Strontium isotope data from megacrysts and xenoliths in quarternary basalts in the Engle Basin (southern Rio Grande Rift), New Mexico

B. Singer, D.G. Brookins, J.C. Kelly, and A.M. Kudo

Isochron/West, Bulletin of Isotopic Geochronology, v. 43, pp. 13-15

This page is intentionally left blank to maintain order of facing pages.

STRONTIUM ISOTOPE DATA FROM MEGACRYSTS AND XENOLITHS IN QUATERNARY BASALTS IN THE ENGLE BASIN (SOUTHERN RIO GRANDE RIFT), NEW MEXICO

BRAD SINGER
DOUGLAS G. BROOKINS
JOHN C. KELLY
ALBERT M. KUDO

Department of Geology, University of New Mexico, Albuquerque, NM 87131

INTRODUCTION

Structurally controlled Quaternary alkali-olivine basalt vents occur localized along north-trending faults and/or fracture zones along the eastern margin of the Engle basin of the southern Rio Grande rift (Kelley, 1955). The vents are composite cinder cones characterized by pyroclastic and lava flows, cone sheets, radial dikes, and often poorly indurated vent-breccias. These breccias often contain single-crystal and lithic inclusions in basaltic clasts (Kelly and others, 1985). This study addresses the Sr isotopy of clinopyroxene and anorthoclase megacrysts, lithic inclusions of charnockitic granulite and spinel lherzolite, and the host alkali-olivine basalt from one of these vent-breccias (lat. 33°13′53″N, long. 107°06′17″W), Sierra County, New Mexico.

ANALYTICAL PROCEDURE

Rb and Sr contents were determined by isotope dilution. Macroscopically fresh samples were crushed in tungsten vials (Spex mixer), removed and crushed to -100 mesh in an agate mortar. After spiking and digestion in a hydrofluoric-perchloric acid solution, filtered aliquots were separated by standard cation-exchange chromatography for Rb and Sr mass spectrometry (method of Hart and Brooks, 1977, as reported by Murphy, 1985). Due to low Sr content and possible interference from other elements such as Ca, samples EB-PER and SL-CPX were run through the exchange columns twice to insure adequate separation and recovery of Sr.

Rb and Sr contents were obtained using a Nier-type 90-degree, 6-inch, thermal ionization mass spectrometer; these data are precise to ±1.0 percent (2σ). $^{87}Sr/^{86}Sr$ ratios were determined from the isotope dilution experiments via on-line data reduction. Internal precision of $^{87}Sr/^{86}Sr$ ratios ranges from ±0.0002 to ±0.0006 (1σ). All Sr isotopic data are normalized to $^{86}Sr/^{88}Sr$ = 0.1194. Three measurements of Eimer and Amend standard $SrCO_3$ obtained during this study yield qualitative constraints on the accuracy of the $^{87}Sr/^{86}Sr$ data.

DISCUSSION

XENOCRYST-HOST BASALT RELATIONSHIPS

Comagmatic phases in a particular igneous rock should retain identical $^{87}Sr/^{86}Sr$ ratios as crystal-liquid partitioning of Sr (and other trace elements) is not a mass-dependent process (Dasch, 1969). Allowing for analytical uncertainty, $^{87}Sr/^{86}Sr$ ratios for the clinopyroxene (.70420) and anorthoclase (.70341) megacrysts overlap the $^{87}Sr/^{86}Sr$ ratio determined for the host basalt (.70374 ± .0005). The Sr isotope data allows for the conclusion that the clinopyroxene and anorthoclase megacrysts are probably of cognate origin with respect to the host basalt.

If the concentrations of Rb and Sr measured in the host basalt are representative of the liquid from which the megacrysts precipitated, then crystal-liquid partition coefficients can be calculated for clinopyroxene/liquid and anorthoclase/liquid from Rb and Sr data in table 1. These "observed" Rb and Sr partition coefficients are compared to known experimental partition coefficients as shown in table 2. Although the agreement between observed and experimental data is not exact, the comparison is favorable in terms of a cognate origin for the megacrysts. The slight discrepancies may hinge on: 1) the fact that the host basalt may have been modified slightly by fractional crystallization of the megacrysts, and 2) pressure dependence of trace-element partition coefficients (Roe, 1964; Mysen, 1981a, 1981b).

SIGNIFICANCE OF Sr ISOTOPIC SIGNATURES OF LHERZOLITE AND GRANULITE XENOLITHS

Elevated $^{87}Sr/^{86}Sr$ ratios of the lithic inclusions precludes their origin as cognate with respect to the host basalt. The unusually high $^{87}Sr/^{86}Sr$ ratios determined from the lherzolite xenolith have two reasonably likely origins (Roe, 1964; Brooks and others, 1976): 1) ancient enrichment of a "primitive" mantle in Rb (and other LIL elements) and subsequent time-integrated production of radiogenic ^{87}Sr, or 2) near-surface contamination by alteration or weathering products with elevated $^{87}Sr/^{86}Sr$ ratios. The authors are in favor of case 1, since the lherzolite is petrographically extremely fresh (minor iddingsite occurs localized along olivine grain boundaries). EDS analysis performed on a Hitachi 450 scanning electron microscope revealed no potassium or other possible alteration-induced anomalies in a polished section of the lherzolite. It is therefore unlikely that the elevated $^{87}Sr/^{86}Sr$ ratio of the lherzolite is due to secondary alteration or weathering.

Similarly unusual $^{87}Sr/^{86}Sr$ ratios have been reported for red spinel lherzolite xenoliths from Bandera Crater, New Mexico (Laughlin and others, 1971). Origin of the Bandera xenoliths as a residuum related to production of the host basalts was ruled out, as the extracted basalt from such a partial melting episode should obtain a much higher $^{87}Sr/^{86}Sr$ ratio than any related residual material due to the high Rb (and radiogenic ^{87}Sr) content of early melting phases during anatexis (Roe, 1964). Similar argument refutes a host basalt-residuum relationship for the lherzolite of this study. Lack of hydrous phases such as amphibole, phlogopite, and apatite argues against mantle-metasomatism as responsible for the high $^{87}Sr/^{86}Sr$ ratio of the lherzolite. The xenomorphic-equigranular texture of the lherzolite indicates high temperature-high pressure recrystallization due to extensive flowage, possible post- or syngenetically related to the partial melting event (Mercier and Nicolas, 1975). The lherzolite could be interpreted as a derivative of an ancient mantle melting or remobilization event, causing enrichment in Rb and time-integrated enrichment in ^{87}Sr prior to incorporation in the host basaltic magma (Roe, 1964; Brooks and others, 1976). Based on data in table 1, a model age of this partial melting event is 1.0 b.y., assuming an initial $^{87}Sr/^{86}Sr$ ratio of 0.702. Of course, this can only be considered a crude estimate due to the uncertainty in choice of an initial $^{87}Sr/^{86}Sr$ ratio.

The significantly elevated $^{87}Sr/^{86}Sr$ signatures of the two granulite xenoliths indicates a crustal origin (Faure, 1977), as does the charnockite mineralogy (table 1). The granulite inclusions are interpreted as lower crustal material stripped from conduit walls during ascent of the host basaltic magma.

Model dates for the two granulite inclusions were calculated assuming an initial $^{87}Sr/^{86}Sr$ ratio of 0.7050 and yield consistent ages of 2.1 b.y. This date is speculative, and it is not known whether this model date records primary crystallization or metamorphic reequilibration. However, such an age would be the oldest thus far reported in New Mexico's Precambrian basement (Condie and Budding, 1979). Indeed, the presence of a lower Proterozoic basement at this latitude in the western United States would be quite a new discovery; however, additional Sr isotope data from granulite xenoliths from these vents is necessary to substantiate the presence of a 2.1-b.y.-old basement in this area.

ACKNOWLEDGMENTS

Dave Ward's help and suggestions in the laboratory were invaluable; Dave also reviewed an early draft of this paper.

TABLE 1. Summary of Rb and Sr isotope dilution data.

Sample	Description	Rb (ppm)	Sr (ppm)	$^{87}Sr/^{86}Sr$	$^{87}Rb/^{86}Sr$	Model age[1] (b.y.)
SL-1[2]	Alkali-olivine basalt, weakly olivine-phyric, host to single-crystal and lithic inclusions	19.1	689.5	0.70374 ± 0.0005		
SL-AN[2]	Coarse-grained, euhedral anorthoclase crystal, homogeneous unzoned composition	2.89	3303.1	0.70341 ± 0.0003		
SL-CPX[2]	Coarse-grained, anhedral vitreous augite crystal	0.93	64.3	0.70420 ± 0.0002		
EB-PER[3]	Lherzolite inclusion, medium-grained, xenomorphic-granular; olivine (70%), orthopyroxene (20%), diopside (10%), red spinel (1-2%)	0.49	2.85 2.84	0.70970 ± 0.0006 0.70853 ± 0.0004	0.49781	1.0
SL-GRAN 1	Charnockite granulite inclusion, medium- to coarse-grained, hypidiomorphic-granular, weakly foliated; quartz (60%), plagioclase (25%), K-feldspar (10%), orthopyroxene (3%), opaques (2%)	45.1	209.9	0.72412 ± 0.0003	0.62303	2.1
SL-GRAN 2	Same as SL-GRAN 1 only slightly more felsic and nonfoliated	102.5	275.0	0.73885 ± 0.0004	1.08232	2.1
E & A standard[4]						
1				0.70804 ± 0.0003		
2				0.70811 ± 0.0002		
3				0.70810 ± 0.0003		

[1] $^{87}Rb/^{86}Sr$ ratios and model ages calculated according to Faure (1977) assuming a $^{87}Sr/^{86}Sr$ initial ratio of 0.705 for the granulites and 0.702 for the lherzolite (mean $^{87}Sr/^{86}Sr$ ratio for lherzolite model age = 0.70912).
[2] No model age calculated.
[3] Replicate Sr isotopic analyses performed on this sample yield slightly different results; the mean $^{87}Sr/^{86}Sr$ ratio from the two experiments is 0.70912 ± 0.0006.
[4] The accepted value of $^{87}Sr/^{86}Sr$ for Eimer and Amend $SrCO_3$ is 0.70804.

TABLE 2. Megacryst/host basalt abundance ratios vs. experimental partition coefficients for Rb and Sr.

Element	Clinopyroxene		Anorthoclase	
	observed[1]	experimental[2]	observed[1]	experimental[2]
Rb	0.049	0.001-0.069	0.152	0.400-0.800
Sr	0.170	0.050-0.150	4.79	3.20 -7.10

[1]Calculated from data in table 1.
[2]Compilation by Bornhorst, 1980.

REFERENCES

Bornhorst, T. J. (1980) Major- and trace-element geochemistry and mineralogy of upper Eocene to Quaternary volcanic rocks of the Moggollon-Datil volcanic field, southwestern New Mexico; unpublished Ph.D. dissertation, University of New Mexico, Albuquerque, New Mexico, 1108 p.

Brooks, D., James, D. E., and Hart, S. R. (1976) Ancient lithosphere: its role in young continental volcanism: Science v. 193, p. 1086–1094.

Condie, K. G., and Budding, A. J. (1979) Geology and geochemistry of Pre-cambrian rocks of central and south-central New Mexico: New Mexico Bureau of Mines and Mineral Resources Memoir 35, 58 p.

Dasch, E. J. (1969) Strontium isotope disequilibrium in a porphyritic alkali basalt and its bearing on magmatic processes: Journal of Geophysical Research: v. 74, p. 560–565.

Faure, G. (1977) Principles of isotope geology: New York, John Wiley & Sons, 464 p.

Kelley, V. C. (1955) Geologic map of the Sierra County region, New Mexico, *in* New Mexico Geological Society 5th field conference guidebook, 209 p.

Kelly, J. C., Singer, B. S., and Kudo, A. M. (1985) Petrology and geochemistry of inclusions in alkali-olivine basalts, Elephant Butte area, New Mexico [abstract]: presented at the 1985 annual meeting of the New Mexico Geological Society.

Laughlin, A. W., Brookins, D. G., Kudo, A. M., and Causey, J. D. (1971) Chemical and strontium isotopic investigations of ultramafic inclusions and basalt, Bandera Crater, New Mexico: Geochimica et Cosmochimica Acta, v. 35, p. 107–113.

Mercier, J-C. C., and Nicholas, A. (1975) Textures and fabrics of upper-mantle peridotites as illustrated by xenoliths from basalts: Journal of Petrology, v. 16, p. 454–487.

Murphy, M. T. (1985) Strontium isotope and trace element geochemistry of the Platoro caldera complex, San Juan Mountains, Colorado: unpublished M.S. thesis, University of New Mexico, Albuquerque, New Mexico, 118 p.

Mysen, B. O. (1981a) Rare earth element partitioning between minerals and (CO_2 + H_2O) vapor as a function of pressure, temperature, and vapor composition: Carnegie Institution of Washington Year Book 80, p. 347–349.

________ (1981b) Trace-element partitioning between garnet peridotite minerals and water-rich vapor—experimental data from 5 to 30 Kbars: American Mineralogist, v. 64, p. 274–287.

Roe, G. O. (1964) Rubidium-strontium analyses of ultramafic rocks and the origin of peridotites, *in* Variations in isotopic abundances of strontium, calcium, and argon and related topics: M.I.T. 12th annual progress report to the U.S. Atomic Energy Commission, 263 p.