EARLY TERTIARY CALC-ALKALINE VOLCANISM ON ALEXANDER ISLAND

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Abstract. Lavas, tuffs and breccias ranging in composition from basalt to dacite, and locally developed rhyolitic ignimbrites occur in a north–south-trending belt through the interior of Alexander Island. The petrographic and field aspects of the rocks are described, and sub-division into the Elgar, Colbert and Vivaldi Formations is proposed. Twenty-one new chemical analyses show the rocks to be part of a high-K calc-alkaline suite, the character of which is consistent with eastward subduction at a trench to the west of Alexander Island. The high-K character of the volcanism is in marked contrast to coeval low-K calc-alkaline activity in the South Shetland Islands and may be related either to a greater arc–trench distance or thicker crust beneath Alexander Island. Radiometric dates suggest that the volcanicity largely took place during the early Tertiary and was broadly contemporaneous with emplacement of chemically similar tonalite–granite plutons. This plutonic/volcanic belt is thought to represent a volcanic arc which had migrated westward on to Alexander Island from its Mesozoic position on the Antarctic Peninsula. The early Tertiary plutonic and volcanic activity at the arc appears to have been in response to subduction of crust created at the hypothetical Aluk Ridge during a late Cretaceous to Palaeocene episode of rapid spreading.

Essentially flat-lying volcanic rocks, of mainly early Tertiary age, occur in a linear north–south belt through Alexander Island, embracing the Elgar Uplands, Colbert Mountains and small outcrops in southern Alexander Island (Fig. 1). The presence of these rocks in the interior of the island was first recognized by Grikurov and others (1967), who estimated that tuffaceous rocks in the eastern Colbert Mountains exceeded 1 000 m in thickness. A K-Ar biotite date of 70 Ma (recalculated to 69 Ma, using constants recommended by Steiger and Jäger (1977)) was obtained from one of these tuffs. Reconnaissance geological mapping in northern Alexander Island during 1970–71 revealed a comparable volcanic sequence at least 500 m thick in the Elgar Uplands, consisting mainly of subaerially erupted hornblende-rich tuffs, agglomerates and lavas (Bell, 1974). Plant material of possible angiosperm origin found in interbedded (?) lacustrine strata supported a late Cretaceous or younger age. Tuffs and lavas similar to those of the Elgar Uplands were described from a locality in the southern Walton Mountains by Edwards (1977). During 1975–76 and 1976–77, the author and B. W. Care carried out field mapping, mainly in northern and central Alexander Island, on which this paper is largely based. New plant material of undisputed angiosperm origin, found during the course of this field work, was described and compared by Thomson and Burn (1977) with a flora dated at 60 Ma from the South Shetland Islands.

STRATIGRAPHY

The stratigraphy of Alexander Island and Rothschild Island is shown in Table I. The early Tertiary volcanic rocks in the Elgar Uplands rest unconformably on the LeMay Formation, a terrain of highly deformed flysch-type sedimentary rocks with subsidiary basic lavas and cherts. These rocks are partly Triassic in age but may extend back into the late Palaeozoic. They underwent folding and low-grade regional metamorphism prior to the depositon of the relatively undisturbed late Jurassic–early Cretaceous shallow-water sediments of the Fossil Bluff Formation, which crops out along the east coast of the island (Fig. 1). The metasediments of the LeMay Formation are cut by basic, intermediate and acid plutons, which, like the early Tertiary volcanic sequences, are largely confined to a 40 km wide north–south belt through the island (Fig. 1). The main centres of plutonic activity are: the Rouen Mountains (granodiorite, adamellite and granite; Care, 1981), Rothschild Island (granodiorite, tonalite and quartz-feldspar-porphyry; Care, 1980), Staccato Peaks and the nunataks to the south (mainly diorite and tonalite; Bell, 1973) and the Walton Mountains (gabbro, diorite and granodiorite; Edwards, 1977). Suggestions by Grikurov and others (1967) and Care (1981) that the volcanic rocks of Alexander Island may be the effusive expression of this plutonic activity are supported by the close spatial relationship between plutonic and volcanic rocks, as well as by their overlapping ages (see below). Care

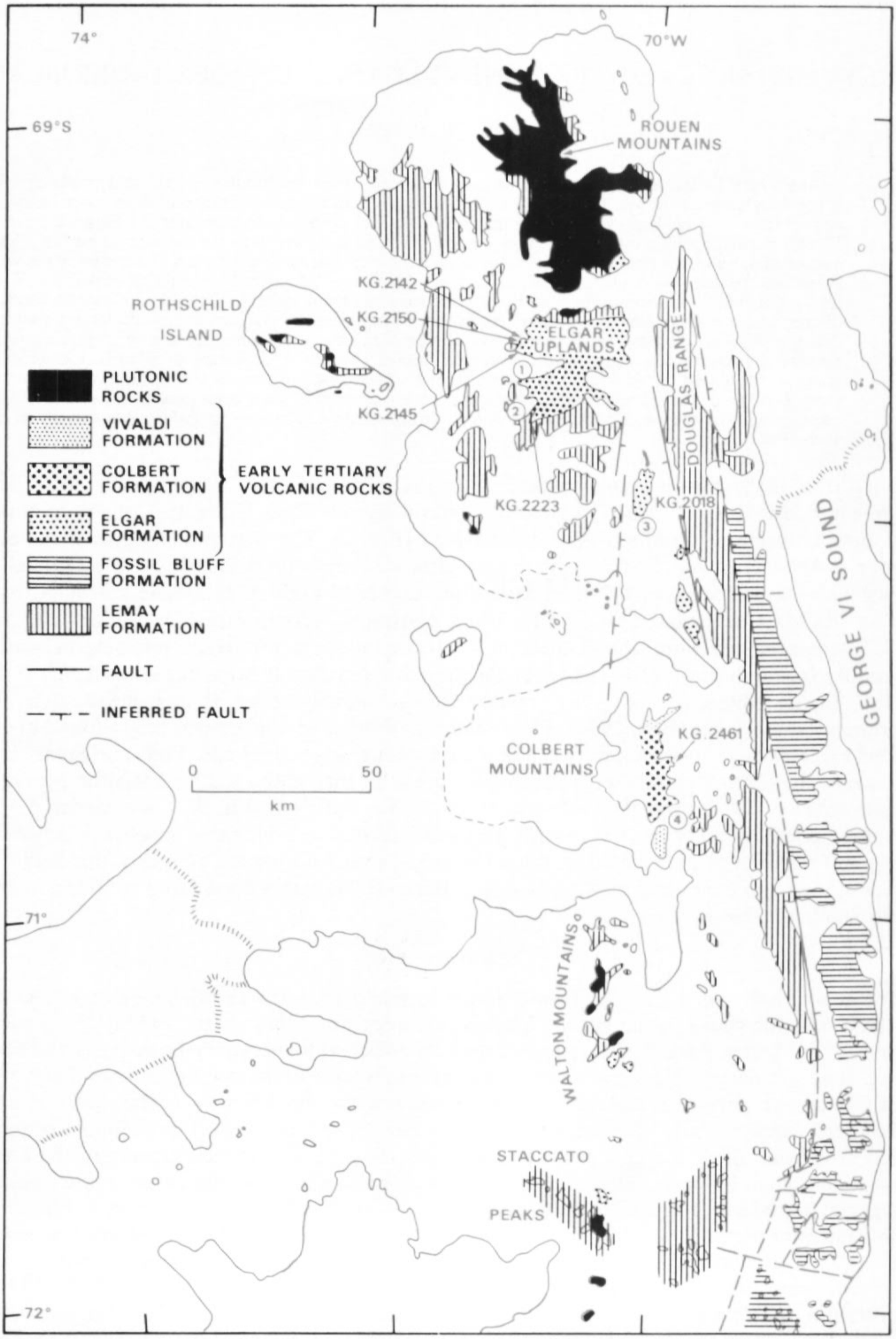

Fig. 1. Geological sketch map of Alexander Island showing the setting of early Tertiary volcanic and plutonic rocks. 1. Delius Glacier; 2. Bartok Glacier; 3. Finlandia Foothills; 4. Vivaldi Gap.

TABLE I. STRATIGRAPHICAL SUCCESSIONS IN ALEXANDER ISLAND AND ROTHSCHILD ISLAND

Age	*Northern Alexander Island*	*Central Alexander Island*	*Rothschild Island*
Late Tertiary	Olivine-basalt lavas and hyaloclastites		Olivine-basalt dykes and hyaloclastites
(?) Late Cretaceous to early Tertiary	Intermediate to basic dykes		Intermediate dykes
	Rouen Mountains batholith (granodiorite to granite plutons)	Quartz-feldspar-porphyry dykes and sills Vivaldi Formation (rhyolitic ignimbrites)	Quartz-feldspar-porphyry dykes Tonalite to adamellite plutons
	Hornblende-andesite dykes		Hornblende-andesite dykes
	Elgar Formation* (basaltic to andesitic lavas, tuffs and agglomerates)	Colbert Formation* (mainly dacitic tuffs and lavas)	
(?) Late Palaeozoic to Triassic	LeMay Formation (low-grade metasediments)	LeMay Formation	LeMay Formation

* There is no unequivocal evidence for the age equivalence of these two formations.

(1981) noted that the plutonic/volcanic belt coincides with linear magnetic anomalies detected by aeromagnetic surveys (Renner and others, in press). Geochemical evidence for a cogenetic origin is discussed on p. 188.

Sub-division of the early Tertiary volcanic rocks into three formal lithostratigraphic units is proposed, on the basis of geographical location, lithology and geochemistry. The salient features of each formation, and their type areas are outlined below. More detailed descriptions follow in the text.

i. The *Elgar Formation* is dominantly composed of basaltic andesite and andesite lavas, tuffs and breccias. Lavas and pyroclastic rocks are of approximately equal importance volumetrically. Bedded sequences of water-lain tuffs are of limited occurrence. The type area is the western Elgar Uplands between Bartok and Delius Glaciers, where sequences up to 100 m thick crop out as steep cliffs and buttresses. The formation underlies most of the Elgar Uplands and also crops out extensively in Finlandia Foothills (Fig. 1), constituting the most extensive unit of volcanic rocks on Alexander Island and probably exceeding 1 500 m in thickness. Little significant variation in overall lithology or composition over this area was detected except for a greater abundance and thickness of bedded water-lain tuffs in the north-western Elgar Uplands. The volcanic rocks rest unconformably on the highly deformed low-grade metasediments of the LeMay Formation at a number of localities (including the type area) and their preservation has been assisted by down-faulting relative to the metasediments, which form the Douglas Range to the east (Fig. 1).

ii. The *Colbert Formation* is dominated by dacitic tuffs (largely ignimbrites) with subsidiary bedded water-lain tuffs and dacitic—andesitic lavas. The type area is station KG.2461 and the ridges 2 km to the north and west, where the above-mentioned lithologies crop out as cliff sections up to 500 m high. If these rocks also underlie the summit dome of the Colbert Mountains, as is suggested by dark stratified outcrops visible on the highest cirque walls, the formation must exceed 1 500 m in thickness. The formation crops out extensively in the eastern Colbert Mountains and probably extends to the geologically unknown western part of the range. Neither the base of the formation nor a contact with the (?) younger Vivaldi Formation is exposed in the eastern Colbert Mountains.

iii. The *Vivaldi Formation* consists of massive rhyolitic ignimbrites which show little variation through the sequence. The type area is an 8 km long north–south ridge, which lies west of Vivaldi Gap and is separated from the southern end of the main part of the Colbert Mountains by a snow-covered pass. The formation in this area is at least 1 000 m thick and is in fault contact with blueschist-facies metamorphic rocks of the LeMay Formation at the extreme southern end of the ridge. Similar pale ignimbrites which crop out on the north-eastern ridges of the Colbert Mountains are also assigned to the Vivaldi Formation.

The stratigraphical relationship between the volcanic and plutonic rocks is not clear in the field. However, there is evidence that the Elgar Formation is post-dated by some of the plutonic activity, although plutonic and volcanic activity was probably broadly coeval:

i. K-Ar whole-rock dates from two lavas from the Colbert Formation and four lavas from the Elgar Formation yield ages of 40–60 Ma. A six-point Rb-Sr isochron obtained from an adamellite in the Rouen Mountains batholith gives an age of 46.3±2.8 Ma, which represents the age of emplacement of part of the batholith (personal communication from R. J. Pankhurst).
ii. (?) Late-stage acid dykes cut Elgar Formation rocks on an inaccessible cliff face in the south-eastern Rouen Mountains (Care, 1981).
iii. A small porphyritic adamellite body cuts Elgar Formation rocks at station KG.2142.
iv. Hornblende-andesite dykes, which cut the Elgar Formation rocks, are not seen to cut plutonic rocks in northern Alexander Island and Rothschild Island (Care, 1980).

In addition there is some field evidence that the rhyolites of the Vivaldi Formation are the youngest of the calc-alkaline rocks on Alexander Island:

i. The only dykes cutting the Vivaldi Formation are of quartz-feldspar-porphyry and fine-grained rhyolite.
ii. The chemistry and phenocryst content of quartz-feldspar-porphyry dykes and sills cutting the Vivaldi Formation suggest that they may be feeders to the ignimbrites. Petrographically and chemically (p. 185), they also resemble a quartz-feldspar-porphyry intrusion within the Rouen Mountains which probably represents the final phase in emplacement of the batholith (Care, 1981). It is therefore likely that the eruption of the rhyolites of the Vivaldi Formation was related to this final phase of plutonic activity.

This conclusion, however, conflicts with the 69 Ma K-Ar biotite age obtained by Grikurov and others (1967) from a tuff in the north-eastern Colbert Mountains, which, if correct, would imply that the rhyolites are older than the Elgar and Colbert Formations.

FIELD OCCURRENCE AND PETROGRAPHY

The volcaniclastic rock nomenclature used in the following descriptions is based on Fisher (1961). In addition, the prefixes "lithic" and "crystal" are used to distinguish tuffs in which the clastic fraction is composed of greater than two-thirds lithic and crystal fragments, respectively. "Crystal-lithic" is used to distinguish those tuffs in which the clastic fraction is composed of between one-third and two-thirds lithic or crystal fragments. Compositional names are based on geochemistry and are defined on p. 185.

Elgar Formation

Lavas form nearly 50% of the exposed sequences of the Elgar Formation, the remainder being composed of massive red, green, purple and grey tuffs, tuff-breccias and agglomerates. Fissures are often filled by banded agate or jasper, the former sometimes occurring in geodes up to 50 cm across. Well-bedded tuffs are scarce and usually restricted to thin sequences a few metres in thickness. Thicker bedded sequences, however, occur in the north-western Elgar Uplands.

The *lavas* are fine-grained, grey or purple porphyritic rocks. Phenocrysts of white or clear feldspar and dark green mafic minerals are usually visible on both fresh and weathered surfaces.

The flows range in thickness from 1 m to 30 m (some of the thicker units probably result from the superposition of several thinner flows). Red brecciated bases to a number of flows were seen in the western Elgar Uplands and weak to strong flow banding is present in some andesitic flows.

The 1–3 mm squat euhedral plagioclase phenocrysts often display Carlsbad-albite twinning, weak to moderate oscillatory zoning, and some contain cores or zones rich in glassy inclusions (Fig. 2a). They range in composition from bytownite (An_{70-75}) in basaltic andesites to andesine (An_{35}) in less basic rocks, and are frequently extensively altered to calcite, sericite and epidote. Pale green to colourless augite is the most widespread mafic mineral which occurs as euhedral prisms up to 1.5 mm long (Fig. 2b). Weakly pleochroic orthopyroxene (α=pink, β=reddish yellow, γ=pale green; $2V\alpha \simeq 80°$) is less widespread and subsidiary to augite. Both pyroxenes show alteration to pale brown biotite. Other secondary minerals replacing mafic phenocrysts include chlorite, calcite, iron ore, antigorite and fibrous amphibole. Chlorite pseudomorphs often show a typical amphibole habit, and phenocrysts of green hornblende occasionally survive. Most lavas have a groundmass of tiny (0.01–0.1 mm) plagioclase laths with granules of iron ore and/or pyroxene (Fig. 2b), and frequently display flow texture. Some interstitial green glass may be present. The lavas are generally non-vesicular but, where present, amygdales are usually filled by chalcedony, quartz or calcite. Groundmass alteration minerals include calcite, quartz, chlorite and rare zeolite. Some lavas have undergone silicification, resulting in the groundmass texture being overprinted by a mosaic of dusky 0.02–0.1 mm quartz grains.

A number of sills were identified but distinguishing sills and flows in the field was not always possible. However, the sills are petrographically identical to the lavas and were probably emplaced while the tuffs and lavas were accumulating.

Coarse *crystal-tuffs, crystal-lithic tuffs* and *lithic lapilli-tuffs* are the main pyroclastic rocks. Bedding is often poorly defined but a fissile parting parallel to bedding surfaces may be present. Sequences of well-bedded water-lain tuffs up to 60 m thick crop out in the north-west Elgar Uplands. They consist of interbedded coarse crystal-tuff, crystal-lithic tuff and fine black shaly tuff in 2–50 cm beds (Fig. 3), with occasional thicker units of lapilli-tuff and tuff-breccia up to 6 m. Sedimentary structures include load-casts, "ball and pillow" structures and planar laminations of crystal-tuff in fine tuff. These features, together with the abundance of poorly preserved plant material, suggest a lacustrine origin.

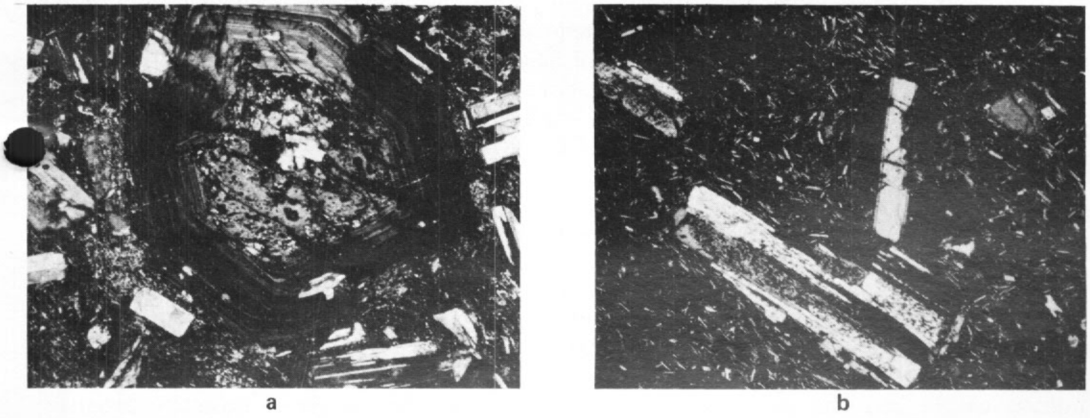

Fig. 2. a. Oscillatory zoning in a plagioclase phenocryst with a core rich in glassy inclusions; andesite, Finlandia Foothills (KG.2015.1; X-nicols; x 25).
b. Phenocrysts of labradorite and twinned augite; basaltic andesite, Finlandia Foothills (KG.2010.2; X-nicols; x 25).

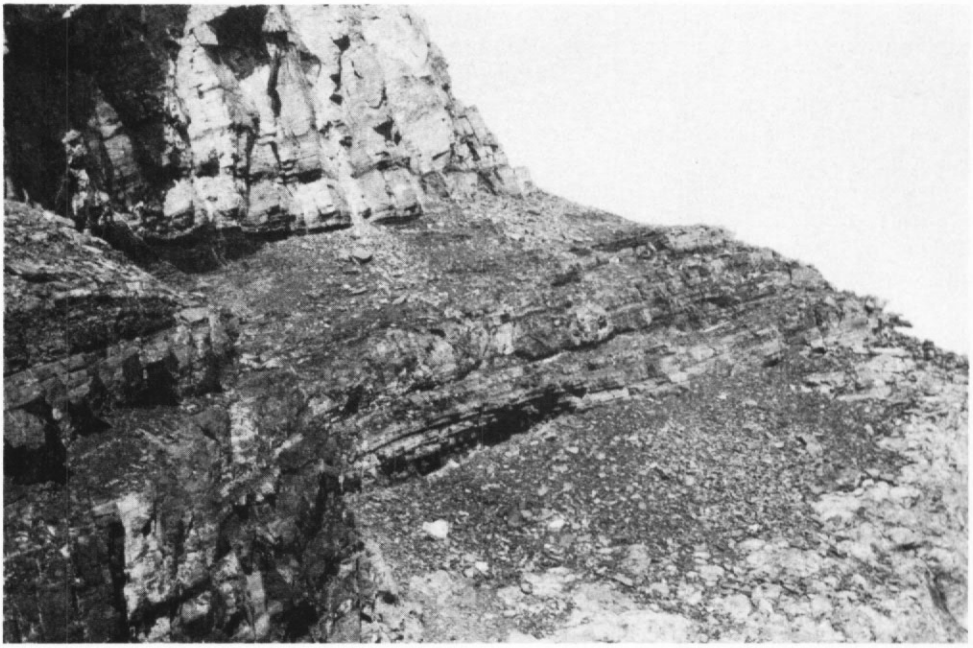

Fig. 3. Well-bedded water-lain tuffs of the Elgar Formation, north-western Elgar Uplands. The upper cliff is 3 m high.

In thin section, the tuffs are poorly or very poorly sorted. Subhedral and broken plagioclase (labradorite), often showing oscillatory zoning and Carlsbad-albite twinning, is the dominant constituent of the crystal-tuffs and is present in most crystal-lithic and lithic tuffs. Extensive alteration of plagioclase to sericite, epidote and calcite is common, and prismatic mafic minerals are usually pseudomorphed by chlorite, sphene, calcite and iron ore. Rarely, fresh pale green augite or amphibole (pleochroic in shades of olive-green, or red and brown) remains. Pseudomorphs after mafic phenocrysts often have a conspicuous amphibole habit. Lithic fragments are typically angular to sub-angular and are composed of non-vesicular dark grey, purple or green porphyritic rocks. Most of these consist of phenocrysts of plagioclase (An_{35-65}) and scarce chlorite pseudomorphs after mafic phenocrysts set in a fine-grained trachytic groundmass. Some glassy fragments contain perlitic cracks. Most tuffs have a fine-grained matrix which includes secondary quartz, ragged iron-ore granules and blebs of calcite. Mosaic veins of zeolite occur in one tu[illegible] from the south-western Douglas Range.

The *breccias, agglomerates* and *tuff-breccias* are unsorted, unstratified or very crudely bedded pyroclastic rocks occurring in beds 50 cm to several tens of metres thick. Despite their internally unbedded nature, they sometimes occur within bedded tuff sequences, where they show prominent planar tops and bases. Clasts are angular to sub-rounded or occasionally rounded (Fig. 4). They range in size up to 50 cm or rarely 150 cm and are mostly similar to fragments in the tuffs. Moderately vesicular fragments, however, are common in breccias from Finlandia Foothills, as are nearly spherical to spindle-shaped volcanic bombs. The vesicles are filled with quartz, calcite and chalcedony or occasionally zeolite. The matrix is normally extensive, comprising 25–50% of the rock, and consists of crystal-lithic tuff. Some breccias from Finlandia Foothills show extensive groundmass alteration to haematite (e.g. KG.2018.6).

The unconformity at the base of the Elgar Formation is exposed at a number of localities. Usually (as at stations KG.2145 and 2223), several metres of crudely bedded breccias,

Fig. 4. Rounded clasts in agglomerate, Elgar Formation, north-western Elgar Uplands. The hammer shaft is 35 cm long.

composed mainly of angular fragments of metasedimentary rocks in a sparse matrix of red sandstone, are interposed between the erosion surface and the overlying volcanic rocks. However, at some localities (e.g. KG.2150) bedded crystal-lithic tuffs and lapilli-tuffs rest directly on the erosion surface. On the cliffs in the vicinity of station KG.2223, where the unconformity is exposed for several kilometres, it shows only gentle undulations, but locally (e.g. KG.2145) breccias and volcanic rocks lap against topographic features tens of metres high.

Dips in the volcanic rocks are generally shallow and variable, resulting from gentle tilting. No evidence for either folding or radial arrangements of dips was found.

Colbert Formation

Where it crops out on the eastern ridges of the Colbert Mountains, the formation consists of an estimated 1 500 m of mainly massive uniform grey and green tuffs and lapilli-tuffs (mostly ignimbrites), lavas and minor bedded tuffs. In contrast to the Elgar Formation, lavas are subordinate to pyroclastic rocks, and are largely restricted to a small number of units 100 m or more thick, each of which probably consists of a number of flows.

The *lavas* are massive, porphyritic, non-vesicular black or dark grey rocks, weathering red, green, brown or purple. Columnar jointing and faint flow banding are common. Some flows have an autobrecciated base which passes up into a 2–3 m zone of intense flow banding. The phenocryst minerals are plagioclase of andesine-labradorite composition (An_{40-53}) often displaying normal or oscillatory zoning, pale green augite, and less common orthopyroxene or amphibole (α=pale green, β=red-brown, γ=greenish brown). Many mafic phenocrysts are pseudomorphed by fibrous antigorite, secondary green amphibole or chlorite. The groundmass is typically very fine-grained with vague outlines of feldspar microlites, and probably represents devitrified glass.

Grey and green lapilli-tuffs, crystal-tuffs and crystal-lithic tuffs of dacitic composition occur as massive beds several metres thick and in poorly or unstratified sequences up to 100 m thick (Fig. 5). The massive character of these tuffs, the common presence of flattened dark green or grey lapilli and lithic fragments, and moderately to strongly compacted shards indicate that much of the succession is composed of welded ignimbrites. The rocks have a high phenocryst content, mainly plagioclase of an andesine composition, 2–3 mm embayed quartz grains (Fig. 6) and pseudomorphs after mafic minerals. Occasionally, pale green augite or pale brown amphibole remains. The lithic fragments and lapilli, which constitute 20–40% of most tuffs, are mainly composed of sutured interlocking quartz and (?) alkali-feldspar, or dusky green (?) devitrified glass.

Bedded sequences, up to several metres thick, of coarse grey crystal-tuff, fine black tuff and green fissile tuff are interbedded with the massive ignimbrites (Fig. 5). Individual beds are 5–15 cm thick and may contain penecontemporaneous deformation structures, indicating a water-lain origin. Scarce plant fragments were found in one such sequence at station KG.2461.

Fig. 5. Massive dacitic ignimbrites with a thin unit of bedded water-lain tuffs (arrowed), Colbert Formation; central-eastern Colbert Mountains. The cliffs are 150 m high.

Breccias and agglomerates are much less abundant than in the Elgar Formation. They form massive beds several metres thick and resemble the lapilli-tuffs except for their content of up to 50% sub-rounded to sub-angular blocks up to 30 cm across. These blocks are of various porphyritic and flow-banded rocks similar to the lithic clasts in the tuffs. Lapilli are sometimes flattened and deformed around the blocks, suggesting an ignimbritic origin for some of the breccias.

As in the Elgar Formation, no evidence of folding or of cone structures was found. The attitude of stratification is shallow and variable with a preponderance of south-easterly and north-easterly dips.

Vivaldi Formation

The rhyolitic ignimbrites of the Vivaldi Formation are massive, porphyritic and vary in colour between pale pinkish buff to pale grey. Stratification is restricted to slight colour variations in zones 20 cm to several metres thick, and variations in degree of induration and columnar jointing. The rocks are mainly crystal-tuffs and lapilli-tuffs, and they differ from the ignimbrites of the Colbert Formation in their much higher quartz content, lower lithic fragment content and the presence of potash feldspar. These tuffs, like those of the Colbert Formation, show many of the characteristic features of welded ignimbrites: massive unstratified field occurrence (Fig. 7), columnar jointing (Fig. 8), flattened lapilli and slight to moderate compaction of shards. It was not always possible to detect the presence of welding in the field, since flattened lapilli may not be visible in the hand specimen. However, the remarkable massive homogeneous character of these rocks suggests that the bulk of the sequence is composed of welded tuffs.

The rocks are very rich in phenocrysts of highly embayed quartz up to 4 mm across, plagioclase of an oligoclase-andesine composition, and clear, cracked subhedral sanidine (Fig. 9). Orthoclase-perthite is present in small quantities and is possibly of an exotic origin. Euhedral green amphibole prisms are prominent in some hand specimens but in thin section all mafic minerals, apart from rare biotite flakes, are pseudomorphed by chlorite, calcite and iron ore. Lithic fragments rarely exceed 20% of the rock and consist of black and dark grey porphyritic and aphyric types, pale grey and red flow-banded rhyolite, and pale grey quartz-feldspar-porphyry. Like the clasts in Colbert Formation ignimbrites, they mainly consist of interlocking mosaics of quartz and (?) alkali-feldspar with or without phenocrysts of quartz and feldspar. Some flattened clasts with brush-like terminations are probably devitrified collapsed pumice. Shards up to 0.2 mm across, replaced by clear quartz, show slight to strong flattening and in

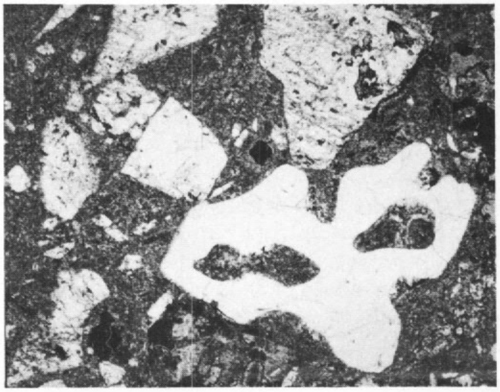

Fig. 6. Resorbed quartz phenocryst and broken andesine grains; dacitic crystal-tuff, eastern Colbert Mountains (KG.2454.1; plane polarized light; x 27).

Fig. 7. Massive rhyolitic ignimbrites of the Vivaldi Formation cut by an irregular dark glassy acid dyke (right centre); southern Colbert Mountains. The cliffs are 100 m high.

extreme cases are deformed around phenocrysts to give a eutaxitic texture indicative of a high degree of welding.

Crude stratification visible on cliff faces appears sub-horizontal but locally the flattening fabric dips at up to 35°.

Southern Alexander Island

The southerly continuation of the calc-alkaline volcanic belt is represented by small outcrops at the southern end of the Walton Mountains and 5 km north of Staccato Peaks. Edwards (1977) described approximately 235 m of massive red, pink and olive-green tuffs, subordinate bedd[illegible] tuffs and lavas unconformably overlying the LeMay Formation metasedimentary rocks at the Walton Mountains locality. The tuffs at the base of the sequence are conglomeratic and rich in metasedimentary clasts. The only accessible lava flow is a basalt or basaltic andesite with phenocrysts of bytownite and augite.

Thick-bedded tuffs, agglomerates and lavas crop out on four isolated nunataks 5 km north of Staccato Peaks (Care, 1977). Specimen KG.2717.3, an andesitic sill or lava from this sequence, consists of phenocrysts of euhedral zoned labradorite (An_{55}) and augite in a fine-grained groundmass of tiny plagioclase laths with granules of iron ore and pyroxene. The augite is partly altered to secondary green amphibole.

Limited petrographic information shows that the lavas at the above localities resemble the basaltic andesites and andesites of the Elgar Formation, and a chemical analysis of a sill or lava from the Staccato Peaks locality shows that it is chemically similar to lavas from the Elgar Formation (Table II).

Table II. Chemical analyses of Tertiary volcanic rocks from Alexander Island

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
SiO_2	77.2	75.8	75.8	64.5	63.8	63.1	62.1	61.6	60.7	60.3	59.9	59.2	59.0	57.5	56.4	56.4	55.7	55.10	52.7	54.0	57.4
TiO_2	0.07	0.10	0.03	0.51	0.66	0.49	0.67	0.60	0.64	0.66	0.76	0.80	0.84	0.73	1.11	1.12	0.84	0.83	0.88	1.27	0.81
Al_2O_3	14.0	14.1	14.4	15.7	16.4	15.8	16.3	14.9	15.5	14.5	16.2	17.2	14.9	15.1	17.3	18.0	16.3	16.0	14.5	17.0	15.6
Fe_2O_3†	1.19	1.20	1.00	4.79	4.41	4.98	5.09	5.60	6.25	5.85	6.49	7.61	7.89	7.75	8.70	8.07	8.35	8.83	9.30	9.33	7.8
MnO	0.04	0.05	0.08	0.11	0.09	0.10	0.14	*	*	*	*	*	*	*	*	*	*	*	*	0.21	*
MgO	0.1	0.2	0.04	1.6	1.1	1.7	1.2	2.9	3.0	2.8	2.8	4.6	5.9	5.8	5.1	4.6	5.2	5.5	9.5	5.7	6.3
CaO	0.73	0.94	0.79	4.37	3.87	4.5	5.16	5.03	6.37	5.89	4.91	6.70	4.20	6.65	7.15	7.55	7.69	8.77	8.89	8.82	6.6
Na_2O	3.1	3.6	3.9	3.7	4.0	3.9	3.6	3.3	2.8	2.3	3.7	3.3	2.5	1.9	3.2	3.4	2.0	2.9	2.6	2.9	2.6
K_2O	4.55	4.55	4.70	2.80	3.16	2.70	2.71	3.02	2.21	3.26	2.40	1.82	3.58	2.36	1.89	1.59	1.93	2.01	1.65	1.39	1.7
P_2O_5	0.01	0.10	0.01	0.14	0.14	0.13	0.18	*	*	*	0.16	0.12	*	*	*	*	*	0.18	*	*	0.14
TOTAL	100.99	100.64	100.75	98.22	97.63	97.40	97.15	96.95	97.47	95.56	97.32	101.35	98.81	97.79	100.85	100.73	98.01	100.12	100.02	100.62	98.95
COORDINATES OF TRIANGULAR DIAGRAMS																					
A	87.21	86.99	90.4	53.77	59.91	53.27	53.32	46.70	38.75	43.33	43.08	32.64	34.68	27.42	30.07	31.34	25.54	28.60	21.19	24.89	26.51
F‡	11.93	11.38	9.33	36.02	33.01	36.14	38.82	36.92	43.31	40.09	41.61	44.19	39.71	44.10	46.48	46.04	48.42	46.40	41.88	49.10	43.33
M	0.86	1.63	0.27	10.20	7.07	10.59	7.85	16.38	17.93	16.57	15.31	23.17	25.61	28.47	23.44	22.61	26.03	25.00	36.92	25.86	30.16
Ca	7.89	9.44	7.63	38.52	33.13	38.56	43.01	41.99	54.95	48.78	42.75	54.93	38.36	58.50	56.46	58.44	64.10	62.20	65.91	65.56	58.46
Na	34.75	37.18	39.24	33.29	35.52	34.61	30.77	28.65	23.96	19.81	33.01	27.75	23.66	17.36	26.19	27.27	17.25	21.23	19.90	22.47	24.00
K	57.36	53.24	53.13	28.19	31.34	26.83	26.22	29.36	21.08	31.40	24.24	17.32	37.97	24.14	17.34	14.28	18.65	16.57	14.20	11.96	17.54
TRACE ELEMENTS (ppm)																					
Ni	—	—	—	—	—	—	—	—	6	8	—	21	12	20	23	14	13	65	199	27	9
Cr§	—	—	—	—	—	—	10	50	10	70	10	80	60	40	70	40	60	220	430	111	80
Ce	58	70	42	61	67	62	71	55	37	60	42	32	60	55	44	37	39	43	43	43	47
La	29	37	19	34	37	35	36	31	20	33	17	16	24	22	17	16	17	20	18	18	19
Zr	80	94	71	195	445	186	336	146	130	182	193	156	194	182	133	158	149	162	133	105	199
Nb	11	10	24	10	17	8	9	7	5	10	6	6	8	7	9	9	10	4	9	4	7
Y	24	23	51	26	37	25	44	20	21	25	30	23	28	29	25	26	25	24	22	25	25
Sr	42	62	19	307	334	302	347	447	329	363	360	317	344	374	398	395	340	450	404	414	472
Rb	137	122	260	90	109	90	83	99	67	104	62	58	131	77	57	39	50	67	49	31	43
Th	17	22	26	13	10	13	—	19	11	18	5	7	15	17	12	—	—	10	10	9	12
Pb	15	22	20	19	19	23	18	19	18	23	12	15	17	20	13	15	11	15	10	12	10
W	433	400	530	131	183	216	130	113	135	82	52	203	104	64	64	117	33	118	52	33	89
Ga	13	14	20	22	19	23	23	22	21	24	21	20	20	22	25	25	26	20	22	22	22
Zn	15	16	20	58	52	52	64	57	61	56	80	57	64	56	67	74	73	65	64	72	63
Ba	530	809	101	725	810	711	503	648	532	572	580	533	704	635	461	477	—	445	385	403	533
Nd	27	30	20	28	36	29	38	22	17	32	*	*	30	26	21	18	19	*	22	20	*
K/Rb	276	310	150	258	241	249	271	253	274	260	321	260	227	254	275	338	320	249	279	372	328
Rb/Sr	3.26	1.97	13.66	0.29	0.33	0.30	0.24	0.22	0.20	0.29	0.17	0.18	0.38	0.21	0.14	0.10	0.15	0.15	0.12	0.07	0.09
Ba/Sr	12.62	13.05	5.31	2.36	2.42	2.35	1.45	1.45	1.62	1.58	1.61	1.68	2.05	1.70	1.16	1.21	—	0.99	0.95	0.97	1.13
$(Ce/Y)_N$	5.9	7.43	2.03	5.84	4.42	6.05	3.94	6.70	4.30	5.86	3.29	3.39	5.23	4.63	4.29	3.47	3.81	4.37	4.77	4.2	4.59

— Below detection limit.
* Not determined.
† Total iron as Fe_2O_3.
‡ Total iron as Fe^{2+}.
§ Values rounded to nearest 10 ppm (not corrected for V interference).

Vivaldi Formation
1. KG.2473.3 Rhyolitic ignimbrite, southern Colbert Mountains.
2. KG.2479.3 Rhyolitic ignimbrite, southern Colbert Mountains.
3. KG.2473.6 Quartz-feldspar-porphyry sill, southern Colbert Mountains.

Colbert Formation
4. KG.2465.5 Dacitic lava, eastern Colbert Mountains.
5. KG.2459.2 Dacitic lava, eastern Colbert Mountains.
6. KG.2454.1 Dacitic ignimbrite, eastern Colbert Mountains.
7. KG.2452.6 Dacitic lava, eastern Colbert Mountains.

Elgar Formation
8. KG.2153.2 Andesitic lava, western Elgar Uplands.
9. KG.2198.2 Andesitic lava, western Elgar Uplands.
10. KG.2169.2 Andesitic lava, western Elgar Uplands.
11. KG.2018.11 Andesitic crystal-tuff, Finlandia Foothills.
12. KG.2015.1 Andesitic lava, Finlandia Foothills.
13. KG.2061.1 Andesitic lava, eastern Elgar Uplands.
14. KG.2166.1 Andesitic lava, western Elgar Uplands.
15. KG.2089.6 Andesitic lava, eastern Elgar Uplands.
16. KG.2129.3 Andesitic lava, south-eastern Elgar Uplands.
17. KG.2195.3 Basaltic andesite lava, western Elgar Uplands.
18. KG.2010.3 Basaltic andesite lava, Geode Nunataks.
19. KG.2081.2 Basaltic lava, eastern Elgar Uplands.

20. KG.2096.2 Basaltic andesite dyke, south-eastern Elgar Uplands.
21. KG.2717.6 Andesitic lava, Staccato Peaks.

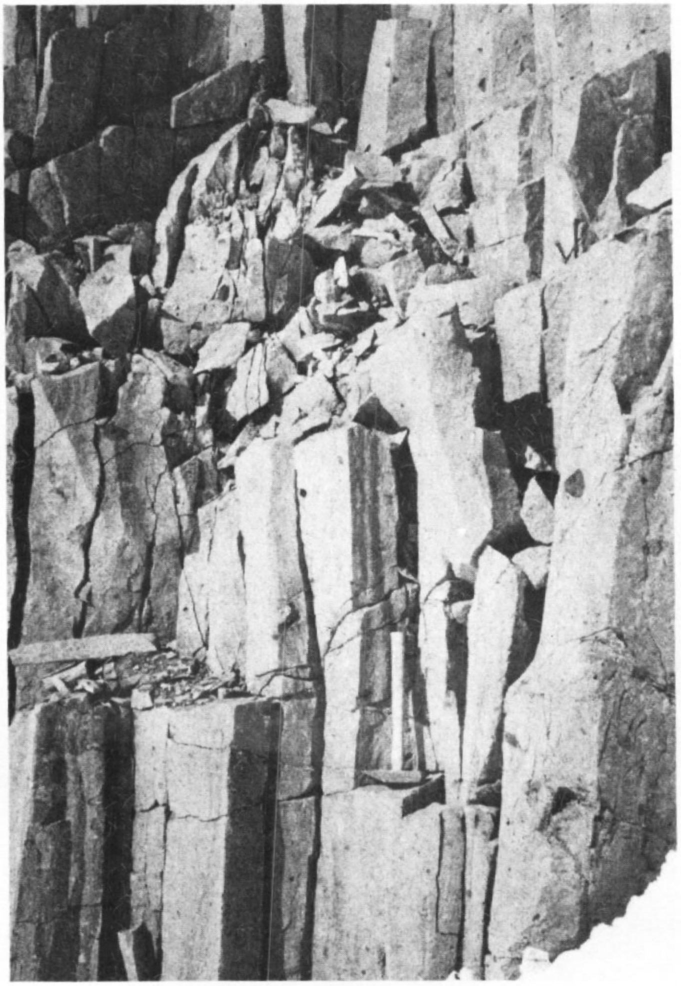

Fig. 8. Columnar jointing in rhyolitic ignimbrite, Vivaldi Formation, north-eastern Colbert Mountains. The hammer shaft is 35 cm long.

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General chemical characteristics

Fifteen lavas, three ignimbrites, one crystal-tuff, one dyke and a sill from the Elgar, Colbert and Vivaldi Formations have been analysed (Table II). The analyses were carried out at the Department of Geological Sciences, University of Birmingham, using a Philips PW 1450 automatic X-ray spectrometer. The classification of volcanic rocks on the basis of SiO_2 content (Weaver, Saunders and Tarney, in press) is used in this paper: <53%, basalt; 55–56%, basaltic andesite; 56–62%, andesite; 62–68%, dacite; 68–72% rhyodacite; and >72%, rhyolite.

The Elgar Formation is dominantly composed of andesites with some basaltic andesites, whereas the rocks of the Colbert Formation are mainly dacites. The rhyolitic ignimbrites of the Vivaldi Formation contain up to 77% SiO_2. No volcanic rocks containing between 65 and 75% SiO_2 were analysed, and the strikingly different aspect of the rhyolites both in the field and in thin section suggests this silica gap is real and not a result of sample selection. Al_2O_3 is high in all the rocks. K_2O is moderate to high and some rocks may be classified as high-K andesites, containing >2.5% K (cf. Taylor, 1969). Triangular A–F–M and Ca–Na–K diagrams (Fig. 10) display typical calc-alkaline trends with negligible iron enrichment. The lack of rhyodacites leads to a distinct bimodal distribution.

The low K/Rb ratios and high Rb and Pb contents are similar to those of high-K calc-alkaline rocks of continental margins (Jakes and White, 1972). Sr and Ba contents are also high and typical for calc-alkaline rocks. High $(Ce/Y)_N$ ratios suggest light rare-earth element enrichment, assuming that Y behaves similarly to the heavy rare-earth elements (Tarney and others, 1977). With increasing SiO_2 in the basalts, andesites and dacites, Zr, Nb, Rb, Ba levels and Rb/Sr ratios increase while Sr contents decrease, implying that plagioclase fractionation took place as the magma evolved (Fig. 11). K/Rb ratios show no marked change with increasing SiO_2. The above trends become obscured by scatter at high SiO_2 values, and Zr and Ba become depleted in the rhyolites.

It appears from the study of this rather small number of analyses that the early Tertiary volcanic rocks of Alexander Island can be assigned to a high-K calc-alkaline association (cf. Jakes and White, 1972).

Comparison with other areas

Table III compares average trace-element abundances and element ratios in calc-alkaline volcanic rocks from the South Shetland Islands, Palmer Land and Alexander Island. The early Tertiary lavas of the South Shetland Islands are at least in part contemporaneous with those of Alexander Island and have a comparable setting on the west of the Antarctic Peninsula. However, the lavas of the South Shetland Islands have higher K/Rb ratios, lower Rb/Sr and Ba/Sr ratios, and lower Rb contents than the Alexander Island volcanic rocks, and in these respects resemble island-arc tholeiites (Tarney and others, 1977; Weaver, Saunders and Tarney, in press). Moreover, average levels of Ba and Cr are lower in the South Shetland Islands rocks, although Sr is higher. Tarney and others (1977) suggested that the Mesozoic and Lower Tertiary volcanism of the South Shetland Islands may be regarded as a low-K, high-Al calc-alkaline suite related to south-eastward subduction at the trench along the seaward side of the islands.

In western Palmer Land, volcanism was partly late Jurassic in age (Culshaw, 1975) but it may have persisted into the Cretaceous (Smith, 1977). Smith recognized two chemically distinct calc-alkaline series, one low-K, the other high-K. These two series are plotted together with the

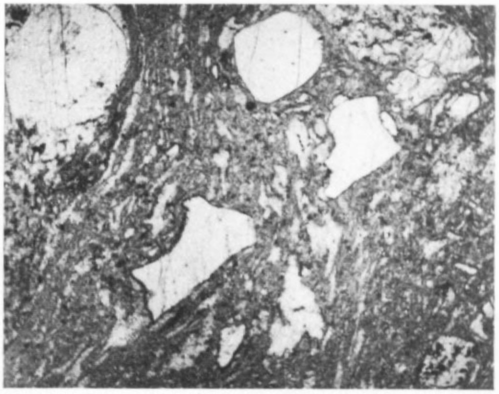

Fig. 9. Phenocrysts of quartz, oligoclase and sanidine in a groundmass of flattened shards; rhyolitic ignimbrite (KG.2473.4; plane polarized light; x 27).

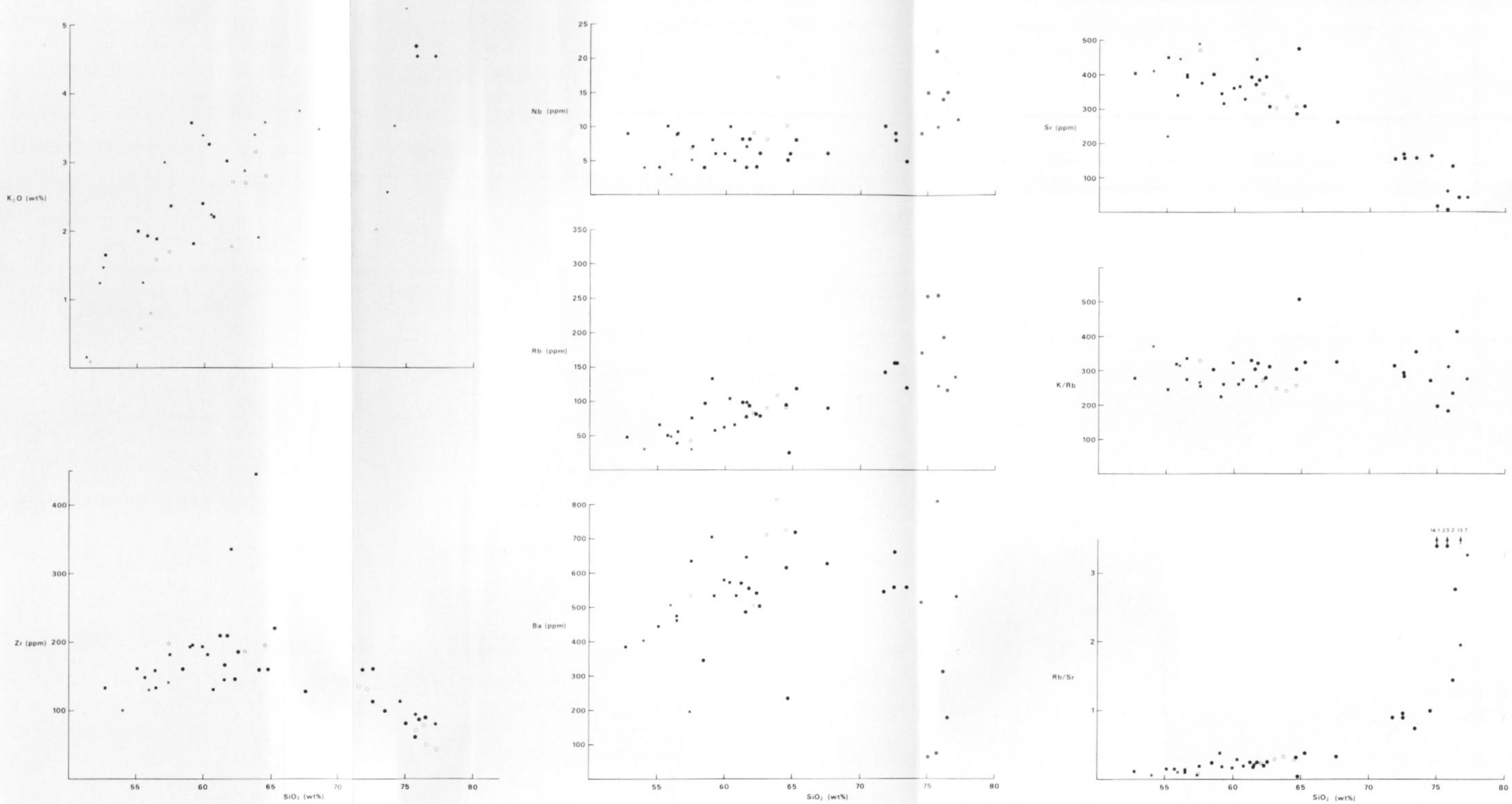

Fig. 11. Plots of K_2O, selected trace elements and element ratios against SiO_2 for early Tertiary volcanic rocks from Alexander Island, Mesozoic volcanic rocks from Palmer Land and plutonic/hypabyssal rocks from Alexander Island and Rothschild Island.

Mesozoic volcanic rocks

▲ High-K series; western Palmer Land (Smith, 1977, table XVI).
△ Low-K series; western Palmer Land (Smith, 1977, table XVI).
▼ North-west Palmer Land (Davies, 1976, table VI).
Other symbols as in Fig. 10.

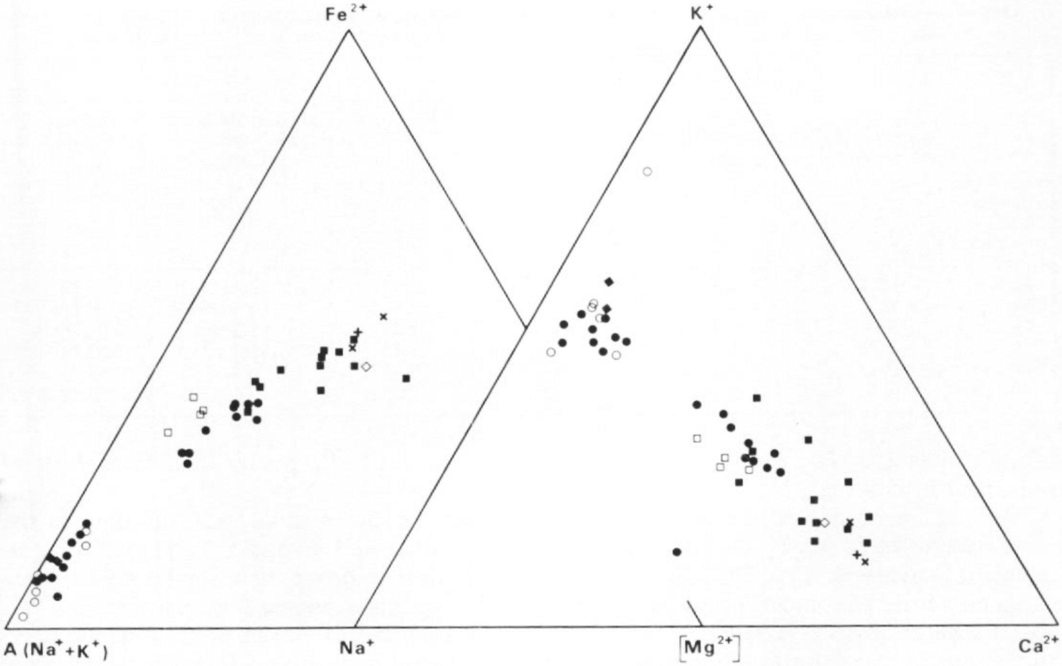

Fig. 10. Triangular A–F–M and Ca–Na–K diagrams for early Tertiary volcanic rocks from Alexander Island, and plutonic/hypabyssal rocks from Rothschild Island (Care, 1980, table IV) and Rouen Mountains (Care, unpublished data).

Volcanic rocks
■ Elgar Formation.
□ Colbert Formation.
◆ Vivaldi Formation.
◇ Andesite, Staccato Peaks.

Plutonic and hypabyssal rocks
● Tonalite, granodiorite, adamellite and granite; Rothschild Island and Rouen Mountains.
○ Quartz-feldspar-porphyry dykes and intrusions; Rothschild Island, Rouen Mountains and Colbert Mountains.
× Hornblende-andesite dykes; Rothschild Island.
\+ Basaltic andesite dyke; Elgar Uplands.
Fe^{2+} is total iron as Fe^{2+}.

Alexander Island volcanic rocks on a K_2O versus SiO_2 graph (Fig. 11). The high-K series andesites resemble those of Alexander Island in their low K/Rb ratios, high Rb/Sr ratios, and high Rb and K contents. However, Ba and Sr levels are notably higher and Cr levels are lower in the Palmer Land rocks. Smith regarded this series as a continental-margin calc-alkaline volcanic suite in contrast to the low-K series which, with its high K/Rb ratios, lower Rb/Sr and Ba/Sr ratios, and lower levels of Ba, Rb, Cr and Ni, has similarities with island-arc calc-alkaline rocks. Smith did not recognize any spatial or age relationship between the two series on Palmer Land but he suggested that they indicate a change from island-arc to continental-margin volcanism during the Mesozoic.

The four analyses of Mesozoic volcanic rocks from north-western Palmer Land show similar major-element chemistry to basalts and rhyolites from Alexander Island. They also lie on a calc-alkaline trend when plotted on an A–F–M diagram (Davies, 1976). The basalts have higher K/Rb ratios, Ba and Sr contents and lower Rb, Cr and Ni contents than those of Alexander

TABLE III. COMPARISON OF AVERAGE INTER-ELEMENT RATIOS FOR PLUTONIC ROCKS FROM ROTHSCHILD ISLAND (CARE, 1980, table V) AND VOLCANIC ROCKS OF SIMILAR SiO_2 CONTENT FROM ALEXANDER ISLAND

	Plutonic rocks			*Volcanic rocks*		
	High-SiO_2 granodiorite (67.6% SiO_2)	*Granodiorite* (61.6—64.7% SiO_2)	*Tonalite* (58.5% SiO_2)	*Rhyolites* (75.8–77.2% SiO_2)	*Dacites/andesites* (61.6–64.5% SiO_2)	*Andesites* (56.4–60.7% SiO_2)
Number of analyses	1	4	1	2	5	9
Zr/Y	8.53	6.99	5.75	3.71	8.41	6.58
Zr/La	5.57	9.35	13.42	2.65	7.44	8.73
Ce/Y	3.07	1.80	1.14	2.73	2.21	1.78
La/Y	1.53	0.76	0.43	1.41	1.22	0.79
Nb/Y	0.40	0.20	0.14	0.45	0.34	0.29
Nb/La	0.26	0.26	0.33	0.33	0.29	0.39

Island (Table III). The rhyolites from Palmer Land are markedly poorer in K than those of Alexander Island (Fig. 11).

Weaver, Saunders and Tarney (in press) remarked on the west to east variation in the Mesozoic volcanic rocks of the South Shetland Islands and Graham Land, notably the eastward increase in K_2O, SiO_2, Rb, Th, Ba. There is little evidence for a similar west to east variation across Alexander Island and Palmer Land, although at present few analyses are available. However, average levels of Ba are somewhat higher in andesites from western Palmer Land and basalts from north-western Palmer Land than equivalent rocks from Alexander Island. Care (1980) noted that K_2O contents of plutonic rocks on Rothschild Island are slightly higher than those on Palmer Land. The reason for this apparent reversal in the general west to east increase in K_2O is not yet understood.

Consanguinity of plutonic and volcanic rocks

Analyses of plutonic rocks from the Rouen Mountains batholith, northern Alexander Island (Care, unpublished data), and plutonic and hypabyssal rocks from Rothschild Island (Care, 1980) have been plotted with the volcanic data (Figs 10 and 11). The dacites and andesites have a similar major-element chemistry to that of the granodiorites and tonalites, while the rhyolites resemble the granites, adamellites and quartz-feldspar-porphyries. Hornblende-andesite dykes on Rothschild Island resemble chemically the basaltic andesites and andesites, substantiating the suggestion by Bell (1974) that similar dykes in northern Alexander Island represent feeders for the lavas of the Elgar Formation. The plutonic and hypabyssal rocks lie on the same calc-alkaline trend as the volcanic rocks when plotted on A–F–M and Ca–Na–K diagrams (Fig. 10).

From similarities in inter-element ratios, Care (1980) inferred a genetic relationship between the plutonic and hypabyssal rocks on Rothschild Island. Both sets of rocks show increasing Zr/Y, Ce/Y La/Y and Nb/Y ratios, and decreasing Zr/La and Nb/La ratios with increasing SiO_2 content. Comparison of these ratios with those in the volcanic rocks is inconclusive (Table IV). Only the Nb/Y and Zr/La ratios show parallel trends in both plutonic and volcanic rocks, whereas the other ratios show differences at high SiO_2 values. Other trace-element abundances and element ratios, however, reveal a general similarity between the volcanic and plutonic rocks. Levels of Zr, Nb, Ba, Rb and Sr, and Rb/Sr and K/rb ratios are comparable, and show similar trends with increasing SiO_2 (Fig. 11). The plutonic and hypabyssal rocks show the same depletion of Zr and Ba at high SiO_2 as occurs in the volcanic rocks.

The similarities in major- and minor-element chemistry outlined above substantiate the view expressed by various previous authors (Grikurov and others, 1967; Care, 1981) that the plutonic rocks of Alexander Island had a common source.

TABLE IV. COMPARISON OF AVERAGE TRACE-ELEMENT ABUNDANCES AND ELEMENT RATIOS IN CALC-ALKALINE VOLCANIC ROCKS FROM THE SOUTH SHETLAND ISLANDS, PALMER LAND AND ALEXANDER ISLAND

	South Shetland Islands		*Western Palmer Land*		*North-western Palmer Land*	*Alexander Island*
	Lower Tertiary	*Mesozoic*	*Low-K series*	*High-K series*		
Basalts	a	a	b	b	c	
Number of analyses	2	2	1	1	1	1
K_2O	0.46	0.42	0.08	0.16	1.34	1.65
K/Rb	1 671	747	0	446	397	279
Ba/Sr	0.30	0.21	0.32	0.26	0.77	0.95
Rb/Sr	0.01	0.02	—	0.01	0.38	0.12
Rb	4.5	6	—	3	30	49
Ba	164	88	120	119	606	385
Sr	543	410	374	466	789	404
Cr	40	150	40	162	12	430
Ni	8	49	14	71	20	199
Andesites	d	a	b	b		
Number of analyses	21	1	2	3		9
K_2O	1.67	1.03	0.95	2.31		2.4
K/Rb	490	317	171	225		279
Ba/Sr	0.75	0.50	1.19	2.06		1.52
Rb/Sr	0.06	0.06	0.13	0.18		0.20
Rb	31	27	71	110		74
Ba	404	237	697	1 208		568
Sr	542	478	615	608		380
Cr	34*	10	22	25		51
Ni	13†	4	12	16		14

* Nine analyses in which Cr was below detection limit (10 ppm) are excluded from the average.
† Two analyses in which Ni was below detection limit (6 ppm) are excluded from the average.

a. Weaver and others (in press).
b. Smith (1977).
c. Davies (1976).
d. Smellie (1979).

Origin of the acid rocks

The rhyolites of the Vivaldi Formation are more acid than the most silicic analysed rocks from Palmer Land (74.19% SiO_2; Fig. 11), the Danco Coast (71.10% SiO_2; West, 1974) and Oscar II Coast (73.36% SiO_2; Weaver, Saunders and Tarney, in press). The acid volcanic rocks of the Danco Coast, like those of Alexander Island, are separated in composition from the dacites by a gap in SiO_2 content (in this case 56–66% SiO_2; West, 1973). This factor, together with similarity in chemistry between rhyolites, and pre-volcanic granodiorites and older metasediments, was taken by West as evidence for an origin by partial melting of these older rocks.

Geochemical evidence regarding the origin of the Alexander Island rhyolites and their intrusive equivalents is inconclusive. Some quartz-feldsparporphyries, granites and adamellites show a continuation of the trends in trace-element variation against silica content observed in the intermediate rocks. They are enriched in Nb and Rb, have high Rb/Sr ratios and are depleted in Sr, implying that they were produced by continued fractionation. Like the Mesozoic acid volcanic rocks of Graham Land (Weaver, Saunders and Tarney, in press), the silicic volcanic and intrusive rocks of Alexander Island are depleted in Zr relative to dacites (Fig. 11). This could result either from zircon fractionation or zircon remaining in the residue during partial melting. Ba is also strongly depleted at SiO_2 contents >70%, possibly reflecting late-stage fractionation of mica, sanidine or intermediate plagioclase. The two analyses of rhyolitic ignimbrites, together with some acid plutonic and hypabyssal rocks, show departures from the trends in trace-element variation commented on above. They show little increase in Nb and Rb levels and Rb/Sr ratios, and have rather high K/Rb ratios. Such departures from fractionation trends have been interpreted as evidence for an origin by partial melting of crustal rocks as against fractional crystallization (e.g. Taylor and others, 1968). More analyses of the acid volcanic and plutonic rocks will be required before any conclusions regarding their origin can be reached.

Discussion

The geochemical and petrological characteristics of the Alexander Island volcanic/plutonic belt are consistent with an origin due to subduction at a trench somewhere to the west of Alexander Island, as suggested by Suárez (1976). Profiler and free-air gravity data for the continental margin off both Alexander Island and Graham Land show no evidence for the existence of such a trench (Houtz, 1974; Herron and Tucholke, 1976). However, it is not unlikely that this trench, which probably ceased activity in the mid-Tertiary (see below), may have become obscured by the combined effects of isostatic re-adjustments and inundation under the thick sediments which blanket the continental shelf and rise in this area.

In contrast to the early Tertiary lavas of the South Shetland Islands, which show some affinities with island-arc tholeiites, the Alexander Island rocks can be regarded as part of a high-K calc-alkaline suite. Increase in K_2O in calc-alkaline magmas has been attributed to depth of the Benioff Zone beneath the arc, the "K-h variation" (e.g. Dickinson, 1975). Hence, mature arcs with a well-defined Benioff Zone appear to show an increase in K_2O away from the trench. The eastward increase in K_2O in the Mesozoic volcanic rocks of the South Shetland Islands and Graham Land may be an example of this (Weaver, Saunders and Tarney in press). The "K-h variation" may also account for the difference in South Shetland Islands and Alexander Island volcanism. The arc–trench distance in the case of the South Shetland Islands is only of the order of 110 km, whereas the distance from the edge of the continental shelf (the presumed site of a buried trench) to the Elgar Uplands and the Colbert Mountains is approximately 250 km and 350 km, respectively. The magma source may thus have been correspondingly deeper under Alexander Island. The high K contents in Alexander Island and in some of the Palmer Land volcanic rocks may also reflect greater crustal thicknesses beneath these two areas compared with the South Shetland Islands.

The lack of detectable eastward increase in the K content of lavas from Alexander Island and Palmer Land, and the apparent reversal in the K-h relationship in plutonic rocks from these two areas, may be at least in part consequential to a westward jump in the location of a volcanic arc situated on Palmer Land during the Mesozoic, to a Tertiary position on Alexander Island. Such a movement of the arc, possibly accompanied by oceanward migration of the trench or steepening of the subduction zone, was first envisaged by Suárez (1976), and is supported b[illegible] 40–60 Ma ages obtained from volcanic and plutonic rocks on Alexander Island. A similar westward movement is seen in the location of *plutonic* activity in the north-western Antarctic Peninsula area, 45–60 Ma ages apparently being restricted to plutons on the north-west coast and on the South Shetland Islands (Saunders and others, in press). However, no reliably dated Tertiary calc-alkaline volcanic rocks have yet been reported from between the South Shetland Islands and Alexander Island, except possibly the basalts of unknown affinities from Tower Island and Two Hummock Island, which have yielded ages of 57–80 and 57 Ma, respectively (Rex, 1976). Possibly some rocks in this area assigned to the Mesozoic volcanic group on lithological grounds could be Tertiary in age.

North-east to south-west trending magnetic anomalies on the ocean floor west and north of the Antarctic Peninsula become older towards the north-west (Fig. 12). They have been interpreted as evidence for the existence of a hypothetical spreading centre (the Aluk Ridge), which was progressively subducted beneath the Antarctic Peninsula from south to north during

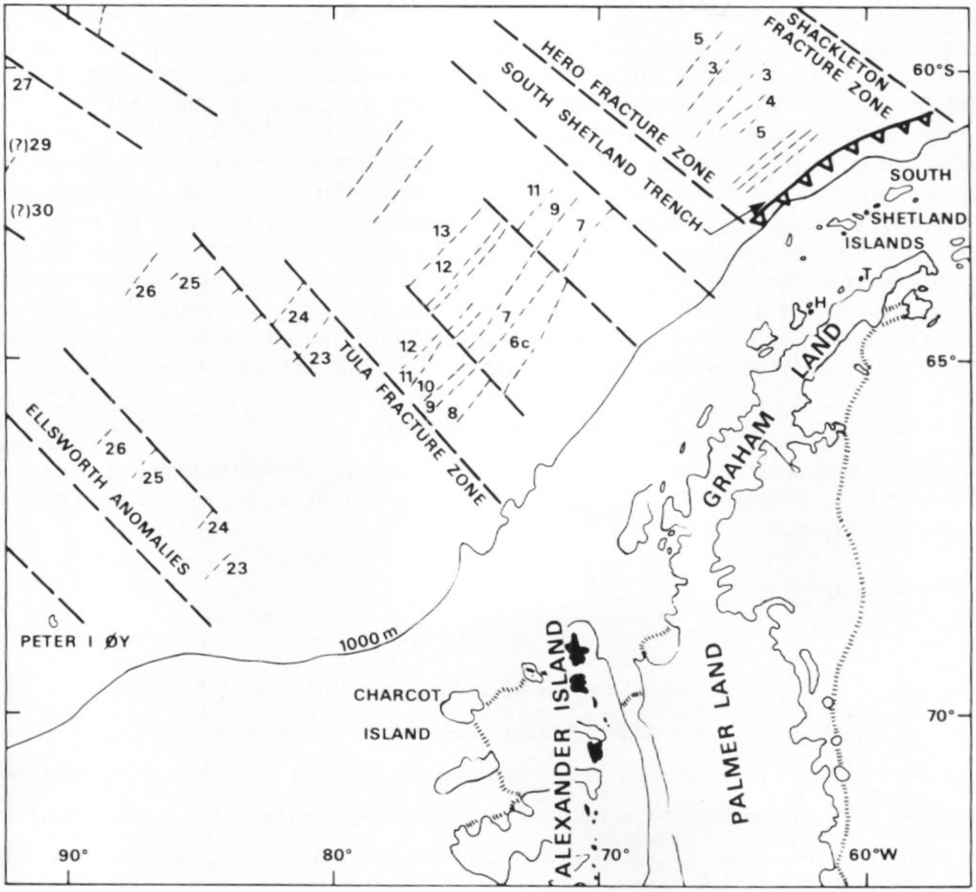

Fig. 12. Summary of magnetic and structural lineaments west and north of the Antarctic Peninsula (after Herron and Tucholke, 1976). Magnetic lineations are shown by light dashed lines (nomenclature after Pitman and others (1968)) and major fracture zones are indicated by heavy dashed lines. Plutonic and volcanic rock outcrops on Alexander Island are shown in solid black. T. Tower Island; H. Two Hummock Island.

Palaeocene to Oligocene times (Herron and Tucholke, 1976). The recently active Drake Passage spreading centre (Barker, 1970; Barker and Burrell, 1977) probably represents the only surviving part of the ridge. The lack of any detectable trench west of the Antarctic Peninsula has led to the suggestion (Weaver and others, in press) that the ridge crests lodged in the trench. The anomalies in the Bellingshausen Sea, west of Alexander Island (the Ellsworth anomalies), are late Cretaceous to Palaeocene in age, and their long wave-lengths indicate rapid spreading (6 cm year^{-1}) at the Aluk Ridge during this period (Herron and Tucholke, 1976). The youngest of these anomalies (approximately 58 Ma) lies about 200 km off the edge of the continental shelf west-north-west of Charcot Island, and Weaver and others (in press) have estimated from observed anomalies, ages and spreading rates that sections of the ridge arrived at the trench approximately 50 Ma ago off southern Alexander Island and 33 Ma ago off northern Alexander Island. Since the oldest dated lavas on Alexander Island overlap the Ellsworth anomalies in age, it appears that volcanism was taking place on Alexander Island in the early Palaeocene as a response to subduction of oceanic crust generated by rapid spreading at the Aluk Ridge. The younger dates from some of the lavas and from the Rouen Mountains batholith are consistent with the above estimates for the timing of the arrival of the ridge at the trench and subsequent ending of subduction. Moreover, it is conceivable that the westward stepping of the arc at the close of the Mesozoic was a direct consequence of the onset of rapid spreading in the late Cretaceous rather than a result of accretion in the trench as suggested by Suárz (1976).

In the model for ridge subduction devised by DeLong and Fox (1977), cessation or reduction of magmatism, uplift of the arc (resulting in widespread unconformity) and low-grade metamorphism are consequential to riding-up of the arc on the flank of the ridge and ultimate subduction of the ridge. Resumption of magmatism and subsidence occur as the ridge passes beneath the arc and subduction of the trailing plate begins. This model is supported by the known geology of the Aleutian arc and the southern Andes, two areas where ridge subduction has taken place. The fact that cessation of magmatism is the only one of these possible consequences of ridge subduction yet identified in the Antarctic Peninsula supports the view that subduction ceased at, or shortly after, the time when the Aluk Ridge arrived in the trench.

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