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Oxygen Isotopic Composition of Minerals from Lepontine Gneisses, Valle Bodengo (Prov. di Sondrio, Italia)

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With 1 figure and 2 tables in the text

Abstract

Oxygen isotope paleotemperatures reported here for quartz-feldspar and quartz-muscovite pairs from Lepontine gneisses are 400, 400, 600, 650, 670, and 690° C, and almost certainly pertain to Tertiary metamorphism. Oxygen isotope exchange between the Garzelli granitoid gneiss and its mantling layer of schist is indicated and could have occurred as part of the Alpidic (Cretaceous/Tertiary) or an earlier metamorphism. Analyses of probable Mesozoic sediments, which now form part of the Lepontine Gneiss Complex, could help resolve this question.

> Above Lake Como towards Germany lies the valley of Chiavenna, where the river Mera enters the Lake. Here are barren and very high mountains with huge crags. *da Vinci*, 1487

Introduction

The Central Alps have been the subject of a number of recent studies in metamorphic petrology and geochronology (Wenk, 1962, 1970; Trommsdorff, 1966; Jäger, 1970; among others), which tend to show broad coincidence of a center of Tertiary metamorphism with the "Lepontine Gneiss Complex" of Wenk (1956). In this paper, some oxygen isotope analyses and paleotemperatures are reported from the Valle Bodengo area, where the Tertiary metamorphism appears to have been at its peak (Fig. 1).

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Results

The analyzed samples (Table 1) and their regional context have been described in more detail by BLATTNER (1965). The method of analysis for oxygen isotopes is basically that of CLAYTON and MAYEDA (1963), which is in turn a modification from BAERTSCHI and SILVERMAN (1951). δO^{18}_{SMOW} (CRAIG, 1961) has been calculated on the assumption that $\alpha^{25°C}_{CO_2-H_2O} = 1.0407$, for consistency. O'NEIL (1969) and BLATTNER (1971) are only the most recent authors to indicate a significantly higher value of this constant (1.0412 and 1.0417).

Table 1. *Oxygen isotope analyses of minerals and reference samples*

Rock no. Bl	Type and occurrence; coordinates, Landeskarte der Schweiz	Mineral	$^0/_{00}\ \delta O^{18}_{SMOW}$ *)
542	Granitoid two-mica gneiss, Garzelli dome; 745.290/124.250	Quartz	11.80**)
		Muscovite	9.20
1416	Biotite-andesine schist, concordantly overlying Garzelli dome in ~50 m thick layer; 745.690/124.200	Quartz	11.80
		Plagioclase (An 33)	9.00
1481	Granitoid two-mica gneiss, Soè dome; 742.950/122.980	Quartz	8.95
		Plagioclase (An 20)	7.15
1613	Granitoid biotite gneiss from zone of migmatites; 743.400/122.100	Quartz	11.35
		K-feldspar	9.20
1882	Two-mica granite from anatectic Tertiary dike; 742.240/122.920	Quartz	10.73
		K-feldspar	9.15
		Muscovite	8.15
Quartz 6195 (WILSON et al., 1970)			10.15 ± 0.1
G-2 (FLANAGAN, 1967)			7.7 ± 0.2

*) $\delta O^{18}_{x\ vs.\ std.} (^0/_{00}) = \left[\frac{(O^{18}/O^{16})_x}{(O^{18}/O^{16})_{std.}} - 1\right] (10^3)$.
**) Precision for unknowns, $\pm 0.15\,^0/_{00}$.

Table 2. *Temperatures obtained from oxygen isotope analysis of mineral pairs*, using calibrations as summarized by EPSTEIN and TAYLOR (1967)

Rock no. Bl	Mineral pair	$10^3 \ln \alpha$ *)	T, °C
542	Quartz-muscovite	2.60	670 ± 70**)
1416	Quartz-K-feldspar	2.15	400 ± 50
1481	Quartz-K-feldspar	1.45	650 ± 100
1613	Quartz-K-feldspar	2.15	400 ± 50
1882	Quartz-K-feldspar	1.55	600 ± 100
	Quartz-muscovite	2.55	690 ± 80

*) $\alpha = (O^{18}/O^{16})_{Min.\,1}/(O^{18}/O^{16})_{Min.\,2}$; $10^3 \ln \alpha \approx \delta_{Min.\,1} - \delta_{Min.\,2}$.
**) Limits of error are based on precision of 0.2 in $10^3 \ln \alpha$.

Oxygen isotope geothermometers have been summarized by EPSTEIN and TAYLOR (1967). For temperatures above 500°C there is little doubt as to their general validity, although their accuracy must remain under review. Quartzalkali feldspar and quartz-muscovite calibration curves used here are derived strictly from the EPSTEIN and TAYLOR summary. Isotopic feldspar compositions have been recalculated in terms of K-feldspar, where necessary, according to the data of O'NEIL and TAYLOR (1967), before being entered into table 2 and fig. 1.

Discussion

Fig. 1 summarizes the results, with sample locations projected onto a modified geological profile from BLATTNER (1965). Of the mineral pairs used for *geothermometry*, quartz-feldspar is the less reliable one, because (1) its sensitivity in °C/permil δO^{18} is twice that for quartz-muscovite, and (2) it is probable that feldspar exchanges oxygen with its environment more easily than either quartz or muscovite. For the moment, therefore, the low values of 400°C for two out of the four quartz-feldspar pairs should be considered with caution. The four temperatures between 600 and 690°C, on the other hand, agree well with conclusions of the first mentioned authors and of HÄNNY (1970) on the grade of Tertiary metamorphism in this area, as well as with that of BLATTNER (1965), that rocks of granitoid composition have been partially fused in the course of this metamorphism.

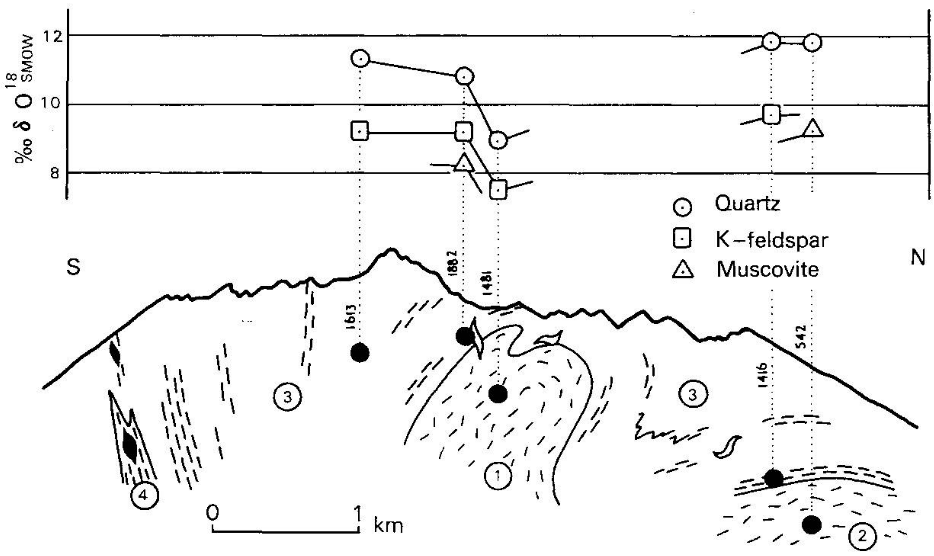

Fig. 1. Geological profile from Valle Darengo (S) to Valle Bodengo (N), modified from BLATTNER (1965), and with oxygen isotope data. Legend: (1) Soè gneiss dome, (2) Garzelli gneiss dome, (3) Zone of migmatites, (4) metasediments with lenses of ultramafites, probably of Mesozoic origin. Heavy dashes indicate metasediments in general. Structures are largely Alpidic and the light lensoid shapes indicate Tertiary anatectic granites.

It remains a major problem of Lepontine geology how to distinguish Mesozoic metasediments, which have suffered only Cretaceous to Tertiary metamorphism, from their basement, which may include reconstituted rocks of almost any age (WENK, 1948; TROMMSDORFF, 1966). All of the data reported here probably concern such "basement" rocks. However, with regard to temperatures, it is doubtful whether high-temperature oxygen isotope fractionations from pre-Mesozoic times could have survived even low amphibolite facies Tertiary metamorphism.

Of equal interest are the actual *abundance* data for O^{18}. For carbonates from the western part of the Lepontine Alps BAERTSCHI (1957) has already discussed this topic. It is well known that sediments, or metasediments that have remained closed systems during metamorphism, are enriched in O^{18} relative to igneous rocks (e. g., GARLICK and EPSTEIN, 1967; EPSTEIN and TAYLOR, 1967). Rock no. 1416, if considered a metasediment, may, within its 40 percent quartz, have retained "igneous" oxygen from an older parent rock. However, the remaining fraction of the original sediment, now constituting biotite and plagioclase, would have virtually ensured a non-igneous oxygen isotopic bulk rock composition, perhaps 1–2 permil δO^{18} above the composition found presently. Conversely, some of the analyzed granitoid rocks are relatively rich in O^{18}.

TAYLOR (1968) has grouped 74 plutonic granitoid rocks according to their δO^{18}, arriving at a strongly negatively skewed distribution. Rock no. 542 ($\delta O^{18}_{SMOW} \approx 10.5$) falls within a small group of high-O^{18} rocks, comprising less than 10 percent of TAYLOR's sample, and including two New Hampshire "binary granites", besides pre-Cambrian examples. Rock no. 1481, on the other hand, seems somewhat lighter in oxygen than the average plutonic granite.

The O^{18} abundance data therefore seem to indicate oxygen isotope exchange between the Garzelli dome and its mantling layer of schist (nos. 542 and 1416), and possibly also between mantling rocks and the margin of the Soè dome (no. 1882). Such exchange may have involved other species as well, and could have affected the Rb and Sr isotopic composition of rock no. 542 (JÄGER, 1965). No known Mesozoic metasediments have yet been analyzed and the indicated oxygen isotopic exchange over a distance of up to 0.5 km may have been part of a pre-Mesozoic event. It will be of considerable interest, in this respect, to measure the oxygen isotopic composition of the metasediments of Valle Darengo, marked (4) in fig. 1, which are of a somewhat different character to most metasediments of the area, and which are probably of Mesozoic origin.

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References

SMPM = Schweiz. Mineralogische und Petrographische Mitteilungen

Baertschi, P. (1957): Messung und Deutung relativer Häufigkeitsvariationen von O^{18} und C^{13} in Karbonatgesteinen und Mineralien. SMPM *37*, 73–152.

Baertschi, P. and S. R. Silverman (1951): The determination of relative abundances of the oxygen isotopes in silicate rocks. Geochim. Cosmochim. Acta *1*, 317–328.

Blattner, P. (1965): Ein anatektisches Gneissmassiv zwischen Valle Bodengo und Valle di Livo (Prov. Sondrio und Como). SMPM *45*, 973–1072.

— (1971): Oxygen isotopes in waters and solutions. *In* N.Z. D.S.I.R., Inst. Nucl. Sciences Progress Report *17*.

Clayton, R. N. and T. K. Mayeda (1963): The use of bromine pentafluoride in the extraction of oxygen from oxides and silicates for isotopic analysis. Geochim. Cosmochim. Acta *27*, 43–52.

Craig, H. (1961): Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. Science *133*, 1833–1834.

Epstein, S. and H. P. Taylor (1967): Variation of O^{18}/O^{16} in minerals and rocks. *In* Researches in Geochemistry *2*, P. A. Abelson, Ed., New York (Wiley), 29–62.

Flanagan, F. J. (1967): U.S. Geol. Survey silicate rock standards. Geochim. Cosmochim. Acta *31*, 289–308.

Garlick, G. D. and S. Epstein (1967): Oxygen isotope ratios in coexisting minerals of regionally metamorphosed rocks. Geochim. Cosmochim. Acta *31*, 181–214.

Hänny, R. (1970): Das Migmatitgebiet der Valle Bodengo (Östliches Lepontin). Dissertation, Zürich.

Jäger, E. (1965): Date reported *in* Blattner (1965).

— (1970): Radiometrische Altersbestimmung in der Erforschung metamorpher Prozesse. Fortschr. Mineral. *47*, 77–83.

O'Neil, J. R. (1969): Value reported *in* O'Neil, Clayton, and Mayeda, J. Chem. Phys. *51*, 1969, 5547–5558.

O'Neil, J. R. and H. P. Taylor (1967): The oxygen isotope and cation exchange chemistry of feldspars. Am. Min. *52*, 1414–1437.

Taylor, H. P. (1968): The oxygen isotope geochemistry of igneous rocks. Contr. Mineral. Petrol. *19*, 1–71.

Trommsdorff, V. (1966): Progressive Metamorphose kieseliger Karbonatgesteine in den Zentralalpen zwischen Bernina und Simplon. SMPM *46*, 431–460.

Wenk, E. (1948): Ostalpines und penninisches Kristallin. SMPM *28*, 761–771.

— (1956): Die lepontinische Gneissregion und die jungen Granite der Valle della Mera. Eclogae geol. Helv. *49*, 251–265.

— (1962): Plagioklas als Indexmineral in den Zentralalpen. Die Paragenese Calcit-Plagioklas. SMPM *42*, 139–152.

— (1970): Zur Regionalmetamorphose und Ultrametamorphose im Lepontin. Fortschr. Mineral. *47*, 34–51.

Wilson, A. F., D. C. Green and L. R. Davidson (1970): The use of oxygen isotope geothermometry on the granulites and related intrusives, Musgrave Ranges, Central Australia. Contr. Mineral. Petrol. *27*, 166–178.

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