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Sr ISOTOPES IN PLAGIOCLASE FROM GĘSINIEC TONALITE USING MICRODRILLING METHOD (STRZELIN CRYSTALLINE MASSIF)

Abstract: Sr isotope ratios in zoned plagioclases from four types of tonalites were studied by microdrilling and mass spectrometry. Plagioclase yields wide range of Sr initial ratios from 0.70728 to 0.70906 depending on rock type, plagioclase grain and the region of plagioclase being analysed. Measured Sr isotope ratios were recalculated to 294 Ma, the age obtained from three internal rock isochrons. The possibility of correlation of isotopic ratios among different rock types may suggest that plagioclase from four tonalites is related. Sr isotope disequilibrium and evidence of resorption indicate that partial melting affected tonalites before emplacement.

Keywords: plagioclase, zonation, Sr isotopic ratios, microdrilling, mass spectrometry.

INTRODUCTION

Sr isotopes are long recognized tool for providing the information about source material of granitoid rocks. However, whole rock data from different rocks of the apparently consanguineous magmatic suites or even from the same rock type, provide us with wide span of isotopic ratios (*e.g.* Roberts *et al.* 2000). The interpretation of such data set may be complex or even impossible and often requires invoking abstract magmatic end members that are not always well constrained isotopically and chemically. The technique that may solve the problem and provide more robust data for end members or processes responsible for apparent isotopic disequilibrium is microdrilling combined with isotopic analysis by MC-ICP-MS and TIMS (*e.g.* Waight *et al.* 2000; Tepley, Davidson 2003).

In this abstract we present results from plagioclase crystals from tonalites (the Gęsiniec intrusion), which has previously yielded a large range of initial whole rock Sr isotopic values (Oberc-Dziedzic *et al.* 1996). The Gęsiniec intrusion is the example of the small dioritic-tonalitic dykes which are widespread in shallow late- to post-orogenic settings. They are characterized by structural and chemical complexity interpreted to reflect assimilation, crystal retention or magma mixing (*e.g.* Roberts *et al.* 2000). Plagioclase preserves the magmatic conditions of crystallization due to sluggish diffusion of its constituents (*e.g.* Giletti, Casserly 1994). Therefore inter- and intra-rock correlation of Sr isotopic composition of plagioclase may be a powerful tool for deciphering magma origins and the processes that led to formation of dioritic-tonalitic complexes.

Five types of tonalite occur in the Gęsiniec Intrusion (Oberc-Dziedzic 1999, unpublished data). Plagioclase grains from four types were selected for detailed study of zoning patterns (1) light, coarse grained tonalite F35, (2) dark tonalite M20, (3) light, medium grained tonalite F24 and (4) dark, medium grained tonalite M23.

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ANALITICAL METHODS

Samples (ca. 1mg) for isotopic analyses were collected from polished mineral surfaces using diamond-coated dentist drills and methods described by Waight *et al.* (2000). Sr and Rb were separated using miniaturized chemical techniques to minimalise blanks. Sr and Rb from whole rock powders were separated by means of normal column chemistry. Both plagioclase and whole rock powders were spiked before chemical preparation.

Sr isotopic values were determined using a VG Axiom MC-ICPMS and TIMS at the Danish Lithosphere Centre and Geological Institute, Copenhagen. Analyses of SRM987 over the period of this study gave $^{87}\text{Sr}/^{86}\text{Sr}=0.71023\pm 3$ (2σ , $n=11$).

Table 1: Representative Sr isotope composition of microdrilled plagioclase (dxx-x-x) and tonalite (WR-Xxx) from the Gęsiniec intrusion.

		Rb (ppm)	Sr (ppm)	$^{87}\text{Rb}/^{86}\text{Sr}$	2SE	$^{87}\text{Sr}/^{86}\text{Sr}$	2SE	$^{87}\text{Sr}/^{86}\text{Sr}_{294}$
WR-F35		95,3	326,16	0,8457	0,091	0,712169	0,0012	0,70852
d35-3-3	IC	5,84	562,62	0,03	0,418	0,707669	0,0031	0,70754
d35-3-3	OC+M	1,63	516,2	0,0091	0,23	0,708332	0,0014	0,70829
d35-3-3	rim	1,99	564,13	0,0102	0,217	0,707918	0,0012	0,70788
d35-4-1	IC	2,71	584,46	0,0134	0,243	0,707529	0,0014	0,70747
WR-M23								n.d.
d23-1-5	rim	1,66	578,11	0,0083	0,215	0,708371	0,0014	0,70834
d23-1-6	core	1,23	630,18	0,0056	0,291	0,709085	0,0019	0,70906
WR-F24		46,43	364,58	0,3685	0,121	0,709495	0,001	0,70793
d24-1-2	whole	1,13	503,67	0,0065	0,22	0,707776	0,0015	0,70775
d24-1-3	whole	10,86	610,99	0,0514	0,317	0,707998	0,0018	0,70778
WR-M20		86,56	223,26	1,1223	0,035	0,71285	0,0029	0,70818
d20-71-1	whole	5,53	682,11	0,0235	0,062	0,70754	0,0014	0,70744
d20-75-1	whole	6,84	993,81	0,0199	0,093	0,7074	0,0019	0,70732

RESULTS

Tonalites vary from being isotopically homogenous to strongly heterogeneous on whole rock and single plagioclase scales. The initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios described below are calculated to 294 Ma – the age obtained from three internal biotite-plagioclase isochrons (unpublished data). Detailed plagioclase zonation styles and An and trace elements contents in plagioclase are described in the companion abstract (Pietranik, Waight 2005, in press):

Whole rock data: The values for tonalites described below vary from 0.70793 to 0.70852.

Light, coarse grained tonalite F35: This tonalite contains ragged remnants of biotite plates enclosed in hornblende. Plagioclase contains An rich cores (50-71%) affected by resorption (Pietranik, Waight 2005, in press). The cores are surrounded by complexly zoned mantles and rims enriched in albite component. Plagioclase is strongly heterogeneous with Sr isotopic data ranging from 0.70743 to 0.70845 (Table 1). The inner cores of plagioclase ($n=5$) gave the lowest Sr ratios of 0.70743 – 0.70754. In one grain where 3 samples were drilled the core was surrounded by radiogenic mantle of $^{87}\text{Sr}/^{86}\text{Sr}=0.70829$. In general the most radiogenic samples were drilled within interiors of plagioclase crystals suggesting that similar high $^{87}\text{Sr}/^{86}\text{Sr}$ mantles occur also in other, however not all, grains. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios decrease again towards the rim and vary from

0.70771 to 0.70787. It is important to note that only the highest values obtained from plagioclase mantles (0.70845) approach the whole rock ratio (0.70852).

Dark tonalite M20: Slightly resorbed biotite plates enclosed in amphibole characterize this sample. The tonalite is rich in mafic minerals. It is bulk rock is characterized by much higher Mg, Ni and Cr content (Pietranik, Waight 2005, in press). Major element content and morphology of plagioclase in M20 tonalite are similar to F35 tonalite. However, $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are lower and vary from 0.70728 to 0.70752 (Table 1). The obtained differences characterize different grains and no consistent variation between core and rim isotope ratios was observed. This may be however due to smaller grain size and difficulties with sampling separate crystal zones. Again plagioclase compositions are much less radiogenic than whole rock (0.70818).

Light, medium grained tonalite F24: Plagioclase is strongly patchy zoned and the maximum An content is 50-57 %. Only one drill per plagioclase was possible so usually whole grain area was sampled. However all results are similar 0.70774 – 0.70783 and moreover the difference between whole rock value (0.70793) and those of plagioclase crystals is only slight.

Dark, medium grained tonalite M23: Plagioclase contains plateau cores with An content of 42-47% or is patchy zoned similar to F24. M23 is the most radiogenic and heterogeneous sample and plagioclase yields Sr ratios from 0.70803 to 0.70906. Each grain is nearly homogenous in respect to Sr isotopes. No whole rock data were feasible due to small occurrences of this rock type. The tonalite is abnormally enriched in mafic and accessory minerals (mainly hornblende, biotite, allanite and titanite).

DISCUSSION AND CONCLUSIONS

Sr isotopic data and morphology of plagioclase from the Geşiniec tonalite may provide information on its crystallization conditions and composition of magma during plagioclase crystallization. Following points should be explained when the model of tonalite magma evolution is being constructed:

- (1) heterogeneity on individual plagioclase and sample scale in F35, M20 and M23 samples, and homogeneity in F24 tonalite;
- (2) discrepancy between whole rock ratios and plagioclase initial $^{87}\text{Sr}/^{86}\text{Sr}_{294}$ ratios;
- (3) similarity of Sr isotopic composition in inner cores of M20 and F35 tonalites;
- (4) resorption evidence in plagioclase and mafic minerals (Pietranik, Waight 2005, in press);

We argue that tonalites are related to each other as suggested by their common occurrence in similar assemblage in similar post-collisional intrusions worldwide (*e.g.* Roberts *et al.* 2000). The similar isotope ratio in the cores of plagioclase in M20 and F35 tonalites, despite different whole rock composition, substantiates this theory. Isotopic heterogeneity in the sample and mineral scale is common and was explained to be due to magma mixing and assimilation (*e.g.* Waight *et al.* 2000; Tepley, Davidson 2003). However such processes require usually consistent change from cores to rims of plagioclase. Also more mafic samples as M20, if related, should have less radiogenic Sr ratios, that is not case in the Geşiniec intrusion (Table 1). Thus we argue that the process responsible for isotopic, chemical and morphological record in plagioclase was partial melting. Partial melting may lead to strong heterogeneity in small scale (Knesel, Davidson 1999). Minerals crystallizing incongruently during partial melting *e.g.* plagioclase may record isotopic heterogeneity of surrounding melt before it homogenizes (*e.g.* Hammouda, Pichavant 2000). The record is preserved in minerals even if the melt eventually reaches equilibrium due to sluggish diffusion in crystal lattice (Giletti, Casserly 1994).

M20 and F35 tonalites were partially molten.

F35 records pervasive biotite (\pm plagioclase) melting. Biotite melting provided radiogenic component in the melt and thus resulted in crystallization of more radiogenic mantles on plagioclase. As isotopic equilibrium was obtained with further melting and diffusion in the melt, less radiogenic rims crystallized.

M20 was affected predominately by plagioclase melting with minor mafic minerals contribution as suggested by abundant restitic biotite. Such a melt was only slightly more radiogenic and did not affect isotopic composition of plagioclase crystallizing immediately after resorption. Different models of melting are supported by trace element in plagioclase data (Pietranik, Waight 2005).

M20 mafic and radiogenic composition is the result of the plagioclase rich melt escape. The F24 tonalite may be the product of melting of M20 on the large scale. Heterogeneity of M23 suggests that it crystallized from the melt enriched in mafic component probably similar to that produced during F35 melting.

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