STRONTIUM ISOTOPIC STUDIES OF THE ROSS ISLAND VOLCANICS, ANTARCTICA*

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Abstract: The isotopic composition of strontium has been determined for samples from DVDP #1 and #2 from Ross Island. It covers the range of olivine basalt, titanaugite-hornblende basalt, hornblende-titanaugite trachy-basalt and hornblende trachyte. The $^{87}Sr/^{86}Sr$ ratio for the M.I.T. Eimer and Amend reagent $SrCO_3$ standard determined in our laboratory is 0.7079 $\pm$0.0001.

The basaltic rocks appear to be comagmatic with similar low initial $^{87}Sr/^{86}Sr$ ratios around 0.7035. This ratio is comparable with ratios of the other alkaline rock series of oceanic islands. The trachytes have initial ratios significantly higher than the basaltic rocks. Compared to the basaltic rocks, the trachytes are enriched in K, Si, Al, Na and Rb and depleted in Ca, Fe, Mg, Ti and Sr. Contamination by submarine sediments and/or by crustal rocks could explain the initial $^{87}Sr/^{86}Sr$ ratio, but it does not account for the peculiarities in chemistry which characterize the trachytes.

The chemical characteristics of the trachytes and the initial $^{87}Sr/^{86}Sr$ ratio can be explained by deriving the trachytes from older igneous rocks due to partial melting of the latter's alkali feldspar-rich portion. However, this model raises problems regarding the nature of parental material.

1. Introduction

DVDP #1 was drilled on the south flank of the Twin Craters, an extinct volcano located near McMurdo Station on the Hut Point Peninsula of Ross Island. 196.54 m of core were recovered. DVDP #2 was drilled on the northwest flank of the Observation Hill very close to McMurdo Station. 171.38 m core were recoved. The Hut Point Peninsula on Ross Island is a 20 km long chain of volcanic cones extending south-southwest from Mt. Erebus to its relatively ice-free, southernmost part at McMurdo Station.

In the present work a number of fresh samples from the cores and from outcrops near McMurdo Station have been analyzed in the expectation that Sr isotopic data will provide new insight into the genesis of alkaline rocks on Antarctica.

2. Petrography

The rocks in the vicinity of McMurdo are mainly basalts or the nepheline-rich equivalents, trachybasalt or basanites. There is also trachyte at the Obser-

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vation Hill and palagonitic volcanic breccia at the Castle Rock. The rocks were classified according to their phenocryst assemblage and given the field names of basalt or trachyte. Subsequent bulk chemical analyses revealed that these rocks are highly undersaturated and contain more than 10 percent normative nepheline, hence they should be given more specific names such as basanites and mugearites. However, until more detailed chemical data become available, the classification as basalt will be retained. The main rock types are olivine-titanaugite basalt, hornblende basalt and hornblende trachyte.

3. Analytical Techniques

In the present study $^{87}Sr/^{86}Sr$ ratios were determined on 12 basaltic and trachytic samples selected from the cores and the Crater Hill and the Observation Hill. The samples were analyzed in a 30-cm, 90° mass spectrometer using a triple rhenium filament mode of ionization (KURASAWA, 1970). The raw $^{87}Sr/^{86}Sr$ ratios were normalized to correspond to $^{86}Sr/^{88}Sr$ of 0.1194. This mass spectrometer yields a mean $^{87}Sr/^{86}Sr$ of 0.7079 for the Eimer and Amend reagent $SrCO_3$. Sr and Rb concentrations were determined by atomic absorption.

4. Discussion of Data

The analytical result and sample locations are given in Table 1 and Fig. 1. The $^{87}Sr/^{86}Sr$ values and Sr, Rb and K concentrations for the twelve samples are shown in Table 2. In Fig. 2, the Rb and Sr concentrations are plotted, together with results from rocks collected from other provinces. The volcanic rocks of Ross Island have higher Rb contents than the Hawaiian alkaline basalts. Figure 3, taken from PETERMAN and HEDGE (1971), shows that in a general way the $^{87}Sr/^{86}Sr$ ratios of oceanic basalts, including sea-floor types, correlate positively with their relative potassium contents defined by (K_2O/Na_2O+K_2O). This trend probably comes about because a region of the upper mantle that is relatively rich in potassium will also be relatively rich in rubidium and therefore in time will develop and produce rocks with higher $^{87}Sr/^{86}Sr$ ratios.

Figure 3 is a $^{87}Sr/^{86}Sr$ ratio versus the (K_2O/Na_2O+K_2O) diagram for the volcanic rocks of the Deccan Traps, for the volcanic rocks of the oceanic ridge basalts, and for the Ross Island volcanics. It is seen from the diagram that rocks of these three groups plot in separate fields, although overlapping is present. The Ross Island volcanics cover the fields of the oceanic islands, whereas the fields of the Deccan Traps, except for the picritic basalts (PB), lie well within the fields of the continental region. It should be noted in Fig. 3 that the Ross Island volcanics lie exactly at the same position as rocks from the oceanic islands.

Oceanic basaltic rocks in general cannot have been significantly contaminated with older sialic material, which is present only in a few isolated places in the ocean basins. Therefore, the initial $^{87}Sr/^{86}Sr$ ratios of oceanic basalts provide the most reliable indicators of the isotopic composition of strontium in the upper mantle. In addition, their ratios are used as a reference level to which those of

Table 1. Strontium isotopic compositions and Sr and Rb concentrations in volcanic rocks from Ross Island.

		ppm			Ratio		$(^{87}Sr/^{86}Sr)_n$	(2 σ)	SI
		Sr	Rb	K	Rb/Sr	K/Rb			
1	Boa	1075	73.4	15000	0.068	204	0.70337	0.00021	25.8
2	T	1041	158.7	40700	0.152	258	0.70421	0.00018	6.9
3	Bah	1456	69.3	20100	0.048	290	0.70350	0.00024	21.7
4	Boah	1014	104.4	16200	0.103	155	0.70338	0.00020	14.2
5	TAh	1020	148.7	31700	0.146	213	0.70403	0.00027	10.0
6	PBao	681	31.8	5400	0.047	170	0.70336	0.00036	41.3
7	Bao	917	52.2	13700	0.057	262	0.70344	0.00031	39.2
8	Bah	1038	77.0	17500	0.074	227	0.70338	0.00028	22.0
9	TBha	1783	133.0	28500	0.075	214	0.70342	0.00026	19.0
10	Boa*	851	52.9	8380	0.062	158	0.70364	0.00022	43.0
11	Boa*	816	57.5	12000	0.070	209	0.70382	0.00020	36.4
12	Boa*	760	51.8	11600	0.068	224	0.70385	0.00023	37.7

* Ankaramitic
SI: Solidification index ($MgO \times 100/MgO+FeO+Fe_2O_3+Na_2O+K_2O$)
Eimer and Amend reagent $SrCO_3$ standard: $(^{87}Sr/^{86}Sr)_n = 0.7079 \pm 0.0001$
Normalized to correspond to $^{86}Sr/^{88}Sr$ of 0.1194.

1. Olivine-augite basalt. Crater Hill, McMurdo Station.
2. Trachyte. Observation Hill, McMurdo Station.
3. Titanaugite-hornblende basalt (andesitic). DVDP #1, 58.93 m (depth).
4. Olivine-titanaugite-hornblende basalt. DVDP #1, 91.23 m.
5. Hornblende trachyandesite. DVDP #1, 133.65m.
6. Titanaugite-olivine picritic basalt. DVDP #1, 147.89m.
7. Titanaugite-olivine basalt. DVDP #1, 189.66m.
8. Titanaugite-hornblende basalt. DVDP #2, 70.41m.
9. Hornblende-titanaugite trachybasalt. DVDP #2, 85.45m.
10. Olivine-titanaugite basalt (trachy-), ankaramitic. DVDP #2, 86.78m.
11. Olivine-titanaugite basalt (trachy-), ankaramitic. DVDP #2, 112.72m.
12. Olivine-titanaugite basalt (trachy-), ankaramitic. DVDP #2, 130.23m.

other rocks, suspected of having an origin wholly or in part in the sialic crust, can be compared. The fact that the initial $^{87}Sr/^{86}Sr$ ratios of the Ross Island volcanics are all within the field of the oceanic island initial ratios implies that these rocks have not been significantly contaminated by sialic crustal material. Considering that Ross Island is on the margin of a continent, it is noteworthy that the Ross Island volcanics are so similar to oceanic island basalts in Rb-Sr systematics.

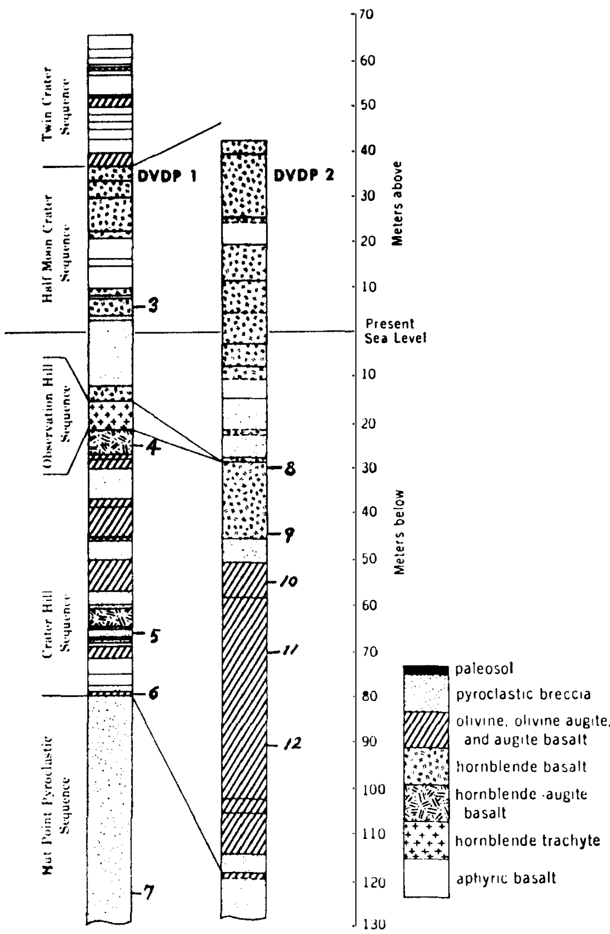

Fig. 1. Compiled geologic logs of DVDP drill holes 1 and 2 (after TREVES and KYLE, 1973). Nos. of analyzed samples refer to Tables 1–3.

In Fig. 4, the Hawaiian basaltic rocks as oceanic islands show a rather narrow normal distribution, with a range of initial $^{87}Sr/^{86}Sr$ ratios of 0.7030 to 0.7043. The only oceanic island basalts represented in Fig. 4 are from the Hawiian Islands, but in spite of this, the very small range observed indicates that 0.7035 is probably a representative average for all oceanic basaltic rocks that have been analyzed to date. It is obvious that the selection of oceanic rocks in the past has been almost completely dominated by those exposed on islands. Such volcanic rocks may be less representative of the upper mantle than the volumetrically-more-important abyssal or sea-floor basalts that are being dredged from the ocean floor. In fact, the very existence of a large volcanic pile may indicate that the mantle beneath it is abnormally rich in heat-producing element and in their daughter products, including radiogenic lead and strontium isotopes.

Table 2. Age correction of strontium isotopic ratios of the volcanic rocks from Ross Island.

		$(^{87}Sr/^{86}Sr)_n$	$(^{37}Rb/^{86}Sr)$	$(^{87}Sr/^{86}Sr)_I$
1	Boa	0.70337	0.1969	0.70336
2	T	0.70421	0.4400	0.70419
3	Bah	0.70350	0.1390	0.70349
4	Boah	0.70338	0.2982	0.70336
5	TAh	0.70403	0.4227	0.70401
6	PBao	0.70336	0.1361	0.70335
7	Bao	0.70344	0.1650	0.70343
8	Bah	0.70338	0.2142	0.70337
9	TBha	0.70342	0.2171	0.70341
10	Boa*	0.70364	0.1795	0.70363
11	Boa*	0.70382	0.2027	0.70381
12	Boa*	0.70385	0.1969	0.70384

* Ankaramitic

Age of Ross Island volcanics assumed to be about 4 m.y. ($\lambda = 1.39 \times 10^{-11}$y).

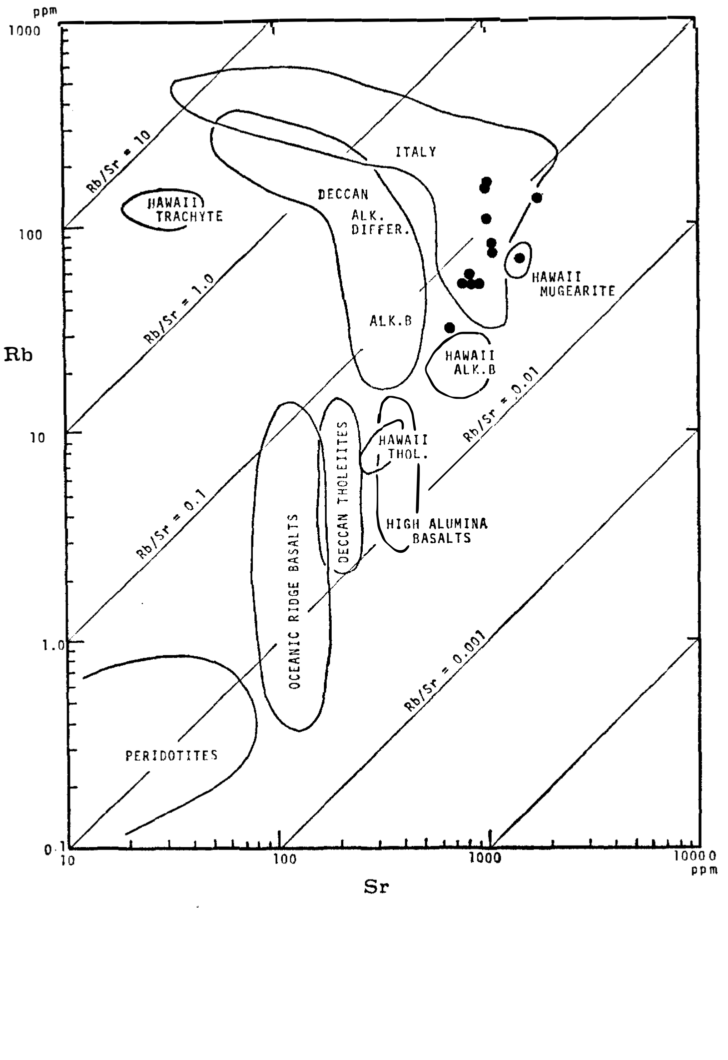

Fig. 2. Log-log plot of Rb and Sr concentrations for Ross Island volcanics (solid circles) compared with that of the other rock provinces in the world.

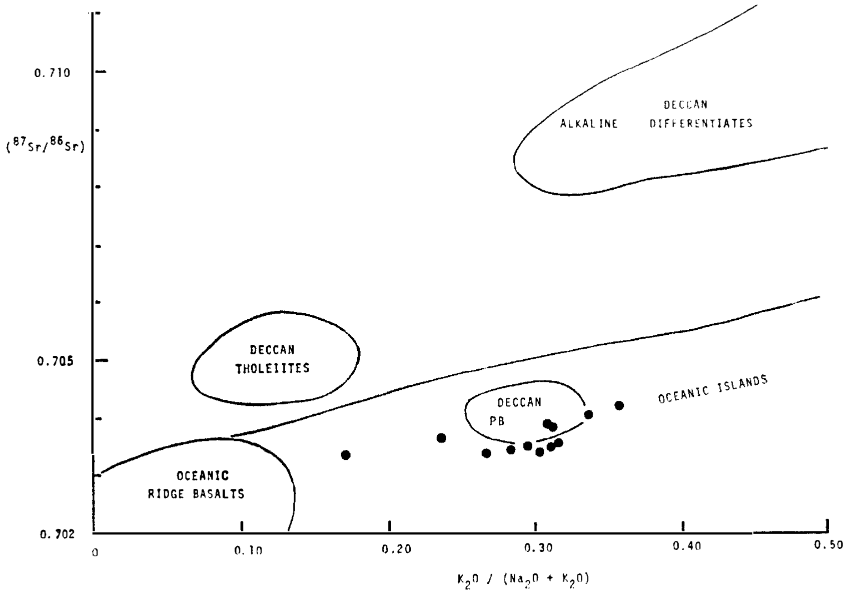

Fig. 3. *$^{87}Sr/^{86}Sr$ plotted against $K_2O/(Na_2O+K_2O)$ for Ross Island volcanics.*

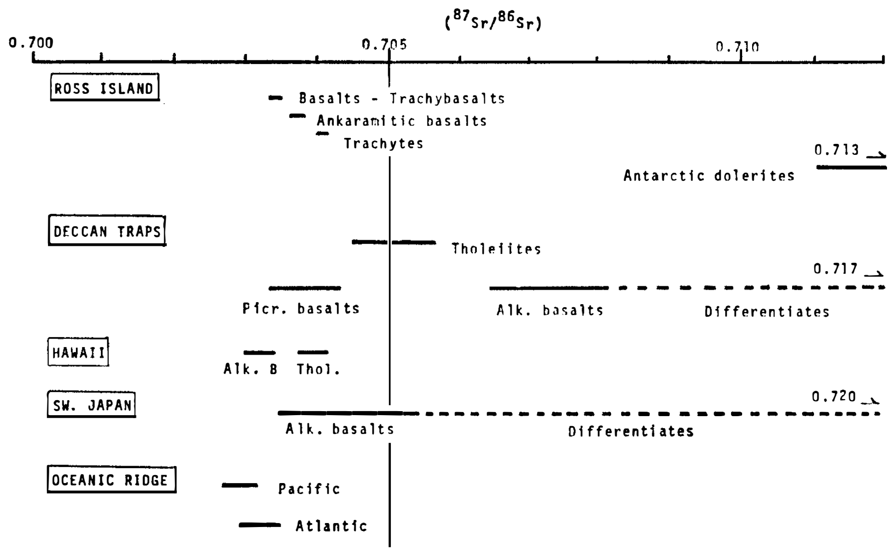

Fig. 4. *Variation of $^{87}Sr/^{86}Sr$ in different regions as typical rock provinces in the world.*

Initial ratios of oceanic ridge basalts (Fig. 4) may more closely approach the initial ratios of the underlying mantle material. These basalts have lower initial ratios than oceanic island basalts and are in the range 0.7025 to 0.7035. The average present-day $^{87}Sr/^{86}Sr$ ratio of the suboceanic upper mantle is certainly no greater than 0.7035, and probably falls in the range of 0.7020 to 0.7030.

Basaltic rocks from Ross Island show a rather narrow range of initial $^{87}Sr/^{86}Sr$ ratio (Table 2). When, however, intermediate and silicic rocks are included, significant isotopic variations are found among the rocks from Ross Island. The trachytes have significantly higher ratios of 0.7040 to 0.7042 than those of the basaltic rocks of 0.70335 to 0.70384. The basaltic rocks appear to be comagmatic with similar low initial $^{87}Sr/^{86}Sr$ ratios around 0.7035. This ratio is comparable with ratios of the other alkaline rocks from oceanic islands. Even though the Ross Island volcanics are similar to oceanic island basalts and do not show a significant component of sialic crustal material, some contamination of such material may be indicated by the variation of initial $^{87}Sr/^{86}Sr$ ratio between Ross Island basalt and Ross Island trachyte (KURASAWA, 1974).

If zone-refining as described by HARRIS (1957) could operate on lower crustal rocks that contained radiogenic strontium, it might explain the initial $^{87}Sr/^{86}Sr$ ratios of the rocks as well as some other aspects of their geochemistry. The zone-refining hypothesis has been modified and extended by GREEN and RINGWOOD (1967) to include reactions that selectively remove incompatible elements such as K, Ti, Ba, Rb, Zr and Sr from a wall-rock into a magma that is cooling against it.

Contamination by submarine sediments and/or by sialic crustal rocks could explain the high initial $^{87}Sr/^{86}Sr$ ratio, but it does not account for the peculiarities in chemistry such as high Rb and Sr which characterize the trachytes. This model also raises problems regarding the nature of parental material. Strontium isotope and some minor elements of the Ross Island volcanics which occur on the margin of the continent are very similar to those of oceanic islands.

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