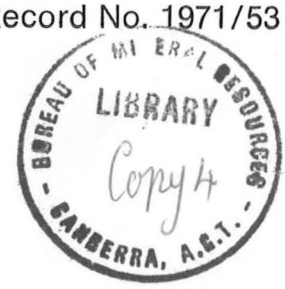
COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1971/53



Some Palynological Observations on Amerada Thunderbolt No. 1 Well, Galilee Basin, Queensland

by

M. Norvick

Record 1971/53

SOME PALYNOLOGICAL OBSERVATIONS ON AMERADA THUNDERBOLT NO 1 WELL, GALILEE BASIN, QUEENSLAND

by

M. Norvick

CONTENTS

SUMMARY

The Permian and Triassic palynology of Amerada Thunderbolt No.1 well, Galilee Basin, Queensland, is reviewed. The distribution of spore and pollen species in Permian samples is presented graphically. A succession of Permian palynological assemblages are described and their relationship with existing named zones is discussed. Upper Carboniferous stage 1 microfloras are absent. Stage 2 is divisable into at least two parts but these cannot be directly correlated with spore units C2, P1a or P1b. Stage 3 is present but stage 4 and possibly lower stage 5 are represented by a major hiatus. The uppermost Permian assemblage present is upper stage 5 and this is succeeded by barren Triassic strata.

INTRODUCTION

This report describes the distribution of spore and pollen assemblages in Amerada Thunderbolt No.1, Galilee Basin, Queensland, with particular reference to the Permian microfloras. The well is of especial importance to Permian palynostratigraphy because of its central location in the Galilee sub-basin (see Fig. 1), thus providing a link between a number of other deep well sections cutting Permian strata. Also the Permian succession, although not complete, was relatively fully sampled. A total of 53 side wall cores, conventional cores and cutting samples were made available for palynological study by the company. Of these 34 yielded recognizable microfossils, including 22 from the Permian and Upper Carboniferous.

For the above reasons the Permo-Carboniferous microfloral succession in Thunderbolt No.1 was examined in some detail and the results are set out here as a separate report. Using this data as a reference section, it is hoped to integrate the well into a biostratigraphic synthesis of the Galilee Basin as a whole. Taxonomic discussion has been kept to a minimum and, where possible, validly published names have been used for spore and pollen species. Relatively little has been published on the taxonomy of Eastern Australian Permian and Upper Carboniferous spores and pollen and consequently many species, some of stratigraphic use, remain undescribed. A taxonomic paper on this subject is planned for the near future but for this report undescribed species have been designated by B M.R. species catalogue numbers. Rare forms (represented by 2 to 5 specimens) have not been identified below generic level.

The well was drilled in March 1967, about 30 miles ENE of Muttaburra (lat. 22°22'02" S; long. 145°00'10" E) on the Muttaburra 1:250,000 sheet area (F 55 9). It intersected 1277 feet of Jurassic to Lower Cretaceous, 1615 feet of Triassic and 1382 feet of Upper Carboniferous (?) to Permian sediments before entering basement at 5274 feet. It bottomed in nonprospective volcanics at 5286 feet (Amerada, 1967).

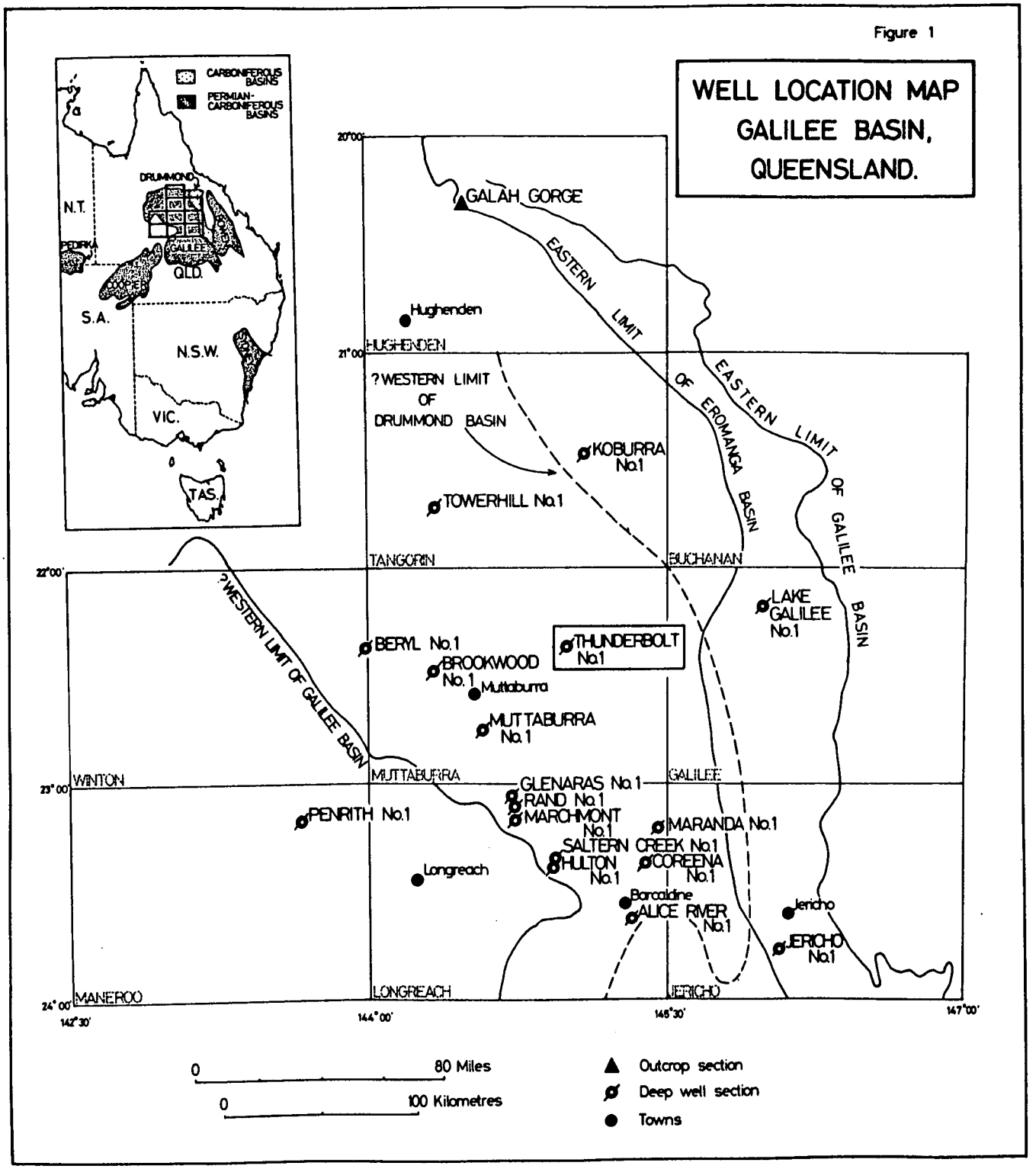
Previous work on this section includes Evans' (in Amerada,1967) short report on the Triassic and Permo-Carboniferous microfloras. He dated the assemblages using his (1964, 1966a) C, P and Tr lettered spore units and the present study broadly agrees with his conclusions. Burger (1970) compared the Thunderbolt sequence with a neighbouring Permian section in Amoco Towerhill No.A-1. Burger and Kemp (in prep.) examined the Jurassic and Cretaceous samples and their results are quoted in this report without further comment.

PREVIOUS WORK ON PALYNOLOGICAL ZONATION

Balme (1964) made one of the first attempts to divide the Australian Upper Palaeozoic on its spore and pollen assemblages. He differentiated a Carboniferous "Lycosporoid" Microflora, a Permian Striatites Microflora and a Lower Triassic Taeniaesporites Microflora. Working chiefly with Western Australian formations containing marine invertebrates (including ammonoids), he subdivided the Striatites Microflora into three parts and correlated them with the standard Russian Permian stage nomenclature. Thus he identified a Nuskoisporites Assemblage, which he dated as Sakmarian to early Artinskian; a Vittatina Assemblage to include most of the Artinskian and "Kungurian"; and a Dulhuntyispora Assemblage, which he correlated with the whole of the Upper Permian (uppermost "Kungurian" to Tartarian). These units are sufficiently broad to allow their identification in Eastern Australia (Evans, 1967a), although some of his overseas stage correlations have been questioned. Later Balme (in Johnson, 1968) refined this zonation by dividing the Nuskoisporites and Vittatina Assemblages into three parts each (units N I to III and V I to III). He based this on a well section (WAPET Blackstone No.1) in the Canning Basin. Some of the species, on which these units are defined, have not yet been identified in Eastern Australia and consequently this subdivision has not been applied to the Permian succession in Queensland.

Upper Carboniferous and Permian strata in the Galilee Basin were subdivided by Evans (1964), using a series of lettered spore units. These were first applied to the Denison Trough and Springsure Shelf, in the southern Bowen Basin. They were based on a number of different criteria, including limits of ranges of major spore groups (e.g. base of Striatiti at C1/C2 boundary), ranges of individual spore species and the occurrence of particular acritarch species (e.g. in P2, P3c, P3d). Unfortunately the geographical distribution of these acritarch "swarms" is controlled by the rather limited incidence of marine or brackish water conditions. As a result, the detailed application of units defined by acritarchs is limited to the Denison Trough and the Galilee Basin as far west as Alliance Jericho No.1. Attempts to correlate Permian strata in areas beyond the reach of microplankton, i.e. where deposition was wholly non-marine, resulted in the use of clumsy combinations of spore units (e.g. P2-P3a, P3d-P4). Thus in the central Galilee Basin (Evans 1966a) up to six units could be recognised (C1, C2, P1a, P1b, P1c-P2, P3-4) and in the Cooper Basin (Evans 1966b) three were differentiated (P1b, P1c-P2, P3b-P4). When the Sydney Basin was examined (Evans 1967b), the marine incursions and the acritarch "swarms" which they contained could not be correlated with those from the Denison Trough. Again recourse was made to groups of units defined entirely upon spores.

Figure 1



TO ACCOMPANY RECORD 1971/53

F55/A9/5

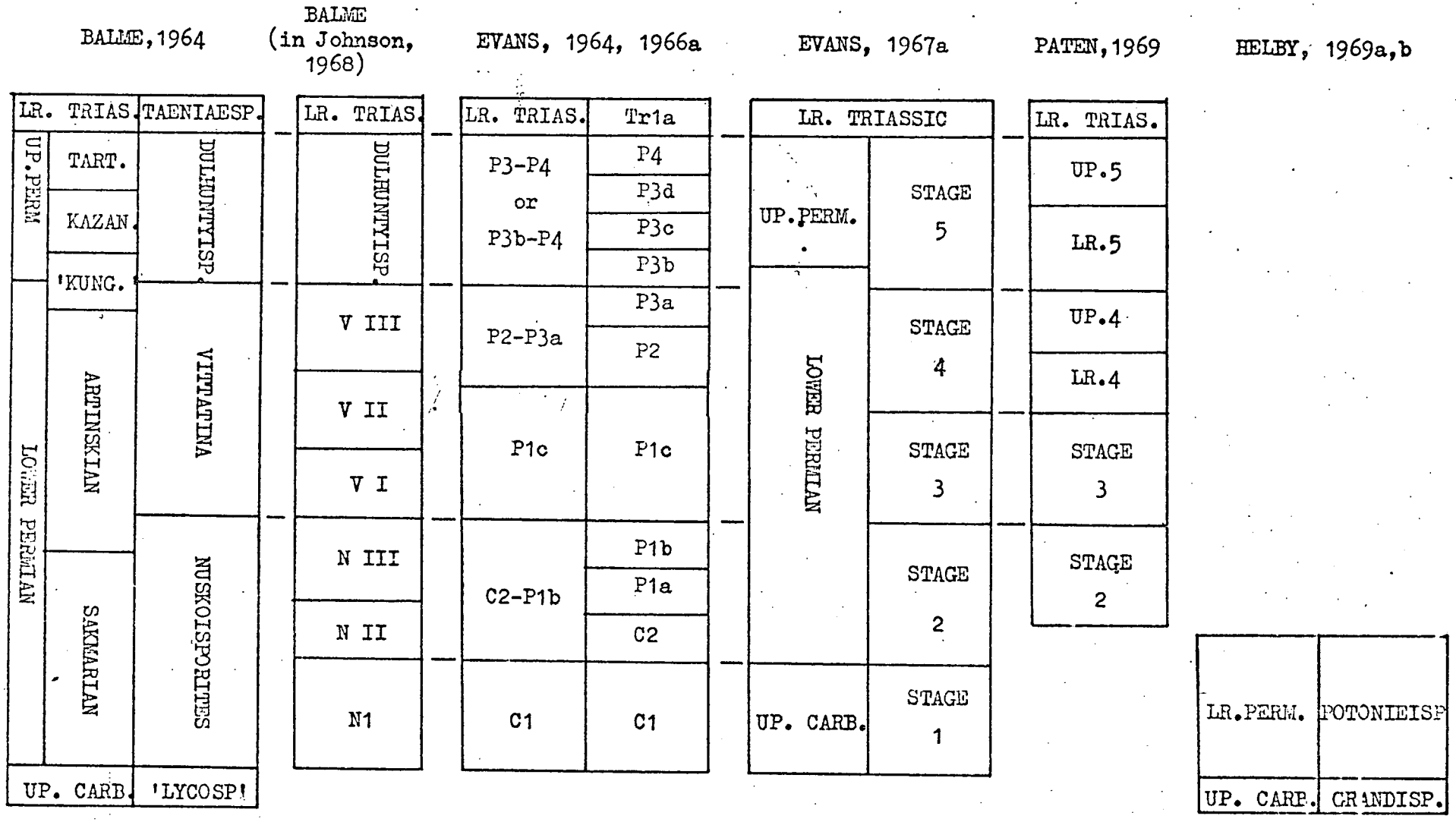


Fig.2. Published palynological zonations of the Australian Permian and Upper Carboniferous.

The confusion surrounding the use of the lettered units was resolved when Evans (1967a, 1969) erected a new palynostratigraphic classification based on the distribution of spores and pollen alone. This division consisted of five numbered stages, running from stage 1, in the Upper Carboniferous, to stage 5, in the Upper Permian. He was able to correlate these throughout most of Eastern Australia and produced maps showing their distribution. Paten (1969) refined this zonation in his study of the Cooper Basin, when he divided stages 4 and 5 on the distribution of certain common and specifically well defined forms.

The work of Evans (1967a, 1969) and Paten (1969) forms the basis of the zonation employed in the present report. The relationship between various zonal schemes used in the past is shown in Fig. 2. One major problem which remains is that many of the species used by Evans have not yet been validly described and were only identified by B.M.R. species catalogue numbers. The numbers were not always quoted when palynological boundaries were described and the complete range of many important species is still in doubt.

Subdivision of the Mesozoic microfloras in Thunderbolt No.1 follows that of Evans (1966a and c). His usage of lettered spore units in the Triassic is in need of revision but unfortunately this is not possible at the present time.

ASSEMBLAGES IN THUNDERBOLT NO.1

Plate 1 shows the vertical distribution of spore and pollen species in the Permo-Carboniferous of Thunderbolt No.1. Described and undescribed forms have been split, rather arbitrarily, into two groups. One group includes all specifically distinct forms, which have restricted stratigraphic ranges and may be of use in biostratigraphic subdivision. Where possible these have been identified with described species or with B.M.R. numbered species. New forms have been assigned B.M.R. species numbers (when more than six specimens have been found). The second group includes forms which either range throughout the succession, or are present in numbers too small to warrant their use at this time. The category also includes all species of saccate pollen. Generic identifications are presented without comment, as a fuller taxonomic study will be published in the near future.

The saccate pollen constitutes a particularly confusing taxonomic problem. Three main groups are present in large numbers in the samples studied; namely, the monosaccates, the non-striate disaccates and the Striatiti. Each of these groups has a wide range of intraspecific variation. Also the morphological limits between species are hard to define accurately and many intermediate forms occur (e.g. between Protohaploxypinus amplus (B & H)[ø] and P. limpidus (B & H)). A thorough taxonomic revision of the whole group is needed before they can be used satisfactorily for zonation. This must await the examination of other assemblages from more well sections.

Carboniferous-Permian:

Long Ranging Forms:

Five species occur more or less frequently throughout the succession and appear to be of little stratigraphic use. These are:

Leiotriletes directus B & H (sp. 207)

Retusotriletes diversiformis (B & H) (sp. 6)

Schizosporis scissus (B & H) (sp. 131)

Apiculatisporis sp. 1104

Cyclogranisporites sp. 107.

Stage 2 (Evans, 1967a, 1969)

Lower Stage 2 (4780 to 5052 feet):

The lowest assemblage present in Thunderbolt No.1 is characterised by abundant:

monosaccate pollen (Parasaccites spp. 51, 190, 191, 50)

Punctatisporites spp.

Phyllothecotriletes spp. 7 & 10

Calamospora spp.

Apiculatisporis sp. 908

Rugulatisporites sp. 22.

[ø]B & H: Balme & Hennelly

A distinctive suite of zonate spores are present, including:

cf. Vallatisporites sp. 36

Vallatisporites sp. 37

Kraeuselisporites sp. 35.

Four other species do not occur above this unit, namely:

Anapiculatisporites sp. 17

cf. Retusotriletes sp. 12

Reticulatisporites sp. 43

Verrucosisporites sp. 910.

Striate pollen occurs very rarely and Protohaploxypinus aff. gorainensis (P & L)+ (sp. 187) makes its first appearance here. Other saccate species present (although not restricted to this assemblage) include:

cf. Vestigisporites sp. 44

Potonieisporites neglectus P & L (sp. 192).

The upper limit of the unit lies between 4694 and 4780 feet, in a series of alternating feldspathic sandstones and shales. There is no evidence from the palaeontology, the lithology or the electric and gamma ray logs for a major sedimentary break at this horizon.

Upper Stage 2 (3940 to 4694 feet):

Samples within this unit show a progressive and gradual change from bottom to top. Thus the lowest samples have abundant:

Phyllothecotriletes spp. 7 and 10*

Calamospora spp. 4* and 58

Punctatisporites gretensis B & H (sp. 5)

Apiculatisporis spp. 908 and 62

Rugulatisporites sp. 22

Monocolpate sp. 106

Lophotriletes spp. 64 and 183

monosaccate pollen spp.

Potonieisporites spp.

+ P & L: Potonié & Lele

with rare

cf. Calamospora sp. 9*

Vallatisporites sp. 37*

cf. Retusotriletes sp. 1105*

Kraeuselisporites sp. 35*

Rugulatisporites sp. 104*

Striatiti spp.

In the uppermost samples a number of these forms have disappeared (those marked with an asterisk above). The Striatiti have become much more abundant and a new group of species have appeared, in particular:

Monocolpate spp. 197 and 186

Granulatisporites sp. 59

Lophotriletes sp. 702.

A boundary between the lower (assemblage A) and upper (assemblage B) microfloras is very hard to define. It is provisionally taken between 4073 and 4168 feet, at the upper limit of:

Cingulati sp. 699

Retusotriletes sp. 1111

cf. Retusotriletes sp. 1105

Didecitriletes sp. 19.

The lowest occurrences at this level of Granulatisporites micronodosus B & H (sp. 111) and Lophotriletes sp. 702 may represent contamination but a third species, Ricaspora sp. 1113, appears to be restricted to assemblage B. The change in lithology at about 4,500 feet, from alternating sandstones and shales to a predominantly shale sequence (see also wireline logs), does not reflect a palynological break.

The upper boundary of upper stage 2 as a whole is marked by the top occurrences of:

Phyllothecotriletes sp. 7

Apiculatisporis sp. 1106

cf. Retusotriletes sp. 1109

cf. Lycospora ap. 1108

Monocolpate sp. 106.

Calamospora sp. 4 has its top just below this level. Rugulatisporites sp. 22, a form whose specific limits are not yet fully understood, becomes much less abundant above this boundary. The base of upper stage 2 is placed at first occurrences of :

Lophotriletes spp. 64 and 183

cf. Granulatisporites sp. 1103

Apiculatisporis sp. 62 appears just above this horizon.

Stage 3 (Evans, 1967a, 1969) (3400 to 3600 feet):

The boundary between stages 2 and 3 cannot be located with accuracy in Thunderbolt No.1, but lies between 3940 and 3600 feet. The side wall core at 3940 feet (M.F.P. 4361) contains an abundant upper stage 2 microflora and marks the top of a number of species listed above. The next sample (at 3714 feet) is heavily contaminated and contains a poor assemblage, all of whose members range above and below. The sample from 3600 feet (M.F.P. 4359) again contains a rich microflora characterised by abundant:

Apiculatisporis spp. 62 and 1104

Sulcatisporites spp.

Striatiti spp.

with significant numbers of

Lophotriletes tereteangulatus (B & H) (sp. 113)

Apiculatisporis sp. 908

Granulatisporites sp. 59

Kraeuselisporites sp. 1112

Lophotriletes sp. 702.

It marks the first appearance of:

Kraeuselisporites sp. 1112

Limitisporites sp. 899

Vitreisporites pallidus (Reissinger) (sp. 135)

Sulcatisporites splendens Leschik (sp. 137).

The succeeding four samples are either completely barren (3510 and 3502 feet), or contain very sparse microfloras (3456 and 3448 feet). The uppermost assemblage in stage 3 (at 3400 feet) is, in contrast, excellently preserved and very rich. It contains most of the species which occur at 3600 feet with a number of new arrivals, including:

Microreticulatisporites sp. 906

Baculatisporites sp. 109

Marsupipollenites triradiatus B & H (sp. 152)

Marsupipollenites sp. 896.

This sample contains the highest occurrences of, among others,

Punctatisporites gretensis B & H (sp. 5)

Apiculatisporis spp. 62 and 908

Monocolpate spp. 197 and 186.

Stage 5 (Evans, 1967a, 1969) (2940 to 3329 feet):

Core 3 (3318-3329 feet) contains a somewhat poorly preserved and restricted microflora, which nevertheless shows a marked contrast to lower samples. It lacks the species mentioned above and contains the first appearance of several others including:

Gnetaceaepollenites sinuosus (B & H) (sp. 151) - Common

Didecitriletes ericianus (B & H) (sp. 115) - Common

Didecitriletes uncinatus (B & H) (sp. 114)

Lunulasporites colliensis (B & H) (sp. 132).

The microflora of the succeeding side wall core (3004 feet) is much better preserved. It is dominated by species of Sulcatisporites and Striatiti and contains all the species mentioned above, together with considerable numbers of:

Baculatisporites sp. 109

Marsupipollenites triradiatus B & H (sp. 152)

Lophotriletes spp. (tereteangulatus and sp. 183)

Granulatisporites sp. 59.

Occurring for the first time are

Dulhuntyispora parvithola (B & H) (sp. 123)

Indospora spp. (incl. 911)

Peltacystia sp. (an undescribed sp.)

The palynological study indicates the presence of a major hiatus between stages 3 and 5, with at least the whole of stage 4 missing. There is an important lithological change in this part of the section, from a less to a more carbonaceous type of sedimentation. At 3444 feet the interpreted lithological log shows a change from a pale siltstone/shale sequence to a carbonaceous siltstone/sandstone/coal sequence. This is accompanied by features on the SP, resistivity and gamma ray logs. Amerada (1967) showed the Upper/Lower Permian boundary at this level.

Unfortunately, an undoubted stage 3 microflora occurs 44 feet above the horizon of this apparent lithological break (3400 feet, M.F.P. 4354). Three possible explanations may cover this discrepancy.

a. The contents of side wall core from 3400 feet may represent an impoverished stage 5 flora, masked by over-riding numbers of reworked species from stage 3. The high standard of preservation in this sample does not agree with large scale recycling.

b. The lithological change (possible disconformity) at 3444 feet is within stage 3, while another one above 3400 feet removes stage 4. Palynological evidence for an hiatus within stage 3 is lacking.

c. The interpretation of the lithological log is incorrect and the change to more carbonaceous sedimentation occurs at a slightly higher level. Electric and gamma ray log characteristics provide little data for this.

None of these hypotheses fully explain all the evidence and the problem remains unsolved.

Triassic (1277 to 2892 feet):

Sample M.F.P. 4411 (2940) feet contains the highest, although poorly preserved, Permian microflora. Just above this horizon the lithology changes from a coaly to a red bed sequence and samples from the succeeding 600 feet are barren. Amerada (1967) correlated the section between 2320 and 2892 feet with the Lower Triassic Rewan Formation. The presumed Permian/Triassic boundary is associated with wireline log features.

Strata between 1892 and 2320 feet were correlated with the Clematis Formation and dated as Lower to Middle Triassic in the well completion report. Two samples from this interval yielded dateable microfloras, the remainder being barren.

The side wall core from 2216 feet (M.F.P. 4403) contained a rich microflora with abundant:

Densoisporites (al. Lundbladispora) cf. playfordi Balme

Densoisporites (al. Lundbladispora) cf. brevicula Balme

Rewanispora spp.

Aratrisporites spp.

Kraeuselisporites spp.

Hamiapollenites insculptus Playford & Dettmann

Striatiti spp. (incl. Taeniaesporites)

and rare:

Stereisporites spp.

Nevesisporites spp.

Calamospora tener (Leschik)

Osmundacidites senectus Balme

Alisporites australis De Jersey

Platysaccus queenslandi De Jersey

Chordasporites australiensis De Jersey.

The presence of common Striatiti, Densoisporites spp. and Aratrisporites spp. are indicative of a Tr2b age (Evans 1966a and c). Evans (in Amerada, 1967) dated this sample Tr2a.

The microflora from core 1 (1972 - 1989 feet; M.F.P. 4413) is less well preserved. It contains common:

Alisporites spp.

Alisporites townrovii Helby

and rare:

Clavatriletes cf. hammenii (Herbst) (sp. 942)

Dictyophyllidites mortoni (De Jersey)

Calamospora tener (Leschik)

Osmundacidites senectus Balme

Aratrisporites spp.

Micrhystridium sp.

Vitreisporites pallidus (Reissinger) (sp. 135).

Striatiti are very rare. The association of Aratrisporites spp. with common Alisporites spp. in the absence of Taeniaesporites spp., Duplexisporites gyratus Playford & Dettmann and Densoisporites spp. suggest a Tr3a-b dating (given as Tr3?a by Evans in Amerada, 1967).

Microfloras from the sequence correlated with the Moolayember Formation (1277-1892 feet) cannot be dated with certainty. They contain recycled Permian forms and angiosperm contaminants from Cretaceous or Tertiary formations. Possible in situ specimens are either heavily corroded and unidentifiable, or belong to long ranging species. Formation boundaries within the Triassic were drawn from lithological and wireline log data. A disconformity at the Triassic/Jurassic boundary is inferred from lithological and palynological evidence.

Jurassic and Cretaceous (38 to 1277 feet):

Microfloral assemblages in a number of samples from the Jurassic and Lower Cretaceous section are described by Burger and Kemp (in prep.) and are quoted without discussion. The two side wall cores contain abundant Permian and Triassic contaminants circulated by drilling mud. The cutting

samples are contaminated by younger Cretaceous forms (spores and dinoflagellates) and datings are based on top ranges of species. No J1-3 assemblages have been described and this interval is probably represented by an hiatus at 1277 feet. Their results are as follows:

Sample No. (M.F.P.)	Depth (feet)	Spore Unit		Formation
4755	cutt. 720-750	K2	)	Wallumbilla
4756	" 750-780	K2	) -	Formation
4757	" 840-870	?	)	
4758	" 900-930	J4-6	)	
4772	" 930-960	J4-6	)	
4773	" 960-990	J4-6	) -	Ronlow Beds
4771	" 990-1020	J4-6	)	
4770	" 1020-1030	J4-6	)	
4389	SWC 1104	J4	)	
4390	" 1124	J4	)	

In the well completion report Amerada (1967) correlated the Cretaceous section with the Toolebuc Member (38 to 118 feet) and Roma Formation (118 to 797 feet). They subdivided the Jurassic into Hooray Sandstone (797 to 838 feet), Westbourne Shale (838 to 972 feet), Adori Sandstone (972 to 1023 feet), Birkhead Shale (1023 to 1128 feet) and Hutton Sandstone (1128 to 1277 feet). The identification of the base of the Toolebuc with a small but significant gamma ray feature is not questioned. However, Vine (1971, in press) revised the rest of this section on gamma ray log stratigraphy and offered a different interpretation. He united the whole of the sequence between 797 and 1277 feet and correlated them with the Ronlow Beds. He indicated that the Ronlow Beds equate with the whole of the Hutton, Birkhead, Westbourne and Hooray units in the west of the Muttaburra area, together with the lowermost Wallumbilla Formation. Strata between 797 feet and the base of the Toolebuc Member were correlated with the remainder of the Wallumbilla Formation, not with the Roma Formation.

DISCUSSION OF ZONATION

Stage 1 and the Carboniferous/Permian boundary

There is some disagreement among palynological workers as to the placing of the Permian/Carbonifeous boundary (see Fig. 2). This is taken generally at the incoming of the Eurydesma fauna (see Runnegar, 1969). Walkom (1945) and David (1950) chose to further define the boundary in

Australia at the replacement of the Upper Carboniferous Rhacopteris macroflora by the Glossopteris macroflora. Balme (1962) demonstrated that the palynological expression of the Glossopteris macroflora lay in the presence of Striatiti. He suggested that striate bisaccate pollen was produced by at least some of the plants with Glossopteris-type venation.

The oldest occurrence of the Glossopteris flora in Australia is in the Boonderoo Beds of Galah Gorge (White, 1964). These are glacigene strata which have yielded microfloras, dated as P1a by Evans (1964)*. The boundary must thus be sought below this level. In continuing his argument from the relationship between the Glossopteris flora and the striate pollen Balme (1964) put the base of the Permian at the base of the lowest division (Nuskoisporites Assemblage) of his Striatites Microflora. Evans (1967a) showed that striate pollen did not appear until above the base of the Nuskoisporites Assemblage; at the NI/NII boundary of Balme (in Johnson, 1968), the C1/C2 boundary of Evans (1964; 1966a) and the stage 1/stage 2 boundary of Evans (1967a). He placed the base of the Permian at this level.

Helby (1969a, b) placed the top of the Carboniferous at a somewhat lower level. He examined evidence from overseas and noted, in the northern hemisphere, coincident palynological (Lycospora to Illinites/Potonieisporites microfloras) and micropalaeontological (Fusulina to Triticites foraminiferal faunas) changes occurring at a level near the base of the Kiaman magnetic reversal. He correlated this horizon with the base of his Potonieisporites microflora and the top of his Grandispora microflora in the Sydney Basin and suggested that the Carboniferous/Permian boundary should lie at this level in Australia. Striatiti do not appear until at least the upper part of the Potonieisporites microflora and so that interval, as described by Helby (1969b), is assignable to stage 1 of Evans (1967a).

For the purpose of this report Walkom's (1945) interpretation of the incoming of the Glossopteris flora and Balme's (1962) and Evans' (1967a) correlation of this event with incoming striate bisaccate pollen are taken for the Permian/Carboniferous boundary. As Striatiti are represented in small numbers in the two lowest samples from Thunderbolt No.1, stage 1 (i.e. Upper Carboniferous strata) is probably not present and the succession begins with stage 2.

* A closely sampled section in Galah Gorge has since been collected by the present author, and a report on the results of the palynological examination of this material will be published in due course.

Stage 2

Evans (1967) erected stage 2 to include assemblages containing the first appearance of striate bisaccate pollen, together with new forms of Apiculatisporis, Lophotriletes and certain cingulate mesosporoids. He equated stage 2 with his earlier spore units C2, P1a and P1b (Evans, 1964, 1966a). Evans (in Amerada, 1967) presented his identification of these spore units in Thunderbolt No.1 without comment (see plate 2) and could not place the C2/P1a boundary with certainty.

From Evans' (1966a) descriptions it appears that spore units C2 and P1a form a palynologically closely related interval. He indicates that the ranges of Phyllothecotriletes (al. Punctatisporites) sp. 7 and Calamospora sp. 4 do not extend above C2, and that Klausipollenites sp. 82 and Monocolpate sp. 164 first occur with P1a. In Thunderbolt No.1 Monocolpate sp.164 has not yet been found and Phyllothecotriletes sp. 7 and Calamospora sp. 4 range to the top of stage 2. In Alliance Jericho No.1 Evans (1966a) found an assemblage intermediate between C2 and P1a (core 6, 3583 feet). In this, characteristic C1/C2 forms, such as Reticulatisporites sp. 43, are associated with Klausipollenites sp. 82 in the absence of Striatiti. He dated this sample as basal P1a or uppermost C2 as Klausipollenites sp. 82 does not appear in ODNL[+] Maranda No.1 until unit P1a. The first occurrence of Klausipollenites sp. 82 in Thunderbolt No.1 lies at the top of stage 2, (presumably upper P1b if the section is complete).

At the P1a/P1b boundary in FD* Alice River No.1 and ODNL Maranda No.1 Evans (1966a) noted the disappearance of

Vallatisporites sp. 37

Rugulatisporites sp. 22,

the first occurrences of

Verrucosisporites pseudoreticulatus B & H (sp. 68)

Marsupipollenites triradiatus B & H (sp. 152)

Protohaploxypinus aff. gorainensis (P & L) (sp. 187)

and an increase in Striatiti and non-taeniate bisaccate pollen. Verrucosisporites pseudoreticulatus B & H (sp. 68) has not been found in the Thunderbolt section. Of the other forms listed, Vallatisporites sp. 37 has been found upto one sample below the P1a/P1b boundary (as given by Evans in Amerada 1967), Marsupipollenites triradiatus B & H (sp. 152) does not appear until high in

[+] ODNL: Oil Development N.L.
* FD: Farmout Drillers N.L.

stage 3, and Protohaploxypinus aff. gorainensis (P & L) (sp. 187) first appears in lower stage 2 samples. The morphological limits of Rugulatisporites sp. 22 are in need of revision but it appears to be abundant at least to the top of stage 2.

Stage 2 has been very fully sampled in Thunderbolt No.1, where at least two subdivisions are recognisable. Unfortunately, the criteria upon which Evans (1964, 1966a) based his units C2, P1a and P1b appear to yield ambiguous results when applied to this well. Their identification with the present subdivision of stage 2 must await examination of additional well sections.

Stage 3

The base of stage 3 was defined by Evans (1967a) at the incoming of

Verrucosisporites pseudoreticulatus B & H (sp. 68)

Granulatisporites trisinus B & H (sp. 703)

new types of cingulate mesosporoids

new types of Lophotriletes and Apiculatisporis.

He also mentioned at the same level, that monosaccate pollen markedly declines in abundance and Striatiti show a corresponding increase. Marsupipollenites spp. rapidly become common at this level, although elsewhere (Evans 1964, 1966a) he noted their first occurrence in spore unit P1b. Paten's (1969) definition of the stage 2/3 stage boundary closely follows that of Evans (1967) when placing it below the first appearance of Verrucosisporites pseudoreticulatus B & H. There is some ambiguity about the lowest range of this species as Evans (1964, 1966a) listed it from as low as unit P1b.

Verrucosisporites pseudoreticulatus B & H (sp. 68) has not been identified from Thunderbolt No.1 and Granulatisporites trisinus B & H (sp. 703) has only been found as two isolated occurrences of questionable worth (in lower stages 2 and stage 5). Marsupipollenites triradiatus B & H (sp. 152) does not appear in the section until high in stage 3. At the moment the stage 2/3 boundary is taken at the major microfloral break between 3600 and 3940 feet, where monosaccate pollen becomes much reduced in abundance, a number of stage 2 forms disappear and where the cingulate mesosporoid sporomorph Kraeuselisporites sp. 1112 appears. Stage 3 may be amenable to subdivision but this must await the examination of more sections. In Thunderbolt No.1 a number of forms appear for the first time in abundance at the top of this unit but intervening samples have very sparse microfloras.

Stage 4

Evans (1966a) experienced difficulty in correlating spore units above P1c outside the Denison Trough. This arose from their definition being based upon microplankton occurrences which have relatively restricted geographical ranges. To overcome the problem he (Evans 1967a, 1969) formulated stages 4 and 5 based entirely on spores and pollen, with the result that they have much wider application.

Stage 4 marks the first appearance of Polypodiidites cicatricosus (B & H) (sp. 134) and Apiculatisporis cornutus (B & H). Evans (1967a) also mentioned the appearance of Didecitriletes ericianus (B & H) (sp. 115) in small numbers near the top of the stage. Paten (1969) used the incoming of Polypodiidites cicatricosus (B & H) to define the base of the stage. He was able to further divide this interval into a lower and an upper part in the Cooper Basin by the first occurrence of Gnetaceaepollenites sinuosus (B & H) (sp.151) at about the middle of stage 4. Polypodiidites cicatricosus (B & H) (sp. 134) and Apiculatisporis cornutus (B & H) have not been identified from Thunderbolt No.1. A rich stage 3 assemblage at 3400 feet is followed by a sample containing abundant Gnetaceaepollenites sinuosus (B & H) (sp. 151) and Didecitriletes ericianus (B & H) (sp. 115), with such characteristic stage 5 microfossils as Didecitriletes uncinatus (B & H) (sp. 114) and Lunulasporites colliensis (B & H) (sp. 132). A major hiatus is postulated between these samples, in which at least the whole of stage 4 and possibly also the lower part of stage 5 are missing. Such an hiatus might explain the apparent absence from the section of Polypodiidites cicatricosus (B & H) (sp. 134) and Apiculatisporis cornutus (B & H). Paten (1969) noted that these two forms disappear or become rare above the middle of stage 5.

Stage 5

Evans' (1967a) stage 5 is marked by the first appearance of Dulhuntyispora spp. and a suite of other distinctive spores. It is characterised by the widespread development of coaly sedimentation and often overlaps older formations or is separated from them by a major disconformity. Evans (1967a) correlated stage 5 with Balme's (1964) Dulhuntyispora Assemblage. Balme placed the Upper/Lower Permian boundary at the base of his Dulhuntyispora Assemblage but Evans has found stage 5 microfloras from below the macrofossil-dated Artinskian Ingelara Formation in the Bowen Basin. From this evidence the Dulhuntyispora Assemblage must be upper Lower to Upper Permian in age.

Paten (1969) recognised an upper and a lower subdivision in stage 5 in the Cooper Basin. The application of his zonation to the Galilee Basin must be checked by examination of more well sections but in Thunderbolt No.1 only upper stage 5 appears to be present. He defined his lower division on the presence of Dulhuntyispora dulhuntyi Potonié (sp. 122). Didecitriletes ericianus (B & H) (sp. 115) is occasionally present, together with some members of the upper stage 4 microflora. These include Polypodiidites cicatricosus (B & H) (sp. 134) in reduced numbers. In his upper unit Dulhuntyispora dulhuntyi Potonié (sp. 122) has not been observed. D. parvithola (B & H) (sp. 123) appears for the first time and is accompanied by abundant Didecitriletes ericianus (B & H) (sp. 115), Microreticulatisporites bitriangulatus B & H (sp. 121) and Gnetaceaepollenites sinuousus (B & H) (sp. 151).

Core 3 in Thunderbolt No.1 lacks species of Dulhuntyispora. It does however contain for the first time, and in abundance, Didecitriletes uncinatus (B & H) (sp. 114), D. ericianus (B & H) (sp. 115), Gnetaceaepollenites sinuosus (B & H) (sp. 151) and Lunulasporites colliensis (B & H) (sp. 132). This would suggest, although not conclusively, that upper stage 5 is present. The succeeding sample (at 3004 feet) has well preserved Dulhuntyispora parvithola (B & H) (sp. 123) and can thus be dated firmly as upper stage 5. It also contains Indospora spp., which Evans (1967a) records only from the top of stage 5. The isolated occurrences of Dulhuntyispora parvithola (B & H) (sp. 123) in side well cores of lower stage 2 and stage 3 age are believed to be drilling mud contaminants.

CONCLUSIONS

The main problem with the previously established Permian palynological zonations is that subdivision boundaries have not in the past been adequately defined. For their use to be made more widely applicable they need to be delimited by the vertical ranges of selected trilete and monolete spores and monocolpate pollen species. For practical purposes, where cutting material is in use, the basis for correlation should be defined on the last occurrences of one or more selected species.

From the study of its closely sampled section in Thunderbolt No.1 it is evident that stage 2 can be subdivided. The units tentatively suggested cannot at present be correlated with Evans (1964, 1966) C2, P1a, P1b divisions. Stage 3 may also be divisable into a number of portions but richer assemblages than those available at the moment need to be examined. Paten's (1969) zonal scheme for stages 4 and 5 in the Cooper Basin provides a useful framework but needs more careful evaluation in other basins in Eastern Australia. Finally, the chief importance of Thunderbolt No.1 lies in its central location in the Galilee Basin.

REFERENCES

AMERADA PETROLEUM CORPORATION OF AUSTRALIA LTD., 1967 - Amerada Thunderbolt No.1 well completion report (unpubl.).

BALME, B E., 1962 - Some palynological evidence bearing on the development of the Glossopteris flora. in LEEPER, G.W. (Ed.) The evolution of living organisms. Melbourne University Press, 269-280.

BALME, B.E., 1964 - The palynological record of Australian pre-Tertiary floras. in CRANWELL, L.M , (Ed.) Ancient Pacific Floras (tenth Pacific science congress series), University of Hawaii Press, 49-80.

BURGER, D., 1970 - Palynological observations on Amoco Towerhill No.A-1 well, Galilee Basin, Queensland. Bur. Miner. Resour. Aust. Rec., 1970/26 (unpubl.).

DAVID, T.W.E., 1950 - The Geology of the Commonwealth of Australia. 3 vols., Edward Arnold & Co., London.

EVANS, P.R., 1964 - A correlation of some deep wells in the north-eastern Eromanga Basin, central Queensland. Bur. Miner. Resour. Aust. Rec., 1964/197 (unpubl.).

EVANS, P.R., 1966a - Palynological studies in the Longreach, Jericho, Galilee, Tambo, Eddystone & Taroom 1:250,000 sheet areas, Queensland. Ibid., 1966/61 (unpubl.).

EVANS, P.R., 1966b - Palynological comparison of the Cooper and Galilee Basins. Ibid., 1966/222 (unpubl.).

EVANS, P.R., 1966c - Mesozoic stratigraphic palynology in Australia. Aust. Oil Gas J., 12(6), 58-63.

EVANS, P.R., 1967a - Upper Carboniferous and Permian palynological stages and their distribution in eastern Australia. Bur. Miner. Resour. Aust. Rec., 1967/99 (unpubl.).

EVANS, P R., 1967b - Review of the Permian palynology of the Sydney Basin, New South Wales. Ibid., 1967/103 (unpubl.).

EVANS, P.R. 1969 - Upper Carboniferous and Permian palynological stages and their distribution in eastern Australia. I Simposio internacional sobre Estratigrafia y Paleontologia de Gondwana, Mar del Plata, Argentina.

HELBY, R.J., 1969a - The Carboniferous-Permian boundary in Eastern Australia: an interpretation on the basis of palynological information. Spec. Publs. geol. Soc. Aust., 2, 69-72.

HELBY, R.J , 1969b - Preliminary palynological study of Kuttung sediments in central eastern New South Wales. Rec. geol. Surv. N.S.W., 11(1), 5-14.

JOHNSON, N.E.A., 1968 - Wapet Blackstone No.1 well completion report. West Australian Petroleum Pty. Ltd., January 1968 (unpubl.).

KEMP, E.M., & BURGER, D., (in prep.) - Palynological observations in the Buchanan, Muttaburra, Tangorin and Hughenden 1:250,000 sheet areas, Queensland. Bur. Miner. Resour. Aust. Rec., (unpubl.).

PATEN, R.J., 1969 - Palynological contribution to petroleum exploration in the Permian formations of the Cooper Basin. A.P.E.A. Journal, 1969, 79-87.

RUNNEGAR, B.N., 1969 - The Permian faunal succession in eastern Australia. Spec. Publs. geol. Soc. Aust., 2, 73-98.

VINE, R.R., 1971 (in press) - Muttaburra, Queensland. Bur. Miner. Resour. Aust. Explan. Notes, SF/55-9.

WALKOM, A.B., 1945 - The succession of Carboniferous and Permian floras in Australia. Proc. Roy. Soc. N.S.W., (1944), 78(1-2), 4-13.

WHITE, M.E., 1964 - 1963 Plant fossil collections from Hughenden area, Great Artesian Basin. Bur. Miner. Resour. Aust. Rec., 1964/64 (unpubl.).

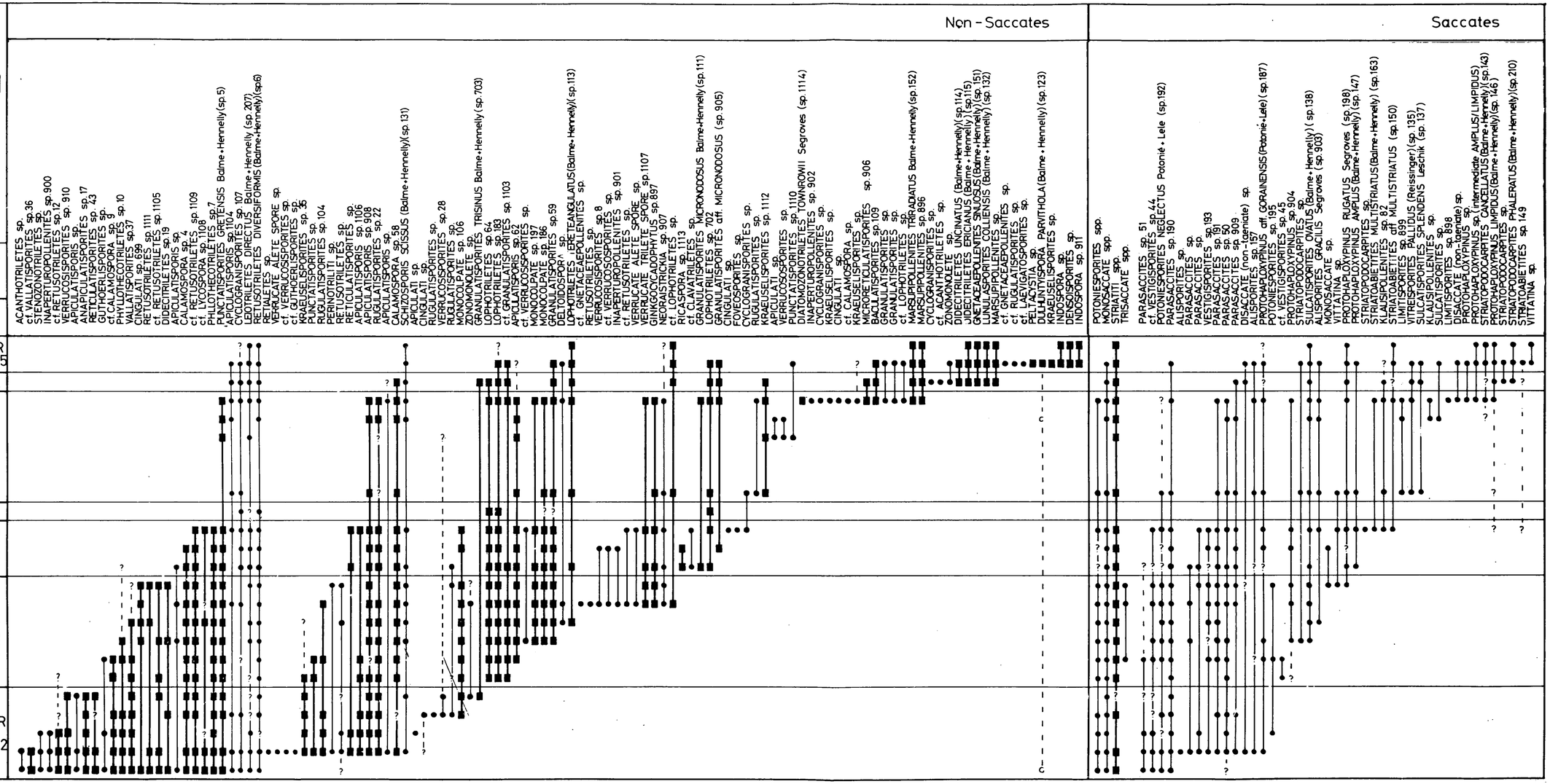
Plate 1

AMERADA THUNDERBOLT No.1

RANGE CHART SHOWING DISTRIBUTION OF SPORE & POLLEN SPECIES

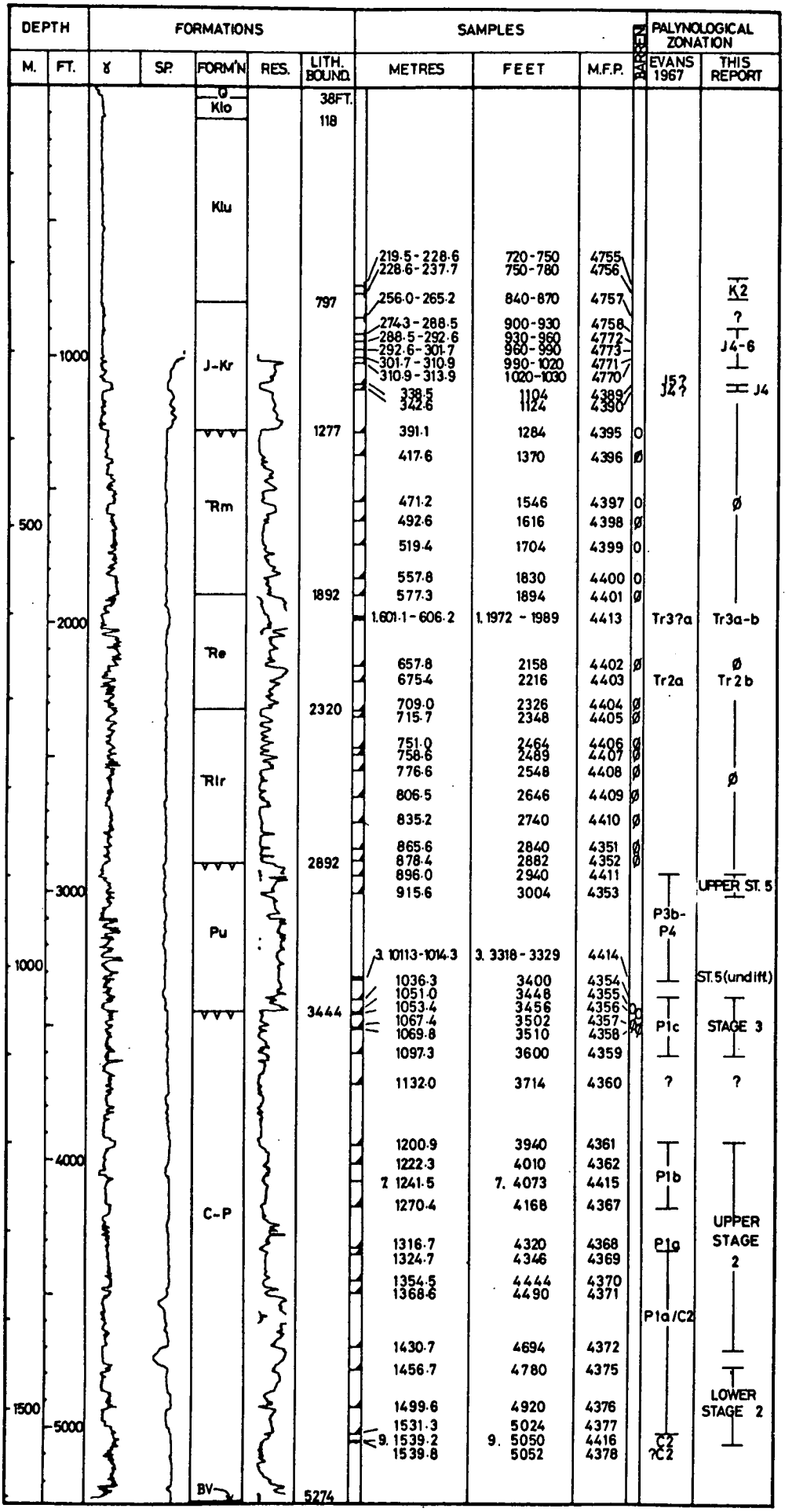
■ Biostratigraphically more useful species
● Other species
∩ Drilling mud contaminants
? Questionable identification

M.F.P. No.	DEPTH Metres	DEPTH Feet	Zonation		
4411	896·0	2940	STAGE 5	UPPER STAGE 5	
4353	915·6	3004			
4414	1011·3 - 1014·3	3318 - 3329		Undiff.	
4354	1036·3	3400	STAGE 3		
4355	1051·0	3448			
4356	1053·4	3456			
4357	1067·4	3502			
4358	1069·8	3510			
4359	1097·3	3600			
4360	1132·0	3714		?	
4361	1200·9	3940	STAGE 2	UPPER STAGE 2	Ass. B
4362	1222·3	4010			
4415	1241·5	4073			
4367	1270·4	4168			Ass. A
4368	1316·7	4320			
4369	1324·7	4346			
4370	1354·5	4444			
4371	1368·6	4490			
4372	1430·7	4694			
4375	1456·9	4780		LOWER STAGE 2	
4376	1499·6	4920			
4377	1531·3	5024			
4416	1539·2	5050			
4378	1539·8	5052			



AMERADA THUNDERBOLT No. 1

STRATIGRAPHY AND SAMPLE DISTRIBUTION



LEGEND

Q	Quaternary
Klo	Toolebuc Member
Klu	Wallumbilla Formation
J-Kr	Ronlow Beds
Rm	Moolayember Formation
Re	Clematis Sandstone
Rlr	Rewan Formation
Pu	Upper Lower • Upper Permian
C-P	?Upper Carboniferous to Lower Permian
BV	Basement volcanics

Cutting sample
Side wall core
Conventional core

Ø Barren sample
0 Indeterminate sample

Lat.: 22° 22' 02" S
Long.: 145° 00' 10" E
K. B.: 761.2 ft. 232.0 m.
G.L.: 742.7 ft. 226.4 m.
T.D.: 5286 ft. 1611.2 m.