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Assembled palynology results for Sub-basalt Drilling Project holes, northwest Tasmania

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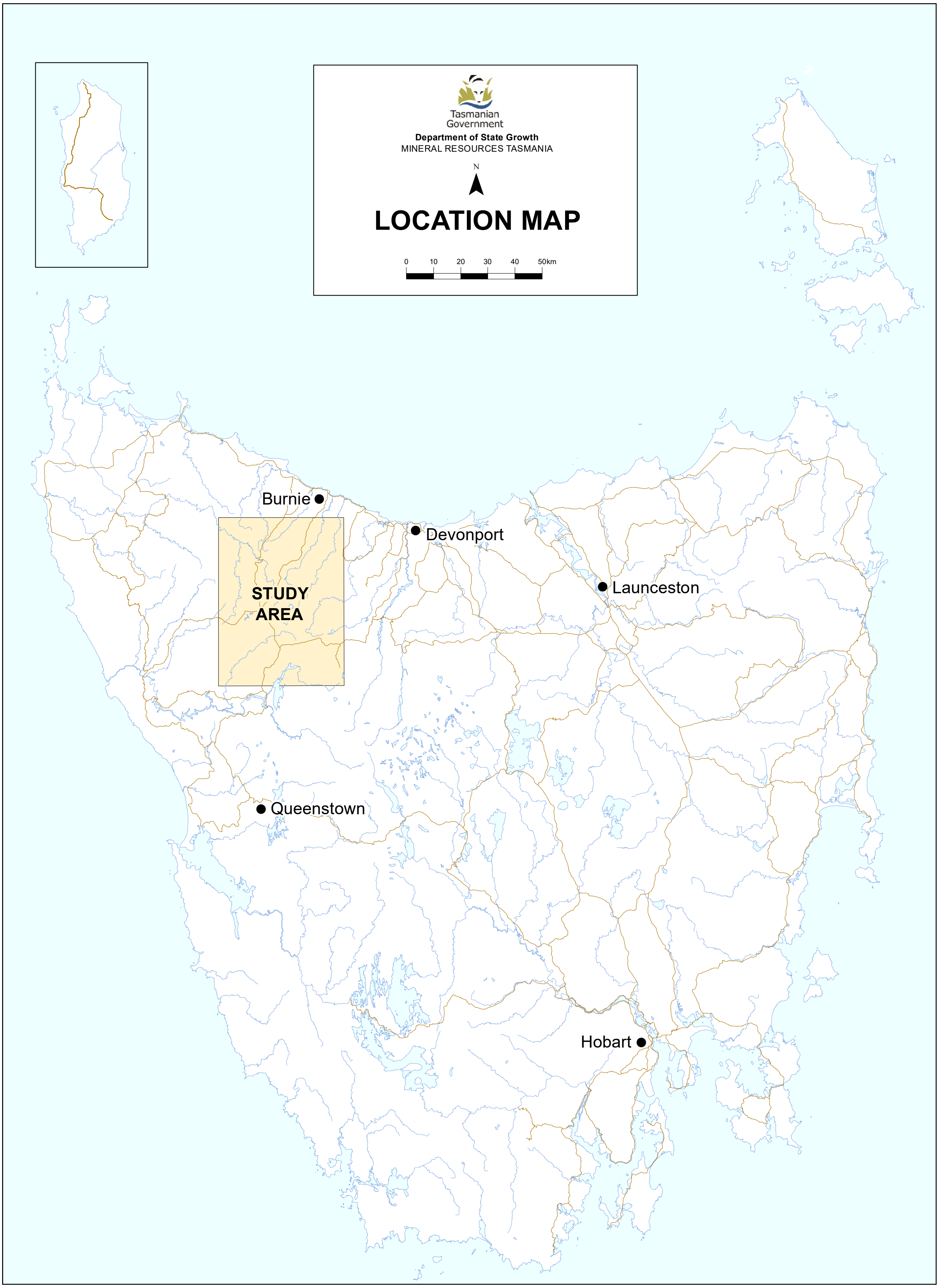

Location of study area.

Mineral Resources Tasmania
Department of State Growth

Geological Survey Technical Report 32:

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by N. J. Roberts

Cover: Dissected edge of the mid-Cenozoic basalt plateau near Waratah (right), northwest Tasmania, viewed from Mt Bischoff looking southeast towards Mt Pearse. (Photo courtesy of John Everard)

Mineral Resources Tasmania

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by N. J. Roberts
Geological Survey Branch - Mineral Resources Tasmania

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1.0 Introduction

During the mid-1980s Tasmania Department of Mines – the predecessor or Mineral Resources Tasmania (MRT) – undertook the Sub-basalt Drilling Project (SBDP) to determine the thickness, geophysical properties, and underlying basement composition of a basalt-covered area in northwest Tasmania (Figure 1) (details in Baillie et al., 1987; Seymour, 1989). The mid-Cenozoic basalts form a plateau ~600-700 m above sea level that now covers >750-km^2. Flow remnants to the west, south, and east suggest that flood basalts were initially much more extensive. The flow sequence overlies diverse pre-Cambrian and Paleozoic (Cambrian to Devonian) geology with variable pre-basalt topography including several localized highs projecting through the plateau surface. Proximity to major ore deposits, particularly at the Mount Bischoff, Hellyer, and Que River mines, make the underlying basement geology of economic interest, which was the principal driver of the SBDP (Seymour, 1989). Additionally, palaeofloras from sediment units associated with mid-Cenozoic basalt flows across central and western Tasmania make the basalt-sediment sequence of palaeontological interest. Sites preserving plant microfossils and macrofossils provide insight into floral turnover and palaeo-environmental shifts during Cenozoic climate change, with several sites holding particular importance because of their high diversity or preservation of plant reproductive structures (Jordan and Hill, 2002).

The SBDP resulted in ten holes (SBDP1, 2, 4, 5, 6, 7, 9, 10, 14 and 15) being drilled between July 1986 and March 1988 that complement nine holes (WA1-7 and WY1-2) drilled slightly to the west and north by BHP in 1983. Numerous holes have since been drilled through the basalt sequence but, unlike the SBDP and BHP holes, they lack palynological constrains; consequently, only the SBDP and BHP holes are shown in Figure 1. An eleventh SBDP site (SBDP16; Baillie et al., 1987) was planned, but not drilled. All 19 completed SBDP and BHP holes are located within the St Valentines Quadrangle (Seymour, 1989), which covers the central part of the extant basalt plateau. The basalt stack, including interbedded sediments, is in places more than 300 m thick (Figure 1) and may include more than 50 flows (Seymour, 1989). Chilled margins adjacent to baked sediment suggests that the lowest basalt zone in SBDP7 is a shallow ~40-m-thick intrusion (Baillie and Green, 1990) and is thus younger than the overlying host sediment.

Completion reports were issued for six of the SBDP holes (Baillie, 1987a,b,c; Baillie and Green, 1988a,b, 1990), but not for holes 5, 10, 14 and 15. Unfortunately, complete drill core now exists only for SBDP5 with only lower portions, largely basement, of the other holes having been archived. Similarly, of the nine nearby BHP drill holes, the core from only one (hole WA6) remains in its complete form. Consequently, previous documentation of the SBDP drill cores has become particularly important.

This report provides a permanent record of palynological analyses from the SBDP. Aside from magnetostratigraphy on SBDP5 (Lucas, 1988), age constraints for these drill cores are currently limited to palynostratigraphy that has been reported in MRT publications for some holes and not published at all for others. Thus, palynology results of SBDP drill core are collated here to make them readily available in a single location.

2.0 Palynology samples and analysis

Soon after drilling, MRT submitted 34 core samples from nine SBDP holes for palynological analysis. One core sample was sediment from a cavern within Ordovician Gordon Limestone underlying basalt in SBDP1, whereas the other 33 samples were of sediment horizons interbedded with the basalts (Table 1). The number of samples submitted from those nine holes ranges from one to ten. No samples were collected from SBDP9, which lacks inter-basalt sediment beds (Bailllie and Green, 1988b). Dr Rodger Morgan (Palynological/Petroleum Geological Consultant) analysed the samples and provided six reports (Appendices 1-6) in 1987 and 1988, detailing the pollen and spore content of each. He assessed spore-pollen assemblages and their approximate ages based on the zonation developed for Gippsland Basin (Stover and Evans, 1973; Stover and Partridge, 1973; Partridge, 1976), which covers southeast coastal Victoria and the adjacent offshore area. The reports also note maturity for hydrocarbon generation as suggested by spore colour.

3.0 Pollen assemblages and ages

Thirty-two of the SBDP core samples contained spores and pollen of sufficient type and preservation for identification of assemblages, and in all cases were identified as belonging to one of two spore-pollen zones: the Upper *Nothofagidites asperus* Zone (20 samples) or the Lower *Proteacidites tuberculatus* Zone (12 samples[1]) (Table 1, Figure 2). These two assemblages indicate, respectively, latest Eocene to earliest Oligocene and early Oligocene ages (Figure 3a) based on the Gippsland Basin zonation. The transition between the zones is captured in three holes: SBDP2 (187.3-184 m); SBDP 4 (371-211.4 m); and SBDP6 (157.2-79.3 m). Each of the other six holes yielded only a single spore-pollen assemblage (only *N. asperus* for holes 1, 7, 10, and 14, and only *P. tuberculatus* for holes 5 and 15).

[1]For SBDP4 (Appendix 3) R. Morgan identifies the spore-pollen zone only as "*P. tuberculatus* Zone" but this is presumably meant to specify the Lower *P. tuberculatus* Zone as he specifically suggests an early Oligocene age.

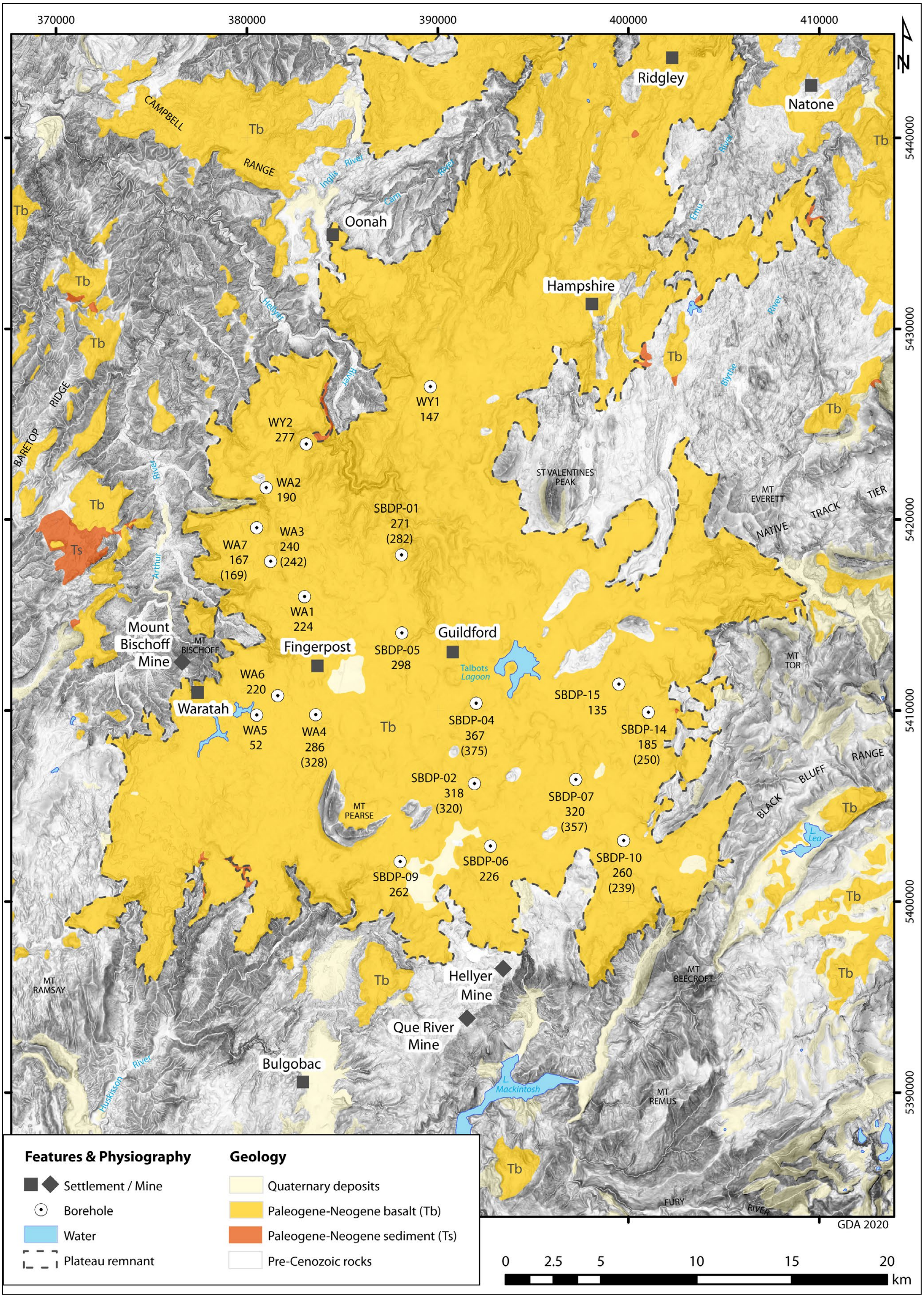


Figure 1. Location map showing the extent of the extant basalt plateau remnant and adjacent areas of incised basalt terrain as well as positions of the ten SBDP holes and nine BHP hole penetrating the sequence. Numbers with each borehole name indicate depth in metres to base of basalt and (in parentheses) to base of any underlying Cenozoic sediment.

Table 1: Sub-Basalt Drilling Project palynological results by core.

Hole[a]	Tiger ID	Sample Count	MRT Report[b]	Sample Details[c]						
				Depth (m)	**Spore-pollen assemblage zone**	**Lower age**	**Upper age**	**Palaeoenvironment**	**Thermal maturity (for oil)**	**Note**
SBDP1	13522	3	UR1987/38	274.2	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				276.0	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				308.5	indeterminate					barren
SBDP2	13521	10	UR1987/40	129.0	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	immature	
				184.0	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	immature	
				187.3	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				197.6	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				220.8	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				229.5	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				268.6	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				279.0	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				303.5	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				318.9	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
SBDP4	13520	5	UR1987/61	168.2	Lower *P. tuberculatus*[d]	early Oligocene	early Oligocene	non-marine	immature to mature	extremely lean
				171.1	Lower *P. tuberculatus*[d]	early Oligocene	early Oligocene	non-marine	immature	very lean
				211.4	Lower *P. tuberculatus*[d]	early Oligocene	early Oligocene	non-marine	marginally mature to mature	very lean, minor Cretaceous reworking
				275.0	indeterminate				post-mature	extremely lean
				371.0	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	early mature	very lean
SBDP5	13590	5	-	30.7	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	immature	
				73.0	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	immature	
				96.8	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine		very lean[e]
				125.4	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	immature	
				241.6	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	early mature for oil, immature for gas/ condensate	

Table 1 continued.

Hole[a]	Tiger ID	Sample Count	MRT Report[b]	Sample Details[c]						
				Depth (m)	**Spore-pollen assemblage zone**	**Lower age**	**Upper age**	**Palaeoenvironment**	**Thermal maturity (for oil)**	**Note**
SBDP6	13586	2	UR1988/06	79.3	Lower *P. tuberculatus*	early Oligocene	early Oligocene	non-marine	immature	
				157.2	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
SBDP7	13585	4	UR1990/05	125.5	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				266.8	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				329.9	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				349.5	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
SBDP10	15264	1	-	173.5	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
SBDP14	13589	3	-	185.8	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				220.5	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
				246.8	Upper *N. asperus*	latest Eocene	earliest Oligocene	non-marine, lacustrine	immature	
SBDP15	15749	1	-	16.0	Lower *P. tuberculatus*	early Oligocene		non-marine	immature	

[a]No palynology samples from SBDP9 (TIGER ID 13587)
[b]UR1987/38, Baillie(1987a); UR1987/40, Baillie (1987b); UR1987/61, Baillie (1987c); UR1988/06, Baillie and Green (1988a); UR1990/05, Baillie and Green (1990)
[c]All samples submitted by P.W. Baillie
[d]R. Morgan identifies the spore-pollen zone only as "*P. tuberculatus* Zone" but he presumably considered it to be the "Lower *P. tuberculatus* Zone" as he specifically suggests an early Oligocene age
[e]possibly because of exposure to very high temperatures during or after deposition

The Upper *N. asperus* Zone is a transitional assemblage between typical Eocene and Oligocene assemblages, constituting species of low-diversity and long-ranging Eocene and Oligocene forms (Stover and Partridge, 1973). The overlying *P. tuberculatus* Zone spans the early Oligocene to early Miocene, which Stover and Partridge (1973) informally subdivide it into three parts based on the last occurrence of roughly 20 spore-pollen species. They do not propose a formal nomenclature for these subdivisions because of uncertainties in the first or last appearance of potential age-diagnostic, Oligocene-Miocene morphospecies in Gippsland Basin. However, some later studies (e.g., Lucas, 1988; Seymour, 1989) including R. Morgan's palynological reports (Appendices 1-6) differentiate Lower (roughly early to middle Rupelian), Middle (roughly late Rupelian to early Chattian), and Upper (roughly late Chattian) zones (cf. Figure 13 of Seymour, 1989; Figure 3a).

Spore-pollen assemblages and thus ages of two samples were indeterminate. The cavern sediment sample from the Gordon Limestone in SBDP1 was barren. A low pollen-spore abundance sample from 275 m depth in SBDP4 was also of uncertain zonation, although it must fall within the same period as the other samples as it is bracketed by *P. tuberculatus* microflora above (211.4 m depth and higher) and *N. asperus* microflora below (371 m depth). The diversity of spores and pollen, and particularly the absence of dinoflagellates, indicates non-marine depositional environments for all 33 spore-pollen bearing samples.

4.0 Chronostratigraphic constrains and biogeoclimatic context

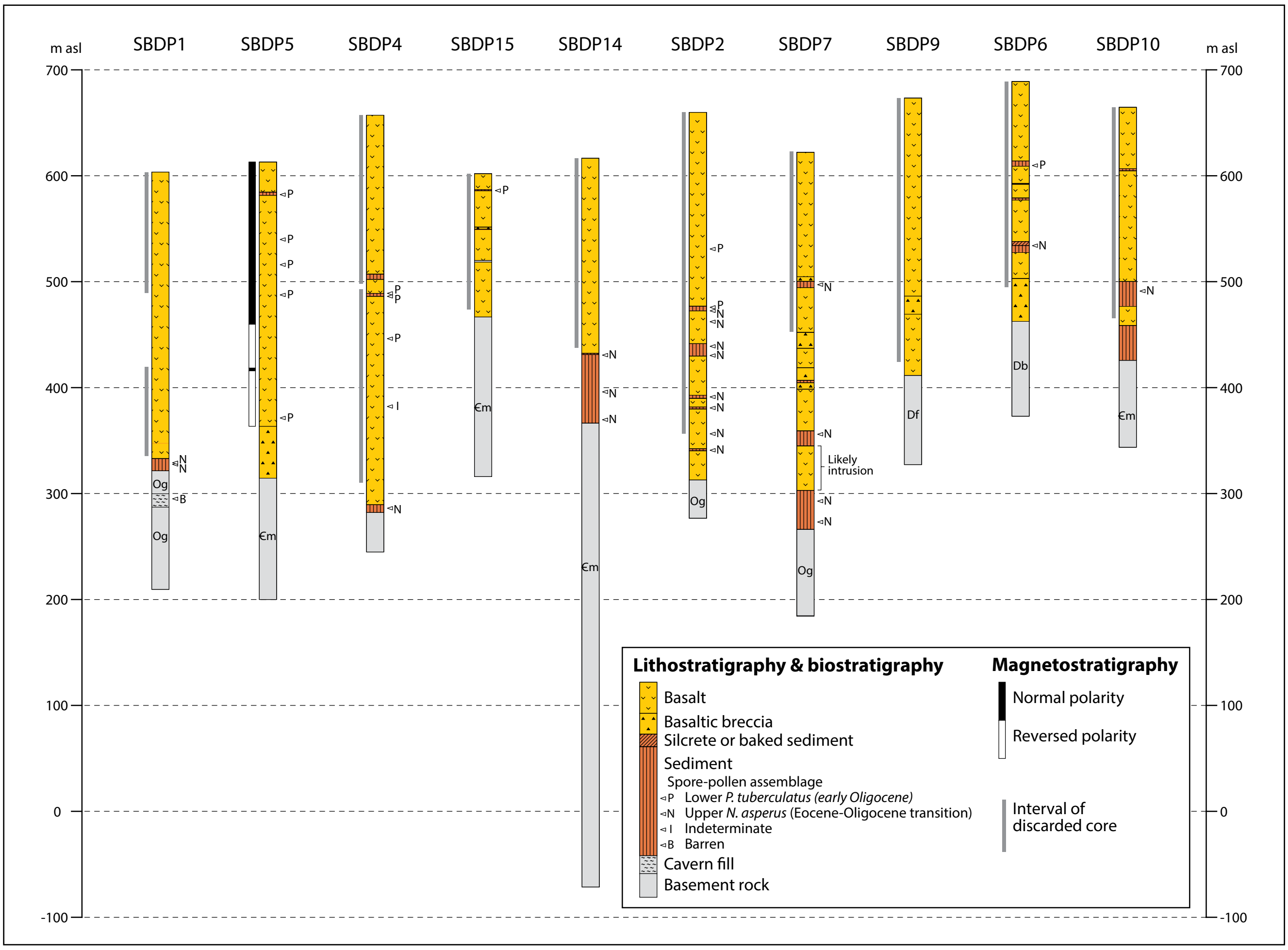
Although broadly informative, chronostratigraphic constraints provided by the Upper *N. asperus* and Lower *P. tuberculatus* zones are only general. Age estimates of the Gippsland Basin spore-pollen zones are based on planktonic foraminifera and microplankton biostratigraphy in associated marine sequences (Stover and Evans, 1973; Stover and Partridge, 1973). Additionally, the applicability of those spore-pollen assemblages to Tasmania's inland microfloras remains uncertain (Seymour, 1989; M. Macphail, pers. comm., 2021).

Palynostratigraphy of the SBDP holes indicates that the units they penetrate approximately span the Eocene-Oligocene boundary. Reporting of the same two sequential spore-pollen assemblages in nearby BHP holes (BHP, 1984) suggests that this period is recorded throughout the region's basalt-sediment sequence. These ages are in general agreement with palynostratigraphically dated, early-Oligocene palaeofloras from outcrops associated with the basalt sequence in valleys eroded into the basalt plateau and its remnants (Jordan and Hill, 2002; Figure 1).

Magnetostratigraphy conducted for SBDP5 currently provides the only opportunity for further narrowing the age of the basalt sequence. There Lucas (1988) reports an R-N-R-N polarity sequence from 249.5 m depth to surface, with the lower normally magnetized polarity zone limited to a single flow (Figure 2). All five samples of SBDP5 core submitted for palynology (depths 241.6 to 30.7 m) contain early-Oligocene microflora (Lower *P. tuberculatus* Zone: Appendix 4). Lucas (1988) thus suggests that the polarity sequence records polarity Chron 13 because it contains the only reversed-to-normal polarity change (C13r-C13n at ca. 35.9 Ma) in the contemporary version (LaBrecque et al., 1977) of the Geomagnetic Polarity Time Scale (GPTS) during the Lower *P. tuberculatus* Zone (Figure 3b). However, improved radiometric control, astronomical tuning, and spline fitting have enabled subsequent repeated revision of the GPTS.

The current GPTS iteration for Late Cretaceous to Quaternary time (Ogg, 2020) includes several polarity chrons during the early Oligocene (Rupelian) beginning with the later part of Chron 13 (Figure 3c). Additionally, Chron 13 is now recognized as comprising only a single reversed period (C13r) followed by a single normal period (C13n) (Ogg, 2020; Malinverno et al., 2020), which means that it alone cannot explain the R-N-R-N polarity sequence measured in SBDP5. Given these GPTS revisions – together with the low precision of Gippsland Basin palynological zonation boundaries, their uncertain equivalence in inland Tasmania, and the possibility of hiatuses within the basalt stack – the polarity sequence measured by Lucas (1988) must include a portion of at least one other approximately Rupelian-age chron and may not record C13 at all. The SBDP5 polarity sequence most likely spans either Chron C11 or the upper part of Chron C12 and part of Chron C11 (Figure 3c) considering the upward shift of the Eocene-Oligocene boundary over the last four decades of GPTS revision (Figure 3b vs 3c) and the identification of only the *P. tuberculatus* Zone in that hole.

Regardless of current chronostratigraphic uncertainties, the basalt-sediment sequence of northwest Tasmania coincides with a key stage of geologic time. It records a period of regional volcanism and physiographic change (Quilty et al., 2014 and references therein) as well as climatic evolution (Haiblen et al., 2019) including shifts in Tasmania's palaeoenvironmental conditions due to its equatorward drift. The sequence also spans at least part of the global transition from greenhouse conditions of the Paleocene and Eocene to icehouse conditions of the Oligocene and since. This period is of interest because of the important palaeoceanographical and global palaeoclimatological changes that characterized it. They include widening and deepening of the Tasman Gate-



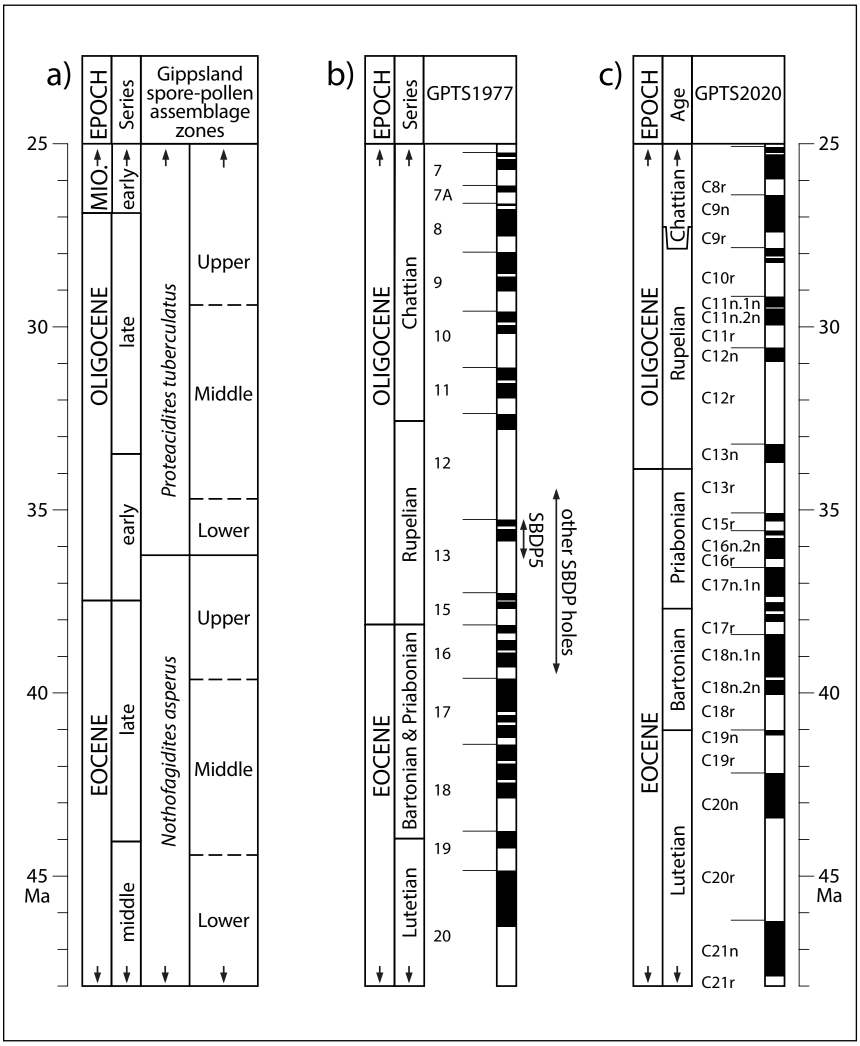


Figure 2 (above). Simplified SBDP core logs arranged roughly from northwest to southeast. Expanded from Seymour (1989) to include SBDP holes 7, 14, and 15 based on details in Baillie and Green (1990 – SBDP7), Tasmania Department of Mines core logs (SBDP14 and 15), and Appendix 6 (SBDP7, 14 and 15). Basalt in SBDP7 at 277.8-319.7 m depth (approximately 303.0 -344.9 m asl) is likely a shallow intrusion within the mid-Cenozoic host sediment. Basement rock units (following nomenclature of Seymour, 1989) are €m, extrusive felsic to intermediate volcanics intermixed with sediments of (middle? to late Cambrian); Og, Fossiliferous limestone and impure limestone of the (Gordon Subgroup correlate – Ordovician); Df, quartz sandstone with minor siltstone (Florence Quartzite correlate – Silurian? to early Devonian); and Db, fossiliferous sandstone and mudstone (Bell Shale correlate – early Devonian).

Figure 3 (left). Geologic timescales spanning the Eocene-Oligocene boundary along with biostratigraphic and magnetostratigraphic constraints on basalt-sediment sequences penetrated by SBDP holes. a. Simplified spore-pollen zonation framework for Gippsland Basin used by R. Morgan spanning the P. tuberculatus and N. asperus zones (modified from Partridge, 1976) with approximate, tri-part subdivision of the P. tuberculatus Zone from Seymour (1989). b. Mid-Cenozoic portion of La Becque et al.'s (1977) GPTS including Seymour's (1989) proposed magnetostratigraphic correlation for SBDP holes. c. Astronomically tuned, mid-Cenozoic portion of the modern GPTS (Ogg, 2020) showing adjustments to the number, timing, and duration of polarity intervals. The changes include identification of only one reversed (C13r) and one normal (C13n) interval during Chron C13, a shift in the timing of Chron C13 from initiation just prior to 37 Ma to initiation just prior to 35 Ma, and slight relative shortening of the reversed periods bracketing C13n (i.e., C13r and C12r). Note: there is no Chron C14 in either GPTS.

way (Exon et al., 2004; Stickley et al., 2004) and Drake Passage (Lawver and Gahagan, 1998) that together facilitated establishment of Southern Hemisphere circumpolar marine circulation (Lawver and Gahagan, 2003), as well as the approximately coincident onset of Antarctic ice-sheet glaciation (Zachos et al., 2001). High-resolution absolute dating of the remaining SBDP drill core material will better constrain the timing and duration of mid-Cenozoic effusive volcanism in northwest Tasmania, assess possible correlations with basalt emplacement in other parts of the state, and evaluate the applicability of Gippsland spore-pollen records to this inland region.

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APPENDICES 1-3

Located :
https://www.mrt.tas.gov.au/mrtdoc/dominfo/download/TR32/

Appendix 1 - Palynology report for SBDP Hole 1 (Morgan, 1987a)

-Download-

Appendix 2 - Palynology report for SBDP Hole 2 (Morgan, 1987b)

-Download-

Appendix 3 - Palynology report for SBDP Hole 4 (Morgan, 1987c)

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APPENDICES 4-6

Located :
https://www.mrt.tas.gov.au/mrtdoc/dominfo/download/TR32/

Appendix 4 - Palynology report for SBDP Hole 5 (Morgan, 1987d). Note: original hardcopy of page 4 crops *Triporopollenites ambiguus*, which appears to be: ‘not present’ at 030.7 m; ‘not present’ at 073.0 m; ‘not present’ at 096.8 m; ‘questionably present’ at 125.4 m; ‘not present’ at 241.6 m. Because no completion report was developed for this borehole, the list of graphic abundance appears not to be recorded elsewhere.

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Appendix 5 - Palynology report for SBDP Holes 6 and 10 (Morgan, 1987e). Note: original hardcopy lacks a list of graphic abundance as well as a species list. The list of graphic abundance by alphabetical order is available in the MRT report for Hole 6 (Baillie and Green, 1988). Because no completion report was developed for Hole 10, its list of graphic abundance appears not to be recorded elsewhere.

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Appendix 6 - Palynology report for SBDP holes 7, 14 and 15 (Morgan, 1987f). Note: original hardcopy lacks a list of graphic abundance as well as a species list. The list of graphic abundance by alphabetical order is available in the MRT report for Hole 7 (Baillie and Green, 1990). Because no completion reports were developed for holes 14 or 15, their lists of graphic abundance appear not to be recorded elsewhere.

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