PALYNOLOGY OF

SCALLOP-1

GIPPSLAND BASIN, AUSTRALIA

by

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1762.0 m swc : *K. edwardsii* Dino Zone

1770.0 m swc : indeterminate : non-marine (floodplain)

1800/05 m cutts – 2204.0 m : *L. balmei* Zone : Paleocene : marginally marine and non-marine

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2402.5 m swc : lower c subzone

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2529.5 m swc : lower a subzone

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2586.7 m swc : upper b subzone

2601.5 m swc : upper a subzone

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2758.0 m swc : upper b subzone

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2898.0 m swc – 3097.2 m swc : lower c subzone

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3165.0 m swc : indeterminate

2 INTRODUCTION

Forty two samples have been studied from Scallop-1 to achieve high resolution using close sampling including cuttings, modern processing, and generating quantitative data. This approach is producing higher resolution especially in the Cretaceous than was achieved in the 1970's when many of the original discovery wells were last studied.

The overall Cretaceous zonation framework is shown in Figure 1, from Helby, Morgan and Partridge (1987). The detailed Cretaceous subzonation is shown on Figure 2, from Morgan (2003), with the finest subdivisions somewhat tentative and still under test. The Tertiary zonation framework is shown in Figure 3 and is from Partridge (1976, pers. comm.).

Although Cretacoeus dinoflagellate zones were recognised in Angler-1 in the *T. lilliei* Zone by Morgan (2002a) the Scallop-1 equivalent section proved to be entirely non-marine and thin, and so the dinoflagellates zones and events cannot be recognised. Discussion of these can be found in Morgan (2002a) and they incorporate extensive new taxonomic work by Marshall (1988, 1990) and Roncaglia et. al (1999) and stratigraphic work by Morgan (1989, 2002a, 2002b) and Partridge (2002a, b).

Palaeoenvironmental assessments are based on specimen counts of 100 specimens, also providing a percentage content of all species. Criterea for the palaeo-environmental subdivisions are given on Table 1. Backup data (listing % content of major plant groups) is given as Table 2. In running text, rare = <1-3%, frequent = 4-10%, common = 11-30%, abundant = 31-50% and superabundant = 51-100%.

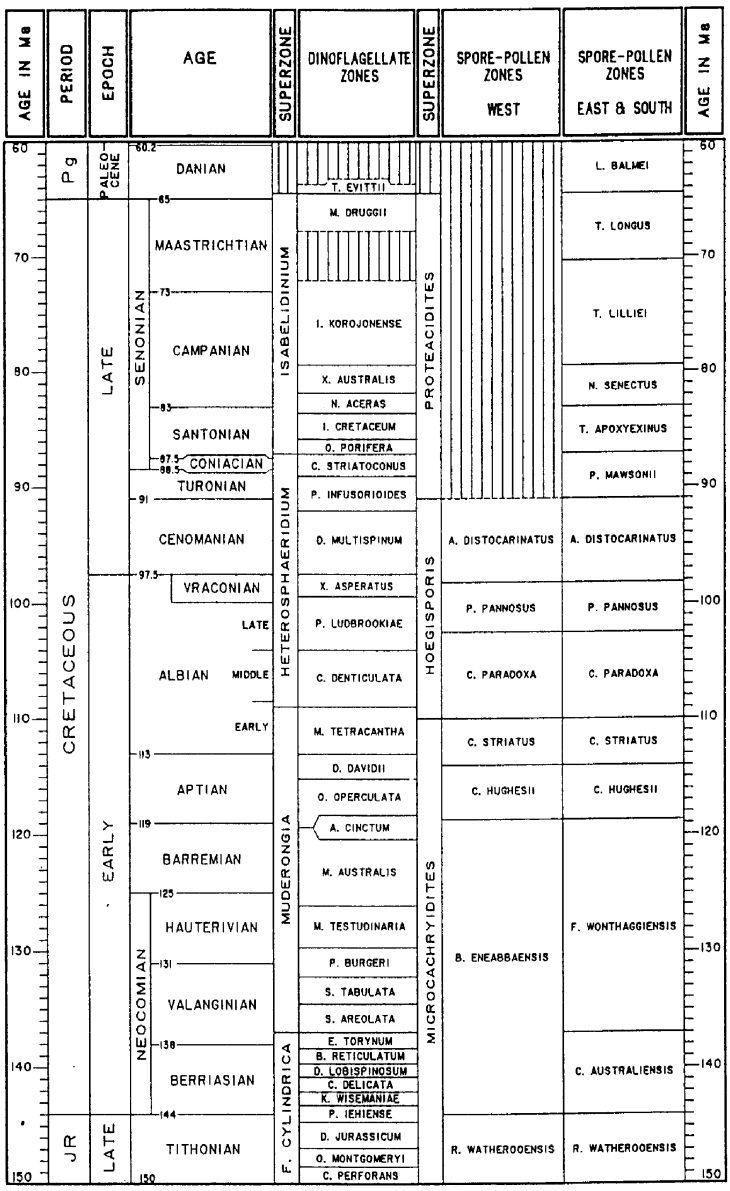

Figure 1a ZONATION FRAMEWORK - LATEST JURASSIC TO PALEOCENE

(from Helby et al, 1987)

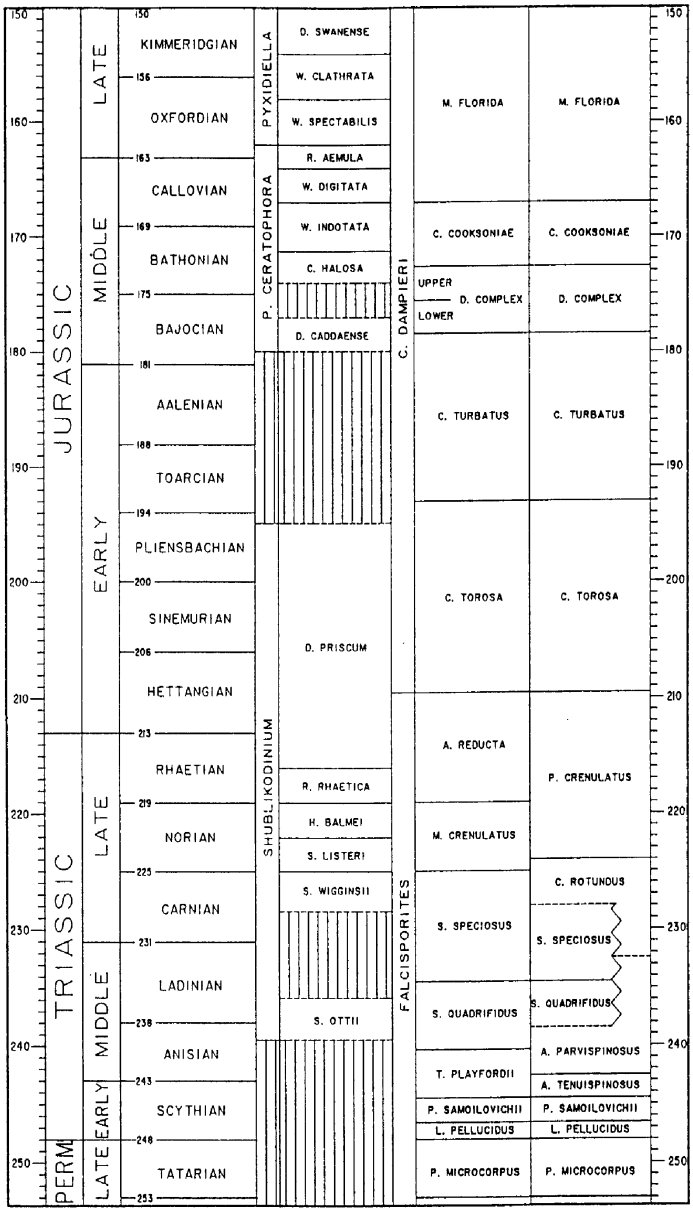

Figure 1b ZONATION FRAMEWORK - LATE PERMIAN TO LATE JURASSIC
(from Helby et al, 1987)

	SPORE-POLLEN EVENTS	SPORE-POLLEN SUBZONES			DINOFLAGELLATE EVENTS	DINOFLAGELLATE SUBZONES	DINOFLAGELLATE SUBZONE (SENSU PARTRIDGE)
	base *P. grandis* *	Upper *L. balmei*				*A. hyperacanthum*	
	top *I. "antipoda"*						
	top frequent *A. obscurus*	Lower *L. balmei*			top *E. crassitabulata*		
	base frequent *A. obscurus*				base *E. crassitabulata*	*E. crassitabulata*	
	base common *L. balmei*						
	base *I. "antipoda"*				top *T. evittii*		
	top consistent *G. rudata*				base *T. evittii*	*T. evittii*	
	top *T. confessus* *	Upper *F. longus*			top *M. conorata*	*M. druggii*	
	top *T. verrucosus*				base *M. conorata*		
	top *T. sectilis, T. lilliei, F. longus*						
	top frequent *G. rudata*						
	top common *A. obscurus*						
	base common *A. obscurus*						
	base *G. rudata* > *N. endurus*						
	base *S. puncatus*						
	top common *N. endurus* *	Lower *F. longus*		c			
	base common *G. rudata* **			b			
	top *T. "megasectilis"* **			a			
	base *T. "megasectilis"*						
1.	base *F. longus* *						
2.	base *T. verrucosus* *						
3.	base *T. waipawaensis*	Upper *T. lilliei*		b			
4.	top *F. sabulosus*						
5.	more consistent *F. sabulosus* **			a			
					6. consistent dinoflagellates *	Upper *I. marshallii*	
					7. freq/common dinoflagellates		
					8. top *I. marshallii*		
					9. base *C. bretonica*		
10.	*N. endurus* influx *	Lower *T. lilliei*		c			
					11. top common *I. marshallii* *	Middle *I. marshallii*	*V. spinulosa*
12.	top consist/frequent *F. sabulosus* **			b			
					13. base common *I. marshallii* *		
14.	top *G. rudata* increase **			a			
					15. base *I. marshallii*	Lower *I. marshallii*	
16.	base *B. sectilis* *						
17.	base *T. lilliei* *						
		Upper *N. senectus*		b	18. base *V. spinulosa*		
					19. top frequent *I. variabile*		
					20. top *T. suspectum* *	Upper *I. variabile*	
21.	top frequent *F. sabulosus* **			a			
					22. top common *I. variabile* *	Middle *I. variabile*	*T. suspectum*
					23. top *Nelsoniella* spp. *		
					24. top frequent *Chatangiella* spp.	Lower *I. variabile*	
25.	base *G. rudata* *						
26.	base frequent *Nothofagidites* **	Lower *N. senectus*		c			
27.	base frequent *F. sabulosus* **			b			
				a	28. top common *C. arvensis* *	*C. arvensis*	*C. arvensis*
					29. base common *C. arvensis* *		
30.	base consist *Nothofagidites* *						
31.	base *F. sabulosus*	Upper *T. apoxyexinus*				*I. ponticum*	*I. ponticum*
					32. top common *I. ponticum*		
					33. base *T. suspectum*		
					34. top common *C. porosa* *	*C. porosa*	*C. porosa*
					35. base common *C. porosa*		
36.	base frequent *Proteacidites* *						

FIGURE 2 **DETAILED SUBZONATION SUMMARY (MORGAN 2003)**
Single Asterisk * shows defining event for upper/lower subzone
Double Asterisk ** shows defining event for a/b/c sub-subzones

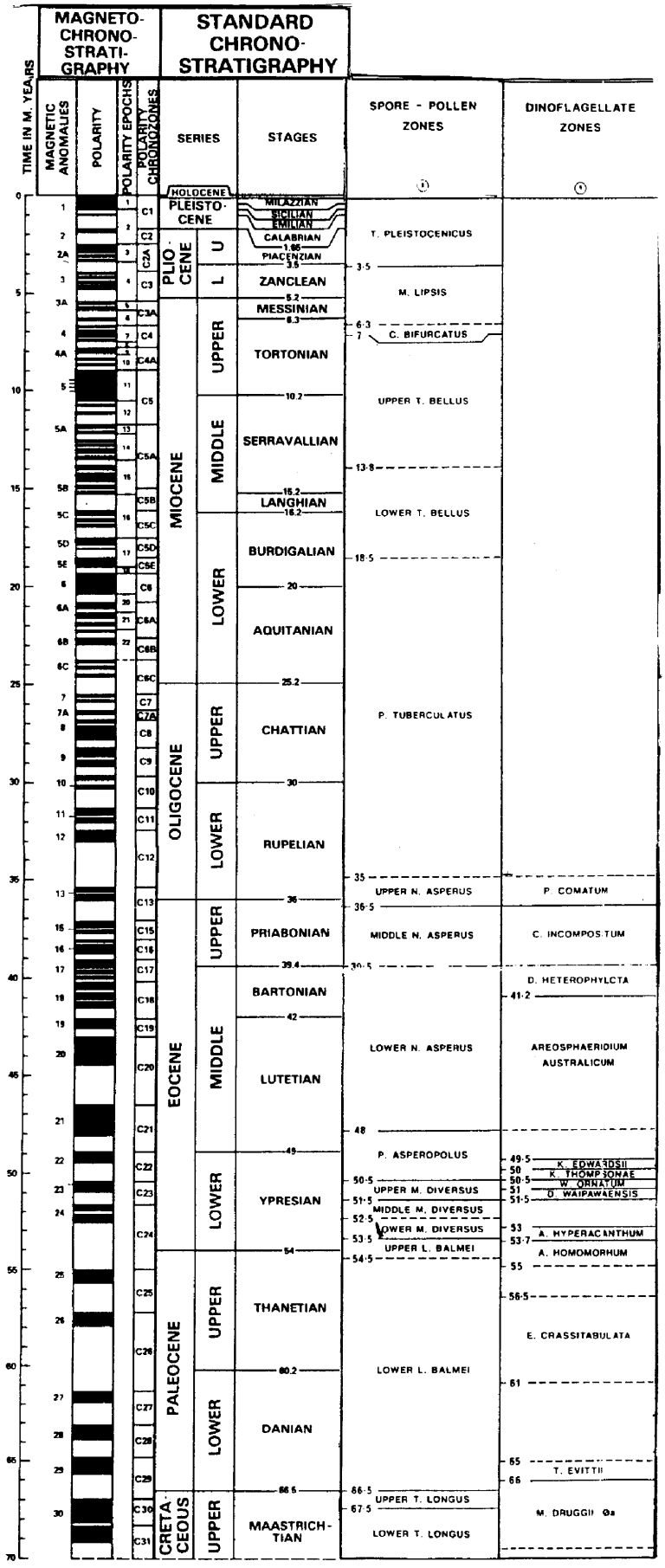

FIGURE 3 **TERTIARY ZONATION SCHEME (Partridge 1976 and pers. comm. using time scale of Haq et al)**

3 PALYNOSTRATIGRAPHY

3.1 1725.0 m (swc) – 1762.0 m (swc) : *P. asperopolus* Zone

Abundant amorphous organic matter (AOM) dominates with spores and pollen minor. Assignment is indicated at the top by youngest *Cupanieidites orthotheichus, Malvacipollis diversus* and frequent *Haloragacidites harrisii*, and the absence of younger markers especially dominant *Nothofagidites* spp., and the base by oldest *Kisselovia edwardsii* supported by oldest *Proteacidites asperopolus* at 1725.0 m (swc). Frequent to common are *Cyathidites minor, Dilwynites granulatus, Falcisporites similis, H. harrisii, Phyllocladidites mawsonii* and *Podosporites microsaccatus*. Rare elements include *Anacolosidites acutullus, C. orthoteichus, Intratriporopollenites notabilis, Malvacipollis diversus, P. asperopolus, Proteacidites pachypolus* and *Santalumidites cainozoicus*. A single *Gambierina rudata* at 1725.0 m (swc) is considered reworked.

Microplankton are different in each sample. At 1725.0 m (swc), *Botryococcus* spp. and *Oligosphaeridium* spp. are common, and rare *Areosphaeridium australicum* and *Deflandrea truncata* indicate the *A. australicum* dinoflagellate Zone. At 1745.0 m (swc), freshwater *Botryococcus* spp. are abundant, and saline markers absent. At 1762.0 m (swc) *Botryococcus* spp. are common with rare *K. edwardsii* indicating the *K. edwardsii* dinoflagellate Zone.

Environments are nearshore marine to non-marine as below. Backup data are in Table 2.

1725.0 m swc	: nearshore marine : common but low diversity saline dinoflagellates
1745.0 m swc	: non-marine lake : abundant freshwater algae (*Botryococcus* spp.), no saline markers, saccate pollen subequal to spores
1762.0 m swc	: marginal marine : minor (<1%) saline dinoflagellates, common freshwater algae (*Botryococcus* spp.)

3.2 1770.0 m (swc) : indeterminate

Abundant AOM dominates. Spores and pollen are minor and long-ranging and not zone diagnostic. Common are *F. similis* and *Vitreisporites pallidus* with frequent *Araucariacites australis, C. minor, Cyathidites splendens, H. harrisii,*

Laevigatosporites ovatus, Microcachryidites antarcticus, P. mawsonii, Proteacidites spp. Rare elements include *Clavifera triplex, Periporopollenites polyoratus, Proteacidites grandis* and *Verrucosisporites kopukuensis,* but are not zone diagnostic. The relative lack of angiosperms probably favours a *L. balmei* Zone assignment over something younger.

Marine taxa are absent, indicating non-marine environments. Backup data are in Figure 2.

1770.0 m swc : non-marine floodplain : no saline markers, few (3%) freshwater algae, saccate pollen dominate spores

3.3 1800/05 m (cutts) – 2204.0 m (swc) : *L. balmei* Zone

Inertinite and AOM dominate these assemblages, diluting the recognisable palynomorphs and reducing precision. Spore-pollen zonal assignment is indicated at the top by youngest *Lygistepollenites balmei* and at the base by *L. balmei* and *G. rudata* without older markers, supported by the dinoflagellates. Dinoflagellates zones are identified at 1800/05 m – 1936.5 m (*A. hyperacanthum* Zone on *Apectodinium homomorphum* throughout without younger markers), 2050/55 m (?*E. crassitabulata* Zone on a marine band including *Deflandrea speciosus* without other markers) and 2204.5 m (*T. evittii* Zone on *Trithyrodinium evittii* without other markers).

Within the interval, the following events may be useful for correlation, at least locally. All samples are listed, but not all contain obvious events.

1800/05 m cutts : top *L. balmei, A. homomorphum*
1837.5 m swc : top frequent *N. endurus,* isolated *G. rudata*
1875/80 m cutts : base frequent *N. endurus*
1905/10 m cutts :
1936.5 m swc : base *A. homomorphum*
1990/95 m cutts : top frequent *A. obscurus*
2050/55 m cutts : acme *A. obscurus* (29%), isolated *D. speciosus*
2090.0 m swc : base frequent *A. obscurus, Proteacidites* spp. spike (26%) top *S. puncatus,* isolated *G. rudata*
2125/30 m cutts : top frequent *S. antiquasporites*
2192.7 m swc : base frequent *S. antiquasporites*
2204.5 m swc : top consistent *G. rudata, T. verrucosus, S. punctatus*

isolated *T. evittii*, dinoflagellate spike (7%)

Common are *C. minor, F. similis, M. antarcticus, P. mawsonii* and *Proteacidites* spp. with frequent *D. granulatus, Gleicheniidites* spp., *Lygistepollenites balmei* and *V. pallidus.* A distinctive acme of frequent to common *Australopollis obscurus* occurs at 1990/95 m cutts – 2090.0 m and has correlative polential. Rare elements include *N. endurus, H. harrisii* and *P. gillii*. Extremely rare are *G. rudata, S. punctatus* and *T. verrucosus*.

Environments are non-marine to marginally marine as below. Backup data are in Table 2.

1800/05 m cutts	: marginal marine : frequent (5%) extremely low diversity saline dinoflagellates
1837.8 m cutts	: nearshore marine : common (13%) extremely low diversity saline dinoflagellates
1875/80 m cutts	: marginal marine : extremely rare (1%) extremely low diversity dinoflagellates
1905/10 m cutts	: marginal marine : extremely rare (<1%) extremely low diversity dinoflagellates
1936.5 m swc	: marginal marine : rare (2%) extremely low diversity dinoflagellates
1990/95 m cutts	: marginal marine : extremely rare (<1%) extremely low diversity dinoflagellates (possibly caved)
2050/55 m cutts	: marginal marine : extremely rare (2%) extremely low diversity dinoflagellates
2090.0 m swc	: non-marine (floodplain) : no saline markers, no freshwater algae, saccate pollen dominate spores, high angiosperms
2125/30 m cutts	: brackish marine : trace saline markers (microforaminifera)
2192.7 m swc	: non-marine (floodplain) : no saline markers, frequent freshwater algae (4%), saccate pollen dominate spores, high angiosperms
2204.5 m swc	: very nearshore marine : frequent low diversity saline dinoflagellates (7%)

3.4 2250/55 m (cutts) – 2350/55 m (cutts) : upper *F. longus* Zone

Assignment is indicated at the top by youngest *Tricolpites confessus* supported by the dinoflagellates, and at the base by oldest *S. punctatus* supported by the absence of

older markers. *M. conorata* at 2250/55 m indicates the *M. druggii* dinoflagellate zone. Within the interval, the following events may be useful for correlation, at least locally. Formal naming of subzones in this interval is premature and awaits the generation of more quantitative data sets.

2250/55 m cutts	: top *T. confessus*, top few L. balmei isolated *M. conorata* (dinoflagellate)
2304.0 m swc	: top *T. lilliei*, spike *S. antiquasporites* (23%), *S. punctatus* (5%)
2350/55 m cutts	: top influx frequent *G. rudata* (9%), influx *A. obscurus* (3%) top *F. longus,* base *S. punctatus* base *G. rudata* consistently dominant over *N. endurus*

Within the interval, common are *C. minor, S. antiquasporites* and *Proteacidites* spp. with frequent *G. rudata*, *F. similis, L. ovatus* and *P. mawsonii*. Rare are *P. gillii* and *T. verrucosus*. Very rare are *L. balmei, G. wahooensis, N. endurus, T. confessus, T. lilliei*, *F. longus* and *T. waipawaensis*.

Environments are marginally marine to non-marine, as below. Backup data are in Table 2.

2250/55 m cutts	: marginal marine : extremely rare (<1%) extremely low diversity dinoflagellates
2304.0 m swc	: non-marine (swamp) : no saline markers, frequent freshwater markers (4%), spores dominate saccate pollen
2350/55 m cutts	: marginal marine : extremely rare (1%) saline markers comprising microforaminifera and extremely low diversity dinoflagellates

3.5 2402.5 m (swc) – 2529.5 m (swc) : *F. longus* Zone, lower subzone

Assignment is indicated at the top by youngest downhole dominance of *N. endurus* over *G. rudata* confirmed by the absence of younger markers, and at the base by oldest *F. longus* and *T. verrucosus*. Within the interval, the following events are considered to be useful for correlation, at least locally.

2402.5 m swc	: top influx *N. endurus* (5%) dominant over *G. rudata* (3%) : top *Q. brossus*, *T. sectilis*

- -

2460/65 m cutts : base *T. waipawaensis* (Event 3) in swcs
2495/500 m cutts :
- -
2529.5 m swc : top and base *Triporopollenites "megasectilis"*
base *F. longus* (Event 1), *T. verrucosus* (Event 2)

Subzones are tentatively identified on the criteria shown in Figure 2 and by dashed lines above and require further testing. They are

- 2402.5 m swc : lower c subzone
- 2460/65 m cutts – 2495/500 m cutts : lower b subzone
- 2529.5 m swc : lower a subzone

Within the interval, common are *C. minor, C. australis, F. similis* and *Proteacidites* spp. with frequent *L. ovatus, M. antarcticus, N. endurus, P. mawsonii* and *V. pallidus.* Rare elements include *A. obscurus, G. rudata, T. verrucosus, T. confessus, F. longus* and *T. lilliei* and at 2529.5 m only, *T. "megasectilis".*

Environments may all be non-marine with the trace saline markers at 2460/65 m possibly caved. Environments are suggested as below.

2402.5 m swc : non-marine (floodplain) : no saline markers, rare freshwater algae (1%), saccate pollen dominate spores, abundant angiosperms
2460/65 m cutts : ?non-marine (floodplain) or possibly marginal marine : saline markers extremely rare and may be all caved, freshwater algae frequent, saccate pollen dominate spores
2495/500 m cutts : non-marine (swamp margin) : no saline markers freshwater algae frequent (4%), saccate pollen subequal to slightly dominant spores
2529.5 m swc : non-marine (swamp) : no slaine markers, freshwater algae frequent (3%) spores dominant over saccate pollen

3.6 2586.7 m (swc) – 2601.5 m (swc) : *T. lilliei* Zone, upper subzone

Assignment is indicated at the top by the absence of younger markers, and at the base by the absence of older markers. These events are useful.

2586.7 m swc : top *F. sabulosus* (Event 4), top consistent *A. spinulosus*

\- -

2601.5 m swc : top more consistent *F. sabulosus* (Event 5)

Subzones are tentatively recognised on the criteria in Figure 2 and by a dashed line above and require further testing. They are

- 2586.7 m swc : upper b subzone
- 2601.5 m swc : upper a subzone

Within the interval, common are *C. minor, F. similis, L. ovatus* and *M. antarcticus* with frequent *A. australis, C. australis, P. mawsonii* and *V. pallidus*. Rare elements include *A. spinulosus, G. rudata, L. balmei, N. endurus, T. confessus, F. sabulosus* and *T. lilliei*.

Environments are non-marine as below.

2586.7 m swc : non-marine (swamp) : no saline markers, minor freshwater markers, spores dominate saccate pollen

2601.5 m swc : non-marine (swamp margin) : no saline markers, minor freshwater markers, saccate pollen subequal to spores

3.7 2750.0 m (swc) : *T. lilliei* Zone, lower subzone

Assignment is indicated by the downhole influx of *N. endurus* at the top, and oldest *T. lilliei* at the base. More detailed subzonal assignment is not attempted with only one sample present below a 150 m sample gap, but the lower a subzone is more likely.

2750.0 m swc : top influx *N. endurus* (8%), base *T. lilliei* (Event 17)
Proteacidites spp. spike (11%)

Common are *F. similis* and *Proteacidites* spp. with frequent *A. australis, C. minor, C. australis, N. endurus, Podosporites microsaccatus* and *V. pallidus*. Rare elements include *A. spinulosus, G. rudata, Forcipites stipulatus, P. gillii* and *T. lilliei*.

The environment is non-marine as below.

2750.0 m swc	: non-marine (floodplain) : no saline markers, frequent (4%) freshwater algae, saccate pollen dominate spores, common angiosperms

3.8 2758.0 m (swc) – 2886.0 m (swc) : *N. senectus* Zone, upper subzone

Assignment is indicated at the top by the absence of younger markers, and at the base by oldest *G. rudata*. Within the interval, the following events are considered to be useful for correlation, at least locally.

2758.0 m swc	: absence of younger markers
- -	-
2835/40 m cutts	: top frequent *F. sabulosus* (Event 21)
2870.2 m swc	
2886.0 m swc	: top influx *N. senectus* (8%), base *G. rudata* (Event 25)

Subzones are tentatively identified on the criteria given in Figure 2 and by a dashed line above and require further testing. They are

- 2758.0 m swc : upper b subzone
- 2835/40 m cutts – 2886.0 m swc : upper a subzone

Within the interval, common are *C. minor* and *F. similis,* with frequent *A. australis, L. ovatus, M. antarcticus, P. mawsonii, Proteacidites* spp., *F. sabulosus* and *V. pallidus*. Rare elements include *A. spinulosus, N. endurus, T. confessus* and *P. gillii*.

Environemnts appear to be non-marine as below.

2758.0 m swc	: non-marine (floodplain) : no saline markers, frequent freshwater algae (7%), saccate pollen dominate spores
2835/40 m cutts	: non-marine (floodplain) : no saline markers, frequent rare freshwater algae (2%), saccate pollen dominate spores
2870.2 m swc	: non-marine (floodplain) : no saline markers, rare, freshwater algae (3%), saccate pollen dominate spores
2886.0 m swc	: non-marine (floodplain) : no saline markers, rare freshwater algae (3%), saccate pollen dominate spores

3.9 2898.0 m (swc) – 3149.5 m (swc) : *N. senectus* Zone, lower subzone

Assignment is indicated at the top by the absence of younger markers, and at the base by oldest *F. sabulosus* and *N. senectus*. Within the interval, the following events have correlative potential, at least locally.

2898.0 m swc : absence of younger markers
2935/40 m cutts : minor spike of *A. obscurus* (3%)
2976.5 m swc : top frequent *D. "pusillum"* (7%)
2991.5 m swc :
3013.0 m swc : spike *R. austroclavatidites* (14%)
3022.5 m swc : top *P. pannosus*
3050.5 m swc :
3097.2 m swc : base frequent *Nothofagidites* spp. (16%) Event 26, *N. senectus* spike 10%

3103.9 m swc : top *C. "pileosa"*
3110.5 m swc :
3130.5 m swc :
3149.5 m swc : base frequent *F. sabulosus* (8%) Event 27

Subzones are tentatively recognised on the criteria in Figure 2 and by a dashed line above, and require further testing. They are

- 2898.0 m swc – 3097.2 m swc : lower c subzone
- 3103.8 m swc – 3149.5 m swc : lower b subzone
- not penetrated : lower a subzone

Common are *C. minor, F. similis* and *M. antarcticus* with frequent *A. australis, C. australis, L. ovatus, N. endurus, N. senectus, P. mawsonii, R. austroclavatidites* and *V. pallidus*. Rare elements include *A. spinulosus, T. confessus* and *P. gillii.*

Environments are non-marine as below. Backup data are in Table 2

2898.0 m swc : non-marine (floodplain) : no saline markers, few freshwater algae (3%), saccate pollen dominate spores
2935/40 m cutts : non-marine (floodplain) : no saline markers, no freshwater algae (3%), saccate pollen dominate spores

2976.5 m swc : non-marine (floodplain) : no saline markers, no freshwater algae (3%), saccate pollen dominate spores

2991.5 m swc : non-marine (lacustrine) : no saline markers, common freshwater algae (11%)

3013.0 m swc : non-marine (swamp) : a single saline markers, perhaps mud contamination, no freshwater algae, spores dominate saccate pollen

3022.5 m swc : non-marine (floodplain) : no saline markers, no freshwater algae, saccate pollen dominate spores

3050.5 m swc : non-marine (floodplain) : no saline markers, minor freshwater algae (3%), saccate pollen dominate spores

3097.2 m swc : non-marine (floodplain) : no saline markers, minor freshwater algae (1%), saccate pollen dominate spores

3103.9 m swc : non-marine (floodplain) : no saline markers, no freshwater algae, saccate pollen dominate spores

3110.5 m swc : non-marine (floodplain) : no saline markers, no freshwater algae, saccate pollen dominate spores

3130.5 m swc : non-marine (floodplain) : no saline markers, few freshwater algae (2%), saccate pollen dominate spores

3149.5 m swc : non-marine (floodplain) : no saline markers, few freshwater algae (1%), saccate pollen dominate spores

3.10 3165.0 m (swc) : indeterminate

Inertinite dominates this assemblage with palynomorphs rare and not zone diagnostic. Abundant is *F. similis* with frequent *A. australis, C. minor, C. australis, O. wellmanii* and *R. austroclavatidites*. Rare elements include *P. gillii*. Only 74 specimens were seen. There is no reason to expect this sample to be significantly older than the ones above.

Environment is non-marine as below

3165.0 m (swc) : non-marine (floodplain) : no saline markers, no freshwater algae, saccate pollen dominate spores

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