Kathleen Grey

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PALYNOLOGY OF DRILLHOLE ALTREE 2 (MARYFIELD 1:100 000 sheet; HODGSON DOWNS 1:250 000 sheet) BEETALOO BASIN, NORTHERN TERRITORY, AUSTRALIA

by

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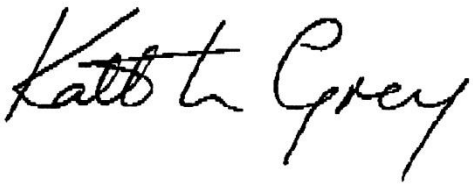
Abstract

Samples from drillhole Altree 2 (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. Nine palynological samples were prepared using a modified preparation technique. Initial examination of the prepared slides indicated abundant assemblages of numerous new taxa that could not be readily be assigned to existing species or precisely dated. Because of the difficulties presented by these previously undescribed assemblages, the 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.



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Drillhole Specifications

COREDAT ID: 1825
Drill Hole / Well Name: Altree 2
Tenement: EP24
Operator: Pacific Oil and Gas
Core Type: Petroleum Core
Location: Darwin
Hylogged: Yes
100K Name: Maryfield
250K Name: HODGSON DOWNS
MGA94 Easting: 370118 MGA94 Northing: 8239133 UTM Zone: 53
Latitude: 15°55'25.13"S, Longitude: 133°47'11.73"E
Geological Region: McArthur Basin
Total depth: 1699.85 m

Locality details and sampling

Drillhole Altree 2, a petroleum drillhole located on HODGSON DOWNS 1:250 000 sheet (Table 1), was drilled by Pacific Oil and Gas on the Walton High on the northern margin of the Beetaloo Basin (Silverman et al., 2007). It reached TD at a depth of 1699.85 m in dolerite below the Corcoran Formation and penetrated the Mesoproterozoic Velkerri Formation of the Roper Group, a mid-Proterozoic potential oil source in northern Australia in the Beetaloo Basin (Jackson et al, 1988; Jackson, and Raiswell, 1991; Silverman et al., 2007; Dutkiewicz et al., 2007), from which the samples were taken (Fig. 1, Table 2). Nine palynological 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, Petroleum Services Division, P.O Box 785, Cloverdale, WA, 6105, Australia, Email : corelab.australia@corelab.com.

The uppermost samples contain a rich assemblage of acritarchs, although many are difficult to identify because of the scarcity of literature covering taxa of this age. The lower samples contain amorphogen (‘fluffy kerogen’) indicating degeneration of fossil organisms probably as a result of hydrocarbon generation. Preliminary results and illustrations of some of the better preserved specimens are given below.

Table 1. Drillhole location

Drillhole	Latitude	Longitude
Altree 2	15°55'25.13"S	**133°47'11.73"E**

Report

Palynomorphs are abundant in parts of the Velkerri Formation but are poorly preserved in the middle and lower part of the formation. Details of distributions in individual samples are given in Appendix 1 and taxonomic details in Appendix 2. Selected specimens are illustrated in Figures 2 and 3.

The upper Velkerri Formation (at 497.5 m and 610.0 m) contains abundant, well preserved palynomorphs (Fig. 2A-S) Degraded filaments are common (Fig, 2A), as are spherical forms, which are mostly simple leiospheres (Fig. 2B-F). However, the assemblage also contains an abundance of various cell clusters and some 'problematic' forms, as well as rare, process-bearing taxa (Fig. 2G) and amorphous fragments of kerogen (probably degraded bacterial mat and fragments of acritarchs). The high percentage of filaments indicates shallow-water, near shore deposition.

The rich upper Velkerri Formation assemblage has not been fully documented because speciation must await detailed systematic studies. It is dominated by hundreds of small cellular clusters (coenobial aggregates). These are generally regarded as cellular colonies that contain a fixed number of cells, with little or no specialization, and are typical of algae. For the purposes of this report, they are tentatively assigned to *Myxococcoides* spp., a genus common in the Mesoproterozoic and Neoproterozoic, where the cell numbers appear irregular and the structure is disorganized (Figs 2H-K), or to *Symplassosphaeridium* (Figs 2L-Q), a taxon common in 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), where cells appear to show some consistency of numbers and organization into a sphere. Fewer, larger, associated cells are assigned to *Synsphaeridium* sp. (Figs 2R, S). The assemblage is consistent with microfossils first described from the upper Roper Group by Peat et al. (1978) from the then McMinn Formation. The assemblage is similar, but not identical, to one in the 1200 to 1300 Ma Bylot Supergroup of Arctic Canada (Hofmann and Jackson, 1994). So far, no specimens of the large, process-bearing *Tappania plana*, previously recorded by Javaux et al. (2001) from the underlying Corcoran, Jalboi and Mainoru Formations, have been observed.

The remainder of the samples, from the middle and lower Velkerri Formation, contain few palynomorphs but are dominated by abundant amorphogen (‘fluffy kerogen’) (Figs 3A-C), a feature consistent with hydrocarbon generation (Bechstädt et al., 2009). The middle Velkerri Formation consists almost entirely of 'amorphous kerogen' and does not contain identifiable palynomorphs.

Organic matter in the lower Velkerri Formation is poorly preserved (Figs 3D-F). In the upper samples, it consists mostly of amorphous kerogen and lacks identifiable palynomorphs. Amorphous kerogen is common in the lower samples, but a few, rare, poorly preserved palynomorphs are present. They consist mainly of leiospheres.

The poor preservation and sparsity of identifiable specimens in the middle and lower Velkerri Formation precludes an assessment of age and water depths based on the palynological assemblage. Better prepared samples could allow a more thorough assessment.

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 has reached a level of at least 3+ in the Kyalla Formation (so it probably lies close to the boundary between oil and gas generation), whereas that in Velkerri Formation is higher, and is 4+. This is over mature for the oil window. 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. Further work is required to determine how Mesoproterozoic acritarch colour varies with thermal gradient and hydrocarbon maturation.

This preliminary study has shown that palynological information has considerable potential for biostratigraphic correlation in the Beetaloo Basin, but much 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: Altree 2

ENI sample no.	Depth (m)	No of slides	Type	Formation	Lithology hand specimen
13045	497.5	5	core	upper Velkerri Formation	fine-grained argillite-claystone
13050	610	5	core		fine-grained argillite
13051	695.35	5	core	middle Velkerri Formation	fine-grained, dark argillite
13502	700.45	5	core		fine-grained, dark argillite
13508	824.2	5	core		fine-grained, dark argillite
13059	876.25	5	core		fine-grained, dark argillite
13060	924.9	5	core		fine-grained, dark argillite
13061	999.8	5	core	lower Velkerri Formation	fine-grained argillite-claystone
13064	1200.9	5	core		fine-grained argillite

Table 2. Summary of palynology

Depth (m)	Palynomorphs	Preservation	TAI*	Probable stratigraphic age
497.5	*Chuaria* cf. *circularis* *Leiosphaeridia jacutica* *Leiosphaeridia minutissima* *Myxococcoides* spp. ?*Symplassosphaeridium* spp. *Synsphaeridium* spp.	excellent	3+	Mesoproterozoic
610	*Leiosphaeridia crassa* *Leiosphaeridia jacutica* *Leiosphaeridia minutissima* *Leiosphaeridia tenuissima* *Synsphaeridium* sp. *Symplassosphaeridium* spp. *Siphonophycus typicum*	excellent	4	Mesoproterozoic
695.35	amorphogen	barren	4+	Mesoproterozoic
700.45	amorphogen	barren	4+	Mesoproterozoic
824.2	amorphogen	barren	4+	Mesoproterozoic
876.25	amorphogen	barren	4	Mesoproterozoic
924.9	amorphogen	barren	4	Mesoproterozoic
999.8	amorphogen	barren	4+	Mesoproterozoic
1200.9	amorphogen	barren	4+	Mesoproterozoic

Conclusions

Preservation of palynomorphs, consisting of acritarchs, cyanobacteria, filaments and several problematic forms is excellent in parts of the Velkerri Formation and the assemblages have good potential for stratigraphic correlation. In particular, a rich assemblage is present in the upper Velkerri Formation. Preservation is much poorer in the middle and lower parts of the formation, but the abundance of amorphogen is consistent with the generation of hydrocarbon at this level. 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

Given the excellent preservation, abundance of previously undescribed taxa and high potential for biostratigraphic correlation, it is strongly recommended that further palynological analysis be undertaken on Altree 2 and other selected drillholes from the Beetaloo Basin. Care must be taken in filtering and mounting samples because the present specimen density is generally too high and this reduces the chances of identification. Further palynological studies would be a suitable project for a PhD or post-doctoral student. Systematic studies should be published as a monograph. 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.

From preliminary work, the ratio of filaments to acritarchs in some samples could be useful in indicating the distance from shore throughout the succession, but further study is needed to confirm this. Additional studies are 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.

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Appendix 1: Log details for individual samples

497.5 m Upper Velkerri Formation

The kerogen and finer filtered mounts contain abundant finely disseminated organic particles, which in some cases obscure specimens because the preparations have not been adequately filtered and the slides have been mounted too densely. Mineral grains, probably pyrite, are common in the kerogen mount. Large, amorphous organic particles, probably of degraded bacterial mat, are common. Numerous degraded spheres of uncertain affinities are common. Many specimens are broken or show the effects of surface corrosion as a result of pyrite framboid formation.

The sample contains abundant, well preserved palynomorphs, many apparently of new species or difficult to assign to known taxa. Spheroidal clusters are abundant and are tentatively assigned to *Symplassosphaeridium*. Several species may be present, but statistical analysis of size and numbers of individual spheres in each cluster will be required to determine this with certainty. There are also dense clusters of small spheres that are too poorly preserved to identify or characterize properly. They are too dark to photograph, and seem to have triangular lumen surrounded by thickened walls. Clusters of larger spheres are also present and are here assigned to *Synsphaeridium* sp., a long ranging taxon, although it is not certain that the forms present here are identical to forms recorded in the Neoproterozoic. Filamentous microfossils, including numerous specimens of *Siphonophycus* spp. are present.

Taxa identified include: *Chuaria* cf. *circularis, Leiosphaeridia jacutica, Leiosphaeridia minutissima, Myxococcoides* spp., ?*Symplassosphaeridium* spp., *Synsphaeridium* spp., *Siphonophycus typicum*, *Siphonophycus* spp.

Zone	Indeterminate
Probable age	Mesoproterozoic

610.0 m Upper Velkerri Formation

Abundant finely disseminated organic particles are present, and in some slides inadequate filtering has resulted specimens being obscured by fine particles. The slides are generally too densely mounted and need to be re-filtered and mounted more sparsely to allow more detailed analysis. Mineral grains are present but not abundant in the kerogen mount. Numerous palynomorphs are present. Some are well preserved, but preservation is variable and generally poor. Many specimens show surface corrosion where pyrite framboids have been dissolved. Numerous degraded spheres of uncertain affinities are common but many well preserved specimens are also present. Most were probably originally specimens of leiospheres. Large, amorphous organic particles, probably of degraded bacterial mat, are common. Some, degraded filaments are present, but are sparse.

Taxa identified include: *Leiosphaeridia crassa*, *Leiosphaeridia jacutica*, *Leiosphaeridia minutissima*, *Leiosphaeridia tenuissima*, *Synsphaeridium* sp., *Symplassosphaeridium* spp., *Siphonophycus typicum*.

Zone	Indeterminate
Probable age	Mesoproterozoic

695.35 m Middle Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen), typical of oil-prone intervals (Bechstädt et al., 2009). Abundant palynomorphs consisting of degraded spheres and filaments are present, but none are immediately diagnostic and preservation is generally poor. It might be possible to obtain a better yield of identifiable taxa by using a +50 µm sieve. Some spheres can be classified as ‘Vanavarotaenia’, an artifact formed by the aggregation of fine particles.

Zone	Indeterminate
Probable age	Indeterminate

700.45 m Middle Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen), typical of oil-prone intervals (Bechstädt et al., 2009). In general the sample is too dark for anything to be identified.

Zone	Indeterminate
Probable age	Indeterminate

824.2 m Middle Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen), typical of oil-prone intervals (Bechstädt et al., 2009). In general the sample is too dark for anything to be identified.

Zone	Indeterminate
Probable age	Indeterminate

876.25 m Middle Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen), typical of oil-prone intervals (Bechstädt et al., 2009). In general the sample is lighter in colour than the two overlying preparations, but still contains no identifiable palynomorphs apart from some degraded spheres. Some spheres can be classified as ‘Vanavarotaenia’, an artifact formed by the aggregation of fine particles. There is evidence of considerable pyritization.

Zone	Indeterminate
Probable age	Indeterminate

924.9 m Middle Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen), typical of oil-prone intervals (Bechstädt et al., 2009). In general the sample is too dark for anything to be identified. The slides are too densely mounted and require better filtration.

Zone	Indeterminate
Probable age	Indeterminate

998.8 m Lower Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen), typical of oil-prone intervals (Bechstädt et al., 2009). In general

the sample is too dark for anything to be identified. The slides contain abundant fluorides and are too densely mounted and require better filtration.

Zone	Indeterminate
Probable age	Indeterminate

1200.9 m Lower Velkerri Formation

The macerate consists mainly of abundant organic material consisting mainly of dark amorphogen ('fluffy' kerogen or type I/II kerogen) typical of oil prone intervals (Bechstädt et al., 2009). In general, the sample has been inadequately filtered, is too densely mounted and contains fluorides.

Zone	Indeterminate
Probable age	Indeterminate

Appendix 2: Taxonomic citations

The names of authors of scientific names were omitted in the text and instead are listed here. They are the names of taxonomic authors, not references, so are not necessarily cited in the references.

Chuaria cf. *circularis* Walcott 1899; emend. Vidal & Ford 1985
Leiosphaeridia crassa (Naumova, 1949) Jankauskas 1989 in Jankauskas et al., 1989
Leiosphaeridia jacutica (Timofeev 1966) Mikhailova and Jankauskas 1989 in Jankauskas et al., 1989
Leiosphaeridia minutissima (Naumova, 1949) emend. Jankauskas 1989 in Jankauskas et al., 1989
Leiosphaeridia tenuissima Eisenack 1958
Myxococcoides Schopf 1968
Siphonophycus Schopf 1968 emend. Knoll, Swett and Mark 1991
Siphonophycus typicum (Hermann, 1974) Butterfield, 1994
Symplassosphaeridium Timofeev 1959 ex Timofeev 1969
Synsphaeridium Eisenack 1965
Tappania plana Yin L 1997

Figure 2. (p. 12) Selected palynomorphs from the upper Velkerri Formation in Altree 2. A, large, degraded filament, 68K0. B, *Leiosphaeridia crassa*, 60X0. C, *Leiosphaeridia jacutica*, 62P4. D, *Leiosphaeridia minutissima*, 69O0. E, *Leiosphaeridia tenuissima*, 67J2. F, *Leiosphaeridia tenuissima*, 59F0. G, sphere with processes, 64E4. H-K, *Myxococcoides* sp., H,64N3; I, 64K0; J, 61E0; K, 57H4; L-Q, *Symplassosphaeridium* sp., 41N0; M, 44G4; N, 57H4; 57G4; P, 57H4; Q, 50U0. R,S, *Synsphaeridium* sp., 35P1. S, 65V0. Figures D, H, I and Q from 495.5 m, slide 2; C, J, K, M-P, and R from 495.5 m, slide 3; B, E-G and S from 610 m, slide 2 and A from 610 m, slide 3. England Finder co-ordinates are given for each specimen. Scale bar is 20 µm.

Figure 2

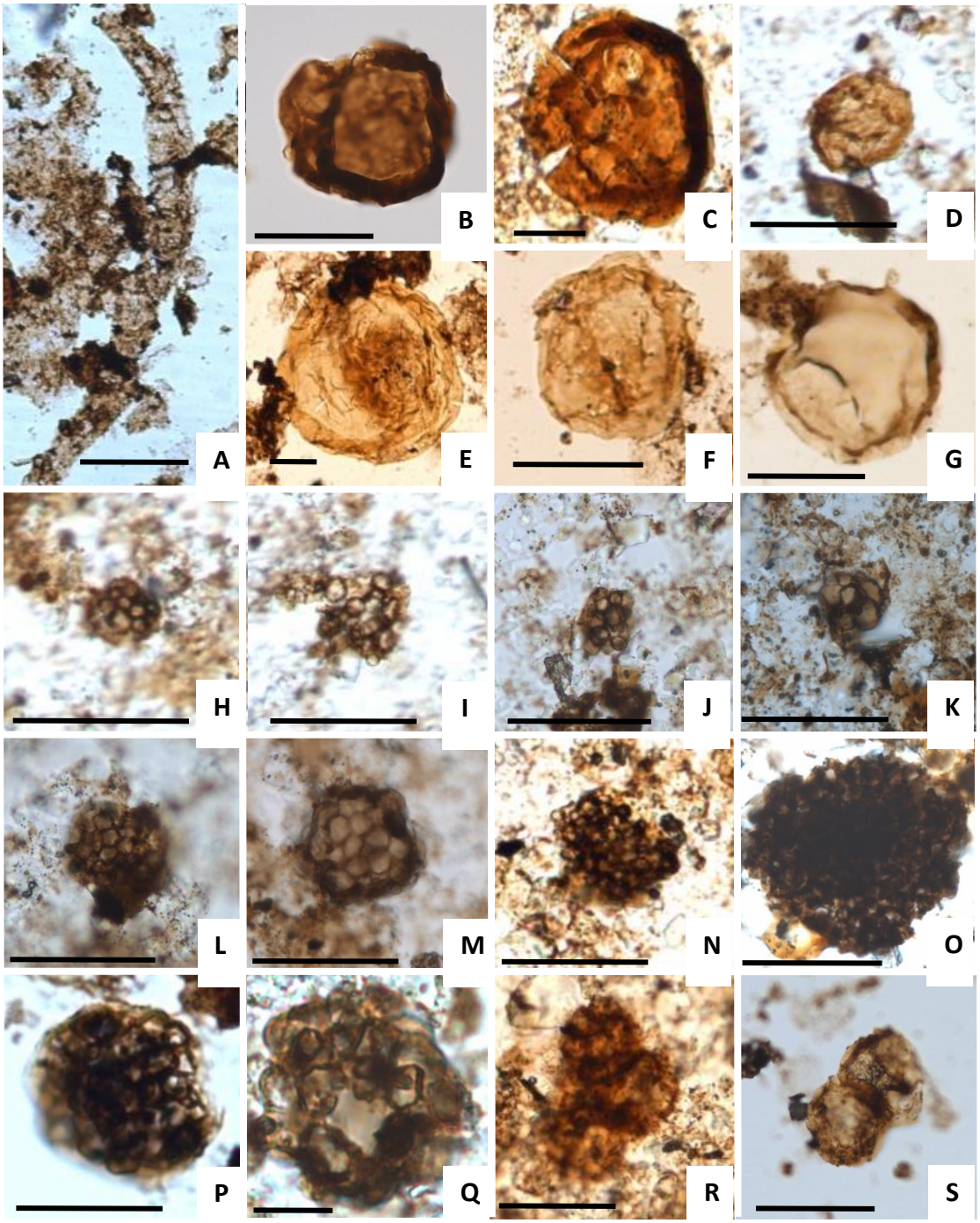

Figure 3

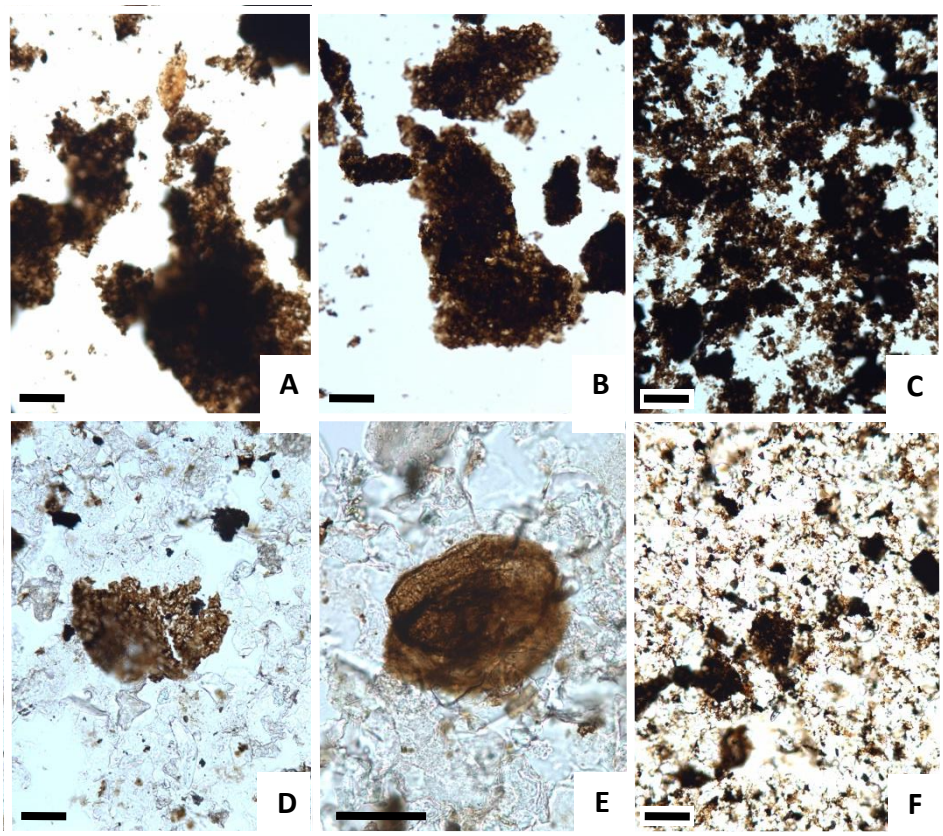

Figure 3. A-C, The middle Velkerri Formation consists almost entirely of amorphous kerogen and does not contain identifiable palynomorphs, A, 695.35 m/2, 48H4; B, 700.45 m/2, 48J0; C, 924.9 m/2, 48G0. The lower Velkerri Formation contains abundant amorphous kerogen, some of which, D, 999.8 m/2, 53D2, appears to be degraded acritarchs. E, well-preserved acritarchs are also present, 999.8 m/2, 53D2. F, The proportion of acritarchs increases in the lower part of the formation, 1200.9 m/2 41J3. England Finder co-ordinates are given for each specimen. Scale bar is 20 µm.