DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT.BK.NO. 87/59 PALYNOLOGICAL DATING AND CORRELATION OF LATE JURASSIC AND EARLY CRETACEOUS SEDIMENTS AROUND PART OF THE SOUTHERN MARGIN OF THE EROMANGA BASIN

GEOLOGICAL SURVEY

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BIOSTRATIGRAPHY

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PALYNOLOGICAL DATING AND CORRELATION OF LATE JURASSIC AND EARLY CRETACEOUS SEDIMENTS AROUND PART OF THE SOUTHERN MARGIN OF THE EROMANGA BASIN

ABSTRACT

In May 1986 grab samples from near Moolawatana, Village Well, Trinity Well and Davenport Springs in the southwestern Eromanga Basin were selected for palynological dating. Following preliminary laboratory analyses further grab samples were obtained in October from the first three localities and also from near Mount Babbage and Cattle Mound Springs. The samples are from weathered sediments and required modifications to the traditional laboratory processing techniques.

A gritty claystone from Moolawatana produced palynofloras correlative with the (?)early *Crybelosporites stylosus* spore/pollen Zone of (?) Early Neocomian age; the sediment is possibly an Algebuckina Sandstone equivalent. Samples from Village Well, Mount Babbage area and Cattle Mound Springs are largely barren of palynomorphs. Palynofloras from a bioturbated claystone at Trinity Well are assigned to the *Cicatricosisporites australiensis* spore/pollen Zone of Early Neocomian age. The presence of a restricted microplankton assemblage is interpreted as a marginal-marine environment and the sediments as either the marine transgressive facies of the basal Cadna-owie Formation or the Mooga Sandstone (Algebuckina equivalent). This marine influence is correlative with marginal marine sediments of Neocomian age occurring in the eastern and central parts of the Eromanga Basin. a palynoflora recovered from a limestone concretion in Bulldog Shale 7 km northeast of Mount Babbage is assigned to the *Cyclosporites hughesii* spore/pollen Zone and the upper "b" or lower "c" subzone of the *Odontochitina operculata* dinoflagellate Zone. Another concretion 10 km northeast of Mount Babbage produced an assemblage which is correlative with the *Crybelosporites striatus* spore/pollen Zone. Thus the Bulldog Shale in this area is middle/late Aptian to early

Albian in age, implying that the lower part of the unit is absent which is consistent with a transgression onto a rising bedrock slope. A mud underlying Cadna-owie Formation near Davenport Springs produced an excellent, terrestrial palynoflora correlative with the *Retitriletes watherooensis* spore/pollen Zone of Late Jurassic age, implying that the mud is an Algebuckina Sandstone equivalent. Assemblages from the Bulldog Shale in the Davenport Springs area are correlative with the *Cyclosporites hughesii* spore/pollen Subzone and the *Odontochitina operculata* microplankton Subzone b of early to middle Aptian age. This indicates that the lower part of Bulldog Shale is present at Davenport Springs.

INTRODUCTION

Early in May, 1986, one week was spent with representatives from Regional Geology (S.A.D.M.E.), Department of Geology and Geophysics (The University of Adelaide) and Department of Earth Sciences (Monash University), examining Late Jurassic to Early Cretaceous sediments around part of the southern margin of the Eromanga Basin. The purpose of the field investigations was to evaluate environments of deposition and problems of dating the Cadna-owie Formation and basal Bulldog Shale in which isolated boulders, pebbles and gravel layers occur. The emplacement of these clasts in otherwise fine-grained sedimentary units is problematic (e.g. Flint *et al.,* 1980), and whether they were dropped from floating ice or from vegetation, or were transported by submarine flows is unknown.

The field party comprised a broad spectrum of geological expertise including regional mapping, stratigraphy, palaeobotany, clay mineralogy, sedimentology, palaeomagnetism and palynology. Four main areas were visited, three of which lie on the northern fringes of the Flinders Ranges (Moolawatana, Village Well and Trinity Well); and Davenport Springs near the northern edge of the Willouran Ranges (Fig. 1).

Following evaluation of the palynofloras recovered from the samples, the sites around the northern fringes of the Flinders Ranges and six others in the same area were revisited in October with representatives from the Department of Geology and Geophysics. The new sites include near Mount Fitton homestead, Mount Babbage, sites 5 km, 7 km and 10 km northeast of Mount Babbage and 6 km southwest of Cattle Mound Springs.

This report provides the results of a palynological investigation of samples from the main sites visited, providing in some cases a means of dating the sediments and an indication of environment of deposition.

GENERAL GEOLOGICAL SETTING

The Mesozoic sequence onlaps the Precambrian rocks of the northern Flinders and Willouran ranges (Fig. 1). Extensive erosion has formed numerous outliers of the Mesozoic sediments, which now lie within or cap the highest parts of the northern ranges (e.g. Mount Babbage).

The stratigraphic units occurring in the Eromanga Basin are summarized in Figure 2. Only three of these units crop out in the areas investigated including (from the oldest) Algebuckina Sandstone, Cadna-owie Formation and Bulldog Shale. Equivalents to these units used by Forbes (1966) in the MARREE mapsheet are also shown on Figure 2.

The Algebuckina Sandstone is a fluvial, crossbedded, kaolinitic quartz sandstone and conglomerate containing plant fossils. Deposition began in the Jurassic and continued through the Early Neocomian (Fig. 3). In the southern and western portions of the Eromanga Basin the sandstone is unconformably overlain by the Cadna-owie Formation. The latter is a partly carbonaceous, fine- to medium-grained sandstone deposited under shallow water, marginal-marine conditions {Wopfner *et al.,* 1970; Forbes, 1982). In the MARREE mapsheet equivalent units are thought to be the Pelican Well Formation and Trinity Well Sandstone (Fig. 2). Isolated boulders and boulder beds occur in the Formation. Probable Gawler Range porphyritic rhyolite pebbles and boulders are locally abundant in the Mount Anna Sandstone member of the Cadna-owie Formation in the southwestern Eromanga Basin (Wopfner *et al*., 1970). Large boulders of rounded and polished quartzite, including Devonian quartzite, are common elsewhere in the Formation (Campbell *et al.,* 1979; Flint et *al.,* 1980).

In view of the marine transgressive origin of the Cadna-owie Formation, its age is progressively younger towards the margins of the basin. Deposition commenced in the Late Neocomian (Fig. 3) and continued into the early Aptian in the southwestern portion of the Eromanga Basin (Alley, 1985). The hiatus between the Algebuckina Sandstone and Cadna-owie Formation in the latter area probably involves all of the Late Neocomian (Alley, 1985).

In deeper parts of the basin the Cadna-owie Formation is succeeded by Bulldog Shale, deposition of which, here, commenced in the early Aptian (Fig. 3), continuing probably into the Middle Albian along the southwestern fringes of the basin (Alley, 1985). The Bulldog Shale is a bioturbated, fossiliferous, carbonaceous, silty claystone containing minor sandstone, concretions and "cone-in-cone" limestone, deposited under shallow water, marine conditions. Isolated boulders and minor gravel layers, including Gawler Range porphyry and Devonian quartzites, are common in the shale, with greater concentrations believed to occur near the base of the unit (Flint *et al.,* 1980). Silicified to ferruginized logs are also common in Bulldog Shale, and tree-ring analysis of these (J. Francis, Department of Geology and Geophysics, The University of Adelaide) may throw some light on climatic conditions prevailing during deposition of the basal part of the shale and thus provide clues as to the mechanism by which the boulders were emplaced.

The lithological similarity between some facies of the Algebuckina Sandstone and Cadna-owie Formation and between the latter and the basal Bulldog Shale makes field determination of the stratigraphic position of the boulders and logs very difficult. This problem is compounded by possible local absences of the basal Bulldog Shale and hiatuses within the shale itself (Alley, 1985, 1986; Dettmann and Williams, 1985). Thus, the palaeo-environmental studies will rely heavily on accurate dating of the sediments enclosing the boulders and the logs.

STRATIGRAPHY OF THE SITES INVESTIGATED

Mount Fitton Homestead

A low rise on the eastern edge of the abandoned homestead is underlain by calcareous and ferruginous sandstone containing casts of wood and other plant fragments. Although the age of the sandstone is unknown it is regarded as an Early Cretaceous unit (Campana *et al.*, 1961; Coats *et al.*, 1969). Unfortunately the calcareous and lithified character of the sediment makes it unsuitable for palynological processing.

Moolawatana

This site is located in the south bank of Hamilton Creek at the rear of Moolawatana homestead shearing shed (Plate 1). From creek bottom the sediments consist of 2 m of dark organic-rich shale interbedded with beds and lenses of gritty to gravelly clay containing plant matter (Fig. 4). The organic-rich clay is succeeded by 4-5 m of fine, well sorted quartz sand which appears largely massive, although minor cross-bedding also occurs. Rare casts of vertical and horizontal worm burrows are present in some horizons of the sand. Unconformably overlying the sand are 1-2 m of calcreted fluvial gravel, probably deposited during the late Cainozoic. Occasional, very large water worn boulders occur on the surface of the gravel. These larger clasts are believed to have been derived from Bulldog Shale which is not present at this site, but crops out elsewhere in the locality.

Field evidence suggests that the organic-rich claystone may be equivalent to the Cadna-owie Formation. Samples were taken during two visits from the claystone and a gritty clay lens for palynological examination.

Mount Babbage

A series of interbedded crossbedded sands, silts and carbonaceous clays overlie an irregular bedrock surface north and west of Mount Babbage (Plate 2). A thin silicified sandstone caps Mount Babbage and the mesa surface to the north (Plate 3). A section of the sediments in the lowlands 2 km north of Mount Babbage was examined since it contained carbonaceous silts and clays with potential for palynological processing (Fig. 5). From the base are a few metres of bedded fine sand overlain by a metre of silicified crossbedded sandstone. The latter passes upwards into a metre of slightly gypseous, organic-rich, woody sandy silt and then a thin sandstone. The overlying metre or so of black, organic-rich, woody silt and mud are in turn overlain by fine sand and then 3-4 m of silicified, crossbedded sandstone.

The age of the sediments is unknown but they are correlated with either the Late Jurassic or the Early Cretaceous sandstones of the Eromanga Basin (Glaessner and Rao, 1955; Woodard, 1955; Campana *et al.,* 1961; Coats *et al.,* 1969). Samples for palynological processing were taken from the carbonaceous silt and mud beds.

Mount Babbage east

A section in Bulldog Shale 5 km northwest of Moolawatana homestead on the track to Gunpowder Bore is informally referred to in this report as Mount Babbage east. Here the shale unconformably overlies a palaeoslope eroded across granitised metasediments of the Precambrian Radium Creek Metamorphics (Fig. 6). The shale reaches a maximum thickness of approximately 20 m but thins rapidly to the south on the steeply rising palaeoslope. At the base of the shale and in direct contact with the bedrock is a layer of boulders containing dominantly rounded and polished quartzite boulders (Plate 4). This layer extends up onto the exposed bedrock slope where it is set in a calcareous matrix and is here regarded as the original regolith on the former slope. Two samples were obtained from near the base of the shale in close proximity to the unconformity with the bedrock.

North of boulder sites

A traverse was made northwards from the boulder bed site for 6 km across the Bulldog Shale to obtain samples to aid in determining which part of the shale is present around the northern fringe of the Flinders Ranges. The shale is too weathered in the area to have any potential for palynological analyses and thus limestone concretions were sampled at two sites in preference since these often produce palynofloras where the shales do not (Alley and Rogers, 1985). The first site is 3 km north of the boulder bed in a broad lowland where the shale is downsequence from the previous site and the other, a further 3 km northeast on the north-facing slope of a prominent mesa. At this latter site the shale is upsequence from the boulder site.

Village Well area

Four sites were examined in this area during the course of the two visits but only two were sampled for palynological analyses, the others containing sediments too weathered to contain palynomorphs. This included a detailed field examination of Western Spur, but unfortunately the Mesozoic sediments outcropping here are unsuitable for sampling.

Site 1

The first site is in the north bank of an upper tributary to Pelican Creek, which Forbes (personal communication) regards as a parastratotype for the Pelican Well Formation (Cadna-owie equivalent). Exposed along 500 m of creek bank are gently, northwest-dipping sand, minor silt, clay and diamictite (Fig. 7). Due to the downstream dip of the beds, the lower part of the sequence is only exposed upstream.

The basal unit (Fig. 7) comprises 3 m of interbedded clay, silt and sand containing isolated pebbles and boulders and minor diamictite lenses near the base. A number of pebbles and boulders in the diamictite are polished and faceted, reminiscent of glacial clasts, although no other surface features such as striae that could confirm a glacial origin are present. Small fragments of oxidised plant material occur along some bedding planes throughout the unit. Two samples of clays were taken for palynological examination during the first visit and another sample of slightly carbonaceous sandy clay during the second visit.

Downstream only the upper unit is present and is comprised largely of 10 m of coarse, crossbedded sand with approximately 0.6 m of conglomerate at the base {Plate 5). Isolated pebbles, boulders and oxidised wood are present in the sandstone, along with a few thin clay beds (lower in the unit), one of which was sampled for palynological analysis. The style of bedding in the sandstone is suggestive of an ebb-tide deposit (N. Lemon, personal communication).

Ludbrook (1966), who previously visited and measured the section, regards the lower unit as being equivalent to the Pelican Well Formation and the upper unit to the Trinity Well Sandstone Member. Samples taken from the two units at the site by Ludbrook proved to be unfossiliferous.

Site 2

This is the type section for the Village Well Formation and Pelican Well Formation, the general stratigraphy and location for which are given in Figure 8.

Only about 4 m of Village Well Formation overlying basement is exposed at this site. From the base the Formation consists of a quartz-rich conglomerate set in a matrix of medium-grained kaolinitic sand overlain by a very fine, largely massive sandstone. Both units are very weathered and thus were unsuitable for palynological examination.

The overlying Pelican Well Formation is separated from the Village Well Formation by a basal, sandy boulder bed, which passes upwards into 12-15 m of bioturbated, fine sand and silt containing occasional "cone-in-cone" limestone and minor beds of clay. The Pelican Well Formation locally is gypseous to calcareous and weathered, indicating that the unit may not be prospective for palynological examination. However, one sample was taken from low in the Formation in a small creek bank, another of cuttings from an abandoned drill-hole and a third from a silty clay bed high in the unit near the top of a small butte a kilometre or so south of Village Well.

Trinity Well

During the May visit a well exposed hill section (now informally named "Recorder Hill") of approximately 24 m of Mesozoic sediments on the west bank of MacDonnell Creek, several kilometres southwest of Trinity Well was examined (Plate 6; Fig. 9). The sequence rests on an irregular palaeosurface eroded across steeply dipping Precambrian rocks.

From the base the sediments comprise a few metres of pebbly, calcareous sandstone, overlain by 10 m of bioturbated, silty claystone containing fine- to medium-grained sandstone pods. The claystone is rich in particulate plant matter and occasional, poorly preserved plants. Thin lenses of diamictite, pebbles and boulders, some as dropstones, occur sporadically throughout the claystone (Plate 7; Fig. 8). Although the unit is strongly bioturbated, occasional lenses of the sand show small scale trough and hummocky cross-stratification.

The claystone is succeeded by 12 m of weathered, finely bedded sandy siltstone containing isolated large boulders. This unit is capped by a few metres of gypseous gravels of probable late Cainozoic age.

Although the age of the Mesozoic sequence is not clearly known, it is regarded as Pelican Well Formation, or Cadna-owie Formation equivalent (Forbes *et al.,* 1965). During the May visit two large excavations were made in the basal claystone unit at 4 m and 8 m above the unconformity with the Precambrian bedrock (Plate 8). Large samples were selected from both sites for palynological examination. During the course of excavation, a number of plant macrofossils were encountered and these were taken for identification by J. Francis, Department of Geology and Geophysics, The University of Adelaide.

The samples produced palynofloras which indicated an age not consistent with the field evidence that the sediments are correlative with the Cadna-owie Formation (see below). Thus the Trinity Well site was revisited during October and examined in detail. A trench a metre deep and up to a metre wide was cut down the face of the section through the slope materials to expose the Mesozoic sediments below, and to allow a detailed section to be measured and described. Large samples for palynological processing were again taken from prospective intervals along the channel and at other sites in the Recorder Hill area. Similar sediments crop out elsewhere in the vicinity of Trinity Well and these were examined, measured and described by N. Lemon. Samples for palynological processing were taken at a few localities but in general the sediments are too weathered to contain palynomorphs.

Cattle Mound Springs

During October a traverse was made from Trinity Well northeastwards towards Cattle Mound Springs to inspect similar sediments to those at Recorder Hill. A site approximately 6 km southwestwards from the springs was examined in detail. Here the precambrian (Sturtian) glacigene Bolla Bollana Formation is overlain by a sequence of gently northward-dipping Mesozoic sediments. From the base the latter comprise a metre or so of laminated sand, silt and clay containing rounded pebbles reworked from the underlying weathered bedrock (Fig. 10). A sample was taken from a dark horizon in the clays but field evidence suggested that the colour of the material is due to manganese rather than organic matter. Overlying the basal unit are 3-4 m of weathered sand, silt and clay that are too weathered for sampling. Because of the irregular contact with the underlying bedrock and the dip of the Mesozoic beds the best exposure of the younger part of the sequence is approximately 0.5 km to the north (Fig. 10). Here a silicified cross-bedded sand containing pebbles and boulders overlies bedrock and in turn is overlain by approximately 7 m of bioturbated sandy mudstone containing thin grit and gravel layers and isolated pebbles. A large excavation was made in the mudstone to obtain a sample for palynological analysis, but the sediment is weathered and appeared to have low palynological potential.

Although no palaeontological evidence is available for the age of these beds, the basal unit is correlated with the Village Well Formation and the overlying mudstone with the Pelican Well Formation.

Davenport Springs

A composite of the stratigraphic units mapped in this locality is given in Figure 11. At no one site can all the sedimentary units that occur in the area be seen.

The Mesozoic sequence overlies a very irregular palaeosurface eroded across Precambrian rocks. The oldest, widespread Mesozoic unit occurring in the area is regarded as the sand, silt and gravel of the Cadna-owie Formation. This is largely a crossbedded fine to medium sand which is conglomeratic near the base and contains silicified and ferruginised wood. At one site the sandstone is underlain by at first 0.5 m of grey, plant-bearing silt and sand containing abraded wood particles, and then at least 1.0 m of organic-rich black mud.

Overlying the sandstone is 20-25 m of Bulldog Shale, although its actual thickness may greatly exceed this in the area. The shale here is a black, bioturbated claystone containing particulate plant matter, isolated pebbles, boulders and thin gravel lenses, and rare shells. Weathering of the shale is variable, with slight to strong ferruginisation, and almost universal gypsification.

Five samples of Bulldog Shale were taken at three sites in the Davenport Springs area for palynological analyses. These samples were taken as nearby as possible to silicified logs taken by J. Francis for identification and tree-ring analysis. Two other palynological samples were recovered from the organic-rich mud underlying the Cadna-owie Formation. Two samples were taken from Bulldog Shale by J. Francis during another visit and the results of these samples are included in this report.

PROCEDURES

Field

One of the great difficulties in undertaking palynological analyses of Mesozoic sediments from outcrop in the Eromanga Basin is the lack, or very poor preservation, of palynomorphs due to weathering (Alley and Rogers, 1985). Any hint of iron oxides, calcium carbonate, gypsum, kaolinisation or salt is an indication that the palynomorphs are probably corroded from the sediments.

In some instances, however, ferruginisation and gypsum growth may only be superficial, with chemical alteration proceeding in a shallow zone parallel to the exposed slope. In these instances, removal of the outer 0.5-1.0 m of sediment may expose much fresher material suitable for sampling. This method of sampling (Plate 8) was undertaken at all of the sites visited.

To provide the best control over dating, palynological samples were taken as closely as possible to where macrofossils were obtained. Sampling for other kinds of analyses was largely done in the hole excavated for palynological samples. In all cases, the latter samples were from fine-grained sediments, particularly organic-rich muds, clays and silts.

Laboratory

All samples were processed in the initial stages by a standard laboratory procedure involving crushing, boiling in conc. HCl followed by conc. HF and heavy liquid separation. Because many samples were weathered, the oxidation stages (Schulze Solution followed by a wash in a dilute solution of K_2CO_3) were omitted or reduced, and in some cases only sieving (129/μ m followed by 10/μ m) was undertaken after heavy liquid separation. Weathering was too severe in eight of the samples and these were found to be barren of palynomorphs following the heavy liguid stage in six cases and after Schulze Solution in two others. Processing of the latter samples was discontinued at these respective stages.

The procedure used for each sample after the heavy liquid stage is shown in Table 1.

Table 1. Laboratory procedure employed following heavy liquid separation

Palynological Number	Time in Schulze Solution (minutes)	K_2CO_3 Solution	Sieve 129 μm	Sieve 10 μm
S 6258	3	0.5%	–	x
S 6272	–	–	–	x
S 6273	7	barren	–	–
S 6274	7	barren	–	–
S 6275	7	–	x	x
S 6279	–	–	x	x
S 6280	barren	–	–	–
S 6281	–	–	x	x
S 6282	7	–	–	x
S 6283	–	–	–	–
S 6284	barren	–	–	–
S 6285	–	–	x	x
S 6286	barren	–	–	–
S 6287	barren	–	–	–
S 6288	barren	–	–	–
S 6289	barren	–	–	–
S6279A	–	–	x	x
S6279B	–	–	x	x
S6337	barren	–	–	–
S6338	barren	–	–	–
S6339	barren	–	–	–
S6340	barren	–	–	–
S6341	barren	–	–	–
S6342	barren	–	–	–
S6343	barren	–	–	–
S6344	barren	–	–	–
S6345	barren	–	–	–
S6346	barren	–	–	–
S6347	barren	–	–	–
S6348	–	–	x	x
S6349	barren	–	–	–
S6350	barren	–	–	–
S6351	–	–	x	x
S6352	–	–	x	x
S6353	–	–	x	x
S6354	barren	–	–	–
S6355	barren	–	–	–
S6356	barren	–	–	–
S6357	barren	–	–	–
S6358	barren	–	–	–
S6359	–	–	x	x
S6362	–	–	–	–
S6279	–	–	x	x
S6376	3	–	x	x
S6377	3	–	x	x

Microscope analyses were undertaken with a Zeiss Photomicroscope III. A count of at least 300 palynomorphs was attempted for each sample to determine relative frequency of the pollen and spores (Appendix 1). The preservation and yield of palynomorphs from each sample were variable ranging from nil to good. Where preservation was poor no counting was undertaken. Extensive scanning of all microscope slides followed counting to record the less common to rare palynomorphs.

The following is a list of palynological numbers assigned to the samples from each site:

Moolawatana	
S 6273	?Cadna-owie Formation
S 6274	" "
S 6275	" "
S 6349	" "
S 6350	" "
S 6351	" "
S 6352	" "
S 6353	" "
Mount Babbage area	
S 6337	unknown
S 6338	"
S 6339	"
S 6340	"
S 6341	"
S 6345	"
S 6346	"
Mount Babbage east	
S 6357	Bulldog Shale
S 6358	" "
North of boulder sites	
S 6359	Bulldog Shale
S 6362	" "

Village Well area		
S 6279	"	"
S 6285	"	"
S 6286	"	"
S 6287	"	"
S 6288	"	"
S 6289	"	"
S 6356	"	"
Trinity Well		
S 6272	"	"
S 6279	"	"
S 6279A	"	"
S 6279B	"	"
S 6342	"	"
S 6343	"	"
S 6344	"	"
S 6347	"	"
S 6348	"	"
Cattle Mound Springs area		
S 6354	Algebuckina Sandstone	
S 6355	Cadna-owie Formation	
Davenport Springs area		
S 6258	Cadna-owie Formation	
S 6280	Bulldog Shale	
S 6281	"	
S 6282	Cadna-owie Formation	
S 6283	Bulldog Shale	
S 6284	"	
S 6376	Bulldog Shale	
S 6377	"	

PALYNOLOGY

Moolawatana

Only samples from the gritty beds (S 6275, S 6351 and S 6352) produced pollen and spores suitable for examination. The yield of palynomorphs is poor and the preservation is very poor.

The palynoflora is dominated by the pteridophytes *Cyathidites minor* (20%), *Retitriletes austroclavatidites* (15%) *Stereisporites antiquasporites* (12%), and *Gleicheniidites circinidites* (6%); and the gymnosperms *Podocarpidites ellipticus* (8%) and *Classopolis chateaunovi* (5%). One sample (S6351) produced a palynoflora consisting almost entirely of *Gleicheniidites circinidites* and *Cyathidites minor.*

The presence of *Crybelosporites stylosus* indicates that the palynoflora can be no older than the *C. stylosus* Zone (Fig. 3). The first and last occurrence of this species is used to define the lower and upper boundaries of the zone (Dettmann and Playford, 1969). Associates in this zone are normally *Aequitriradites hispidus* Dettmann & Playford 1968 (restricted to the zone), *Murospora florida* (Balme) Pocock 1961, *Cyclosporites hughesii* (Cookson & Dettmann} Cookson & Dettmann 1959, *Kraeuselisporites linearis* (Cookson & Dettmann) Dettmann 1963, *Cicatricosisporites australiensis, Contignisporites cooksonii* and *Biretisporites spectabilis,* but only the latter two species are present in the Moolawatana sample. This absence is more likely a function of the poor preservation of the palynomorphs rather than an absence due to ecological or facies reasons.

Although 55 species have been identified in the samples, they are still regarded as relatively restricted palynofloras and this is borne out by the absence of the associate species. This is unfortunate because it is impossible to determine whether the palynofloras are correlative with the lower or upper subzone of *Crybelosporites stylosus* Zone (Fig. 3).

Not only is *Cicatricosiporites australiensis* absent but also *Foraminisporis worthaggiensis,* the first appearance of which is used to define the base of the upper subzone.

The assemblage is tentatively placed in the earlier subzone based on the presence of species more common in the Jurassic than later. These include *Camarozonosporites clivosus, C. ramosus,* the fine mesh form of *Dictyotosporites complex* (Filatoff, 1975), N*eoraistrickia suratensis*, *N. taylorii*, *Retitriletes huttonensis, R. semimuris* and *Rogalskaisporites cicatricosus.* The evidence thus suggests that the age of the palynoflora is Neocomian, possibly Early Neocomian. Marine microplankton are not present in the palynoflora and thus the deposit at Moolawatana is regarded as fluviatile in origin.

If the deposit is non-marine and Early Neocomian, then the lithostratigraphic equivalent would be the upper part of the Algebuckina Sandstone. Although the Cadna-owie Formation has been defined as a marginal-marine deposit, non-marine facies of the unit can be detected around the margins of the Eromanga Basin (Alley, 1985). Thus, the possibility also exists that the organic-rich deposit at Moolawatana may be equivalent to the non-marine facies of the Cadna-owie Formation.

A few plant macrofossils previously recovered from this site (Glaessner and Rao, 1955) were regarded as Lower Cretaceous in age. The age of the palynoflora assigned above thus defines the age of the macroflora more precisely as Neocomian.

Mount Babbage area

Although the samples appeared to contain abundant organic matter including wood, no palynomorphs were produced by the laboratory processing. The dark colouration to the samples is due to the abundance of vitrinite and wood fragments; palynomorphs were undoubtedly present during deposition of the beds but were subsequently weathered out.

Mount Babbage east

The two samples from the boulder bed site produced no palynomorphs.

North of boulder sites

The sample from site 1 produced a good yield of palynomorphs but they are too poorly preserved to warrant counting. The spore/pollen assemblage is assigned to the *Cyclosporites hughesii* Subzone of the *Dictyosporites speciosus* Zone (Fig. 3) on the basis of the presence of the latter species in conjunction with *Cyclosporites hughesii* and the absence of *Crybelosporites striatus.*

The sample also contains a restricted microplankton assemblage that is assigned to the *Odontochitina operculata* Subzone c on the basis of the following evidence (Fig. 3). The zonal fossil *0. operculata* is not present in the assemblage although associates are present and support the above designation. The presence of *Diconodinium davidii* is used to define the base of subzone c whereas *Leptodinium asymmetricum* has its oldest occurrence at or the top of the preceding subzone (Morgan, 1980b).

Again no count was undertaken for the sample at site 2. The presence of *Crybelosporites striatus* in the absence of *Coptospora paradoxa* indicates that the spore/pollen assemblage is correlative with the *Crybelosporites striatus* Subzone of the *Dictyosporites speciosus* Zone. Only a few microplankton were recovered from the sample but the presence of *Spinidinium styloniferum* is consistent with the spore/pollen zone, since this dinoflagellate first occurs near the base of the *Pseudoceratium turneri* Subzone b (Fig. 3).

The above palynological zonations suggest that: the older part of the Bulldog shale that is normally present in deeper parts of the Eromanga Basin (Fig. 3) is absent in this area, and

- the younger part of the sequence as determined by site 2 is upper Bulldog Shale

The absence of the early Aptian interval of the Bulldog Shale is probably related to the rising bedrock floor across which the Early Cretaceous sea transgressed.

Village Well area

One sample (cuttings from drillhole) produced palynomorphs, which are very poorly preserved and comprise only 8 species, all of which are non-diagnostic of age.

Trinity Well

Samples from this site were productive, providing good yield and fair preservation.

The palynoflora is dominated by the pollen from gymnosperms including *Microcachryidites antarcticus* (32-36%), *Podocarpidites ellipticus* (21-27%), *Alisporites grandis* (4-6%), *A. similis* (2-8%), *Classopolis chateaunovi* (3-6%) and *Trisaccites microsaccatus* (1-4%); and spores of the pteridophytes *Cyathidites minor* (5-19%), *C. australis* (2-4%) and *Gleicheniidites circinidites* (2-6%). The samples contain rare acritarchs and dinoflagellates.

Crybelosporites stylosus is present in the samples indicating that the assemblage is no older than the *C. stylosus* Zone. The zonal species is associated with *Cicatricosisporites australiensis*, but *Foraminisporis wonthaggiensis* is absent; thus the assemblage is assigned to the *C. australiensis* Subzone of Early Neocomian age (Fig. 3). The occurrence of the Neocomian dinoflagellate *Fusiformacysta salasii* in all of the samples is consistent with this interpretation.

Based on available published information for the Eromanga Basin the presence of restricted microplankton assemblages implies that the sediments are likely to be equivalent to the marginal-marine Cadna-owie Formation. If this is the case, then the Early Neocomian age would also imply that the sediments are basal Cadna-owie Formation. Although evidence of a marine facies of the Algebuckina Sandstone is lacking around the southwestern margin of the Eromanga Basin, restricted microplankton assemblages have been reported from the Hooray Sandstone (upper Algebuckina Sandstone equivalent) from a few wells in deeper parts of the basin (Morgan, 1980a). This marine influence is now regarded as being far more widespread during the Neocomian and restricted microplankton assemblages from the Mooga and Hooray sandstones are common along the eastern part of the Eromanga Basin (R. Morgan, personal communication). Necomian microplankton assemblages have been reported from the Carpentaria Basin of northern Queensland (Burger, 1980, 1982). Three informal zones are recognised here including (from the oldest) DKl (latest Jurassic-Berriasian), DK2 (Valanginian) and DK3 (Hauterivian). The *Cicatricosisporites australiensis* spore/pollen Subzone thus encompasses DKl and the lower portion of DK2, although only one species of dinoflagellate *(Spiniferites ramosus ramosus)* occurring in those zones is present in the palynofloral assemblages at "Recorder Hill". This species first occurs in DK2 which implies that the assemblages at "Recorder Hill" can be no older than DK2 (Valanginian) and thus only the uppermost part of the *Cicatricosporites australiensis* spore/pollen Zone is present.

The presence of a paralic facies of the upper Algebuckina Sandstone at Trinity Well is consistent with the above evidence. Thus, the beds at "Recorder Hill" are either basal Cadna-owie Foramtion or upper Algebuckina Sandstone.

Burger (1982) suggests that during the Valanginian (DK2) the southward penetration of the sea was blocked by a basement high across the northeastern part of the Carpentaria Basin. The presence of restricted Neocomian microplankton assemblages as far south as the northern Flinders Ranges means that some form of marine influence had already penetrated the Eromanga Basin by at least the Valanginian. This conclusion is in agreement with the recent concept proposed that during the Valanginian and Hauterivian a narrow arm of the sea had penetrated southwards through central Queensland into northeastern South Australia and northwestern N.S.W. (Frakes *et al.,* 1987)

A few species of Permian palynomorphs occur in the beds at "Recorder Hill". These were probably recycled from the Permian sediments underlying the Eromanga Basin and carried southwards by the transgressing Neocomian sea.

Davenport Springs

1. Mud underlying ?Cadna-owie Formation:

One sample from the mud produced a good palynomorph assemblage, the other, only a fair yield with similar preservation.

Pollen from the conifers far exceeds all other types in both samples: *Microcaohicyidites antarctiaus* (32-43%), *Podocarpidites ellipticus* (20-32%), *Alisporites similis* (3-12%), *A. grandis* (6-7%) and *Classopolis chateaunovi* (6% in one sample). The pteridophytes are dominated by *Cyathidites minor* (3-11%), *C. australis* (1%) and *Gleicheniidites circinidites* (1-6%).

The presence of *Retitriletes watherooensis* in the absence of *Crybelosporites stylosus* and *Cicatricosisporites australiensis* indicates a correlation of the assemblage with the *Retitriletes watherooensis* Zone of Backhouse (1978). This zone is equivalent to the lower *Microcachryidites antarcticus* Assemblage-zone (Filatoff, 1975), the lower J6 of Evans (1966a, b), and to PJ 6 spore/pollen zone (Price *et al.,* 1985). The palynological zonation for the assemblages can be further refined on the basis of index forms employed by Price *et al.* (1985) (Fig. 12). Thus, the presence of *Ceratosporites equalis* and *Foraminisporis dailyi* places the assemblages in PJ6.2.2 (Fig. 12).

The age of the assemblages and the mud at Davenport Springs in thus Late Jurassic. This designation implies that the mud would be approximately equivalent to the middle Algebuckina Sandstone (Fig. 3). Marine microplankton were not recorded in the samples even after extensive scanning, indicating a terrestrial environment of deposition, which is consistent with the non-marine origin for the Algebuckina Sandstone.

If the crossbedded sandstone overlying the mud is still regarded as Cadna-owie Formation, then a disconformity occurs between the two units. On the other hand, if the mud and the sandstone form part of the same depositional event, then the sandstone could also be Algebuckina Sandstone.

2. Bulldog Shale

Four samples were productive, although two of them (S 6281 and S 63 76) are of no palynostratigraphic value since they produced only a few pollen, spores and acritarchs (Appendix 1). The other samples (S 6283 and S 6377), however, gave good yields with fair preservation.

The assemblage in sample S 6283 is dominated by abundant acritarchs (40%) of the genus *Micrhystridium,* with less than 1% of the remaining microplankton comprising largely dinoflagellates (12 species). Frequently occurring pollen and spores are *Cyathidites minor* (13%), *Microcachryidites antarcticus* (9%), *Gleicheniidites circinidites* (6%), *Podocarpidites elliptious* (5%), *Retitriletes austroclavatidites* (4%), *Cycadopites nitidus* (4%) and *Dictyophyllidites harrisii* (4%).

Sample S 637 7 contains a much lower frequency (4%) of microplankton consisting of three taxa (Appendix 1). Commonly occurring spores and pollen include *Microcachryidites antarcticus* (18%), *Podocarpidites ellipticus* (15%), *Alisporites gvandis* (15%), *A. similis* (10%), *Cyathidites minor* (14%) and *Gleicheniidites circinidites* (7%).

The spore/pollen assemblage in sample S 6283 is assigned to the *Cyclosporites hughesii* Subzone of the *Dictyotosporites speciosus* Zone (Fig. 3) on the basis of the presence of the latter species in conjunction with *Foraminisporis asymmetricus,* and the absence of *Crybelosporites striatus.* The first occurrence of the latter species is used to define the upper boundary of the *Cyclosporites hughesii* Subzone. This zonation is correlative with PK3 of Price *et al.* (1985), which is subdivided into two subzones PK3.1 and PK3.2 on the basis of the first occurrence of *Pilosisporites parvispinosus* Dettmann 1963. Since the latter species is not present, the assemblage is assigned to subzone PK3.1 (Fig. 3).

Although the microplankton assemblage is restricted, the presence of *Odontochitina opereulata* in the absence of *Pseudoeeratium tuvneri* Cookson & Eisenack 1958, indicates a correlation with the *0. operculata* Zone of Morgan (1980b; Fig. 3). The presence of *Canningia* sp. A and *Lithodinia helbyi* suggests that the microplankton assemblage can be no older than *0. operculata* Subzone b.

The palynomorph assemblage is thus from the lower Bulldog Shale and early to middle Aptian in age. The low dinoflagellate diversity and high acritarch content imply a very restricted marine environment. Morgan (1984) regards the abundance of *Micrhystridium* in *Odontochitina operculata* Subzone b to be consistent with the regressive marine phase during the early to middle Aptian.

No zonation can be given to sample S 6377 because, even though there are sufficient palynomorphs to make a count, no zonal fossils (apart from *Dictyotosporites speciosus)* are present in the assemblage. In view of the significant difference in the character of the assemblages between samples S 6283 and S 6377 it is unlikely that the latter is from the same horizon in the Bulldog Shale, but whether it is younger or older is unknown.

CONCLUSIONS

The palynology and dating of samples from outcrop in the southwestern Eromanga Basin is hampered by the weathered character of the sediments and their marine transgressive origin. This problem is compounded by the lithological similarity of units encountered in the area, particularly the shallow-water marine to paralic facies.

At sites where the sediments are only slightly or superficially weathered, a deep excavation 0.5 m to 1.0 m deep may be required to obtain productive samples. These samples do not respond well to traditional laboratory extraction techniques and the oxidation stages need to be omitted or greatly reduced. In some cases only sieving following heavy liquid separation is necessary. In all cases, however, each sample requires very close scrutiny prior to any additional processing stage subsequent to heavy liquid separation.

Slightly weathered samples may only produce palynomorph assemblages of restricted diversity and are thus of limited value in palynological dating. These samples (e.g. Moolawatana) may be assigned to broad palynological zones, but further refinement to subzones is either tentative or not possible.

Apart from the dates obtained from sites which were previously of unknown age and the value that the dates have in elucidating the geological history of the areas, the most significant aspect of this study is the recognition of a paralic facies of the Algebuckina Sandstone or lowermost Cadna-owie Formation at Trinity Well. This provides evidence of a marine transgression in the eastern and central parts of the Eromanga Basin which extended at least as far south as the northern fringe of the Flinders Ranges. The transgression is part of the Early Neocomian rise in sea level that is known to have extended at least into northwestern N.S.W. and northeastern South Australia (Morgan, 1980a).

In view of the paralic origin of the beds at Trinity Well the microplankton may be of restricted diversity, very low frequency or absent. This is highlighted by the present study which could only determine the presence of microplankton after extensive scanning of multiple microscope slides for each sample.

Finally, the age designations given to the samples throw some light on the age range during which the boulders and "dropstones" were possibly deposited. Sediments containing the clasts at Trinity Well are Early Neocomian in age. Northeast of Mount Babbage Bulldog Shale containing pebbles ranges in age from middle to late Aptian and possibly early Albian. At Davenport Springs the clasts are contained in the Bulldog Shale which here is early to middle Aptian in age. If the mud underlying the ?Cadna-owie Formation at the Springs is part of the Formation, then the clasts may range back into the Late Jurassic. Clasts found at the type section of the Cadna-owie Formation were deposited during the early Aptian (N.F. Alley, unpublished information).

Thus, the clasts occur in sediments ranging in age from at least Early Neocomian to late Aptian (possibly to early Albian). If the stones were emplaced by floating ice, then cold conditions would need to have prevailed in this part of the Eromanga Basin for 50 million years or more. Such a model by itself seems unlikely and other alternatives need to be examined.

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APPENDIX I

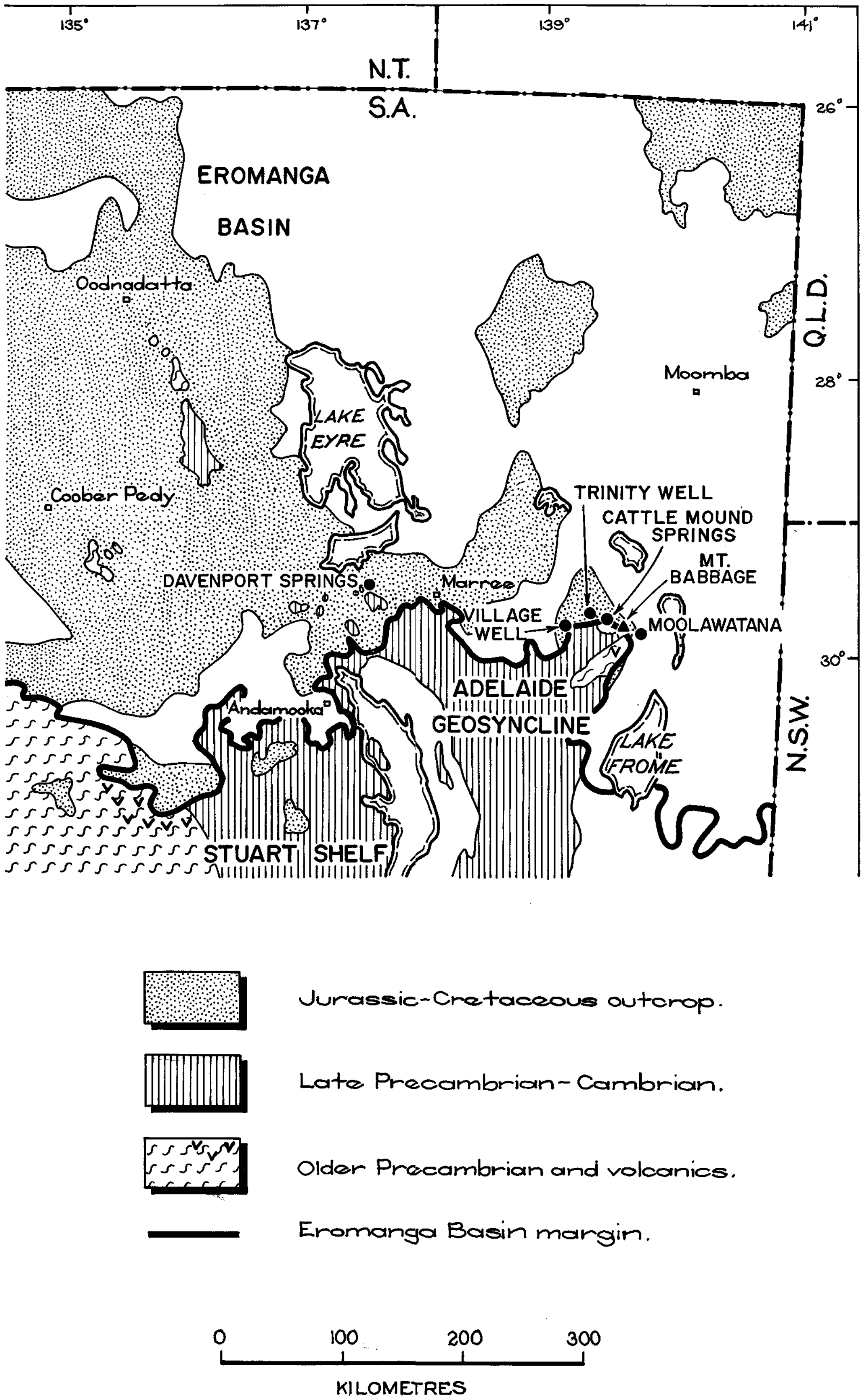
LIST AND FREQUENCY OF PALYNOMORPHS

Location	Moolawatana			Village Well	Trinity Well (Recorder Hill)				Mt. Babbage east (north of boulder sites)		Davenport Springs					
													Bulldog Shale			
	S6275	S6351	S6352	S6285	S6272	S6279	S6279A	S6279B	S6359	S6362	S6258	S6282	S6281	S6283	S6376	S6377
Palynological Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
(x indicates less than 1%)																
PRESERVATION: Good-G, Fair-F, Very Poor-VP	VP	P	P	VP	VP	F	F	F	P	P	F	G	VP	F	P	P
YIELD: Good-G, Fair-F, Poor-P, VP-Very Poor	P	P	P	VP	P	G	G	G	G	P	F	G	VP	G	VP	F
PERCENTAGE FREQUENCY IN ASSEMBLAGE:																
Pollen and spores	100	100	100	100	99+	99+	99+	99+	–	–	100	100	99+	60	–	96
Microplankton	–	–	–	–	–	–	–	–	–	–	–	–	–	40	–	4
POLLEN AND SPORES																
Aequitriradites spinulosus (Cookson & Dettmann) Cookson and Dettmann 1961	–	–	–	–	–	–	x	–	–	x	–	–	–	–	–	–
Alisporites grandis (Cookson) Dettmann 1963	3	x	x	–	4	5	5	6	x	–	7	6	–	1	x	15
A. lowoodensis de Jersey 1963	–	–	–	–	–	x	x	x	–	–	–	x	–	–	–	–
A. similis (Balme) Dettmann 1963	–	–	x	–	2	5	5	8	x	x	3	12	–	x	–	10
Anapiculatisporites dawsonensis. Reiser and Williams 1969	–	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–
A. pristidentatus Reiser & Williams 1969	x	–	–	x	x	–	x	x	–	–	–	x	–	x	–	–
Annulispora folliculosa (Rogalska) de Jersey 1959	x	–	x	–	–	–	x	–	x	–	–	–	–	x	–	–
Araucariacites australis Cookson 1947	–	–	x	–	2	x	–	4	x	x	–	x	–	x	–	1
Baculatisporites comaumensis (Cookson) Potonie 1956	2	–	x	–	x	x	x	x	x	x	–	1	–	x	–	x
Biretisporites spectabilis Dettmann 1963	x	–	x	–	x	x	x	x	–	–	–	x	–	x	–	–
Callialasporites dampierii (Balme) Sukh Dev 1961	x	–	x	–	x	–	x	x	–	–	–	–	–	x	–	–
C. segmentatus (Balme) Srivastava 1963	–	–	–	–	x	x	x	x	–	–	x	x	–	x	–	–
C. trilobatus (Balme) Sukh Dev 1961	–	–	–	–	–	x	x	x	–	–	–	x	–	–	–	x
C. turbatus (Balme) Schulz 1967	–	–	–	–	–	–	x	–	–	–	–	–	–	x	–	–
Camarozonosporites clivosus (Williams & McKellar) McKellar 1974	x	–	–	–	–	–	–	–	–	–	–	x	–	x	–	–
C. ramosus (Williams & McKellar) McKellar 1974 et emend.	x	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
Ceratosporites equalis Cookson & Dettmann 1958	x	–	–	–	x	x	x	–	x	x	–	x	–	x	–	–
C. helidonensis de Jersey 1971	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cibotiumspora jurienensis (Balme) Filatoff 1975	x	–	–	–	–	–	–	–	–	–	x	x	–	x	–	–
Cicatricosisporites australiensis (Cookson) Potonie 1956	–	–	–	–	–	x	x	x	x	x	–	–	–	x	–	–

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
C. cuneiformis Pocock 1965	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. hughesii Dettmann 1963	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
C. ludbrookii Dettmann 1963	-	-	-	-	-	-	x	x	x	-	-	-	-	-	-	-
Classopolis chateaunovi Reyre 1953	5	x	x	-	5	3	3	6	x	-	x	6	-	1	x	-
C. simplex (Danze - Corsin & Laveine) Reiser & Williams 1969	x	-	-	-	-	-	x	x	-	-	-	x	-	x	-	-
Concavissimisporites penolaensis Dettmann 1963	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
Contignisporites cooksoniae (Balme) Dettmann 1963	x	-	-	-	x	x	x	x	-	-	-	x	-	x	-	-
C. multimuratus Dettmann 1963	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Crybelosporites berberioides Burger 1976	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
C. stylosus Dettmann 1963	x	x	-	-	?	x	x	-	x	-	-	-	-	x	-	-
C. striatus (Cookson & Dettmann) Dettmann 1963	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Cyathidites australis Couper 1953	2	x	x	-	2	3	3	4	x	-	x	2	-	3	x	1
C. concavus (Bolkhovitina) Dettmann 1963	-	-	-	-	-	-	-	-	-	-	x	x	-	x	-	-
C. minor Couper 1953	20	x	x	x	5	13	13	18	x	x	3	11	-	13	x	14
Cycadopites nitidus (Balme) de Jersey 1964	x	x	x	x	1	2	2	2	x	-	x	2	-	4	x	1
Dictyophyllidites crenatus Dettmann 1963	-	-	-	-	x	1	1	x	-	-	-	-	-	x	-	-
D. harrisii Couper 1958	1	x	-	-	1	2	2	x	x	-	x	x	-	4	x	1
Dictyotosporites complex Cookson & Dettmann 1958	x	-	-	-	x	x	x	x	x	-	-	x	-	x	-	x
D. filosus Dettmann 1963	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	x
D. speciosus Cookson & Dettmann 1958	-	-	-	-	-	-	-	-	x	-	-	-	-	x	-	x
Foveosporites canalis Balme 1957	3	x	-	x	-	-	x	x	-	-	-	x	-	x	x	x
Foveotriletes parviretus (Balme) Dettmann 1963	x	x	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Foraminisporis asymmetricus (Cookson & Dettmann) Dettmann 1963	-	-	-	-	-	-	-	-	-	x	-	-	-	x	-	-
F. dailyi (Cookson & Dettmann) Dettmann 1963	-	-	-	-	x	x	x	x	-	x	-	-	-	-	-	-
F. tribulosus Playford & Dettmann 1965	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
F. wonthaggiensis (Cookson & Dettmann) Dettmann 1963	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Gleicheniidites circinidites (Cookson) Dettmann 1963	6	x	x	-	6	2	2	2	x	x	6	1	-	6	x	7
G. senonicus Ross emend. Skarby 1964	1	-	-	-	1	x	x	x	x	-	x	x	-	x	-	x
Ischyosporites crateris Balme 1957	-	-	-	-	x	x	x	x	-	-	-	-	-	x	-	x
Klukisporites scaberis (Cookson & Dettmann) Dettmann 1963	-	-	-	-	-	-	x	-	x	-	-	-	-	x	-	-
Kuylisporites lunaris Cookson & Dettmann 1958	-	-	-	-	-	x	x	x	-	-	-	-	-	-	-	-
Laevigatosporites belfordii Burger 1976	1	-	-	-	-	x	x	x	-	-	-	-	-	-	x	-
L. ovatus Wilson & Webster 1946	1	x	-	-	x	x	x	x	-	-	-	-	-	x	-	x
Leptolepidites major Couper 1958	1	x	-	-	x	x	x	x	x	-	-	-	-	2	-	x
L. verrucatus Couper 1953	x	-	x	-	-	x	x	x	x	-	x	x	-	x	-	-
Lycopodiacidites asperatus Dettmann 1963	x	-	x	-	x	-	x	x	-	-	x	x	-	x	-	x
L. dettmannae Burger 1980	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Matonisporites cooksoniae Dettmann 1963	x	-	-	-	-	x	x	-	-	-	-	-	-	-	-	x
M. crassiangulatus (Balme) Dettmann 1963	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x
Microcachryidites antarcticus Cookson 1947	3	x	x	x	36	31	31	32	x	x	43	32	-	9	x	18
Murospora florida (Balme) Pocock 1961	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Neoraistrickia densata Filatoff 1975	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-
N. elongata Reiser & Williams 1969	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
N. suratensis McKellar 1974	-	x	-	-	x	-	-	-	-	-	-	x	-	-	-	-
N. taylorii Playford & Dettann 1965	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N. truncatus (Cookson) Potonie 1956	2	-	x	-	x	x	x	x	x	x	x	x	-	x	-	x
Nevesisporites vallatus de Jersey & Paten 1964	-	-	-	-	x	x	x	x	-	-	-	-	-	-	-	-
Obtusisporis canadensis Pocock 1970	-	-	-	-	x	x	x	-	x	-	-	-	-	-	-	-
Osmundacidites dubius Burger 1980	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
O. wellmanii Couper 1953	-	x	-	-	x	1	x	x	x	x	-	1	-	x	-	x
Podocarpidites ellipticus Cookson 1947	8	x	x	x	26	27	27	14	x	x	32	20	x	5	-	15
Polycingulatisporites clavus (Balme) Burger 1980	1	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-
P. densatus (de Jersey) Playford & Dettmann 1965	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
Punctatosporites scabratus (Couper) Norris 1965	-	-	-	-	-	-	x	-	-	-	-	-	-	x	-	x
Reticulatisporites pudens Balme 1957	x	x	x	-	-	x	x	-	-	-	-	x	-	3	-	x
Reticuloidosporites arcus (Balme) Dettmann 1963	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Retitriletes austroclavatidites (Cookson) Doring *et al.* 1963	15	x	-	x	x	x	x	1	x	x	x	1	-	4	-	x
R. circolumenus (Cookson & Dettmann) (Dettmann 1963)	x	x	-	-	x	x	x	-	x	-	-	x	-	x	-	-
R. eminulus (Dettmann 1963)	-	-	-	-	-	-	-	-	x	-	-	x	-	x	-	-
R. huttonensis McKellar 1974	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R. nodosus (Dettmann) Srivastava 1977	1	x	-	-	-	x	x	-	x	-	x	x	-	x	-	x
R. reticulumsporites (Rouse) Doring *et al.* 1963	x	x	-	-	1	-	-	x	x	-	-	x	-	-	-	-
R. rosewoodensis (de Jersey) McKellar 1974	1	x	x	-	x	1	1	x	x	-	x	x	-	x	-	3
R. semimuris (Danze-Corsin & Laveine) McKellar 1974	x	-	-	-	-	x	x	-	-	-	-	x	-	-	-	-
R. solidus (Burger 1980)	-	-	-	-	-	-	x	-	-	-	-	-	-	x	-	-
R. watherooensis Backhouse 1978	x	x	-	-	x	-	x	x	x	-	-	x	-	x	-	-
Rogalskaisporites cicatricosus (Rogalska) Danze-Corsin & Laveine 1963	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sestrosporites pseudoalveolatus (Couper) Dettmann 1963	3	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Staplinisporites caminus (Balme) Pocock 1962	x	x	-	-	-	x	x	x	-	-	-	x	-	-	-	-
Stereisporites antiquasporites (Wilson & Webster) Dettmann 1963	12	x	-	x	x	x	x	2	x	x	x	x	x	2	x	x
S. pocockii Burger 1980	x	x	-	-	-	-	x	-	x	x	-	x	-	x	-	-
Trilites tuberculiformis Cookson 1947	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x
Trilobosporites purverulentus (Verbitskaya) Dettmann 1963	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Triporoletes reticulatus (Pocock) Playford 1971	-	-	-	-	x	-	x	x	-	-	-	-	-	-	-	-
Trisaccites microsaccatus (Couper) Couper 1960	1	-	-	-	4	1	x	x	x	x	3	1	-	2	x	2
Velosporites triquetrus (Lanz) Dettmann 1963	-	-	-	-	-	-	x	-	x	-	-	x	-	x	-	-
Vitreisporites pallidus (Reissinger) Nilsson 1958	-	-	-	-	x	x	x	x	x	-	-	x	-	-	-	-
REMANIE																
Granulatisporites quadruplex Segroves 1970	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
Plicatipollenites densus Srivastava 1970	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Protohaploxypinus limpidus (Balme & Hennelly) Balme & Playford 1967	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
Striatopodocarpidites cancellatus (Balme & Hennelly) Hart 1963	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
MICROPLANKTON																
Apteodinium granulatum Eisenack 1958	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Canningia sp. *A* Morgan 1980	-	-	-	-	-	-	-	-	x	-	-	-	-	x	-	-
Canningia colliveri Cookson & Eisenack 1960	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Callaiosphaeridium asymmetricum (Deflandre & Courteville) Davey & Williams 1965	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Chlamydophorella nyei Cookson & Eisenack 1958	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–
Cleistosphaeridium polypes (Cookson & Eisenack) Davey 1969	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Cleistosphaeridium sp.	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–
Coronifera oceanica Cookson & Eisenack 1958	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Cribroperidium muderongense (Cookson & Eisenack) Davey 1969	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
C. perforante (Cookson & Eisenack) Morgan 1980	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Diconodinium davidii Morgan 1975	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Dingodinium cerviculum Cookson & Eisenack 1958	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Exochosphaeridium phragmites Davey *et al.* 1966	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Fusiformacysta salasii Morgan 1975	–	–	–	–	–	x	x	x	–	–	–	–	–	–	–	–
Leptodinium asymmetricum Morgan 1980	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
L. flammeoium Morgan 1980	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Lithodinia helbyi Morgan 1980	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–
Membranosphaera romaensis Burger 1980	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Micrhystridium sp.	–	–	–	–	–	x	x	–	x	x	–	–	x	40	–	2
Muderongia mcwhaei Cookson & Eisenack 1958	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–
M. tetracantha (Gocht) Alberti 1961	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Odontochitina operculata (Wetzel) Deflandre & Cookson 1955	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
O. sp.	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–
Palaeoperidinium cretaceum Pocock ex Davey 1970	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–
Pterospermopsis aureolata Cookson & Eisenack 1958	–	–	–	–	–	x	x	–	–	–	–	–	x	x	x	–
P. australiensis Deflandre & Cookson 1955	–	–	–	–	–	x	x	–	–	–	–	–	x	x	–	–
Schizosporis reticulatus Cookson & Dettmann 1965	–	–	–	–	–	–	x	–	x	–	–	–	–	–	–	–
Spinidinium styloniferum Cookson & Eisenack 1962	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Spiniferites ramosus ramosus (Ehrenburg) Loeblich & Loeblich 1966	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–
Tenua colligata Morgan 1980	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Trichodinium sp.	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
Veryhachium reductum (Deunff) Jekhowsky 1961	–	–	–	–	–	–	–	–	x	x	–	–	–	x	–	–
Wallodinium lunum (Cookson & Eisenack) Lentin & Williams 1973	–	–	–	–	–	–	–	–	x	–	–	–	–	x	–	–

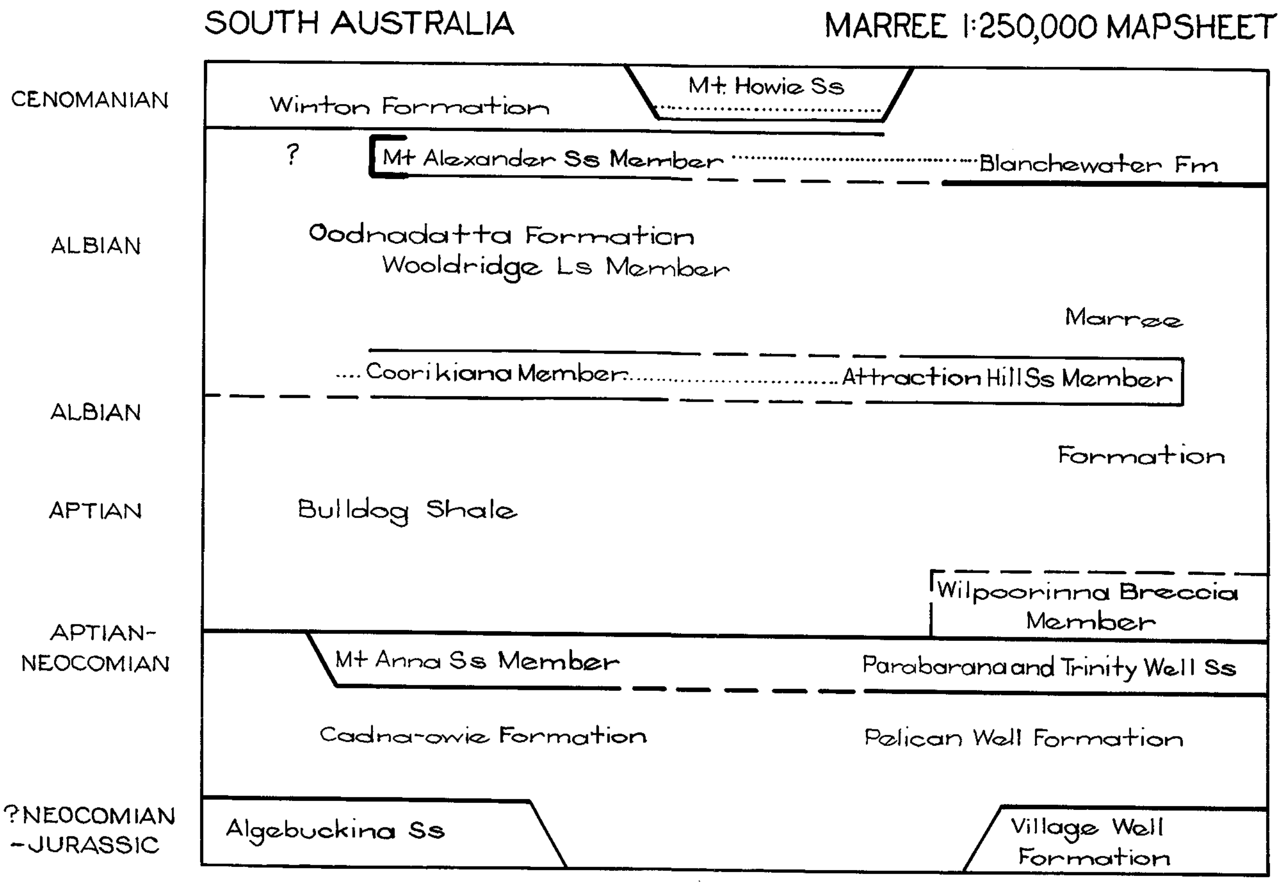


NOTE: Modified from Forbes, 1982.

FIG. 1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED N. Alley	C.D.O. 24·3·87 DATE
PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN	DRAWN J.W.	SCALE 1:5,000,000
REGIONAL GEOLOGY	DATE 19-9-86 CHECKED	PLAN NUMBER S18927

4226



NOTE: Modified from Forbes 1982

FIG. 2

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN

STRATIGRAPHIC UNITS AND PROBABLE CORRELATIVES IN THE MARREE 1:250,000 MAP SHEET AREA

COMPILED N. Alley	C.D.O. DATE 24·3·87
DRAWN J.W.	SCALE
DATE 19-9-86	PLAN NUMBER S18928
CHECKED	

4226

AGE (After Morgan 1980 b)	SPORE-POLLEN UNITS (After Dettmann and Playford, 1969).	SPORE-POLLEN UNITS (After Price et. al. 1985)	MICROPLANKTON UNIT (After Morgan 1980 b)	CORRELATION OF LITHO- AND PALYNO-STRATIGRAPHIC UNITS ELSEWHERE IN THE WESTERN EROMANGA BASIN (Dettman & Williams 1985; Morgan, 1980a; Price et al, 1985)
CENOMANIAN	*Appendicisporites distocarinatus*	PK7		
CENOMANIAN	*Phimopollenites pannosus*	PK6	*Endoceratium Ludbrookiae* c	WINTON FORMATION
CENOMANIAN / ALBIAN	*Phimopollenites pannosus*	PK6	*Endoceratium Ludbrookiae* b	OODNADATTA FORMATION
ALBIAN	*Phimopollenites pannosus*	PK6	*Endoceratium Ludbrookiae* a	OODNADATTA FORMATION
ALBIAN	*Coptospora paradoxa*	PK5 – PK5.2	*Pseudoceratium turneri* c	COORIKIANA SANDSTONE
ALBIAN	*Coptospora paradoxa*	PK5 – PK5.1	*Pseudoceratium turneri* b	BULLDOG SHALE
ALBIAN / APTIAN	*Dictyotosporites speciosus* / *Crybelosporites striatus*	PK4	*Pseudoceratium turneri* a	BULLDOG SHALE
APTIAN	*Dictyotosporites speciosus* / *Cyclosporites hughesii*	PK3 – PK3.2	*Odontochitina operculata* c	BULLDOG SHALE
APTIAN	*Dictyotosporites speciosus* / *Cyclosporites hughesii*	PK3 – PK3.1	*Odontochitina operculata* b	BULLDOG SHALE
APTIAN	*Dictyotosporites speciosus* / *Cyclosporites hughesii*	PK3 – PK3.1	*Odontochitina operculata* a	CADNA-OWIE FORMATION
LATE NEOCOMIAN	*Crybelosporites stylosus* / *Foraminisporis wonthaggiensis*	PK2 – PK2.2	Non-marine	CADNA-OWIE FORMATION
LATE NEOCOMIAN	*Crybelosporites stylosus* / *Foraminisporis wonthaggiensis*	PK2 – PK2.1	Non-marine	CADNA-OWIE FORMATION
EARLY NEOCOMIAN	*Crybelosporites stylosus* / *Cicatricosisporites australiesis*	PK1 – PK1.2, PK 1.1	Non-marine	ALGEBUCKINA SANDSTONE
LATE JURASSIC	*Microcachryidites antarcticus* (Filatoff 1975)	PJ6	Non-marine	ALGEBUCKINA SANDSTONE

FIG. 3

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN

PALYNOSTRATIGRAPHIC ZONES

COMPILED N. Alley	C.D.O. [signature]	DATE 24-3-87	
DRAWN J.W.	SCALE		
DATE 19-9-86	PLAN NUMBER		
CHECKED	S18929		

4226

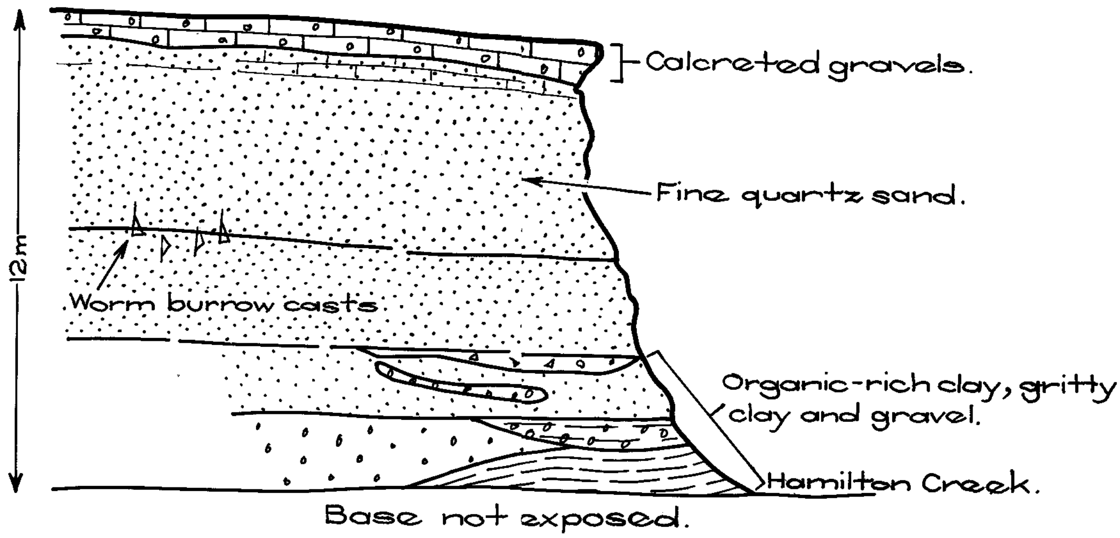


FIG. 4: Stratigraphy at Moolawatana

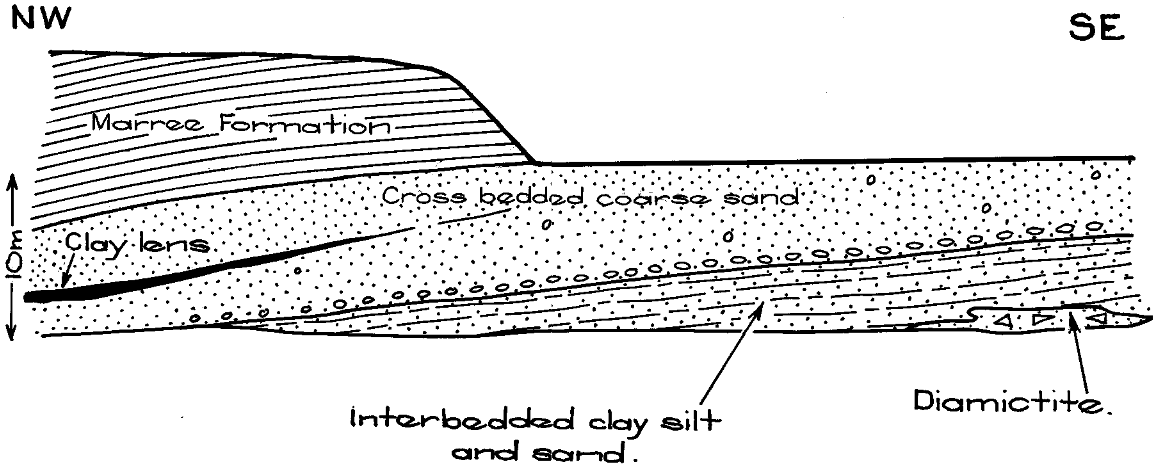


FIG. 7: Stratigraphy of the Pelican Well Formation (Cadna-owie Formation) at Site 1, near Village Well.

FIGS. 4 & 7

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED N. Alley	C.D.O. 24·3·87 DATE
PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN	DRAWN J.W.	SCALE
STRATIGRAPHY AT MOOLAWATANA (FIG. 4) AND PELICAN WELL FORMATION (FIG. 5)	DATE 18-9-86	PLAN NUMBER
	CHECKED	S18930

4226

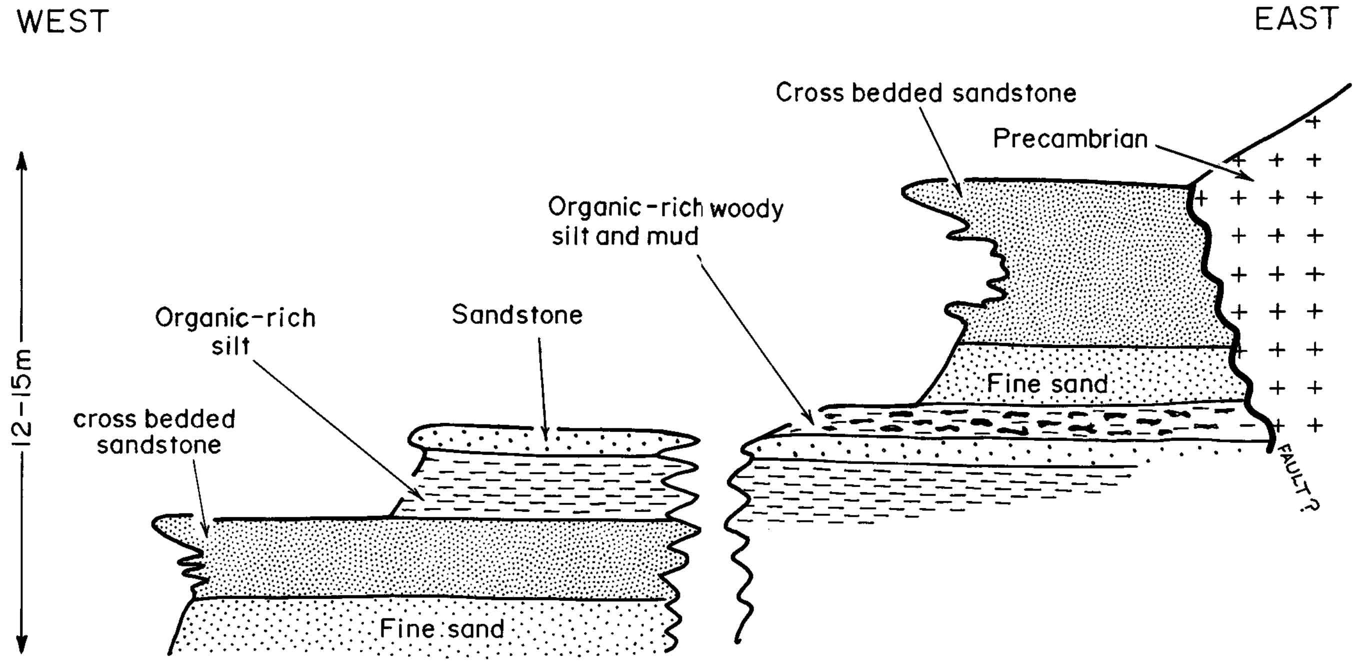


FIG. 5 STRATIGRAPHY OF THE MESOZOIC SEDIMENTS NEAR MT. BABBAGE

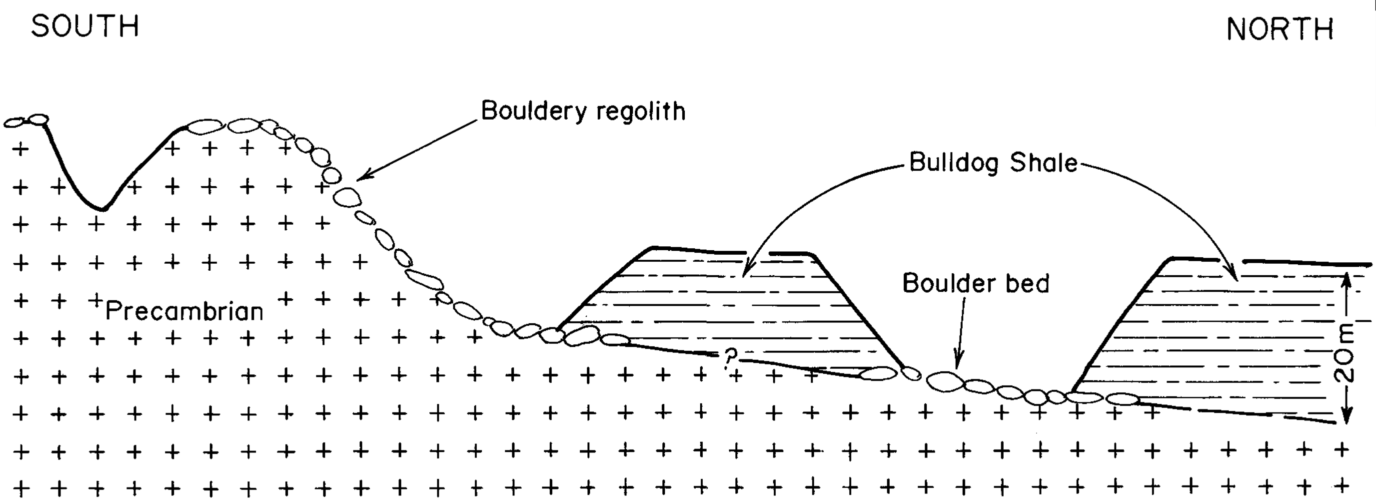
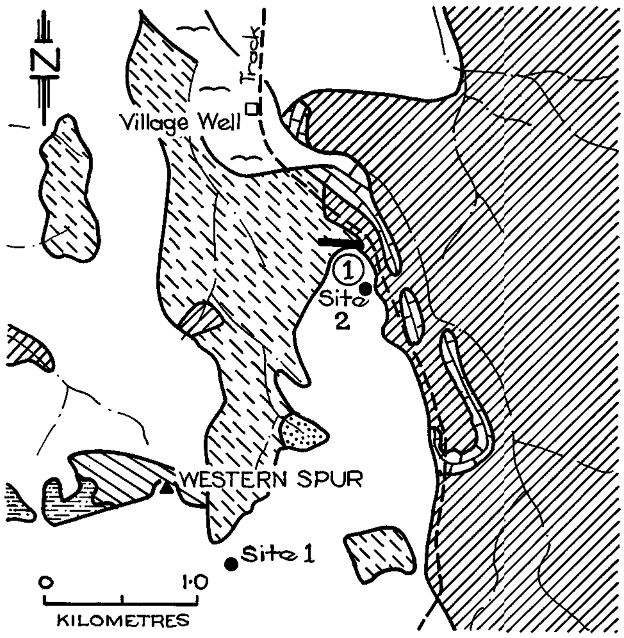


FIG. 6 GENERALISED STRATIGRAPHY AT MT. BABBAGE EAST

FIG. 5 & 6

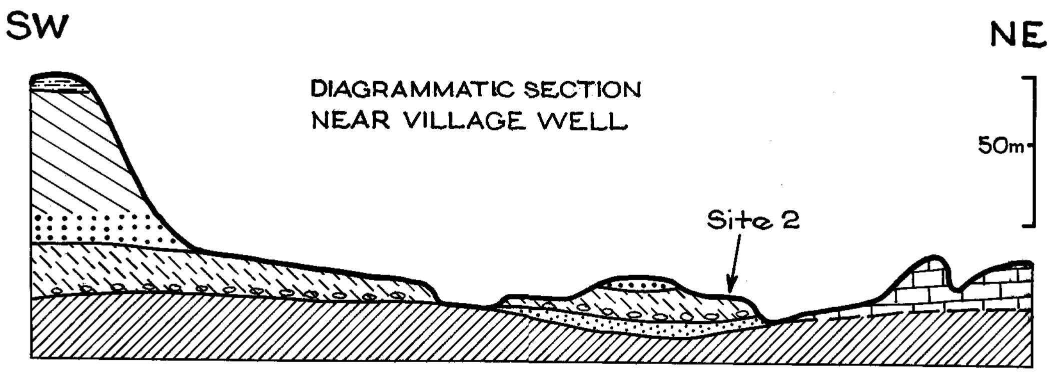
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED N. Alley	C.D.O. 24·3·87 DATE
PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN	DRAWN J.W.	SCALE
STRATIGRAPHY AT MT. BABBAGE	DATE / CHECKED	PLAN NUMBER S19122

4226



GEOLOGICAL SKETCH PLAN
- showing location of type-sections near Village Well.

① Village Well Formation (JKv) and Pelican Well Formation (Klp).



QUATERNARY
- Alluvium.
- Gravels.

TERTIARY
- Ts Silcrete.

CRETACEOUS
- Klm Marree Formation (Bulldog Shale).
- tw Trinity Well Sandstone (Mt. Anna Sandstone Member).

CRETACEOUS
- Klp Pelican Well Formation (Cadna-owie Formation).

? JURASSIC-CRETACEOUS
- JKv Village Well Formation (Algebuckina Sandstone).

PRECAMBRIAN
- Ew Wilpena Group: Quartzite, siltstone, marble.

NOTE: Modified from Forbes, 1982.

FIG. 8

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN

GENERAL GEOLOGY IN THE VILLAGE WELL AREA

COMPILED N. Alley	C.D.O.	DATE 24·3·87
DRAWN J.W	SCALE 1:50,000	
DATE 19-9-86	PLAN NUMBER	
CHECKED	S18931	

4226

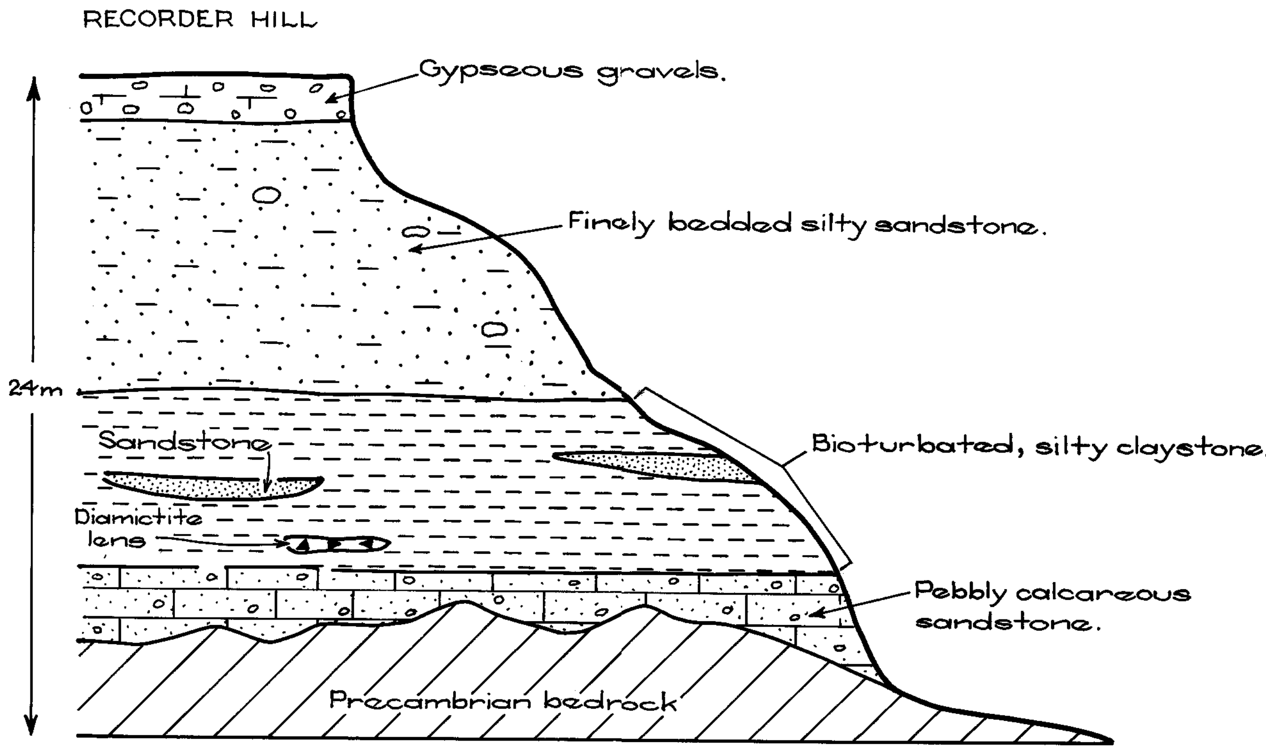


FIG. 9

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN
OF THE EROMANGA BASIN
STRATIGRAPHY OF THE MESOZOIC SEQUENCE
NEAR TRINITY WELL

COMPILED N. Alley	C.D.O. 24·3·87 DATE	
DRAWN J.W	SCALE	
DATE 19-9-86	PLAN NUMBER	
CHECKED	S18932	

4226

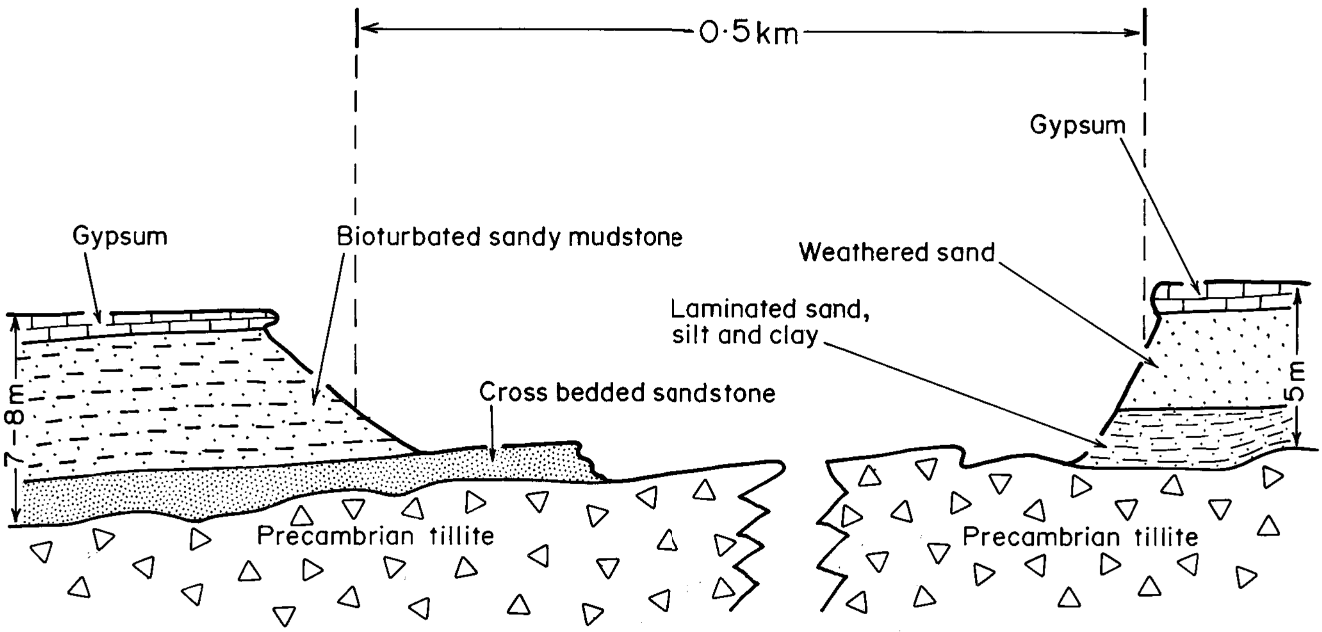


FIG. 10

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN

GENERALIZED STRATIGRAPHY OF THE MESOZOIC SEQUENCE NEAR CATTLE MOUND SPRINGS

COMPILED N. Alley	C.D.O.	DATE 24-3-87
DRAWN J.W.	SCALE	
DATE	PLAN NUMBER	
CHECKED	S19123	

4226

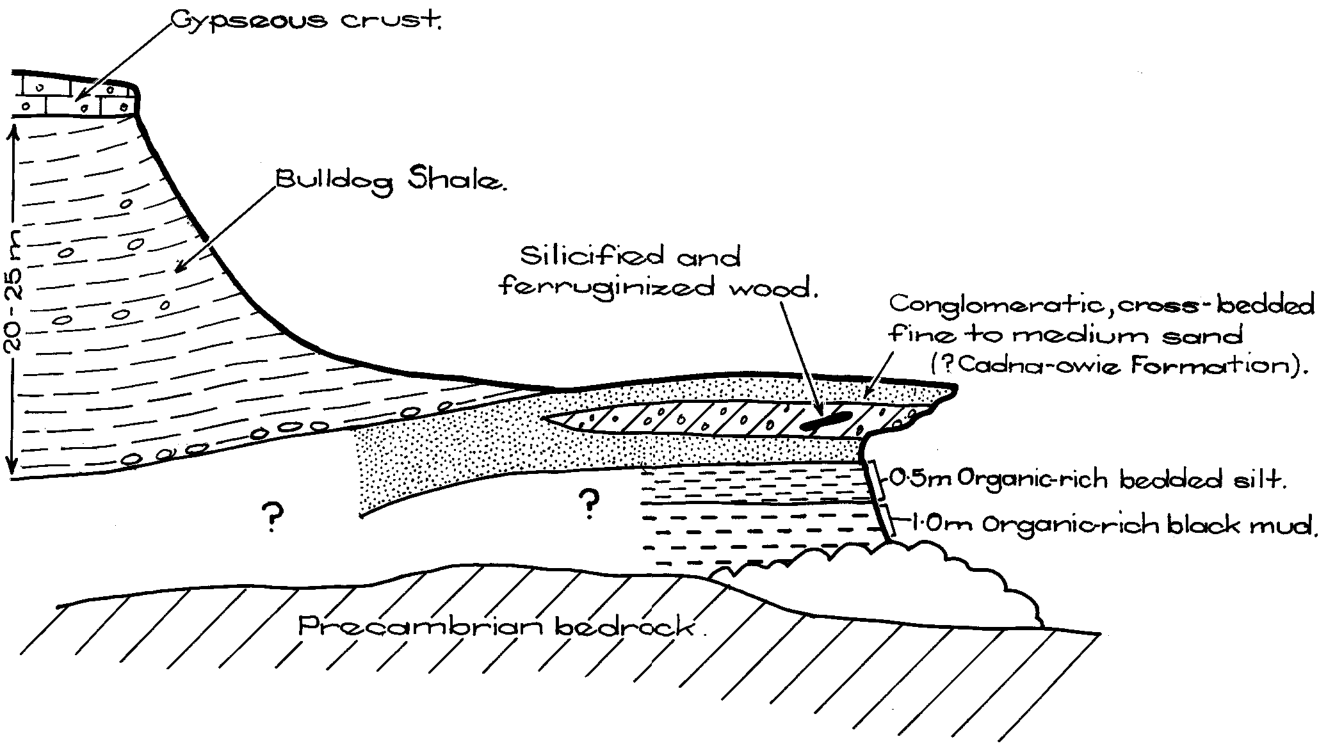


FIG. 11

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN OF THE EROMANGA BASIN

COMPOSITE OF THE STRATIGRAPHY OF THE MESOZOIC UNITS AT DAVENPORT SPRINGS

COMPILED N. Alley	C.D.O.	DATE 24·3·87	
DRAWN J.W.	SCALE		
DATE 19-9-86	PLAN NUMBER		
CHECKED	S18933		

4226

<table>
<tr><th>Stage</th><th colspan="2">Filatoff (1975)</th><th>Backhouse (1978)</th><th colspan="3">Price et al (1985)</th><th>Evans (1966a,b)</th><th>Dettmann & Playford (1969)</th></tr>
<tr><td rowspan="5">NEOCOMIAN
----?-- ?----
LATE JURASSIC</td><td rowspan="5"></td><td rowspan="5">Microcachryidites antarcticus Assemblage-zone</td><td rowspan="2">Biretisporites eneabbaensis Zone</td><td rowspan="2">PK1</td><td>PK1.2</td><td></td><td rowspan="2">K1a</td><td rowspan="2">Crybelosporites stylosus Zone
--- ? --- ? ---</td></tr>
<tr><td>PK1.1</td><td></td></tr>
<tr><td>Aequitriradites acusus Zone</td><td rowspan="3">PJ6</td><td rowspan="2">PJ6.2</td><td>PJ6.2.2.</td><td rowspan="3">J6</td><td rowspan="6"></td></tr>
<tr><td rowspan="2">Retitriletes watherooensis Zone</td><td>PJ6.2.1</td></tr>
<tr><td>PJ6.1</td><td></td></tr>
<tr><td rowspan="3">MIDDLE JURASSIC</td><td>Murospora florida Microflora</td><td rowspan="3">Callialasporites dampieri Assemblage-zone</td><td rowspan="3"></td><td colspan="3">PJ5</td><td rowspan="2">J4-5</td></tr>
<tr><td>Contignisporites cooksonii Oppel-zone</td><td colspan="3">PJ4</td></tr>
<tr><td>Klukisporites scaberis Oppel-zone</td><td colspan="3">PJ3</td><td>J3-4</td></tr>
</table>

FIG. 12

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PALYNOLOGICAL DATING, SOUTHERN MARGIN
OF THE EROMANGA BASIN

CORRELATION OF MIDDLE AND LATE JURASSIC
PALYNOLOGICAL ZONES IN AUSTRALIA

COMPILED N. Alley	C.D.O. DATE 24 · 3 · 87
DRAWN J.W.	SCALE
DATE 19-9-86	PLAN NUMBER S18934
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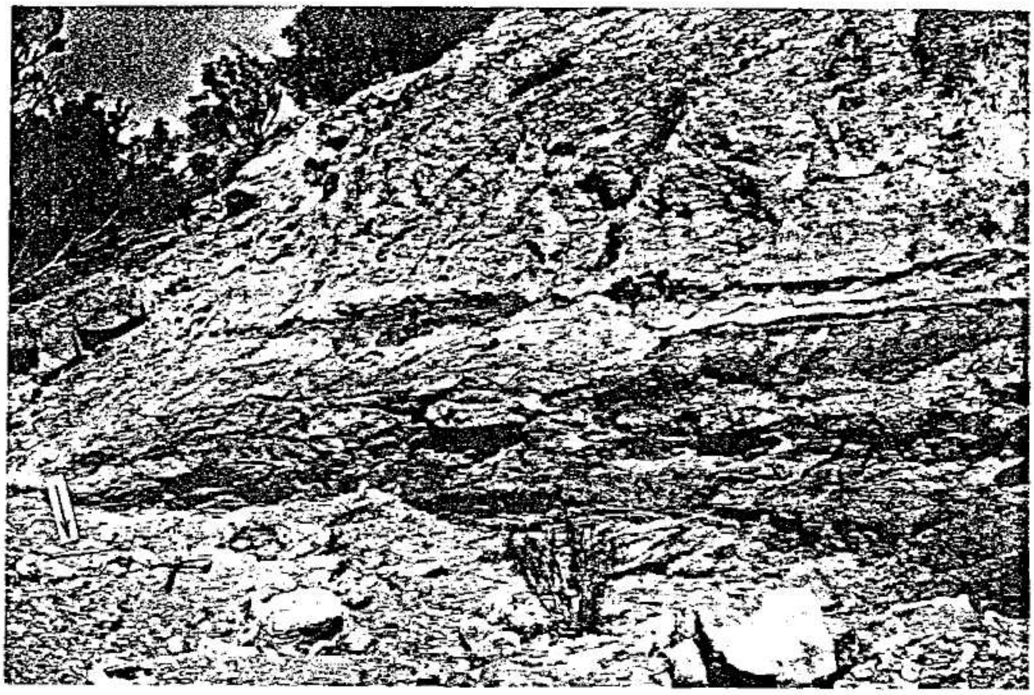

PLATE 1. Organic-rich shale with intercalations of gritty to gravelly clay lenses exposed near Moolawatana homestead. Spade handle (arrowed) for scale.

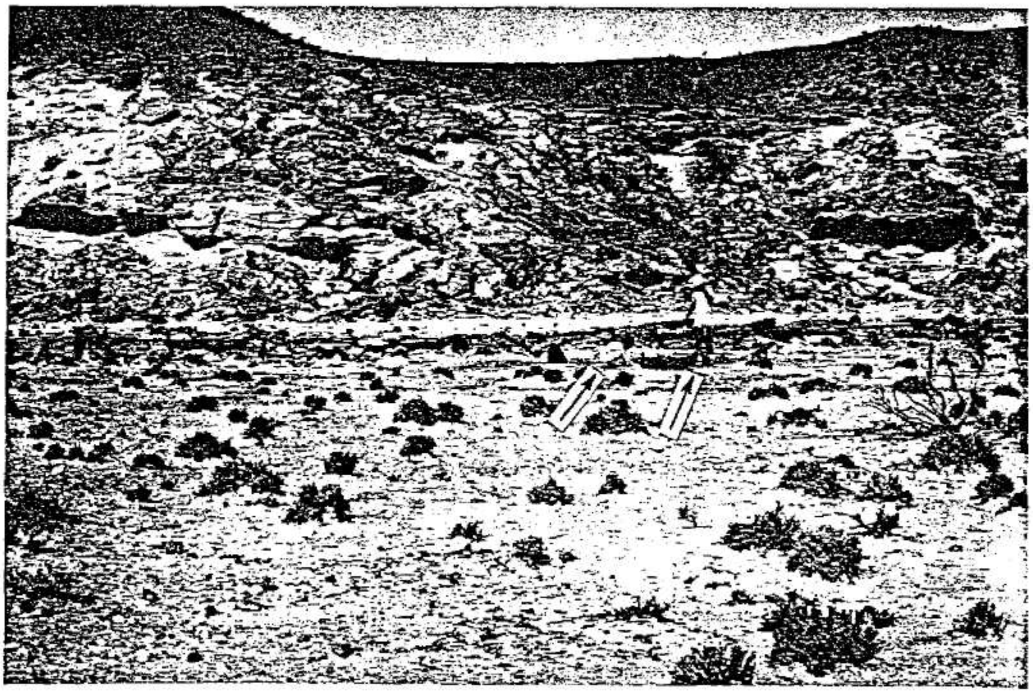

PLATE 2. Mesozoic sandstones and interbedded carbonaceous silts and clays in the lowland 2 km north of Mount Babbage (photo by J. Francis, University of Adelaide). Figures (arrowed) for scale.

PLATE 3. Thin silicified sandstone overlying bedrock on the mesa surface north of Mount Babbage. View looking northeast.

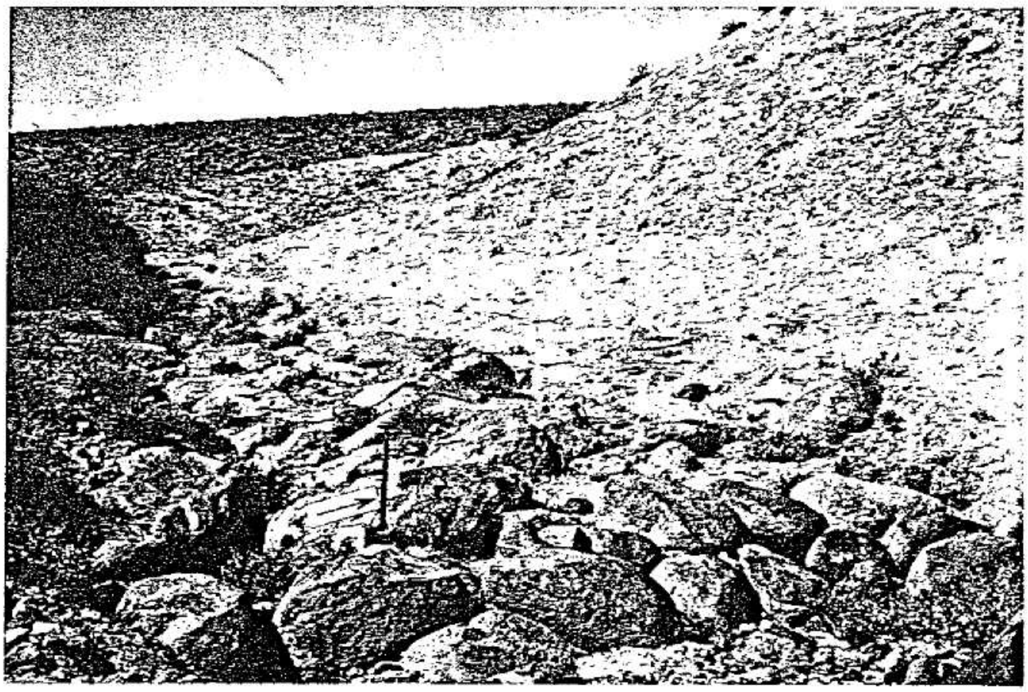

PLATE 4. Boulder bed overlying bedrock at the base of Bulldog Shale at Mount Babbage east site, on Moolawatana station track to Gunpowder Bore. Bulldog Shale on right; bedrock slope in background. Spade (arrowed) for scale.

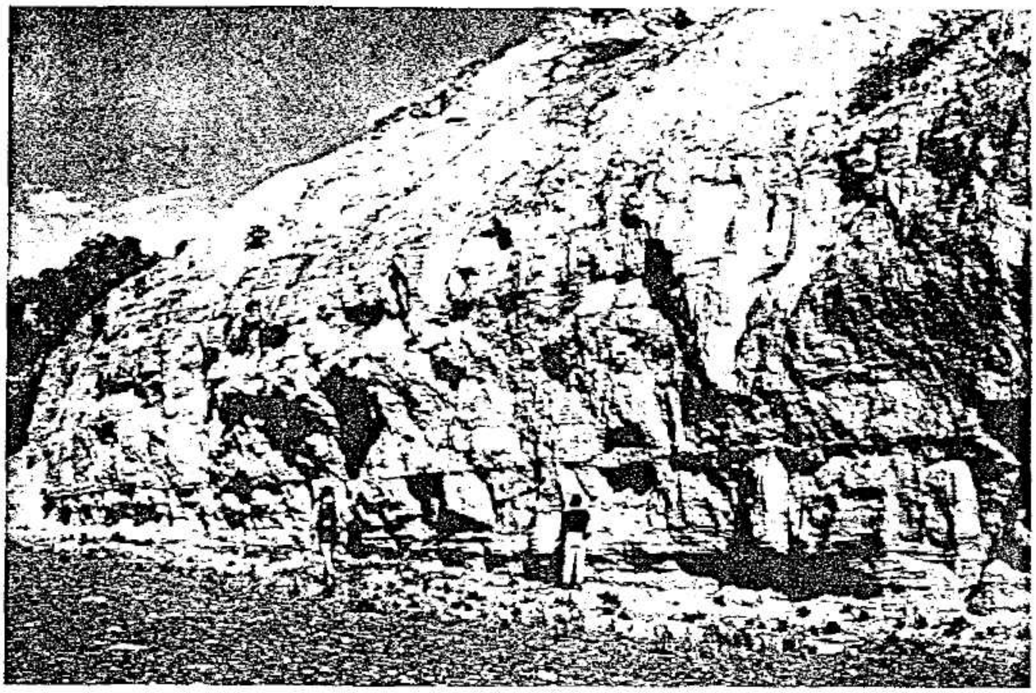

PLATE 5. Crossbedded sand unit at site 1 near Village Well.

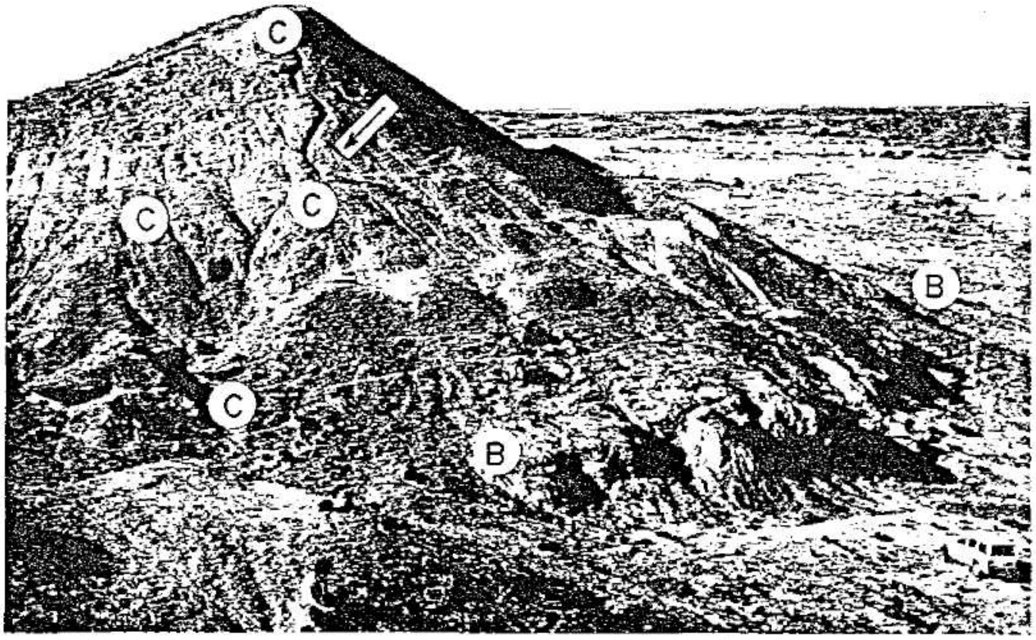

PLATE 6. Mesozoic sequence in the east-facing slope of "Recorder Hill". Two channels (C-C) cut down slope to expose relatively fresh sediment for study. Two figures (arrowed) and vehicle in bottom right corner for scale. Irregular terrain on lower right of slope is bedrock (B-B). View looking north.

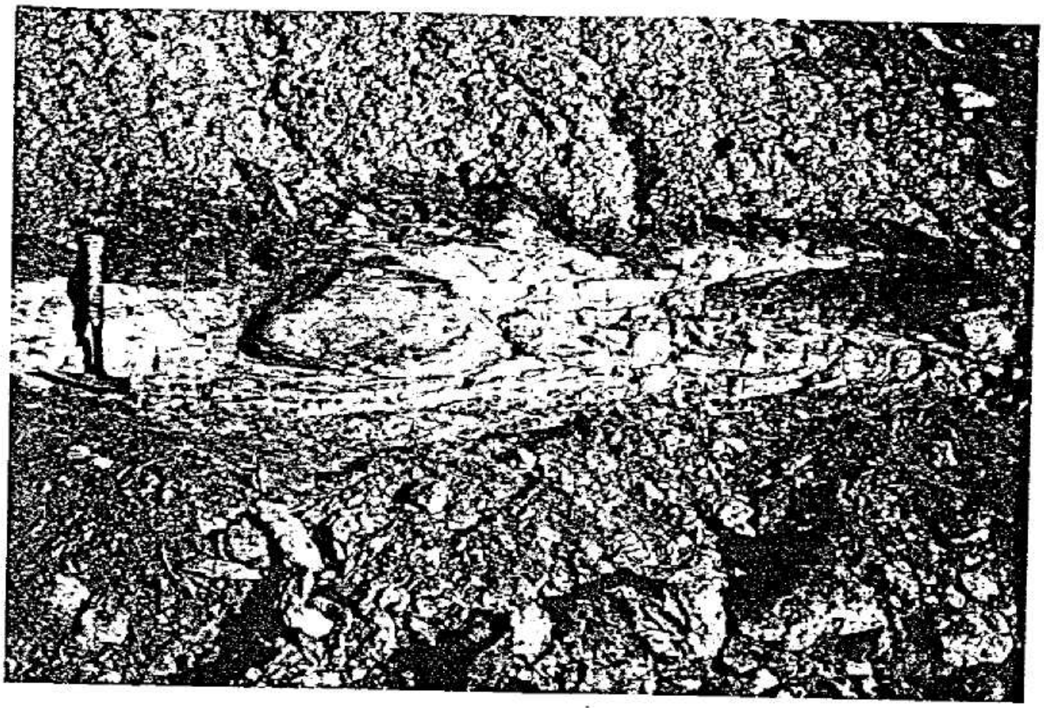

PLATE 7. Diamictite lens near the base of the Mesozoic sediments in "Recorder Hill".

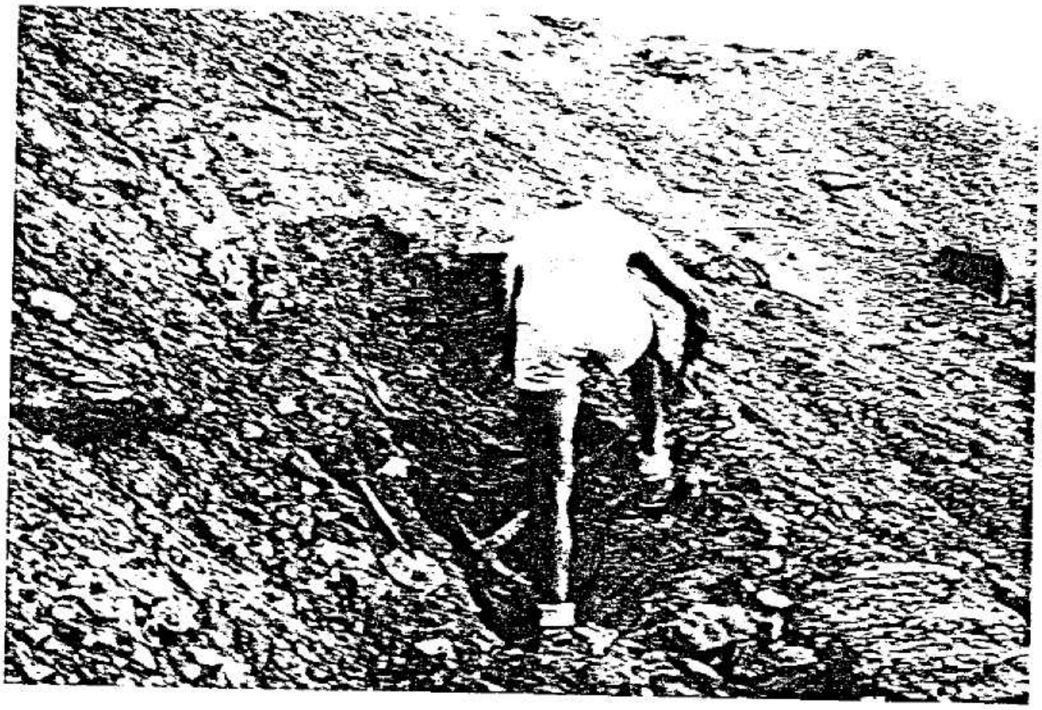

PLATE 8. Large hole excavated in "Recorder Hill" sediments to obtain samples suitable for palynological processing.