PALYNOLOGY OF DRILLHOLE ELLIOTT 1
(BEETALOO 1:100 000 SHEET; BEETALOO 1:250 000 SHEET) BEETALOO BASIN, NORTHERN TERRITORY, AUSTRALIA

by

Kathleen Grey
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Palynology of drillhole Elliott 1 (Beetaloo 1:100 000 Sheet; BEETALOO 1:250 000 Sheet), Beetaloo Basin, Northern Territory, Australia

Abstract

Samples from drillhole Elliott 1 (held in the NTGS core library in Darwin, Northern Territory) were collected by John Gorter on behalf of ENI and examined by Kathleen Grey as part of a reassessment of the hydrocarbon prospectivity of the Beetaloo Basin. Four palynological samples, one from the upper, two from the middle and one from the lower Kyalla Formation, were prepared using a modified preparation technique. Initial examination indicated abundant, diverse, extremely well-preserved palynomorphs but many of numerous new taxa could not be readily be assigned to existing species or precisely dated. Because of the difficulties presented by these previously undescribed taxa, slides were set aside until time was available for a more detailed examination. Further work has now been carried out, but it still has not been possible to do more than document some of the more common species. A more extensive study is needed to define the taxa present and document their stratigraphic distribution. The general aspect of the assemblage indicates a Mesoproterozoic age. More detailed analyses should provide a biostratigraphic scheme covering much of the Mesoproterozoic Beetaloo Basin succession. Such a scheme would have considerable potential for correlation of hydrocarbon exploration drillholes in the Beetaloo Basin.

Kathleen Grey
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Visiting Researcher, Uppsala University
Drillhole Specifications

COREDAT ID: 1908
Drill Hole / Well Name: Elliott 1
Tenement: EP33
Operator: Pacific Oil and Gas
Core Type: Petroleum Core
Location: Darwin
Hylogged: Yes
100K Name: Beetaloo
250K Name: BEETALOO
MGA94 Easting: 368248, MGA94 Northing: 8076997, UTM Zone: 53
Latitude: 17°23'20.00"S, Longitude: 133°45'35.01"E
Geological Region: McArthur Basin
Total depth: 1729.1 m

Locality details and sampling

Drillhole Elliott 1, a petroleum drillhole located on BEETALOO 1:250 000 sheet, was drilled by Pacific Oil and Gas in the southern Beetaloo Basin (Table 1), northwest of the Helen Springs High (Silverman et al., 2007). It reached TD at a depth of 1729.1 m in the Moroak Sandstone after penetrating the Kyala Formation, from which four palynological samples were collected by John Gorter on behalf of ENI (Fig. 1, Table 2). Samples were prepared using a modified preparation technique designed to extract large fragile specimens from Proterozoic samples (Grey, 1999) by Core Laboratories Australia Pty. Ltd, P.O Box 785, Cloverdale, WA, 6105, Australia, Email : corelab.australia@corelab.com.

The four samples examined are generally more poorly preserved and the biota is not as diverse as in samples from drillholes elsewhere in the Beetaloo Basin. Nevertheless, some well preserved taxa are present, and further systematic study is indicated. Some specimens are difficult to assign to species because of the scarcity of literature covering taxa of this age, and they may be new species. Preliminary results and illustrations of some of the better preserved specimens are given below.
Table 1. Drillhole location

<table>
<thead>
<tr>
<th>Drillhole</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliott 1</td>
<td>17°23′20.00″S</td>
<td>133°45′35.01″E</td>
</tr>
</tbody>
</table>

Report

Palynomorphs are present in the Kyalla Formation in Elliott 1, but are not as well preserved or abundant as in other drillholes in the basin. The sample from the upper Kyalla Formation (710.95 m) is better preserved than two from the middle of the formation (925 m and 1051.5 m). A sample from the lower part of the formation (1275 m) is poorly preserved and contains very few identifiable specimens. Samples from the middle and lower part of the formation contain abundant amorphogen ('fluffy kerogen') consistent with oil generation. Details of species present are given in Appendix 1 and taxonomic details in Appendix 2. Selected specimens are illustrated in Figures 2A-K and 3A-K.

Problems with sample preparation have hindered identification and results could be considerably improved if more attention was paid to laboratory work. Standard palynological methods often do not produce good results for Proterozoic material. Preparation methods that reduce the stages of processing and eliminate vigorous methods, which tend to fragment large specimens, generally give better results (Grey, 1999). Although Grey’s methods were supposedly applied here, not enough care was taken with preparation. A high proportion of fluorides is present, indicating insufficient treatment with boiling hydrochloric acid. Samples were inadequately filtered, so even coarse fractions contain large amounts of fine debris, resulting in flocculation and the formation of ‘Vanavarataenia’ (an artifact formed by fine particle aggregation, sometimes incorrectly identified as a palynomorphs). Specimen density is too high in most slides, hampering identification and specimens are obscured by fine debris. Some slides were overheated, browning the mounting medium, affecting specimen colour, and cracking both the medium and contained specimens. Contamination is common, and includes modern pollen grains and a fungi that grows in out-of-date polyvinyl alcohol, a dispersing agent used to spread the macerate evenly on slides (Fig. 3K).

Generally, samples contain few identifiable palynomorphs, although poorly preserved filaments and spheres (not identifiable) are present in most slides. Finely disseminated organic particles and large
amorphous organic fragments, both probably derived from degraded bacterial mat, are abundant. Pyrite grains are common. Amorphogen is abundant in the lower samples. Degraded filaments and sheaths, probably representing more than one species of *Clavitrichoides* sp., are common (Figs 2A-E), together with various specimens of *Siphonophycus* spp. (Fig. 2F). There are also several clusters of spheres (Figs 2G-K), including *Synsphaeridium* sp. (Fig. 2H), as well as others linked in chains (Figs 2I-K). A few, poorly preserved, small, structured coenobial clusters of the type normally assigned to *Symplassosphaeridium* are present, but not as abundant as in samples previously examined from the Chambers River and Velkerri Formations.

Among identifiable taxa are numerous leiospheres, such as *Leiosphaeridia crassa*, *Leiosphaeridia jacutica*, *Leiosphaeridia minutissima* and *Leiosphaeridia tenuissima* (Figs 3A-D). The large, wrinkled-walled acritarch, *Chuaria* cf. *circularis* is present in small numbers (Figs 3E,F). One poorly preserved fragment with faint parallel ridges is tentatively identified as *Valeria lophostriata*, a form common in Mesoproterozoic successions and which may range up to the early Neoproterozoic (Fig. 3G). A possible new species, with irregular thick ridges (Figs 3H-J) was observed in several slides.

The assemblage has some elements seen in other Beetaloo Basin drill cores, but lacks the abundant small coenobial aggregates common in the older Chambers River Formation and Velkerri Formation, although some are present. It is consistent with microfossils first described from the Roper Group by Peat et al. (1978) from the McMinn Formation but so far, no specimens of the large, process-bearing *Tappania plana* or associated forms, previously recorded by Javaux et al. (2001) from the underlying Corcoran, Jalboi and Mainoru Formations, have been observed. It has a few elements of the 1270±4 to c. 850 Ma Bylot Supergroup of Arctic Canada (Hofmann and Jackson, 1994, Knoll et al., 2013) and a few taxa similar to ones reported from younger Mesoproterozoic stratigraphic units such as the c. 1000 Ma Lakhanda Formation and late Mesoproterozoic Miroyedikha Formations of Siberia (Jankauskas et al., 1989; Bartley et al., 2001).

The thermal alteration index of organic material (TAI), based on well-established Phanerozoic measurements of organic maturity (Batten, 1996; Traverse, 2007), indicates that organic matter in the Kyala Formation has reached a level of 3+ (and 4 in the the lowest sample), so the middle and upper parts of the formation lie close to the boundary between oil and gas generation and the lower Kyalla Formation is overmature for both. These results may be slightly inconsistent with Rock-Eval pyrolysis and vitrinite reflectance studies (Warren et al., 1998). TAI is determined from pre-oxidation macerate slides.
Determinations are currently based on spore colouration, which is a rough guide only, partly because acritarchs biopolymers have a slightly different chemical composition to sporopollenin, and partly because Precambrian organic material has not so far been adequately calibrated with Phanerozoic material, or with burial history. Kerogen colour in Precambrian rocks has more to do with depth of burial, tectonic stress, or heating by thermal fluids than it does to age or redox values (Schiffbauer et al., 2012), and follows similar pathways to those observed in Phanerozoic successions (Batten, 1996; Traverse, 2007).

This preliminary study shows that a moderately preserved palynological assemblage is present in parts of the Kyalla Formation. Although more poorly preserved than assemblages in other drillholes in the Beetaloo basin, it has potential for biostratigraphic correlation. More detailed analysis, including systematic studies and the description of potentially new species, is required. Palynology could also assist in determining both sedimentary facies and organic facies and shed further light on the thermal maturity of Mesoproterozoic strata within the basin.

Summary of samples

Figure 1. Samples and lithology

Drillhole: Elliott 1

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Depth (m)</th>
<th>No of slides</th>
<th>Type</th>
<th>Formation</th>
<th>Lithology hand specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>12970</td>
<td>710.95</td>
<td>5</td>
<td>core</td>
<td>upper Kyalla Formation</td>
<td>fine-grained argillite</td>
</tr>
<tr>
<td>12976</td>
<td>925</td>
<td>5</td>
<td>core</td>
<td>middle Kyalla Formation</td>
<td>fine-grained argillite</td>
</tr>
<tr>
<td>12977</td>
<td>1051.5</td>
<td>5</td>
<td>core</td>
<td></td>
<td>fine-grained argillite</td>
</tr>
<tr>
<td>12982</td>
<td>1275</td>
<td>5</td>
<td>core</td>
<td>lower Kyalla Formation</td>
<td>interbedded arenite and argillite</td>
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</tbody>
</table>
Table 2. Summary of palynology

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Palynomorphs</th>
<th>Preservation</th>
<th>TAI*</th>
<th>Probable stratigraphic age</th>
</tr>
</thead>
<tbody>
<tr>
<td>710.95</td>
<td><em>Chuaria</em> cf. <em>circularis</em> Clavitrichoides sp.</td>
<td>moderate</td>
<td>3+</td>
<td>Mesoproterozoic</td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia crassa</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia jacutica</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia minutissima</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia tenuissima</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Siphonophycus robustum</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Siphonophycus</em> spp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Synsphaeridium</em> sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>linked chains</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>925 m</td>
<td><em>Chuaria</em> cf. <em>circularis</em> Clavitrichoides sp.</td>
<td>moderate</td>
<td>3+</td>
<td>Mesoproterozoic</td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia crassa</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia jacutica</em></td>
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<tr>
<td></td>
<td><em>Leiosphaeridia minutissima</em></td>
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</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia tenuissima</em></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td><em>Siphonophycus</em> spp.</td>
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<td></td>
</tr>
<tr>
<td></td>
<td><em>Synsphaeridium</em> sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>?<em>Valeria lophostriata</em> Acritarch with ridged ornament</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>linked chains</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1051.5 m</td>
<td><em>Leiosphaeridia minutissima</em></td>
<td>moderate</td>
<td>3+</td>
<td>Mesoproterozoic</td>
</tr>
<tr>
<td></td>
<td><em>linked chain</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>poorly preserved spheres</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1275 m</td>
<td><em>Chuaria</em> cf. <em>circularis</em> Clavitrichoides sp.</td>
<td>moderate</td>
<td>3+</td>
<td>Mesoproterozoic</td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia crassa</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Leiosphaeridia minutissima</em></td>
<td></td>
<td></td>
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</tbody>
</table>

Conclusions

Palynomorphs, comprising acritarchs, cyanobacteria, filaments and problematic forms are present, but only occasionally well preserved, in the Kyalla Formation in Elliott 1. The degraded nature of the assemblage seems to result from the formation of amorphogen (‘fluffy kerogen’), which indicates that the rocks are close to maturity for the oil or gas window. Despite the poor preservation, sufficient information
is available to indicate that palynomorphs from the Kyalla Formation have correlation potential for the upper Roper Group. It is difficult to determine the stratigraphic age at present, other than to suggest that the assemblage has a Mesoproterozoic aspect. Many of the taxa require description and categorization before a zonal scheme can be proposed.

**Recommendations for further work**

Although poorly preserved, Kyalla Formation samples from Elliott 1 indicate that the formation contains palynomorphs suitable for use in biostratigraphic correlation. Moreover, the underlying Moroak Sandstone, known to have high yields of palynomorphs elsewhere in the basin, was not sampled for this study. It is strongly recommended that further palynological analysis be undertaken on Elliott 1 and other selected Beetaloo Basin drillholes. Additional sampling from this drillhole is indicated. Sample preparation requires attention, especially in filtering and mounting samples. The present specimen density is so high it hinders identification.

There is potential for the development of a correlation scheme that would have application both for the hydrocarbon-prone Beetaloo Basin, as well as globally. Additional study is also needed to calibrate the thermal alteration index as determined from the colour of organic matter in Proterozoic sediments with maturity determined from vitrinite reflectance and Rock-Eval pyrolysis. TAI has the potential to be a valuable indicator of thermal gradient, especially at early stages of analysis, but requires standardization before it can be used with confidence. Further palynological studies would be a suitable project for a PhD or post-doctoral student.

**References**


Appendix 1: Log details for individual samples

710.90 m upper Kyalla Formation

Preservation is poor and organic matter consists of abundant finely disseminated organic particles, large, amorphous organic particles, probably of degraded bacterial mat, and fragments of degraded spheres of uncertain affinity. There are very few identifiable palynomorphs apart from rare Leiosphaeridia crassa. Large, badly fragmented spheres of ?Chuaria cf. circularis, seen in the kerogen slide, were not observed in the oxidized fractions. The sample does not contain anything that is diagnostic. Mineral grains, probably pyrite, are common in the kerogen mount and there is evidence of surface corrosion by pyrite framboids. Fluorides formed during preparation obscure much of the material and longer boiling with hydrochloric acid and more thorough sieving is needed to eliminate fine particles in coarse fractions. Material should be less densely mounted.

Taxa present include: ?Chuaria cf. circularis; Leiosphaeridia crassa; Leiosphaeridia jacutica; Leiosphaeridia minutissima; Leiosphaeridia tenuissima; Synsphaeridium sp.; acritarch with ridged ornament; rare, linked chains of cells, some with a terminal cell; rare, poorly preserved filaments, including Siphonophycus spp.; filament sheaths (Clavitrichoides spp.);

Zone Indeterminate
Probable age Mesoproterozoic

925.00 m middle Kyalla Formation

Abundant palynomorphs are present but preservation is only moderate and none are immediately diagnostic. Many specimens show surface corrosion from pyrite framboids. Amorphous organic material is prolific and is probably derived from degraded bacterial mat. Slides have been overheated and the mounting medium has cracked.

Taxa present include: ?Chuaria cf. circularis; Leiosphaeridia crassa; Leiosphaeridia jacutica; Leiosphaeridia minutissima; Leiosphaeridia tenuissima; Synsphaeridium sp.; a poorly preserved fragment that may have concentric thickenings and is tentatively placed in ?Valeria lophostriata; acritarch with ridged ornament; rare, linked chains of cells, some with a terminal cell; rare, poorly preserved, coenobial aggregates; rare,
poorly preserved filaments, including *Siphonophycus robustum* and *Siphonophycus* spp.; and filament sheaths (\(^?\) *Clavitrichoides* spp.).

**Zone** Indeterminate
**Probable age** Mesoproterozoic

### 1051.5 m middle Kyalla Formation

The sample is contaminated by a fungal growth typically found in out-of-date polyvinyl alcohol, a dispersing agent. The contaminant consists of chains of small cells and because of overheating these chains are sometimes darker than their natural colour and resemble the colour of the autochthonous organic material. There are also pollen grain contaminants, mineral grains, including pyrite, and abundant fluorides. Preservation is poor and organic matter consists of abundant fragments of degraded bacterial mat and rare spheres. There are very few identifiable palynomorphs apart from *Leiosphaeridia minutissima*, a few poorly preserved filaments and a linked chain of slightly elongate spheres, which is broken and degraded. There is nothing immediately diagnostic. Much of the sample consists of amorphogen ('fluffy kerogen').

**Zone** Indeterminate
**Probable age** Mesoproterozoic

### 1275 m lower Kyalla Formation

Preparation is again poor with abundant fluoride crystals and overheating that has caused the fine particle material to crack into a mosaic as well as cracking several large acritarchs. The hotplate temperature was too high, and this in turn means the colour of the kerogen slide is unreliable. Preservation is poor and organic matter consists of abundant finely disseminated organic matter and fragments of degraded spheres. There are very few identifiable palynomorphs apart from rare *Leiosphaeridia crassa* and *Leiosphaeridia minutissima* and a couple of large, badly fragmented spheres of \(^?\) *Chuaria* cf. *circularis*, which are present in the kerogen slide, but not observed in the oxidized fractions. The sample does not contain anything that is diagnostic.
Appendix 2  List of Taxa

Chuaria cf. circularis Walcott 1899; emend. Vidal & Ford 1985
Clavitrichoides Mikhailova in Jankauskas et al. 1989
Leiosphaeridia jacutica (Timofeev 1966) Mikhailova and Jankauskas 1989 in Jankauskas et al., 1989
Leiosphaeridia tenuissima Eisenack 1958
Siphonophycus robustum (Schopf 1968) emend. Knoll, Swett and Mark 1991
Symplassosphaeridium Timofeev 1959 ex Timofeev 1969
Synsphaeridium Eisenack 1965
Tappania plana Yin L 1997
Valeria lophostriata (Jankauskas, 1979) Jankauskas, 1982

Figure 3. (p. 12). Selected palynomorphs from the Kyalla Formation in Elliott 1. A-E, sheaths; A, Clavitrichoides sp. 925 m/3, 55R0. B, Clavitrichoides sp. with tapered end, 710.95 m/3, 71J0. C, irregular sheath, 710.95 m/3, 37E2. D, Clavitrichoides sp. with bulbous end, 925 m/2, 46Q0. E, sheath with terminal cell, 710.95 m/3, outside grid. F, Siphonophycus robustum, 925 m/3, 65D_outside grid. G, small, poorly preserved cluster, 925 m/2, 56R0. H, Synsphaeridium sp., 710.95 m/3, outside grid. I, chain of three cells, 710.95/3, outside grid. J, linked chain of cells, 1051.5 m/1, F720. K, linked chain of cells, 710.95 m/3, 36V0. England Finder co-ordinates are given for each specimen. Scale bar is 20 µm.
Figure 2
Figure 3. Selected palynomorphs from the Kyalla Formation in Elliott 1. A-D, leiospheres. A, *Leiosphaeridia jacutica*, 925 m/3, 70J0. B, *Leiosphaeridia minutissima*, 925 m/3, 72L0. C-D, *Leiosphaeridia tenuissima*; C, 710.95 m/2, 62V0; D, 710.95 m/3, 62V0. E-F, *Chuaria* cf. *circularis*; E, 710.95 m/3, 34S3; F, 48M3. G, *?Valeria lophostriata*, fragment, poorly preserved, detail of ornament, 925 m/2, 67W3. H-J, acritarch with ridges; H, 710.95 m/3, outside grid. I; 710.95 m/3, 66R0. J, 710.95 m/3, 50U3. K, fungal contaminant from polyvinyl alcohol, 1051/1, F720. England Finder co-ordinates are given for each specimen. Scale bar is 20 µm.