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HIGH-TEMPERATURE RESTITE ENCLAVE AS AN EVIDENCE OF DEEP-SEATED PARENT MAGMA MELTING OF THE BĘDKOWSKA VALLEY GRANODIORITE (SILESIAN-CRACOW AREA, SOUTH POLAND) – PRELIMINARY PETROGRAPHIC AND MINERALOGICAL STUDY

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Abstract: In the borehole DB-5, at a depth 1370.0 m dark micaceous enclave in granodiorite from Będkowska Valley was found. A sharp contact enclave/granodiorite is observed. The transition zone is irregularly developed around the enclave studied. It is a small enclave (3 x 6 cm), discoidal in shape. The microstructure of micaceous enclave is fine-blastic; crystalloblasts of rock-forming minerals are 0.2–0.5 mm in size. This enclave consists of: Fe-biotite (56–62 vol.%), plagioclase Ca-Na (34–40 vol. %), spinel (magnetite), corundum, and sericitic pseudomorphs after cordierite. Its mineralogical composition is different from the Będkowska Valley granodiorite, what suggests that this rock is a medium/high-temperature restite. This rock represents residuum after partial melting of granodiorite magma in deep levels of basement of the Małopolska Massif.

Key words: Będkowska Valley granodiorite, dark micaceous enclave, restite.

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INTRODUCTION

The Silesian-Cracow area (also called Cracow-Lubliniec or Cracow-Myszków zone) is a narrow zone striking NW–SE and situated in southern Poland near Kraków.

Stratigraphic, lithologic and tectonic data indicate that it is a major fault zone cross-cutting the Silesian-Cracow area and defining the boundary between Upper Silesian and Mało- polska blocks (terranes). Its localization and characteristics are described by numerous authors (vide Żaba, 1999; Buła, 2000). According to Harańczyk (1994a, b) and Unrug *et al.* (1999), a small terrane Lubliniec-Zawiercie-Wieluń occurs in the basement of the Silesian-Cracow area. The boundary fault zone between the Upper Silesian and Małopolska blocks is presented in Fig. 1.

The tectonic Jerzmanowice block occurs in the southern part of the elevated margin of the Małopolska block in its boundary zone with the Upper Silesian block. It represents fragment of Cracovides (Harańczyk, 1982, 1994 a, b). In the core of this block there occurs a granodiorite intrusion situated in the Będkowska Valley. In deep levels of the Palaeozoic basement of elevated margin of the Małopolska block granodiorite intrusions were found (by boreholes) in four areas: Będkowska Valley, Zawiercie, Pilica, and Myszków-Mrzygłód. It is supposed that these intrusions are representing apophyses of a larger (ca. 100 km in size) granitoid batolith located at deeper horizons (Żaba, 1999). All these granodiorite bodies are representing hypoabyssal levels of intrusion (Karwowski, 1988; Kośnik & Muszyński, 1990). They have the same petrological character what indicates the same age and genesis.

The granodiorite intrusion in the Będkowska Valley is the cause of distinct magnetic anomaly indicating its size to be about 10–12 km in diameter (Skorupa, 1953). The depth of its emplacement is estimated at 8 km (Harańczyk *et al.*, 1995). In this author's (Harańczyk *et al.*, 1995) opinion, the localization of this intrusion at the margin of Małopolska block at the crossing of two dislocation systems: compressional fault parallel to the Zawiercie-Rzeszotary terrane suture zone and perpendicular to the former Będkowska Valley fault, indicates it to represent a stitching intrusion.

In the Krzeszowice area, the enclaves of microgranodiorites and micromonzodiorites in young Palaeozoic rhyodacite porphyries were found. These enclaves were described from a dyke in Siedlec (Gaweł, 1955), in the Zalas laccolith (Heflik & Muszyński, 1993; Muszyński & Czerny,

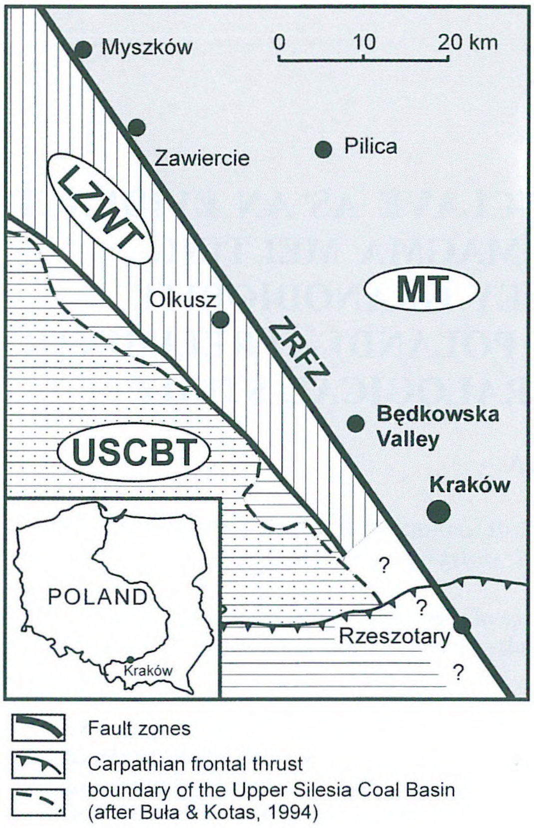

Fig. 1. Localization of granodiorite intrusion from Będkowska Valley (after Harańczyk 1988, 1994a). LZWT – Lubliniec-Zawiercie-Wieluń Terrane; USCBT – Upper Silesian Coal Basin Terrane; MT – Małopolska Terrane; ZRFZ – Zawiercie-Rzeszotary Fault Zone (Terrane Suture Zone)

1999; Lewandowska & Bochenek, 2001), and within the Miękinia extrusion (Rozen, 1909; Czerny & Muszyński, 2002).

The occurrence of metamorphic rock enclaves in the Będkowska Valley granodiorite has not been reported till now.

GRANODIORITE FROM BĘDKOWSKA VALLEY

The Będkowska Valley is situated 20 km west of Kraków. In the central part of this Jurassic valley several boreholes were located (Harańczyk *et al.*, 1995). The granodiorite intrusion was drilled only in two boreholes DB-5 and WB-102 A at depths of 1092.0 m and 1142.7 m, respectively and it was not penetrated to the bottom till 1406.9 m and 1455.0 m, respectively, (Harańczyk *et al.*, 1995).

Petrographic studies of the Będkowska Valley granodiorite were carried out by several authors (Kośnik & Muszyński, 1990; Harańczyk *et al.*, 1995; Płonczyńska, 2000; Wolska, 2000). This is a white-grey, holocrystalline rock, often showing porphyritic texture. It consists of zoned plagioclases (oligoclase-andesine), showing predominantly lamellar twining albite law, albite-Carlsbad law, rarely pericline, Carlsbad and Ala-A laws (Płonczyńska, 2000). Besides, there occur anhedral alkali feldspars. They represent orthoclase microperthite, more rarely orthoclase or microcline (Płonczyńska, 2000). Quartz (10–15 vol.%) shows slight dynamic deformations (Płonczyńska, 2000). Dark minerals in granodiorite are represented by dark brown biotite occurring in variable amounts (10–35 vol.%) and green hornblende (Harańczyk *et al.*, 1995). Among accessories, there occur zircon, sphene and apatite. Locally, xenotime was found in the granodiorite studied (Harańczyk *et al.*, 1995).

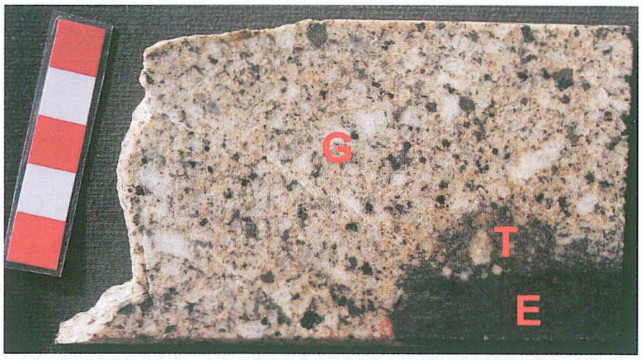

Fig. 2. Dark micaceous enclave in granodiorite from Będkowska Valley – borehole DB-5 depth 1370.0 m. E – enclave; T – transition zone; G – granodiorite

The intrusion of the Będkowska Valley granodiorite caused thermal alteration of Early Palaeozoic country rocks, forming fairly wide contact zone consisting of fine-crystalline cordierite and andalusite hornfelses (Koszowska & Wolska, 2000a, b). They were formed from protolith consisting of mudstones and pelites under conditions of medium to high-grade contact metamorphism, corresponding to hornblende-hornfels and orthoclase-cordierite-hornfels facies at temperature range from about 500 to 630°C.

As already reported (Harańczyk *et al.*, 1995), the Będkowska Valley granodiorite is penetrated by apophyses of "porphyritic" granodiorite, as well as by diabase, andesite, rhyodacite dykes and it is cut by potassium rhyolite neck. Granodiorite body and dykes of magmatic rocks were subjected to hydrothermal alterations related with mineralization of Cu-Mo porphyry type deposits. Biotitization and K-feldspathization (of the so called "potassic silicate"), sericitization, and argillitization are the processes evidenced in granodiorite body (Wolska, 2000). These alterations are selective in character and developed around later veins (Wolska, 2000). Ore veins cutting feldspathic zone contain chalcopyrite, pyrite and molybdenite (Harańczyk *et al.*, 1995).

In the core material from the borehole DB-5 at a depth of 1370.0 m a fragment of dark enclave was found, showing discoidal shape, megascopically differing distinctly from the Będkowska Valley host granodiorite (Fig. 2).

Preliminary petrographic-mineralogical studies were carried out using petrological polarizing microscope Amplival (Carl Zeiss Jena) and electron scanning microscope JEOL-5410 equipped with dispersive energy spectrometer Voyager 3100 (NORAN), enabling microprobe analysis of rock-forming minerals.

Small volume of this enclave did not allow to perform chemical analysis of the whole rock.

MEGASCOPIC CHARACTERISTICS OF ENCLAVE-CONTAINING HOST GRANODIORITE

BĘDKOWSKA VALLEY GRANODIORITE

This enclave-embedding rock is light pinkish-gray in colour, showing holocrystalline, medium-crystalline structure and locally porphyritic and unoriented structure (Fig. 2). It contains large (0.5–1.0 cm) tabular, white feldspar crystals and dark biotite flakes, 0.1–0.5 cm in size. The groundmass is light pink in colour due to the presence of pinkish K-feldspar, accompanied by plagioclases, quartz and biotite. These minerals are 0.1–0.2 cm in size.

TRANSITION ZONE

This reaction zone is irregularly arranged around the enclave. Locally, this zone is lacking and a sharp contact enclave/granodiorite is observed (Fig. 2). The colour of the groundmass in transition zone is black compared with normal granodiorite. Sporadically, there occur white feldspar plates, 0.2–0.5 cm in size. The boundary between enclave and transition zone is distinct and sharp (Fig. 2). The formation of reaction zones at the boundary enclave/granite is a common phenomenon and the mechanism of developing this process was described by Didier (1973).

DARK MICACEOUS ENCLAVE

The contact of yhe enclave both with granodiorite and, locally, with transition zone is sharp and distinct. The enclave in question represents, probably, a fragment of a larger zone (Fig. 2). It is 3 × 6 cm in size but the diameter of the drilling core has forced its shape. Consequently, it cannot be defined. It is dark green in colour and showing very fine-crystalline structure. In the groundmass very small flakes of dark micas (biotite) are observed.

Both granodiorite and enclaves are cut by veinlets (below 0.1 cm thick) of light pink feldspar. The occurrence of K-feldspar veinlets is connected with the ativity of mineralising solutions related with the formation of the porphyry-type Cu-Mo deposits (K-feldspathic zone). The alterations were developed both in granodiorite (Wolska, 2000) and in dykes of igneous rocks (Harańczyk *et al.*, 1995).

ENCLAVE CHARACTERISTICS

The rock shows very fine-crystalline microstructure and contains inclusions and mutual intergrowth of some minerals (poikiloblastic microstructure). The number and content of biotite flakes is diversified when compared with the amount of light minerals (mainly plagioclases). Locally, some stripes and lenses enriched in biotite are observed.

The most important coloured mineral is chaotically distributed olive-brown biotite occurring as anhedral, often mutually intergrown, flakes (Fig. 3) of variable size (0.04–0.11 mm wide and 0.09–0.32 mm long). This biotite shows intense pleochroism: α light yellow, γ olive-brown. The z/γ extinction angle amounts to 2–3°. Very small zircon and mainly monacite inclusions within biotite flakes are surrounded by numerous pleochroic haloes. The MgO content in biotite varies from 8.32 to 9.25 wt.% and that of FeO – 23.36–24.42 wt.%. Fe/Mg atomic ratio amounts to 1.43–1.65 and $FeO_{tot.}/MgO$ – 2.55–2.94. The TiO_2 and MnO contents amount to 2.43–3.15 wt.% and 0.38–0.69 wt.%, respectively. The results of chemical analyses of olive-brown biotites studied are presented in Table 1. On the classification diagram (Fig. 4), the olive-brown biotites are plotted in its higher part. Very small biotite flakes (0.01–0.03 mm in size) are often intergrown with plagioclases (Fig. 5).

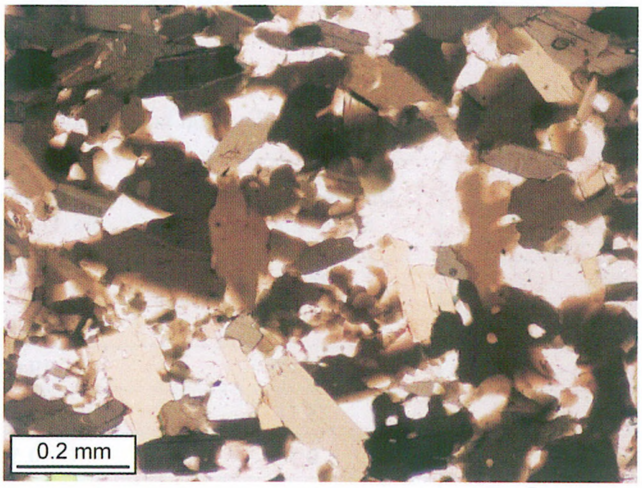

Fig. 3. Olive-brown biotite – dark micaceous enclave, borehole DB-5 depth 1370.0 m. Plane-polarized light

Light minerals are represented mainly by plagioclase crystalloblasts, 0.04–0.21 mm in size, fairly well preserved and colourless. They form anhedral crystalloblasts, only rarely showing repeated lamellar twinned, usually according to albite law. However, the bulk of them shows no twinning but patchy structure. Chemical analysis (Table 2) indicates that these plagioclases are represented by labradorite ($Ab_{44}An_{55}Or_1$) and andesine ($Ab_{52}An_{46}Or_2$), or less common oligoclase ($Ab_{74}An_{25}Or_1$).

The rock contains pseudomorphs (Fig. 6) filled with fine-grained white mica incrusted with very small blasts of opaque minerals (0.007–0.03 mm in size). These are, probably, pseudomorphs after cordierite filled with a mixture of sericite and an admixture of minerals of chlorite and serpentine group ("pinite"). Microprobe chemical analyses have shown local occurrence of "relict" cordierite of mainly normative composition, but usually there were mixtures of non-stoichiometric composition containing SiO_2, FeO, MgO, and Al_2O_3 with some K_2O admixture. The results of chemical analyses of cordierite from the enclave studied compared with cordierites from other rocks are presented in Table 3.

Corundum occurs within light minerals (plagioclases) and within pseudomorphs filled to variable degree with sericite. Large corundum crystalloblasts (ca. 0.1 mm) are euhedral or subhedral (Fig. 7) and occur separately, whereby,

Table 1

Chemical composition (in wt.%): of different types of biotites from dark micaceous enclave and granodiorite (transition zone) from Będkowska Valley, and hornblende from granodiorite (transition zone) from Będkowska Valley

Oxides	Olive-brown biotite no.107 enclave		Olive-green biotite no. 113 enclave		Red-brown biotite np. 51 granodiorite transition zone		Hornblende no. 23 granodiorite	
SiO_2	34.78		35.22		37.51		50.91	
TiO_2	2.48		2.01		4.84		0.57	
Al_2O_3	19.17		19.02		13.84		4.04	
FeO	23.71		23.81		19.96		15.41	
MnO	0.50		0.51		0.52		0.63	
MgO	8.90		9.22		13.02		14.77	
CaO	0.00		0.00		0.01		11.94	
Na_2O	0.00		0.00		0.31		1.42	
K_2O	10.45		10.22		9.99		0.33	
Total	99.99		100.01		100.00		100.02	
	recalculated to 22 O		recalculated to 22 O		recalculated to 22 O		recalculated to 23 O	
Si	5.192		5.246		5.501		7.335	
Al	2.808	8.00	2.754	8.00	2.393	8.00	0.665	8.00
Ti					0.106			
Al	0.565		0.585		–		0.021	
Ti	0.226		0.278		0.428		0.061	
Fe^{2+}	2.960	5.44	2.966	5.94	2.448	5.79	1.857	5.19
Mn	0.064		0.063		0.064		0.076	
Mg	1.981		2.047		2.847		3.172	
Ca	–		–		0.002		1.844	
Na	–	1.943	–	1.991	0.089	1.96	0.395	2.3
K	1.943		1.991		1.869		0.061	
OH	2.00		2.00		2.00		2.00	
Fe/Mg	1.49		1.45		0.86		0.59	
$FeO_{tot.}/MgO$	2.66		2.58		1.53		1.04	
$Fe_{tot.}/Fe_{tot.} + Mg$	0.61		0.59		0.46			

small blasts (0.03 mm) form the so-called bead-like forms. This mineral exhibits weak but distinct, often spotty, pleochroism from light green (ε) to light blue (ω). Microprobe chemical analysis has shown that more pleochroic blasts contain more Fe_2O_3 (0.95–1.84 wt.%) and significant admixture of WO_3 (0.10–0.75 wt.%) what was not reported for corundum till now.

Opaque minerals occur chaotically in the enclave studied as subhedral or anhedral blasts, 0.02–0.26 mm in size. They are represented mainly by magnetite containing 0.23–0.46 wt.% V_2O_5. Very small aggregates (blasts) of opaque minerals (0.007–0.03 mm in size) occur within pseudomorphs after cordierite.

Besides, heterogeneities of "light spot" type are observed in the enclave studied, composed predominantly of anhedral plagioclases, 0.03–0.15 mm in size, and small biotite flakes (0.01–0.13 mm in size).

Within the enclave studied there are zones in which larger olive-green biotite flakes and few light minerals (mainly plagioclases) occur. Biotite is forming there coarser agglomerates when compared with biotites in fine-crystalline enclave (Fig. 8). The size of biotite flakes in this zone varies from 0.11 to 0.75 mm. It is characterized by intense pleochroism from light yellow (α) to olive-green (γ). The z/γ extinction angle amounts to 5°. Opaque minerals are evolving along cleavage cracks. Biotites in this zone contain

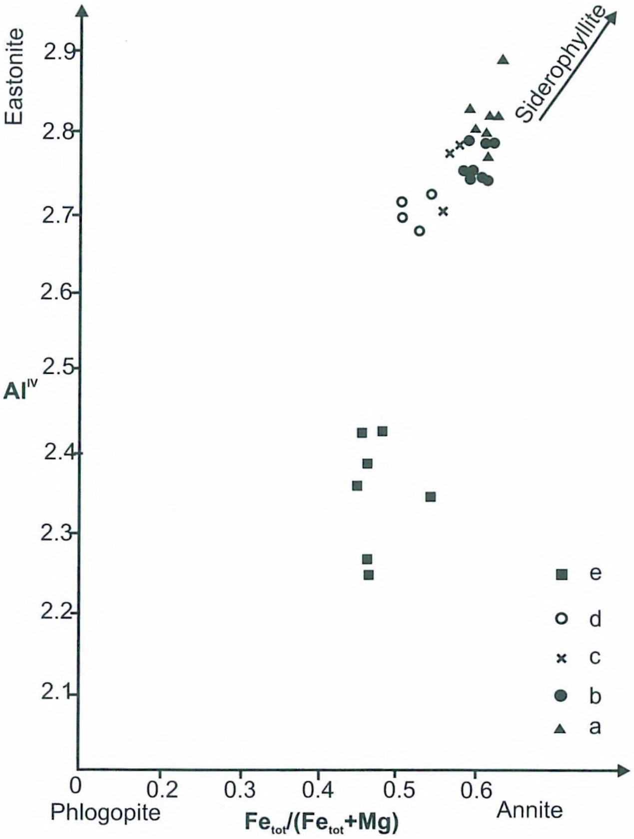

Fig. 4. Al^{IV} - $Fe_{tot}/(Fe_{tot}+Mg)$ classification diagram of biotites; the position of biotites from micaceous enclaves and granodiorite from the Będkowska Valley. a – olive-brown biotites (dark micaceous enclave); b – olive-green biotites (dark micaceous enclave); c – olive-green biotites (transition zone in enclave); d – olive-brown biotites (transition zone in enclave); e – red-brown biotites (transition zone in granodiorite)

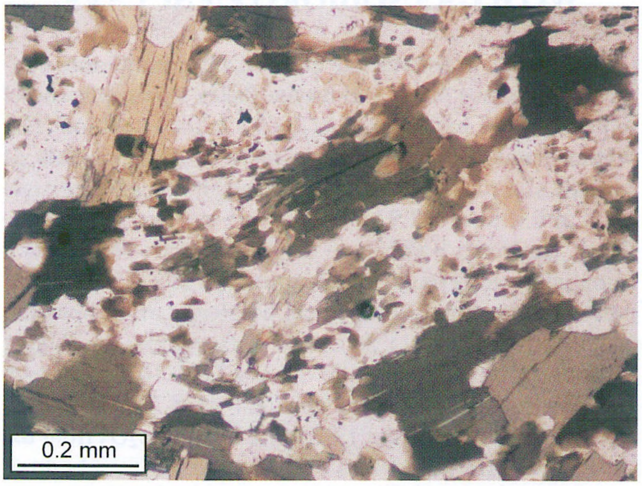

Fig. 5. Intergrowth of biotites flakes in sericitic pseudomorphs after cordierite in dark micaceous enclave, borehole DB-5, depth 1370.0 m. Plane-polarized light

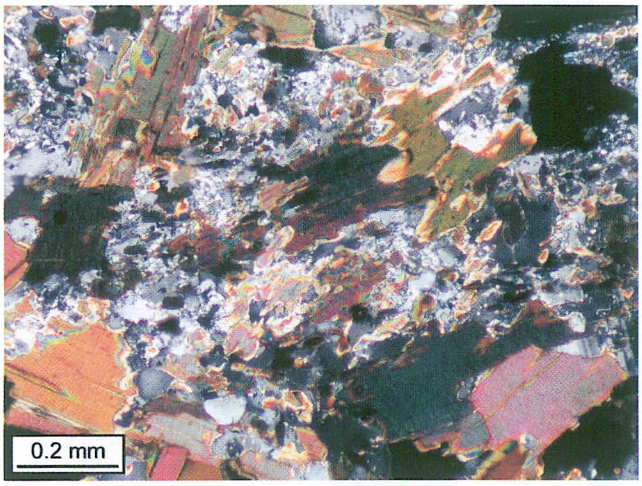

Fig. 6. Pseudomorph after cordierite filled with fine-grained light mica (sericite) in dark micaceous enclave, borehole DB-5, depth 1370.0 m. Crossed polars

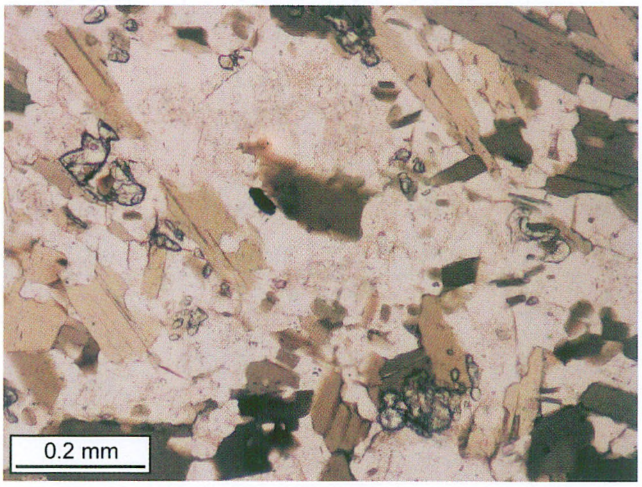

Fig. 7. Euhedral and subhedral corundum crystalloblasts in dark micaceous enclave, borehole DB-5, depth 1370.0 m. Plane-polarized light

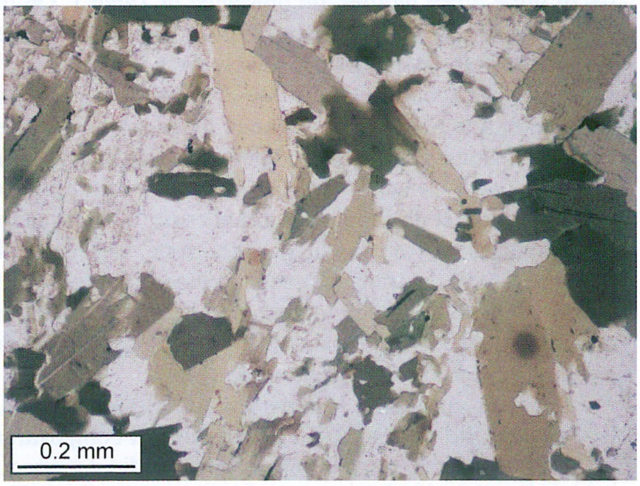

Fig. 8. Olive-green biotite in dark micaceous enclave (transition zone), borehole DB-5, depth 1370.0 m. Plane-polarized light

Table 2

Chemical composition of plagioclases (in wt.%): from dark micaceous enclave and granodiorite (transition zone) from the Będkowska Valley

Oxides	Labradorite no. 38 enclave	Andesine no. 8 enclave	Andesine no. 15 enclave-transition zone	Oligoclase no. 14 enclave-transition zone	Andesine (inner part) no.59 granodiorite transition zone	Oligoclase (outer part) no. 60 granodiorite transition zone	K-feldspar no. 41 granodiorite transition zone
SiO_2	54.52	56.48	61.12	61.97	58.83	61.22	64.69
Al_2O_3	29.20	27.54	24.94	24.21	25.94	24.96	18.64
Fe_2O_3	0.00	0.15	0.00	0.00	0.00	0.00	0.00
CaO	11.25	9.49	6.91	5.37	8.07	5.98	0.00
Na_2O	4.91	6.01	6.81	8.09	6.79	7.51	1.03
K_2O	0.11	0.33	0.23	0.36	0.37	0.33	15.64
Total	99.99	100.00	100.01	100.00	100.00	100.00	100.00
	at 32 O	at 32 O	at 32 O	at 32 O	at 32 O	at 32 O	at 32 O
Si	9.826	10.153	10.837	10.983	10.518	10.858	11.944
Al	6.203	5.832	5.212	5.056	5.467	5.217	4.057
Fe^{3+}	–	0.020	–	–	–	–	–
Na	1.175	2.092	2.340	2.779	2.253	2.582	0.368
Ca	2.173	1.828	1.312	1.019	1.546	1.135	–
K	0.026	0.076	0.051	0.082	0.084	0.075	3.684
Ab	43.8	52.4	63.2	71.6	59.1	68.2	9.1
An	55.5	45.7	35.4	26.3	38.8	29.9	–
Or	0.7	1.9	1.4	2.1	2.1	2.0	90.9

8.95–9.52 wt.% MgO and 23.28–24.62 wt.% FeO. Atomic Fe/Mg ratio amounts to 1.38–1.54, and $FeO_{tot.}/MgO$ 2.44–2.75. The TiO_2 and MnO contents are 1.92–2.19 wt.% and 0.37–0.68 wt.% respectively. The results of chemical analyses of olive-green biotites are presented in Table 1. On the Al^{IV} - $Fe_{tot}/(Fe_{tot}+Mg)$ diagram (Fig. 4) the biotites studied are plotted in the same field as olive-brown biotites.

Small plagioclase blasts (0.04–0.21 mm in size) occur between biotite flakes. Only some of them exhibit repeated lamellar twinning structure whilst the majority of them shows a patchy one. Their chemical composition corresponds to more sodic plagioclases: andesine ($Ab_{63}An_{36}Or_1$) and oligoclase ($Ab_{72}An_{26}Or_2$). This zone was probably formed close to the transition zone to granodiorite or at the contact with K-feldspahtic zone. The latter ones are connected with the later mineralization of porphyry Cu-Mo deposits, superposed on the granodiorite body.

The dark micaceous enclave from theBędkowska Valley granodiorite shows the following mineral composition: biotite, plagioclase, pseudomorphs after cordierite, opaque minerals and corundum (Table 4).

CHARACTERISTICS OF TRANSITION ZONE IN GRANODIORITE AT THE CONTACT WITH GRANODIORITE/ENCLAVE

In contact zone with the enclave, the granodiorite contains plagioclase plates and biotite flakes, arranged parallel to boundary of the two rocks (Fig.9). In the transition zone within granodiorite there occur more opaque minerals of variable size (0.03–0.42 mm). Prismatic hornblende crystals (0.74 mm wide and 2.92 mm long) are more or less altered. Green, unaltered hornblende displays distinct pleochroism from light yellow (α) to intense green (γ). Its chemical composition corresponds to a typical horblende of hornblende-edenite series (Table 1). At a short distance from the contact there occur relict hornblende crystals (Fig. 10) intergrown with blasts of Nb-bearing sphene (0.38 wt.% Nb_2O_5), showing zoned structure (from 1.07 to 1.61 wt.% Fe_2O_3 from the core to outer rim) as well as opaque minerals (mainly ilmenite).

At a distance of ca. 1 mm from the boundary line there appear clouded plagioclase crystals, 0.83–0.2.71 mm in size, showing zoned structure. Their inner parts consist of

Table 3

Chemical composition (in wt.%) of cordierite from dark micaceous enclave studied compared with cordierites of other rocks (after: Stewart, 1942; Mathias, 1952; Chinner, 1958 – vide Deer *et al.*, 1962)

Oxides	Cordierite no.91 enclave Będkowska Valley DB-5 depth 1370 m		Cordierite argillaceous hornfels, Sparcraigs, Aberdeenshire, Scotland (Stewart, 1942)		Cordierite xenolith in granite, Upington, South Africa (Mathias, 1952)		Cordierite hornfels Glen Clova, Scotland (Chinner, 1958)	
SiO_2	43.37		47.69		48.40		46.69	
TiO_2	0.00		tr		0.05		0.34	
Al_2O_3	29.94		32.52		32.15		32.00	
Fe_2O_3	n.d.		0.63		0.00		0.39	
FeO	8.79		8.04		9.80		12.04	
MnO	0.00		0.04		0.23		0.09	
MgO	17.64		7.56		7.25		5.91	
CaO	0.26		0.52		tr		0.18	
Na_2O	0.00		0.53		0.39		0.28	
K_2O	0.00		0.42		0.07		0.16	
H_2O^+	n.d.		1.85		1.58		1.95	
H_2O^-	n.d.		0.55		0.16		n.d.	
Total	100.00		100.35		100.08		100.03	
	recalculated to 18 O		recalculated to 18 O		recalculated to 18 O		recalculated to 18 O	
Si	4.497		4.964		5.026		4.931	
		6.00		6.00		6.00		6.00
Al	1.503		1.036		0.974		1.069	
Al	2.155		2.954		2.962		2.915	
Ti	–		–		0.004		0.027	
Fe^{3+}	–		0.048		–		0.030	
Mg	2.727		1.172		1.122		0.930	
Fe^{2+}	0.762	5.64	0.700	5.09	0.851	5.11	1.063	5.59
Mn	–		0.003		0.020		0.008	
Na	–		0.106		0.080		0.058	
Ca	0.029		0.058		–		0.020	
K	–		0.055		0.08		0.020	

n. d. – not detected; tr – trace

andesine $Ab_{59}An_{39}Or_2$ whilst the outer ones of oligoclase $Ab_{81-66}An_{15-30}Or_{1-4}$ (Table 2). Moreover, the rock contains anhedral K-feldspar ($Or_{92-91}Ab_{8-9}$ perthitic orthoclase) – Table 2.

Biotite occurs in granodiorite as large flakes, 0.95–1.88 mm in size, showing distinct pleochroism from light-yellow (α) to red-brown (γ) – (Fig. 11). It contains inclusions of apatite, zircon, and opaque minerals (ilmenite). Chemical analysis has shown that this biotite contains 12.10–14.03 wt.% MgO and 19.47–20.70 wt.% $FeO_{tot.}$ Fairly high is also TiO_2 content (4.36–5.17 wt.%). The MnO content in biotite amounts to 0.36–0.52 wt.%. The atomic Fe/Mg ratio varies in the range of 0.80–0.94 and $FeO_{tot.}/MgO$ from 1.42 to 1.71. The results of chemical analyses of red-brown biotite are presented in Table 1. On the classification diagram (Fig. 4) the biotites studied are plotted in its lower part.

Anhedral quartz crystals (0.63–0.83 mm in size) appear in granodiorite, but at a distance of 2–3 mm from the contact with enclave. Opaque minerals (0.04–0.42 mm in size), occurring both in biotites and hornblendes, are represented by ilmenite containing ca. 0.96 wt.% V_2O_5 and 0.57–4.87 wt.% MnO.

Table 4

Modal composition of the dark micaceous enclave (in vol.%)

	DB-5 (a) depth 1370 m	DB-5 (b) depth 1370 m
Plagioclase	40.0	33.7
Biotite	56.4	61.7
Corundum	0.3	0.7
Pseudomorphs after cordierite	2.0	2.6
Opaque minerals (magnetite)	1.0	1.2
Apatite	0.3	0.0
Total	100.0	100.1

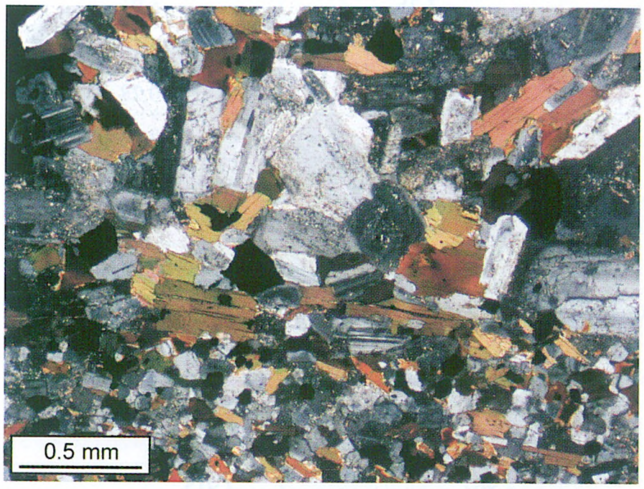

Fig. 9. Plagioclase plates and biotite flakes arranged parallel to the boundary of dark micaceous enclave and granodiorite from Będkowska Valley, borehole DB-5, depth 1370.0 m. Crossed polars

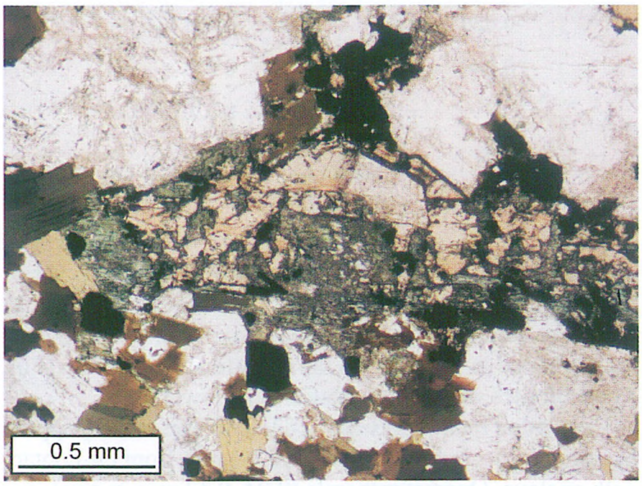

Fig. 10. Relict hornblende crystals intergrown with blasts of sphene and ilmenite in granodiorite (transition zone), borehole DB-5, depth 1370.0 m. Plane-polarized light

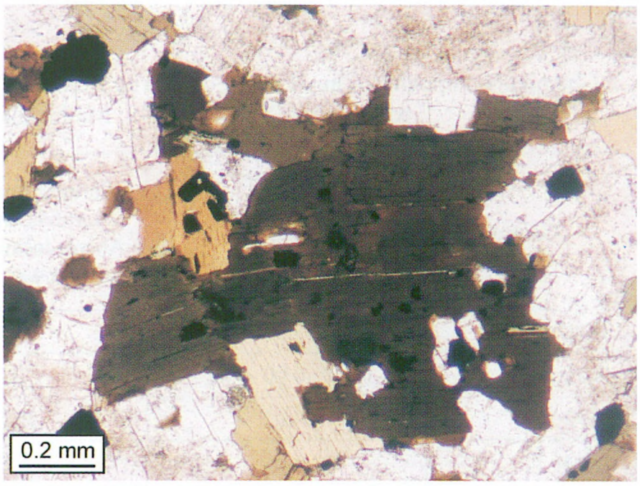

Fig. 11. Red-brown biotite in granodiorite (transition zone), borehole DB-5, depth 1370.0 m. Plane-polarized light

CHARACTERISTICS OF MARGINAL ZONE OF ENCLAVE AT THE CONTACT WITH GRANODIORITE

This marginal (outer) zone is 3–4 mm in size and consists of plagioclase plates (0.11–0.43 mm in size) and olive-brown biotite flakes (0.11–0.21 mm wide and 0.21–0.32 mm long). The latter mineral shows intense pleochroism from light-yellow (α) to olive-brown (γ). The z/γ extinction angle is close to 0°. The chemical composition of biotites from the outer zone is similar to that of biotites from the inner part of the enclave. These minerals are slightly enriched in TiO_2 when compared with biotites from the inner part of the enclave.

Plagioclase (anhedral, rarely euhedral) blasts are small (0.11–0.43 mm) and well-preserved when compared with plagioclases from the inner zone of the enclave studied. Some blasts are characterized by lamellar twinnig of albite law. Plagioclases are represented by andesine ($Ab_{63}An_{35}Or_1$) and oligoclase ($Ab_{72}An_{26}Or_2$) – (Table 2).

In this zone, there also occur increased amounts of opaque minerals. They are represented by magnetite containing ca. 2.7 wt.% TiO_2 and 0.95 wt.% MnO compared with magnetite from the inner part of the enclave. Magnetite blasts are characterized by the presence of lamellar ilmenite overgrowths.

In this zone sericitic pseudomorphs after cordierite (0.21–0.32 mm in size) were found – (Fig. 6) – being filled with biotite (very small flakes 0.01 mm in size), and opaque minerals (very small aggregates 0.01 mm in size). Corundum blasts are not observed in this zone.

DISCUSSION

The study of enclaves in granitic rocks may give some information concerning host and deep-crustal rocks in the area of origin of their parent magma (Didier, 1973; Didier & Barbarin, 1991).

The enclave from granodiorite of the Będkowska Valley studied can be considered as metamorphosed crustal material. Its microstructure is fine-blastic, and granofelsic. The smallest blasts are ca. 0.007 mm, predominantly – up to 0.2– 0.5 mm in size. Fairly common are intergrowths of minerals, best observed in pseudomorphs after cordierite, where biotite occurs within fine-flaky white mica (sericite). Besides, biotite-plagioclase intergrows, are observed. Structural inhomogeneites, stripes and lenses enriched in Mg-bearing biotite may suggests small-scale assimilation of the enclave by grandiorite. However, these phenomena can be also the effect of later hydrothermal proceses related with porphyry-type Cu-Mo mineralization superposed on already solidified granodiorite and enclave embedded in it.

The shape of enclaves is a very significant feature. Micaceous enclaves known in various occurrences of granitic rocks are small and lenticular in shape (Didier, 1973). In the case of the enclave studied by the present author its shape is probably discoidal but the sample was found in drill core material (Fig. 2). Therefore this shape is, merely, supposed. The contact of the enclave with the Będkowska Valley granodiorite is sharp, whereby the transition zone shows variable thickness (3–4 mm in size), indicating some selectivity of assimilation (resorption) processes by not completely solidified granodiorite magma. In this case a rapid cooling and solidification of magma could stop the assimilation at initial stage of fragmentary resorption. Moreover, the material of the enclave studied could be relatively resistant to thermal action of cooling granodiorite magma.

The mineral composition of the enclave studied is characterized by the dominance of biotite (56–62 vol.%) over plagioclase (40–34 vol.%) – Table 4. The former mineral displays variable TiO_2 admixture, whereby plagioclase is represented by: labradorite-andesine and more rarely, oligoclase in inner enclave part, and andesine-oligoclase in outer enclave part. Besides, there occur sericitic pseudomorphs after cordierite, corundum and opaque minerals (magnetite).

The presence of Al-rich minerals as corundum, Al-rich Fe-biotite and spinel (magnetite) was reported for micaceous enclaves in granites (Didier, 1973; Didier & Barbarin, 1991). Similar mineral assemblages were found in enclaves of Massif Central (Sidobre Massif), France (Montel *et al.*, 1991), and in Rochovice granite, Western Carpathians, within Lubenik tectonic zone (Hraško *et al.*, 1998). These minerals are the products of reaction of melting at high temperatures (ca. 800°C) of micas, alumosilicates and such Fe-Mg minerals, as garnet, cordierite, staurolite, etc. Such enclaves are considered to be either the rocks coming from source area of parent granite magma, which did not melt owing to their different chemical composition compared with granite, or they represent fragments of the country rocks incorporated into deeper parts of the crust, the so-called xenoliths of deep basement.

The present studies have shown that the material of this enclave was of another composition and origin than granodiorite (Fig. 2). It was not an autolith, i.e. a fragment of not completely resorbed tonalite or diorite. Its mineral composition indicates that the material in question is distinctly enriched in Al_2O_3 (the presence of corundum), as well as in FeO and MgO when compared with granodiorite. Micaceous enclaves of similar composition, reported to occur in granites, are considered by numerous authors to represent restites after partial melting of granitic magma (Didier, 1973). However, such quartz-free rock can be formed during repeating melting episodes (Montel *et al.*, 1986) or as a result of continuous removal of granitic melt formed by partial melting (Harris, 1981). The obtained data suggest that the studied enclave embedded in the Będkowska Valley granodiorite is a fragment of restite, i. e. of the residuum left after partial melting of its parent granitic/granodioritic magma.

The enclaves of metamorphic rocks were found in the Strzelin granitoid massif and described as xenoliths of host gneisses by Lorenc (1984). This author (Lorenc, 1984) has subdivided them into four types: fine-layered gneiss, laminated gneiss, augen gneiss, and granite-gneiss. All these xenoliths show plate-like forms, because these rock fragments were formed by disintegration of the parent gneisses along foliation planes. The contacts of the gneissic xenoliths with host Strzelin granite are very sharp, sporadically marked by narrow leucocratic rims (5 mm in size) – (Lorenc, 1984). Numerous fine-layered gneissic xenoliths occur in granite of the Strzelin massif. Some of gneissic xenoliths (Lorenc, 1984) are similar to micaceous schists because their mineral composition is characterized by predominance of biotite over light minerals (feldspars).

Petrographic investigations of the enclave in question have shown that the dark micaceous enclave from the Będkowska Valley granodiorite is a medium/high grade metamorphic rock. It can be named plagioclase-biotite schist, quartz-free cordierite-bearing plagioclase-biotite gneiss or biotite-rich part of migmatite (mezosome or melanosome).

Most probably, it is representing a fragment of restite left after partial melting of light components (quartz, albite, orthoclase) from the pre-existing solid rocks (probably gneisses) in deeper part of the continental crust of the Małopolska block. In the presence of water vapour, the melting must occur in gneissic rocks containing quartz + albite + orthoclase at the water-saturated solidus of granite – as low as 650°C at 3.5 kb – (Clements, 1984; Kilinc, 1972).

Corundum is a common component of micaceous enclaves in granites (vide Didier, 1973). Pattison & Tracy (1991) described the reaction of melting and dehydratation of biotite in the presence of Al_2SiO_5 and cordierite results in the formation of corundum and/or spinel. Such reaction takes place during melting of muscovite. Corundum is stable in the quartz-deficient rocks. It is more often met in contact rocks, being the effect of thermal action on them of high-temperature magma of intermediate or basic composition. Corundum in association with spinel may be formed under nearly anatectic conditions (Godard, 1990).

The occurrence of Fe-biotite (Table 1) and corundum (Fig. 7) in the enclave studied may suggest the reaction under conditions of medium temperature range of almandine-amphibolite regional metamorphic facies, whereby staurolite is decomposed (Chinner, 1965):

$$\text{staurolite} + \text{muscovite} + \text{biotite}_1 + \text{quartz} \rightarrow Al_2O_3 + \\ + \text{biotite}_2\ (\text{enriched in Fe}) + H_2O$$

Numerous authors (vide Didier, 1973) report the occurrence of cordierite or, more often, pseudomorphs of this mineral filled with fine-grained micaceous residues in enclaves. The enclave studied contains sericitic pseudomorphs after cordierite (Fig. 6). Cordierite may occur also in hornfelses formed during medium- or high-degree contact metamorphism. The below reaction characteristic of hornblende-hornfels facies takes place in temperature range 510–525°C and P_{H_2O}=0.5–2 kb (Winkler, 1974):

$$\text{chlorite} + \text{muscovite} + \text{quartz} \rightarrow \text{cordierite} + \text{biotite} + Al_2O_3 + H_2O$$

Cordierite occurs also in regionally metamorphosed rocks, e.g. in gneisses formed under conditions of high metamorphic grade (Harker, 1939). In this author's opinion, the formation of cordierite is connected exclusively with regional metamorphism unrelated with shear zones. Lack of garnet in cordierite gneisses is defined by reaction taking place under PT conditions of normal pressure. In such conditions, the mineral assemblage garnet + muscovite, characteristic of regional metamorphism is replaced by cordierite + biotite, following the below reaction (Harker, 1939):

$$\underset{\text{garnet}}{4(Mg,Fe)_3Al_2SiO_3O_{12}} + \underset{\text{muscovite}}{2KAl_3Si_3O_{10}(OH)_2} + 3SiO_2 \rightarrow \underset{\text{cordierite}}{3(Mg,Fe)_2Al_4Si_5O_{18}} + \underset{\text{biotite}}{2K(Mg,Fe)_3AlSi_3O_{10}(OH)_2}$$

The presence of biotite and sericitic pseudomorphs after cordierite in the enclave studied, indicate that such reaction could take place.

Cordierite may alsoo ccur in acid magmatic rocks (muscovite-biotite granite) as xenocrysts, derived from mechanical disruption of cordierite-bearing xenoliths (Brammel & Harwood, 1932 – vide Deer *et al.*, 1962). Nevertheless, some euhedral cordierite crystals in granites are of pyrogenetic origin. Probably they have crystallized from granitic magma enriched in aluminium by assimilation of adjacent argillaceous sediments (Tattam, 1925 – vide Deer *et al.*, 1962). In the case of the Będkowska Valley granodiorite studied no cordierite crystals were observed. Mineralogical and geochemical characteristics correspond to normal, calc-alkaline granodiorite (Płonczyńska, 2000).

In the boundary zone of granodiorite, at the contact with the enclave studied, biotite and plagioclases are arranged parallel to the enclave margin (Fig. 9). This may suggest floating of fragment of restite in plastic magmatic melt.

Limited assimilation of enclave (as well as the resistance of restite to higher temperature) by granodiorite melt is evidenced by the occurrence of small-size "transition" zone (Fig. 2), developed only locally. Increased content of biotite (up to 30 vol.%) in the Będkowska Valley granodiorite (Harańczyk *et al.*, 1995) may suggest the assimilation of considerable amount of enclaves of more basic character.

The transition zone in granodiorite at the contact with the enclave is enriched (when compared with typical granodiorite) in opaque minerals (ilmenite), as well as in larger flakes of Mg-biotite (Fig. 11) and larger plates of plagioclase. The latter display similar composition as plagioclases in typical granodiorite. Hornblende crystals situated close to the contact, are altered (Fig. 10) into mineral aggregate of sphene intergrowths showing zoned structure, embedding opaque minerals (ilmenite). The anhedral quartz crystals appear in granodiorite at a distance of 2–3 mm from the granodiorite/enclave boundary margin. In the contact zone only biotite and plagioclase crystals are observed. This phenomenon may evidence small-scale (2–3 mm range) assimilation processes and enrichment of residual melt in FeO, MgO, CaO and Al_2O_3, as well as impoverishment in SiO_2. Alternatively, it may indicate metasomatic activity at the boundary of two environments showing different chemical composition.

The transition zone in the enclave at the contact with granodiorite is thin (3–4 mm in size). It consists of more sodic plagioclases (andesine $Ab_{63}An_{35}Or_1$-oligoclase $Ab_{72}An_{26}Or_2$ – Table 2) and olive-brown biotite enriched in TiO_2. In this zone increased amounts of opaque minerals (magnetite with admixture of TiO_2 and MnO) are observed.

The occurrence of feldspathic, biotitic, sericitic and argillitic zones in Będkowska Valey granodiorite related with the evolution of the porphyry-type Cu-Mo mineralization was already reported by the present author (Wolska, 2000). The activity of potassium-bearing hydrothermal solutions on granodiorite and the enclave has probably obliterated the traces of earlier process related with melting of crustal material and later limited assimilation (resorption) of enclave material by granodiorite melt. It resulted in alteration (sericitization) of cordierite and the formation of Mg-enriched (up. to 10 wt.% MgO) biotites. The latter occurs in the enclave in these places which are in contact with feldspathization zone. These Mg-biotites, as characteristic secondary minerals, appearing in the zone of "potassic silicates" (Mg-biotite + K-feldspar assemblage) related with hydrothermal alteration of Cu-Mo porphyry deposit type, are often described by other authors (Burnham, 1962; Meyer & Hemley, 1967; Lowell & Guilbert, 1970; Rose, 1970; Beane & Titley, 1981). Mg-biotite was reported to occur in the zones of selective biotitization in the Będkowska Valley granodiorite (Wolska, 2000). It is not excluded that hydrothermal processes related with the mobilization of K and Mg influenced the modification of mineral composition of the enclave (restite) and total transformation or partial alteration of some primary minerals (cordierite, biotite).

Small size of the enclave and, consequently, small amount of material studied did not allow to carry out geochemical investigations, particularly, the estimation of REE pattern. It is supposed that other findings of enclaves will allow supplementing these studies in geochemical data of significant importance for the problems presented in this paper.

CONCLUSIONS

1. The dark micaceous enclave studied was incorporated into semi-liquid granodiorite magma. This is evidenced by oriented textures of the enclave-granodiorite boundary, marked by parallel distribution of minerals in granodiorite

2. The mineral assemblage: Fe-biotite + plagioclase + sericitic pseudomorphs after cordierite + spinel (magnetite)

+ corundum is characteristic of transformation reaction under condition of medium/high-grade regional metamorphism

3. The enclave studied is considered to be a restite, being medium/high-temperature residuum after partial melting under hydrous conditions at 650°C and 3.5 kb of granodioritic magma from the pre-existing solid rocks (probably gneisses) in deeper parts of continental crust of Małopolska block basement.

4. The dark micaceous restite may be named: plagioclase-biotite schist or quartz-free, cordierite-bearing plagioclase-biotite gneiss or dark micaceous part of migmatite enriched in biotite (melanosome, mezosome).

5. The present studies have evidenced distinct resistance of the enclave to assimilation by granodiorite magma. The assimilation process was small-scale (ca. 2–3 mm) in character, being related to limited resorption of enclave material and enrichment of granodiorite magma in Al_2O_3, FeO, MgO, CaO and impoverishment in SiO_2 in boundary part of granodiorite close to its contact with the enclave

6. Later hydrothermal processes connected with Cu-Mo mineralization of porphyry deposit type were superposed on granodiorite and enclave material. In the latter they resulted in sericitization of cordierite. They were also responsible for the origin of lenticular and striped zones enriched in Mg-bearing biotite within this enclave, as well as in the formation of zones of potassic silicates (K-feldspar + Mg-biotite assemblage) and biotitization during influx of this element to chemically more basic enclave. The occurrence of pink feldspar veinlets, cutting this enclave and granodiorite, distinctly confirms the evolution and superposition of the above processes.

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REFERENCES

Beane, R. E. & Titley, S. R., 1981. Porphyry copper deposits. *Economic Geology, 75-th Anniversary Volume 1905–1980*: 235–269.

Buła, Z., 2000. The Lower Palaeozoic of Upper Silesia and West Małopolska. (In Polish, English summary). *Prace Państwowego Instytutu Geologicznego*, 171: 1–89.

Buła, Z. & Kotas, A., 1994. *Atlas geologiczny Górnośląskiego Zagłębia Węglowego Cz. 3: Mapy geologiczno-strukturalne, 1: 100 000*. (In Polish). Państwowy Instytut Geologiczny, Warszawa.

Burnham, C. W., 1962. Facies and types of hydrothermal alteration. *Economic Geology*, 57: 768–784.

Chinner, G. A., 1965. The kyanite isograd in Glen Clova, Angus, Scotland. *Mineralogical Magazine*, 34: 132–143.

Clements, J. D., 1984. Water contents of silicic to intermediate magmas. *Lithos*, 17: 273–287.

Czerny, J. & Muszyński, M., 2002. Enclaves of microgranodiorites and micromonzodiorites in the the rhyodacitic porphyries from Miękinia near Krzeszowice. *Mineralogia Polonica*, 33 (2): 49–59.

Deer, W. A., Howie, R. A. & Zussman, J., 1962. *Rock-forming minerals. Volume one: Ortho- and Ring Silicates*. (ed.) Longmans, Green and Co Ltd, London. (part 1). 327 pp.

Didier, J., 1973. *Granites and their enclaves*. Elsevier, Amsterdam, London, N. York, 393 pp.

Didier J. & Barbarin B., 1991. *Enclaves and Granite Petrology*. Elsevier, Amsterdam-N. York-Tokyo. 625 pp.

Gaweł, A., 1955. Xenolith of plutonic rock in the porphyry of Siedlec near Krzeszowice. (In Polish, English summary). *Biuletyn Instytutu Geologicznego*, 97: 102–113.

Godard, G., 1990. Decouverte d'eclogites, de peridotites á apinelle et d'amphibolites á anorthite, spinelle et corundon dans le Morvan. *Comptes Rendus de L'Academie des Sciences, Ser. II, (Paris)*, 310 (3): 227–232.

Harańczyk, C., 1982. The Cracovides as a Caledonian orogen. (In Polish, English summary). *Przegląd Geologiczny*, 30 (11): 575–582.

Harańczyk, C., 1988. Significance of the sutural geofracture Zawiercie-Rzeszotary for development and occurrence of Paleozoic mineralization and ore deposits of Zn-Pb. (In Polish, English summary). *Przegląd Geologiczny*, 36 (7): 379–381.

Harańczyk, C., 1994a. Znaczenie sutury terranowej Zawiercie–Rzeszotary dla poznania kaledońskiego trnspresyjnego górotworu Krakowidów. (In Polish). In: Przewodnik 65 Zjazdu Polskiego Towarzystwa Geologicznego w Sosnowcu. *Prace Naukowe Uniwersytetu Śląskiego*, 1431: 69–79.

Harańczyk, C., 1994b. Caledonian Cracovides (SW Poland) as a transpressional orogen. (In Polish, English summary). *Przegląd Geologiczny*, 42 (11): 893–901

Harańczyk, C., Lankosz, M., & Wolska, A., 1995. Granodioryt Jerzmanowicki, porfiry i kruszce Cu-Mo. (In Polish). *Rudy i Metale Nieżelazne*, 40 (9): 334–341.

Harker, A., 1939. *Metamorphism; a study of the transformation of rock masses*. Methuen, London, 350pp.

Harris, N., 1981. The application of spinel-bearing metapelites to P/T determinations: an example from south India. *Contributions to Mineralogy and Petrology*, 76 (1): 229–233.

Heflik, W. & Muszyński, M., 1993. A granitoid xenolith from rhyodacites of Zalas near Krzeszowice. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 41 (4): 201–205.

Hraško, L., Kotov, A. B., Salnikova, E. B. & Kovach, V., 1998. Enclaves in the Rochovice intrusion as indicators of the temperature and origin of the magma. *Geologica Carpathica*, 49 (2): 125–138.Karwowski, Ł., 1988. Mineral-forming fluids of the Variscan Cu-porphyry formation from the Myszków-Mrzygłód area Cracovides (Silesian-Cracow region). (In Polish, English summary). *Prace Naukowe Uniwersytetu Śląskiego*, 929: 1–89.

Kilinc, I. A., 1972. Experimental study of partial melting of crustal rocks and formation of migmatites. *Abstracts of 24^{th} International Geological Congress*, 47–48.

Koszowska, E. & Wolska, A., 2000a. Mineralogical and geochemical study of thermally altered country rocks of granodiorite intrusion in the Będkowska Valley near Kraków (S Poland). *Annales Societatis Geologorum Poloniae*, 70: 261–281.

Koszowska, E. & Wolska, A., 2000b. Contact metamorphism related to granodiorite intrusion from Będkowska Valley (South Poland). *Mineralogical Society of Poland – Special Papers*, 17: 27–31.

Kośnik, I. & Muszyński, M., 1990. Granitoids of the Silesian-Cracow monocline basement – the present-day state of knowledge. (In Polish, English summary). *Zeszyty Naukowe*

AGH, 1381, *Geologia*, 16 (4): 89–120.

Lewandowska, A. & Bochenek, K., 2001. New granitoid enclaves from Zalas rhyodacite, Kraków area (S-Poland). *Mineralogical Society of Poland – Special Papers*, 19: 106–108.

Lorenc, M., 1984. Petrogenesis of xenoliths in the Strzelin granitoids. (In Polish, English summary). *Geologia Sudetica*, 28 (2): 133–163.

Lowell, J. D. & Guilbert, J. M., 1970. Lateral and vertical alteration mineralization zoning in porphyry ore deposits. *Economic Geology*, 65: 373–408.

Meyer, C. & Hemley J. J., 1967. Wall rock alteration. In: H. L. Barnes (ed) *Geochemistry of hydrothermal ore deposits*. Holt, Rinchart & Winston, N. York, 166–235.

Montel, J. M., Weber, C. & Pichavant, M., 1986. Biotite-sillimanite-spinel assemblages in high-grade metamorphic rocks: occurrences, chemographic analysis and thermobarometric interest. *Bulletin de Minéralogie*, 109: 555–573.

Montel, J., Didier, J. & Pichavant, M., 1991. Origin of micaceous enclaves in intrusive granites. In: Didier J. & Barbarin B. (eds) *Enclaves and Granite Petrology*. Elsevier, Amsterdam-N. York-Tokyo, 625 pp.

Muszyński, M. & Czerny, J., 1999. Granitoid autholits from porphyry of Zalas near Krzeszowice. *Mineralogia Polonica*, 30 (1): 85–97.

Pattison, D. R. M. & Tracy, R. J., 1991. Phase equilibria and thermobarometry of metapelites. Contact metamorphism. *Reviews in Mineralogy Mineralogical Society of America*, 26: 105–205.

Płonczyńska, I., 2000. Granitoids of the Silesian-cracow monocline basement – mineralogical and geochemical characteristics and petrogenesis. *Mineralogical Society of Poland – Special Papers*, 17: 63–71.

Rose, A. W., 1970. Zonal relations of wall rock alteration and sulfide distribution at porphyry copper deposits. *Economic Geology*, 65: 920–936.

Rozen, Z., 1909. Dawne lawy W. Ks. Krakowskiego – studyum petrograficzno-chemiczne. (In Polish). *Rozprawy Wydziału Matematyczno-Przyrodniczego Akademii Umiejętności*, Ser. III, 9: 293–368.

Skorupa, J., 1953. Badania magnetyczne w obszarze na NE od Krzeszowic. (In Polish). *Biuletyn Instytutu Geologicznego*, 13: 1–23.

Unrug, R., Harańczyk, C. & Chocyk-Jamińska, M., 1999. Easternmost Avalonian and Armorican-Cadomian terranes of Central Europe and Caledonian-Variscan evolution of the polydeformed Kraków mobile belt: geological constraints. *Tectonophysics*, 302: 133–157.

Winkler, H. G. F., 1974. *Petrogenesis of metamorphic rocks*. (3rd edn.), Springer Verlag, New York, 348 pp.

Wolska, A., 2000. Hydrothermal alterations of granodiorite from Będkowska Valley (southern Poland). *Mineralogical Society of Poland – Special Papers*, 17: 75–77.

Żaba, J., 1999. Structural evolution of Lower Palaeozoic succession in the Upper Silesia block and Małopolska block zone (southern Poland). (In Polish, English summary). *Prace Państwowego Instytutu Geologicznego*, 166: 5–162.

Streszczenie

WYSOKOTEMPERATUROWY RESTYT JAKO DOWÓD GŁĘBOKIEGO WYTAPIANIA MACIERZYSTEJ MAGMY GRANODIORYTU Z DOLINY BĘDKOWSKIEJ (OBSZAR ŚLĄSKO-KRAKOWSKI) – WSTĘPNE STUDIUM PETROGRAFICZNO-MINERALOGICZNE

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W południowej części wypiętrzonej krawędzi Masywu Małopolskiego, w strefie granicznej z Masywem Górnośląskim, znajduje się tektoniczny Blok Jerzmanowic (Harańczyk i in. 1995). W trzonie tego bloku zlokalizowano otworami wiertniczymi DB-5 i WB-102 A intruzję granodiorytu z Doliny Będkowskiej (Fig. 1). W otworze DB-5, na głębokości 1370.0 m, znaleziono ciemną mikową enklawę. Enklawa tkwi w granodiorycie, który charakteryzuje się strukturą średniokrystaliczną, a tekstura bezładną i miejscami "porfirową" (Fig. 2). Granodioryt jest zbudowany z białych plagioklazów, ciemnozielonego biotytu oraz ksenomorficznego szarego kwarcu i różowego skalenia alkalicznego.

Kontakt miedzy enklawą a granodiorytem i między strefą przejściową a granodiorytem jest wyraźny i ostry. Enklawa o kształcie dyskoidalnym (wymiary 3 × 6 cm) posiada ciemnozieloną barwę i bardzo drobnokrystaliczną strukturę. Stwierdzono, że zarówno enklawa jak i granodioryt przecinane są późniejszymi różowymi żyłkami skaleniowymi.

Skład mineralny enklawy przedstawiono w Tabeli 4. Enklawa jest zbudowana głównie z oliwkowobrązowego biotytu (Fig. 3) i plagioklazów. Natomiast oliwkowozielony biotyt, o większych rozmiarach, występuje w nieregularnych smugach lub soczewkach (Fig. 8). Skład chemiczny obu biotytów różni się zawartością FeO, MgO i TiO_2 (Tabela 1). Punkty projekcyjne obu rodzajów biotytów na diagramie klasyfikacyjnym dla biotytów (Fig. 4) znajdują się w górnej części diagramu.

Plagioklazy są dobrze zachowane, wykształcone w postaci hipautomorficznych kryształów, reprezentują człony labrador-andezyn (Tabela 2). Pseudomorfozy po cordierycie (Fig. 6) są wypełnione agregatami jasnego łyszczyku i oliwkowobrązowego biotytu oraz inkrustowane blastami spineli (magnetyt). Korund występuje w postaci automorficznych krystaloblastów lub tworzy tzw. formy "sznureczkowe" (Fig. 7).

Obecność bogatych w glin minerałów takich jak korund, Fe-biotyty z dużą zawartością glinu i spineli była wielokrotnie notowana w enklawach mikowych obecnych w granitach (vide Didier, 1973; Didier & Barbarin 1991). Minerały te mogą powstawać w wyniku reakcji topienia w wysokich temperaturach (powyżej 800°C) mik i innych glinokrzemianów oraz granatów, cordierytu i staurolitu.

Na kontakcie granodioryt/enklawa stwierdzono, że tabliczki plagioklazów i blaszki biotytów występujące w obrębie granodiorytu układają się równolegle do granicy (Fig.9).

W strefie przejściowej w granodiorycie pasowe kryształy plagioklazów (andezyn-oligoklaz) ulegają serycytyzacji. Kryształy hornblendy zielonej są w różnym stopniu poprzerastane tytanitem i ilmenitem (Fig. 10). Natomiast, kryształy kwarcu pojawiają się w granodiorycie w odległości 2–3 mm od granicy z enklawą. Czerwonobrązowy biotyt (Fig. 11), charakteryzuje się wysoką zawartością MgO i TiO_2 a jego punkty projekcyjne na diagramie klasyfikacyjnym dla biotytów (Fig. 4) znajdują się w dolnej części.

Ułożenie w granodiorycie kryształów plagioklazów i biotytów na granicy z enklawą zgodnie z jej obrysem, może sugerować, że enklawa przemieszczając się w półpłynnej magmie granodiorytowej była w stanie stałym i była w ograniczonym stopniu odporna na termiczne oddziaływanie stopu. Nie można jednak wykluczać zaistnienia procesu asymilacji enklawy przez magmę granodiorytową. Prawdopodobnie była to asymilacja na małą skalę (ok. 3–4 mm). O procesie asymilacji mogą świadczyć struktury smugowe w enklawie, oraz zmiana składu chemicznego plagioklazów na bardziej sodowe i zwiększona ilość magnetytu (z domieszką TiO_2) w zewnętrznej strefie enklawy przy granicy enklawa/granodioryt. W granodiorycie kryształy kwarcu pojawiają się w odległości 2–3 mm od granicy z enklawą.

Późniejsze procesy hydrotermalne związane z mineralizacją typu porfirowych złóż Cu i Mo nałożyły się na granodioryt z Doliny Będkowskiej i, w mniejszym stopniu, także na materiał enklawy. Obecność różowych żyłek K-skalenia przecinających enklawę i granodioryt oraz obecność Mg-biotytu w granodiorycie potwierdza rozwój przeobrażeń hydrotermalnych zarówno w granodiorycie jak i, na mniejszą skalę, w enklawie.

Przeprowadzone wstępne badania stwierdziły odmienność mineralogiczną enklawy i granodiorytu, dużą odporność enklawy na wysokie temperatury, słabą asymilację enklawy przez magmę granodiorytową, oraz różny stopień podatności tych dwóch skał na późniejsze procesy przeobrażeń hydrotermalnych związanych z rozwojem porfirowych złóż Cu i Mo.

Enklawa jest restytem i reprezentuje fragment średnio/wysokotemperaturowego residuum pozostałego po wytopieniu magmy granodiorytowej w jej obszarze źródłowym usytuowanym w głębokiej strefie podłoża bloku Małopolskiego. Badaną enklawę można zakwalifikować do skał typu: plagioklazowo-biotytowego łupku krystalicznego lub bezkwarcowego, cordierytonośnego plagioklazowo-biotytowego gnejsu albo wzbogaconej w biotyt części migmatytu (melanosomu lub mezosomu).