

POTASSIUM-ARGON AGES OF TERTIARY VOLCANIC ROCKS, TASMANIA

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(with one table and four text-figures)

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Sixteen new K-Ar dates are presented from Tasmanian and Bass Basin basalts, more than doubling the previously published number. Eight volcanic regions are described, based on boundaries established on the range of the basalt types contained in each geographic region. Volcanism occurred within the span from Eocene to Miocene (47 to 13+ Ma), but mainly within the time range Middle Eocene to Early Miocene. Alkali basalts erupted throughout this span and are interspersed with tholeiites (22-31 Ma), fractionated alkaline rocks (22-27 Ma) and rare melilite-bearing varieties (26-35 Ma).

Key Words: basalt, Tasmania, K-Ar ages.

INTRODUCTION

The Cainozoic igneous rocks of Tasmania are all mafic, but they have a wide range in composition — from tholeiitic to alkaline and including some fractionated types with $Ab/Ab+An > 0.55$ (Edwards 1950; Spry 1962; Sutherland 1969a, 1974; Frey *et al.* 1978). In most areas the flows include a variety of basalt types and their field relationships often suggest separate volcanic episodes with intervening sedimentation and/or erosion (sections, figs 2-3). Previous K-Ar dating consists of 12 dates from five areas (Sutherland *et al.* 1975; Green 1976; Sutherland 1976, 1977a; Brown 1977; Cromer 1980). Although 16 new dates (table 1) are presented, more K-Ar dating is required to define adequately the age of Cainozoic volcanism. The basaltic rocks are assigned here to eight volcanic regions (fig. 1 and table 1) each with geographic boundaries enclosing a different range of basalt types. These volcanic regions fall within the time spans and chemical variations found in petrographic provinces (Rock 1981), but are not clear cut provinces with discrete and distinct chemical character.

Where older dates in the literature are quoted, they have been recalculated using modern values of constants (after Dalrymple 1979), i.e. $^{40}K/K = 1.167 \times 10^{-10}$ moles/mol, $\lambda\beta = 4.962 \times 10^{-10} \text{ yr}^{-1}$, $\lambda\epsilon = 0.05811 \times 10^{-10} \text{ yr}^{-1}$. Freshness of samples with respect to loss of radiogenic argon is estimated as A (completely fresh phases), A-B (fresh K-bearing phases, but with slight alteration of other phases or

presence of minor glass), B (some alteration of K-bearing phases) or C (significant alteration of K-bearing phases). The relevant boundaries of the time scale used here (Hardenbol & Berggren 1978), involving the new decay constants are: Quaternary — 1.8 Ma; Pliocene — 5.5 Ma; Miocene — 24.6 Ma; Oligocene — 38.0 Ma; Eocene — 54.9 Ma; Palaeocene — 66.6 Ma.

REGIONS AND AGES

Northeastern Tasmania (Figs 1 and 2)

This region contains undersaturated basalts which both cap hills and crop out in the valleys (Brown *et al.* 1977).

Weldborough area Three basalts give dates of 46.2 ± 0.6 , 47.4 ± 0.5 and 47.2 ± 0.6 Ma (Early Eocene, table 1). Although the rocks are slightly altered (A-B), the age of the volcanism is thought to be 47 Ma, because the K-Ar dates agree to within experimental error, and alluvial zircons associated with the basalt give fission track dates that agree with the K-Ar age to within experimental error (Yim *et al.* 1985). This is the oldest Tertiary volcanism identified in Tasmania and the volcanic structure shows considerable erosion (Section A-B, fig. 2).

Analyses of the basalts show that they range from mildly undersaturated to transitional alkaline basalts of sodic affinities (Brown, in McClenaghan *et al.* 1982). Between Blue Tier and Weldborough Pass the base of the volcanics ranges from 500 to

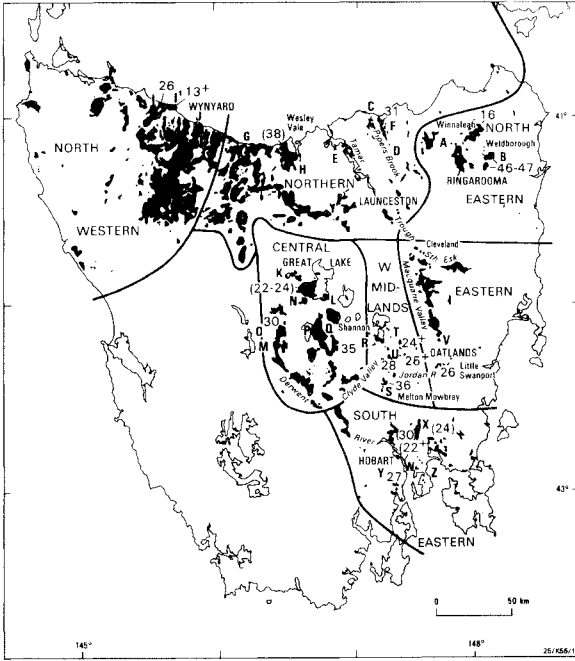


FIG.1 — Tasmania showing distribution of basalts (black), Tasmanian volcanic regions (boundary lines), K-Ar dates from both this (unbracketed) and previous (bracketed) reports and section lines.

800 m; 150 m of agglomerate and tuffs stratigraphically underlie 230 m of flows. Eruptive centres are thought to be at Weldborough Pass, 2 km SW of Forest Lodge and possibly under Mt Littlechild. Basalts with similar petrology form outlying dykes and cap Grays Hill 16 km to the west above 420–500 m altitude. Winnaleah-Ringarooma area.

The basalts here form partly dissected flows giving Middle Miocene ages of 16.0 , 16.3 and 16.4 ± 0.3 Ma (Brown 1977; McClenaghan *et al.* 1982). Analysed flows range from olivine nephelinite to glomeroporphyritic alkali basalt. Flows extend 40 km along the Ringarooma Valley, with a base from 300 m (in the south) to 160 m (in the north) in altitude; they are 20 to 70 m above the Ringarooma River bed. In places they overlie Early Miocene sediments (Brown 1978).

The younger ages of these basalts compared to the Weldborough hill caps confirm the physiographic interpretations of two ages by Nye (1924), Nye & Blake (1938) and Edwards (1939), but the actual ages are greater than their estimates.

Northern Tasmania (Figs 1 and 2)

Basaltic flows lie mainly within valleys draining northward into Bass Strait (Sections C-D, E-F, G-H, fig. 2). They commonly overlie or are interbedded with Cainozoic sediments (Spry 1958; Jennings 1963; Burns 1964; Marshall 1969; Jennings & Sutherland 1969; Sutherland 1971a) and in places the basalts flowed into dammed river systems (Sutherland 1980). The flows are olivine nephelinites ranging through alkali basalts to quartz tholeiite.

In the eastern part, at Pipers Brook the basalts extend from 600 m to below sea-level over a distance of 20 km. Alkali olivine basalt is overlain by tholeiitic flows, and capped by Cainozoic sediments, alkaline basalt and olivine nephelinite. A reasonably fresh quartz tholeiite (A-B) from the lower sequence gave a date of 30.7 ± 0.4 Ma (Middle Oligocene, table 1). The interbedded non-marine sediments here at Pipers Brook and elsewhere in the region (Burns 1964; Sutherland 1973a) are thought to be related to nearby high sea-levels in the mid-Tertiary. Some flows overlying these sediments are extensively dissected and weathered, so they may be older than the less dissected Middle Miocene flows of the Winnaleah region.

The Early Oligocene basalt fill in Pipers Brook supports the contention that many of the valleys draining into Bass Basin were already blocked by lavas, which impeded ingress of mid-Tertiary high seas (Sutherland 1973a). These blocked valleys only allowed minor Miocene marine incursions on to the coast, judging by the limited outcrops of marine sediments (Quilty 1972). The evidence suggests that volcanism within the drainage system into Bass Strait mostly occurred from Middle Eocene to at least Early Miocene time.

In the western part, a lower porphyritic olivine basalt flow in the Wesley Vale sequence gave a 38.1 ± 0.6 Ma date (latest Eocene, Cromer 1980). Nearby basalts at East Devonport may be of similar age because they are interbedded with palaeontologically dated Late Eocene-Early Oligocene sediments (Sutherland 1973a).

Slightly older alkali basalts may be present in the Longford Basin where they are interbedded with sediments which contain Middle to Late Eocene palynological assemblages, but sampled basalts proved unsuitable for K-Ar dating (Matthews 1983).

Northwestern Tasmania (Figs 1 and 2)

The largest volume of Cainozoic lava is in northwestern Tasmania. The flows range from

TABLE 1
K-Ar Ages for Samples from Tasmanian Regions

Sample No. and Location	Latitude S	Longitude E	Alt.	K %	$^{40}\text{Ar}^*$ ($\times 10^{-10}$ moles/g)	$^{40}\text{Ar}^*/^{40}\text{Ar}$ total	Age \pm I.S.D. (Ma)
Northeast Tasmania:							
BT2, 5.5km SSE of Weldborough	41° 14.4'	147° 55.3'	A-B	0.732,0.735	0.59511	0.879	46.2 \pm 0.6
BT4, 7.5km S of Weldborough	41° 16.0'	147° 55.2'	A-B	0.691,0.691	0.57408	0.788	47.3 \pm 0.5
BT5, 6.6km SE of Weldborough	41° 14.7'	147° 57.1'	A-B	0.771 0.772	0.64299 0.63815	0.870 0.862	47.4 \pm 0.6 47.0 \pm 0.6
Northern Tasmania:							
PB1, 2.2km NW of Pipers Brook	41° 04.2'	147° 09.7'	A-B	0.291,0.292	0.15680	0.709	30.7 \pm 0.4
Northwestern Tasmania:							
TC1, Tollemore quarry, Table Cape	40° 57.1'	145° 42.3'	B	1.276,1.281	0.29616	0.815	13.3 \pm 0.2
SC1, Shekleton Creek, Boat Harbour	41° 00'	145° 36'	A-B	1.125,1.124	0.5169	0.927	26.3 \pm 0.3
Central Tasmania:							
ST1, Haystack, Shannon Tier	42° 11.1'	146° 56.9'	A-B	1.589,1.587	0.98416	0.946	35.4 \pm 0.4
LJ1, Laughing Jack Marsh, 10.3km WSW of Bronte	42° 09.5'	146° 22.3'	A	1.123,1.119	0.59110	0.910	30.1 \pm 0.4
Southeastern Tasmania:							
SB1, Sandy Bay 4km SE of Hobart GPO	42° 55.9'	147° 21.4'	A-B	2.680,2.680	1.24160	0.968	26.5 \pm 0.3
CR1, Coal River, 3km NW of Campania	42° 39.0'	147° 27.2'	?	1.76	0.1379*	0.673	24.2 \pm 1.0
Western Midlands and Eastern Tasmania:							
BW1, Big White Hill, 4.7km NNE Melton Mowbray	42° 25.9'	147° 11.9'	A-B	1.288,1.286	0.81971	0.570	36.3 \pm 0.5
RH1, Rose Hill Farm, 4km WNW of Jericho	42° 22.4'	147° 14.2'	A	1.214,1.213	0.58493	0.901	27.6 \pm 0.4
BH1, Barwicks Hill, 3.5km WNW of Oatlands	42° 16.9'	147° 20.3'	B	2.060,2.050	0.89760	0.905	25.0 \pm 0.3
FH1, Fernleigh Hill, 4km WNW of Oatlands	42° 16.9'	147° 19.6'	B	1.740,1.740	0.73818	0.945	24.3 \pm 0.3
PP1, Pencil Point, 9km ESE of Andover	42° 21.2'	147° 33.3'	A-B	0.497,0.495	0.2220	0.416	25.6 \pm 0.2
Bass Basin:							
CN1, Cormorant No.1, Core 11, 8100-8116 ft	39° 34.3'	145° 31.8'	A-B	6.874,6.866	2.690	0.784	22.4 \pm 0.1
Alt. = alteration					* ($\times 10^{-5}$ cc/gm)		

Potassium-argon ages of Tertiary volcanic rocks, Tasmania

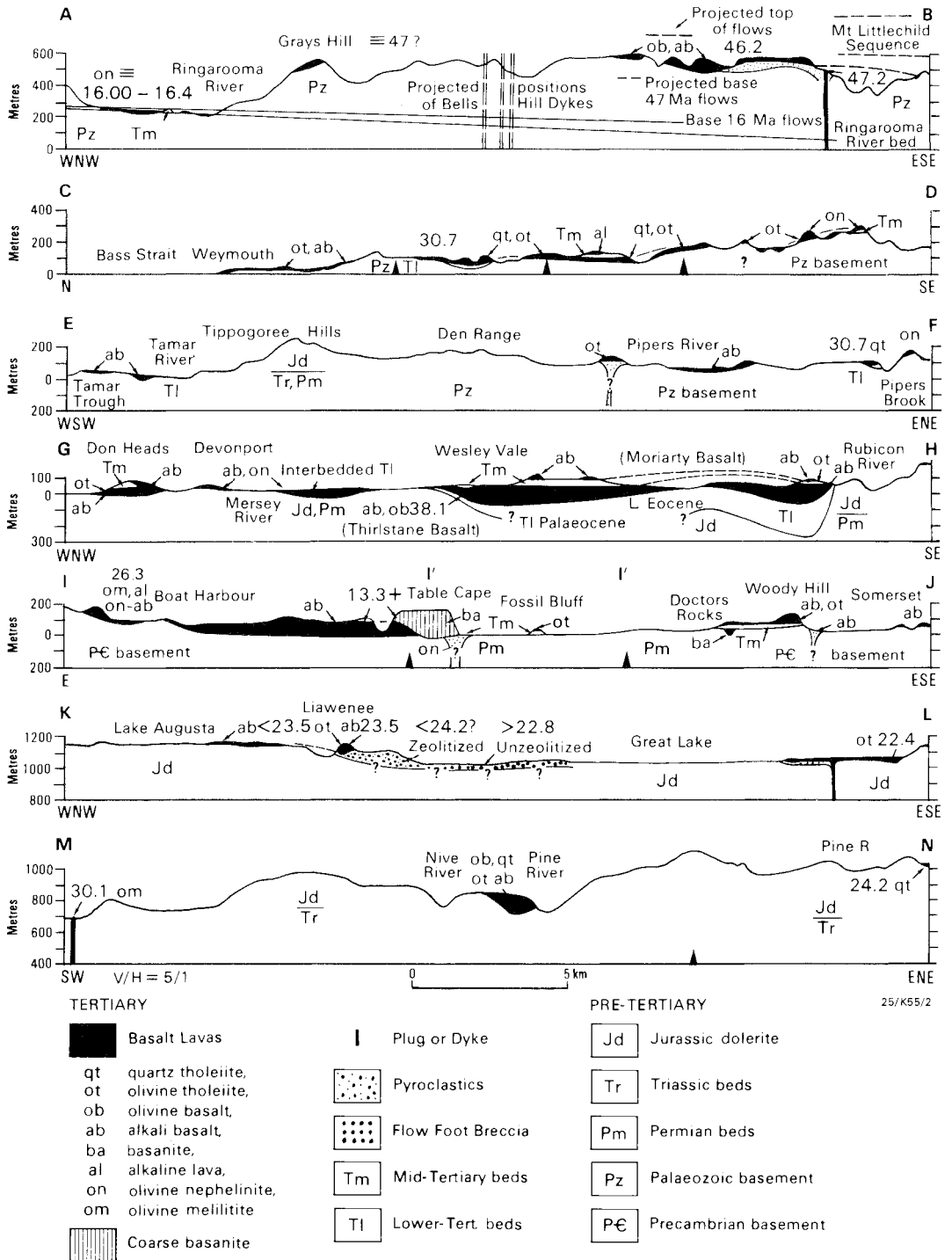


FIG. 2 — Sections through dated basalt regions, NE, N, NW and central Tasmania, in relation to physiography, petrology and volcanic sources.

Notches on the section base indicate dog-legs in the section line to show basalt sequences to best advantage.

olivine melilite nephelinite to olivine tholeiite. The lavas overtopped the valleys to form an extensive lava plain, including Late Eocene-Early Oligocene sediments (Brown & Forsyth 1984). This plain has an upper surface near 100 m in altitude at Wynyard and rises to the south, reaching 750 m altitude 70 km inland (Burns 1964; Barton *et al.* 1966; Sutherland 1969b; Gee 1971, 1977; Brown & Forsyth 1984). In the far northwestern part of the island lavas are less extensive but are notable for the high proportion of aquagene basalts erupted into mid-Tertiary seas (Sutherland & Corbett 1967; Quilty 1972; Sutherland 1969b, 1973a, 1980).

Between Wynyard and Somerset limburgitic basalts are overlain by latest Oligocene-earliest Miocene marine sediments and minor aquagene breccias of olivine tholeiite (Gee 1971, 1977; Sutherland 1973a). These are overlain by a thick sequence of basalt flows (Section I-J, fig. 2), weathered for the most part. West of Table Cape the basalt succession has been eroded and lateritised. A thick fill (177 m) of coarse unlateritised basanite overlies nephelinitic pyroclastics at Table Cape. A slightly altered sample of this basanite (B) gave a Middle Miocene age of 13.3 ± 0.2 Ma (table 1).

In the sequence between Table Cape and Boat Harbour, an olivine melilite nephelinite flow overlies an orthoclase-bearing nepheline mugearite in Shekleton Creek, and is the source of the gem zircon and corundum of the district (Gee 1971; Matthews 1973; Hollis & Sutherland 1985). Dating of the Shekleton Creek melilite nephelinite gave 26.3 ± 0.3 Ma. Thus, the basalts in the Wynyard region include Late Oligocene or older alkaline rocks (>26.3 Ma), Early Miocene olivine tholeiite and Middle Miocene nephelinite-basanites (>13.3 Ma).

Central Tasmania (Figs 1, 2 and 3)

This region contains lavas that were erupted onto the Central Plateau, and also lavas that descended south from the plateau, into the Derwent drainage west of the Clyde Valley. Lavas range from olivine nephelinite to quartz tholeiite and there are rare plugs of olivine melilitite and melilite nephelinite. The flows extend over 80 km, being extruded both subaerially and into lava-dammed rivers in sequences up to 400 m in thickness (Spry 1962; Sutherland & Hale 1970; Sutherland 1973b, 1980). Sutherland *et al.* (1973) dated five lavas from the predominantly tholeiitic sequence near Great Lake (Sections K-L, M-N, fig. 2). As the ages of the lavas range from 22.4 to 24.2 ± 0.6 Ma, most of the lavas of the region are likely to be Late Oligocene-

earliest Miocene in age.

Plugs of olivine (monticellite) nepheline/melilite rocks are known at Shannon Tier on the eastern side of the region (Twelvetrees 1902; Edwards 1950). A sample from one (A-B) gave a 35.4 ± 0.4 Ma age (Early Oligocene, table 1). A plug of olivine nepheline melilitite (A) at Laughing Jack Marsh (Sutherland 1973b; Brey & Green 1975; Frey *et al.* 1978) gave a younger, $30.1 \pm$ Ma age (Middle Oligocene, table 1). Both these highly silica-undersaturated intrusions are therefore older than the dated flows in the region (Sections M-N, O-P, Q-R, figs 2 and 3).

Western Midlands (Figs 1 and 3)

Basalts here range from olivine nephelinite to alkali basalts and include fractionated alkaline lavas. On the southwestern side undersaturated lavas extend from the Central Plateau at around 900 m near Interlaken to 420 m altitude near Oatlands (Forsyth 1976). The basalts at different levels (Sections S-T, U-V, fig. 3) differ petrologically and many are related to local centres (Sutherland 1971b, 1984). Although originally in valleys many now form cappings to hills; individual flows can be traced from hilltop to hilltop for up to 10 km. The flow at Big White Hill north-northeast of Melton Mowbray gave a date of 36.3 ± 0.5 Ma (Early Oligocene, table 1). It is up to 90 m thick and filled a valley. It caps two isolated hills close to the Jordan River — its base is 500 to 380 m altitude and well above the Jordan River at 210 m. The Jericho plug at Rose Hill Farm some 6 km to the north gave a date of 27.6 ± 0.4 Ma (Late Oligocene, table 1). It is at 400 m altitude and is the inferred feeder for a petrologically similar flow filling an ancestral gully of Rose Hill Creek at 420 to 500 m altitude some 2 km to the west. About 13 km to the northeast, near Oatlands township two flows overlie volcanic breccias (Sutherland 1984). The eastern flow (at Barwicks Hill) is a nepheline hawaiiite flow, with a base at 420 to 460 m; a sample (B) gave a minimum age of 25.0 ± 0.3 Ma (Late Oligocene, table 1). The western flow (at Fernleigh Hill; Sutherland 1984 and Forsyth 1984, p. 154) according to field evidence is a younger hawaiiite flow which has a base at 540 to 560 m. Samples are rarely fresh (B) and give a minimum date of 24.3 ± 0.3 Ma (Oligocene-Miocene boundary, table 1). The undersaturated lavas in this region therefore mostly give Middle to Late Oligocene ages, considerably older than suggested by Edwards (1939) on physiographic interpretations.

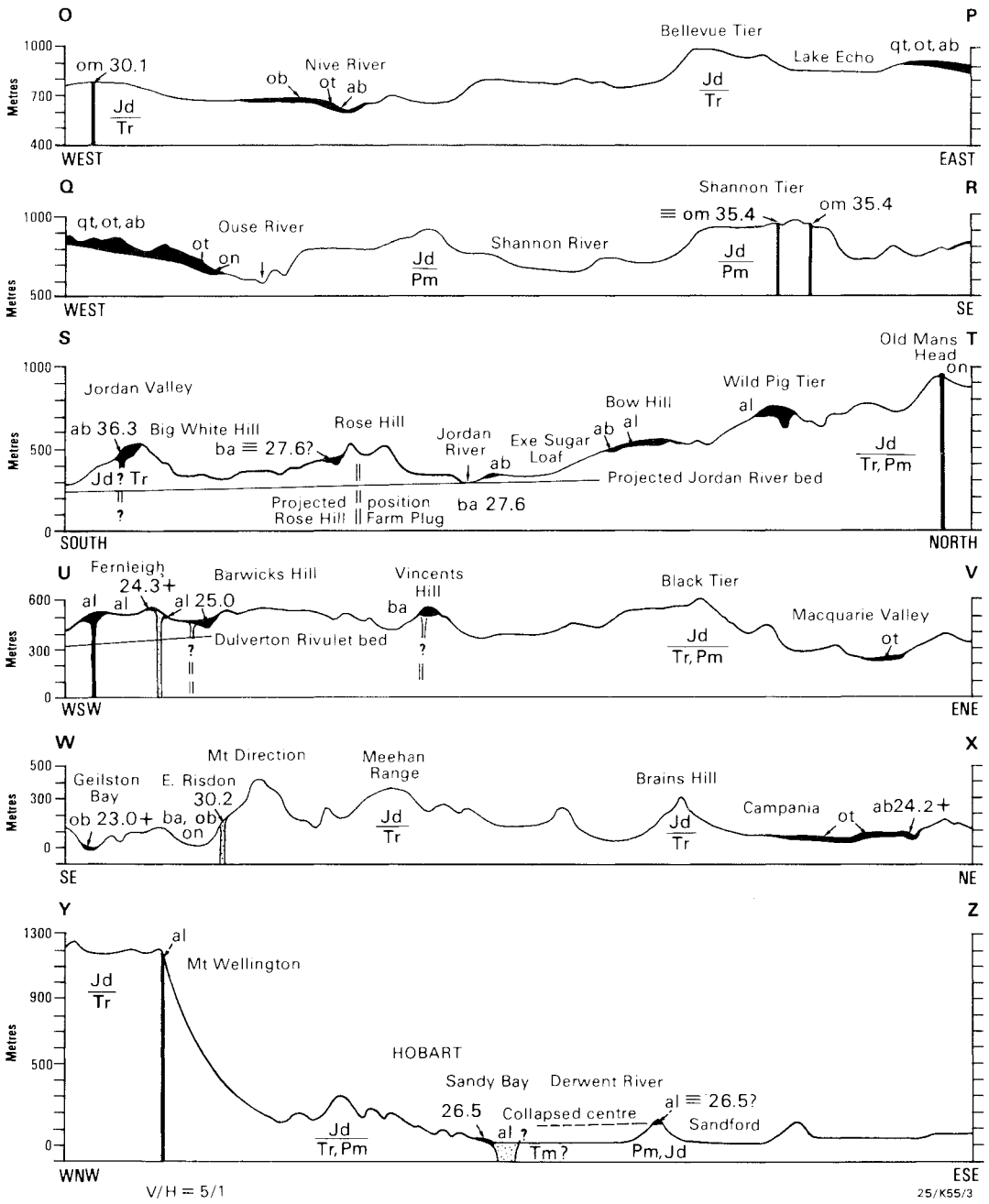


FIG.3 — Section lines through central, western Midlands, eastern and southern Tasmania. Legend as in Fig. 2.

Eastern Tasmania (Figs 1 and 3)

Tholeiitic lavas are more common than undersaturated lavas in this region and flowed for 50 km north down the ancestral Macquarie and South Esk and east down the Little Swanport River valleys. They descend from about 400 m to between 180 and 230 m altitude in the north. Here, near Cleveland, the flows fill valleys cut into sediments dated palynologically as Middle to Late Eocene (W.L. Matthews and S.M. Forsyth, pers. comm.). The lateritised flows form part of the Woodstock Surface of probable Pliocene age (Nicolls 1960; Matthews 1974). Samples collected were not fresh enough for K-Ar dating. Following Nye & Blake (1938) we believe that most of these tholeiitic basalts may be younger than the Oligocene alkaline lavas of the western midlands immediately to the southwest (Section U-V). We infer that they are probably Early to Middle Miocene in age. However, in the south at Pencil Point near Andover, an unusual olivine tholeiite flow erupted from a centre; it carries mantle lherzolite xenoliths (Sutherland 1974). This basalt (A-B) gives a date of 25.6 ± 0.2 Ma (table 1). This indicates some Late Oligocene overlap between the tholeiites and the alkaline eruptions of the western Midlands even though quartz tholeiite overlies nepheline mugearite near Lemont.

Southeastern Tasmania (Figs 1 and 3)

The most widespread flows are olivine tholeiites erupted into the valleys of the lower Derwent and Coal Rivers (McDougall 1959; Sutherland 1976, 1977a, 1980). Some of these lavas erupted into or flowed into water. No suitable tholeiitic rocks for K-Ar dating have been found. Tholeiites overlie an alkali basalt near Campania in the Coal Valley (Section W-X, fig. 3); the alkali basalt gives a minimum 24.2 ± 1.0 Ma age (earliest Miocene, table 1; Sutherland *et al.* 1973; Green 1976; Sutherland 1977a) and a sample of considerably altered tholeiite (C) gave an age older than 10 Ma (D.C. Green and F.L. Sutherland, unpublished). The tholeiitic lavas therefore may be latest Oligocene or Early Miocene in age.

Alkali basalts and fractionated alkaline lavas form short valley flows and pyroclastic centres around Hobart from D'Entrecasteaux Channel to Tasman Peninsula (Brill & Hale 1954; Spry 1962; Sutherland 1985). Amphibole from a tuff interbedded in the East Risdon volcanic centre gave a 30.2 ± 1.0 Ma age (Middle Oligocene; Sutherland 1976; Green 1976). A nearby olivine basalt flow

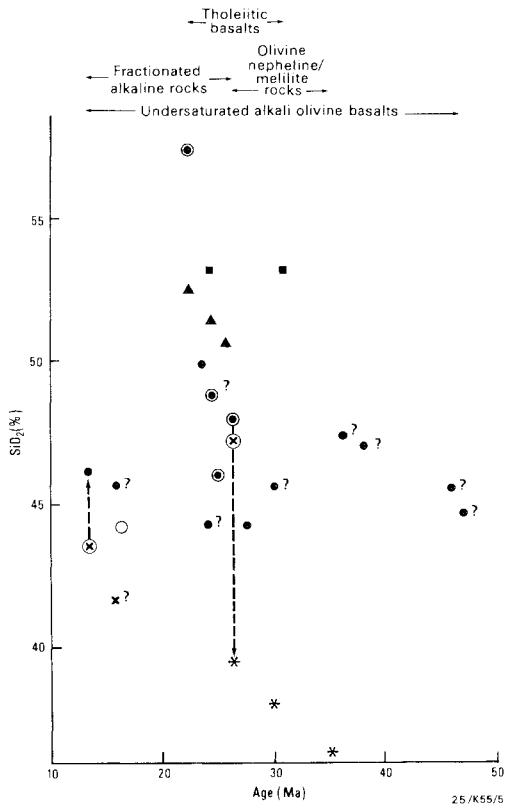


FIG.4 — SiO_2 versus age (Ma) plots for dated Tasmanian basalts, showing petrographic types vis. olivine melilitite/nephelinite rocks (asterisks) vis. olivine nephelinites (crosses), basanites (open circles), olivine tholeiites and transitional basalts (filled triangles) and quartz tholeiites (filled squares). More fractionated alkaline rocks of these lineages ($Ab/Ab+Ab > 0.55$) are indicated by circles enclosing the lineage type. Dated rocks with no available chemical analyses are shown at approximate SiO_2 content, based on analogy with petrographically similar analysed rocks taken from the cited literature, and are indicated by question marks. Age spreads of highly undersaturated melilitite-bearing rocks, undersaturated alkali basalts, tholeiitic basalts and more fractionated alkaline rocks are shown by tied arrows. Rocks immediately underlying and closely connected with dated basalts are linked by dashed arrows.

overlying a fossil marsupial site gave a minimum age of 23.0 ± 0.5 Ma (Tedford *et al.* 1975). The well-studied Sandy Bay volcanic centre (Charles Darwin, reported in Banks 1971; Johnston 1888;

Spry 1955) overlies Cainozoic sediments, with a palynological age of younger than Eocene and probably Yallournian (Oligocene; Gill 1962). The top flow of mafic nepheline benmorite (Sutherland 1974, 1976) has fresh rock (A-B) yielding a date of 26.5 ± 0.3 Ma (Late Oligocene, table 1). The dated alkaline volcanics in southeastern Tasmania (Sections W-X, Y-Z, fig. 3) are therefore Mid-Oligocene to Early Miocene in age.

Bass Basin

In Bass Basin, a similar volume of basalts to that occurring above sea level in Tasmania is interbedded with the sediments (Robinson 1974; Brown 1976). Palaeontological dating suggests that this volcanism ranges from Eocene to Miocene. This is a similar time span to that shown by dated on-shore Tasmanian basalts. The oldest dated Tasmanian basalt (47 Ma, NE Tasmania) is significantly younger than the graben formation and Late Cretaceous-Early Palaeocene sedimentation that extends from Bass Basin into the Tasmanian mainland (Moore *et al.* 1984).

The volcanic successions intersected in Bass Basin bore holes are generally too altered for satisfactory dating, but an intrusion in Early Eocene sediments in Cormorant No.1 bore (B.R. Brown 1976, fig. 5) seemed suitable. The intrusion is an unusual alkaline rock with no known counterpart on-shore in Tasmania; it grades from a picritic cumulate with a hydrous altered groundmass to a coarser analcime-bearing highly sodic and felsic gabbro. It appears to represent a monchiquite intruded into and fractionated within the wet sediments. Biotite separated from the rock is only slightly altered and gives a minimum date of 22.4 ± 0.1 Ma (unpublished data, Bureau of Mineral Resources). The date (table 1) suggests Early Miocene alkaline activity towards the close of Bass Strait volcanism. This activity may include an Early-Middle Miocene monchiquite intrusion at Portland, Victoria (Glenie & Reed 1962), dated as at least 17.5 Ma (Harding 1966).

PETROLOGY AND AGES

The dating and petrological information discussed above is summarised in figure 4. Initial, restricted and mildly alkaline basaltic volcanism in the Early Eocene (Weldborough area; 47 Ma) was followed by more widespread undersaturated volcanism from Middle to Late Eocene to earliest Oligocene (Northern, Central and Midlands regions: 35-38 Ma). Strongly undersaturated to saturated lavas were erupted in the Early-Middle

Oligocene (Central, Southeastern, Northwestern and Northern regions: 26-35 Ma). This widespread volcanism continued through the Late Oligocene-Early Miocene but overlapped with some activity leading to fractionated alkaline lavas (Midlands, Eastern, Southeastern, Bass Basin regions: 22-27 Ma). A final phase of undersaturated volcanism is recognised in northern Tasmania around the Middle Miocene (Ringarooma-Winnaleah, Table Cape regions: 13-16 Ma). The total volume of lava erupted in Tasmania was only about 400 km^3 (Sutherland 1969a).

The main 'magmatic message' emerging from the dating of Tasmanian Tertiary volcanic rocks is that oversaturated basalts (approximating to SiO_2 contents above 50% in figure 4) are virtually confined to the Mid-Tertiary episodes (21 to 31 Ma). If these tholeiites represent relatively high degrees of partial melting of mantle source rocks (Frey *et al.* 1978) this correlates with an Oligocene-Early Miocene peak of volcanism. The only other rock with SiO_2 significantly over 50% is the highly fractionated sodic gabbro from Cormorant-1 well in Bass Strait. However, this rock is derived from an undersaturated parent and belongs to the waning stage of volcanic activity in Bass Strait.

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