High-K_2O island-arc volcanic rocks from the Finisterre and Adelbert Ranges, northern Papua New Guinea

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ABSTRACT

A thick, extensive volcanic formation of Oligocene to early Miocene age, the Finisterre Volcanics, forms part of a Cenozoic sequence comprising the Finisterre and Adelbert Ranges of northern Papua New Guinea. The formation contains a high proportion of diverse volcaniclastic rocks and is lithologically similar to volcanic sequences described from island-arc assemblages elsewhere. The volcanic rocks are dominantly potassic basalt and low-silica andesite (48 to 56 percent SiO_2) containing 1.5 to 6.5 percent K_2O and having low TiO_2 content typical of circumoceanic volcanic rocks. Two main groups can be recognized: abundant shoshonite and related rocks (absarokite, rare leucite trachyte) and high-K, high-Al basalt (with some high-K, low-Si andesite).

The Finisterre Volcanics are chemically similar to high-K rocks described from island arcs elsewhere in the southwest Pacific and in the Mediterranean. However, unlike some other island arcs, there is no evidence of a three-stage evolution from arc tholeiite to calc-alkalic andesite to shoshonite. The volcanic rocks probably formed in a volcanic arc that developed north of a northeastward-dipping subduction zone in response to early Tertiary plate interactions. The Finisterre volcanic magmas may have originated by partial melting of mantle material modified by slab-derived silicic melts. *Key words: igneous petrology, geochemistry, island arc, shoshonite.*

INTRODUCTION

Petrochemical studies of island-arc volcanic rocks from the southwest Pacific have previously been confined largely to the Quaternary examples, particularly in the Papua New Guinea region (for example, Jakeš and White, 1969; Johnson and others, 1971, 1973). Although less amenable to study, the volcanic (largely volcaniclastic) sequences of the Tertiary arcs are also of interest. The north coast ranges of northern Papua New Guinea have long been thought to be an island-arc association (for example, Thompson and Fisher, 1965), and Dewey and Bird (1970) cited the region as a probable example of a continent–island-arc collision. Recent mapping of the previously little known Adelbert–Finisterre Range–Huon Peninsula region by the Geological Survey of Papua New Guinea (Robinson and others, 1974; Robinson and Jaques, 1974; Jaques and Robinson, 1975; Robinson, 1975) has substantiated the concept of an island-arc origin followed by continent–island-arc collision in middle Tertiary time (Robinson, 1973; A. L. Jaques and others, in prep.). This paper represents a study of a thick volcanic sequence of Oligocene age, the Finisterre Volcanics, encountered during regional mapping of the Finisterre and Adelbert Ranges. Data presented for the first time show the volcanic rocks to be a dominantly potassic, basaltic island-arc suite that probably developed in response to early Tertiary plate interactions.

OUTLINE OF GEOLOGY

The Finisterre and Adelbert Ranges consist of Cenozoic sedimentary and volcanic rocks (with minor intrusive rocks) exposed in a series of northward-dipping fault blocks with northwestward trend. The geology shown in simplified form in Figure 1 is described elsewhere (A. L. Jaques and others, in prep.). The Finisterre Volcanics, which form the central peaks of the ranges, are underlain by Eocene pelagic and hemipelagic sedimentary rocks and unconformably overlain by thick sequences of Neogene clastic sedimentary rocks and limestone. A chain of Quaternary volcanic islands lies immediately to the north, forming part of the Bismarck volcanic arc, the geology and petrology of which are described elsewhere (for example, Johnson and others, 1971, 1973; Johnson, 1976).

The Finisterre Volcanics consist of basalt and low-silica andesite lava and volcaniclastic rocks with some intercalated argillite, cherty micrite, and radiolarian chert near the base and limestone lenses near the top. The sequence contains no rocks of continental derivation. Formation thickness is difficult to ascertain because of the rugged mountainous topography and prevalence of strike faulting, but an average thickness of about 4,500 m seems likely. The age of the Finisterre Volcanics is well established; limestone lenses in the upper portion of the formation contain Tertiary "e stage" fauna (late Oligocene to early Miocene), and K-Ar dating of the volcanic rocks has yielded ages ranging from early Oligocene to earliest Miocene (Table 1).

Pillow lava and associated pillow breccias of deep-water origin are found near the base of the formation overlying the argillite sequence. The greater proportion of the Finisterre Volcanics, however, consists of a wide variety of fragmented rocks formed by explosive vesiculation and disruption of lava at shallower depths, with subsequent redistribution.

The volcaniclastic rocks are of autoclastic, pyroclastic, and epiclastic origin and include lava breccia, peperitic breccia, a wide variety of aquagene breccias and tuff (especially palagonitic types), tuffaceous lithic graywacke and siltstone, volcanic graywacke and conglomerate, lithic and crystal tuff, and agglomerate. They bear strong similarities to volcaniclastic rocks described from the Solomon Islands (Coleman, 1965; Hackman, 1973), the New Hebrides (Jones, 1967; Robinson, 1969, 1973; Mitchell and Warden, 1971), and New Britain (Macnab, 1970).

PETROLOGY

General

Examination of about 140 thin sections showed that most rocks of the Finisterre Volcanics contain abundant coarse clinopyroxene and plagioclase phenocrysts; olivine, hornblende, and pleochroic orthopyroxene are additional phenocryst phases. Aphyric rocks are scarce. Although many rocks, particularly the volcaniclastic rocks, contain some chlorite, carbonate, zeolite, and (or) chalcedony lava with fresh minerals including olivine is common throughout the sequence.

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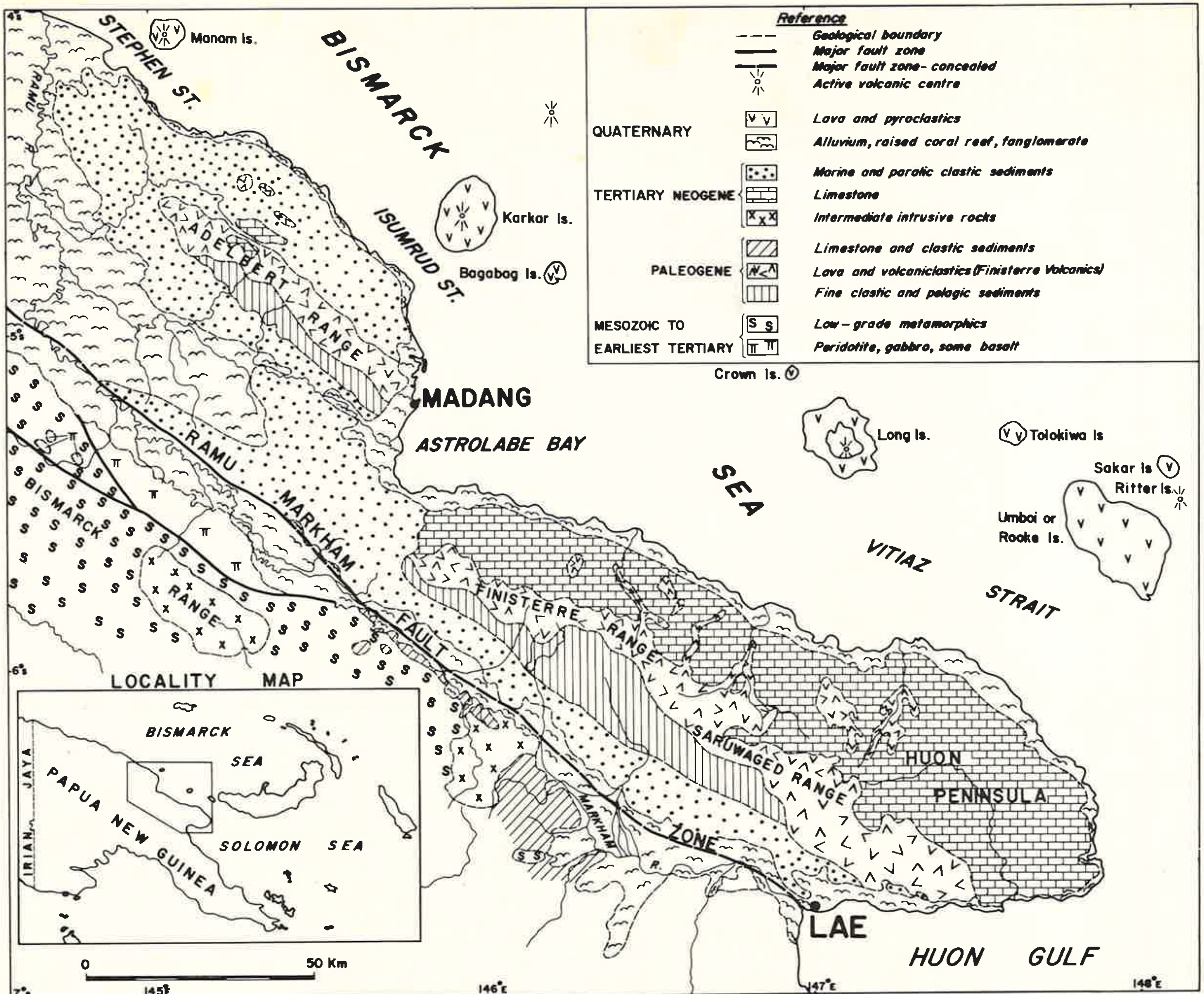

Figure 1. Simplified geology of the Adelbert–Finisterre Range–Huon Peninsula region, northern New Guinea. Geology adapted after BMR (1972), Robinson and others (1974), Robinson and Jaques (1974), Jaques and Robinson (1975), and Robinson (1975).

Figure 2. Nomenclature adopted for Finisterre Volcanics (after Mackenzie and Chappell, 1972). Full circles = shoshonite and absarokite, full circle + bar = leucite trachyte, triangles = high-K, high-Al basalt, open circle = picrite. All samples plotted volatile free.

TABLE 1. K-Ar AGES FROM THE FINISTERRE VOLCANICS

Sample no.	Rock type	Component analyzed	K (wt %)	Ar^{40}/K^{40*}	Ar^{40} (atm. %)	Age (m.y.)
270064	High-K, high-Al basalt	Hornblende	0.566, 0.564	0.002026	38.8	34.4 ± 1.0
260744	Shoshonite	Hornblende	0.531, 0.534	0.001665	38.2	28.3 ± 0.8
270577	Absarokite	Plagioclase	0.699, 0.697	0.001652	25.2	28.1 ± 0.8
190810	Shoshonite	Plagioclase	0.664, 0.659	0.001443	13.9	24.5 ± 0.7
270718	Shoshonite	Plagioclase	0.756, 0.751	0.001415	11.3	24.1 ± 0.7
260743	High-K, high-Al basalt	Hornblende	0.886, 0.884	0.001377	31.9	23.4 ± 0.7
191135	Shoshonite	Plagioclase	0.754, 0.750	0.001303	28.0	22.2 ± 0.7
271570	Picrite	Total rock	0.872, 0.883	0.0009101	24.8	15.5 ± 0.6†

Note: Determinations by Australian Mineral Development Laboratories (AMDEL), South Australia; analyst A. Webb, AMDEL Report An 353/74. Constants used in age calculations are K^{40} = 0.0119 atom percent, $\lambda_\beta = 4.72 \times 10^{-10}\ yr^{-1}$, $\lambda_e = 0.584 \times 10^{-10}\ yr^{-1}$. Errors quoted are for one standard deviation.

* Radiogenic Ar.

† Anomalous young age may be due to argon loss from partly recrystallized interstitial glass.

Chemical analyses including trace elements and CIPW norms of 17 least altered representative lava samples from the Finisterre Volcanics are presented in Table 2. Analyses were carried out by the Australian Mineral Development Laboratories (AMDEL) using a combination of XRF and wet-chemical means following the method of Norrish and Hutton (1969). To overcome oxidation effects, CIPW norms have been calculated on a volatile-free basis with the Fe_2O_3/FeO ratio standardized so that weight percent Fe_2O_3 does not exceed weight percent TiO_2 + 1.5 (Irvine and Baragar, 1971).

The Finisterre and Adelbert Ranges form a basaltic, potassic province. More than two- thirds of the sampled rocks are basalt, and the remainder are low-silica andesite and rare rhyolite; rocks in the silica range from 56 to 73 percent were not found. The chemical classification of the Mackenzie and Chappell (1972) has been adopted for the Finisterre Volcanics, which range from high-K, high-Al basalt to shoshonite to leucite trachyte (Fig. 2); shoshonitic lava is more abundant than the high-K, high-Al basalt. In addition a small number of low-K rocks (basalt and rhyolite) were found as float in rivers draining the southwest Finisterre Range. The temporal and spatial distribution of the three groups is not clear, but stratigraphic and geochronological evidence suggests that the high-K, calc-alkalic rocks are slightly older than but largely contemporaneous with the shoshonite; the relationship of the low-K rocks is in doubt.

Most rocks plot on the alkalic side of the MacDonald-Katsura line on an alkalis versus silica content diagram but are saturated or nearly saturated rather than strongly nepheline normative. When plotted on the olivine-quartz-nepheline projection of the "basalt tetrahedron," the rocks straddle the critical plane of silica undersaturation; this is reflected petrographically in the fact that many rocks have plagioclase + clinopyroxene + olivine phenocrysts.

Shoshonite Group

The potassic rocks range from olivine basalt (absarokite) to shoshonitic basalt to shoshonitic two-pyroxene ± hornblende low-silica andesite to leucite trachyte.

The absarokite and shoshonitic absarokite have coarse clinopyroxene phenocrysts (commonly as much as 1 cm across) and smaller phenocrysts of olivine in a black-brown glass containing microphenocrysts of plagioclase, clinopyroxene, olivine, pleochroic orthopyroxene, FeTi oxides, and, in some lava, K-feldspar. Olivine crystals show no evidence of olivine-liquid reaction. The rocks are predominantly slightly undersaturated (both in transformed and untransformed norms) and have high MgO (about 8 to 12 percent) and moderate Al_2O_3 contents. Differentiation indices (D.I. =

TABLE 2. CHEMICAL ANALYSES AND CIPW NORMS OF REPRESENTATIVE SAMPLES OF FINISTERRE VOLCANIC LAVA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SiO_2	44.99	48.34	48.46	49.21	50.99	51.10	51.17	51.48	52.99	53.55	55.43	53.43	48.34	49.42	49.83	49.92	50.33
TiO_2	0.46	0.93	0.67	0.68	0.78	0.91	0.92	0.68	0.69	0.81	0.69	0.57	1.02	0.89	0.80	0.67	1.05
Al_2O_3	7.30	16.34	11.92	13.36	18.34	15.68	15.18	18.58	18.38	18.35	16.81	16.14	17.74	14.08	17.23	18.61	15.50
Fe_2O_3	4.88	5.67	3.39	3.90	3.80	4.71	4.04	4.22	4.23	2.51	3.02	4.37	5.07	4.32	4.72	5.33	5.10
FeO	6.60	3.95	6.71	6.13	4.01	5.02	6.15	3.56	2.31	5.16	3.48	3.40	3.63	6.33	5.63	2.44	6.17
MnO	0.21	0.18	0.19	0.17	0.17	0.17	0.19	0.18	0.13	0.17	0.15	0.14	0.15	0.18	0.19	0.17	0.21
MgO	18.70	5.36	11.00	7.83	4.05	4.24	4.81	2.95	2.24	2.21	4.37	4.44	5.00	6.37	4.21	4.48	4.37
CaO	10.34	8.03	9.43	9.08	8.22	9.34	9.06	8.63	7.98	7.76	6.15	6.64	11.14	11.17	10.16	8.36	9.72
Na_2O	1.65	3.55	2.36	2.52	2.95	2.99	2.90	3.57	3.57	3.65	2.90	2.15	2.99	2.65	3.06	3.16	2.79
K_2O	1.03	2.51	2.61	2.70	3.16	2.30	2.32	2.37	3.21	2.86	4.94	6.61	1.66	1.51	1.42	1.52	1.62
P_2O_5	0.27	0.42	0.50	0.54	0.22	0.46	0.48	0.30	0.52	0.65	0.36	0.52	0.32	0.38	0.37	0.45	0.38
H_2O^+	0.58	0.56	0.74	2.39	1.17	1.49	0.73	1.33	1.17	0.66	0.57	0.43	0.84	0.80	1.15	3.53	1.34
H_2O^-	2.21	2.40	1.51	0.99	0.59	1.55	1.11	0.83	1.61	1.01	0.77	0.35	1.16	0.56	1.10	0.55	1.08
CO_2	0.05	1.15	0.05	0.10	0.15	0.10	0.05	0.05	0.30	0.05	0.05	0.05	0.15	0.05	0.10	0.35	0.00
Total	99.27	99.39	99.54	99.60	98.61	100.06	99.11	98.73	99.33	99.42	99.69	99.24	99.21	98.71	99.97	99.54	99.66
Q	..	..	..	..	..	..	..	..	1.30	2.07	0.83	..	..	..	..	0.60	0.64
Or	6.33	15.62	15.88	16.63	19.34	14.05	14.12	14.54	19.75	17.30	29.72	39.78	10.13	9.19	8.62	9.47	9.87
Ab	7.84	26.24	16.62	22.21	25.84	26.15	25.27	31.35	31.44	31.78	24.97	17.23	23.26	23.08	26.58	28.19	24.33
An	9.85	22.37	14.65	17.90	28.46	23.35	22.21	28.74	25.67	25.75	18.60	15.15	31.08	22.72	29.87	33.87	25.77
Ne	3.61	2.91	2.13	..	..	..	..	..	..	..	..	0.70	1.55	..	..	..	
Di-wo	17.39	6.97	12.59	10.59	5.13	8.96	8.71	5.71	5.01	3.89	4.20	6.24	9.95	13.27	8.10	2.83	8.93
Di-en	12.08	3.92	8.20	6.32	2.90	4.53	4.46	2.81	2.60	1.72	2.68	3.53	5.92	7.34	3.82	1.64	4.18
Di-fs	3.88	2.76	3.53	3.73	2.02	4.22	4.03	2.80	2.28	2.15	1.25	2.45	3.52	5.42	4.18	1.05	4.65
Hy-en	..	..	..	1.16	3.24	6.17	7.20	3.11	3.21	3.91	8.40	..	..	2.88	4.08	10.12	7.04
Hy-fs	..	..	..	0.68	2.25	5.75	6.50	3.10	2.83	4.89	3.93	..	..	2.12	4.47	6.47	7.82
Ol-fo	25.47	7.10	14.02	9.00	3.02	0.15	0.47	1.20	..	..	..	5.42	4.86	4.28	2.00	..	..
Ol-fa	9.02	5.52	6.65	5.84	2.32	0.16	0.47	1.31	..	..	..	4.13	3.18	3.48	2.42	..	..
Mt	2.96	3.71	3.24	3.29	3.42	3.61	3.62	3.28	3.31	3.43	3.23	3.06	3.77	3.57	3.42	3.32	3.81
Il	0.91	1.86	1.31	1.35	1.53	1.79	1.80	1.34	1.36	1.57	1.33	1.10	2.00	1.74	1.56	1.34	2.06
Ap	0.67	1.05	1.22	1.33	0.54	1.13	1.17	0.75	1.28	1.58	0.87	1.26	0.78	0.93	0.90	1.13	0.93
D.I.	17.79	44.77	34.63	38.84	45.18	40.21	39.39	45.89	52.48	51.15	55.52	57.70	34.94	32.27	35.19	38.26	34.84
Rb	24	70	48	50	24	36	38	32	48	55	65	60	17	24	15	38	15
Ba	320	380	680	700	240	460	460	660	560	560	280	820	200	1,000	360	280	140
Sr	330	620	880	1,000	660	680	660	800	940	720	520	600	720	640	680	840	560
Rb/Sr	0.073	0.112	0.055	0.050	0,036	0.053	0.058	0.040	0.051	0.076	0.125	0.010	0.024	0.038	0.022	0.045	0.027
K/Rb	356	298	451	448	1,093	530	507	615	555	432	631	915	919	522	1,192	332	897
Ni	250	17	135	8	55	65	40	20	15	5	40	23	13	80	10	50	25
Co	68	30	48	8	20	28	32	24	10	14	18	24	22	42	24	20	34
V	235	280	320	255	460	500	485	400	240	185	240	360	530	470	380	250	550

Note: Analyses by Australian Mineral Development Laboratories, Adelaide. CIPW norms computed by Bureau of Mineral Resources, Canberra.

1. Picrite,* lava, Nankina River; 5°44'S, 146°26'E; 271570. 2. Shoshonite, boulder, Evapier River; 5°47'S, 145°38'E; 270715. 3. Absarokite, lava flow, Lalam River; 5°43'S, 146°07'E; 270607. 4. Absarokite,* lava breccia, Lalam tributary; 5°43'S, 146°05'E; 270577. 5. Shoshonite,* float, Dibor River; 4°40'S, 145°35'E; 260744. 6. Shoshonite,* lava boulder, Evapier River; 5°47'S, 145°38'E; 270718. 7. Shoshonite, float, Dibor River, 4°43'S, 145°30'E; 270745. 8. Shoshonite, lava breccia, Lalam River; 5°45'S, 146°05'E; 270609. 9. Shoshonite, conglomerate clast, Dibor River; 4°44'S, 145°29'E; 260749. 10. Shoshonite,* agglomerate boulder, Guam River; 4°35'S, 145°13'E; 190810. 11. Shoshonite, boulder, Evapier River; 5°47'S, 146°38'E; 270722. 12. Leucite trachyte, lava boulder, Kumil River; 4°33'S, 145°16'E; 190772. 13. High-K, high-Al basalt,* float, Dibor River; 4°40'S, 145°35'E; 260743. 14. High-K, high-Al basalt, Guam River; 4°35'S, 145°12'E; 190823. 15. High-K, high-Al basalt, Guam River; 4°35'S, 145°12'E; 190815. 16. High-K, high-Al basalt,* lava flow, Upper Gusap River; 5°50'S, 146°08'E; 270064. 17. High-K, high-Al basalt, lava boulder, Mene River; 5°50'S, 145°40'E; 270711.

* K-Ar age available, Table 1.

normative Ab + Or + Ne + Qz) range from about 35 to 45.

The shoshonite contains coarse clinopyroxene, labradorite ± olivine phenocrysts, together with pleochroic orthopyroxene as either a phenocryst or groundmass phase. K-feldspar generally rims plagioclase but in some lava occurs as microlites or fills interstices in the groundmass. The shoshonite is mainly saturated, hypersthene ± olivine normative, and has lower MgO contents (about 4 to 5 percent) and higher Al_2O_3 contents (16 to 19 percent) than the absarokite. Differentiation indices are slightly higher than for the absarokite, ranging from 40 to 50.

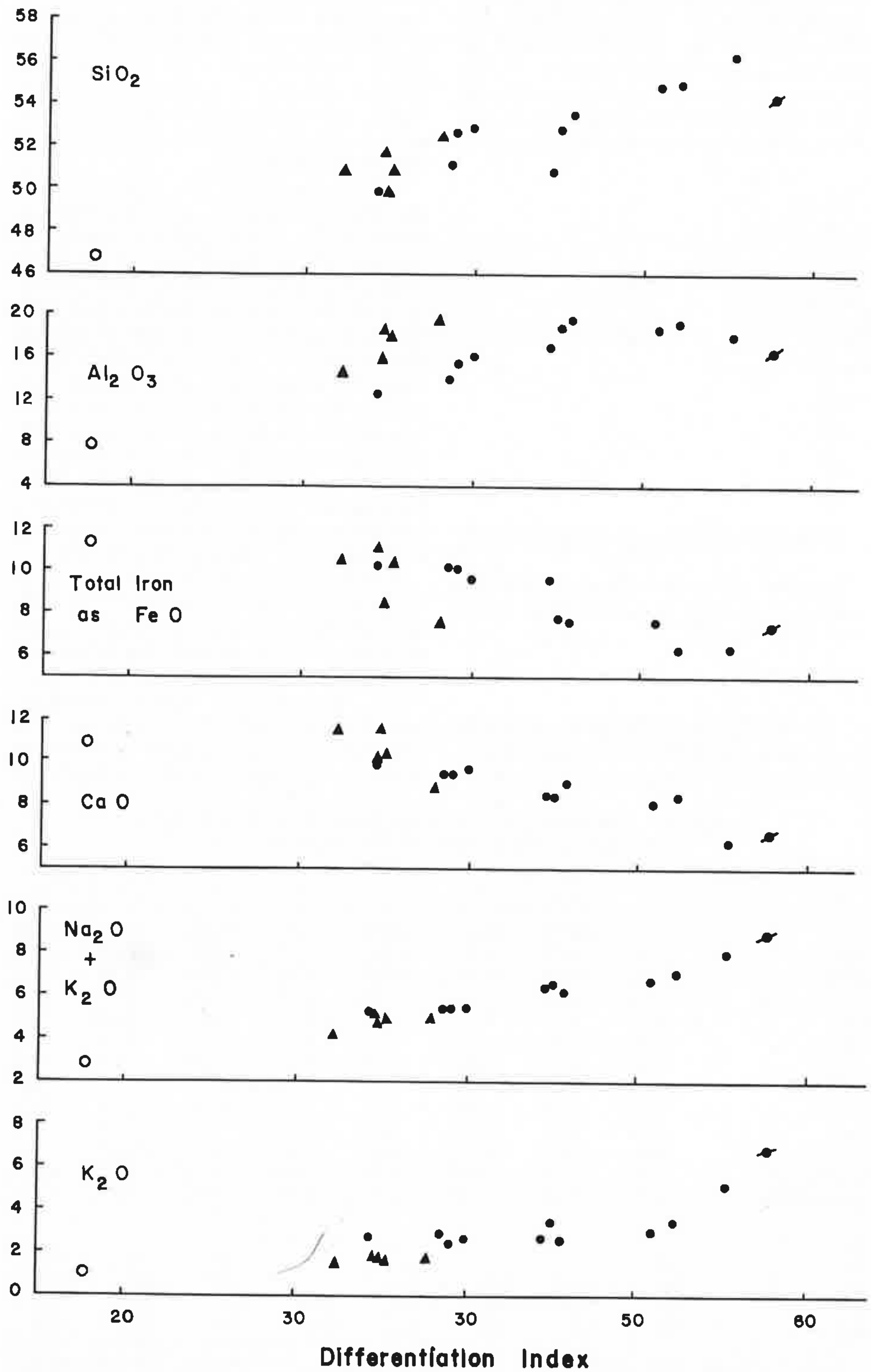

Figure 3. Oxide variation (weight percent volatile free) versus differentiation index for Finisterre Volcanics. Symbols are the same as for Figure 2.

Shoshonitic low-silica andesite includes two pyroxene and hornblende varieties; both contain phenocrysts of strongly zoned plagioclase (labradorite to sodic andesine or oligoclase), and some hornblende andesite samples have sanidine in the groundmass. Hornblende is commonly rimmed or replaced by magnetite, clinopyroxene, and plagioclase. Compositions are saturated to slightly oversaturated, and SiO_2 contents range from 53 to 56 percent. Al_2O_3 and alkali contents are high, and MgO content is generally lower than for the shoshonitic basalts. Differentiation indices range from 45 to 55.

Rare leucite trachyte found mainly in the Adelbert Range is pale gray and has numerous coarse green hornblende phenocrysts set in a fine crystalline groundmass of plagioclase, clinopyroxene, K-feldspar, leucite, and apatite. The leucite trachyte is slightly nepheline normative and has a very high content of K_2O (6.6 percent), high content of Al_2O_3, and low content of CaO.

Some lava, particularly the more K_2O-rich low-silica andesite, carries rounded, cognate xenoliths of medium-grained aggregates of low-pressure mineral assemblages: plagioclase (labradorite), clinopyroxene, hornblende, and magnetite. These are thought to be crystal cumulates.

Nepheline-normative alkali picrite occurs at several localities on the northern slopes of the Finisterre Range. Field evidence and an equivocal K-Ar date indicate that the picrite marks the last stages of early Miocene volcanism. The picrite is probably accumulative and contains a high proportion of euhedral forsteritic olivine (2*V* near 90°) and clinopyroxene phenocrysts in a clinopyroxene-rich groundmass. The very high content of MgO (18.7 percent), high content of CaO, and high content of K_2O are notable.

High-K, High-Al Basalt Group

Rocks within this group range from high-K, high-Al olivine basalt to two-pyroxene (± hornblende) low-silica andesite. All are highly porphyritic and contain strongly zoned plagioclase (calcic labradorite to sodic andesine), clinopyroxene, pleochroic orthopyroxene, and (or) olivine phenocrysts. Many plagioclase crystals show evidence of resorption and contain numerous inclusions. The low-silica andesite is petrographically similar to the shoshonitic varieties but contains a higher proportion of plagioclase; groundmass K-feldspar is generally lacking. All rocks of the group have high Al_2O_3 and CaO contents, typical of calc-alkalic lava, but their total alkali content is higher than most calc-alkalic suites. Both total alkalis and K_2O/Na_2O ratios are distinctly lower than in the shoshonite.

Low-K Group

These rocks are the least abundant (<5 percent) of the three groups and include olivine basalt, low-silica andesite, and rhyolite. The olivine basalts are olivine-hypersthene normative and have olivine, clinopyroxene, and plagioclase phenocrysts. Pigeonite was not identified, but some groundmass pyroxenes have 2*V*s suggestive of subcalcic augite; orthopyroxene does not occur. Low-silica andesite has clinopyroxene and hornblende phenocrysts, and one sample contained biotite. Rare boulders of low-K rhyolite (78 percent SiO_2) and eutaxitic rhyolite ash-flow tuff (ignimbrite) of unknown age have been found at the western end of the Finisterre Range.

VARIATION DIAGRAMS

Trends displayed on an oxide versus differentiation index (D.I.) diagram (Fig. 3), the ubiquitous coarse phenocrysts of the lava, and presence of the cognate xenoliths all suggest that crystal fractionation of the shoshonitic rocks may have occurred. Trends of increasing alkalis (K_2O in particular) and decreasing CaO with D.I. (Fig. 3) suggest that the leucite trachyte might be a fractionation product of shoshonite, as found elsewhere (for example, Barberi and others, 1974). Possible liquidus phases for such fractionation would be clinopyroxene + olivine ± plagioclase and plagioclase + clinopyroxene + hornblende + magnetite. There is no evidence that fractionation yielded liquids of andesite-dacite composition.

The high-K, high-Al basalt appears to have been dominated by plagioclase accumulation and shows limited compositional variation. A clustering of these rocks near the two-feldspar solid-solution boundary when plotted on the Ab-Or-An ternary projection of the quaternary system quartz-albite-orthoclase-anorthite is consistent with plagioclase accumulation.

TRACE ELEMENTS

The Finisterre Volcanics have high levels of Rb, Sr, and Ba. The shoshonite group is the most enriched; Rb values range from 24 to 70 ppm, averaging 50 ppm, and Ba and Sr average 500 and 750 ppm, respectively. K/Rb ratios are high but variable, ranging from 300 to 1,000, averaging 560. The leucite trachyte has comparable levels of K-type cations to the shoshonites, in particular, very high Ba, high Rb, and a high K/Rb ratio. The picrite has moderately high levels of Rb, Ba, and Sr but lower levels than most of the shoshonite group. The relatively high Ni contents of both the picrite and absarokite are consistent with olivine and clinopyroxene accumulation.

The high-K, high-Al basalt has lower Rb than but comparable Sr contents to the shoshonite (Fig. 4). Ba values are less than for the shoshonite, and the average K/Rb ratio for these rocks is higher than that for the shoshonite, as found by Jakeš and White (1970). The different levels of enrichment in incompatible elements (K, Rb, Ba, Sr) imply that the high-K, high-Al basalt is not derived from the shoshonite, or vice versa, by low-pressure crystal fractionation.

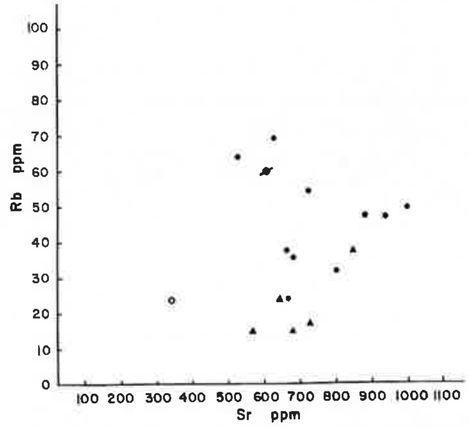

Figure 4. Rb versus Sr diagram for Finisterre volcanic rocks. Data in ppm. Symbols are the same as for Figure 2.

DISCUSSION

The shoshonite and high-K calc-alkalic rocks of the Finisterre Volcanics are of similar composition to potassic lavas found in island-arc environments elsewhere in the southwest Pacific and in the Mediterranean (Table 3). All are characterized by low TiO_2 content; high CaO and Al_2O_3; a lack of iron enrichment; high levels of K_2O, Rb, Ba, and Sr; and high levels of oxidation. The average Finisterre shoshonite appears enriched in alkalis (especially K_2O) compared to the Papua New Guinea Highlands shoshonite of Mackenzie and Chappell (1972). The high-K, high-Al basalt of the Finisterre Volcanics is enriched in K_2O relative to other high-K calc-alkalic basalt. Levels of trace elements Rb, Ba, and Sr are distinctly lower than in the shoshonite.

Shoshonitic rocks are believed to be characteristic of newly stabilized orogenic areas (Joplin, 1968) and of island arcs showing an advanced stage of evolution (Gill, 1970; Jakeš and White, 1969, 1972). Lava of the island-arc tholeiite and calc-alkalic associations is thought to precede the eruption of shoshonite, which represents the final stages of island-arc volcanism. The dominantly potassic basalt and low-silica andesite of the Finisterre Volcanics do not appear to be the end phase of such a three-stage cycle. Rather, the available evidence suggests that potassic basaltic rocks were erupted throughout most of the development of a Paleogene island arc.

Present-day shoshonitic volcanism in island arcs is generally associated with deep-focus earthquakes, corresponding to deeper portions of a Benioff zone (Hatherton and Dickinson, 1969; Ninkovitch and Hayes, 1972). Consequently, high-K calc-alkalic and shoshonitic rocks have in the past been interpreted as partial melts of subducted crust or of hydrous mantle peridotite (for

TABLE 3. COMPARISON OF FINISTERRE VOLCANICS WITH POTASSIC LAVA FROM OTHER ISLAND ARCS

	1	2	3	4	5	6	7	8
SiO_2	52.90	54.51	51.66	51.40	51.55	51.16	50.86	51.46
TiO_2	0.80	1.07	0.83	0.62	1.17	0.92	1.05	0.52
Al_2O_3	16.86	16.07	16.45	17.23	16.50	17.16	16.38	18.00
Fe_2O_3	4.08	3.30	4.03	4.91	4.27	5.08	3.68	3.76
FeO	4.80	4.92	4.70	3.68	4.55	5.00	5.11	5.60
MnO	0.18	0.11	..	0.17	0.16	0.19	0.17	..
MgO	5.07	6.45	5.48	5.52	6.66	5.06	9.01	5.80
CaO	8.66	8.01	9.04	9.78	9.10	10.43	9.55	10.55
Na_2O	3.20	2.41	2.98	3.22	3.08	3.02	2.91	2.30
K_2O	2.99	2.61	2.94	3.04	2.35	1.60	1.08	0.99
P_2O_5	0.46	0.55	0.32	0.43	0.62	0.39	0.21	0.17
K_2O/Na_2O	0.93	1.08	0.99	0.94	0.76	0.53	0.37	0.48
Total alkalis	6.19	5.02	5.92	6.26	5.43	4.62	3.99	3.3
ppm								
Rb	48	75	73	67	58	22	10	29
Ba	498	1,000	832	664	..	384	115	343
Sr	748	700	1,140	1,193	983	690	330	703
K/Rb	556	200	333	416	336	770	340	290

Note: 1. Average of 10 shoshonites from Finisterre Volcanics. 2. Shoshonite, New Guinea Highlands (Jakeš and White, 1972). 3. Average of 8 shoshonitic lava samples, Aeolian Islands (Keller, 1974). 4. Average of 9 shoshonite samples from Fiji (Gill, 1970). 5. Average of 6 shoshonite samples, Central Highlands, Papua New Guinea (Mackenzie and Chappell, 1972). 6. Average of 5 high-K, high-Al basalt samples, Finisterre Volcanics. 7. High-Al basalt, southeast Papua (Jakeš and Smith, 1970). 8. Average of 8 high-Al basalt samples, Aeolian Islands (Keller, 1974).

example, Hatherton and Dickinson, 1969; McBirney, 1969; Taylor, 1969; Jakeš and White, 1970, 1972; Green, 1972). However, the results of experimental petrology have shown that the partial melts of subducted eclogitic oceanic crust are likely to be rhyodacitic in composition (Green and Ringwood, 1968, 1972). Nicholls (1974) has also pointed out the difficulty of producing shoshonitic magmas by direct partial melting of hydrous mantle peridotite. A recently proposed model for the origin and evolution of island-arc volcanism (Nicholls and Ringwood, 1973; Nicholls, 1974; Ringwood, 1974) seems more likely. In this model water derived from dehydrated subducted crust initiates partial melting of mantle peridotite to produce the island-arc tholeiite series. At greater depths slab-derived silicic partial melts react with overlying mantle peridotite, producing peridotite-pyroxene bodies that rise diapirically and partially melt to yield calc-alkalic magmas.

A similar three-stage melting model might have produced the dominantly potassic basaltic rocks of the Finisterre Volcanics, which the regional geology suggests formed in a volcanic arc north of a northeastward-dipping subduction zone in response to early Tertiary plate interactions (Robinson, 1973; Jaques and Robinson, 1975; A. L. Jaques and others, in prep.). However, although the subducted leading edge of the northward-moving Indo-Australian plate probably consisted of oceanic crust, the possibility that continental crust and thick sedimentary sequences to the south of the arc might have influenced magma compositions complicates direct application of simplistic models of arc magmatism.

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