

Penola Trough Palynostratigraphic Review

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| | |
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Penola Trough Palynostratigraphic Review

Summary of Conclusions

- C 11 Palynostratigraphic units and subunits can be resolved in the Early Cretaceous lower Eumeralla Formation, Crayfish Group and Casterton Formation of the Katnook #2, Laira #1 and Sawpit #1 reference sections (Appendix 1 Fig 1).
- C The Otway palynostratigraphic succession bears strong similarities with that of the Eromanga Basin; this increases confidence in the chosen datums.
- C Unit APK321 represents a ubiquitous, readily recognised Palynostratigraphic unit confined to the lower Eumeralla Formation extending down to the top of the Windermere Sandstone Member.
- C The initial phase of Eumeralla deposition lies within APK22; Units APK22 and APK31 are widely distributed in the Penola Trough and generally confined to a thin basal sand (Windermere Sandstone) which may represent fluvial channel fills on the Crayfish unconformity surface.
- C The Windermere Sandstone Member - Katnook Sandstone boundary in Katnook #2 does not coincide with base *P. notensis* Zone (APK22) boundary; these sand units seem conformable. There is no palynostratigraphic evidence of an hiatus within the APK321 to APK2 section in Katnook #2.
- C In Laira #1 there is evidence of the Eumeralla - Crayfish unconformity which lies at the base of APK22; Unit Upper APK21 is lost with the youngest Laira being Middle APK21.
- C In Sawpit #1 only the lower part (base of Lower APK21 and Upper APK122) of the Laira Formation is preserved.
- C *Microfaster evansii* persists into the lower Eumeralla (sometimes in notable numbers) and thus is not a definitive indicator of the top of the Crayfish Group.
- C The Crayfish of Katnook #2 and Sawpit #1 overlap but the Katnook section does not extend down to the "Sawpit Sandstone" Member.
- C In Sawpit #1 the Casterton and Pretty Hill are conformable; this probably is the case in Gordon also, although the overlying Pretty Hill is not as well defined palynostratigraphically in this section.
- C The shale at the base of Digby #1 is younger than the Casterton Formation at Sawpit #1 and Gordon #1. The lower sands of the Pretty Hill Formation in Mocambo #11 and Digby #1 are younger than the "Sawpit Sandstone" Member.
- C In Casterton #1 and Gordon #1 the McEachern Sandstone Member is possibly a lower Sawpit "basal shale" equivalent and the "Sawpit Sandstone" equivalent is represented above this.
- C The formation tops and palynostratigraphic limits for the wells considered in this study are summarised on Appendix 1, Figures 5 to 12.

Penola Trough Palynostratigraphic Review

Introduction

The correlation of the Crayfish group across the Penola Trough (and the Otway Basin in general) has been held back in part by the relatively poor resolution of the pollen - spore Early Cretaceous biostratigraphy. Attempts to improve the palynostratigraphic resolution have been hindered by the absence of a sampled section in the axial region that spans the entire interval or a confident log correlation between adjacent overlapping well sequences building to a complete succession. The latter is a result of the rather uniform log and seismic signatures of the Crayfish Group and the complex fault patterns known from seismic sections. Additionally, the palynomorph data used, in common with almost all non marine palynostratigraphies, rely on index taxa that are rare and sporadic at their point of oldest occurrence, facies sensitive and with fluid morphological limits, all contributing to blurred boundary determinations. In the Penola Trough these problems are exasperated by the poor preservation and recoveries from the sandy fluvial sequences (oxidising depositional settings) particularly towards the base of many well sections and at the Eumeralla - Crayfish unconformity. Two problems were focussed upon in the present study.

The first problem addressed is the palynostratigraphic succession over the Eumeralla - Crayfish boundary. Questions of interpretation of the palynological succession arose from the Merino High sections and some of the Robe Trough (eg Nunga Mia #1) and western Penola Trough wells (eg Viewbank #1) where *M. evansii* overlapped *P. notensis* and *Pilosiporites spp* often were intermittent in their distribution. In the latter sections, the need was to define the position of a sand as being either within the Pretty Hill lying at the top of the erosion surface or a channel sand deposited on the Crayfish unconformity surface representing the initial Eumeralla sedimentation; the latter being a more predictable exploration target. The Katnook #2 and Laira #1 sections provided the detailed palynostratigraphic data across the Eumeralla - Crayfish boundary and for the upper Crayfish down to the Laira - Pretty Hill boundary clarifying the palynostratigraphic-lithostratigraphic inter-relationships needed to resolve these problems.

The second problem relates to the extent of the Crayfish Group and how it thins from the axial regions to the flank. Associated with this is the question of how continuous are the Pretty Hill reservoir sands and whether they provide a migration path from the axial region to the flanks. Thus, the other main objective of this study was to provide finer palynostratigraphic control for the Pretty Hill - basal Laira section and to define their relationship to reservoir sequences on the Penola Trough margins. The review of slide materials from Katnook #2 and Laira #1 did provide some palynostratigraphic control for the Pretty Hill section but, overall, the slide preparations and preservation of assemblages deteriorated significantly below the Laira Formation (note the decline in the species diversity of the assemblages graphed on Appendix 1, Figure 13). It was considered from a brief review of the slide preparations from Ladbroke Grove that little more resolution would be obtained from review of the deeper section. In order to relate the revised palynostratigraphy in the Penola Trough wells in this study to the at present informally defined Crayfish sequences of Morton *et al*, 1995 in the Trough margins and in the PEP 119 wells, the relatively better preserved and more diverse assemblages from the Crayfish section in Sawpit #1 (originally studied by Price, 1993) were substituted; their complete and detailed re-examination was required to take into account the changed (usually narrower) species concepts for many of the established index forms and to locate the newly recognised potential index taxa. The Sawpit Crayfish Group section has been pivotal in the definition of the stratigraphically lower of the new palynostratigraphic subdivisions proposed herein. The key to problem was highlighted by Morton *et al* 1995 figure 5.13; it is to relate the Katnook and Sawpit Crayfish sections. Prior to this study, palynostratigraphic resolution has not been sufficient and the log correlation ambiguous; both being complicated by the possibility of faulting in the Sawpit section.

Samples from Katnook 2 (44 samples), Laira #1 (29 samples) and Sawpit #1 (26 samples) were re-examined in detail. The Katnook #2 and Laira #1 samples were prepared by Morgan Palaeo Services Pty Ltd with one to eight oxidised floats slides being available; an unoxidised total “kerogen” slide was also available but not examined in detail in this study. The Sawpit samples were prepared by Laola Pty Ltd

with a + 20 μm unoxidized 2.0sg floats fraction and two or three + 15 μm oxidised 1.65sg floats fraction being examined; the unoxidised total “kerogen” slide was not examined. The slides were scanned with either 16/0.50 or 25/0.80 Plan-Neofluar oil objectives (usually the latter, but depending upon the palynomorph density on the slides) with taxa identifications established under 40/1.0, 63/1.40 and 100/1.35 Planapochromat oil objectives to determine their palynomorph assemblage characteristics; species lists were compiled from these examinations (Enclosures 1 & 2). Counts (100 to 500 palynomorphs) to estimate the relative abundance of the dominant and major subordinate taxa were taken with the 100/1.35 objective; the diversity and relative abundance of species within various palynomorph groups is presented graphically (Enclosures 3 to 6).

The biostratigraphic, broad qualitative palynofacies and environmental data for the study area are tabulated on the Palynostratigraphical Data Tables (Appendix 2); the text provides an overview of the results supplementing the sample by sample descriptions set out in the Data Tables. The palynostratigraphic determinations given on the Data Tables follow the convention of offering an assignment defining the most probable biostratigraphic limits for the sampled horizon. This confident, but often rather broad, assignment is supplemented by a more specific (“best assessment”) determination but with varying degrees of uncertainty depending upon the perceived potential for contamination, preservation and diversity of the palynoflora recovered. The inferred lithostratigraphic and Age assignments are based upon this latter, sometimes more speculative, palynostratigraphic estimate.

In addition to the detailed examination of these samples, the associations from Casterton #1, Gordon #1, Mocamboro #11 and Digby #1 described by Price, 1995 & 1998 were reconsidered with some samples briefly re-examined. Revised species checklists (Enclosure 1) and Palynostratigraphic Data Tables (Appendix 2) are provided. The positions of the palynostratigraphic and lithostratigraphic units in the various well sections considered are summarised against reduced electric logs (Appendix 1)

Sample Distribution

The distribution of samples with adequate palynomorph recoveries in the reference sections studied in this review (Katnook #2, Laira #1 and Sawpit #1) was variable with some notable sample gaps.

In Sawpit #1 the lower Eumeralla sequence was sparsely sampled and the few available had poor palynomorph recoveries such that the Eumeralla - Crayfish unconformity was not defined palynostratigraphically. The lower Pretty Hill and Casterton Formations were well sampled in Sawpit #1 and, despite deterioration of the recovered palynomorphs with increasing thermal maturity, the palynostratigraphy was well defined.

With Katnook #2 only conventional and side wall cores palynofloras were considered so as to avoid problems of contamination from higher in the section that are associated with cuttings (the cuttings were useful in defining the acritarch acmes). The Eumeralla - Crayfish transition was generally well covered although sample gaps between 1932m and 2103m and between 2177m and 2566m hindered the full definition of the APK22 and Upper APK21 sequences; the poor recoveries associated with the sandy sequence in this part of the section was a further hindrance. The Katnook #2 Pretty Hill recoveries were poor reflecting the sandiness of the section and thermal alteration; unit APK122 could not be subdivided.

The Eumeralla - Laira interval in Laira #1 was fairly well covered although a critical sample gap between 2204m and 2457m hindered the resolution of the Middle APK21 - Lower APK21 boundary; fortunately the gaps in the Katnook sequence and Laira did not coincide allowing a composite succession to be built. As with Katnook #2, the upper Pretty Hill sands proved to be too poorly preserved to recognise the subdivisions of APK122.

Otway Basin Stratigraphy

Lithostratigraphic Nomenclature

Morton *et al* 1995 provided a comprehensive review and revision of the Otway Basin lithostratigraphy; their nomenclature has been adopted and set out on Appendix 1 Figure 1. Data acquired since 1995, including some of the palynological results reviewed in this study, suggest further revision may be required.

The present investigations offer no biostratigraphic evidence for a major time break or significant regional unconformity between the Casterton Formation and the lower Crayfish Group (hence the original exclusion of the Casterton Formation from the Otway Supergroup) in the Trough axis or on the Merino High. The presence of *Cyclosporites "quasihughesii"* 839 in several Casterton sections and the recovery of *Ruffordiaspora spp* in the lower parts of the Casterton in Gordon #1 suggest the Casterton Formation is confined to APK1 (or the *R. australiensis* Zone). *Cyclosporites hughesii* has its origins in the upper parts of the Casterton Formation in Sawpit indicating that Unit APK121 is represented and is conformable with overlying Sawpit "Basal Shale" member as Unit APK121 spans the lower third of this basal Crayfish unit. From the better preserved palynofloras recovered from the Casterton sections of Sawpit and Gordon, the perceived antiquity of the Casterton palynofloras (prominence of inaperturate pollen, lack of Cretaceous index taxa) seems to relate to restricted palynofloras representative of a lacustrine and bog depositional environments.

There is a need for a formal definition of the various lithofacies ("Sawpit Sandstone", "Sawpit Basal Shale unit", etc) of the Pretty Hill Formation. The informal "members" adopted by Moreton *et al*, 1995, OCA and SANTOS (Appendix 1 Fig. 1 & 8) are used in this study.

The informal subunits of the Laira Formation in Katnook #2 and Laira #1 (Appendix 1 Figs 5, 6 & 7) are those of Hill, 1995 and are based upon log correlation and acritarch acme events.

A different interpretation of the palynostratigraphy over the base Eumeralla - upper Crayfish boundary has been offered by Price, 1998 and this study (Page 17) that suggests there is no hiatus between the Windermere Sandstone Member and the Katnook Sandstone in Katnook #2. If this is accepted, then the retention of these as separate lithological entities and their placement in the Eumeralla Formation and Crayfish Group respectively needs review. The accepted lithostratigraphic subdivision of the Katnook #2 section by Morton *et al*, 1995 is depicted on Appendix 1 Fig. 5 while an alternative, consistent with the present palynostratigraphy interpretation, is given on Appendix 1 Fig 6. It is emphasised that, before this alternative is accepted for the Katnook reference section, the differences of sand provenance between the Windermere and the Katnook cited by Morton *et al*, 1995 and detailed log correlation over the Katnook field are to be accounted for.

Previous Otway Basin Palynostratigraphic Nomenclatures

The units of Dettmann, 1963 and 1986, Dettmann and Playford, 1969; Burger, 1973, 1988 and 1989; Morgan, 1985, 1988, 1989 and 1992; Helby *et al* 1987 have been used widely in Otway Basin studies and their relationships are summarised on Appendix 1 Fig 2. These nomenclatures however, have been applied in different ways in the various well sections giving some confusion as to what is represented by a particular unit in any given study. The confusion is heightened where similarly named units have been applied with some variation of definition in the Great Australian (Artesian) Basin (GAB) region and in West Australia. Further, there is no absolute consensus as to the precise order of appearance of certain of the Early Cretaceous index taxa in the Otway Basin (and other Early Cretaceous Australian provinces) as their introduction is blurred by factors including the extent of the base Eumeralla unconformity, facies constraints, differing concepts as to the morphological limits of the index taxa and, possibly, floral migration if the interpretation of Dettmann, 1986 is accepted.

The differing order of appearance of certain of the index taxa given by Dettmann, 1986 (figure 3 page 85) relative to that of the GAB or to the order accepted by Morgan *et al*, 1995, Price, 1998 and herein perhaps relates to the data set available to Dettmann, 1986 which lacked an axial well with a complete basal Eumeralla - upper Crayfish sequence (such as Katnook #2) and included the seemingly unique and puzzling distribution of *P. notensis* in Woolsthorpe #1.

Morgan *et al*, 1995 reviewed and revised the Otway Basin palynostratigraphy as part of the comprehensive stratigraphic review of the western Otway Basin by MESA (Morton and Drexel Eds., 1995). The revised nomenclature of Morgan *et al*, 1995 gives some stability to the Otway Basin palynostratigraphy overcoming the ambiguity of the "*C. hughesii* Zone" with the introduction of the "*P. notensis* Zone". This relates to different concepts of the *C. hughesii* Subzone as established by Dettmann and Playford, 1969 (top *C. stylosus* to base *C. striatus* together with some

assemblage constraints particularly in respect of the base of the Subzone) and the “*C. hughesii* Zone (or Subzone)” in its various guises as used by Morgan 1980, 1985, 1992, Price *et al* 1985, Helby *et al* 1987 and Burger, 1973, 1988 (Appendix 1, Fig 2).

The retention by Morgan *et al*, 1995 of the “*F. wonthaggiensis* Zone” for the interval between the entry (base) of *D. speciosus* and *P. notensis* seems unfortunate in respect of its differing use in other parts of Australia and the GAB region in particular. The data of Price, 1998 and the present study, when interpreted in conjunction with Sawpit #1, Digby #1, Gordon #1 and Casterton #1 data, suggests that the range of *D. speciosus* is more like its range in the GAB (eg Burger 1980, 1989) where it extends down closer to the oldest occurrence of *C. hughesii* than to *F. wonthaggiensis* (Appendix 1, Figure 2 & 3). Isolated specimens of *D. speciosus* have been recorded in the Casterton Formation of Sawpit #1 and possibly Camelback #1 and the Westbourne Formation (close to the base *Ruffordiaspora spp* datum) of the Eromanga Basin (Page 20 & 23 for further comment). In the context of potential palynostratigraphic nomenclatural confusion at this stratigraphic level, it is worth noting that Burger, 1989 regarded the base of his 1973 “*C. australiensis* Subzone” as being at the base *D. speciosus* datum and not at the oldest occurrence *R. australiensis* datum (Burger, 1989 fig 3); ie the “*C. australiensis* Subzone” *sensu* Burger, 1973 would lie **within** the “*F. wonthaggiensis* zone” *sensu* Morgan *et al* 1995; (note that the base of the “*C. australiensis* Zone” *sensu* Burger, 1989 is that adopted by most others; that is, the base *R. australiensis* datum).

Thus, the use of *D. speciosus* to define the base of the “*F. wonthaggiensis* Zone” significantly extends its stratigraphic span in terms of both Burger’s 1973 original concept (from base *F. asymmetricus* and *P. notensis* to base *R. ludbrookiae* and *F. wonthaggiensis*) and that of Helby *et al* 1987 (from base *F. asymmetricus* to base *F. wonthaggiensis*). In stratigraphic terms, the “*F. wonthaggiensis* Zone” *sensu* Morgan *et al*, 1995 (equivalent to APK122 + APK21) part of the Crayfish Group is the equivalent of the Cadna Owie + Murta + much of the Namur rather than just the Cadna Owie if an equivalence of the *F. wonthaggiensis* Zone *sensu* Helby *et al*, 1987 and Burger, 1973 1989 (equivalent to APK2) of the Eromanga Basin is accepted

(Appendix 1, Fig 3).¹ In terms of the Eromanga Basin concept of the *F. wonthaggiensis* Zone *sensu* Burger, 1989, the “upper *F. wonthaggiensis* zone” of Morgan, 1993 and Morgan *et al* 1995 is closer to its stratigraphic span; in Katnook #2, Heathfield #1, Laira #1, and Viewbank #1 there is some 200m or less separating the base *T. reticulatus* datum and base *F. wonthaggiensis* datum. In contrast the “lower *F. wonthaggiensis* zone” in Sawpit #1 (some 1,000m+) spans almost all of the upper *C. australiensis* Zone of Burger, 1989.

¹ [Note that the present interpretation of the lithostratigraphic range of some of the index taxa in the Eromanga Basin differs from that given by Alley and White, 1996].

Palynostratigraphic Nomenclature & Application

Introduction

The palynostratigraphic nomenclature adopted for this study is based upon that of Price *et al*, 1985 and Filatoff & Price, 1988 developed initially for the Surat and Eromanga Basin sections but adapted for the Otway Basin by Price, 1993, 1995, 1996, 1997, 1998, 1999; this study further revises it. It has been used instead of the that of Morgan *et al*, 1995 in an attempt to increase the biostratigraphic resolution and to lessen any possible ambiguity with the application of the earlier nomenclatures. The equivalent units of Morgan *et al*, 1995 however, are given on Appendix 1, Fig. 1 and 2 to assist in relating the results of this study to the stratigraphic interpretation given in the 1995 MESA compilation; reference should be made to Appendix 1, Fig. 2 if there is a need to relate the earlier nomenclature of Morgan, 1985 and 1992, Dettmann, 1986 and Dettmann and Playford, 1969, Burger, 1973, 1982, 1989 and Morgan *et al*, 1995 to this study.

The relationship of the palynostratigraphic units to the Otway Basin and Eromanga Basin lithostratigraphy is presented on Appendix 1, Fig. 1 and 3; their relationship to the Katnook #2, Laira #1 and Sawpit #1 Penola Trough Reference Sections are given on Appendix 1, Figures 5 to 12. The range of selected index taxa relative to the present units is given on Appendix 1 Fig. 4; these ranges draw on data both from the GAB region and the Otway Basin.

The present nomenclature's units are based mostly upon oldest occurrence datum of individual taxa arranged hierarchically (Appendix 1 Fig. 1, 2 & 4) more or less according to their regional and facies extent and ease of application. The application of individual units to a particular well section is tempered by local factors such as preservation and the palynofacies association. It should be noted that a number of taxa are undescribed and many of those described have been used with a more restricted morphological range than may be accepted by other workers; the "splitting" of established taxa has been in an attempt to increase palynostratigraphic resolution. The philosophy of the units and species concepts are more fully

described by Price and Filatoff, 1987 and Price, 1997.

In addition to the more established regional units, three fold subdivisions of units APK21 and APK321 are introduced; these are based partly on assemblage concepts (supported by some species oldest occurrences). While they follow the general palynofloral succession in the GAB, they are based primarily on the Otway associations and remain to be tested and refined on a more regional basis.

Palynofacies Associations

In an attempt to better define the index taxa distribution in terms of environmental and facies constraints, the broad species abundance data were used to define several “palynofacies” associations which are recorded on the appended Palynostratigraphic Data Tables.

- “**Ruffordiaspora - Cyathidites Palynofacies**” Ferns dominant; mostly *Cyathidites*; *Cyathidites* mostly *C. minor*; *Ruffordiaspora* notable &/or modestly diverse; *Pilosisorites* scarce or absent.
- “**Pilosisorites - Cyathidites Palynofacies**” Ferns dominant; mostly *Cyathidites*; *Cyathidites* mostly *C. minor*; *Pilosisorites* notable and diverse; *Ruffordiaspora* notable &/or modestly diverse.
- “**Pilosisorites - Osmundacidites Palynofacies**” Ferns dominant; *Osmundacidites* \$ *Cyathidites*; *Pilosisorites* notable and diverse.
- “**Ruffordiaspora - Osmundacidites Palynofacies**” Ferns dominant; *Osmundacidites* \$ *Cyathidites*; *Ruffordiaspora* notable &/or modestly diverse; *Pilosisorites* scarce or absent; Lycopods conspicuous.
- “**Conifer - Ruffordiaspora Palynofacies**” Conifer pollen dominant with inaperturate pollen conspicuous to prominent. Fern spores prominent; *Ruffordiaspora* conspicuous to notable; *Pilosisorites* scarce or absent. Lycopod spores notable.
- “**Osmundacidites - Retitriletes Palynofacies**” Ferns dominant; *Pilosisorites* absent; *Ruffordiaspora* scarce or absent; *Osmundacidites* — or \$ *Cyathidites*; *Cyathidites* mostly *C. australis*; Lycopods conspicuous or notable and relatively diverse.
- “**Osmundacidites Palynofacies**” Ferns dominant; *Pilosisorites* absent; *Ruffordiaspora* scarce or absent; *Osmundacidites* O *Cyathidites*; *Cyathidites* mostly *C. australis*; Lycopods scarce.
- “**Cyathidites Palynofacies**” Ferns dominant; *Pilosisorites* absent; *Ruffordiaspora* scarce or absent; *Cyathidites* > *Osmundacidites*; *Cyathidites* mostly *C. australis*; Lycopods scarce.
- “**Lycopod Palynofacies**” Lycopod > Ferns \$ Gymnosperms.
- Conifer - Osmundacidites Palynofacies**” Gymnosperm \$ cryptogams; Ferns prominent; *Pilosisorites* absent; *Ruffordiaspora* scarce or absent; *Osmundacidites* \$ *Cyathidites*; *Cyathidites* mostly *C. australis*; Lycopods notable and modestly diverse.
- “**Conifer Palynofacies**” Gymnosperm O cryptogams. *Pilosisorites* absent; *Ruffordiaspora* scarce or absent.
- “**Casterton Palynofacies**” Palynodebris diffuse; Palynoflora restricted; mostly conifer remnants.
- “**Casterton aquatic Palynofacies**” Palynodebris diffuse; Palynoflora restricted; mostly conifer and leiosphere remnants

Unit APK321

The distinctive palynofloras of APK321 are usually diverse including a wide range of morphological variation within *Pilosisorites* complex (with both *P. parvispinosus* and *P. notensis* represented). A variant of *Foraminisporis wonthaggiensis* (*F. wonthaggiensis* “*lunaris*” 1519) seems confined to APK321 and perhaps does not extend to the very base; *F. wonthaggiensis* “*wonthaggiensis*” is usually consistent to the base of APK321 but becomes scarce and intermittent below. APK321 palynofloras are the most consistent and easily recognised palynostratigraphic datum in the Eumeralla - Crayfish section. In many cases the base APK321 coincides with the placement of the base *P. notensis* Zone by Morgan Palaeo Services (Morgan, *pers com* July 1999). In contrast to the GAB, where *Foraminisporis asymmetricus* (the base APK31 datum) seems more reliable, unit APK321 is a primary unit in the Otway Basin.

Its application however, can be difficult in some sections. Interspersed with and immediately underlying the typical diverse APK321 palynofloras are both fern dominated and conifer dominated associations that are very restricted in species diversity; some of which are almost indistinguishable from Crayfish Group APK12 associations (eg Churinga #1 SWC16 1225.0m; Nunga Mia #1 SWC24 1302.5m and SWC22 1349.0m; Penley #1 SWC29 1075m and also in many of the Merino High wells). Thus, the reliable resolution of APK321 often requires close sampling; the base of the unit could not be defined in the sparsely sampled upper section of Sawpit #1 for example.

Units Upper APK21, APK22 and APK31

Below the range of *P. parvispinosus*, *Pilosisorites* spp become scarce but may retain a degree of morphological variation initially; they have their deepest occurrence (base APK22) within these associations. *Foraminisporis asymmetricus* makes its appearance (base APK31) above the oldest occurrence of the *Pilosisorites* spp however, a stratigraphic separation of these two taxa is not resolvable in many

sections. Although the APK22 and APK31 palynofloras can be reasonably diverse including a consistent and modest diversity of *Ruffordiaspora spp* together with the last of the morphologically similar *Plicatella spp* (*P. "giganticus"* 1283 and *P. sp cf P. problematicus* 915), many are restricted (perhaps reflecting the sand facies; note the Katnook #2 diversity plots Appendix 1 Fig 13 and Enclosures 3 & 5) fern dominated (often mostly *Cyathidites minor*) associations and conifer dominated palynofloras both with very rare, intermittent occurrences of *P. notensis* and / or *F. asymmetricus*.

Individually, in the absence of the index taxa, these associations are difficult to assign; however, the consistent occurrence of notable numbers and modestly diversity (in terms of two or more 'species' being represented) *Ruffordiaspora spp* (and related forms) characterise the Upper APK21 - APK22 - APK31 palynofloras. *Foraminisporis wonthaggiensis sl* and some other bryophyte-like forms are reasonably consistent in the more diverse of these associations. They have been resolved in closely sampled wells across the eastern Robe Trough (eg Nunga Mia #1, Churinga #1), Penola Trough (eg Penley #1, Killanoola #1 and Katnook #2) and Merino High of Victoria where they form a consistent palynostratigraphic interval. Sometimes the individual units of Upper APK21, APK22 and APK31 are resolved but often, if sparsely sampled and with restricted assemblages that characterise the interval, are referred more broadly to "Upper APK21 to APK31" or "no older than Upper APK21". It should be noted that these restricted "no older than upper APK21" association can occur also within the diverse associations of APK321 (eg Churinga #1 SWC16 1225.0m; Nunga Mia #1 SWC24 1302.5m and SWC22 1349.0m; Penley #1 SWC29 1075m).

It is of interest to note that the deepest of the some of the rarer morphologically similar forms to *Ruffordiaspora* (eg *Plicatella "giganticus"* 1283 and *Fisciniasporites "burgeri"* 818) (both present at the base of the APK22 - APK31 sequence in Churinga #1 (SWC13 1252m) for example) and the base of the *Ruffordiaspora* "consistent occurrence of notable numbers and modest diversity" interval (base Upper APK21) have a similar distribution in the Surat and Eromanga

Basins. *F. "burgeri"* extends a to about the base *F. wonthaggiensis* datum but *P. "giganticus"* seems to extend no lower than the base *P. notensis* datum.

There is perhaps a slight suggestion that isolated occurrences of *P. notensis* may occur lower in the Crayfish Group; for example that of Woolsthorpe #1 and a rather tantalizing occurrence in Penley #1 (the latter most likely to be contamination because of the state of the SWC, but cannot be totally dismissed until Woolsthorpe is re-examined). Thus, emphasis is placed on the association of a modest diversity of *Ruffordiaspora* complex and other palynofacies criteria in association with these isolated to rare *P. notensis* occurrences in terms of the placement of the lower APK22 boundary.

The separation of the oldest occurrence datum of *F. asymmetricus* and *P. notensis* in the GAB is relatively slight being essentially coincident in the absence of very close sampling; perhaps there is a suggestion of a slight hiatus in parts of the Eromanga Basin as the APK2 - APK3 boundary lies near the top of the Cadna Owie and the base of the marine influenced Wallumbilla sediments.² The stratigraphic separation of these taxa in the Otway Basin is probably equally small but this is difficult to fully assess as *F. asymmetricus* is very patchy in its distribution in the Otway section below APK321 particularly in the more specialised *Cyathidites* and Conifer dominated palynofloras from parts of the Windermere Sandstone where all Bryophytic forms can be scarce. Also, its stratigraphic extent may be blurred by records of a similarly ornamented form ("*Verrucosasporites*" "*pseudoasymmetricus*"); for example, the records of *F. asymmetricus* at 1475.5m in Tullich #1, 1006m in Mocamboro #11, 1825.8m in Heathfield #1 and 1388.5m in Greenways #1 may need some scrutiny. It is worth noting that, in the Eromanga Basin, *F. asymmetricus* and *F. wonthaggiensis* seem more consistent and reliable markers than *P. parvispinosus* and *P. notensis*; this seems to be the converse of the Otway Basin palynostratigraphic succession.

² [Alley and White, 1996 fig 6.1 and Alexander and Sansome 1996 fig 5.17 show a significant separation but there may be some confusion over the different definitions of "PK22" of Price *et al* 1985 (base *Trilobosporites purverulentus*) and "APK22" of the present nomenclature (base *Pilosporites notensis*)].

Thus, the distinction between section assigned to one of Upper APK21, APK22 and APK31 should be accorded a degree of scepticism unless there is very close sampling and some reasonably diverse associations are recovered **but** their separation from APK32 (above) or Middle APK21 and Lower APK21 (below) is much more easily sustained and reliable (but not invariably so).

The Eumeralla - Crayfish Regional Unconformity

In many parts of the Otway Basin the mid Otway Supergroup unconformity is readily defined by the contrast of the diverse APK321 Eumeralla associations directly overlying the bland APK122 Crayfish palynofloras. In some locations (eg Nunga Mia #1 SWC22 1349.0m; Churinga #1 SWC 13 1252m) these associations are separated by a thin veneer Upper APK21 - APK31 section often associated with a sand (interpreted here to be the Windermere Sandstone Member) but lack the middle APK21 and lower APK21 associations (including those with notable proportions of the presumed algae *Microfosta evansii*) of the Laira Formation represented in Katnook #2 and to a lesser extent in Laira #1, Viewbank #1, Heathfield #1 amongst others.

Katnook #2 well contains the most complete section sampled over the basal Eumeralla and Laira Formations on the basis of both log correlation and the palynostratigraphic succession; it is probable that the Eumeralla - Crayfish sediments are conformable (or at the least, very close to). The widely accepted lithostratigraphic interpretation of Morton *et al* 1995 depicted on Appendix 1 Figure 5 places the Eumeralla - Crayfish boundary at 1892.0m separating the Windermere Sandstone Member from the Katnook Sandstone and is coincident with their placement of the *P. notensis* Zone - "*F. wonthaggiensis* Zone" boundary (Morton *et al* 1995 fig 5.14). However, *Pilosporites notensis* extend down lower to at least 1896.5m and possibly 2103.0m (depending on whether the latter isolated specimen is considered as being endemic or contamination) while *Foraminisporis asymmetricus* extends to 1925.0m. Thus, in the type section of the Katnook

Sandstone, the *P. notensis* Zone (or APK22 - APK32) extends at least into the top of the Katnook Sandstone (to at least 1896.5m) and possibly encompasses it if the present interpretation of the palynostratigraphy is accepted (Appendix 1 Fig 5). Irrespective of whether it is accepted that the *P. notensis* at 2103.0m is contamination or not, the assemblages to 2155.0m and probably 2177.0m are representative of the Upper APK21 - APK31 transition associations. In assessing the distribution of Upper APK21 - APK22 - APK31 and *P. notensis* in Katnook #2 it should be noted that many of the palynomorph recoveries over the interval 1875m to 2132m were low and restricted (Appendix 1 Fig. 13 and Enclosures 3 & 5) and no diagnostic assemblages were recovered from between 1932m and 2103m.

Bearing in mind that Upper APK21 - APK22 - APK31 associations occur immediately above APK122 sediments in areas where an angular unconformity is clearly visible on seismic (eg Churinga, Nunga Mia), it seems reasonable to associate this section with the Eumeralla depositional cycle. It is possible that the Upper APK21 - APK22 - APK31 sections (often a sand or including sands) represent river channel fill on the Crayfish erosion surface. However, if it is accepted that the Eumeralla - Crayfish boundary is conformable in the Katnook #2 reference section then there is no reason for the APK22 - APK21 (*P. notensis* Zone - "*F. wonthaggiensis* Zone") boundary to coincide with it by necessity (and the present study suggests it does not). The modified lithostratigraphic subdivision given on Appendix 1 Fig. 6 reflects this interpretation in which the lithostratigraphic boundaries are not tied to the biostratigraphic boundaries and Units Upper APK21 and probably APK22 extend into the top (rarely preserved part) of the Crayfish Group.

In considering the distribution of the Upper APK21 - APK22 - APK31 in relation to the basal Eumeralla - uppermost Laira sections in the individual wells, account must be taken of the palynomorph recoveries when applying the subunits. In Laira #1 and Gordon #1 for example, the log signature and position would suggest the interval should be APK31 but neither *F. asymmetricus* nor *P. notensis* were located indicating an Upper APK21 assignment. While it is possible that with a basal sand, there may have slight variation in age between disparate channel fills on the Crayfish

unconformity surface and/or a minor local hiatus between the Windermere sand and Eumeralla Shale, it is more likely that it is a reflection of the fickleness of the index taxa distribution and the palynofloras are best broadly assigned to “Upper APK21 to APK31”. Indeed, in the areas where the “Upper APK21 - APK22 - APK31” associations lie directly on APK122 (ie where there is the erosion/non deposition break) it is probable that these represent an impoverished APK22 or APK31 association.

The other palynostratigraphic criterion that has been used previously to distinguish the the *P. notensis* Zone basal Eumeralla from the “*F. wonthaggiensis* Zone” Crayfish is the extinction (youngest occurrence) of the presumed algae *Microfosta evansii* (Morgan *et al*, 1995). However, recent studies (including the present study) indicate that this acritarch frequently occurs (sometimes as a notable component) with *Pilosisorites spp* both in typical APK321 palynofloras; (eg Casterton #1 at 1096m, Mocamboro #11 at 832.6m, Gordon #1 at 1118.0m, Digby #1 at 1096.8m) and in APK22 - APK31 associations (eg Nunga Mia #1 at 1349m, Churinga #1 at 1252m, Digby #1 at 1220.8m, Gordon #1 at 1184.0m, Penley #1 at 1075m) in the eastern Robe Trough, Penola Trough and Merino High. In the case of the Katnook #2 reference section, it occurs within the lower Eumeralla Formation (1874.46m, 1874.97m, 1877.24m) and is conspicuous at 1877.24m in the Eumeralla Formation immediately above the Windermere Sandstone Member. Its occurrence in APK321 and APK31 - APK22 section is consistent with its distribution recorded in the GAB sequence (eg Burger, 1973, 1982, 1989 who recorded its extinction at the top of his *F. asymmetricus* Zone (that is, in the uppermost part of APK321)) and has been recovered in APK321 section in the onshore Gippsland Basin (eg Dettmann, 1986).

Thus, *Microfosta evansii* is not the “golden bullet” (infallible indicator) for the identification of the pre *P. notensis* Zone Crayfish section.

Units Middle APK21 & Lower APK21

Following Morgan 1993 and Morgan *et al* 1995 use of the base *Triporoletes reticulatus* datum to subdivide the “*F. wonthaggiensis* zone”, Price, 1993, 1997, 1998, 1999 adopted this datum as the indicator for the base of APK212 by and the base of its consistent occurrence defines the base of Middle APK21 of the present study separating it from Lower APK2. The base of APK2 (and Lower APK2) is defined by the appearance of *Foraminisporis wonthaggiensis* In the Eromanga Basin, distribution of *T. reticulatus* as it is known to extend down below the range of *F. wonthaggiensis* to just above the base of *D. speciosus* albeit as very rare, scattered occurrences. [cf Alley and White, 1996 Fig 6.1]. In the Otway Basin it is assumed that the *T. reticulatus* datum is above the *F. wonthaggiensis* datum; however, in many sections *F. wonthaggiensis* and *T. reticulatus* appear to have similar oldest occurrence points (eg, the Katnook #2 data of Morgan, 1989 and herein; Heathfield #1, Morgan, 1989; Viewbank #1, Price 1997, Laira #1 Morgan, 1990, 1993 and herein.³ In this context, it is worth considering that *T. reticulatus* is reasonably consistent in the Eromanga Basin down to within APK21 and very rare and sporadic below the base *F. wonthaggiensis* datum. It is possible the relative stratigraphic distribution of these taxa in the Otway Basin will prove to be similar to that of the Eromanga Basin (perhaps its distribution in East Avenue #1 (Hooker, 1998) may be giving a hint of this). The present estimation of their Otway distribution may be obscured both by their scarcity at the base of its range (often for reasons of poor preservation) and by the assumption that the “*F. wonthaggiensis* Zone” is the equivalent unit in both the GAB (Burger’s Zone) and Otway Basin (Morgan’s Zone).

The APK22 and APK31 palynofloras of the Otway Basin (and the GAB equivalents) typically include a diversity (but often are only a minor component of the palynoflora) of liverwort forms that include *Triporoletes reticulatus* *Aequitriradites* spp, *Cooksonites* spp, *C. variabilis*, “*Verrucosasporites*” spp and *Januasporites* spp. These forms decline down section in Upper and Middle APK21

³ [Note that Morton *et al* 1995 Fig 5.14 indicate that the “upper *F. wonthaggiensis* zone” extends down only to about 2150m in Katnook #2 but the taxa distribution data of Morgan, 1989 and the present data indicate *T. reticulatus* is present to at least 2595.5m].

and are generally absent in the Lower APK21 and APK1 associations. A similar down section decline is noted in the Eromanga and Surat Basins, but some of these forms may become established again (albeit sporadically) in units APK11, APJ6 and APJ5. Thus, Middle APK21 (equivalent to APK212 of Price, 1998) perhaps is best considered as being in part an assemblage zone (the consistent occurrence of *T. reticulatus* as being but one of its characteristics) with a somewhat vaguely defined base.

The recognition of Middle and Lower APK21 allows the discrimination of the upper Laira Formation of Katnook, Viewbank and Heathfield regions from the lower Crayfish above the "Sawpit Sandstone" in Sawpit (Appendix 1, Figures 1 and 5 to 8) and may facilitate the resolution of the upper Cadna-Owie from the lower Cadna-Owie and Murta in the Eromanga Basin; their recognition is crucial to the resolution of the Merino High Crayfish section and their absence is the principal biostratigraphic evidence of erosion at the top of the Crayfish Group in the Nunga Mia - Churinga region of the Robe Trough and the Penley - Killanoola region of the Penola Trough. The Lower APK21 - Middle APK21 and the APK122 - Lower APK21 boundaries lie within the lower Laira in Katnook #2 and Laira # 1 and parallel the acritarch - log correlation of Hill, 1995 between these wells (Appendix 1 Figs. 5, 6 & 7).

The order of pollen and spore taxa entry given for the Western Australian section by Helby *et al* 1987 and Backhouse, 1988 remains enigmatic in relation to the Eromanga and Otway palynofloral succession. Almost all of the index taxa lying between the entry of *Ruffordiaspora* (= *Cicatricosisporites*) *australiensis* and *Foraminisporis asymmetricus* in eastern Australia appear at about the one level in the West (that of the *R. australiensis* oldest occurrence datum; Helby *et al* 1987 Fig 13 and Backhouse 1988 Fig 34). This gives the impression of an older (earlier) entry (with respect of the *F. asymmetricus* and *Ruffordiaspora* oldest occurrence data) for many of these index taxa (eg *P. notensis*) in West Australian sections. Compounding the problem of east - west correlation (and also for the Eromanga to Otway correlation), is the differing perceptions of the base of the range of *Foraminisporis asymmetricus* in the Otway Basin; (for example, compare Dettmann, 1986 Fig 3 with the present interpretation on Appendix 1, Fig 1, 2 and 4).

Upper Laira Formation Correlation

As discussed above (Page 14 & 17) the Upper APK21 - APK22 - APK31 interval is usually either lost to the Eumeralla - Crayfish unconformity or preserved as thin veneer with the commencement of the Eumeralla deposition; it is only represented at the top of the Laira in the conformable Katnook #2 sequence where Upper APK21 and APK22 span the upper Laira Formation litho-units 5 and 4 (Appendix 1, Figs 5 & 6). They seem absent in the top of the Laira in Laira #1 where Middle APK21 is represented confirming the erosion of the top Laira implied by log correlation. In Sawpit #1 the youngest Laira preserved is representative of the base of Lower APK21; the distinctive Middle APK21 and Upper APK21 associations of the upper Laira Formation (which, in Laira and Katnook, include a prominence of *Microfaster evansii*) were not present. Thus, all but the lower part of the Laira has been eroded.

Within the Middle APK21 sequence of Laira #1 several assemblages (SWC37 1945m, SWC35 1961 and SWC31 2204m) included two or more species of *Ruffordiaspora* and related forms. While it is tempting to assign the shallowest two of these to Upper APK21 (in keeping with the litho-subunit 4 assignment which, in Katnook #2, yielded Upper APK21 palynofloras), they are inter-dispersed with typical Middle APK21 associations and the *Ruffordiaspora* are a very scarce component. Similar "Middle APK21 - like" palynofloras with sparse *Ruffordiaspora* were encountered in the Merino High wells of Digby #1 (1318.1m & 1364.4m) and Mocamboro #11 (942.7m & 943.0m). In this case, their assignment was less clear cut and perhaps distorted by an isolated *P. notensis* recorded in Mocamboro #11 at 965m by Morgan, 1991; this occurrence implies that APK22 is represented and the section is a Windermere Sandstone correlative. The log signature of these wells is not easily interpreted in terms of the "usual" Penola Trough Crayfish log pattern and the possibility of contamination of SWC at 965m must be considered with respect of the *P. notensis* (some contamination is noted in adjacent samples in Morgan's 1991 study).

Despite the thinness of the Crayfish Group on the Merino High, Middle APK21 were recovered in Gordon #1, Mocamboro #11 and possibly Digby #1 underlying the APK22 - APK31 Windermere equivalents. This suggests a mid Laira Formation equivalent is represented although in Digby #1 and Mocamboro #11 it is a rather arenaceous section perhaps more typical of the Pretty Hill in lithological character. In Gordon #1 the Middle APK21 associations overlie Upper APK122 section representative of the basal Laira and upper Pretty Hill; it seems possible that either a fault intersection or a mid Crayfish hiatus is present to account for the loss of the Lower APK21. A similar pattern seems to occur in the Mocamboro and Digby sections although no lower Laira Formation seems present and the underlying APK122 is representative of the upper Pretty Hill Formation.

Unit APK12

As noted above, the base *D. speciosus* datum (base APK122) lies well down into the Crayfish Group within the Sawpit #1 “basal shale” unit (the top of subunit B “McEachern Sandstone” equivalent; Appendix 1, Figure 2). Isolated specimens of *D. speciosus sl* have been recorded almost to the base of APK1 in the upper Westbourne Formation of Eromanga Basin and also in the Casterton of Sawpit #1 and possibly in Killanoola #1 and Camelback #1; of those examined recently, the deeper occurrences seem to conform to *D. speciosus “strigosus”* 4668. Thus, the base of APK122 is taken as the base of consistent *D. speciosus sensu lato* in general and *D. speciosus “speciosus”* 824 in particular. It should be noted that the distribution of the APK1 index taxa in the Otway Basin is often limited by the decline of preservation down section reflecting the increase of maturity and the generally poor preservation of the palynofloras in the silt and sand facies of the lower Crayfish. For example, in Katnook #2 *D. speciosus* is not recorded below 3035m which is the deepest sample with reasonable palynomorph recoveries and diversity (Appendix 1 Fig. 13; Enclosures 3 & 5); its absence in the palynofloras below this cannot be taken as an indication of the section’s antiquity.

Three subunits have been established in Unit APK122 in the Sawpit #1 reference section reflecting the deepest consistent occurrence of liverwort - like forms particularly *Aequitriradites spinulosus* (base Upper APK122) and the deepest occurrence of the “large” *Ruffordiaspora* including *R. ludbrookiae* “*parallelus*” 5057, *R. ludbrookiae* “*controversius*” 680 and *R. “mega-australiensis*” 5047 (base Middle APK122). These boundaries fall above and below (respectively) the Pretty Hill “Sawpit Sandstone” member. The distribution of these subunits are not well tested but are consistent with palynomorph distribution trends in the Eromanga Basin. These subzones have their limitations; Upper APK122 index taxa are easily lost particularly in poorly preserved assemblages and the Lower APK122 forms are extremely rare and sporadic in their distribution. Thus many of the APK122 sections will remain undifferentiated with the subunits being applicable only closely sampled sections with some reasonably diverse assemblages (and a high degree of perseverance to find them!). The preservation and recoveries in the APK122 associations of Katnook #2 and the lower parts of Laira #1, Casterton #1, Gordon #1, Mocamboro #11 and Digby #1 limit their application in these sections; however, they suggest that the lower sands in Mocamboro #11 are younger than the “Sawpit Sandstone” member and that the lower shale in Digby may be younger than the Casterton of Sawpit or Gordon.

The base *Cyclosporites hughesii* 693 and 4662 datum (base APK121) is only a little below the *D. speciosus* datum and in the Sawpit #1 reference section lying at the top of what was considered here to be the Casterton Formation (Appendix 1, Figure 1 & 8) and in a similar position in Bus Swamp #1. It should be noted that Morton *et al* 1995 (Morton *et al* 1995, fig 5.10) and Price, 1993, 1996, 1997 regarded the lowest sub unit of the “basal shale” in Sawpit #1 (2450m - 2461.5m) as being part of the Pretty Hill Formation (and Crayfish Group); however, a recent compilation by the Minerals and Petroleum Victoria (MPV) considered it as being the uppermost part of the Casterton Formation. This broader concept of the Casterton Formation was accepted by Price, 1997, 1998 and applied in this study.

Basal Laira - Pretty Hill Formation Correlation

The palynological interpretation favours a partly overlapping relation of the lower Laira and Pretty Hill sections in Sawpit and Katnook #2 more or less equivalent to Morton *et al* 1995 fig 5.13b correlation in which the upper Laira Formation is eroded in Sawpit at the Eumeralla - Crayfish unconformity and the "Sawpit Sandstone" member lies below the extent of the Katnook well section. In the present correlation of Sawpit #1 (Appendix 1, Fig. 8), only the Lower APK21 basal Laira is preserved with the distinctive Middle and Upper APK21 assemblages and associated *M. evansii* "blooms" of the upper and middle Laira Formation not being represented. There is a suggestion from seismic evidence that the top of the Pretty Hill in Sawpit may be abbreviated by faulting but this is beyond the resolution of the palynostratigraphic sampling.

The alternative correlation (Morton *et al*, 1995 figure 5.15a), in which it is suggested that the well sections cover much of the same extent of the Laira and upper Pretty Hill with the "Sawpit Sandstone" representing the top Pretty Hill sand in Katnook #2, is seductive if the well log sections are considered in isolation. The palynological data from the Pretty Hill could be interpreted to lend support by correlation of the "no older than Middle APK122" assignment at 2870.6m and 2875.5m in Katnook #2 (at the Laira - Pretty Hill boundary; Appendix 1, Fig. 5) with the Sawpit #1 "Middle APK122" assignments from the top of the "Sawpit Sandstone" and lower part of the overlying "Sawpit upper shale" (1751m to 1890m; Appendix 1, Fig. 8). This correlation however, does not conform with the Upper APK122 assignment over the basal Laira Formation in Laira #1 (2630m and 2676.5m; Appendix 1, Fig. 7) nor to the positioning of the Upper APK122 *Microfaster evansii* deficient associations from between 1292.5m to 1743m in Sawpit #1 opposite the Middle APK21 and Upper APK21 *M. evansii* rich palynofloras from Laira #1 (1938.0m to 2204m) and Katnook #2 (2111.5m to 2595.5m). Additionally, the seismic data indicates the need to accommodate some 1300m of Pretty Hill at the base of and below Katnook #2 well section (Moreton *et al* 1995 fig 5.13) in the 575m top "Sawpit Sandstone" to base "Sawpit Basal Shale" interval of Sawpit. This can be achieved either by thinning (reduced depositional/subsidence rate) of the total interval

(however, the seismic does not show significant convergence of the Pretty Hill horizons between Katnook and Sawpit) or by onlap of the upper Pretty Hill over the basal Pretty Hill (the part below the Katnook well section) across the Casterton Formation (however, no angularity or truncation of the lower Pretty Hill against the Casterton boundary can be seen on seismic; the palynological evidence in Sawpit indicates the Casterton and basal Pretty Hill are conformable with no significant time break (see discussion below)).

The correlation of the Crayfish Group from the axial reference sections east to the Victorian Merino High is not significantly changed by this study which generally supports the conclusions of Price, 1998. In this region there are few assemblages recovered from the basal Pretty Hill McEachern Sandstone Member and none have sufficient recoveries to be certain that they are representative of Lower APK122 as apposed to being from the Middle or Upper APK122 subunits.

Immediately above the McEachern Sandstone in Gordon #1, an assemblage (SWC40 1761m) indicated that Middle APK122 is represented; this broadly supports the Price, 1998 correlation of this part of the section with the upper part of the Sawpit "Basal Shale" unit and the overlying sand to the "Sawpit Sandstone" member. In Casterton #1 the assemblages from 1711.2m and 1374.0m are typical of Upper APK122. The presence of Upper APK122 at 1711,0m indicates that the Pretty Hill sand immediately above this sample is younger than the "Sawpit Sandstone" rather than its correlative as suggested by Price, 1998. In view of this, the sand underlying the sample at 1711.2m is now thought to equate with the "Sawpit Sandstone" and suggests that there is a degree of thickening of the overall lower Pretty Hill section from Casterton to Gordon (compare Appendix 1, Figure 9 with Figure 10). No other sample from this interval in the McEachern - Casterton - Gordon region of the Merino High had a sufficient recovery to be relied upon in terms of the finer subdivision of AKK122. The suggestion discussed by Price, 1998 of a mid Crayfish unconformity separating the Pretty Hill from the Laira in this region remains a point for consideration.

Further to the south east, the Mocamboro #11 data suggests the lower Pretty Hill sands there are younger than the Sawpit Sandstone equivalent (being assignable to Upper APK122; Appendix 1 Fig. 11) and the basal shale in Digby #1 probably is younger than the Casterton Formation of Sawpit or Gordon with a no older than Middle APK122 assemblage being recorded from the only sample with reasonable recoveries (Appendix 1 Fig 12). The base Digby shale is probably the equivalent of the shale above the "Sawpit Sandstone" and the Upper APK122 dated deepest sand of Mocamboro #11 (equivalent on log correlation to the Digby sand that overlies the Middle APK122 shale) is younger than the "Sawpit Sandstone". Thus, contrary to the conclusion of Price, 1998 that the "Sawpit Sandstone" and younger Pretty Hill was lost (to the mid Crayfish unconformity) in the Mocamboro - Digby region, it seems that it is McEachern Sandstone and the "Sawpit Sandstone" equivalent that is absent with the Mocamboro - Digby basement being emergent in Casterton and early Pretty Hill times.

Unit APK11

The assignment of the Casterton palynofloras has posed a problem as they are usually very restricted in species diversity sometimes reflecting poor preservation due to thermal maturity but also as a function of the specialised palynofloras associated with the lacustrine, swamp and peat bog environments. These associations are typically dominated by inaperturate pollen (wind dispersed conifer pollen) and leiospheres (aquatic algae); these phylogenetically disparate groups are often hard to distinguish in the indifferent preservation conditions. However, the presence (albeit as isolated specimens) of *Ruffordiaspora spp* almost to the base of Gordon #1 (the best preserved Casterton palynofloras recovered to date) and *Cyclosporites "quasihughesii"* 839 within the Casterton Formation of Gordon #1, Sawpit #1, Killanoola #1 and Casterton #1 (in its broader sense) suggests that the Casterton Formation lies wholly within APK1 with its upper limits probably extending into APK121.

The presence of APK121 in the uppermost Casterton Formation (depending on how the Sawpit, Robertson and Bus Swamp sections are interpreted) in the context of the APK121 - APK122 boundary lying within the Pretty Hill (not its base)

suggests that the Casterton Formation and the Pretty Hill Formation are conformable at least in the Penola Trough and probably also in the Merino High sections. In the GAB region APK121 is relatively thin and probably confined to the lower Namur Sandstone and possibly the uppermost Westbourne Formation (Appendix 1 Fig 4); it seems the Casterton Formation is the time equivalent (more or less) of the Westbourne Formation.

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