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# Tectonic setting and geochemistry of Miocene alkalic basalts from the Jones Mountains, West Antarctica

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**Abstract:** Within the Jones Mountains, which form part of the Thurston Island crustal block, up to 700 m of Miocene (*c.*10 Ma) pillow basalt and palagonitized volcaniclastic rocks unconformably overlie Jurassic granitic basement and Cretaceous volcanic rocks and dykes. New geochemical analyses demonstrate the alkalic nature of the basalts, which range in composition from alkali basalt to basanite. Unradiogenic Sr-isotope ratios (0.7031–0.7034), coupled with low LILE/HFSE ratios (e.g. Th/Ta c. 1.4, Rb/Nb 0.3–0.9) indicate a predominantly asthenospheric source for the basalts. The Jones Mountains basalts are geochemically similar to the alkalic basalts of Marie Byrd Land, but have consistently lower K/Ba and higher Ba/Nb ratios than Late Cenozoic alkalic basalts along the Antarctic Peninsula. These regional variations in geochemical composition apparently reflect differences in tectonic setting and are not the result of lithospheric interaction or partial melting/crystallization effects. The generation of alkalic magmas along the Antarctic Peninsula was causally related to the formation of slab windows following ridge crest-trench collision and the cessation of subduction, whereas the Jones Mountains alkalic basalts may represent the expression of the northward propagation of the head of the Marie Byrd Land plume.

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**Key words:** alkali basalts, plume volcanism, asthenospheric magmas, crustal thinning

## Introduction

Cenozoic alkalic volcanic rocks are exposed within three of the five main crustal blocks within West Antarctica; Marie Byrd Land, Thurston Island and the Antarctic Peninsula (Fig. 1). The Marie Byrd Land alkaline province consists of alkalic basaltic rocks and associated acid differentiates which form shield volcanoes, which were erupted during the past 28 Ma (Futa & LeMasurier 1982, LeMasurier & Rex 1989, LeMasurier 1990, Hole & LeMasurier in press). They formed on the flanks of an intracontinental rift system and have been related by LeMasurier & Rex (1989) to a mantle hot spot beneath the area.

In contrast to this, alkalic basalts younger than 15 Ma were erupted from numerous small centres scattered widely throughout the Antarctic Peninsula (Smellie *et al.* 1988). Hole *et al.* (1991a) have related these rocks to mantle melting following cessation of long-lived subduction brought about by collision of small offset segments of the Antarctic-Phoenix spreading system with the trench. Continued sinking of the leading oceanic lithospheric plate resulted in the formation of a slab-window, which facilitated the uprise and decompression melting of fertile asthenospheric mantle.

Alkalic basalts in the Jones Mountains, part of the Thurston Island crustal block, are the least known part of the West Antarctic alkaline volcanic province. They were originally described by Craddock *et al.* (1964) and Rutford *et al.* (1972) and the present study is based on a collection of rocks samples and field observations made during a 1984/85 visit of the joint BAS-USAP West Antarctic Tectonic Project to the area. New geochemical and isotopic data are presented and compared with the neighbouring Marie Byrd Land and Antarctic Peninsula provinces, the latter of which includes occurrences in N Ellsworth Land (Hudson Mountains, Rydberg Peninsula and Snow Nunataks) close to the margin of the Thurston Island crustal block.

## Tectonic setting

The Thurston Island crustal block, on the Pacific margin of West Antarctica, is separated from neighbouring Marie Byrd Land and the Antarctic Peninsula crustal blocks by deep sub glacial troughs (Fig. 1), and on its southern side from the Ellsworth-Whitmore mountains crustal block by the Byrd sub glacial basin. It may have moved from an earlier position closer to the Transantarctic Mountains in response to Cenozoic rifting and extension which produced these sub glacial troughs and basins (Storey 1991).

Prior to the Late Cretaceous, New Zealand belonged to this part of the proto-Pacific margin of Antarctica (Fig. 2a). Pacific ocean floor generated at the Pacific-Phoenix spreading system was being subducted in this region and Late Jurassic (152–142 Ma) and Early Cretaceous (125–110 Ma) calc-alkaline magmas were emplaced in Thurston Island (Pankhurst *et al.* in press). Bradshaw (1989) has postulated that subduction ceased off part of the New Zealand crustal block, oceanward of Thurston Island, by collision of offset segments of the Pacific-Phoenix spreading ridge with the trench at 105±5 Ma. This was

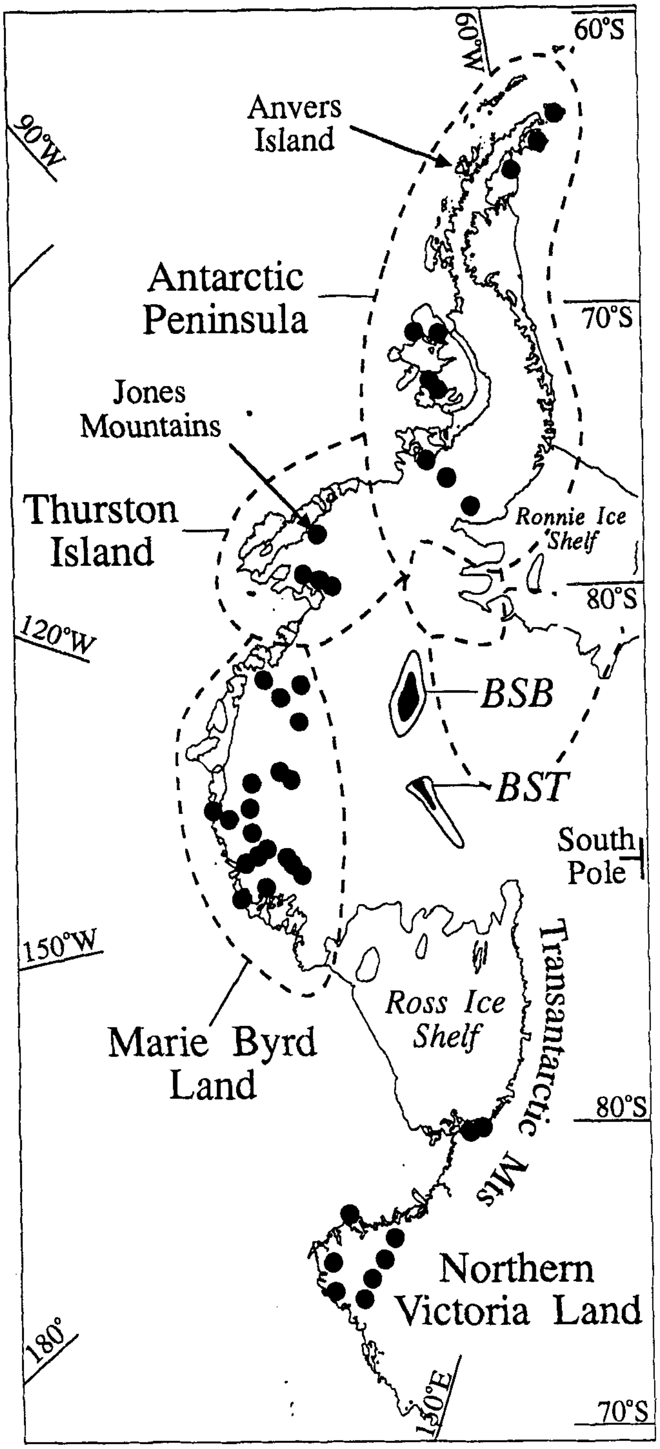

**Fig. 1.** Map of Part of West Antarctica showing the approximate distribution of Late Cenozoic volcanic rocks (filled circles) in relation to crustal blocks. Sub-ice topography is also shown. BSB, Byrd Subglacial Basin; BST, Bentley Subglacial Trench.

closely followed by separation of New Zealand from Antarctica with the earliest sea-floor magnetic anomaly identified by Mayes *et al.* (1990) as chron 34 (84 Ma). Magmatic activity continued in the Thurston Island block with the emplacement of coast-parallel bimodal dyke suites and associated volcanic rocks at approximately 90–100 Ma.

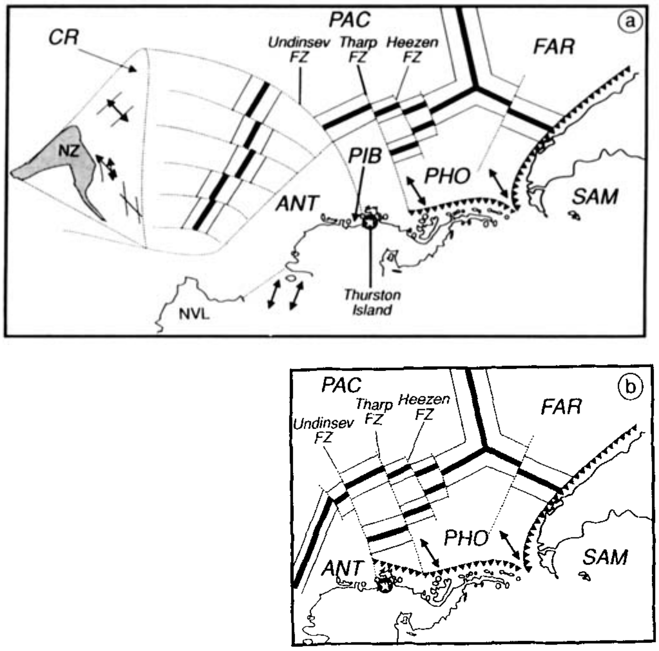

**Fig. 2.** Sketch map of the proto-Pacific margin of West Antarctica, South America and New Zealand illustrating two alternative tectonic settings for the Thurston Island crustal block at 60 Ma. a) subduction ceased off the Thurston Island margin at 105±5 Ma (Bradshaw 1989) b) subduction still active prior to collision of the Antarctic Phoenix spreading ridge with the Thurston Island margin (after Larter & Barker 1991). Star is the position of the Jones Mountains. PAC, Pacific Plate; FAR, Farallon Plate; PHO, Phoenix Plate; SAM, South American Plate; ANT, Antarctic Plate; NZ, New Zealand crustal block; NVL, Northern Victoria Land; CR, Chatham Rise; PIB, Pine Island Bay. Arrows, convergence directions.

The precise pre-drift position of New Zealand is, however, uncertain due to the scarcity of sea-floor magnetic data in the Bellingshausen and Admundsen seas but is an important constraint on the Cenozoic tectonic setting of Thurston Island. Sea floor topography revealed by GEOSAT altimetry data (Sandwell & McAdoo 1988, Royer *et al.* 1990) gives a clear indication of continental separation. The trace of the Udinsev fracture zone links the tip of the Chatham Rise to the Antarctic margin in the Pine Island Bay area, thus separating the extensional Marie Byrd Land-New Zealand rifted margins from the Thurston Island and Antarctic Peninsula margin (Fig. 2a).

North of the Tharp fracture zone, the Pacific-Phoenix ridge was replaced around the time of sea-floor magnetic anomaly 28 (63 Ma), by a dual system of spreading centres; the Pacific-Antarctic and Antarctic-Phoenix ridges (Cande *et al.* 1982) (Fig. 2a). The Antarctic Phoenix ridge migrated towards the West Antarctic margin and collided with the trench causing subduction to cease. The age of diachronous collision between the Tharp and Heezen fracture zones is estimated to be 57±1 to

45±3 Ma (Larter & Barker 1991). Little is known about the area offshore of Thurston Island between the Tharp and Udinsev fracture zones. Larter & Barker (1991) have suggested, based on the magnetic anomalies identified by Kimura (1982), that the first collision of the Antarctic Phoenix spreading system occurred off this margin between 63–55 Ma, soon after the initiation of the spreading system (Fig. 2b). The implication for this is that the Thurston Island crustal block was situated at a convergent margin up to 60 Ma, whereafter it formed part of the passive margin of the Antarctic Plate. The alkalic basalts of the Jones Mountains would have been erupted *c.* 40 Ma after this possible collision episode offshore of Thurston Island.

## Field relations and petrography

The Cenozoic alkalic basalts in the Jones Mountains are up to 700 m thick. They overlie unconformably Jurassic granitic basement and associated Cretaceous volcanic rocks and dykes (Storey *et al.* 1991), the unconformity being marked by a gently undulating, glacially striated surface. Thin, discontinuous lenses of light-brown diamictite containing striated clasts of underlying basement and fragmented pillow basalt, form the base of the Cenozoic succession. The diamictite lenses are interpreted as tillites, suggesting that the volcanism was broadly contemporaneous with glaciation. The overlying basalts are divided into broadly similar upper and lower units, each representing an individual eruptive phase. The base of each unit contains up to 10 m of variably stratified, cross-bedded, reworked lapillistones and tuffs. Normal and reverse graded units suggest some are mass-flow deposits. Both upper and lower units are formed predominantly of massive, highly vesicular pillow lavas with conspicuous glassy chilled margins. Pillow breccias and palagonitized hyaloclastite debris of variable grain-size are common. Irregular lenses of pale-yellow and brown reworked tuffs and lapillistones are contained within the main lava sequence.

All the studied samples are fresh and olivine-phyric, with up to 10% total modal volume of phenocrysts. Samples from locality R.3116 contain additional rare, scattered clinopyroxene phenocrysts and plagioclase micro-phenocrysts. One sample (R.3103.14), exhibits a well-developed variolytic texture. Purple-brown titaniferous augite and plagioclase laths are present in the groundmass of all samples.

## Geochronology

Rutford *et al.* (1972) documented whole-rock K–Ar ages for the volcanic rocks which unconformably overlie the Cretaceous granitoids and noted a strong discordance in age determinations. Ages varied from 332 to 6.1 Ma and it was noted that samples collected from within 3 m of the unconformity yielded ages of 332–9 Ma, whereas samples from more than 100m above the unconformity yielded consistent Miocene ages (24–6.1 Ma). The reason for this anomalous range in age determinations is unclear, but samples yielding ages older than the Miocene were presumed to contain excess radiogenic argon Rutford *et al.* (1972). New determinations on two samples collected during the 1984–85 season, yield 125 Ma and 10.5±0.5 Ma (Table I). We agree that 10–7 Ma is the best estimate of the time of eruption of these basalts, and thus assign a Miocene age to them, although imprecise ages of 24±12 and 22±12 have been reported .

**Table I.** New K-Ar data on basalts from the Jones Mountains. (dup) = duplicate analysis. Decay constants from Steiger and Jager (1977). Analyses carried out at the NERC Isotope Geoscience Laboratories, Gray's Inn Road, London.

| Sample no. | K% | $^{40}$Ar radiogenic (nl/g) | % $^{40}$Ar radiogenic | age Ma |
|---|---|---|---|---|
| R.3103.14 | 0.52 | 2.7490 | 77.28 | 132 ± 10 |
| R.3103.14 (dup) | 0.52 | 2.6905 | 76.93 | 129 ± 10 |
| R.3116.2 | 0.65 | 0.2670 | 48.59 | 10.5 ± 0.5 |
| R.3116.2 (dup) | 0.65 | 0.2545 | 49.08 | 9.99 ± 0.36 |

## Geochemistry

Nine fresh samples of basalts were analysed for major and trace elements by XRF at the University of Keele, UK. Two samples were analysed for the rare earth elements (REE), Th, Ta, Hf, Cs, U, Sc and Co by INAA at the Open University, UK. All samples were crushed in an agate TEMA mill to avoid the Co and Ta contamination reported from WC mills. Data are presented in Tables II & III.

Two samples (R.3003.4 and R.3105.2) fall in the basanite field on the total alkalis-silica classification diagram of Cox *et al.* (1982), whereas the remaining samples are alkali basalts. All samples are *ne*-normative (2.4–10.2%), the basanites containing the highest percentage of *ne* in the norm. An important feature of all analysed samples is their primitive nature; MgO contents vary from 10.8–12.3% and are accompanied by high Ni and Cr abundances (225–308 and 370–440 ppm respectively).

MORB-normalized plots for basanite R.3003.4 and alkali basalt R.3004.1 (Fig. 3), exhibit smooth convex upwards patterns which peak at Nb and Ta, and converge at Y. These two samples are also LREE-enriched ($La_n/Yb_n$ 7.5 and 13.9 for alkali basalt and basanite respectively). All analysed samples have low Zr/Nb (5.6–7.9) and LILE/HFSE ratios (e.g. Rb/Nb 0.33–0.89, Th/Ta c. 1.2) and high but variable Nb/Y and Zr/Y ratios (0.79–1.6 and 5.3–9.0 respectively) with relatively consistent abundances of Y (23–19ppm). The consistency of Y abundances, but the variability in HFSE/Y ratios suggest that all samples were derived by small degrees of partial melting of the mantle, and at some stage during their genesis were in equilibrium with garnet lherzolite. These types of geochemical signatures are characteristic of alkalic basalts from a variety of tectonic settings, including ocean island basalts (OIB; e.g. Weaver 1991, Palacz & Saunders 1986), continental alkali basalts (e.g. Western USA; Thompson *et al.* 1984) and post-subduction slab-window related basalts from Baja California (Storey *et al.* 1989), the Antarctic Peninsula (Hole 1988, 1990, Hole *et al.* 1991a,b, Hole

**Table II.** New XRF major and trace element analyses for the Jones Mountains Cenozoic basalts.

| Sample # | R.3003.4 | R.3004.1 | R.3013.14 | R.3013.13 | R.3105.2 | R.3116.2 | R.3116.5 | R.3116.6 | R.3116.4 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 43.31 | 45.09 | 44.38 | 42.54 | 43.63 | 45.02 | 45.42 | 45.26 | 45.60 |
| $TiO_2$ | 2.05 | 1.62 | 1.64 | 1.70 | 2.16 | 2.07 | 2.16 | 2.19 | 2.23 |
| $Al_2O_3$ | 12.89 | 13.98 | 13.86 | 14.16 | 13.19 | 13.56 | 14.13 | 14.09 | 14.27 |
| $Fe_2O_3$ | 13.31 | 13.26 | 12.88 | 13.28 | 13.39 | 13.42 | 13.28 | 13.58 | 13.33 |
| MnO | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| MgO | 10.97 | 11.23 | 10.89 | 11.16 | 10.81 | 12.13 | 10.98 | 11.06 | 10.90 |
| CaO | 9.23 | 9.19 | 9.17 | 9.11 | 9.39 | 9.42 | 9.74 | 9.60 | 9.78 |
| $Na_2O$ | 3.55 | 2.98 | 2.73 | 2.76 | 3.56 | 2.74 | 3.05 | 2.94 | 2.99 |
| $K_2O$ | 1.07 | 0.66 | 0.64 | 0.68 | 1.10 | 0.93 | 0.75 | 0.72 | 0.84 |
| $P_2O_5$ | 0.48 | 0.26 | 0.26 | 0.26 | 0.48 | 0.35 | 0.38 | 0.39 | 0.39 |
| LOI | 2.10 | 1.40 | 3.10 | 4.10 | 1.78 | -0.14 | -0.09 | 0.32 | -0.12 |
| Total | 99.13 | 99.84 | 99.72 | 99.93 | 99.67 | 99.68 | 99.98 | 100.33 | 100.39 |
| Trace elements (XRF) | | | | | | | | | |
| Rb | 18 | 15 | 15 | 13 | 19 | 13 | 11 | 8 | 12 |
| Ba | 259 | 174 | 187 | 174 | 233 | 181 | 194 | 185 | 189 |
| Sr | 627 | 387 | 382 | 275 | 619 | 496 | 501 | 508 | 513 |
| Y | 21 | 23 | 22 | 22 | 22 | 22 | 23 | 23 | 25 |
| Zr | 185 | 122 | 120 | 117 | 183 | 155 | 159 | 165 | 163 |
| Nb | 33 | 19 | 17 | 16 | 31 | 22 | 23 | 24 | 24 |
| Cr | 406 | 389 | 385 | 381 | 388 | 440 | 402 | 370 | 373 |
| Ni | 287 | 308 | 282 | 290 | 263 | 320 | 263 | 269 | 255 |

Hole *et al.* in press), British Columbia (Bevier *et al.* 1979, Bevier 1983, Thorkelson & Taylor 1989) and Patagonia (Ramos & Kay 1992).

On a plot of MgO versus Ni, (Fig. 4) the Jones Mountains samples fall close to the theoretical partial melting trajectories for a garnet-bearing lherzolite (Hart & Davies 1978, Clague & Frey 1982). In addition, all analysed samples have high concentrations of Cr (370–440 ppm). These basalts can therefore be considered to represent near-primary mantle-derived magmas. By contrast, data for the post-subduction alkalic basalts from the Antarctic Peninsula form a field extending considerably below the partial melting trajectories in Fig. 4, have a much broader range of Cr abundances (350–25 ppm) and have clearly undergone some fractional crystallization of olivine ± clinopyroxene (Hole 1988, 1990). The Jones Mountains basaltic rocks are therefore some of the most primitive alkalic magmas yet described for the Cenozoic basalts of West Antarctica. As such, variability in their incompatible trace element abundances presumably reflect source region heterogeneities and/or variations in the degree of partial melting rather than the effects of high-level fractional crystallization. It is difficult to place absolute constraints on the degree of partial melting

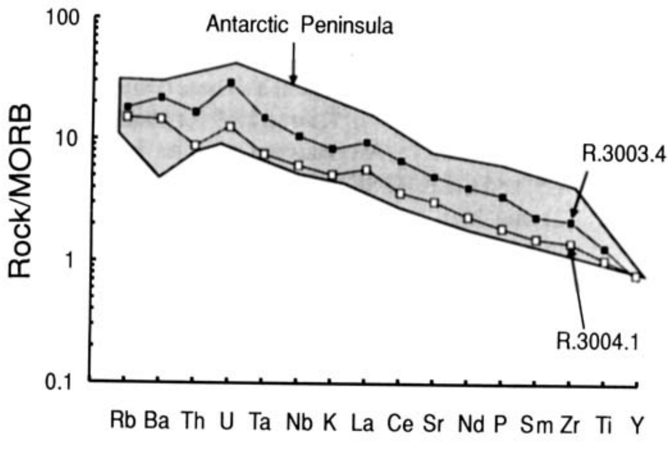

**Fig. 3.** MORB-normalized multi-element plots for alkali basalt R.3004.1 and basanite R.3003.4 from the Jones Mountains. The range of compositions for basalts from the Antarctic Peninsula (Hole 1988, 1990) are also shown. Normalizing values from Sun & McDonough (1989).

**Table III.** REE, Th, Ta, Hf, Sc, Co and Sr- and Nd-isotope data for a Jones Mountains basanite and alkali basalt.

| Sample # | R.3003.4 | R.3004.1 |
|---|---|---|
| La | 28.60 | 17.20 |
| Ce | 61.00 | 33.20 |
| Nd | 31.70 | 18.20 |
| Sm | 6.62 | 4.36 |
| Eu | 2.09 | 1.49 |
| Tb | 0.87 | 0.79 |
| Yb | 1.38 | 1.80 |
| Lu | 0.21 | 0.27 |
| Th | 3.34 | 1.76 |
| Ta | 2.41 | 1.21 |
| Hf | 4.15 | 2.80 |
| U | 2.91 | 1.27 |
| Cs | 0.33 | 0.30 |
| Sc | 24.10 | 29.60 |
| Co | 61.80 | 63.80 |
| $^{87}Sr/^{86}Sr$ | 0.70337 | 0.70311 |
| $^{143}Nd/^{144}Nd$ | 0.512825 | – |

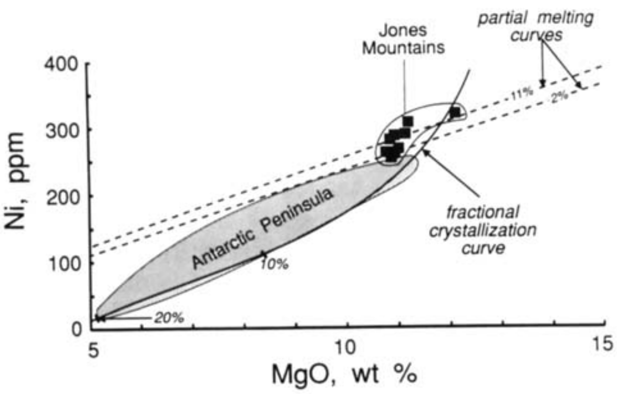

**Fig. 4.** Plot of MgO versus Ni for the Jones Mountains and Antarctic Peninsula samples, illustrating the primitive nature of the former. Partial melting curves for 2 and 11% melting of mantle peridotite, and the fractional crystallization trajectory are taken from Hart & Davies (1978) and Clague & Frey (1982).

required to produce the Jones Mountains basalts. For example, published estimates of the amount of melting required to produce Hawaiian basanites vary from 5–11% (Clague & Frey 1982) whilst Fitton & Dunlop (1985) suggest that alkalic basalts from the Cameroon Line, West Africa, were produced by less than 0.35% partial melting of mantle peridotite. However, for the present it is sufficient to state that the degree of partial melting required to produce the Jones Mountains suite decreases with increasing Nb/Y ratios and degree of silica undersaturation, the basanites being derived by smaller amounts of partial melting than the alkali basalts.

## Petrogenesis

### *Incompatible trace element fractionation*

Before considering regional variations in the geochemical composition of alkalic basalts from the Jones Mountains and Antarctic Peninsula, we will briefly discuss the origin of trace element variations within the Jones Mountains suite. It is well established that some trace elements that behave highly incompatibly during relatively high degrees of partial melting (e.g. during the formation of MORB and continental tholeiitic basalts) are variably incompatible during low degrees of partial melting (< 1%). For example, Hole (1988, 1990), Smedley (1988) and Greenough (1988) demonstrated that during the low degrees of partial melting required to produce undersaturated basanites and alkali basalts, Zr/Nb ratios vary systematically with degree of silica undersaturation, LREE-enrichment and Nb/Y ratios, variations that are independent of isotopic criteria. Similar trends are seen for the alkalic basalts of West Antarctica (Fig. 5), strongly implying that variations in Zr/Nb ratios are the result of partial melting effects, possibly due to the slightly higher distribution coefficients for Zr compared to Nb in residual clinopyroxene (Clague & Frey 1982). Similarly, it has been noted that Ti/Nb, P/Nb and Sr/Zr ratios are also fractionated during low degrees of partial melting. The above inter-element ratios are therefore not reliable indicators of source-region heterogeneity for undersaturated alkalic basalts. Although strong fractionation of K relative to the other LILE and LREE has been demonstrated for extremely undersaturated nephelinites and melilitites (larnite normative compositions; Davies *et al.* 1989, Greenough 1988), relative LILE fractionation does not appear to be important for basanites and alkali basalts. Therefore, LILE/Nb and K/LILE ratios are the most likely elemental ratios to record source region heterogeneities and/or asthenosphere-lithosphere interaction.

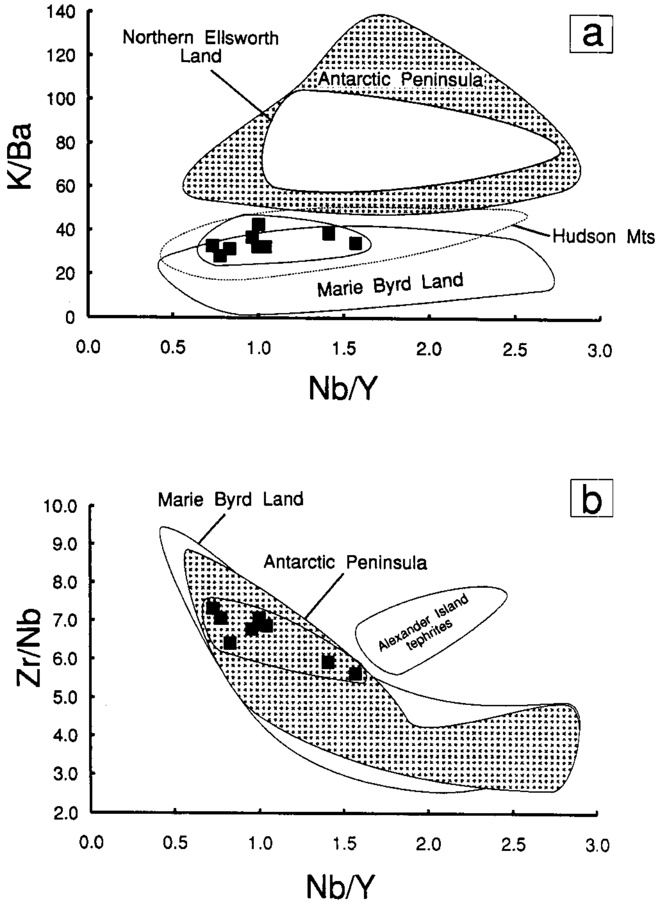

**Fig. 5.** Nb/Y versus a) K/Ba and b) Zr/Nb for the Jones Mountains (this study), Hudson Mountains, Northern Ellsworth Land (includes Merrick Mountains, Snow Nunataks, Rydberg Peninsula), Marie Byrd Land and the Antarctic Peninsula (Hole 1988, 1990). Other data from LeMasurier (1990) and Rowley *et al.* (1990). Note that some of the tephrites from Alexander Island fall outwith the field for the rest of the Antarctic Peninsula basalts. This is probably a function of high-level clinopyroxene crystallization in these relatively evolved samples.

The Jones Mountains samples generally have higher LILE/Nb ratios and lower K/Ba ratios than the alkalic basalts of the Antarctic Peninsula, and overlap with the compositional fields for the Hudson Mountains and Marie Byrd Land, a feature

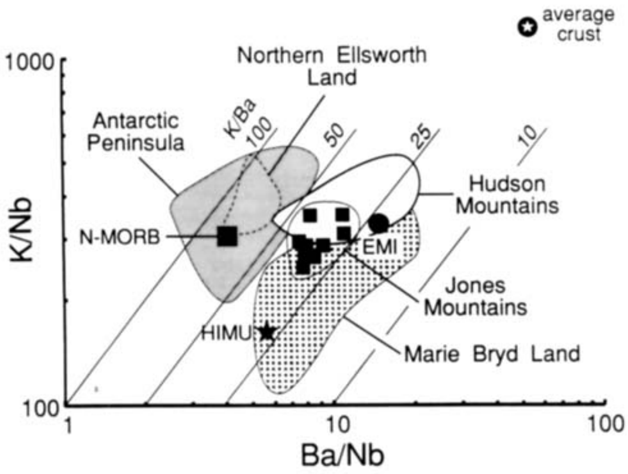

**Fig. 6**. Ba/Nb versus K/Nb for West Antarctic Late Cenozoic basalts. Data sources as for Fig. 5. Average crust and OIB compositions from Weaver (1991). HIMU and EMI and EMII, enriched mantle components from Hart (1988).

which is clearly independent of degree of partial melting (e.g. Fig. 5). Two of the Jones Mountains samples have been analysed for strontium isotopic compositions, and both have $^{87}Sr/^{86}Sr$ ratios (0.70311 and 0.70334, Table III) which are within the range for basalts from the Antarctic Peninsula region ($^{87}Sr/^{86}Sr$ = 0.7027–0.7034). The unradiogenic Sr– isotope ratios (and radiogenic Nd; Table III), coupled with the primitive nature and low LILE/HFSE ratios of the Jones Mountains samples, suggest that they cannot have been subject to any significant lithospheric interaction and can be considered to be largely asthenosphere derived. On a plot of Ba/Nb versus K/Nb for alkalic basalts from a variety of locations from West Antarctica (Fig. 6), the data are clearly divided into two distinct fields which correspond with geographical location; samples from the Antarctic Peninsula (including Northern Ellsworth Land; Rydberg Peninsula, Snow Nunataks and Merrick Mountains) all plot at significantly lower Ba/Nb but high K/Ba ratios for a given K/Nb ratio than samples from the Jones and Hudson mountains and Marie Byrd Land. Indeed, the unusually high K/Ba, K/Rb and low Ba/Nb ratios of the Antarctic Peninsula basalts distinguish them from most OIB and many other occurrences of continental alkali basalts. A two-fold geographical division of incompatible trace element ratios is therefore evident, with a sharp "boundary" being present between the Antarctic Peninsula and Thurston Island crustal blocks (Fig. 1). These differences in incompatible trace element ratios between the Jones Mountains and Antarctic Peninsula basalts must therefore be a result of the sampling of geochemically different asthenospheric domains.

## Tectonic controls on alkalic magmatism

Hole *et al.* (1991a) have related the generation of the alkalic basalts of the Antarctic Peninsula to the propagation of slab-windows beneath the continental margin following progressive ridge-crest trench collisions. This is not a unique association, slab windows have been related to alkalic magmatism in a number of other areas (e.g. British Columbia, Thorkelson & Taylor 1989, Patagonia, Ramos & Kay 1992, Baja California, Storey *et al.* 1989). For the Antarctic Peninsula crustal block, ridge crest-trench collision times, and the initiation of slab window formation vary from c. 50 Ma at the Tharp FZ to less than 4 Ma off the coast of Anvers Island in the northern Antarctic Peninsula. The generation of slab-windows along the Antarctic Peninsula requires the continued subduction of the leading oceanic lithospheric plate beneath the continental margin after collision (Hole *et al.* 1991a, Hole & Larter 1993, Hole *et al.* in press). Generation of alkalic basalts was apparently linked causally to the process of slab window formation.

The timing of the cessation of subduction in relation to the age of the associated alkalic magmatism is complex and depends on the distance of the alkalic basalts from the trench, the subduction rate of the adjacent oceanic plate and the angle of subduction (Ramos & Kay 1992, Hole & Larter 1993). In addition, another important control on the timing of magmatism appears to be the location of the volcanic centres relative to the landward trace of subducted fracture zones. For example, it was noted by Hole (1990) and Hole *et al.* (1991a) that at Seal Nunataks, in the northern Antarctic Peninsula, there is a distinct parallelism of individual eruptive centres with the landward trace of subducted transforms, a feature that is also seen in the slab-window related basalts of British Columbia (Bevier *et al.* 1979). In this case there was very little time gap (< 4 Ma) between ridge crest trench collision and the initiation of alkalic magmatism. Conversely, in areas above the central part of slab-windows there may be a long time lapse between cessation of subduction and initiation of alkalic magmatism (up to 40 Ma), and the magmatic products may be more voluminous (e.g. southern Alexander Island, Hole 1988).

Because of the difficulties in constraining the timing of cessation of subduction off the Thurston Island crustal block, the temporal association between ridge crest-trench collision and initiation of alkalic magmatism in the Jones Mountains is unclear. The plate reconstructions of Larter & Barker (1991) (Fig. 2b) suggest that alkalic magmatism both in the Jones and Hudson mountains was initiated *c.* 40 Ma after cessation of subduction. This time lapse is similar to that for the alkalic basalts of southern Alexander Island in the Antarctic Peninsula crustal block, which Hole *et al.* (1991a) suggested were causally related to slab window formation. However, an important consideration here, is that whilst some of the slab window-related basalts of the Antarctic Peninsula post-date cessation of subduction by up to 40 Ma, magmatism was generally initiated considerably earlier, and in some cases less than 4 Ma after ridge crest-trench collision. By contrast, in the Thurston Island crustal block, the minimum time lapse possible is *c.* 40 Ma. Indeed, if the hypothesis of Bradshaw (1989) is correct, and collision took place at 105±5 Ma outboard of the Thurston Island block, then the Jones and Hudson mountains alkalic basalts post-date cessation of subduction by more than 75 Ma. In this case, there cannot be a simple association between cessation of subduction and initiation of alkalic magmatism, and alternative mechanisms for melt generation must be considered.

Other possible explanations for the generation of basalts with compositions like those of the Jones Mountains are;

1) adiabatic upwelling and decompression melting associated with lithospheric attenuation (White & McKenzie 1989)
2) melting associated with mantle plume (McKenzie & Bickle 1988)
3) a combination of both lithospheric stretching and a plume (e.g. Saunders *et al.* 1992, Thompson & Gibson 1991)

Indeed, some authors argue that to generate melt from a subcontinental plume, the mechanical boundary layer must have been previously thinned (Thompson & Gibson 1991, Saunders *et al.* 1992). The generation of these lithospheric "thinspots" prior to plume activity can also facilitate sub-lithospheric channelling of hot, rising plume material.

LeMasurier & Rex (1989) suggested that the existence of a mantle plume was a satisfactory explanation for the tectono-magmatic regime and generation of alkalic basalts in Marie Byrd Land, a hypothesis with which we concur. The question which then arises is whether the volcanism in the Hudson and Jones mountains could represent the northward extension of the Marie Byrd Land plume "head", possibly aided by sub-lithospheric channelling. The subglacial troughs and basins which separate Thurston Island from the Antarctic Peninsula and Marie Byrd Land crustal blocks, may represent the crustal expressions of such lithospheric attenuation and "thinspots". However the precise timing of their generation is poorly constrained, but may be Cenozoic (Storey 1991). Plume activity in Marie Byrd Land appears to have been initiated at around 30 Ma (Futa & LeMasurier 1982, LeMasurier & Rex 1989), such that if lithospheric thinning had already taken place at the Thurston Island Crustal Block prior to that time, northward propagation of the Marie Byrd Land Plume to the locus of magmatism at the Jones and Hudson mountains could have occurred. Whether the Cenozoic extension itself was of sufficient magnitude to produce alkalic magmas without plume interaction is difficult to assess if the precise timing and pre-rifting lithospheric thicknesses are not accurately known.

Whilst the occurrences of alkalic basalts along the Antarctic Peninsula can be related largely to the generation of slab windows following cessation of subduction, we suggest that this may not be a satisfactory explanation for the alkalic magmatism within the Thurston Island crustal block. There appear to be other tectonic events, namely Cenozoic or earlier lithospheric attenuation and plume activity in Marie Byrd Land, which contributed to the genesis of Late Cenozoic magmatism at the Jones and Hudson mountains. Indeed, both the Marie Byrd Land and Jones Mountains basaltic rocks have certain incompatible trace element (e.g low K/Ba and K/Nb ratios) and Sr- and Nd-isotope ratios which are characteristic basalts associated with HIMU plumes (Hole & LeMasurier, in press). The sharp delineation of two geographically constrained geochemical provinces is consistent with this hypothesis; the slab window-related basalts of the Antarctic Peninsula are geochemically distinct from other areas of Late Cenozoic magmatism in West Antarctica, as well as from OIB and other continental alkali basalt provinces. Indeed, Hole *et al.* (in press) argued that the alkalic basalts of the Antarctic Peninsula crustal block are one of the few known occurrences of small-degree melts of the asthenosphere that are neither associated with a mantle plume nor significant lithospheric attenuation. The geochemical differences between the two provinces probably reflects differences in the composition of plume associated melts and small-degree melts of MORB-source mantle.

## Conclusions

The alkalic basalts of the Jones Mountains are primitive melts derived from the asthenosphere and were not modified by interaction with the lithosphere.

They are geochemically distinct from the slab window-related basalts of the Antarctic Peninsula crustal block, but similar to the alkalic basalts of Marie Byrd Land, which are associated with a mantle plume.

The slab window-related basalts represent small-degree melts of MORB-source mantle, and are not associated with a mantle plume or significant lithospheric attenuation. Conversely, the Jones Mountains basalts are more likely to have been generated as a result of the northward propagation of the Marie Byrd Land plume-head, possibly facilitated by sub-lithospheric channelling due to earlier lithospheric stretching in the region.

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