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The geological significance of the Rb-Sr whole-rock isochron of hornfelsed schists from the Izerskie Garby Zone, Karkonosze-Izera block, southern west Poland

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ABSTRACT:

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Preliminary Rb-Sr isotope data for hornfelsed schists from the 'Stanisław' quarry in the Izerskie Garby Zone are reported. An isochron based on three points representing three whole-rock samples yields an age of 333 ± 4 Ma (Visean) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.709567.

The Rb-Sr age of 333 ± 4 Ma, indicating the date of the Rb-Sr system closure, can be interpreted as the cessation of contact metamorphism in the Izerskie Garby Zone. The age of 333 ± 4 Ma is close to the peak of contact metamorphism in this zone. Contact metamorphism and silicification in the Izerskie Garby Zone were genetically related to the activity of the Variscan Karkonosze pluton. Contact metamorphism was older than the biotite cooling at ca. 320 Ma.

Key words: Hornfelsed schists, Contact metamorphism, Silicification, Rb-Sr isochron, Izerskie Garby Zone, Karkonosze-Izera block

INTRODUCTION

The Rb-Sr isochron method is often used by geologists for both whole-rock and individual mineral age determinations. However Rb-Sr geochronological data are not always easy to interpret. It should be remembered that Rb and Sr are relatively mobile elements and consequently the isotopic system may easily become disrupted either by the influx of fluids or by a later thermal event. Rb-Sr isochrons are therefore rarely useful in constraining crust formation ages. Nevertheless, a Rb-Sr isochron can usually be attributed to a definite event such as the age of metamorphism or alteration, even if the primary age of the rock cannot be determined (Dickin 1995).

From a geochronological point of view, the Izerskie Garby Zone in the Karkonosze-Izera block (Text-fig. 1) is of considerable interest. One of the many rocks from this zone is hornfelsed schist, which has hitherto not been characterized isotopically. This paper is intended to introduce the results of a study that yielded isotope data of the Rb-Sr whole-rock system, and to provide an interpretation of the geological significance of the Rb-Sr whole-rock isochron of hornfelsed schists from the 'Stanisław' quarry in the Izerskie Garby Zone.

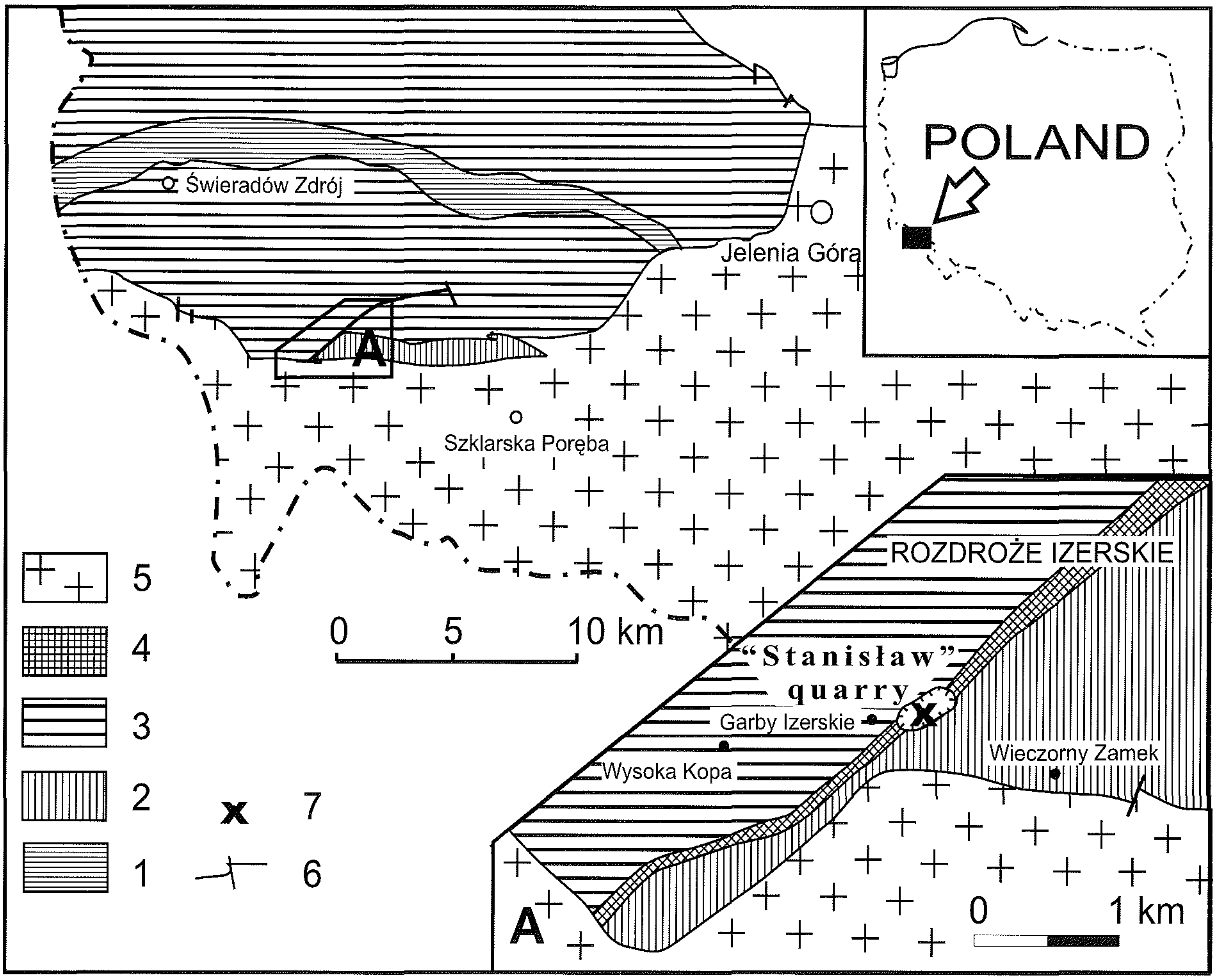

Fig. 1. Geological sketch-map of the Karkonosze-Izera block (after BERG 1920, cf. KOZŁOWSKI 1978); 1 –mica schists, 2 – hornfelses, 3 – Izera gneiss and Rumburk granite, 4 – quartz zone, 5 – Karkonosze granitoid, 6 – faults, 7 – location of skarn; A- Izerskie Garby Zone

Earlier research on the dating of the Karkonosze-Izera rocks provides a point of reference for the interpretation of subsequent isotopic investigations. The estimation of the age of the Karkonosze granite by DUTHOU & *al.* (1991), using the Rb-Sr whole-rock isochron method, showed that the magma emplacement occurred at 329 ± 17 Ma (porphyritic granite). The emplacement of the late-tectonic Karkonosze pluton by MARHEINE & *al.* (2002) occurred at 320 ± 2 Ma (biotite, $^{40}Ar/^{39}Ar$ cooling age). The U-Pb isochron age of the Izera gneisses, based on zircons, came to between 515 and 480 Ma, which has been suggested as the age of the intrusion of the protolith (KORYTOWSKI & *al.* 1993, OLIVER & *al.* 1993, PHILIPPE & *al.* 1995). Rb-Sr whole-rock analyses obtained by BORKOWSKA & *al.* (1980) yielded ages between 510 and 500 Ma for the Rumburk granite and between 480 and 450 Ma for the Izera gneisses.

GEOLOGY

The Izera metamorphic complex is composed mainly of varieties of the so-called Izera gneisses, comprising four parallel crystalline schist zones: the Szklarska Poręba, Stara Kamienica, Mirsk and Złotniki Lubańskie belts. These zones are probably the relicts of the Proterozoic cover of the Izera granites, both of which were altered by subsequent Variscan regional metamorphism and deformation (see ALEKSANDROWSKI & *al.* 2000, ŻELAŹNIEWICZ 1997). The Szklarska Poręba schist zone, which is in contact with the Variscan Karkonosze intrusion, was altered into hornfelses by contact metamorphism that was most probably connected with this intrusion (BORKOWSKA 1966, SMULIKOWSKI 1972, KOZŁOWSKI 1978, FILA-WÓJCICKA 2000).

To the Szklarska Poręba belt belongs the Izerskie Garby Zone, where the complex effects of the Karkonosze intrusion can be observed. The contact of the Karkonosze granitoids with the gneisses and hornfelses of the Izera area near Jakuszyce, to the west of Szklarska Poręba, is in part intrusive, and in part tectonic along the Izerskie Garby Zone. The Izerskie Garby Zone (a complex fault zone) is several km long with a SW – NE strike. The mineralized zone, associated with a complex fault zone, is 100–400 m wide and dips steeply to SE. The SW end of this zone is in contact with the intrusion, and its NE end can be observed at Mt. Jastrzębia. The rocks on the SE side of the zone consist of hornfelsed schists with intercalations of calc-silicate skarns (FILA-WÓJCICKA 2000). The NW part of the zone is composed of blastomylonitic and fine-grained gneisses with biotite blasts; the NE side cuts several varieties of the so-called Izera gneisses. The complex fault zone is mineralized with quartz, and a continous increase in quartz content can be observed in both the gneisses and hornfelses toward the centre of this zone, to form a monomineralic quartz rock (LEWOWICKI 1965, SZAŁAMACHA 1965, KOZŁOWSKI 1978). The rocks of the zone are cut by granitoid apophyses that are presumably connected with the Karkonosze intrusion (KOZŁOWSKI 1978). In KOZŁOWSKI's (1978) opinion, the fractured hornfelses from the Izerskie Garby Zone, were subjected to the activity of fluorine-bearing solutions, after silicification.

PETROGRAPHY

Hornfelsed schists from the 'Stanisław' quarry in the Izerskie Garby Zone are dark grey, usually fine-grained, and enriched in SiO_2. The texture of these hornfelses under the microscope, is directional and the structure is allotriomorphic grain-poikilitic. Andalusite and pinite (pseudomorphs after cordierite) are typical components of these rocks (SZAŁAMACHA & SZAŁAMACHA 1966, KOZŁOWSKI 1978). Alternating layers have different mineral compositions and different thicknesses. One type of layer may be composed of biotite, quartz, andalusite, microcline, post-cordierite pinite, muscovite, clinochlore, plagioclase, sericite (replacing andalusite, muscovite or biotite), post-microcline albite, post-biotite chlorite or post-sericite biotite. Muscovite and biotite seem to be both blastic and primary. The second type of layer consists of quartz blasts. The final mineral association in the fractured hornfelses results from the paragenesis of fluorine minerals: fluorite and apophyllite with porous white quartz and late calcite or stilbite and chlorite (KOZŁOWSKI 1978). Fluorite developed extensively in the hornfelses, associated with pyrite and chalcopyrite (KOZŁOWSKI 1978).

Samples of hornfelsed schists contain the assemblage quartz + biotite + muscovite + K-feldspar + andalusite + post-cordierite pinite, suggesting that the reaction (PATTISON & TRACY 1991): muscovite + quartz + biotite $\rightarrow$ andalusite + cordierite + K-feldspar $+H_2O$ has occurred in these samples. At 2 kbar (FILA-WÓJCICKA 2000), this reaction took place below 600°C.

SELECTION OF SAMPLES

During the fieldwork in 1998 at the 'Stanisław' quarry, 12 samples were collected from the freshly exposed SE wall of the quarry, all at the same distance from the Karkonosze massif. The maximum distance between the samples was two metres. After initial inspection, seven of these samples were selected for further microscope investigations, and three of these were eventually used for isotopic analysis. A minimum of three points for Rb-Sr age determination is considered necessary by geochronological laboratories throughout the world.

The three samples selected for analysis were not taken from the contact between the granitoide apophyses and the hornsfelsed schists. Indications of fractures and the activity of F-bearing solutions were not observed. All three samples were intensively silicified and consisted of the following minerals: quartz (commonly with microlites of muscovite, biotite and andalusite), biotite, andalusite, muscovite, microcline and plagioclase. Negligible quantities of post-cordierite pinite and sericite were also present.

ANALYTICAL PROCEDURE

Rb and Sr isotope analyses were performed in the Department of Geochronology of the Institute of Geological Sciences of the Polish Academy of Sciences. The whole-rock samples of the hornfelsed schists were carefully crushed in a jaw breaker and ground in a ball mill. All samples were then dissolved in HNO_3+ HF+HCl and Sr and Rb were separated on chromatographic columns. Rb and Sr concentrations were determined by the isotope dilution method. The isotope ratios were measured on a VG Sector 54 mass spectrometer. A value of $^{86}Sr/^{88}Sr = 0.1194$ was used to correct for ion beam fractionation. During Sr isotope analysis the NBS SRM 987 standard was measured, yielding an average ratio of $^{87}Sr/^{86}Sr = 0.710255 \pm 0.000011$.

RESULTS OF THE ISOTOPIC ANALYSIS

The results for the hornfelsed schists of the Izerskie Garby Zone are listed in Table 1.

sample	$^{87}Sr/^{86}Sr$	(corr) [%]	Sr [ppm]	Rb [ppm]	$^{87}Rb/^{86}Sr$
H1	0,760131	0,0025	50,6	189,5	10,6247
H2	0,765932	0,0019	43,2	181,0	11,9038
H3	0,715743	0,0035	71,1	32,7	1,3011

Table 1. Analytical data of the Rb-Sr whole-rock analyses for hornfelsed schists from the 'Stanisław' quarry

An isochron can be constructed in the diagram of $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ isotope ratios (Text-fig. 2). Error bars were too small to draw at the scale of the diagram.

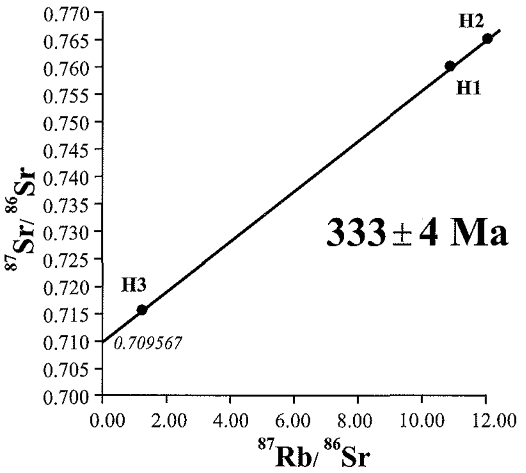

Fig. 2. Rb-Sr isochron diagram for whole-rock samples of hornfelsed schists from the Izerskie Garby Zone, 'Stanisław' quarry; initial $^{87}Sr/^{86}Sr$: 0.709567

DISCUSSION AND CONCLUSIONS

The Izerskie Garby Zone is of considerable geochronological interest because here the complex interaction of regional metamorphism, deformation, contact metamorphism, silica metasomatosis and fluorine metasomatosis can be observed.

In the present paper, preliminary isotopic data for the intensively silicified hornfelsed schists of the Izerskie Garby Zone are reported. The isochron, based on three points representing three whole-rock samples, yields an age of 333 ± 4 Ma (Visean) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.709567.

Contact metamorphism genetically related to the thermal influence of the Karkonosze pluton was the last thermal event, documented by the hornfelsed schists and calc-silicate skarns from the Izerskie Garby Zone. The maximum temperature of hornfelsed schist formation probably was below 600°C. The peak of contact metamorphism occurred at ca. 650°C (calc-silicate skarns, FILA-WÓJCICKA 2000). In the light of the field observation in the Izerskie Garby Zone, the temperature conditions of the formation of minerals in this zone (see KOZŁOWSKI 1978, FILA-WÓJCICKA 2000) and the age of magma emplacement of the Karkonosze granite (see DUTHOU & *al.* 1991, MARHEINE & *al.* 2002) it follows that the age of 333 ± 4 Ma for the hornfelsed schists of the Izerskie Garby Zone is best interpreted as the cessation of contact metamorphism. The isochron-derived age of 333 ± 4 Ma corresponds to an emplacement age for the Karkonosze granite (see DUTHOU & *al.* 1991, MARHEINE & *al.* (2002). Contact metamorphism in the Izerskie Garby Zone was older than the biotite cooling at ca. 320 Ma obtained by MARHEINE & *al.* (2002). The age of 333 ± 4 Ma is close to the peak of contact metamorphism in this zone.

Recrystallization of the mylonitised minerals of the rocks in the 'Stanisław' quarry (SZAŁAMACHA 1965, SZAŁAMACHA & SZAŁAMACHA 1966) was accompanied by extensive silicification in a complex fault zone (KOZŁOWSKI 1978). Silicification took place after cataclasis and mylonitisation (SZAŁAMACHA 1965, SZAŁAMACHA & SZAŁAMACHA 1966). The beginning of the formation of the quartz metasomatite could not be precisely determined (KOZŁOWSKI 1978). KOZŁOWSKI (1978) stated that, although the schists were silicified, it was not clear whether they were already altered by contact metamorphism, or were not yet altered, i. e. whether silicification developed before, or during as well as after the formation of the Karkonosze massif. In his opinion, the granitoid apophyses cutting the silicified hornfels were not silicified themselves, then silicification finished before the final consolidation of the Karkonosze massif. Data from the metamorphic reactions that occurred in hornfelsed schists and skarns (FILA-WÓJCICKA 2000) during the prograde and retrograde contact metamorphism suggest that silica-bearing solutions were present. Silicification could have partly overprinted the stages of contact metamorphism in time.

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