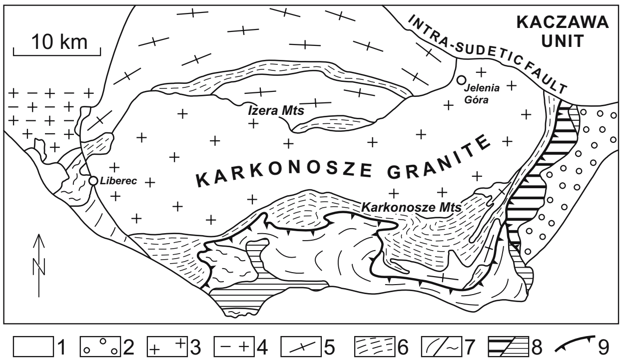

Fig. 1. *Geological map of the Karkonosze-Izera block and adjacent area (after Aleksandrowski and Mazur, 2002). Description: 1 – sediments and volcanics; metasediments ; 2 – conglomerates; 3 – Carboniferous granite (C_1); 4 – Precambrian – Old Palaeozoic granodiorite (Pt_3 – Cm_1); 5 – Old Palaeozoic gneisses (Or_1); 6 – Precambrian mica schists (Pt_3); 7 – Old Palaeozoic phyllites (S_2); 8 - metabasites and gneisses; 9 – Saxothuringian suture.*

greywackes; gneissified Izera granites and rocks from their metamorphic cover (the Izera complex); altered sedimentary sequences (Ordovician – Early Carboniferous) in the Jěstěd Mts and south Karkonosze as well as the Zelezny Brod metavolcanic series; altered sedimentary and volcanogenic sequences of the Eastern Karkonosze; the Karkonosze granite (Żelaźniewicz *et al.*, op. cit.).

The study area covers the eastern part of the northern metamorphic envelope of the Karkonosze granitoid body between Szklarska Poręba and Pasiecznik/Barcinek (**Fig. 2**). This means that the area under study lies in the zonally gneissified Izera Granite north of Szklarska Poręba. Different types of the rocks may be distinguished there, as follows: 1) the Szklarska Poręba schists, 2) paragneisses, 3) coarse-grained porphyritic granite, 4) leucogranites, 5) mica schists (the Stara Kamienica schist belt), 6) intra-schist gneisses. The presence of parallel schist belts is a characteristic feature of the region. The Stara Kamienica schist belt evidently separates the Izera complex into two parts of different lithology. The granites dominate north of the belt, while paragneisses are more frequent in the south. The Izera granite and gneisses correspond to rocks of different origin and petrological characteristics. Detailed petrographic descriptions of these rocks are referenced in the bibliography (Oberc-Dziedzic, 1988; Oberc-Dziedzic *et al.*, 2005, 2007).

3. GEOCHRONOLOGY

The isotope age of the Rumburk granite and Izera gneisses lies in the interval of 514-480 Ma, while the age of the crosscutting aplite is 480 Ma (Korytowski *et al.*, 1993).

Rb-Sr isotope age data in the Karkonosze-Izera Block were determined by Borkowska *et al.* (1980). These authors dated the rocks at 500-450 Ma and 480-450 Ma, respectively. According to these authors the age of the granite intrusion is 480-450 Ma. Zircon dating by U-Pb and Pb-Pb methods slightly moved the age limits and fixed the crystallization of the Izera granite at 514-480 Ma as mentioned above (Korytowski *et al.*, 1993; Oliver *et al.*, 1993; Kröner *et al.*, 1994; Philippe *et al.*, 1995; Marheine *et al.*, 2002). According to Żelaźniewicz *et al.* (2003) dating of zircons from the intraschists gneisses from Gierczyn has shown that their granite protolith intruded into the envelope at 505 Ma, the Świeradów gneisses (diatextites) were partially melted between 513-483 Ma, while leucogranites from Kotlina crystallized/intruded in the interval of 508-483 Ma.

The rocks in the area between Szklarska Poręba and Pasiecznik/Barcinek were earlier dated by the fission track method that resulted in the following values:

- apatite from 63±9 to 121±10 Ma;
- titanite from 328±32 to 489±43 Ma;
- zircon from 311±19 to 469±51 Ma (Jarmołowicz-Szulc, 1984).

In case of titanite and zircon FT ages these results are the reset ages due to the presence of the Karkonosze granite below its metamorphic envelope (as was suggested e.g. by Oberc, 1972). The apatite ages record the time after cooling below 100±25ºC (the closure temperature of this mineral).

The Karkonosze granite age determinations were performed by different authors. The Late Carboniferous Rb-Sr ages of 320-310 Ma (using one muscovite and two biotite grains) within the Karkonosze-Izera Block were interpreted as the products of isotopic resetting due to the Krknoše-Jizera pluton intrusion (Borkowska *et al.*, 1980). According to Pin *et al.* (1987) and Duthou *et al.* (1991),

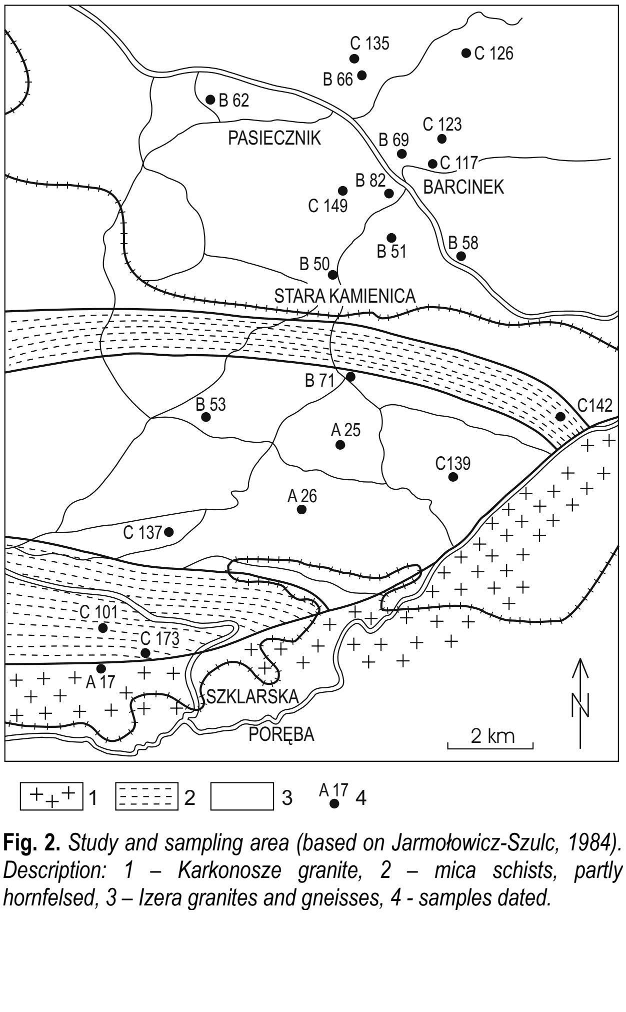

Fig. 2. *Study and sampling area (based on Jarmołowicz-Szulc, 1984). Description: 1 – Karkonosze granite, 2 – mica schists, partly hornfelsed, 3 – Izera granites and gneisses, 4 - samples dated.*

the Karkonosze granite emplacement occurred at about 328±12 Ma.

Early K-Ar investigations on biotites extracted from the granitoids in the Sudetes and from the metamorphic envelope of the Karkonosze granite reveal a wide range of data (Przewłocki *et al.*, 1962; Borucki, 1966). For the Karkonosze granite they were reported to average at 304 Ma and 290 Ma (K-Ar and Rb-Sr, respectively) that is somehow controversial taking into account the closure temperature of the Rb-Sr system higher than that of the K-Ar system. According to $^{40}Ar/^{39}Ar$ determinations of Marheine *et al.* (2002), the shearing activity within the Krknoše-Jizera terrane dated at about 325-320 Ma was accompanied by comtemporary pluton emplacement (Pin *et al.*, 1987; Mierzejewski *et al.*, 1994). The upper limit of the tectonometamorphic and magmatic activity has been estimated at 314-312 Ma ($^{40}Ar/^{39}Ar$) – the Namurian/Westphalian boundary (Manheine *et al.*, 2002). The SHRIMP zircon ages for the Karkonosze porphyric and equigranular granites are about 318 and 314 Ma, respectively (Machowiak and Armstrong, 2007).

The present K-Ar determinations have been conducted on the background of the unclear earlier argon radiometric data, interesting apparent age distribution in the area and in the rocks earlier dated by fission track methods on apatite, titanite and zircon (Jarmołowicz-Szulc, 1984).

4. METHODS APPLIED AND ANALYTICAL MATERIAL

The K-Ar studies have been performed dually. Earlier data have been obtained in the Polish Geological Institute by means of the volumetric method (Jarmołowicz-Szulc, 1983, archive materials). This method based on gas extraction from the heated sample in the glass line, chemical purification of the extracted gases and final measurement of the noble gas in the McLeod mercury vacuum-meter. The present mass-spectrometric K-Ar dating has been performed on 10 samples of biotite and the whole rock sampled from the Izera granite, gneisses, the Karkonosze granite, amphibolite and schists.

The rock samples were crushed using a jaw crusher and sieved into 0.088-0.12, 0.12-0.25 and 0.25-0.35 mm size fractions. The material was then washed and dried. Mineral concentrates were separated in heavy liquids. Magnetic separation of heavy fraction, paper shaking, handpicking under the binocular followed the separation and resulted in biotite and biotite-amphibole concentrates from two lesser size fractions.

The potassium concentrations in the samples were determined by flame photometry in the Central Chemical Laboratory of Polish Geological Institute, Warsaw and in the Institute of Geological Sciences, Polish Academy of Sciences, Cracow, with the use of Sherwood 420 spectrophotometer. The argon determinations were performed using a modified mass spectrometer MS-10 in the Mass Spectrometry Laboratory at the Maria Curie-Sklodowska University, Lublin. The methodology and standard procedures as well as constants are described by Hałas (1995) and Turniak *et al.* (2007). XRD analyses were performed for biotite, amphibole and rock samples to provide data on the mineral composition of the studied samples (B 50, B 53, B 58b, B 62, C 139, C 173). X-ray diffraction patterns for twin aliquots of the dated samples were obtained at Polish Geological Institute in Warsaw using an X'Pert PW 3020 instrument operating at 40 kV, 45 mA and $CuK_{\alpha1}$ radiation. Scans were made from 3 to 60^o (2Theta) with a step of 0.05^o in 1 sec step-time.

As it has been observed in the sampled rocks, the augen gneisses are light grey coarse grained rock displaying a regular augen structure of coarse minerals. The rocks are composed of: quartz, microcline, plagioclase, hornblende, and mica accumulations (biotite, slightly chloritized; some new formed muscovite). Apatite and titanite are accessory in dark minerals (sample B 50). The fine- and medium grained thin-laminated gneisses are grey rocks with foliation defined by thin biotite laminae. Their mineralogical content is: quartz, alkali feldspars, plagioclase, biotite, muscovite, some iron oxides. Biotite is not chloritized, but

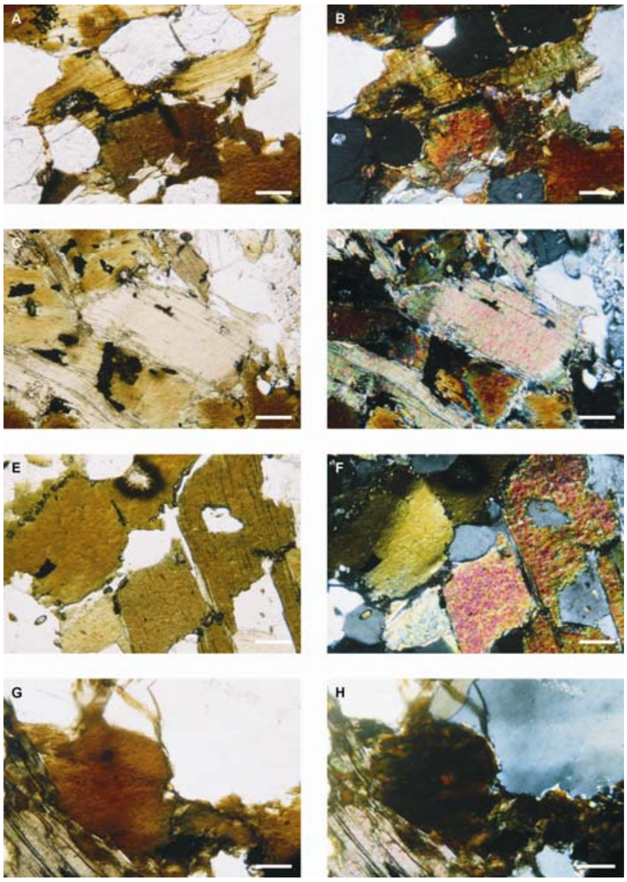

Fig. 3. *Microphotographs of selected rock samples in the studied area. Description: A - Biotite, apatite and titanite in gneiss, one nicol (Czartowskie Skały, sample B 62); B - Biotite, apatite and titanite in sample B 62, crossed nicols; C - Slight plastic deformation in biotite and coarse flakes of biotite in granodiorite, one nicol (Barcinek, sample C 117); D - Slight plastic deformation in biotite and coarse flakes of biotite in sample C 117, crossed nicols; E - Biotite, apatite and titanite in granodiorite, one nicol (Barcinek, sample C 123); F - Biotite, apatite and titanite in sample C 123, crossed nicols; G - Dark and light minerals in gneiss, one nicol (Pasiecznik, C 135); H- Dark and light minerals in gneiss in sample C 135, crossed nicols. Scale bar – 0.1 mm.*

undulated. Apatite, titanite and zircon are accessory (sample C 135). Porphyritic granite is a light-coloured rock with lenses of dark minerals. It displays a coarse porphyritic texture and unoriented structure. Mineral composition is: microcline microperthite, plagioclase, quartz, biotite, muscovite (samples A 25, B 53, B 62, B 69). Biotite forms large, dark-brown flakes, that significantly dominate over fine-grained light mica and brownish biotite crystals in two-mica aggregates (**Fig. 3**). Granodiorites (granodioritic gneisses) represent dark grey rocks of structure changing from unoriented (sample C 117) to evidently oriented (samples C 123, C 126). They display a blastic structure and are built of plagioclase, quartz, biotite, muscovite, alkali feldspar and sericite. Apatite, magnetite and zircon are accessory, distributed in dark mineral accumulations (samples C 117, C 123, C 126). Two generations of biotite may be observed (sample C 117) – coarse and fine-grained and some chloritization phenomenon (C 123). Amphibolites and amphibolite schists which form enclaves in the mica schists (the Szklarska Poręba and Stara Kamienica belts) are dark, almost black rocks of blastic texture and unoriented to oriented structure (samples C 173, B 58b, C 142). They contain hypautomorphic hornblende, hypidiomorphic plagioclase, chlorite, quartz, potassium-sodium feldspars, rare biotite, chlorite. Titanite is accessory (sample C 173).

5. K-Ar GEOCHRONOLOGICAL RESULTS

The potassium content in the studied 16 samples ranges from 0.96% to 7.00%. This is a relatively large scatter which, however, results from the rock and mineral characteristics.

The values of the K-Ar age for minerals and rocks from the Karkonosze-Izera block lie in the interval from 226.0±6.7 Ma to 386.1±3.0 Ma (**Table 1**). The lowest value corresponds to the whole rock sample (B 58b), while the highest is the biotite age from the sample in the northernmost part of the study area (C 135). The earlier (archive) K-Ar data show a lesser scatter ranging from 308±21 Ma to 372±26 Ma, but higher errors (**Table 2**).

The histogram of the K-Ar age values shows that the maximum frequency lies in the interval from 310 to 330 Ma (**Fig. 4**).

As it is seen in the tables and figures, the Izera granite rocks from the southern part of the studied area display

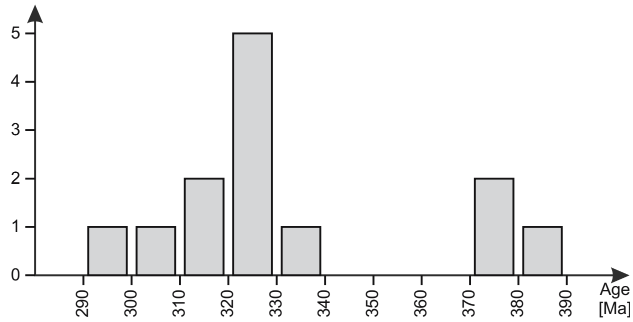

Fig. 4. *Histogram of the K-Ar age values.*

K-Ar isotope ages between 308±21 Ma (sample A 25) and 318.4±3.1 Ma (B 53). The values obtained in the northern part of the study area are from 290.0±3.0 Ma (gneiss, B62) and 322±22 Ma, (granite B 69), through 327±3.3 Ma (Augengneiss, B 50) to 327±3.0 Ma and 338±2.7 Ma (granodiorite, C 123, C 117). The sample from the Karkonosze granite reveals the age of 320±22 Ma. Data from the mica schists from Stara Kamienica and Wysoki Grzbiet Izerski are 327.6±3.6 Ma (**Table 1**) and 311±21 Ma (**Table 2**), respectively. Amphibolites show a great age scatter from 226.0±6.7 Ma (B 58a, Rybnica) and 234.1±3.0 Ma (Szklarska Poręba) in the south through 284.8±7.2 Ma (C 139) to 370±26 Ma northwards (C 142, amphibole schist, Wojcieszyce). The Izera gneisses in the northernmost part of the study area reveal the highest K-Ar age of 386.1±3.0 Ma (C 135), while the Więziec granite – 372±27 Ma.

6. DISCUSSION

The values of the K-Ar age for minerals and rocks from the Karkonosze-Izera Block obtained at present lie in the wide interval ranging from 226.0±6.7 Ma to 386.1±3.0 Ma (**Table 1**). The K-Ar age data by volumetric method range from 308±21 to 372±26 Ma. These values have been obtained for the minerals (and rocks) in the block, where the isotope age of the Rumburk granite and Izera gneisses lies in the interval of 514-480 Ma, while the crosscutting aplite is 480 Ma (Korytowski *et al.*, 1993). The Rumburk granites were dated by Rb-Sr method at 501±32 Ma and the Izera gneisses at 462±15 Ma (Borkowska *et al.*, 1980).

Table 1. *K-Ar age determinations for minerals and rocks in the northern envelope of the Karkonosze massif.*

Sample	Location and description	K (%)	^{40}Ar rad. (pmol/g)	% ^{40}Ar rad.	Age (Ma)
C 135 biotite	Pasiecznik, gneiss	6.86	5121	97.2	386.1±3.0
C 117 biotite + individual amphibols	Barcinek, granodiorite	5.81	3752	95.6	338.6±2.8
B 71 biotite	Stara Kamienica,mica schist	4.24	2641	93.4	327.6±3.6
B 62 biotite	Czartowskie Skały, gneiss	5.85	3191	92.9	290.0±2.5
C 123 biotite	Barcinek, granodiorite	4.10	2553	97.8	327.5±3.0
B 58b whole rock	Rybnica, amphibolite	1.13	472	87.6	226.0±6.7
B 53 biotite	Chromiec, porphyritic granite	7.00	4226	97.3	318.4±3.1
B 50 biotite	Guzek, Augengneiss	4.16	2586	95.1	327.0±3.3
C 139 whole rock	Wojcieszyce, amphibolite	1.10	588	83.3	284.8±7.2
C 173 whole rock	Szklarska Poręba, amphibolite	0.96	416	79.8	234.1±8.2

Average age 316.1±3.3 Ma (based on seven values; one lowest and two highest data excluded).

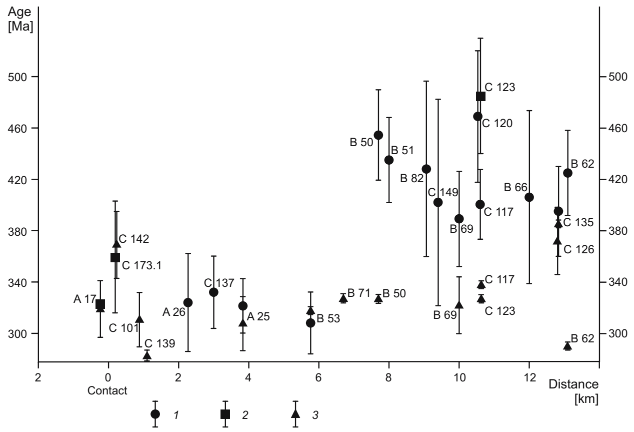

Fig. 5. *K-Ar age values in comparison to FT data in the study area in function of distance from the surface contact of the Karkonosze granite and its envelope (partly based on Jarmołowicz-Szulc, 1984). Description: 1 – titanite FT age, 2 – zircon FT age, 3 – present K-Ar data.*

The data obtained in the present paper evidently differ from those last ones. It is completely understandable since the closure temperature of K-Ar system is lower than that of Rb-Sr one.

The results of the fission track determinations in the area between Szklarska Poręba and Pasiecznik/Barcinek were as follows: – apatite from 63±9 to 121±10 Ma; – titanite from 328±32 to 489±43 Ma; – zircon from 311±19 to 469±51 Ma (Jarmołowicz-Szulc, 1984).These minerals were separated from the same rock types as described in the present paper. The FT age diversity was obtained in reference to the lithology and the relative distance from the surficial contact between the Karkonosze massif and its cover. Apart from the apatite, the closure temperature of which is much lower than that of the K-Ar system, the present K-Ar age values may be compared with the FT ages of titanite and zircon. Therefore, they are presented in the figure together with quoted FT data as a function of a relative distance from the surficial contact between the Karkonosze massif and its metamorphic envelope in Szklarska Poręba (**Fig. 5**). According to the suggestions of numerous researchers (e.g. Oberc, 1972), the Karkonosze granite underlies its northern cover, dipping gently northward at the angle of several degrees. That was confirmed by a total rejuvenation of the apparent fission track ages of zircons and titanites in the Izera granite and gneisses (Jarmołowicz-Szulc, 1984).

It is clearly seen in the figure, that in majority, the K-Ar biotite data correspond to the lower values of the titanite and zircon fission track ages close to 320 Ma (e.g. 328±32 Ma and 311±19 Ma) and interpreted as the reset age due to the emplacement of the Variscan granitoid body of the Karkonosze massif. They are also close to the age values for the granitoid body reported by D. Marheine and co-authors ($^{40}Ar/^{39}Ar$ plateau, muscovite, 324-320 Ma; Marheine *et al.*, 2002).

In contrary to the geochronological fission track determinations for titanite and zircon, which display an evident "jump" in values north of the Stara Kamienica belt, the K-Ar data obtained recently are more homogeneous. They do not show a characteristic differentiation – much lower dates in the south, higher in the north, as in the case of fission track ages in zircon and sphene (**Fig. 5**), although a slight increase northward may be noticed.

The biotite K-Ar age values of the Izera granite-gneisses complex seem, therefore, to be almost uniformly resetted by the Karkonosze granite, in the area spreading from Wysoki Grzbiet Izerski in the south and Pasiecznik in the north.

As it is seen in the tables, there are some exceptions to this rule. Two K-Ar age values are much below 300 Ma, whereas other three are much higher than the majority of age data.

The lowest values correspond to determinations performed on whole rock samples and in a general context, they seem to be too low and rather controversial. The samples evidently display lower potassium content, and the determination uncertainity is, therefore, very high. The change in potassium content (a decrease in respect to the other rock varieties) that strongly influenced age data may be explained by transformation of biotite into chlorite and by K-feldspar breakdown and increase of white mica due to deformation. Such phenomena were observed in the rocks in the studied area, while similar relations and mechanisms were described by D. Białek in the rocks of the Zawidów complex adjacent to the studied ones (Białek, 1999). Moreover, as it results from the XRD determinations, these samples have a high component of light minerals (quartz and feldspars; **Fig. 6**) that negatively influence the age results.

The performed XRD analysis enabled a detailed determination of mineral composition of the concentrates. The macroscopically distinguished biotite which displays

Table 2. *The K-Ar age data for biotite and amphibole from the rocks from the northern envelope of the Karkonosze granitoid body (volumetric method – archive data).*

Archive number	Sample	Location and description	K (%)	Age*(Ma)
850/Ar	B 69 biotite	Baszty near Barcinek, Izera granite	6.35	322 ± 22
851/Ar	C 101 biotite (+amphibole)	Wysoki Grzbiet Izerski, biotite schist	4.40	311 ± 21
852/Ar	C 126 biotite (+amphibole)	Więziec (N), granodiorite	4.00	372 ± 26
853/Ar	A 25 biotite	Zaroślak, Izera granitoid	5.54	308 ± 21
858/Ar	A 17 biotite	Szklarska Poręba, Karkonosze granite	6.00	320 ± 22
865/Ar	C 142 amphibole	Wojcieszyce, amphibole schist	2.43	370 ± 26

**The analytical error is estimated as about 7% and is connected with: – analytical error of potassium determinations , – error of argon analysis.*

Average age 315 ± 22 Ma (based on four values; two highest data excluded).

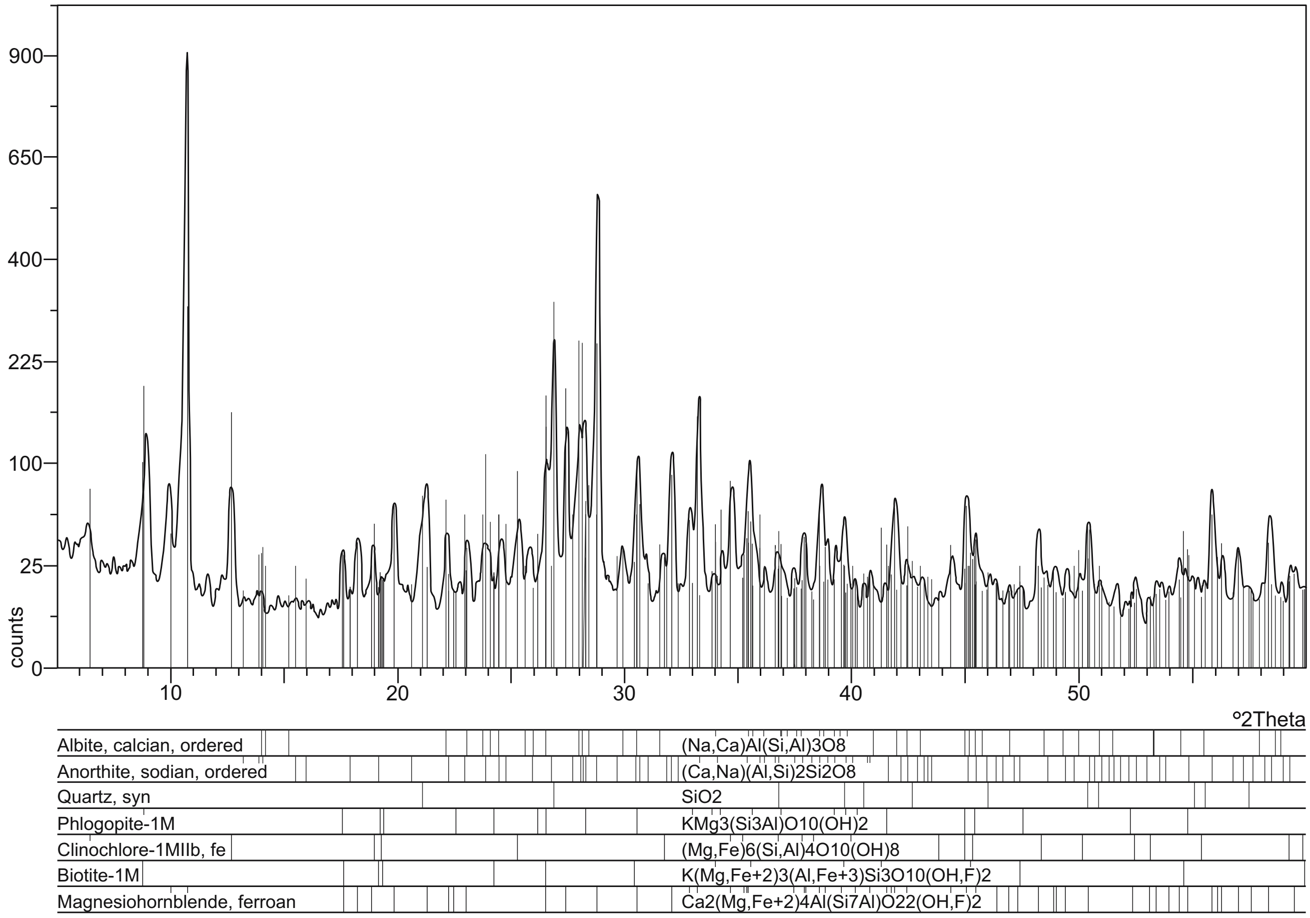

Fig. 6. *X-ray diffractogram of the dated concentrate (sample B 58b). Explanations: Bio – biotite, Phlo – phlogopite, Fel – feldspars, Chl – chlorite, Amph – amphibole, Q – quartz.*

a high potassium content is not chloritized (samples A 25, A 17, B 53, B 69, C 135) or slightly chloritized (samples B 50, C 123). The whole rock samples (amphibolites), however, have the following composition: amphibole, chlorite, feldspars, biotite, quartz – at different proportions. The percentage of light minerals and chlorite influences the K content to such an extent that the apparent age values of 226 and 234 Ma must be considered as insignificant from the geochronological point of view, i.e. unreliable.

Northwards of the Pasiecznik settlement (**Figs. 2, 4**), the age values are of mixed character. This is reflected by “the oldest” K-Ar data (386.1±3.0 Ma, C 135 in **Table 1** and 372±26 Ma, C 126 in **Table 2**) which are older than the Variscan values and younger than the Izera granite intrusion ages. Despite a high uncertainity of the age values, a group of four determinations – K-Ar age values (samples C 135, C 126, C 142) and FT titanite (C 173.1) – may be combined there. They somewhat resemble the data presented by D. Marheine and co-authors (Marheine *et al.*, 2002) based on Maluski and Patočka data (1997) but there is no evidence for the same interpretation. These K-Ar/FT values may correspond to the not total resetting of the isotopic clock and are mixed ages between the Karkonosze granite and Izera granite ages.The Variscan values of the K-Ar biotite age for the Izera granites shown in the present paper display a distinct conformity to the data reported by J. Borucki for the Karkonosze granite (Borucki, 1966), the Izera reset Rb-Sr ages in the interval from 310 to 320 Ma (Borkowska *et al.*, 1980) as well as to 328±12 Ma (Duthou *et al.*, 1991). The only K-Ar age for biotite from the Karkonosze granite (320±22 Ma, A 17, **Table 2**.) also confirms these age data as well as the mean of the K-Ar reset ages from the whole area. Most biotite K-Ar values of the Izera granites complex give, namely, an average of 316.1±3.3 Ma (**Table 1**). This value corresponds in its error limits to e.g. SHRIMP zircon ages of about 318-314 Ma for the Karkonosze granites (Machowiak and Armstrong, 2007). The apparent ages of 301±3 Ma, 289±3 Ma (Marheine *et al.*, 2002) and 290.0±2.5, 284.8±7.2 Ma (this paper) may be regarded as minimum ages which probably postdate the latest granite intrusion of the Krknoše-Jizera pluton (310±5 Ma, Mierzejewski *et al.*, 1994; 304±14 Ma, Kröner *et al.*, 1994; 312±2 Ma, Marheine *et al.*, op. cit.).

7. CONCLUSIONS

1) The K-Ar ages in the northern envelope of the Karkonosze granite are the reset values and reflect the influence of the granitoid on its envelope.
2) The apparent K-Ar age results may be arranged into three groups: (1) dominant, from 284.8±7.2 Ma to 338.6±2.8 Ma; (2) subordinate, from 370±22 Ma to

386.1±3.0 Ma; (3) insignificant, from 226.7±6.7 Ma to 234.1±8.2 Ma.

3) The interpretation of the obtained results may be as follows:

- Average of 316±3.3 Ma – the reset of the K-Ar clock – corresponding to the influence of the Karkonosze pluton;
- < 300 Ma – minimum age postdating the last granite intrusion of the Krkonoše-Jizera pluton.
- The ages >370 Ma are mixed between the Izera granite intrusion and the Karkonosze granite ages.

4) The K-Ar age distribution in the studied region has a different pattern than that of FT in zircon and titanite in the same area.

ACKNOWLEDGEMENTS

We are grateful to Dorota Bakowska from the Institute of Geological Sciences, Polish Academy of Sciences, Kraków, for potassium determinations in newly dated samples.

Constructive reviews of Marek Michalik and Stanisław Mikulski are acknowledged and highly appreciated.

Pete Modreski from USGS is thanked for language corrections.

REFERENCES

Aleksandrowski P and Mazur S, 2002. Collage tectonics in the northeasternmost part of the Variscan Belt: the Sudetes, Bohemian Massif. In: Winchester JA, Pharaoh TC and Verniers J, Eds., Amalgamation of Central Europe. *Geological Society Special Publications* 201: 237-277.

Białek D, 1999. Chemical changes associated with deformation of granites under greenschist facies conditions: the example of the Zawidów Granodiorites (SE Lusitian Granodiorite Complex, Poland). *Tectonophysics* 303: 251-261, DOI 10.1016/S0040-1951(98)00248-0.

Borkowska M, Hameurt J and Vidal P, 1980. Origin and age of Izera gneisses and Rumburk granites in the Western Sudetes. *Acta Geologica Polonica* 30: 121-145.

Borucki J, 1966. Wstępne wyniki datowań bezwzględnych K-Ar granitoidów dolnośląskich. (Preliminary results of absolute K-Ar dating of the Lower Silesia granitoids). *Kwartalnik Geologiczny* 10: 1-18 (in Polish).

Duthou JL, Couturie JP, Mierzejewski MP and Pin C, 1991. Next dating of granite sample from the Karkonosze Mountains using Rb-Sr total rock isochrone method (in Polish with English summary). *Przegląd Geologiczny* 36: 75-79.

Hałas S, 1995. Geochronologia izotopowa oparta na rozpadzie promieniotwórczym potasu-40. (Isotope geochronology based on radioactive decay of potassium-40). *Przegląd Geologiczny* 43: 993-998 (in Polish).

Jarmołowicz-Szulc K, 1984. Geochronologiczne studium części północnej osłony granitu Karkonoszy za pomocą metod trakowych. *Archiwum Mineralogiczne* 39: 139-183.

Korytowski A, Dörr W and Żelaźniewicz A, 1993. U-Pb dating of (meta-) granitoids in the NW Sudetes (Poland) and their bearing on tectonostratigraphic correlation. *Terra Nova* 5, Abstract Supplement no 1: 331-332.

Kröner A, Hegner E, Hammer J, Haase G, Bielicki K-H, Krauss M and Eidam J, 1994. Geochronology and Nd-Sr systematics of Lusatian granitoids: significance for the evolution of the Variscan orogen in east-central Europe. *Geologische Rundschau* 83: 357-376.

Machowiak K and Armstrong R, 2007. SHRIMP U-Pb zircon age from the Karkonosze granite. *Mineralogia Polonica Special Papers* 31:193-196.

Maluski H and Patočka F, 1997. Geochemistry and 40Ar-39Ar geochronology of the mafic metavolcanic rocks from the Rýchory Mountains complex (west Sudetes, Bohemian Massif): paleotectonic significance. *Geological Magazine* 134: 703-716.

Marheine D, Kachlik V, Maluski H, Patočka F and Żelaźniewicz A, 2002. The $^{40}Ar/^{39}Ar$ ages from the West Sudetes (NE Bohemian Massiv): constraints on the Variscan polyphase tectonothermal development. In: Winchester JA, Pharaoh TC and Verniers J, Eds., Amalgamation of Central Europe. *Geological Society Special Publications* 201: 133-155.

Mierzejewski MP, Pin C, Duthou JL and Couturie JP, 1994. Sr-Nd isotopic study of the Karkonosze granite (Western Sudetes). In: Kryza R, Ed., Igneous activity and metamorphic evolution of the Sudetes area. *Abstracts*. Wrocław University. 82.

Mikulski SZ and Stein H, 2007. Re-Os age for molybdenite from the West Sudetes, SW Poland. *Graintoids in Poland*, AM Monograph 1: 203-216.

Mochnacka K, Oberc-Dziedzic T, Mayer W and Pieczka A, 2008. Ti remobilization and sulphide/ sulphoarsenide mineralization in amphibolites: effect of granite intrusion (the Karkonosze-Izera Massif, SW Poland). *Geological Quarterly* 52: 349-368.

Oberc J, 1972. *Budowa Geologiczna Polsk*i, t. 4., Tektonika, cz. 2, Sudety i obszary przyległe (Geological structure of Poland. Vol. 4, Tectonics, Part 2, Sudetes and the adjacent area). Wydawnictwa Geologiczne. Warszawa (in Polish): 307 pp.

Oberc-Dziedzic T, 1988. The development of gneisses and granites in the eastern part of the Izera crystalline unit in the light of the textural investigations. *Acta Universitatis Wratislaviensis* 997; Prace Geol-Miner 13:1-184. (in Polish with English summary).

Oberc-Dziedzic T, Pin C and Kryza R, 2005. Early Palaeozoic crustal melting in an extensional setting: petrological and Sm-Nd evidence from the Izera granite-gneisses, Polish Sudetes. *International Journal of Earth Sciences* 94: 354-368, DOI 10.1007/s00531-005-0507-y.

Oberc-Dziedzic T, 2007. Early Palaeozoic Izera (Rumurk) granites from West Sudetes, Poland, *Graintoids in Poland*, AM Monograph 1: 101-110.

Oliver GHJ, Corfu F and Krogh TE, 1993. U-Pb ages from SW Poland: evidence for a Caledonian suture zone between Baltica and Gondwana. *Journal of Geological Society* 150: 355-369, DOI 10.1144/gsjgs.150.2.0355.

Philippe S, Haack U, Żelaźniewicz A, Dörr W and Franke W, 1995. Preliminary geochemical and geochronological results on shear zones in the Izera-Karkonosze Block (Sudetes, Poland). *Terra Nostra* 8:122.

Pin C, Mierzejewski MP and Duthou JL, 1987. Wiek izochronowy Rb/Sr granitu karkonoskiego z kamieniołomu Szklarska Poręba Huta oraz oznaczenie stosunku inicjalnego $^{87}Sr/^{86}Sr$ w tymże granicie. (Rb-Sr isochron age of the Karkonosze granite from the quarry Szklarska Poręba Huta and determination of its $^{87}Sr/^{86}Sr$ initial ratio). *Przegląd Geologiczny* 35: 512-517 (in Polish).

Przewłocki K, Magda W, Thomas HH and Faul H, 1962. Ages of some granitic rocks in Poland. *Geochimica et Cosmochimica Acta* 26: 1069-1075.

Turniak K, Hałas S and Wójtowicz A, 2007. New K-Ar cooling ages of graitoids from the Strzegom-Sobótka Massif, SW Poland. *Geochronometria* 27: 5-9, DOI 10.2478/v10003-007-0019-9.

Żelaźniewicz A, Nowak I, Achramowicz S and Czapliński W, 2003. The northern part of the Izera-Karkonosze block: a passive margin of the Saxothuringian terrane. In: *Sudety Zachodnie od wendu do czwartorzędu*, eds. W. Ciężkowski, J. Wojewoda and A. Żelaźniewicz, WIND, Wrocław: 17-32. (in Polish with English summary).