Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 63 (1970)

Heft: 1: Geochronology of phanerozoic orogenic belts : papers presented at the "Colloquium on the Geochronology of Phanerozoic Orogenic Belts"

Artikel: Isotopic composition of lead in basic and ultrabasic rocks from the Alps

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DOI: https://doi.org/10.5169/seals-163822

Eclogae geol. Helv.	Vol. 63/1	Pages 105–109	With 2 figures in the text and 3 tables	Basle, April 1970

Isotopic Composition of Lead in Basic and Ultrabasic Rocks From the Alps

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ABSTRACT

From a number of basic and ultrabasic rocks from the Swiss and Italian Alps lead has been extracted by the pyrochemical method described by MASUDA (1964). The extracted lead was mass spectrometrically analysed and the isotopic compositions were corrected to approximately absolute values using correction factors calculated for the CIT lead standard (CATANZARO, 1967). Values for $[^{238}U/^{204}Pb]_{today}$ (= μ) and $[^{232}Th/^{238}U]_{today}$ (= $\varkappa$) were computed from the isotopic compositions. Most of the rock leads yielded μ-values that are much lower than those calculated for ordinary galena leads. The low μ-values might indicate that these rocks originate in the upper mantle or in the transition zone between mantle and crust, and are in good agreement with a model for lead isotope evolution calculated by ARMSTRONG (1968). Although the lead isotope data differ quite strongly in composition, most of the rock leads lie close to a common growth curve with a μ-value of about 8.7 (for the HOUTERMANS' model). Special geological circumstances may represent a reason for the strange fact that upper mantle rocks have reached the earth's surface in this region: most of the rocks outcrop close to the Insubric Line which is a zone of intensive vertical movements during the Alpine orogeny.

Introduction

Within the last ten years the study of ultrabasic rocks and the problems in connection with their genesis has become more and more important. The Ivrea Zone, a region between Italy and Switzerland, consisting to a big part of basic and ultrabasic rocks, has been studied by numerous investigators. Early geophysical investigations (NIGGLI, 1946) yielded results that were difficult to explain. During a symposium on the Ivrea Zone in 1968, several contributors indicated the possibility that part of the Ivrea rocks represent upper mantle material (cf. Schweiz. Min. Petr. Mitt. vol. 48/1, 1968). Similarly, a lense of garnet-peridotite and kyanite-eclogite in the Pennide gneiss area at Alpe Arami (near Bellinzona, Ticino) was explained by geochemical studies as a slice of upper mantle material (O'HARA and MERCY, 1966). In a recent paper, the present author has reported isotope compositions of trace lead in basic and ultrabasic rocks from the above-mentioned regions which also indicated the upper mantle origin of these rocks (GRAESER, 1969).

Samples

SG 937 garnet-peridotite, Alpe Arami, consisting of olivine, enstatite, diopside and garnet.

SG 937a kyanite-eclogite, Alpe Arami.

KAW 81 phlogopite-peridotite from Finero/Italy (Ivrea Zone).

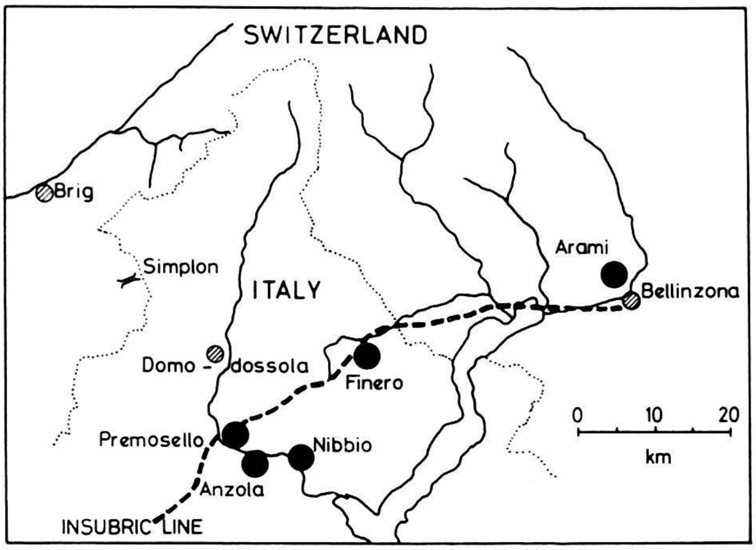

Fig. 1. Sketch-map of the region between Italy and Switzerland showing location of samples.

KAW 446 meta-gabbro from Anzola/Italy (Ivrea Zone).
KAW 488 amphibolite from Nibbio/Italy (Ivrea Zone).
KAW 487 gabbro-norite from Premosello/Italy (Ivrea Zone).

Procedure

(a) Extraction of lead

The lead was extracted by the slightly modified pyrochemical method described by MASUDA (1964). The rock samples were pulverized in a steel mortar and were mixed with 5% specpure carbon powder. 10 to 20 g of the rock powder were placed into an evacuated quartz tube and were heated for 1 hour at 1050 °C. The volatilized lead was collected on a quartz cool finger and then washed off with hot 2% HNO_3 and purified by dithizone extraction in presence of KCN.

(b) Mass spectrometry

The purified lead was precipitated with H_2S and loaded on to a Re filament. All samples were measured on an Atlas CH_4 mass spectrometer using an electron multiplier. The precision of the measurements was controlled by replicate analyses of the CIT lead standard.

Table 1. Comparison of CIT lead standard data.

$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	References
16.657	15.569	36.717	GRAESER, 1969 (Re-filament)
16.625	15.475	36.300	CATANZARO, 1967
16.605	15.465	36.276	this paper (Ta-filament)

In Table 1, the determined isotope ratios for this standard are given as obtained by sulphide measurements on Re filaments (mean of 6 determinations). Compared to the absolute isotopic abundance ratios for the CIT standard (CATANZARO, 1967), our values are slightly too high. On the other hand, CATANZARO's ratios are almost identical with the values determined by us using Ta filaments.

Results

Table 2 gives the isotopic abundance ratios of the rock leads. All the data are corrected to the absolute values for the CIT lead standard as reported by CATANZARO.

Table 2. Isotopic composition of lead in basic and ultrabasic rocks. Data corrected to approximately absolute values using correction factors calculated for CIT lead standard.

Samples	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Garnet-peridotite, Arami	18.519	15.322	37.583
Kyanite-eclogite, Arami	17.831	15.262	36.960
Peridotite, Finero	18.046	15.314	37.349
Meta-gabbro, Anzola	18.074	15.304	37.193
Amphibolite, Nibbio	18.057	15.311	37.178
Norite, Premosello	18.579	15.455	37.996

From the isotopic compositions of the rock leads, the following values for μ and $\varkappa$ have been calculated:

Table 3. Values for μ and $\varkappa$ calculated for different constants.

Samples		μ	$\varkappa$	μ	$\varkappa$	μ	$\varkappa$
Garnet-peridotite, Arami		8.73	3.62	8.15	3.23	8.50	3.66
Kyanite-eclogite, Arami		8.67	3.70	8.09	3.28	8.44	3.75
Peridotite, Finero		8.76	3.77	8.16	3.36	8.52	3.82
Meta-gabbro, Anzola		8.73	3.68	8.15	3.27	8.49	3.73
Amphibolite, Nibbio		8.75	3.69	8.16	3.28	8.51	3.73
Norite, Premosello		8.97	3.79	8.39	3.41	8.74	3.84
"Primeval Lead"	$[^{206}Pb/^{204}Pb]_0$	9.41		9.56		9.346	
	$[^{207}Pb/^{204}Pb]_0$	10.27		10.42		10.218	
	$[^{208}Pb/^{204}Pb]_0$	29.16		30.10		28.963	
λ_1		$0.1540 \times 10^{-9} y^{-1}$		$0.1537 \times 10^{-9} y^{-1}$		$0.1537 \times 10^{-9} y^{-1}$	
λ_2		$0.980 \times 10^{-9} y^{-1}$		$0.9722 \times 10^{-9} y^{-1}$		$0.9722 \times 10^{-9} y^{-1}$	
λ_3		$0.0499 \times 10^{-9} y^{-1}$		$0.0499 \times 10^{-9} y^{-1}$		$0.0499 \times 10^{-9} y^{-1}$	
$^{238}U/^{235}U$		139.0		137.8		137.8	
T_0		$4.486 \times 10^9 y$		$4.55 \times 10^9 y$		$4.55 \times 10^9 y$	
		HOUTERMANS (1947)		STACEY et al. (1968)		STACEY et al. (1969)	

All the μ-values of the rock leads show one very characteristic feature: they are much lower than those reported for ordinary galena leads; galenas from adjacent regions have μ-values of $\geqq 9.3$ for HOUTERMANS' constants (GRAESER, 1968).

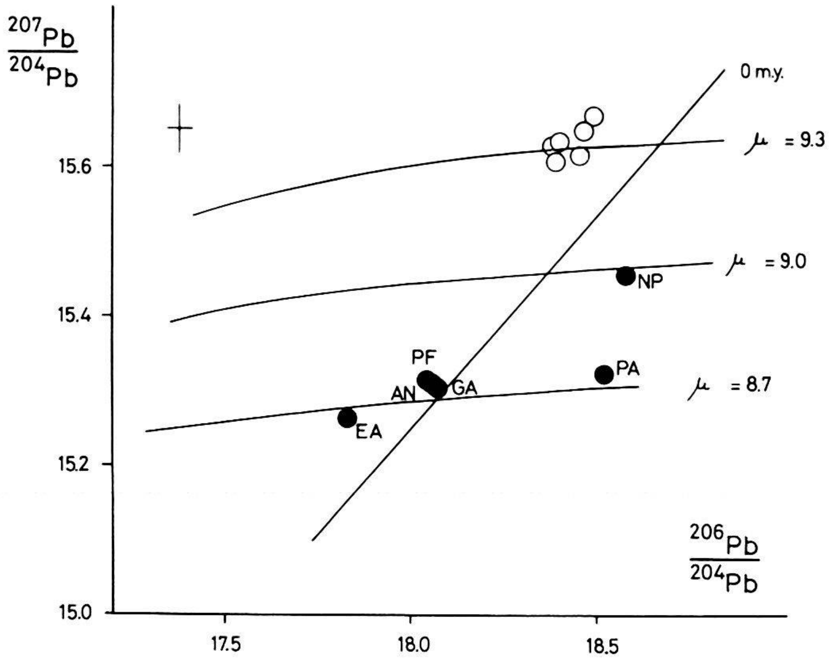

Fig. 2. Houtermans diagram for lead in basic and ultrabasic rocks, and some galena leads. EA = eclogite, Arami; PF = peridotite, Finero; AN = amphibolite, Nibbio; GA = gabbro, Anzola; PA = peridotite, Arami; NP = norite, Premosello; open circles = galena leads; cross = error range.

In Figure 2, the HOUTERMANS model for lead isotope evolution is drawn showing the compositions of the rock leads in comparison to some galena leads. The differences between the μ-values of rock leads and galenas are significantly greater than the error range reported.

Discussion

The data might indicate that the lead in these rocks has evolved in an environment with lower $^{238}U/^{204}Pb$ than represents the crust. This would be due to an upward enrichment of uranium relative to lead, so that the earth's crust is a higher μ system than the mantle (ARMSTRONG, 1968). A number of isotopic determinations of lead in basic rocks yielded similar results (TATSUMOTO, 1966; KURASAWA, 1968). DOE et al. (1969) reported isotopic data of lead in primitive and contaminated basalts from the Rocky Mountains, where they obtained in most cases lower μ-values for lead in primitive basalts than for lead in contaminated basalts.

Geological factors might supply us a means to explain the fact that upper mantle rocks outcrop at the earth's surface: Ivrea Zone lies just south of the highly important tectonical Insubric Line, Arami a short distance north of it. The Insubric Line sharply separates Central from Southern Alps; it represents a zone of compression and vertical movement: the block of the Southern Alps has been moved towards the Central Alps. It might well be possible that by this process deep-seated rocks of the transition zone between crust and mantle reached the surface.

The author is very grateful to Prof. Dr. E. Jäger, in whose laboratory this work has been carried out. The study has been supported by the "Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung".

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