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SPORE PRESERVATION IN THE BOWEN BASIN

by

P.R. Evans

[redacted]

RECORD 1963/100 :

CORRECTIONS

p.15, para 4, line 4. For "Lower Jurassic oil" read - "oil in the Lower Jurassic".

p.15, para 4, line 8. For "Triassic oil" read "oil in the Triassic".

p.15, para 4, line 11. For "Permian oil" read "oil in the Permian"

p.15, para 6, line 13. For "a source of oil" read "the location of oil pools."

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CONTENTS

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SUMMARY

Although well preserved spores are readily extractable from Permian beds in the southern Bowen Basin, it has been difficult to obtain similarly preserved forms from northern parts of the basin. Examination of seismic shot-hole samples from geophysical surveys in the area has confirmed this problem. Spore preservation is related to degree of coalification, which cannot be explained simply in terms of overburden.

Similar variations in spore preservation and coalification are noticeable in the Mesozoic of eastern Australia. Coalification, expressed as the carbon ratio, has been used previously to estimate the oil potential of a region. The principles of the theory could be extended to include quality of spore preservation, in which case if the theory were upheld, much of the northern Bowen Basin would not be a good oil prospect. This conclusion applies only to hydro-carbons generated during the Palaeozoic development of the basin and does not affect any that could have migrated into the region during later tectonic movement. Reservoir characteristics of sandstones in the area must be considered together with this conclusion.

Spores obtained from the Upper Bowen Coal Measures west of the Carborough Sandstone demonstrate the northerly extension of Lower Triassic red beds from the southern parts of the basin.

INTRODUCTION

Independently conducted examinations of A.F.O. Cooroorah No.1 on the Comet Platform of the Bowen Basin by Balme and Evans (Appendix 3 in Derrington, 1959) showed that spores were not sufficiently well preserved in Middle Bowen Beds of that area to be specifically identifiable. Dallwitz (Appendix 2 in Derrington, 1959) showed that the "Churchyard sandstone" in the Cooroorah well was recrystallized so that it cannot be considered as a good potential reservoir rock. Mr. D.M. Traves of Mines Administrations Pty Ltd recently suggested that spore preservation in other areas of the northern Bowen Basin might be examined as there could be a relationship between spore preservation and the likelihood of oil accumulation. Mr. Traves suggested that selected bottom-of-hole samples from seismic surveys in the area could be used for this purpose and he specified fourteen sections from the Commonwealth subsidized Clermont/Annandale, Rolleston/Springsure and Purbrook/Arcadia surveys as suitable for test.

The problem posed by Mr. Traves carries many implications and, as difficulties in obtaining well preserved spores from several locations in the Bowen Basin had already been experienced, it was decided to consider all available data from the basin as well as any obtained from the suggested traverses. The results of this consideration are embodied in the following report.

The project also provided an opportunity to consider the age relationships of certain late Permian and early Triassic beds in the Bowen Basin, so that, where possible, both the state of alteration and the correlation of samples are reported, and separate comments on the age of the Upper Bowen Coal Measures are added to the end report.

SOURCES OF MATERIAL

Bottom-of-hole samples from the Clermont/Annandale Rolleston/Springsure and Purbrook/Arcadia surveys were supplied by Mines Administration Pty. Ltd. Samples from Line "1", east-west through Bauhinia Downs on ATP89P were obtained from Ohio Oil (Marathon Petroleum). Traverse "A", east of Blackwater, (Robertson, 1961) was sampled by the Geophysical Section of the Bureau of Mineral Resources.

Cores, cuttings and sidewall cores from A.F.O. Cooroorah No. 1, Westgrove Nos 1 - 3 Wells were available to the Bureau of Mineral Resources through Subsidy Act contracts. Cores and cuttings from O.S.L.3 (Arcadia) and A.A.O.7 (Arcadia) were available in the Bureau of Mineral Resources Museum.

OBSERVATIONS

The following notes were listed according to geographic location, commencing at the southern end of the Basin where preservation is good and stratigraphic subdivision is better known. They are summarized on the accompanying Plate.

A.A.O. Westgrove No . 1 - 3.

Spores were sufficiently well preserved to be identified to a depth of 5256 feet in Westgrove No. 1 and badly preserved specimens were located to 6232 feet. These depths are well below the lower unit (P2)* of the Middle Bowen. Most of units P2-4 contained much opaque or slightly translucent carbonaceous debris that obscures the spores in a slide and which cannot be removed by known processing techniques. Like animal charcoal, it acts as an adsorber of stains so that it is not always easy to stain and view the spores☆.

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* This unit nomenclature was derived from outcrop and subsurface studies and was summarized in reports on the Westgrove Nos 1 - 3 Wells (Mines Administration Pty. Ltd., 1962 a,b, 1963). P4 includes the upper Bandanna Formation, P3d lower Bandanna Formation, P3c shales above the Catherine Sandstone (="Dry Creek Shale"), P3b Ingelara Formation, P3a ?pre-Ingelara, P2 Cattle Creek Formation, Sirius Shale, P1 not known in outcrop, pre-Cattle Creek in subsurface.

☆ Safranine is added to all preparations. Methyl Violet and Methylene Blue are usually more readily accepted than Safranine, but the resultant colours are not sufficiently stable or clear. In consequence, references to stains in this report concern only Safranine.

The spores themselves show an inability to accept stain that progressively increases with depth. Spores in the late Permian (P4) and the Mesozoic may be readily stained.

O.S.L. 3 and A.A.O. 7 (Arcadia)

Both these wells have been sampled to total depth but no full report on them has yet been written. Spores of P3 and younger ages were stainable. They were not specifically recognizable below 3805 feet (in P1, below the Middle Bowen), but one heavily carbonized specimen was recognizable as a bisaccate pollen at 5022 feet.

A provisional palynological subdivision of A.A.O.7 was given in the well completion report on A.A.O. Westgrove No.2.

Purbrook-Arcadia Survey (Mines Administration Pty Ltd)

Line 1, SP 55-65.

SP 55. Spores well preserved, stainable, abundant. Age:Permian, P3d. The assemblage includes:

Calamospora diversiformis Balme and Hennelly

Leiotriletes directus Balme & Hennelly

Granulatisporites micronodosus Balme & Hennelly

G. trisinus Balme & Hennelly

Baculatisporites sp.

Acanthotriletes ericianus Balme & Hennelly

A. uncinatus Balme & Hennelly

A. tereteangulatus Balme and Hennelly

Micro reticulatisporites bitriangularis Balme & Hennelly

Dulhuntyispora parvitholus Balme & Hennelly

Kraeuselisporites apiculatus Jansonius

Lunatisporites limpidus (Balme & Hennelly)

Alisporites ovatus (Balme & Hennelly)

Marsupipollenites sinuosus Balme & Hennelly

M. triradiatus Balme and Hennelly

Micrhystridium sp.3 (one specimen).

Murornate sp. indet.

The association of relatively common D.parvitholus, M.bitriangularis, very rare M. sp.3 suggest a P3d age. The "Murornate sp.indet." is a palynomorph of indeterminate affinities but which was previously detected in A.A.O. 7, c.3, 899 feet.

Serocold Anticline

Outcrop samples from shaly formations of the Serocold Anticline have yielded well preserved spores and microplankton. The transition from stainable to not readily stainable specimens occurs between the Ingelara Formation (P3) and the Cattle Creek Formation (P2) as in the Westgrove wells.

de Jersey (1962) recognized spores below the Cattle Creek Formation to a depth of 4698 feet in A.O.E. Reid's Dome No. 1 (P1), but he gave no information concerning their preservation. Outcrop samples from the Sirius Shale, south of the Springsure - Rolleston road, contained well preserved, not stainable spores (P2). None could be extracted from the Staircase Sandstone, Stanleigh Shale and Orion Shale. However, the samples of Staircase Sandstone and Stanleigh Shale were possibly too weathered for spores to be preserved.

Rolleston - Springsure (Mines Administration Pty. Ltd.)

(Geophysical Service International, 1963).

Inderi Area

Line 15, SP 1164. Spores well preserved, stainable, abundant. Age: Permian P3d. The assemblage included most species listed for PA/SP55, with such markers as *Dulhuntyispora parvitholus* and *Marsupipollenites sinuosus* prominent. Several specimens of *Veryhachium* sp.2, a good marker of P3d, were recognizable.

Memooloo Area

Line 3, SP1350-1360. Not suitable for examination: rock types of red-beds or weathered sandstones.

Emerald-Duaringa Survey 1960 (B.M.R.)

Traverse "A", SP2 - 23, 75-96. (Robertson, 1961).

SP2. 150-175 feet: Spores abundant, corroded, carbonized. Recognizable forms showed that the assemblage contained abundant *Alisporites* and striate pollens of the *Striatites* type. Typical Permian forms were apparently absent and it is probably better to regard this as a Lower Triassic assemblage.

SP.8. 80-96 feet: No spores. Carbonized organic debris fairly abundant.

SP 14, 80-96 feet: No spores.

SP 20, 80-96 feet: Very rare pollens of non-striate bisaccate form.

SP 77, 70-80 feet: Spores abundant, carbonized.

They included:

Todisporites sp.

Discisporites sp.

Distalanulisporites sp.

Taeniaesporites sp.

Striatiti spp.

Alisporites spp.

Trizonaesporites sp.

?Quadrisporites horridus Hennelly

This is a typical Lower Triassic assemblage.

SP79, 70 - 80 feet: Spores abundant, carbonized.

The yield consisted mainly of an undescribed zonate form, known from the Narrabeen Group (Clifton Sub-Group) of N.S.W. and from the Rewan Formation with very rare Alisporites and Trizonaesporites. Age: Lower Triassic.

Excell Mine at Bluff

Three samples of coal and roof shale from the Excel coal mine at Bluff were obtained by E. J. Malone for spore examination but none yielded recognizable microfossils. de Jersey (1946) recorded a number of species from Bluff including "16a" = Acanthotriletes ericianus Balme & Hennelly (acc. Balme & Hennelly, 1956), "25A" = ?Circulisporites parvus de Jersey (1962) that suggest the coals are no older than P3. de Jersey made no comment on preservation of his fossils.

Bauhinia Downs Survey (Ohio Oil (Marathon Pet.))

Line 1, SP 1 - 145.

Shot points between SP46 and SP134 from this survey have been examined and their microfloras warrant description in a separate report. However all these samples contained "M - U. Triassic "Zone 1" assemblages (Evans, 1963a). SP100-134 contained the closest comparisons to those east of Roma where this zone is well known (e.g. Latemore No. 1, Combarngo No. 1, Sunnybank No. 1). Spores were present and well preserved in all samples: all could be readily stained.

A.F.O. Cooroorah No. 1.

Cooroorah No. 1 commenced in the Crocker Formation, but no identifiable spores could be extracted by either Balme or Evans (Appendix 3 in Derrington, 1959). However, Balme had been able to identify spores of late Permian age in the Crocker Formation outcropping to the south of the Cooroorah anticline. No details of preservation are available.

Blair Athol

de Jersey (1946) identified spores from the coals of Blair Athol.

Clermont-Annandale Survey (Mines Administration Pty. Ltd.)

Mount Demipique Area: CA5, SP 474-479, 483-488.

SP 477, 45 feet: No spores. Finely divided opaque and brown translucent organic debris only.

SP 487, 120 feet: Spores present, but so fragmentary and carbonized that none was specifically identifiable.

Cotherstone Area: CA3, SP236 - 245.

SP237, 90 feet: A few poorly preserved and indeterminate spores.

SP245, 90 feet: Spores abundant, sufficiently well preserved to be identified. They included:

Leiotriletes directus
Laevigate spp.
Apiculati spp. indet.
Nuskoisporites triangularis (Mehta)
Micrhystridium sp.

None of these is diagnostic of a known subdivision of the Permian. The hystrichosphere suggests the rock had marine origins. The number of apiculate forms (not determinable) might suggest a P3 rather than a P2 age, but this can be no more than a speculation.

CA3,SP255-265.

SP265, 90 feet: The residue consisted almost entirely of opaque organic debris, but one or two specimens were recognized.

CA3, SP275-285.

SP276, 150 feet: No spores; opaque carbonaceous debris only.

SP 279, 140 feet: As for SP 276.

Luxor Area

CA4, SP378, 386, 395.

SP 378, 90 feet: Spores are present and several are identifiable. Bulk of residue of opaque organic debris and fragmented, carbonized spores. Recognizable forms included:

Leiotriletes directus
Granulatisporites trisinus

A more precise age than Permian is not definable.

SP385, 135 feet: Preservation as for SP378.

Leiotriletes directus

Punctatisporites sp.

Granulatisporites trisinus

Nuskoisporites triangularis

Disaccites spp. indet. (fairly common) were recognized.

SP395: Not suitable for examination, too oxidized.

Leichhardt Downs Area CA 14, SP 820 - 822.

SP 821, 195 feet, Opaque carbonaceous matter only.

Grosvenor Downs Area CA1, SP1 - 7.

SP7, 75 feet: No spores: general lack of organic material.

SP3,100 feet: Spores common, carbonized and broken. Striate, bisaccate pollens of the L. limpidus and L. amplus types were common. Other forms included:

Acanthotriletes tereteangulatus

Conbaculatisporites sp.

Baculatisporites sp.

This might be a very late Permian assemblage, P3d or P4, but the identity of the fragmented specimens is needed to confirm the suggestion.

Annandale Area CA1, SP97 - 108.

None of these was suitable for examination. They included a mixture of creamy sands (?Cainozoic) and red shales and siltstones. As Malone et al. (1961) mapped outcropping Upper Bowen Coal Measures to the east of this section, SP 110 - 115 were examined. Again red shales and siltstones were noted, but SP110 was of grey siltstone.

SP110, 120 feet: Spores rare, carbonized, occasionally taking stain; opaque and translucent material fairly common. The spores were insufficient for positive age identification.

They included:

Alisporites sp. (Several specimens)

?Trizonaesporites

that are probably sufficient to allocate the sample to the Triassic.

Elphinstone Area CA2, SP205 - 208.

SP208, 120 feet: No spores; opaque organic debris only.

As no other samples along this section, mapped as Upper Bowen Coal Measures between occurrences of Triassic Carborough Sandstone, were suitable for examination, a number of samples from traverse CA 2 to the west of SP 205 and in a comparable stratigraphic position (Malone *et al*. 1961) were examined.

SP176, 120 feet: No spores, low organic yield.

SP179, 120 feet: No spores, low organic yield.

SP180, 120 feet: No spores, low organic yield.

SP189, 120 feet: Spores fairly common, carbonized but recognizable. They included:

aff. *Cyathidites*

Distalanulisporites

Cingulati sp. (common).

Taeniaesporites sp.

Alisporites spp. (fairly common)

All these species are known from the Lower Triassic of the southern Bowen and Surat Basin.

SP198, 120 feet: Very few spores. They included:

Alisporites sp. that indicates a Triassic age but finer resolution is not possible.

Comments on the stratigraphic significance of these findings from an area mapped as the Upper Bowen Coal Measures to the west of the Carborough Sandstone are to be found in Appendix I.

Discussion

Geographic separation of the quality of preservation of spores in pre-Middle Triassic beds is apparent from these results. The Lower Triassic spores of Westgrove, Arcadia and the Serocold Anticline are almost as well preserved as, say, those of the Cretaceous in the Eromanga Basin. However, the Lower Triassic spores of the Rewan Formation between Blackwater and Bluff and below the Carborough Sandstone to the north are carbonized. The late Permian (P3d/4) spores of the southern areas are similarly well preserved, but it was difficult to find any spores between Blackwater and Grosvenor Downs. The late Permian (?P4) of the Grosvenor Downs Area is poorly preserved and carbonized. Spores in the marine units (P2/3) of the Middle Bowen Beds are readily identifiable south of Springsure but they were rarely detectable to the north.

It is convenient to classify the states of preservation as follows:

1. a. Exine details entire: spores readily stainable.

   b. Exine details entire: spores do not stain readily under standard processing techniques: if the stain is accepted, its effect is usually excessive.

2. Exine details sufficient in most cases for specific recognition: spores carbonized, do not stain.

3. Spores fragmented, too carbonized to be identified. (Fragmentation probably occurs during processing. The carbonized exines probably have insufficient mechanical strength to withstand centrifuging, etc.).

4. Spores completely destroyed.

State 4 is only a negative condition and in isolated samples could be confused with other causes: no spores originally occurred in the rock; spores were destroyed by weathering or oxidation either in Recent times or during its geological history. Negative results are common, for example, in the Lower-Triassic of the Bowen and Surat Basins of which the greenish tuffaceous sandstones are rarely fossiliferous and the red-shales are always barren, presumably on account of oxidizing conditions of deposition.

Other complications may be introduced when the spores have acted as nuclei for pyritization (Glover, 1960). The spores are deformed and lose their ornament because of the growth of pyrite grains. Spores are identifiable to a depth of 7088 feet in U.K.A. Burunga No.1, but many in the Permian marine beds have been affected in this manner.

POSSIBLE CAUSES OF ALTERATION

Kuyl, Muller & Waterbolk (1955,p.56) noticed progressive alteration of fossil pollens with depth in the Tertiary and Upper Cretaceous of Venezuela which they attributed to pressure and temperature effects of overburden. Balme (1957,p.10) could not find "useful assemblages" in the Mesozoic of the Exmouth Gulf area of Western Australia below a depth of about 8,000 feet and it seemed to him that "below this depth the combined effects of temperature and pressure have been sufficient to destroy the spore and pollen exines."

However, it is not possible to consider the degradation effect simply in terms of overburden as the "cut off" depth varies greatly in regions where it is not always easy to postulate the existence in the past of considerable overburden. Cookson & Eisenack (1958), for example, were able to recognize Jurassic microplankton at a depth of 13,769 feet* in A.P.C. Omati No.1 Well, Papua, although preservation was poor. Evans (1962) was able to recognize Cretaceous spore exines at 11,500 feet at the base

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* Cookson & Eisenack did not stipulate the depths from which their samples were taken. This figure was obtained from the unpublished well completion report.

of F.B.H. Flaxman's Hill No.1 in the eastern Otway Basin. He also observed even better preserved Cretaceous spores at 10,044 feet in O.D.N.L. Mount Salt No.1 in the western part of that basin (Evans,1963b). However, spore preservation was poor at about 10,000 feet in U.K.A. Cabawin No.1 and no recognizable species were found below 11,000 feet. Further, spores are in "state 2" in the near surface Mesozoic of Clifden No.3 in the Clarence Basin.

A time component might be attritueble to preservation at great depths in Papua, as the Omati Mesozoic was rapidly buried under about 7000 feet of overburden during the Middle Miocene alone. However, the Otway Basin overburden has built up relatively uniformly during Cretaceous and Tertiary times.

Pressure effects may be caused not only by overburden but by lateral tectonic pressures. It is probably significant that those areas of the Bowen Basin with carbonized spores in late Permian sediments are closely related to the margin of the "Folded Zone" (Malone et al, 1963). Derrington & Morgan (in Hill & Denmead,1960) distinguished the "Dawson Tectonic Zone" and an "Intermediate Zone" within the "Folded Zone". The localities under consideration are closer to the "Intermediate Zone" than to the highly folded "Dawson Tectonic Zone".

Spore alteration is closely related to degree of coalification (Potonie & Kemp, 1955). Teichmuller & Teichmuller (1954) considered that temperature and time were the most important of the many physical and chemical conditions related to coalification.

van Krevelen & Schuyer (1957,p.40) thought that temperature alone is significant beyond the lignite stage. Thus, the geothermal gradient of a given location would have considerable influence on spore preservation. Again, no simple means of expressing the relation is available as the gradient depends on chemical (mineralogical) environments (Packham & Cook, 1960).

SPORE PRESERVATION AND COALIFICATION

As the factors involved are so numerous it is only possible at this stage to refer to a single apparent relationship that in fact embodies the end results of all these influences - spore preservation and the degree of coalification of containing rocks.

Potonie & Kremp (1955, p.16) noted the progressive disappearance of exine constituents with increase in coal rank. Sporonin, the last to survive, disappears before the Magerkohle (semi-Anthracite) state is reached.

To pursue this relationship further, spore preservation and coal rank in areas within and outside the Bowen Basin are considered below. However, expressions of rank in qualitative terms will not readily assist discussion and so the degree of coalification has been calculated in terms of the carbon ratio, i.e. the ratio of fixed carbon to fixed carbon plus volatiles, expressed as a percentage. Some illustrative figures are listed in Table I. Proximate analyses have been obtained from a number of sources*, so that note of possible variations due to differing analytical techniques must be taken into account. Figures for coals from U.K.A. Cabawin No.1 (Union Oil Development Corporation, 1963) are listed in Table II. Locations of these coals are plotted in Figure 1.

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* 1. de Jersey, 1949, Table 9.

2. Standards Association of Australia, 1955, Table XXIX.

3. S.A.A., 1955, Table XXVI.

4. S.A.A., 1955, Table XXX.

5. S.A.A., 1955, Table XV.

6. Denmead, 1943, p.70.

7. Jensen, 1926, p.16.

8. Q.G.M.J. 1958, 59, 798 (no author).

TABLE I.

PROXIMATE ANALYSES, CARBON RATIOS AND SPORE PRESERVATION IN SOME EASTERN AUSTRALIAN COALS

Location	Author	Age	Vol.(%)	Fx.Carb.(%)	V+FxC	C-ratio(%)	Spore State
Collinsville Bowen Seam	1	Permian(?P3)	20.2	55.9	76.1	73.4	?3
Blair Athol	1	Permian(?P4)	29.1	57.2	86.3	66.3	Present
Blackwater	2	Permian(P4)	19.5	70.1	89.6	78.1	2/3
Bluff Excel	3	Permian(?P4)	14.5	75.7	90.2	83.8	3 or 4
Baralaba	1	Permian(?P4)	13.1	81.0	94.1	86.1	Unknown
Kianga	8	Permian(?P4)	31.9	57.8	89.7	64.3	1
Carnarvon 4'2"	6	Permian(?P4)	30.6	50.2	80.8	62.2	1
Callide (specimens)	1	Triassic	31.7	54.6	86.3	63.3	Present
Abadare	1	Triassic	34.7	58.5	93.2	62.7	Unknown
Ipswich Eclipse	1	Triassic	27.9	63.3	91.2	69.4	Present
Rosewood Lanefield No.4	1	Jurassic	45.6	43.6	89.2	48.9	Present
Oakey	4	Jurassic	39.4	34.6	74.0	46.8	Unknown
Injune 7'	7	Jurassic	40.2	48.0	88.2	54.3	1
Clarence	5	Jurassic	23.1	47.5	70.6	67.3	2/3
Styx (main seam)	1	Cretaceous	26.9	48.9	75.8	64.6	Present
Burrum (Jubilee)	3	Cretaceous	25.8	61.7	87.5	70.6	Present
Oaklands	5	Permian(P4)	26.4	45.3	71.7	63.2	1
Wallarah	5	Permian(P4)	32.7	55.4	88.1	62.8	1
Bulli	5	Permian(P4)	24.9	65.3	90.2	72.4	2 or 3.

TABLE II

PROXIMATE ANALYSES, CARBON RATIOS AND SPORE PRESERVATION IN U.K.A. CABAWIN NO.1*

Depth (ft.)	Age	Vol.(%)	Fx Carb(%)	V+FxC	C-ratio(%)	Spore State
1280 - 90) 1310 - 20)	Lower Cretaceous	32.3	40.5	72.8	55.6	1
1756 - 66) 1766 - 76) 1790 - 1800)	Lower Cretaceous	32.0	41.2	73.2	56.2	1
2190 - 2200	Lower Cretaceous	32.1	43.7	75.8	57.6	1
3170 - 80	Jurassic	34.2	38.2	72.4	52.7	1
4310 - 20	Jurassic	41.5	42.7	84.2	50.7	1
4730 - 40	Jurassic	46.2	41.0	87.2	47.1	1
5300 - 10	Jurassic	42.5	36.1	78.6	45.9	1
5370 - 80	Jurassic	32.8	43.1	75.9	56.8	1
6020 - 30	Jurassic "Zone 3"	39.4	44.2	83.6	52.8	1
6450 - 60	Jurassic "Zone 2"	44.0	43.9	87.9	50.0	1
6970 - 80	"	43.5	43.0	86.5	49.7	1
7510 - 20	Triassic "Zone 1"	41.2	45.6	86.8	52.6	1
7870 - 80) 7880 - 90)	" "	40.6	41.1	81.7	50.3	1
9620 - 30	Permian(P4)	25.3	55.7	81.0	68.9	2
9870 - 72) 9877 - 80) 9880 - 90)	Permian(P4) Permian(P4)	23.0	50.4	73.4	68.7	2
10260 - 70	Permian(P4)	26.0	60.5	86.5	70.0	2
10570 - 90	Permian(P3)	24.9	49.4	74.3	66.6	2
10590 -620	Permian(P3)	23.6	51.1	74.7	68.9	2
10700 - 10	Permian(P3)	24.5	48.1	72.6	66.3	2

Note: Stage 4 below 11,000 feet.

* Analyzed by Queensland Government Chemical Laboratory.

Taken from Union Oil Development Corporation, 1963, Appendix 2.

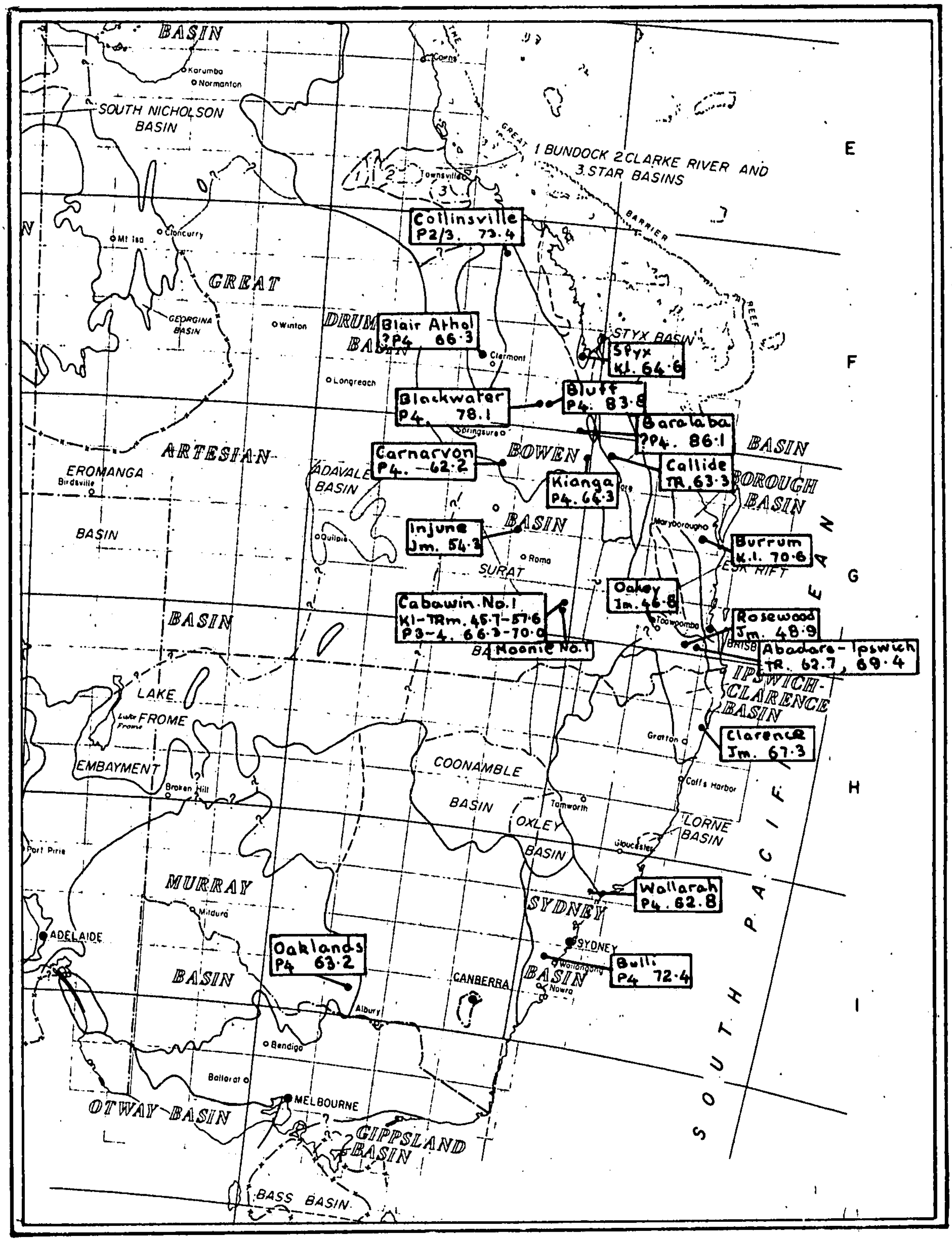

FIGURE 1. *Some Carbon Ratios of Eastern Australian Coals.*

To accompany Record 1963/100

It can be deduced from these figures that preservation "state 1" - exine and sculpture entire - is to be found in coal with carbon ratios up to about 65%. Serious carbonization of the exines commences above 65%, while few useful identifications may be made on samples whose ratios are greater than 75%.

Differences in spore preservation observed in the Upper Bowen of the Bowen Basin are clearly reflected by the carbon ratio. The coals of Oil Shale Gully on Carnarvon Creek, for example, from which well preserved spores have been obtained, and that may be correlated with the section on Consuelo Creek, have a carbon ratio of 62.2%. Stratigraphically similar coals at Blackwater, where spores in the overlying Lower Triassic are heavily carbonized, have a ratio of 78.1%. The carbon ratio at Bluff, 83.8% is second highest in the basin and no worthwhile assemblages could be identified from the area.

If the figures from the late Permian coals of Cabawin No.1 are included in an overall comparison, the Surat Basin and western flank of the southern Bowen Basin are markedly different from the northern and eastern (Baralaba) Bowen Basin. (Whereas the transition level is near Blackwater on the western margin of the basin, it probably occurs at more southerly latitudes on the eastern flank; the Baralaba semi-anthracitic coals have the highest carbon ratio in the state, while the coals at Kianga are high volatile bituminous and spore-bearing).

Figures derived from the Mesozoic also show a marked geographic separation. Cretaceous, Jurassic and Triassic coals in Cabawin No.1 are relatively low rank (47.1 to 57.6%) compared with those of the Permian coals (66.3 - 68.9%). Figures from the Middle Jurassic (Walloon Coal Measures) of Oakey, Injune and Rosewood accord with the Cabawin values. They differ significantly from the Middle Jurassic Clarence Coal Measures (67.3%) of the Clarence Basin and from the Lower Cretaceous Styx Coal Measures (64.6%) and the Burrum Coal Measures (70.6%) of the Maryborough Basin.

RELATIONSHIP OF OIL OCCURRENCE AND SPORE PRESERVATION

Firm conclusions as to whether oil may or may not occur in a given area cannot possibly be deduced solely from the preceding very generalized observations. Nevertheless they do invoke the sequence of thoughts followed below, but, as in all such cases, they can only be validated by testing and by drilling.

The degree of carbonization was measured in terms of the carbon ratio partly because this expression has also been employed as an empirical parameter in estimates of oil potential for some time past. Much discussion of the carbon ratio theory is available in the literature. It was reviewed by Russell (1951) and no elaboration is intended here. Insufficient data are available to apply the theory to Australia, but one inference might be drawn from the preceding results. If the likelihood of oil occurrence (whatever the ultimate cause) falls off rapidly as the carbon ratio exceeds 60%(Russell), the chances of finding oil where spores are heavily carbonized or destroyed (carbon ratio greater than 75%), are very slender. The state of spore preservation in the northern Bowen Basin would thus considerably reduce the possibility of finding oil in the Permian of that region.

This conclusion only concerns hydrocarbon generation during the Palaeozoic development of the basin, it does not affect hydrocarbons that have perhaps migrated into the region during later tectonic movement (tilting). Characteristics of potential reservoir rocks in the basin must be considered together with the indications given above. Other than data from Cooroorah No.1, none is available.

Although advocacy for the carbon ratio theory is not intended in this paper, two general results applicable to the theory are indicated by these observations. The first relates to the strong objections voiced by Reeves (1928) who, by applying Hilt's Law, thought that carbon ratios would increase with depth. Russell (p.254) countered with evidence supplied by Wade (1926) of carbon ratios of 60-65% in the Newcastle Coal Measures and of only 50-55% in the Greta Coal Measures "which lie over 7000 ft. lower in the section"in the Sydney Basin. Wade's evidence is fully supported by the figures from Cabawin No.1 in which little variation occurs throughout 7000 feet of Triassic, Jurassic and Cretaceous rocks.

The second point is concerned with the fact that known occurrences of oil in eastern Australia are associated with carbon ratios within or close to the 60% limit prescribed by Russell. The Lower Jurassic oil of Moonie No.1 for example, occurs in beds to be correlated with the 6450 - 6970 feet "Zone 2" (palynological zone, Evans,1963a) levels of Cabawin No.1 where the observed carbon ratios are in the range 49.7 - 50.3%, and the Triassic oil of Combarngo No.1 is related to the M - U.Triassic "Zone 1" ratios of 50.3 - 52.6% of Cabawin No.1. On the other hand the Permian oil of Cabawin No.1 is associated with carbon ratios of 68.7 - 70%, values which the theory would suggest areunlikely oil prospects.

The gas of Westgrove Nos. 1 - 3 underlies coals relatable to the Carharvon (63.3%) coals and is still within Russell's 70% limit for this form of hydrocarbon.

CONCLUSIONS

This brief survey of spore preservation in the Bowen Basin shows a relationship between spore alteration and carbonization in terms of the carbon ratio. The alteration can be related to regional deformation or geothermal gradient rather than just to overburden. In consequence, the poor preservation of spores in beds as young as the late Permian and early Triassic of the northern Bowen Basin could be attributed to regional alteration, while prospects of locating spores in the underlying marine Middle Bowen Beds are slight. If the theory of carbon ratios related to oil occurrence is acceptable this preservation state greatly reduces the prospect of the northern Bowen Basin as a source of oil.

APPENDIX I.

AGE OF THE UPPER BOWEN COAL MEASURES

Spores from shot-point samples west of the Carborough Sandstone have finally proved a stratigraphic relationship that has gradually become apparent through the systematic mapping of the Bowen Basin currently undertaken by the Bureau of Mineral Resources. Malone et al. (1961) followed Jack and Reid by referring to all sediments above the Permian Middle Bowen Beds and below the Triassic Carborough Sandstone as the Permian Upper Bowen Coal Measures. Reeves (1947) placed beds of similar stratigraphic position below the Clematis Sandstone at the southern end of the basin in the Upper Bowen Series. This unit includes both the Bandanna Formation and Rewan Formation of Shell (Queensland) Development (1952). Shell placed the Rewan Formation in the Triassic. Hill (1957) accepted Shell's determination, but Phillips (in Hill & Denmead, 1960,p.188) preferred a Permian age for the unit. Spores from the Rewan Formation of A.A.O. Westgrove No.1 Well (Evans, in Mines Administration Pty Ltd, 1962a) are comparable with Lower Triassic forms from the Narrabeen Group of the Sydney Basin. Evans (1963a) pointed to the persistence of red-beds of Rewan type in the Lower Triassic of eastern Australia. Shell Queensland Development Pty Ltd (1952) mapped the Rewan Formation to the east of Blackwater where Derrington & Morgan (1959) mapped them as the "Arduran Formation". Malone et al. (1963) recognized the Rewan Formation above the Upper Bowen Coal Measures and commented (p.88) that equivalents of the Rewan Formation were included in the Upper Bowen Coal Measures in the Mount Coolon Area.

The spore assemblages from B.M.R. "Traverse A", east of Blackwater and from Minad "CA1" and "CA2" west of the Carborough Sandstone fully support this proposition. Not only Lower Triassic spores, but associated red-beds of Rewan type are to be seen in the shot-point samples. This Triassic red-bed sequence is to be correlated with the subsurface Pickanjinnie and Cabawin Formations of the Surat Basin. As a similar relationship of red-beds above Permian coal measures is found as far north as Mt. Mulligan, it is to be expected that this feature of late Permian and early Triassic times is characteristic of most of eastern Australia.

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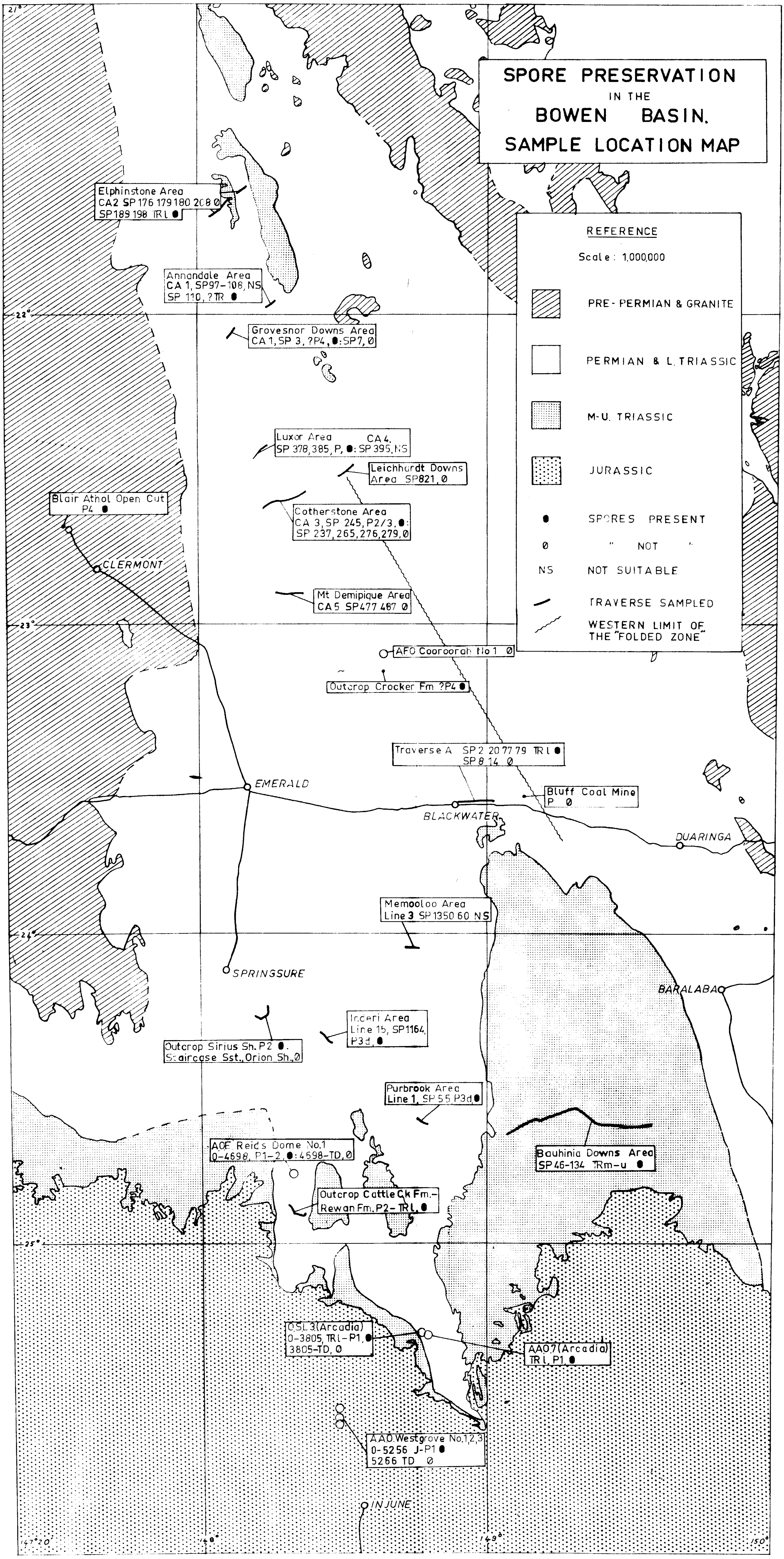
SPORE PRESERVATION
IN THE
BOWEN BASIN.
SAMPLE LOCATION MAP
REFERENCE
Scale: 1,000,000
PRE-PERMIAN & GRANITE
PERMIAN & L. TRIASSIC
M-U. TRIASSIC
JURASSIC
SPORES PRESENT
0 " NOT "
NS NOT SUITABLE
TRAVERSE SAMPLED
WESTERN LIMIT OF THE "FOLDED ZONE"
Elphinstone Area
CA2 SP 176 179 180 208 0
SP 189 198 TRL ●
Annandale Area
CA 1, SP97-108, NS
SP 110, ?TR ●
Grovesnor Downs Area
CA 1, SP 3, ?P4, ●: SP7, 0
Luxor Area CA 4.
SP 378, 385, P, ●: SP 395, NS
Leichhardt Downs
Area SP821, 0
Blair Athol Open Cut
P4 ●
Cotherstone Area
CA 3, SP 245, P2/3, ●:
SP 237, 265, 276, 279, 0
CLERMONT
Mt Demipique Area
CA 5 SP477 487 0
AFO Cooroorah No 1 0
Outcrop Crocker Fm ?P4 ●
Traverse A SP 2 20 77 79 TRL ●
SP 8 14 0
EMERALD
Bluff Coal Mine
P 0
BLACKWATER
DUARINGA
Memooloo Area
Line 3 SP 1350 60 NS
SPRINGSURE
BARALABA
Inderi Area
Line 15, SP1164,
P3d, ●
Outcrop Sirius Sh. P2 ●.
Staircase Sst., Orion Sh., 0
Purbrook Area
Line 1, SP 55 P3d ●
AOE Reid's Dome No.1
0-4698, P1-2, ●: 4698-TD, 0
Bauhinia Downs Area
SP 46-134 TRm-u ●
Outcrop Cattle Ck Fm.-
Rewan Fm. P2-TRL ●
OSL 3 (Arcadia)
0-3805, TRL-P1 ●
3805-TD, 0
AAO 7 (Arcadia)
TRL, P1 ●
AAO. Westgrove No. 1, 2, 3
0-5256 J-P1 ●
5266 TD 0
INJUNE
21°
22°
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147°20'
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