 1, 2 and 3 yielded moderately abundant and diverse palynomorph assemblages. The other two samples, 4 and 5, produced relatively sparse, low diversity florules. The kerogen associations are dominated by dark woody tissue with lesser proportions of plant material and palynomorphs. Amorphous organic material is consistently rare. Sample 5 is rich in resistant mineral grains. The palynomorph assemblages are relatively similar in both species spectra and relative proportions and are hence assumed to be from the same genetic sedimentary unit. Miospores observed comprise *Appendicisporites* sp., bisaccate pollen, *Cicatricosisporites* spp., *Classopollis classoides, Cyathidites* spp., *Gleicheniidites senonicus*, *Inaperturopollenites* spp., indeterminate miospores, *Interulobites intraverrucatus, Ischyosporites* spp. and *Microcachryidites antarcticus*. The terrestrially-derived flora is dominated by *Cyathidites* spp. and bisaccate pollen grains (Table 1). The dinoflagellate cysts are more diverse and include *Ascodinium acrophorum, Ascodinium* cf. *serratum, Ascodinium* sp., *Chlamydophorella* sp., chorate cysts, *Cribroperidinium* spp., *Diconodinium multispinum, Dioxya armata,* ?*Endoceratium ludbrookiae,* indeterminate forms, *Odontochitina operculata, Pterodinium cingulatum* and *Spiniferites ramosus* (Table 1). Of these taxa, *Ascodinium* cf. *serratum, Diconodinium multispinum,* indeterminate forms and *Odontochitina operculata* are the most common and persistent. Miscellaneous microplankton are relatively rare and represented only by the acritarch *Veryhachium* spp. in samples 2 and 3 (Table 1).

The dinoflagellate cyst floras are of unequivocal Australasian affinity and include some key markers such as *Ascodinium acrophorum, Ascodinium* cf. *serratum, Diconodinium multispinum, Dioxya armata* and ?*Endoceratium ludbrookiae,* which are all indicative of an age close to the

Albian-Cenomanian transition. Sample 1 yielded rare specimens of *Dioxya armata*. This distinctive species is characteristic of the Albian (excluding the Vraconian) of Australia (Morgan, 1980). This occurrence is not consistent with the presence of *Ascodinium acrophorum* in sample 1. *Ascodinium acrophorum* ranges from the mid Vraconian to the early Cenomanian (Morgan, 1980). These disjunct occurrences indicate that the specimens of *Dioxya armata* are probably reworked from the Albian into the mid Vraconian-early Cenomanian. *Ascodinium acrophorum* and the closely related form *Ascodinium* cf. *serratum* are present throughout the succession (Table 1). *Ascodinium* cf. *serratum* is a morphological variant of *Ascodinium acrophorum* and is probably an intermediate form between *Ascodinium serratum sensu stricto* and *Ascodinium acrophorum*. *Ascodinium* cf. *serratum* lacks the sharp polar horns of *Ascodinium acrophorum*, but also does not have the typical antapical serration present in *Ascodinium serratum sensu stricto* (see Cookson and Eisenack, 1960). *Ascodinium serratum sensu stricto* is confined to the early Cenomanian according to Morgan (1980, fig. 8). The consistent presence of *Ascodinium acrophorum* therefore indicates a mid Vraconian to early Cenomanian age for this succession (Morgan, 1980). It appears that *Ascodinium serratum sensu stricto* branched off from *Ascodinium acrophorum* during the earliest Cenomanian, hence station DJ.1456 is deemed to be latest Albian (Vraconian) to earliest Cenomanian age. It is considered that the presence of *Ascodinium* cf. *serratum* is not *prima facie* evidence of an earliest Cenomanian age. The occurrences of *Diconodinium multispinum* and ?*Endoceratium ludbrookiae* are entirely consistent with this assessment as these species both have Cenomanian range tops (Morgan, 1980; Helby *et al*., 1987). The Albian-Cenomanian stage boundary is difficult to resolve with certainty. Some of the quantitative data illustrated by Helby et al. (1987, fig. 37) mitigate toward the Cenomanian. This is the prominence of *Diconodinium multispinum* and the relative paucity of *Odontochitina* spp. and *Spiniferites* spp. However, this evidence should not be regarded as unequivocal.

Keating et al. (1992) and Riding et al. (1992) studied the palynology of the Lewis Hill Member from west of Brandy Bay (BAS station D.8637) and the Brandy Bay Member at BAS stations D.8637 and D.8632. From the Lewis Hill Member, Riding et al. (1992) used the presence of *Ascodinium acrophorum, Diconodinium cristatum* and *Diconodinium pelliferum* to derive a late Albian age. Keating et al. (1992) gave more detailed data (see section 2.1). This flora appears to be older than the succession at DJ.1456. No positive evidence of Cenomanian strata was given by Keating et al. (1992), Riding et al. (1992) or Riding and Crame (2003). Riding and Crame (2003, fig. 5) reported *Isabelidinium glabrum* from the uppermost Lewis Hill Member and the Brandy Bay Member of this region and invoked a Turonian age for this interval. The data in this report indicates that Cenomanian strata are present in north-west James Ross Island and that the hiatus between the late Albian and mid-late Turonian illustrated by Riding and Crame (2003, fig. 5) is not present everywhere in this area (see section 2.3).

2.2 STATION DJ.1502 (63° 50.907' 58° 01.899')

Four samples, numbers 6 to 9 inclusive, were taken from this succession of siltstones from 59.5 m to 98.5-99.3 m. According to geological mapping, this interval entirely within the Lewis Hill Member (Whisky Bay Formation) and is believed to be of late Albian age. Riding and Crame (2003) found that, on palynological evidence, the Lewis Hill Member is largely late Albian.

The four samples studied here all produced abundant organic residues and palynofloras (Table 2). The palynomorphs include marine and terrestrial elements in subequal proportions and the preservation proved good to fair throughout. Wood fragments and other plant tissues were consistently abundant and common respectively. Amorphous organic material and resistant mineral grains were both rare. The palynofloras are largely similar and indicate that this interval belongs to a single genetic sedimentary unit. The spore-pollen floras include *Aequitriradites* sp., bisaccate pollen, *Cicatricosisporites* spp., *Classopollis classoides, Cyatheacidites tectifera, Cyathidites* spp., *Gleicheniidites senonicus*, indeterminate spores, *Microcachryidites antarcticus*

and *Retitriletes* spp. Of these forms, *Cyathidites* spp. are especially common. The dinoflagellate cysts are more diverse and include *Ascodinium acrophorum, Ascodinium* cf. *serratum, Balcattia cirrifera, Chlamydophorella* spp., chorate cysts, *Cribroperidinium edwardsii, Diconodinium cristatum, Diconodinium multispinum, Diconodinium psilatum, Diconodinium* spp., ?*Dioxya armata, Disphaera macropyla, Endoceratium ludbrookiae, Endoceratium turneri,* ?*Hapsocysta peridictya, Leberidocysta chlamydata, Litosphaeridium siphoniphorum, Odontochitina costata* (= *Odontochitina striatoperforata* of Morgan 1980*), Odontochitina operculata, Odontochitina singhii, Palaeoperidinium cretaceum, Pterodinium cingulatum* and *Spiniferites ramosus*. Of these taxa, *Cribroperidinium edwardsii, Diconodinium multispinosum* and *Odontochitina operculata* are the most common.

Miscellaneous microplankton are also present and include occasional acritarchs (*Veryhachium* spp.) and *Botryococcus braunii*. Jurassic to lowermost Cretaceous reworking was observed in sample 8, where the dinoflagellate cyst *Scriniodinium*? *ceratophorum* was recovered. This species is a known marker for the Late Jurassic (Oxfordian-Tithonian) to earliest Cretaceous (Berriasian) (Helby *et al*., 1987; Riding and Fensome, 2002) and is interpreted as having been reworked from the Nordenskjöld Formation. Riding *et al*. (1992) reported both Jurassic and intra-Cretaceous reworking within the Whisky Bay Formation.

The dinoflagellate cyst floras are relatively diverse and are of Australasian affinity and include many key markers. They are generally indicative of an age close to the Albian-Cenomanian boundary. *Ascodinium acrophorum, Balcattia cirrifera, Diconodinium multispinum, Diconodinium psilatum, Endoceratium ludbrookiae, Leberidocysta chlamydata, Litosphaeridium siphoniphorum, Palaeoperidinium cretaceum* and *Odontochitina costata* (= *Odontochitina striatoperforata* of Morgan, 1980) are all highly characteristic of the late Albian-Cenomanian transition. The presence of species such as *Ascodinium acrophorum, Balcattia cirrifera* and *Disphaera macropyla* are evidence of an age no older than latest Albian (Vraconian) (Morgan, 1980; Helby *et al*., 1987). The oldest range tops are those of *Ascodinium acrophorum, Ascodinium* cf. *serratum, Balcattia cirrifera, Diconodinium multispinum, Diconodinium psilatum* and *Endoceratium ludbrookiae,* which are early Cenomanian according to Morgan (1980). Therefore these key taxa are indicative of the Vraconian-early Cenomanian interval. It is considered that the consistent occurrences of *Ascodinium* cf. *serratum* are not unequivocal evidence for an early Cenomanin age. *Ascodinium serratum sensu stricto* is restricted to the early Cenomanian according to Morgan (1980, fig. 8) (see section 2.1). The Albian-Cenomanian stage boundary in the Southern Hemisphere is difficult to resolve unequivocally. Certain of the quantitative data illustrated by Helby et al. (1987, fig. 37) mitigate toward the early Cenomanian. This is the prominence of *Cribroperidinium edwardsii* and *Diconodinium multispinum* and the relative paucity of *Spiniferites* spp. However, this evidence should not be regarded as reliable. For example Helby et al. (1987) reported high levels of *Endoceratium ludbrookiae* in the earliest Cenomanian of Australia, and this species is rare in this succession (Table 1).

Low levels of intra-Albian reworking were noted sporadically in this succession. ?*Dioxya armata, Endoceratium turneri* and *Odontochitina singhii* were recorded in extremely low proportions from samples 8 and 9 (Table 2). These species characterise the Albian, excluding the Vraconian according to Morgan (1980). Therefore these occurrences are interpreted as representing reworking. Allochthonous Early Cretaceous dinoflagellate cysts were also observed at station DJ.1456 (see section 2.1).

Keating et al. (1992) and Riding et al. (1992) studied the palynology of the Lewis Hill Member from west of Brandy Bay (BAS station D.8637). These authors reported relatively low diversity floras. Riding et al. (1992) mentioned the occurrences of *Ascodinium acrophorum, Diconodinium cristatum* and *Diconodinium pelliferum* and invoked a late Albian age. Keating et al. (1992), who worked on the same sample set, gave detailed occurrence data. These authors recorded the dinoflagellate cysts *Chlamydophorella nyei, Diconodinium cristatum, Diconodinium pelliferum, Diconodinium pusillum, Dingodinium cerviculum, Kiokansium*

polypes, *Odontochitina operculata*, *Odontochitina singhii*, *Oligosphaeridium complex*, *Oligosphaeridium pulcherrimum* and *Prolixosphaeridium parvispinum* (Keating et al. (1992, fig. 5a). This flora appears to be older than the succession at DJ.1502. There is no positive evidence of Cenomanian strata. For example, *Diconodinium cristatum* and *Odontochitina singhii* are entirely Albian taxa (Morgan, 1980).

2.3 STATION DJ.1504 (63° 50.636' 58° 00.998')

Twelve samples were collected from DJ.1504, on the south side of Brandy Bay, north-west James Ross Island (Pirrie, 2002. fig. 3). This succession is within the Lewis Hill and Brandy Bay members of the Whisky Bay Formation. This succession is of late Albian to late Turonian age according to Riding and Crame (2003). The twelve samples yielded variably productive palynofloras (Table 3); preservation is also variable. Samples 10, 11, 13, 14 and 20 produced abundant associations; the remaining samples were relatively sparse (Table 3). Generally the Lewis Hill Member samples were more organically-rich than from the overlying Brandy Bay Member. The palynomorphs include marine and terrestrial elements, generally in relatively similar proportions. Wood fragments and various other plant tissues were generally abundant and common respectively. Amorphous organic material is largely absent.

The palynomorph floras are similar to those recorded from station DJ.1502 (section 2.2). The spore-pollen floras include *Appendicisporites* sp., bisaccate pollen, *Cibotiumspora juriensis*, *Cicatricosisporites* spp., *Classopollis classoides, Clavifera triplex, Cyatheacidites tectifera, Cyathidites* spp., *Gleicheniidites senonicus*, *Inaperturopollenites hiatus, Ischyosporites* spp., *Laevigatosporites* spp., *Microcachryidites antarcticus, Perotriletes* spp., *Retitriletes austroclavatidites* and *Velosporites triquetrus*. The terrestrially-derived flora is dominated by bisaccate pollen grains, *Cyathidites* spp., indeterminate spores and *Microcachryidites antarcticus* (Table 3). The dinoflagellate cyst floras are more diverse and include: *Ascodinium acrophorum, Ascodinium serratum, Ascodinium* cf. *serratum, Ascodinium* spp., *Balcattia cirrifera, Canninginopsis denticulata,* chorate cysts, *Chlamydophorella* sp., *Circulodinium* spp., *Cribroperidinium edwardsii, Cyclonephelium compactum, Diconodinium multispinum, Diconodinium psilatum, Endoceratium ludbrookiae, Exochosphaeridium* spp., *Florentinia* sp., indeterminate forms, *Isabelidinium acuminatum, Isabelidinium glabrum, Isabelidinium* spp., *Leberidocysta chlamydata, Leptodinium asymmetricum, Odontochitina costata* (= *Odontochitina striatoperforata* of Morgan, 1980), ?*Odontochitina cribropoda, Odontochitina operculata, Oligosphaeridium* spp., *Palaeoperidinium cretaceum, Pterodinium cingulatum* and *Spiniferites ramosus* (Table 3). Of these, *Ascodinium* spp., chorate cysts, *Cribroperidinium edwardsii, Diconodinium multispinum, Odontochitina operculata* and *Oligosphaeridium* spp. are the most common and persistent. Miscellaneous microplankton are relatively rare and represented by the freshwater/brackish alga *Botryococcus braunii* and the acritarch *Veryhachium* (Table 3).

2.3.1 Lewis Hill Member (samples 10-15)

Samples 10 to 15 yielded relatively diverse dinoflagellate cyst associations of Australasian affinity, include several key markers. They are indicative of an age close to the Albian-Cenomanian stage transition. *Ascodinium acrophorum, Balcattia cirrifera, Canninginopsis denticulata, Diconodinium multispinum, Diconodinium psilatum, Endoceratium ludbrookiae, Leberidocysta chlamydata, Odontochitina costata* (= *Odontochitina striatoperforata* of Morgan, 1980) and *Palaeoperidinium cretaceum* are all highly characteristic of the late Albian-Cenomanian boundary interval. The presence of *Ascodinium acrophorum* and *Balcattia cirrifera* from the base of this section is evidence of an age no older than latest Albian (Vraconian) (Morgan, 1980). The oldest range tops are those of *Ascodinium acrophorum, Ascodinium serratum, Balcattia cirrifera, Diconodinium multispinum, Diconodinium psilatum* and *Endoceratium ludbrookiae,* which are early Cenomanian according to Morgan (1980), hence these key markers are indicative of the Vraconian-early Cenomanian. *Ascodinium serratum* is

present in samples 13, 14 and 15 (Table 3). This distinctive species is confined to the early Cenomanian according to Morgan (1980, fig. 8). These occurrences represent the first records of *Ascodinium serratum* in Antarctica and also represent the first unequivocal palynological evidence for the Cenomanian Stage in the James Ross Basin. *Ascodinium* cf. *serratum* (see sections 2.1, 2.2) is present in all the samples except 15 (Table 3). Because of the close morphological similarity to *Ascodinium serratum*, these forms are considered also to be indicative of a probable Cenomanian age for samples 10, 11 and 12, which do not contain *Ascodinium serratum sensu stricto.*. Some of the semi-quantitative data of Helby et al. (1987, fig. 37) also support this Cenomanian age assessment. These are the prominence of *Cribroperidinium edwardsii, Diconodinium multispinum* and *Endoceratium ludbrookiae* and the relative paucity of *Spiniferites* spp. No reworking was noted.

Keating et al. (1992) and Riding et al. (1992) worked on the palynology of the Lewis Hill Member from west of Brandy Bay and reported relatively low diversity floras. Riding et al. (1992) suggested a late Albian age based on the occurrences of *Ascodinium acrophorum, Diconodinium cristatum* and *Diconodinium pelliferum*. Keating et al. (1992) observed more diverse floras (see sections 2.1, 2.2). These assemblages appear to be older than the succession at DJ.1504 and Keating et al. (1992), Riding et al. (1992) or Riding and Crame (2003) did not report Cenomanian strata. Riding and Crame (2003, fig. 5) observed *Isabelidinium glabrum* from the uppermost Lewis Hill Member and the Brandy Bay Member of this area and invoked a Turonian age for this interval. The data herein indicates that Cenomanian strata are present in north-west James Ross Island and that the hiatus between the late Albian and mid-late Turonian illustrated by Riding and Crame (2003, fig. 5) is not developed throughout north-west James Ross Island.

2.3.2 Brandy Bay Member (samples 16-21)

Samples 16 to 21 yielded relatively low diversity dinoflagellate cysts (Table 1). They are dominated by undifferentiated chorate cysts and *Oligosphaeridium* spp. The key marker forms present are *Isabelidinium acuminatum* and *Isabelidinium glabrum*. These taxa have ranges of late Cenomanian to early Turonian and early Turonian to mid Coniacian respectively (Morgan, 1980; Marshall, 1984; Helby et al., 1987). This association therefore indicates an early Turonian age. These findings are consistent with previous work on this unit (Keating et al., 1992; Riding et al., 1992). Riding and Crame (2003, fig. 5) reported *Isabelidinium glabrum* from the uppermost Lewis Hill Member and the Brandy Bay Member, and proposed a Turonian age for this interval. This assessment is not precisely consistent with the findings of McArthur et al. (2000), who reported a late Turonian age for the uppermost Lewis Hill Member. Therefore, an unequivocal Turonian age is indicated for this member on both palynology and chemostratigraphy. It is possible that there is a disparity in the correlations of some Australian palynological zones (Riding and Crame, 2003).

2.4 STATION DJ.1507 (63° 51.776’ 58° 00.633’)

Eleven samples were collected from station DJ.1507, again on the south side of Brandy Bay in north-west James Ross Island (Pirrie, 2002. fig. 3). This succession is entirely within the Hidden Lake Formation, which is of Coniacian age according to Riding et al. (1992), McArthur et al. (2000) and Riding and Crame (2003). The samples yielded variably productive palynofloras in which miospores are consistently more abundant than marine microplankton (Table 4). Samples 22, 23, 25, 26, 27 and 32 produced abundant palynofloras; the remainder were relatively sparse. Preservation also proved somewhat variable. Wood fragments and other plant tissues were consistently abundant and common respectively; amorphous organic material was extremely rare. The palynofloras are broadly similar, and indicate that this interval belongs to a single genetic sedimentary unit. The spore-pollen floras include *Baculatisporites* spp., bisaccate pollen, *Ceratosporites* sp., *Cicatricosisporites* spp., *Classopollis classoides, Clavifera triplex,*

Contignisporites spp., *Cyatheacidites tectifera, Cyathidites* spp., *Gleicheniidites senonicus*, *Inaperturopollenites hiatus, Ischyosporites* spp., *Microcachryidites antarcticus, Perotriletes laceratus*, *Retitriletes austroclavatidites, Rugulatisporites mallatus* and *Vitreosporites pallidus* (Table 4). The dinoflagellate cyst floras include: ?*Actinotheca aphroditae,* ?*Balcattia cirrifera,* chorate cysts, *Circulodinium* spp., *Conosphaeridium striatoconus*, *Cribroperidinium* sp., *Diconodinium* sp., *Florentinia* sp., *Heterosphaeridium*? *heteracanthum*, indeterminate forms, *Odontochitina operculata, Oligosphaeridium* spp., *Pterodinium cingulatum, Spinidinium echinoideum* subsp. *rhombicum, Spiniferites ramosus, Trythyrodinium* spp. and *Xenascus* spp. (Table 4).

The dinoflagellate cysts are of Australasian affinity and include certain key markers such as ?*Actinotheca aphroditae, Conosphaeridium striatoconus*, *Spinidinium echinoideum* subsp. *rhombicum* and *Xenascus australensis,* which are indicative of a Coniacian age (Marshall, 1984; Helby et al, 1987; McMinn, 1988). The range base of *Spinidinium echinoideum* subsp. *rhombicum* is intra Coniacian according to Marshall (1984), and the range top of *Conosphaeridium striatoconus* is earliest Santonian (Helby et al, 1987). This study represents the first report of the marker species *Spinidinium echinoideum* subsp. *rhombicum* from the James Ross Basin.

Minor levels of intra-Cretaceous reworking were noted. These comprise the occurrences of ?*Balcattia cirrifera* and *Muderongia* sp. in samples 29 and 26 respectively (Table 4). The Coniacian age assessment is entirely consistent with previous work on the Hidden Lake Formation based on chemostratigraphy (McArthur et al., 2000) and palynology Riding et al., 1992; Riding and Crame, 2003).

3 Conclusions/Summary

The five samples collected at station DJ.1456/DJ.1504 on the south side of Brandy Bay are from the Lewis Hill and Brandy Bay members of the Whisky Bay Formation. This succession was previously thought to be of late Albian to late Turonian age. The dinoflagellate cysts observed are of Australasian affinity and include key markers such as *Ascodinium acrophorum, Ascodinium* cf. *serratum, Diconodinium multispinum, Dioxya armata* and ?*Endoceratium ludbrookiae,* which indicative an age close to the Albian-Cenomanian transition. The consistent presence of *Ascodinium acrophorum* indicates a mid Vraconian (latest Albian) to early Cenomanian age for this succession. *Ascodinium serratum sensu stricto* is confined to the early Cenomanian and presence of *Ascodinium* cf. *serratum* is suggestive of this substage, but cannot be considered to be unequivocal evidence of an early Cenomanian age. Certain semi-quantitative data also mitigate toward the early Cenomanian. Previously the Cenomanian Stage has not been demonstrated to be present in the James Ross Basin based on palynological evidence.

Four samples were collected from station DJ.1502; this succession is entirely within the Lewis Hill Member of the Whisky Bay Formation and is believed to be of late Albian age. The dinoflagellate cyst floras are diverse and include several key Australasian markers which indicate an age close to the Albian-Cenomanian transition. These taxa comprise *Ascodinium acrophorum, Ascodinium* cf. *serratum, Balcattia cirrifera, Diconodinium multispinum, Diconodinium psilatum, Disphaera macropyla, Endoceratium ludbrookiae, Leberidocysta chlamydata, Litosphaeridium siphoniphorum, Palaeoperidinium cretaceum* and *Odontochitina costata (= Odontochitina striatoperforata* of Morgan, 1980). These taxa are indicative of the Vraconian (latest Albian)-early Cenomanian interval. The consistent occurrences of *Ascodinium* cf. *serratum* strongly suggest the early Cenomanian, but cannot be deemed to be unequivocal evidence of this substage. Semi-quantitative dinoflagellate cyst data also suggest the early

Cenomanian. The Cenomanian Stage has not been previously demonstrated to be present in the James Ross Basin on palynological evidence.

Twelve samples were studied from station DJ.1504, located on the south side of Brandy Bay. The samples are from the Lewis Hill and Brandy Bay members (Whisky Bay Formation) and are thought to be of late Albian to late Turonian age. The six Lewis Hill Member samples proved more organically-rich than the six samples from the overlying Brandy Bay Member.

The palynofloras from the Lewis Hill Member (samples 10 to 15) are similar to those from this unit at station DJ.1502. They include several key Australasian dinoflagellate cyst markers which indicate an age close to the Albian-Cenomanian stage transition. These species are *Ascodinium acrophorum, Ascodinium* cf. *serratum, Balcattia cirrifera, Canninginopsis denticulata, Diconodinium multispinum, Diconodinium psilatum, Endoceratium ludbrookiae, Leberidocysta chlamydata, Odontochitina costata* (= *Odontochitina striatoperforata* of Morgan, 1980) and *Palaeoperidinium cretaceum*. These markers are indicative of the Vraconian-early Cenomanian. The occurrence of *Ascodinium serratum* refines this assessment to early Cenomanian. This study represents the first records of *Ascodinium serratum* in Antarctica and also is the first unequivocal palynological evidence for the Cenomanian Stage in the James Ross Basin. Semi-quantitative dinoflagellate cyst data also are consistent with the early Cenomanian. Previous studies on this succession have not encountered Cenomanian strata in this region. The identification of Cenomanian strata in this region means that the previously invoked hiatus between the late Albian and mid-late Turonian is not developed throughout north-west James Ross Island.

The material from the Brandy Bay Member (samples 16 to 21) produced relatively low diversity dinoflagellate cysts including the key markers *Isabelidinium acuminatum* and *Isabelidinium glabrum*. This association is indicative of the early Turonian. This conclusion is consistent with previous palynological studies, but not strontium isotope stratigraphy that invoked a late Turonian age for the underlying uppermost Lewis Hill Member.

The eleven samples from the Hidden Lake Formation at station DJ.1507, located at Brandy Bay produced moderately abundant palynofloras. They include the dinoflagellate cyst markers such as ?*Actinotheca aphroditae, Conosphaeridium striatoconus*, *Spinidinium echinoideum* subsp. *rhombicum* and *Xenascus australensis,* which indicate a Coniacian age and this is consistent with previous work.

Appendix 1

This Appendix lists the 32 north-west James Ross Island samples in this study, which were collected from four sections (stations) during January and early February 2002.

1. Station DJ.1456 (= DJ.1504 of D. Pirrie) 63° 50.636’ 58° 00.998’ Lewis Hill and Brandy Bay members (Whisky Bay Formation):

1	DJ.1456.1	MPA 51286	?siltstone/mudstone	? m
2	DJ.1456.2	MPA 51287	?siltstone/mudstone	? m
3	DJ.1456.18	MPA 51288	?siltstone/mudstone	? m
4	DJ.1456.19	MPA 51289	?siltstone/mudstone	? m

5	DJ.1456.20	MPA 51290	?siltstone/mudstone	? m

2. Station DJ.1502 63° 50.907' 58° 01.899' Lewis Hill Member (Whisky Bay Formation).

This locality is at 100-120 m of altitude and was measured/sampled between 10.01.02 and 16.01.02 by D. Pirrie and J. A. Crame. A total of 65 samples were taken. The Lewis Hill Member is believed to be of late Albian age.

6	DJ.1502.9	MPA 51291	siltstone	59.5 m
7	DJ.1502.10	MPA 51292	siltstone	? m
8	DJ.1502.13	MPA 51293	siltstone	95.5 m
9	DJ.1502.14	MPA 51294	siltstone	98.5-99.3 m

3. Station DJ.1504 63° 50.636' 58° 00.998' Lewis Hill/Brandy Bay members (Whisky Bay Formation).

This locality is at 80 m of altitude and was measured/sampled between 17.01.02 and 21.01.02 by D. Pirrie and J. A. Crame. A total of 89 samples were taken.

10	DJ.1504.9	MPA 51295	siltstone	114.50 m	Lewis Hill Mbr (late Albian)
11	DJ.1504.10	MPA 51296	siltstone	119.00 m	Lewis Hill Mbr (late Albian)
12	DJ.1504.14	MPA 51297	siltstone	259.60 m	Lewis Hill Mbr (late Albian)
13	DJ.1504.15	MPA 51298	siltstone	260.45 m	Lewis Hill Mbr (late Albian)
14	DJ.1504.17	MPA 51299	mudstone	262.10 m	Lewis Hill Mbr (late Albian)
15	DJ.1504.18	MPA 51300	mudstone	263.30 m	Lewis Hill Mbr (late Albian)
16	DJ.1504.31	MPA 51301	siltstone	364.00 m	Brandy Bay Mbr (Turonian)
17	DJ.1504.33	MPA 51302	mudstone	380.50 m	Brandy Bay Mbr (Turonian)
18	DJ.1504.36	MPA 51303	mudstone	?396.00 m	Brandy Bay Mbr (Turonian)
19	DJ.1504.39	MPA 51304	mudstone	416.00 m	Brandy Bay Mbr (Turonian)
20	DJ.1504.41	MPA 51305	mudstone	?441.50 m	Brandy Bay Mbr (Turonian)
21	DJ.1504.42	MPA 51306	mudstone	456.50 m	Brandy Bay Mbr (Turonian)

4. Station DJ.1507 63° 51.776' 58° 00.633' Hidden Lake Formation (Coniacian).

This locality is at 120 m of altitude and was measured/sampled between 24.01.02 and 31.01.02 by D. Pirrie and J. A. Crame. A total of 137 samples were taken.

22	DJ.1507.30	MPA 51307	mudstone	?12.60 m
23	DJ.1507.39	MPA 51308	mudstone	?12.80 m
24	DJ.1507.53	MPA 51309	siltstone	?74.50 m
25	DJ.1507.57	MPA 51310	siltstone	?82.50 m
26	DJ.1507.61	MPA 51311	mudstone	?87.50 m
27	DJ.1507.62	MPA 51312	mudstone	?102.00 m
28	DJ.1507.63	MPA 51313	mudstone	?108.00 m
29	DJ.1507.71	MPA 51314	mudstone	?139.00 m

30	DJ.1507.75	MPA 51315	mudstone	?
31	DJ.1507.99	MPA 51316	siltstone	?250.00 m
32	DJ.1507.103	MPA 51317	mudstone	?342.50 m

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4 TABLES

Sample number	**1**	**2**	**3**	**4**	**5**
DJ.1456. number	**1**	**2**	**18**	**19**	**20**
Depth from base (m)	**?**	**?**	**?**	**?**	**?**
Spores:					
Appendicisporites spp.	…	1	…	…	…
Cicatricosisporites spp.	3	…	7	…	…
Cyathidites spp.	161	156	132	76	45
Gleicheniidites senonicus	14	15	…	…	…
Interulobites intraverrucatus	2	…	…	…	…
Ischyosporites spp.	…	…	4	…	…
spores - indeterminate	56	44	31	4	…
Pollen:					
bisaccate pollen - undifferentiated	41	77	67	26	17
Classopollis classoides	18	19	18	21	30
Inaperturopollenites spp.	…	1	3	…	…
Microcachryidites antarcticus	20	10	7	…	…
pollen - indeterminate	10	21	1	…	…
Dinoflagellate cysts:					
Acanthaulax spp.	5	…	…	…	…
Ascodinium acrophorum	1 + ?1	12	6	4	…
Ascodinium cf. *serratum*	1	18	32	7	…
Ascodinium spp.	…	4 + ?1	…	…	?1
cavate dino. cyst - indeterminate	8	…	…	…	…
chorate dino. cysts - indeterminate	6	…	3	…	…
Chlamydophorella spp.	…	…	2	…	…
Circulodinium spp.	5	…	2	…	…
Cribroperidinium edwardsii	7	…	3	…	…
Cribroperidinium spp.	11	9	…	…	…
Diconodinium multispinum	29	4	14	12	5
dinoflagellate cysts - indeterminate	18	15	22	11	…
Dioxya armata	2	?1	…	…	…

Endoceratium ludbrookiae	?1	…	…	…	…
Florentinia sp.	…	…	1	…	…
Isabelidinium spp.	?1	…	…	…	…
Odontochitina operculata	5	4	9	3	?1
Oligosphaeridium spp.	…	2	…	…	…
Pterodinium cingulatum	…	…	5	…	…
Spiniferites ramosus	3	5	2	…	…
Miscellaneous microplankton:					
Veryhachium spp.	…	4	1	…	…

TABLE 1. The distribution of palynomorphs from the five samples studied from BAS station DJ.1456 at Brandy Bay, James Ross Island. The samples are from the Lewis Hill and Brandy Bay members of the Whisky Bay Formation. The palynomorphs are listed alphabetically within the four principal palynomorph groups. The numbers represent counts of the respective palynomorph per microscope slide. Three dots (…) indicate that the respective taxon is not present.

Sample number	**6**	**7**	**8**	**9**
DJ.1502. number	**9**	**10**	**13**	**14**
Depth from base (m)	**59.5**	**?**	**95.5**	**98.5-99.3**
Spores:				
Aequitriradites spp.	…	…	7	…
Cicatricosisporites spp.	4	29	9	…
Cyatheacidites tectifera	14	17	…	…
Cyathidites spp.	203	87	126	189
Gleicheniidites senonicus	…	…	3	4
Ischyosporites spp.	…	…	5	…
spores - indeterminate	47	31	10	17
Retitriletes austroclavatidites	…	…	1	…
Velosporites triquetrus	…	…	1	…
Pollen:				
bisaccate pollen - undifferentiated	105	74	57	52
Classopollis classoides	…	19	30	39
Inaperturopollenites spp.	3	…	27	…
Microcachryidites antarcticus	…	9	15	…
Dinoflagellate cysts:				
Ascodinium acrophorum	…	…	8	16

Ascodinium cf. *serratum*	…	2	24	17
Balcattia cirrifera	…	…	3	…
Canningia sp.	1	…	…	?3
Chlamydophorella spp.	2	…	7	20
chorate dino. cysts - indeterminate	7	…	5	18
Cribroperidinium edwardsii	32	181	241	47
Diconodinium cristatum	…	…	1	…
Diconodinium multispinum	189	10 + ?6	27	24
Diconodinium psilatum	3	…	…	1
Diconodinium spp.	…	…	3	…
dinoflagellate cysts - indeterminate	23	5	15	4
Dioxya armata	…	…	…	?1
Disphaera macropyla	…	2 + ?1	…	…
Endoceratium ludbrookiae	…	1 + ?1	2	3 + ?3
Endoceratium turneri	…	…	…	1
Hapsocysta peridictya	…	…	?1	…
Kleithriasphaeridium sp.	…	…	?1	…
Leberidocysta chlamydata	…	…	…	1
Litosphaeridium siphoniphorum	…	1	…	…
Odontochitina costata	…	…	2	3
Odontochitina operculata	87 + ?1	32	27	42
Odontochitina singhii	?1	…	1	…
Oligosphaeridium spp.	…	…	…	4
Palaeoperiodinium cretaceum	…	…	36	2
Prolixosphaeridium spp.	…	…	…	2
Pterodinium cingulatum	1	…	4	3
Scriniodinium ceratophorum (rw)	…	…	1 + ?1	…
Spiniferites ramosus	…	…	2	…
Spiniferites spp.	…	…	1	…
Miscellaneous microplankton:				
Botryococcus braunii	27	23	1	…
Veryhachium spp.	…	1	1	1

TABLE 2. The distribution of palynomorphs from the four samples studied from BAS station DJ.1502 at Brandy Bay, James Ross Island. The samples are from the Lewis Hill Member of the Whisky Bay Formation. The palynomorphs are listed alphabetically within the four principal palynomorph groups. The numbers represent counts of the respective palynomorph per microscope slide. Three dots (…) indicate that the respective taxon is not present.

Sample number	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
DJ.1504. number	**9**	**10**	**14**	**15**	**17**	**18**	**31**	**33**	**36**	**39**	**41**	**42**
Depth from base (m)	**114.5**	**119**	**259.6**	**260.45**	**262.1**	**263.3**	**364**	**380.5**	**?396**	**416**	**?441.5**	**456.5**
Member	**LH**	**LH**	**LH**	**LH**	**LH**	**LH**	**BB**	**BB**	**BB**	**BB**	**BB**	**BB**
Spores:												
Appendicisporites spp.	…	…	1	1	2	…	…	…	…	…	…	…
Cibotiumspora juriensis	…	…	…	1	…	…	…	…	…	…	…	…
Cicatricosisporites spp.	17	10	…	29	…	…	…	3	2	…	…	…
Clavifera triplex	…	…	…	…	…	…	…	…	…	…	16	…
Cyatheacidites tectifera	…	…	2	…	18	…	…	6	3	…	29	5
Cyathidites spp.	257	227	59	589	311	7	8	166	67	39	627	235
Gleicheniidites senonicus	1	…	…	47	…	…	…	…	…	…	21	…
Ischyosporites spp.	4	…	…	171	14	…	…	…	…	1	25	…
Laevigatosporites spp.	…	…	…	…	…	…	…	1	…	…	9	…
Perotriletes spp.	16	1	…	…	…	…	…	…	…	…	…	…
spores - indeterminate	5	7	…	358	423	3	…	4	2	11	366	…
Retitriletes austroclavatidites	…	…	…	34	…	…	…	…	…	…	…	2
Velosporites triquetrus	…	…	…	1	…	…	…	…	…	…	…	…
Pollen:												
bisaccate pollen - undifferentiated	147	141	67	89	77	7	2	174	32	47	40	47
Classopollis classoides	97	41	…	47	…	1	1	…	12	…	…	…
Inaperturopollenites hiatus	8	…	…	…	…	1	…	…	…	…	…	…
Microcachryidites antarcticus	37	22	11	27	…	…	…	20	5	7	…	…
pollen - indeterminate	…	…	1	10	9	1	…	…	…	…	…	…
Dinoflagellate cysts:												
Aptea sp.	…	…	…	…	…	…	…	…	…	1	…	…
Ascodinium acrophorum	5	31	5	5	2	…	…	…	…	…	…	…
Ascodinium serratum	…	…	…	4	5	4	…	…	…	…	…	…
Ascodinium cf. *serratum*	28	5	1	26	15	…	…	…	…	1	…	…
Ascodinium spp.	…	…	…	1	4	…	…	…	…	…	…	…
Balcattia cirrifera	4	14	?1	…	…	…	…	…	…	…	…	…
Canninginopsis denticulata	…	…	4	…	…	…	…	…	…	…	…	…
Chorate dino. cysts - indeterminate	25	25	13	2	…	15	…	18	8	9	…	32
Chlamydophorella spp.	45	57	…	…	…	…	…	…	…	…	…	…
Circulodinium spp.	7	…	…	…	…	…	…	3	…	12	…	…
Cribroperidinium edwardsii	49	66	…	?3	…	…	…	…	…	?1	…	…
Cyclonephelium compactum	7	17	…	…	…	54	…	…	…	…	…	247
Diconodinium multispinum	71	84		4	37	274	…		1	…		…
Diconodinium psilatum	…	11 + ?2	…	…	…	…	…	…	…	…	…	…
dinoflagellate cysts - indeterminate	4	…	…	2	2	4	…	2	1	4	1	3
Endoceratium ludbrookiae	24	29	…	…	…	…	…	…	…	…	…	…

Exochosphaeridium striolatum	4	…	…	…	…	…	…	…	…	…	…	…
Exochosphaeridium sp.	…	4	…	…	…	…	…	…	…	…	…	…
Florentinia sp.	…	1	…	…	…	…	…	…	…	…	…	…
Hystrichodinium pulchrum	…	…	?1	…	…	…	…	…	…	…	…	…
Isabelidinium acuminatum	…	…	…	…	…	…	…	1	…	…	…	…
Isabelidinium glabrum	…	…	…	…	…	…	…	4 + ?1	?1	…	…	…
Isabelidinium spp.	…	…	…	…	…	…	…	5	…	4	?1	?1
Leberidocysta chlamydata	2	3	…	…	…	…	…	…	…	…	…	…
Leptodinium asymmetricum	1	…	…	…	…	…	…	…	…	…	…	…
Microdinium sp.	…	…	…	…	…	1	…	…	…	…	…	…
Odontochitina costata	…	12	2	…	…	47	…	…	…	…	…	…
Odontochitina cribropoda	…	?1	…	…	…	?3	…	…	…	…	…	…
Odontochitina operculata	67	74	7	3	24	197	…	17	…	…	…	…
Oligosphaeridium spp.	…	…	10	8	1	26	…	10	7	5	4	17
Palaeoperidinium cretaceum	…	17	…	…	…	…	…	…	…	…	…	…
Pterodinium cingulatum	2	10	…	…	1	…	…	…	…	…	…	…
Spiniferites ramosus	…	4	6	2	…	2	…	5	…	…	…	…
Spiniferites spp.	…	…	…	1	1	…	…	…	…	…	…	17
Systematophora sp.	1	…	…	…	…	…	…	…	…	…	…	…
Miscellaneous microplankton:												
Botryococcus braunii	34	39	5	…	3	…	…	…	…	2	36	…
Veryhachium spp.	2	…	…	…	…	…	…	…	…	…	…	…

TABLE 3. The distribution of palynomorphs from the twelve samples studied from BAS station DJ.1504 at Brandy Bay, James Ross Island. The samples are from the Lewis Hill (LH) and Brandy Bay (BB) members of the Whisky Bay Formation. The palynomorphs are listed alphabetically within the four principal palynomorph groups. The numbers represent counts of the respective palynomorph per microscope slide. Three dots (…) indicate that the respective taxon is not present.

Sample number	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
DJ.1507. number	**30**	**39**	**53**	**57**	**61**	**62**	**63**	**71**	**75**	**99**	**103**
Depth from base (m)	**12.6**	**12.8**	**74.5**	**82.5**	**87.5**	**102**	**108**	**139**	**?**	**250**	**342.5**
Spores:											
Baculatisporites spp.	…	1	…	7	5	…	…	…	…	…	1
Ceratosporites sp.	…	17	…	…	1	…	…	…	…	…	…
Cicatricosisporites spp.	2	11	…	6	3	…	…	…	…	…	…
Clavifera triplex	1	14	…	…	4	…	3	1	…	…	…
Contignisporites cf. *multimuratus*	…	1	…	…	…	…	…	…	…	…	…
Contignisporites spp.	…	…	…	4	…	…	…	…	…	…	…
Cyatheacidites tectifera	9	19	1	8	2	17	14	2	…	…	…
Cyathidites spp.	301	505	92	331	96	98	129	92	27	37	219

Fungal spores - undifferentiated	7	3	1	3	4	…	1	…	1	…	3
Gleicheniidites senonicus	2	9	1	8	…	…	…	…	…	3	9
Ischyosporites spp.	…	30	1	5	…	7	1	2	…	…	…
Perotriletes laceratus	3	28	…	2	…	…	…	…	…	…	…
spores - indeterminate	32	48	3	41	2	21	7	5	…	6	39
Retitriletes austroclavatidites	1	3	…	…	…	…	…	…	…	…	…
Rugulatisporites mallatus	…	…	…	1	…	…	…	…	…	…	…
Pollen:											
bisaccate pollen - undifferentiated	231	279	17	234	107	62	156	24	14	16	97
Classopollis classoides	…	…	…	…	…	13	…	…	1	…	…
Inaperturopollenites hiatus	4	39	1	…	3	…	…	…	…	…	13
Microcachryidites antarcticus	288	217	14	87	43	…	74	…	…	…	17
pollen - indeterminate	52	120	…	62	32	…	…	…	5	7	…
Vitreosporites pallidus	1	…	…	2	…	…	…	…	…	…	…
											…
Dinoflagellate cysts:											…
Actinotheca aphroditae	…	…	…	…	…	…	…	?1	…	…	…
Balcattia cirrifera (reworked)	…	…	…	?1	…	…	…	…	…	…	…
Balteocysta perforata	…	…	…	?1	…	…	…	…	…	…	…
chorate dino. cysts - indeterminate	17	47	…	14	1	…	3	…	1	2	22
Circulodinium spp.	…	41	…	…	…	…	2	…	…	…	14
Conosphaeridium striatoconus	…	…	…	2 + ?1	…	…	…	…	…	…	…
Cribroperidinium sp.	…	…	…	…	…	…	…	…	…	…	1
Diconodinium sp.	…	1	…	1	…	…	…	…	…	…	…
dinoflagellate cysts - indeterminate	47	54	…	7	17	7	2	2	…	2	2
Florentinia sp.	…	…	…	…	…	…	1	…	…	…	…
Heterosphaeridium? *heteracanthum*	5	56	…	32	24	7	…	…	…	…	17
Hystrichodinium pulchrum	…	…	…	…	…	…	…	…	…	…	1
Odontochitina cribropoda	…	…	…	…	…	…	…	…	…	…	7
Odontochitina operculata	3	7	…	49	10	4	2	?1	…	1	9
Oligosphaeridium spp.	…	…	…	…	…	…	…	…	…	…	30
Muderongia sp. (reworked)	…	…	…	…	1	…	…	…	…	…	…
Pareodinia spp.	…	1	…	…	…	…	…	…	…	…	…
Pterodinium cingulatum	…	…	…	…	…	…	…	…	…	…	5
Spinidinium echinoideum rhombicum	2	23	…	10	…	…	…	…	…	…	…
Spiniferites ramosus	14	35	…	3	4	…	…	…	…	…	24
Spiniferites spp.	…	…	…	…	1	…	1	…	…	?1	3
Subtilisphaera sp.	…	…	…	…	…	…	…	…	…	…	1
Trythyrodinium spp.	…	3	…	…	…	2 + ?4	1	…	…	…	1
Xenascus australensis	…	…	…	…	…	2	…	…	…	…	…
Xenascus spp.	…	…	…	68	…	…	…	…	…	…	…
Miscellaneous microplankton:											

Botryococcus braunii	…	…	…	…	…	5	9	…	…	…	14
Pterospermella spp.	1	1	…	…	…	…	…	…	…	…	…
Tasmanites spp.	…	…	1	…	…	…	…	…	…	3	…

TABLE 4. The distribution of palynomorphs from the eleven samples studied from BAS station DJ.1507 at Brandy Bay, James Ross Island. The samples are from the Hidden Lake Member of the Whisky Bay Formation. The palynomorphs are listed alphabetically within the four principal palynomorph groups. The numbers represent counts of the respective palynomorph per microscope slide. Three dots (…) indicate that the respective taxon is not present.