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STRONTIUM ISOTOPE RATIOS OF QUATERNARY VOLCANIC ROCKS FROM PAPUA NEW GUINEA

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STRONTIUM ISOTOPE RATIOS OF QUATERNARY VOLCANIC ROCKS FROM PAPUA NEW GUINEA

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Tables and figures

Table 1. Sr^{87}/Sr^{86} ratios and rubidium and strontium values for Quaternary volcanic rocks from Papua New Guinea.

Figure 1. Sample locality map, Papua New Guinea, showing sample sites given in Table 1.

Figure 2. Sr^{87}/Sr^{86} ratio *vs* strontium content.

Figure 3. Sr^{87}/Sr^{86} ratio *vs* Rb/Sr ratio. Symbols as for figure 2. The two samples from St. Andrew Strait have extremely high Rb/Sr ratios (1.289 and 3.240), and plot off this diagram.

Figure 4. Sr^{87}/Sr^{86} ratio *vs* silica content for rocks of the Bismarck Volcanic Arc. Open circles with dots represent samples of Table 1. Filled circles represent rocks analysed by Peterman et al. (10) and Lowder and Carmichael (16).

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ABSTRACT

Sr^{87}/Sr^{86}, rubidium, and strontium values have been determined for 39 Quaternary volcanic rocks from six separate areas in Papua New Guinea. The Sr^{87}/Sr^{86} ratios, determined on a wide variety of rock compositions, range between 0.7034 and 0.7054, and show that the volcanoes can be divided into two broad groups.

One group consists of volcanoes from the following four areas: (i) the southern margin of the Bismarck Sea ("Bismarck Volcanic Arc"), (ii) islands in St. Andrew Strait, (iii) islands northeast of New Ireland, and (iv) Bougainville Island. The rocks of these volcanoes show comparatively low Sr^{87}/Sr^{86} ratios (mostly 0.7034 to 0.7043). Samples from each of areas (i), (iii), and (iv) show isotopic homogeneity; it is considered that these rocks were produced from relatively homogeneous source regions in the upper mantle, and that they have not been significantly affected by crustal contamination. Two obsidian samples from St. Andrew Strait (area ii) have the highest isotopic ratios of the four areas; for reasons given elsewhere, it is thought these rocks may be the products of crustal melts.

The second group consists of the volcanoes of eastern Papua and the Highlands. Compared to those of the first group, the rocks of these mainland volcanoes have generally higher Sr^{87}/Sr^{86} ratios (mostly 0.7043 to 0.7054). Moreover, in both areas, the isotope ratios show a much wider range of values. It is thought that the magmas of these volcanoes were affected by different degrees of sialic crustal contamination, or were derived from heterogeneous sources in the upper mantle.

INTRODUCTION

The results of strontium isotopic measurements were first applied to problems of magma genesis by Hurley et al. (1) and Faure and Hurley (2). They suggested that because crustal sialic rocks have higher Rb/Sr ratios (and consequently are richer in Sr^{87}) than upper mantle materials, magmas generated by fusion or assimilation of continental crust should have measurably higher initial Sr^{87}/Sr^{86} ratios than magmas formed in the upper mantle. The present day Sr^{87}/Sr^{86} ratios of young oceanic basalts, which are thought to have originated in the upper mantle, range between about 0.702 and 0.706 (see, for example, Gast (3)). In contrast, many continental volcanic rocks are more radiogenically enriched, and their ratios range from 0.702 to more than 0.711. Higher Sr^{87}/Sr^{86} values are generally interpreted as indicating some degree of crustal contamination.

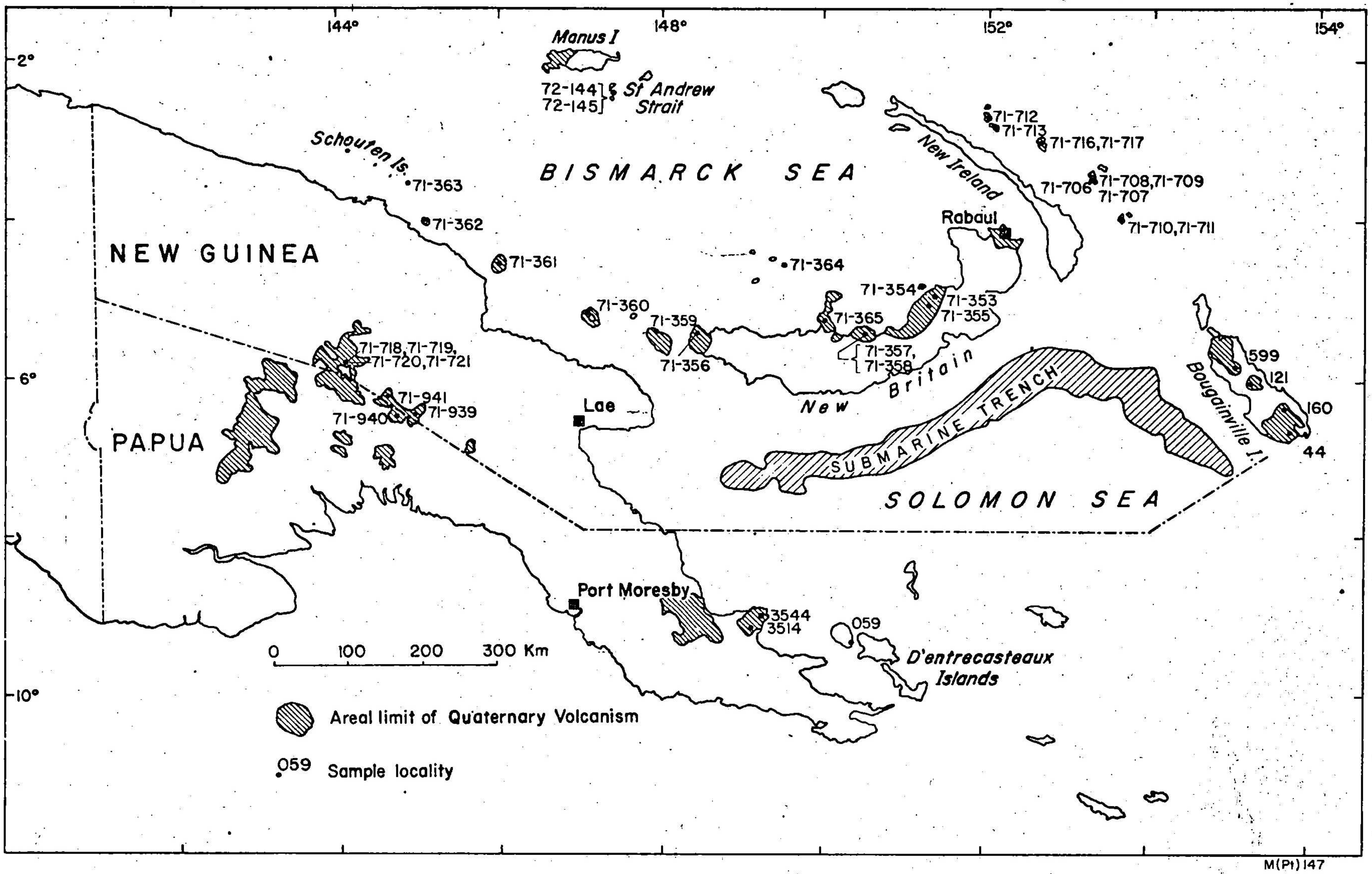
During the past few years, several workers have attempted to employ this isotopic constraint, especially in comparative studies of volcanic rock associations in young island arc, oceanic, and mid-oceanic ridge environments. The variations in Sr^{87}/Sr^{86} ratios found between volcanic rocks in these environments are not as pronounced as those between continental and oceanic volcanic rocks. The ratios of rocks from island arcs and oceanic islands are generally similar at about 0.703-0.705; they have an identical mean value of 0.7037 (data summarized by Faure and Powell, (4)). On the other hand, ocean floor and mid-ocean ridge volcanic rocks commonly have lower ratios of 0.702-0.703.

A wealth of strontium isotope data is available for most of the island arcs between Japan and New Zealand, at the western margin of the Pacific Ocean (5-12). However, except for the results of Peterman et al. (10) for a restricted area of volcanic rocks near Talasea, New Britain, until now no isotopic results have been available for Quaternary volcanic rocks in Papua New Guinea.

This paper reports new Sr^{87}/Sr^{86}, rubidium, and strontium measurements on 39 samples from six principal Quaternary Volcanic areas in Papua New Guinea, and compares them with values obtained elsewhere in the island arcs of the western Pacific. The six volcanic areas (figure 1) are: (i) volcanoes along the southern margin of the Bismarck Sea (between Rabaul in the east and the Schouten Islands in the west), which are here referred to collectively as the "Bismarck Volcanic Arc", (ii) the St Andrew Strait islands in the northern Bismarck Sea, (iii) islands northeast of New Ireland, (iv) Bougainville Island, (v) eastern Papua, and (vi) the Highlands of Papua New Guinea. The volcanic geology, petrography, and chemistry of the samples used in this study are described elsewhere (for a summary, see Johnson et al. (13)), and it is from these sources that the rock names of Table 1 have been derived.

Table 1 presents the analytical data for Sr^{87}/Sr^{86}, rubidium, and strontium. Because of the generally low Rb/Sr ratios and obvious youthfulness of the volcanic rocks, the present day (measured) Sr^{87}/SR^{86} ratios are taken as the initial Sr^{87}/Sr^{86} compositions of the magmas.

The results show pronounced compositional differences between, and within, each of the six volcanic areas. This number of samples is insufficient to reach a full understanding of isotopic variability throughout the volcanic regions of Papua New Guinea, and these results should therefore be taken as exploratory. Additional data are required for most of the six areas, and for other areas.



A

Reduce base to A B

B

FIG. 1

ANALYTICAL METHODS

A representative 0.2 g aliquot of powdered total rock sample was dissolved in HF, $HClO_4$ and HCl, and Sr was concentrated from the solution using first a medium-sized cation exchange column (2.5 g dry weight Bio-Rad 50, 8% cross linkage, 200-400 mesh size) followed by a small (1g dry weight) column. Isotopic ratios were measured using a Nuclide Analysis Associates Model 12-60-SU machine (30.5 cm or 12 inch radius, 60° sector), equipped with magnetic field switching using a Varian FR-40 field controller and with digitized output as described by Compston et al. (14). Data were taken with the Sr^{88} beam intensity at approximately 10^{-10} amperes, using the Faraday cup collector and a Model 31 Cary electrometer. Two sets, each of twelve Sr^{87}/Sr^{86} ratio measurements, were run between Sr^{88}/Sr^{86} ratio sets, and normalized to 8.3752 for Sr^{88}/Sr^{86}. Maximum tail corrections required were 0.015%, but most runs required zero tail correction. Rb^{87} corrections were usually negligible.

Under these conditions, the following values were obtained for replicate measurements of the Eimer and Amend $SrCO_3$ standard:

0.70809	
0.70814	
0.70811	Mean = 0.70813 ± 0.00004
0.70815	
0.70808	
0.70818	

On the above basis, our data for Sr^{87}/Sr^{86} in this paper will be systematically 0.00013 higher than those corrected to 0.7080 for E and A standard (e.g. Peterman et al. (10); Gill and Compston (12)).

Rubidium and strontium contents were determined on a Philips 1220 X-ray spectrometer. For moderate concentrations (greater than 20 ppm) the precision is about 2 percent; for lower concentrations it is about 5 percent (P.H. Beazley, pers. comm.).

BISMARCK VOLCANIC ARC

The volcanoes of the Bismarck Volcanic Arc coincide with a belt of intense seismicity at the southern margin of the Bismarck Sea. Beneath New Britain, earthquakes define a northward dipping Benioff Zone, but in the west the seismic pattern is more diffuse, and the presence of volcanic islands off the north coast of mainland Papua New Guinea cannot be clearly related to an underlying inclined seismic plane (15). The most abundant rock type of these volcanoes is low-silica andesite. Tholeiitic basalt, high-silica andesite, and dacite are also common, but rhyolite is rare (Johnson, unpublished data).

Thirteen rocks from the Bismarck Volcanic Arc showing a wide range in silica content were selected for analysis of Sr^{87}/Sr^{86}, rubidium, and strontium (Table 1). Excluding the anomalously high value for a basalt from Karkar Island (sample 71-361), the Sr^{87}/Sr^{86} ratios show a narrow range of 0.7034 - 0.7038 and a mean of 0.7036 $\pm$ 0.0001 (standard deviation). The values appear to be independent of strontium content and Rb/Sr ratio (figures 2 and 3). They are typical of Sr^{87}/Sr^{86} ratios for many island-arc rocks (compare, for example, 6, 12), and are within the range reported for oceanic island basalts (3).

Peterman et al. (10) found a similarly narrow range of Sr^{87}/Sr^{86} values for twelve samples from the Talasea area, New Britain (near sample locality 71-365, figure 1); their data are also plotted

TABLE 1. Sr^{87}/Sr^{86} RATIOS OF QUATERNARY LAVAS FROM PAPUA NEW GUINEA

Sample No.	Field No.	Rock Type and Location	Rb (ppm)	Sr (ppm)	Rb/Sr	Sr^{87}/Sr^{86}	
BISMARCK VOLCANIC ARC							
71-353	51NG 0089	Basalt, Ulawun	5	282	0.018	0.7035	
						0.7035	
71-354	53NG 2526A	Dacite, Lolobau Island	21	263	0.080	0.7038	
71-355	51NG 0195X	Andesite, Bamus	8	244	0.033	0.7034	
71-356	32NG 0040	Basalt, Cape Gloucester area	20	581	0.034	0.7035	
71-357	6849 0107	Andesite, Cape Hoskins area	11	443	0.025	0.7037	
71-358	7049 0517	Dacite pumice, Cape Hoskins area	15	350	0.043	0.7037	
71-359	32NG 0075	Andesite, Umboi Island	29	536	0.054	0.7035	Mean = 0.70362
71-360	32NG 0124	Andesite, Long Island	36	621	0.058	0.7034	
71-361	R15630	Andesite, Karkar Island	18	413	0.044	0.7041	
						0.7041	
						0.7040	
71-362	R15647	Basalt, Manam Island	8	505	0.016	0.7036	
71-363	18NG 1010	Andesite, Bam Island	19	700	0.027	0.7034	
71-364	48NG 0549	Dacite, Garove Island, Witu Group	17	190	0.089	0.7038	
71-365	51NG 0271	Rhyolite obsidian, Talasea area	53	201	0.264	0.7038	
						0.7037	
ST ANDREW STRAIT ISLANDS							
72-144	25NG 0016	Dacite obsidian, Tuluman Island	116	90	1.289	0.7044	Mean = 0.70435
72-145	25NG 0056	Rhyolite obsidian, Pam Mandian Island	162	50	3.240	0.7043	
ISLANDS NORTHEAST OF NEW IRELAND							
71-706	6940 0267	Absarokite, Lif Island (Tanga Group)	124	1571	0.079	0.7040	
71-707	6940 0271	Absarokite, Tefa Island (Tanga Group)	87	1443	0.060	0.7041	
71-708	6940 0286	Absarokite, Malendok Island (Tanga Group)	17	1620	0.010	0.7041	
71-709	6940 0292	Absarokite, Malendok Island (Tanga Group)	51	1646	0.031	0.7042	
71-710	6940 0312	Shoshonite, Ambitle Island (Feni Group)	48	1529	0.031	0.7041	Mean = 0.70413
71-711	6940 0314	Shoshonite, Ambitle Island (Feni Group)	47	1667	0.028	0.7041	
71-712	6940 0404	Absarokite, Tatau Island (Tabar Group)	50	1621	0.031	0.7044	
71-713	6940 0434	Absarokite, Tabar Island (Tabar Group)	56	1430	0.039	0.7041	
71-716	6940 0338	Absarokite, Lihir Island (Lihir Group)	116	1289	0.090	0.7042	
71-717	6940 0374	Absarokite, Lihir Island (Lihir Group)	47	1223	0.038	0.7040	
BOUGAINVILLE ISLAND							
599		Andesite, Mt Balbi	80	584	0.137	0.7039	
121		Andesite, Mt Bagana	25	810	0.031	0.7038	Mean = 0.70390
160		Dacite, Takuan	43	814	0.053	0.7040	
44		Andesite, Buin area	68	569	0.120	0.7039	
EASTERN PAPUA							
3514		Andesite, Mt Victory	61	856	0.071	0.7047	
3544		Basalt, Mt Trafalgar	21	506	0.042	0.7054	
059		Andesite, Goodenough Island	38	1196	0.032	0.7043	
NEW GUINEA HIGHLANDS							
71-718	20NG 1398	Shoshonite, Mt Hagen	92	589	0.156	0.7045	
71-719	20NG 1604	Andesite, Mt Hagen	42	818	0.051	0.7045	
71-720	20NG 1607	Andesite, Mt Hagen	31	609	0.051	0.7044	
71-721	12NG 1504	Andesite, Mt Hagen	54	847	0.064	0.7045	
71-939	21NG 2101	Andesite, Crater Mt	42	562	0.075	0.7041	
71-940	21NG 2107	Shoshonite, Mt Karimui	65	1308	0.050	0.7037	
71-941	21NG 2108	Shoshonite, Mt Suaru	52	1279	0.041	0.7038	

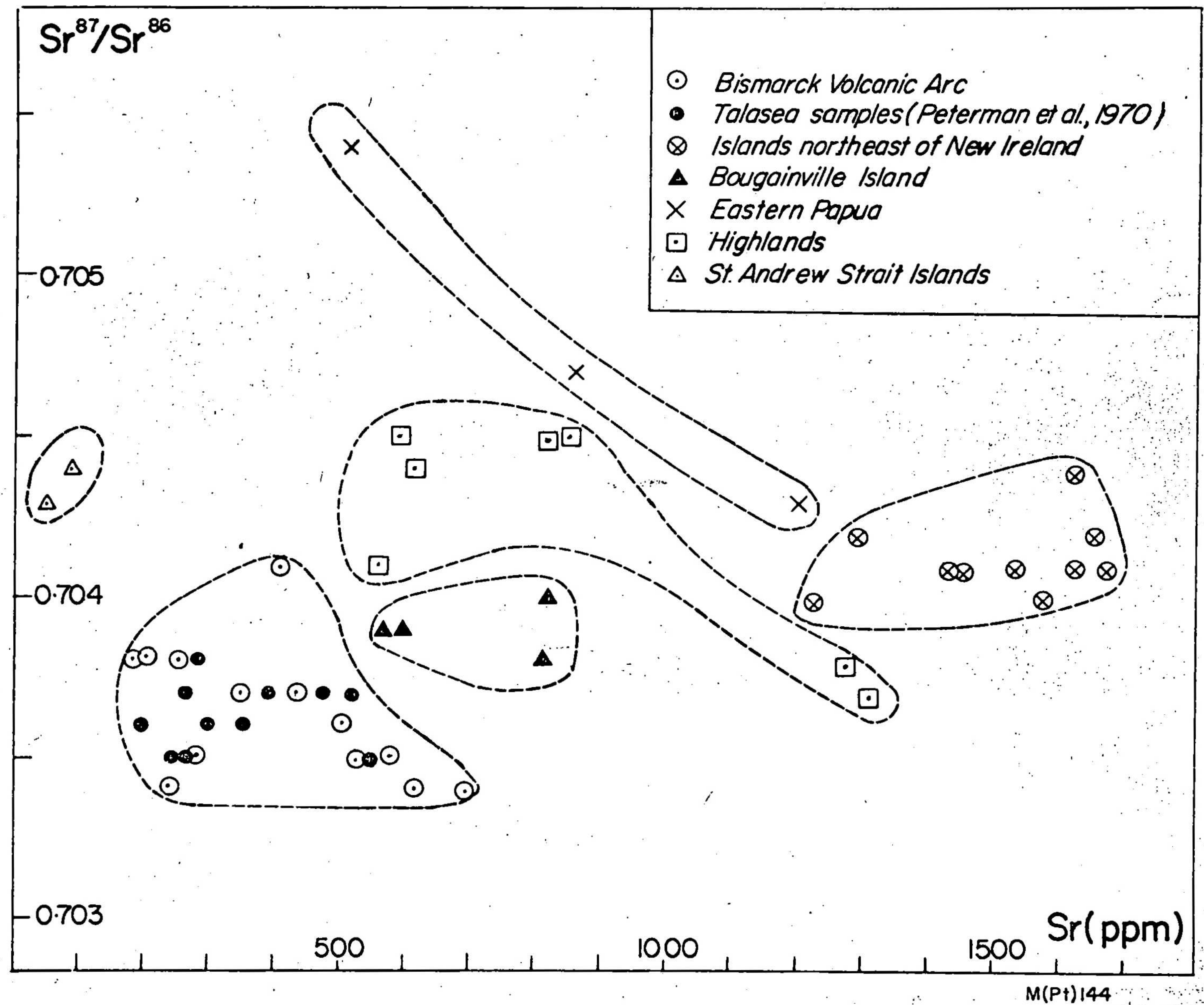

Sr87/Sr86
Bismarck Volcanic Arc
Talasea samples (Peterman et al., 1970)
Islands northeast of New Ireland
Bougainville Island
Eastern Papua
Highlands
St. Andrew Strait Islands
0·705
0·704
0·703
500
1000
1500
Sr (ppm)
M(Pt)144

FIG. 2.

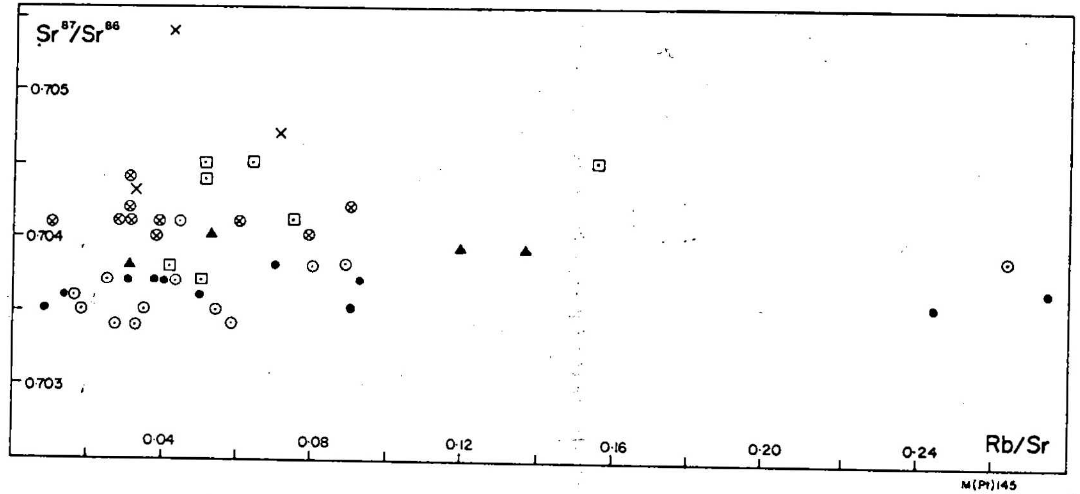
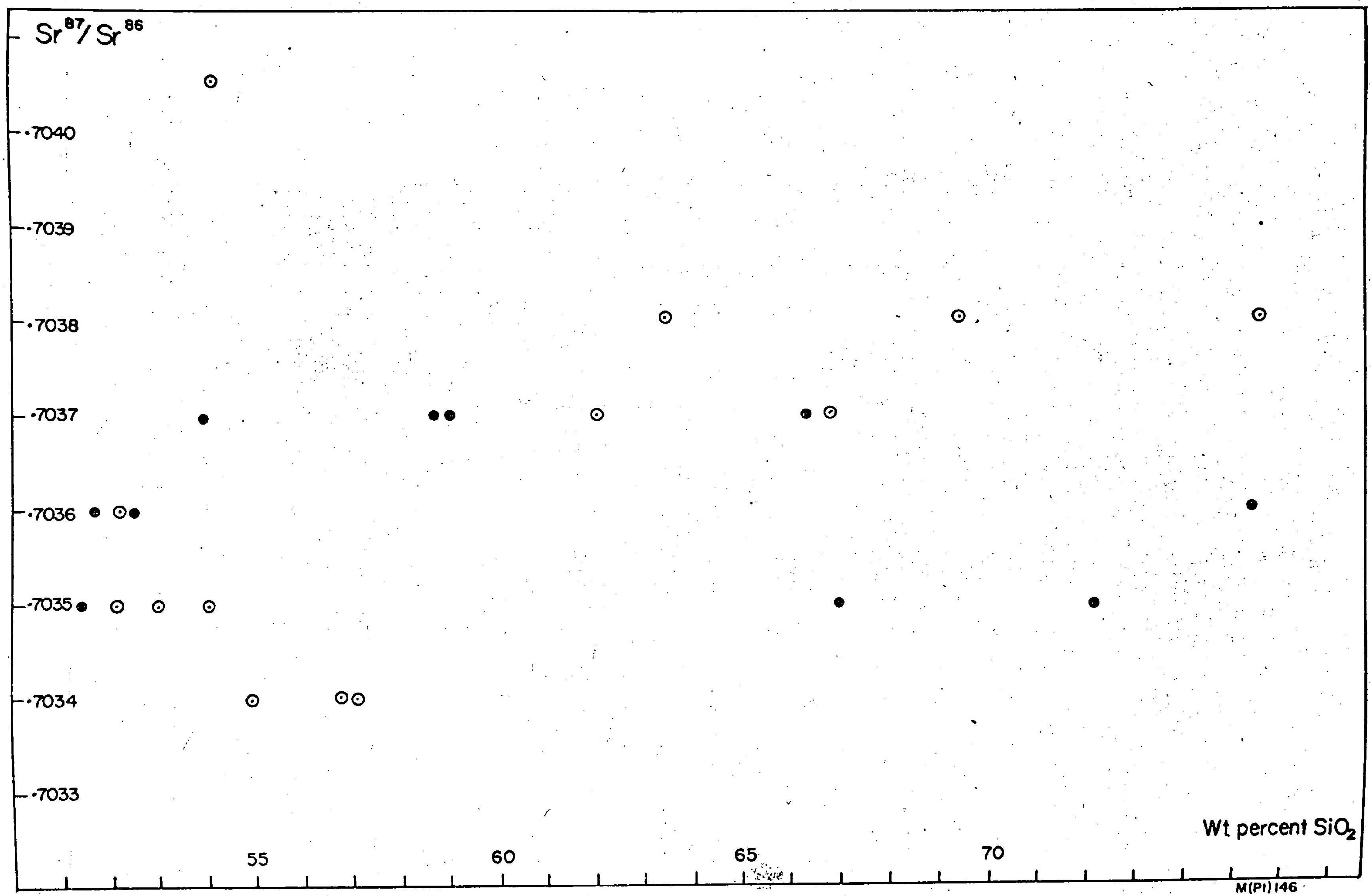


FIG. 3



Sr87/Sr86
·7040
·7039
·7038
·7037
·7036
·7035
·7034
·7033
55
60
65
70
Wt percent SiO2
M(Pl) 146

FIG. 4.

in figures 2 and 3. The mean value of 0.7036 for the thirteen samples of Table 1 is identical with the corrected mean value for the twelve Talasea samples (Peterman et al. adjusted their measured Sr^{87}/Sr^{86} to 0.7080 for the E and A standard).

With the exception of the value for the Karkar Island andesite, the Sr^{87}/Sr^{86} ratios of the Table 1 samples appear to correlate broadly with silica content. As shown in figure 4, rocks containing more than about 60 wt. percent silica have slightly higher isotopic ratios than do those containing less than 60 percent silica. This relationship, however, is not shown by the Talasea rocks analysed by Peterman et al. (10) and Lowder and Carmichael (16) (figure 4).

For the New Britain samples (figure 1), there appears to be no relationship between Sr^{87}/Sr^{86} ratios and depth to the underlying Benioff Zone.

ST. ANDREW STRAIT ISLANDS

The volcanoes of St. Andrew Strait form a restricted group of islands in the northern Bismarck Sea (figure 1). One of the volcanoes, Tuluman, erupted between 1953 and 1958 (17); it formed two new islands, and produced obsidians of alkali-rich dacitic compositions (18). Similar rocks are found on other islands in St. Andrew Strait. From arguments based on variations in major element chemistry, Johnson and Smith (18) have proposed that these rocks are the products of crustal melting. Twenty five km of crust are thought to be present beneath the Strait (J.B. Willcox, pers. comm.).

Two alkali-rich obsidians were selected for isotopic study. These were a dacite from Tuluman Island (69.41 wt. percent silica, 8.51 percent total alkalies) and a rhyolite from Pam Mandian Island (73.70 percent silica, 9.05 percent total alkalies). The alkali-rich character of these rocks is reflected by their high Rb/Sr ratios (Table 1). The Sr^{87}/Sr^{86} values of 0.7044 and 0.7043 (Table 1) are experimentally indistinguishable from each other. They show that the rocks are distinctly more radiogenically enriched than any of the analysed samples from the Bismarck Volcanic Arc.

ISLANDS NORTHEAST OF NEW IRELAND

Four groups of islands showing Quaternary volcanic rocks form a chain over 250 km long northeast of, and parallel to, New Ireland (figure 1). Some of the islands have thermal areas, but no eruptions have been reported (19). The volcanic chain shows comparatively little seismicity (20).

The rocks of these islands are unusual in that they are feldspathoid-bearing basic members of the shoshonite association (Johnson et al., in press). Ten samples selected for strontium isotope analysis were collected by the late G.A.M. Taylor from seven islands in the chain. They have 3-4% K_2O, show moderate rubidium contents, notably high contents of strontium, and Rb/Sr ratios similar to those of rocks from the Bismarck Volcanic Arc (figures 2 and 3).

The Sr^{87}/Sr^{86} ratios range between narrow limits (0.7040 to 0.7044). Their mean value of 0.7041 $\pm$ 0.0001 (standard deviation) is greater than the average for the Bismarck Volcanic Arc, but is only slightly less than the two values for the St. Andrew Strait obsidians.

BOUGAINVILLE ISLAND

Quaternary volcanic rocks cover much of Bougainville Island (21). They are the products of several volcanoes, one of which - Bagana - has erupted several times this century. Other volcanoes, such as Balbi, show thermal activity and are considered to be potentially active (19). Bougainville coincides with a zone of intense seismicity which defines an almost vertical seismic plane beneath the island (20). This seismic zone, and a submarine trench to the west, are continuations of the same features in the New Britain area (figure 1). South of Bougainville the trench is no longer clearly defined, but the belt of seismicity continues south-eastwards along the Solomon Islands chain, defining the active boundary between the Australian and Pacific plates.

The petrology of the Bougainville volcanoes was described by Blake and Miezitis (21) and Taylor et al. (22). Strontium isotope analyses of four of their samples from four separate volcanoes are given in Table 1, together with rubidum and strontium determinations.

The Sr^{87}/Sr^{86} ratios have a mean of 0.7039, and there is little variation between the four samples. Two "high-K andesites" (599 and 44) have higher Rb/Sr ratios than the remaining samples, but their Sr^{87}/Sr^{86} values - both 0.7039 - are indistinguishable from those of the other samples. The Bougainville rocks are slightly more radiogenically enriched than samples from the Bismarck Volcanic Arc, but are less so than the undersaturated rocks northeast of New Ireland. It is also noted that the mean Sr^{87}/Sr^{86} values given by Gill and Compston (12) for thirteen rocks from New Georgia (on the Solomon Islands chain, 300 km southeast of Bougainville) is 0.7037. When corrected for a value of 0.7081 for the E and A standard, this New Georgia average is almost identical with the mean of the four Bougainville samples.

EASTERN PAPUA

Results for three rocks from Victory and Trafalgar volcanoes and from Goodenough Island are given in Table 1. These eruptive centres are part of a Quaternary volcanic complex in eastern Papua that includes the active volcano of Mount Lamington (23). The volcanic rocks have shoshonitic and high-K calc-alkaline compositions (24-27). The geology of the region was described by Davies and Smith (28), who noted that the volcanoes, and other Cainozoic rocks, flank a core of Mesozoic sialic materials. Crustal thicknesses are of the order of 30 km (29).

Compared to the rocks dealt with in the previous sections, the three samples from eastern Papua - two andesites and a basalt - show higher and more variable Sr^{87}/Sr^{86} ratios (Table 1). The high ratios (maximum value of 0.7054) suggest that Quaternary volcanic rocks in eastern Papua may be more radiogenically enriched than those from other Quaternary volcanic areas in Papua New Guinea. New Zealand andesites analysed by Ewart and Stipp (9) also have relatively high Sr^{87}/Sr^{86} ratios (mean of 0.7056). This, together with other geochemical results, led Ewart and Stipp to suggest varying amounts of crustal hybridization of basaltic magma as one possible process of andesite genesis in New Zealand.

The strontium isotope ratios of the east Papuan rocks do not appear to be related to Rb/Sr ratios (figure 3). There is, however, an inverse correlation with strontium content (figure 2). The spread of the three Sr^{87}/Sr^{86} values contrasts with the striking uniformity of ratios for the Bismarck Volcanic Arc, for the islands northeast of New Ireland, and for Bougainville Island (figure 2). This suggests either a heterogeneous magma source for the east Papuan lavas, or differential crustal contamination (or both).

NEW GUINEA HIGHLANDS

About twenty major Quaternary stratovolcanoes form a widespread area of volcanic rocks in the central and southern Highlands of Papua New Guinea (figure 1). Most of the volcanoes are extinct and deeply eroded, but at least two of them show solfataric activity. The volcanic rocks rest on several thousand metres of Mesozoic and Tertiary sediments which are thought to be underlain by a late Palaeozoic or early Mesozoic sialic basement (30). Continental crustal thicknesses in the region are about 40 km (31). The geological setting of the Highlands volcanoes is therefore similar, in many respects, to that of the east Papuan volcanoes. The Pleistocene age generally assigned to the Highlands volcanoes has been confirmed in part by K-Ar dating of three of the samples used in this isotopic study. The age data so far available (reported in the Appendix) indicate that volcanism commenced in the Highlands at least 0.2 m.y. ago.

Preliminary petrological results reported by Jakeš and White (26) and Mackenzie and Chappell (32) show the rocks of the Highlands volcanoes - like those of eastern Papua - have shoshonitic and high-K calc-alkaline compositions. Basic rocks appear to be more common than intermediate ones, and acid rocks are extremely rare. Mackenzie and Chappell reported the presence of country rock inclusions ("coarse-grained intrusive rocks, amphibolite, gneiss, sandstone, shale and quartz") in some Highlands lavas, but none has been found in seven samples used in the present study.

The seven rocks are three andesites and a shoshonite from Mount Hagen, an andesite from Crater Mountain, and two shoshonites from Mounts Karimui and Suaru (figure 1, Table 1). All four Hagen rocks have the same Sr^{87}/Sr^{86} ratio of about 0.7045; the shoshonite has a much higher Rb/Sr value. The isotopic ratios of the samples from the other three centres range from 0.7037 to 0.7041, and — like the east Papuan rocks— appear to be inversely related to strontium content (figure 2).

The higher Sr^{87}/Sr^{86} values for the Mount Hagen rocks may be due to slight crustal contamination, but their striking uniformity suggests a homogeneous source region more radiogenically enriched than that for the other three volcanoes. Considering the data from all four Highland volcanoes, it is suggested that the spread of Sr^{87}/Sr^{86} ratios (0.7037 to 0.7045) reflects a slight but differential crustal imprint on the rocks.

SUMMARY AND DISCUSSION

(i) Rocks from the Bismarck Volcanic Arc show a narrow range of Sr^{87}/Sr^{86} values; the ratios average 0.7036 ± 0.0001, and they appear to increase slightly with increasing silica content.

(ii) Two alkali-rich acid rocks from St. Andrew Strait have ratios of 0.7043 and 0.7044.

(iii) Undersaturated rocks from the islands northeast of New Ireland show a narrow range of Sr^{87}/Sr^{86}; the ratios have a mean value of 0.7041 ± 0.0001.

(iv) Four rocks from Bougainville Island also show isotopic unity; their average is 0.7039.

(v) Sr^{87}/Sr^{86} values from three east Papuan rocks range between 0.7043 and 0.7054.

(vi) Variable isotopic values are also found among seven rocks from the Highlands volcanoes. Ratios of about 0.7045 are found for four Mount Hagen samples; the three other samples range between 0.7037 and 0.7041.

The results obtained for all 39 samples show a range of initial Sr^{87}/Sr^{86} ratios from 0.7034 to 0.7054. This is of the same order as that found in many other island arcs of the western Pacific region. A strontium isotope study of Tertiary volcanic and plutonic complexes in Papua New Guinea (33) also reveals similar initial Sr^{87}/Sr^{86} ratios (average of 0.704).

The broad correlation of Sr^{87}/Sr^{86} ratios with silica content in the Bismarck Volcanic Arc samples may be a subtle expression of the kind of contamination suggested from a similar positive correlation in some Antarctic dolerites (34). However, the range in Sr^{87}/Sr^{86} within the Bismarck Volcanic Arc is relatively small (4 in 7000), and until the correlation is more firmly established, little can be said regarding its genetic implications.

The Sr^{87}/Sr^{86} ratios of the Quaternary volcanic samples appear to be related to strontium content. This inter-regional relationship is shown in figure 2, where, with the exception of the two St. Andrew Strait rocks, there is a general increase in isotopic ratio with increasing strontium content. However, for the rocks within both the east Papuan and Highlands groups this relationship is reversed, and higher Sr^{87}/Sr^{86} ratios correlate with lower strontium values. Powell (35) suggested this inverse relationship could, in some circumstances, be taken as an indication of crustal contamination. This is probably because Sr^{87}/Sr^{86} ratios in rocks with lower Sr contents are more easily changed by contamination (4).

A striking feature of figure 2 is the way in which rocks from each of the six groups plot in separate fields. This intra-arc uniformity is especially distinct for the rocks of the Bismarck Volcanic Arc, the St. Andrew Strait islands, the islands northeast of New Ireland, and Bougainville Island. The rocks from each of three of these four areas (excluding the St. Andrew Strait islands from which only two rocks were analysed) show a much narrower range of Sr^{87}/Sr^{86} ratios when compared with those of the two mainland groups of eastern Papua and the Highlands. These uniform and relatively low ratios imply derivation from relatively homogeneous upper mantle sources, and relatively little (if any) crustal contamination. Although small, the differences in isotopic composition between the three groups are significant, and could reflect lateral or depth variations in upper mantle composition beneath this part of Papua New Guinea.

The two obsidian samples from St. Andrew Strait appear to be exceptional: they have the highest Sr^{87}/Sr^{86} ratios of areas 1 to 4 (above); they have by far the highest Rb/Sr ratios (figure 3); and they do not accord with the overall correlation of increasing isotope ratio and increasing strontium content (figure 2). These features are not inconsistent with the interpretation that the obsidians are products of crustal melts (18). However, additional isotopic data are required, particularly for basaltic rocks which are known to be present on some islands in the Strait. If the basalts are mantle-derived and the obsidians are crustal melts, marked differences in isotopic ratios can be expected.

The ranges of isotopic values for rocks of eastern Papua and the Highlands are much wider than those for the other four groups. In addition, the mainland samples have generally higher Sr^{87}/Sr^{86} ratios of up to 0.7054. These results suggest either heterogeneous magma sources, or differential contamination by sialic crust which is known to be present in both eastern Papua and the Highlands.

CONCLUSION

As emphasised earlier, this is a reconnaissance study. More isotopic data are required, particularly for rocks from the Highlands and east Papuan volcanoes (including the D'entrecasteaux Islands) which show isotopic variability. Results are also needed for rocks from unmapped volcanoes on and near Manus Island (figure 1) and from other islands in St. Andrew Strait. This work is in progress.

The present data suggest that the volcanoes of Papua New Guinea can be divided into two broad groups: (1) a less radiogenically enriched and isotopically more uniform group associated with island-arc structures north and east of the mainland; (2) a more enriched, but isotopically variable group on the mainland at, or near, the edge of the Australian continental mass. Except for the St. Andrew Strait acid volcanoes, magmas produced by the first group appear to have been derived from isotopically homogeneous regions in the upper mantle; they seem to be relatively uncontaminated. Magmas produced by the second group appear to have been affected by different degrees of contamination by sialic crust, or to have been derived from heterogeneous sources in the upper mantle.

APPENDIX

To obtain a better perspective of the age of the Highlands volcanic rocks, two samples from Mount Hagen (71-720, 71-721) and one from Mount Karimui (71-940) were dated by the K-Ar method. The techniques employed in the K-Ar dating are the same as described by McDougall (36) and Cooper (37). The physical constants used in the age calculations are: $\lambda_\beta = 4.72 \times 10^{-10} yr^{-1}$; $\lambda_e = 0.585 \times 10^{-10} yr^{-1}$; $K^{40}/K = 1.19 \times 10^{-2}$ atom percent.

The two andesites and shoshonite were dated as whole rock samples. The andesites are strongly porphyritic rocks containing fresh euhedral phenocrysts of plagioclase, clinopyroxene, hypersthene, and hornblende (converted to iron oxides around the rims). The shoshonite contains phenocrysts of fresh plagioclase and clinopyroxene, and minor partly pseudomorphed olivine. The groundmass of both rock types is a holocrystalline intergranular aggregate of plagioclase, pyroxene, and minor iron oxides; there is interstitial K-feldspar in the shoshonite. The K-Ar results are given in the accompanying Table.

The relative stratigraphic position of the two andesites from Mount Hagen is not known, but the sample sites are 18 km apart on the southeastern (71-720) and western (71-721) flanks of the mountain, approximately on the same contour level. The two ages, at around 210,000 years, agree to within the experimental uncertainties. The Mount Karimui shoshonite sample gave a similar age of 202,000 years. The general concordancy of the three ages may be fortuitous, or it may signify a widespread volcanic event in the Highlands. Until a more comprehensive geochronological study is undertaken, we stress that the present age data are preliminary and merely indicate that volcanism in the Highlands commenced at least 0.2 m.y. ago.

TABLE. K-Ar AGES OF QUATERNARY LAVAS FROM THE NEW GUINEA HIGHLANDS

Sample No.	K%	Ragiogenic Ar^{40} ($\times 10^{-12}$ mole/gm)	$\frac{100 \text{ Rad. } Ar^{40}}{\text{Total } Ar^{40}}$	Age (m.y.) $\pm$ 2 s.d.	Locality
71-720 Whole rock	1.140) 1.148) 1.144	0.444	9.2	0.218 $\pm$ 0.010	Mt. Hagen
71-721 Whole rock	1.606) 1.600) 1.603	0.581	8.2	0.204 $\pm$ 0.010	Mt. Hagen
71-940 Whole rock	2.465) 2.438) 2.452	0.881	14.4	0.202 $\pm$ 0.011	Mt. Karimui

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