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OCCURRENCE AND GENETIC RELATIONSHIPS OF URANIUM AND THORIUM MINERALIZATION IN THE KARKONOSZE–IZERA BLOCK (THE SUDETY MTS, SW POLAND)

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Abstract: The paper summarizes available data on uranium and thorium deposits and occurrences in the Karkonosze–Izera Block (the Sudety Mts, SW Poland). The following types were distinguished: 1. Mineralization in the Karkonosze granite and its pegmatites: 1.1 disseminated broeggerite in granite, 1.2 uranium minerals filling the cracks in granite, 1.3 disseminated uranium and U-Th minerals in pegmatites, 2. Mineralization in the metamorphic cover: 2.1 uranium and thorium mineralization in nests, 2.2 pitchblende-fluorite mineralization in veins and nests, 2.3 pitchblende mineralization in veins and nests, 2.4 pitchblende-polymetallic mineralization in veins and nests, 2.5 vein- and nest-type secondary uranium mineralization, 2.5.1 secondary accumulations with traces of primary mineralization, 2.5.2 secondary accumulations without trace of primary mineralization. The origin of these accumulations is mostly related to the Karkonosze Granite and its hydrothermal activity.

Abstrakt: W pracy przedstawiono informacje dotyczące występowania złóż i przejawów mineralizacji uranem i torem w bloku Karkonosko-Izerskim. Wyróżniono następujące typy okruszcowania: 1 Mineralizacja w granicie Karkonoszy i w pegmatytach 1.1. broeggeryt rozproszony w granicie, 1.2. mineralizacja uranowa wypełniająca szczeliny w granicie, 1.3. mineralizacja uranowa i uranowo-torowa w pegmatytach, 2. Mineralizacja w osłonie metamorficznej: 2.1. mineralizacja uranowa i torowa w postaci gniazd, 2.2. smółkowo-fluorytowa mineralizacja w formie żył i gniazd, 2.3. smółkowa mineralizacja w formie żył i gniazd, 2.4. smółkowo-polimetaliczna mineralizacja w formie żył i gniazd, 2.5. wtórna mineralizacja uranowa w formie żył i gniazd, 2.5.1 ze śladami mineralizacji pierwotnej, 2.5.2. bez mineralizacji pierwotnej. W większości przypadków są to wystąpienia genetycznie związane z granitem Karkonoszy i jego działalnością hydrotermalną.

Key words: uranium, thorium, vein-type mineralization, disseminated mineralization, Karkonosze–Izera Block, Karkonosze Granite.

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INTRODUCTION

Several types of ore mineralization including uranium and thorium are known in the Polish part of the Karkonosze–Izera Block (KIB). Small uranium deposits found in this area have been intensively exploited and worked out in 1960-ties. Thus, only dumps and few old workings are recently accessible. Moreover, some minor occurrences of uranium mineralization were localized, all of only mineralogical importance.

Both the deposits and occurrences discussed below show variable structures and are characterized by different ore-mineral associations.

The following paper aims to prove that various types of uranium and thorium mineralizations originated from the succession of geological processes, which resulted in various types of ore accumulations.

GEOLOGICAL SETTING

The Karkonosze–Izera Block belongs to the Western Sudety Mts (Fig. 1). It includes the Variscan Karkonosze Granite and its metamorphic cover. The northern and eastern parts of this cover are situated in the area of Poland.

EASTERN PART OF THE METAMORPHIC COVER

The eastern part of the metamorphic cover comprises the following members (after Teisseyre 1973):

– Kowary Gneiss Group,

– Rudawy Janowickie Group which is divided into: Czarnów Schist Formation (Lower-Middle Silurian) and Leszczyniec Volcanic Formation (Upper, partly Middle Silurian)

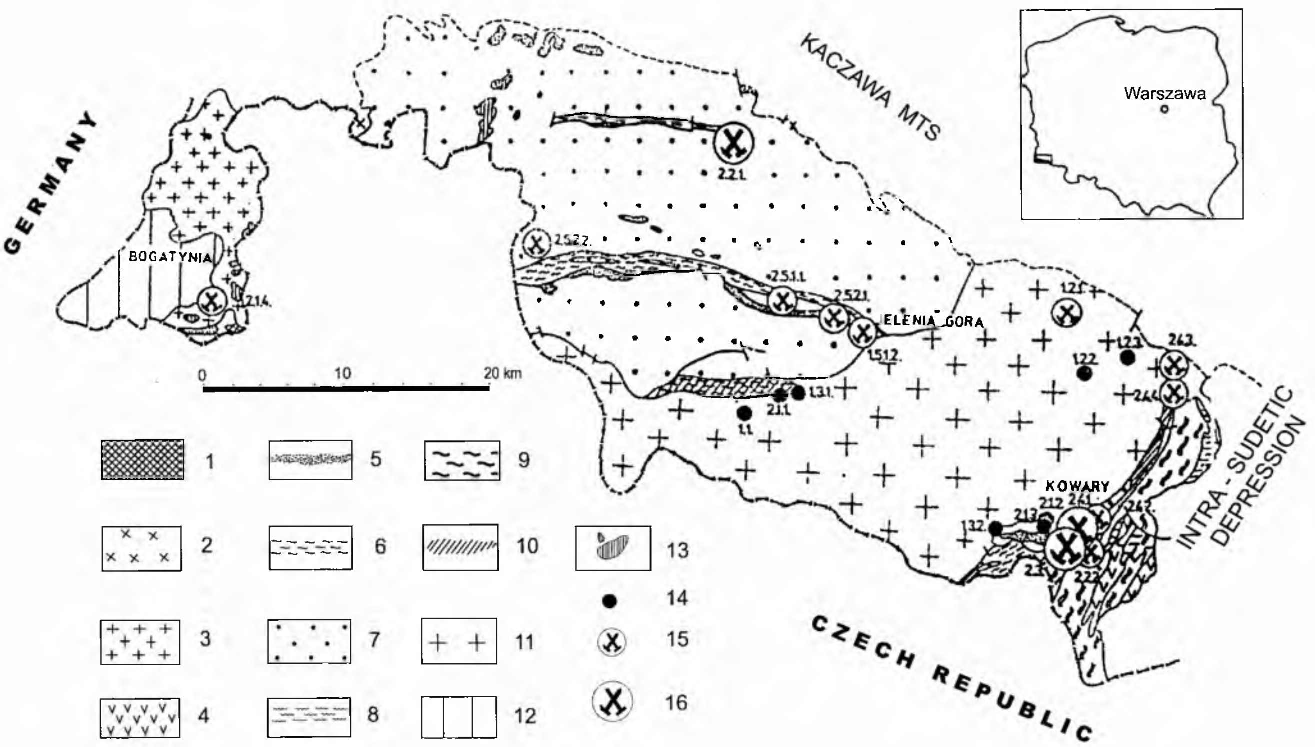

Fig. 1. Geological map of the Karkonosze Izera Block and occurrences of uranium and thorium mineralization (geology after Sawicki 1966 simplified). Eocambrian: *1* – Łużyce greywacke, partly contact-metasomatically altered (hornfelses); Lower Paleozoic; *2* – Zawidów Granite, *3* – Rumburk Granite, *4* – chlorite-hornblende gneisses, *5* – leucogranites, *6* – mica schists, *7* – gneisses mainly augengneisses, *8* – migmatites, *9* – amphibolites, phyllites, cataclasites, chlorite schists, pyrite-bearing schists, *10* – contact-metasomatically altered schists (hornfelses); *11* – Karkonosze Granite, Tertiary series, *12* – sands, clays, *13* – basic volcanic rocks and trachytic phonolites, *14* – occurrences of U-Th mineralization, *15* – smaller deposits. *16* – larger deposits. Localities: 1.1. – Szklarska Poręba I, 1.2.1. – Maciejowa (Majewo), 1.2.2. – Bobrów, 1.2.3. – Trzcińsko, 1.3.1. – Szklarska Poręba I, 1.3.2. – Karpacz, 2.1.1. – Szklarska Poręba III, 2.1.2. – Wołowa Góra near Kowary, 2.1.3. – Budniki near Kowary, 2.2.1. – Radoniów, 2.2.2. – Podgórze-Ruebezahl Mine, 2.3. –Podgórze, 2.4.1. – Kowary, 2.4.2. – Ogorzelec-Victoria Mine, 2.4.3. – Miedzianka, 2.4.4. – Mniszków, 2.5.1.1. – Kopaniec-Mała Kamienica, 2.5.1.2. – Wojcieszyce, 2.5.2.1. – Kromnów, 2.5.2.2. – Czerniawa

Basing on stratigraphy after Teisseyre (1973), the Kowary Gneiss Group comprises homophanic, augen and laminated gneisses intercalated by schists. The group includes the Podgórze Ore-bearing Formation composed of marbles, erlanes, skarns, hornfelses, schists and magnetite. The Czarnów Schist Formation consists of lower mica schists (with graphitic quartzites), lower striped amphibolites (with marbles), upper mica schists (with leptinites or quartzites) and upper striped amphibolites. The Leszczyniec Volcanic Formation includes acid and basic metavolcanites, metapyroclasts and the Paczyn Gneisses (Fig. 2 II).

This "classic" stratigraphy of the eastern part of KIB metamorphic cover has been modified several times. The recent stratigraphy was proposed by Mazur (1995).

The origin of gneisses in the Kowary Gneiss Group as well as the age of the KIB eastern metamorphic cover still remains controversial (Fig. 2 III, IV). The current ideas range from Proterozoic (Oberc, 1960; Oberc-Dziedzic & Oberc, 1972) to Precambrian–Silurian (Szałamacha & Szałamacha, 1958). The new isotopic age determinations published by Oliver et al. (1993) gave U-Pb age 481–492 Ma for the Kowary gneiss, 492±2 Ma for the Leszczyniec metagabro and 500±5 for the Leszczyniec felsic metavolcanics.

The ^{40}Ar-^{39}Ar datings of phengites from the Rychory Mts (extension of the Rudawy Janowickie) (Maluski & Patocka, 1997) allowed to distinguish two metamorphism episodes corresponding to the Variscan tectono-metamorphic evolution of the Bohemian Massif. The earlier episode (360 Ma) falling into the range of blueschist facies was overlapped by the later, greenschist facies one (340 Ma).

Transformations caused by progressive metamorphism were succeeded by the retrograde events (Teisseyre, 1973) (Fig. 2 V).

NORTHERN PART OF THE METAMORPHIC COVER

The northern part of the metamorphic cover consists mostly of the Izera Gneisses accompanied by granitic gneisses, Izera Granites, Rumburk Granite and Zawidów Granodiorites. The Izera Gneisses enclose three E–W-trending belts of mica schists. Locally, leucogranites, amphibolites and very rare greisens and calc-silicate rocks were noted.

The mica schists represent presumably the Algonkian (Kozłowski, 1974) and originated from the regional metamorphism of primarily clayey rocks in the range of greenschists/almandine facies (Fig. 2 I, II).

The origin of gneisses, granites and leucogranites is a

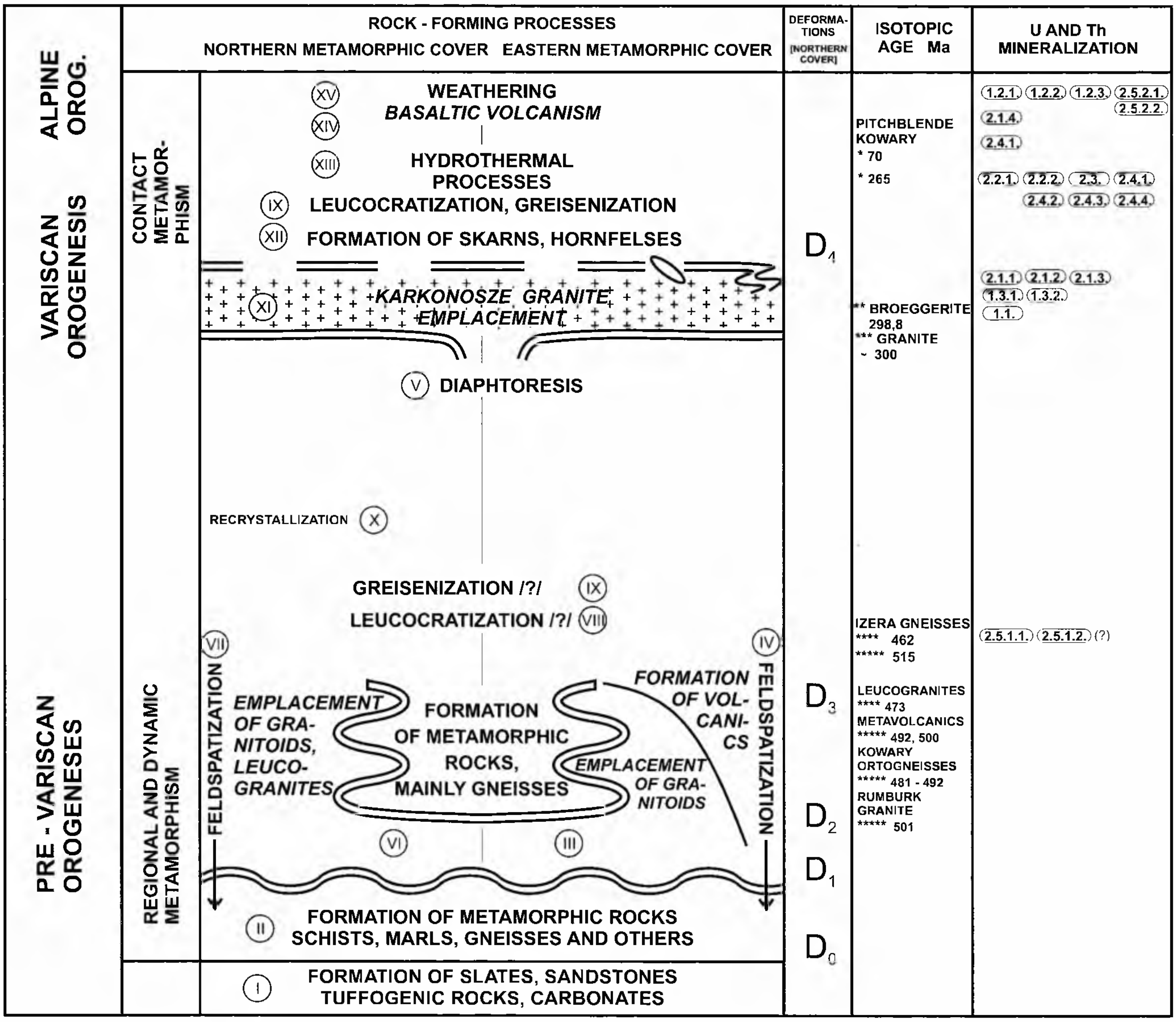

Fig. 2. Uranium and thorium mineralization related to the developmenent of the Karkonosze Izera Block. Localities: 1.1. – Szklarska Poręba I, 1.2.1. – Maciejowa (Majewo), 1.2.2. – Bobrów, 1.2.3. – Trzcińsko, 1.3.1. – Szklarska Poręba I, 1.3.2. – Karpacz, 2.1.1. – Szklarska Poręba III, 2.1.2. – Wołowa Góra near Kowary, 2.1.3. – Budniki near Kowary, 2.2.1. – Radoniów, 2.2.2. – Podgórze-Ruebezahl Mine, 2.3. –Podgórze, 2.4.1. – Kowary, 2.4.2. – Ogorzelec-Victoria Mine, 2.4.3. – Miedzianka, 2.4.4. – Mniszków, 2.5.1.1. – Kopaniec-Mała Kamienica, 2.5.1.2. – Wojcieszyce, 2.5.2.1. – Kromnów, 2.5.2.2. – Czerniawa; * after Lis *et al.* (1971), ** after Kucha *et al.*(1986), *** approximate isotopic age after several authors, **** after Borkowska *et al.* (1980), ***** after Oliver *et al.* (1993), ***** after Korytowski *et al.* (1993)

matter of discussion. Oberc (1960, 1965), Kozłowska-Koch (1965) and Smulikowski (1972) suggested that at least a part of the gneisses resulted from feldspatization of mica schists during regional metamorphism (Fig. 2 VII). Leucocratization took place locally at the contacts of gneisses and mica schists giving rise to the formation of leucogranites and leucogneisses (Fig. 2 VIII). Progressing metasomatism resulted in local greisenization (Fig. 2 IX) (Pawłowska, 1968) followed by local microclinization (Kozłowski, 1974). This simplified succession of metasomatic processes is, however, inconsistent with the results of detailed studies e.g., several, repeating stages of feldspar blastesis reported by Żaba (1984).

The age of processes mentioned above was discussed by several authors. Oberc (1965) confined leucocratization to the Cadomian events and suggested that Caledonian movements caused only the deformations of rocks. Smulikowski (1958) advocated the Caledonian age of leucocratization. Smulikowski (1972) suggested that metasomatic activity has lasted from Precambrian to Ordovician. The upper age limit for leucogranites has been precised by Chaloupsky (1961) who described leucogranite pebbles from the Ordovician conglomerates in the southern part of the KIB. Finally, Heflik (1964) and Karwowski (1975) ascribed Variscan age to both the leucocratization and greisenization. Examinations of fluid inclusion revealed that the Karkonosze Granite has mobilised metasomatic fronts responsible for the formation of metasomatites in the northern metamorphic cover but has not been the source of metasomatic solutions (Fila *et al.*, 1996).

Borkowska *et al.* (1980) provided new data concerning the origin and age of the Izera Gneisses. These authors accept magmatic (intrusive) character of at least a part of gneisses (Fig. 2 VI). The Rb-Sr datings gave 501±32 Ma for the Rumburk Granites, 473±16 Ma for leucogranites and 462±15 Ma for gneisses which places the intrusion in the Upper Cambrian–Lower Ordovician time span. According to Grocholski (1986), it seems highly probable that the isotopic age of Rumburk Granite corresponds to magma crystallization whereas that of the Izera Gneisses represents their recrystallization (Fig. 2 X). Leucogranites seem to be magmatic, "more infracrustal and possibly mantle derived" (Borkowska *et al.*, 1980).

The $^{207}Pb/^{206}Pb$ age of the Izera Gneisses from Liberec area in Czech Republic is 515±8 Ma (Kroener *et al.*, 1994). According to these authors, it corresponds to the emplacement of their granite protolith. This age is in agreement with the U-Pb dating (515±5/7 Ma) obtained for gneisses from the Pilchowice Lake area (Korytowski *et al.*, 1993).

Oberc-Dziedzic (1988) distinguished four stages of formation of the Izera Gneisses, Izera Granites and Rumburk Granites:

1. formation of schists,
2. formation of other metamorphic rocks from the schist precursors,
3. formation of augen-gneisses,
4. emplacement of granites.

These stages were separated by deformation stages denoted D0-D4 (Fig. 2). Granites enclosed in the Izera Metamorphic Block are polygenetic and resulted from the partial melting of preexisting rocks and from the magma differentiation.

According to Achramowicz & Żelaźniewicz (1998), the Izera granites are post-orogenic, per-alkaline S-type granites.

The mica schists were formed as a result of multiple deformations. Basing on detailed examination of schists and intra-schist gneisses, the four tectonic events were distinguished by Dziemianczuk & Dziemianczuk (1982) and Czapliński (1998).

THE KARKONOSZE GRANITE

The Karkonosze Granite is a Variscan intrusion of polygenetic origin (Borkowska, 1966) (Fig. 2 XI). Its isotopic age measurements made with various methods are consistent: 300 Ma (K-Ar) and 292 Ma (Pb-Sr), both after Przewłocki *et al.* (1962), 301.8 Ma (K-Ar) (after Depciuch & Lis, 1971), and 328±12 Ma (Rb-Sr, Pin *et al.*, 1987). The $^{87}Sr/^{86}Sr$ isotopic ratios (Pin *et al.*, 1987) revealed features typical of "S"-type granite. Such granites are related to collision of continental plates.

Contact metamorphism caused by the Karkonosze Granite is documented by the formation of hornfelses and skarns, and by manifestations of other contact-metasomatic processes (Zimnoch, 1961; Borkowska, 1966; Mochnacka, 1967; Teisseyre, 1973; Oberc-Dziedzic, 1985) (Fig. 2 XII).

Hydrothermal activity connected with the Variscan orogeny resulted in the formation of numerous ore deposits (Fig. 2 XIII).

The youngest igneous rocks in the Karkonosze–Izera Block are Tertiary basalts (Fig. 2 XIV).

The KIB and its ore deposits and occurrences have been subjected to the weathering processes (Fig. 2 XV).

Schematic development of the KIB within the territory of Poland is shown in Fig. 2. This scheme is a basis for discussion on the genetic relationships between rocks and uranium and thorium mineralization.

URANIUM AND THORIUM DEPOSITS AND OCCURRENCES

Data on uranium and thorium occurrences in the KIB were summarized in previous papers by Mochnacka (1979) and Bareja *et al.* (1982). Basing on the classification after Dahlkamp (1979), these occurrences fall into the "intra-intrusive mineralization" or "vein-type" (Banaś & Mochnacka, 1986, 1989). Short description of uranium and thorium mineralization in the KIB was presented in the SGA abstract (Mochnacka & Banaś, 1995).

Figure 1 illustrates the distribution of known U and Th deposits and occurrences in the KIB. Most of the sites are located in the metamorphic cover of the Karkonosze Granite. Few, including small Maciejowa deposit, belong to the Karkonosze Granite itself. Some of these localities have already been described in details: Radoniów deposit (Jaskólski, 1967, 1967a), Kowary deposit (Hohne, 1936; Zimnoch, 1961; Mochnacka, 1966, 1967), Kopaniec-Mała Kamienica deposit and neighbouring anomalies (Krawczyk & Mochnacka, 1973; Mochnacka 1975), Wołowa Góra high-temperature mineralization (Lis *et al.*, 1965), Bogatynia Th -Nb "pegmatites" (Banaś & Kucha, 1984) and Jagniątków broeggerite mineralization in the Karkonosze Granite (Lis & Sylwestrzak, 1977; Kucha & Sylwestrzak 1978). These papers also provide comprehensive references to the subject. Descriptions of the remaining localities shown in Fig. 1 are available only in the unpublished industrial reports. However, the identification of U and Th minerals contained in such reports may be uncertain.

The uranium and thorium deposits and occurrences in the KIB can be classified into the following types and subtypes:

1. Mineralization in the Karkonosze Granite and pegmatites:
   1.1 disseminated broeggerite in granite,
   1.2 U minerals filling the cracks in granite,
   1.3 disseminated U and U-Th minerals in pegmatites,
2. Mineralization in the metamorphic cover:
   2.1 U and Th mineralization in nests,
   2.2 pitchblende-fluorite mineralization in veins and nests,
   2.3 pitchblende mineralization in veins and nests,
   2.4 pitchblende-polymetallic mineralization in veins and nests,
   2.5 secondary vein- and nest-type uranium mineralization,

Table 1

Assemblages of uranium and thorium mineralizations

Type of mineralization – locality		Ore minerals	Vein minerals	References
1.	Mineralization in Karkonosze granite and pegmatites			
1.1.	disseminated brøggerite in granite – Szklarska Poręba I	brøggerite, pyrite		Lis & Sylwestrzak (1977), Kucha *et al.* (1986)
1.2.	uranium minerals filling the cracks in granite			
1.2.1.	– Maciejowa (Majewo)	sooty pitchblende, autunite, marcasite, molybdenite	quartz, calcite	Kaczmarek L. (1959)
1.2.2.	– Bobrów	torbenite, autunite		Kaczmarek L. (1959)
1.2.3.	– Trzcińsko	torbenite, autunite, hematite		Lis & Sylwestrzak (1986)
1.3.	disseminated U and U-Th minerals			
1.3.1.	– Szklarska Poręba II	magnetite, hematite, siderite, niobite, kermesite, monazite, fergusonite, ksenotime, thorite, uraninite, autunite, wolvramite, gadolinite, dumortierite, Ag-minerals, aresopyrite, pyrite		Gajda (1960a, b)
1.3.2.	– Karpacz	uraninite, gummite, pitchblende		Berg (1932), Lis & Sylwestrzak (1986)
2.	Mineralization in the metamorphic cover			
2.1.	U and Th mineralization in nests			
2.1.1.	– Szklarska Poręba III	thorite, monazite, xenotime, zircon		Bareja *et al.* (1982)
2.1.2.	– Wołowa Góra near Kowary	brannerite, pyrite, gersdorffite, pharmacosiderite, autunite (?)	quartz, tourmaline, biotite, apatite	Lis *et al.* (1965)
2.1.3.	– Budniki near Kowary	uranothorite, sooty pitchblende, chalcopyrite, autunite	fluorite, calcite, quartz smoke	Kaczmarek L. (1959)
2.1.4.	– Markocice	thorite, thorogummite, ferrothorite (?), Th-phosphates, brockite, cheralite, Fe-mossite, ilmenorutile, Nb-rutile, cuprite, malachite, tenorite, psylomelane, xenotime, native: copper	fluorite	Banaś & Kucha (1975, 1984), Kucha (1989), Kucha & Wieczorek (1980), Marcinkowski (1985), Jęczmykowa (1985), Jęczmyk & Juskowiakowa (1989)
2.2	pitchblende-fluorite mineralization in veins and nests			
2.2.1.	– Radoniów	pitchblende uranopilite, gummite, autunite, metauranocite, elacherite, torbernite, iron-oxides, galena, pyrite	fluorite	Jaskólski (1967a, b)
2.2.2.	– Podgórze - Rűbelzahl mine	pitchblende, sooty pitchblende, hematite, pyrite, chalcopyrite	fluorite, calcite	Kaczmarek L. 91959)
2.3.	pitchblende mineralization in veins and nests – Podgórze	pitchblende, sooty pitchblende, autunite, uranophane, hematite, pyrite, chalcopyrite, galena (?)	calcite, barite, traces of fluorite	Kaczmarek L. (1959)
2.4	pitchblende-polymetallic mineralization in veins and nests			
2.4.1.	– Kowary	pitchblende, coffinite, liebigite, uranotil, gummite, sklodowskite, uranophane, routherfordite, schroeckingerite, autunite, sooty pitchblende, arsenopyrite, lőllingite, tiemannite, clausthalite, sphalerite, pyrite, chalcopyrite, cinnabar, bornite, covellite, native silver, emplectite, native bismuth, tetrahedrite, smaltite, rammelsbergite, niccolite, galena, hematite (specularite), stromeyerite, bismuthine (?), matildite (?), schirmerite (?). native arsenic (?), malachite, umangite, aikinite, rittingerite, pyrargirite, wittichenite	carbonates (calcite, dolomite), traces of barite and fluorite	Meister (1926), Hoehne (1936), Meixner (1940), Ramdohr (1961, 1975), Mochnacka (1966)
2.4.2.	– Ogorzelec - Wiktoria mine	pitchblende, gummite, autunite, torbernite, hematite, pyrite, chalcopyrite, galena	calsote, small amounts of quartz	Kaczmarek L. (1959)
2.4.3.	– Miedzianka	pitchblende, uraninite, gummite, sooty pitchblende, uranophane, autunite, torbernite, chalcopyrite, bornite, pyrite, arsenopyrite, galena, hematite, volborthite, wulfenite, oliwenite		Kaczmarek L. (1959), Websky (1853), vide Zimnoch (1978)

Table 1 (continued)

Type of mineralization – locality		Ore minerals	Vein minerals	References
2.4.4.	– Mniszków	pitchblende, sooty pitchblende, gummite, autunite, torbernite, arsenopyrite, chalcopyrite, hematite	traces of quartz and calcite	Kaczmarek L. (1959)
2.5.	secondary vein and nest type uranium mineralization			
2.5.1.	secondary accumulations with traces of primary mineralization			
2.5.1.1.	– Kopaniec, Mała Kamienica	pitchblende, sooty pitchblende, gummite, zeunerite, metazeunerite (?), uranocircite, metauranocircite, metaautunite, metatorbernite, uranophane, uranothorite, albernathyite (?)	fluorite, quartz	Banaś (1969), Mochnacka (1975)
2.5.1.2.	– Wojcieszyce	traces of pitchblende, autunite, valpurgite, hematite, pyrite, sphalerite, galena		Kaczmarek A. (1959)
2.5.2.	secondary accumulations without traces of primary mineralization			
2.5.2.1.	– Kromnów	uranospinite, hematite	fluorite	Kaczmarek A. (1959)
2.5.2.2.	– Czerniawa	autunite		Kaczmarek A. (1959)

Note: all localities are also noted by Lis & Sylwestrzak (1986)

2.5.1 secondary accumulations with traces of primary mineralization,

2.5.2 secondary accumulations without traces of primary mineralization.

1 Mineralization in the Karkonosze Granite

1.1 Disseminated broeggerite in granite

Minute, disseminated grains of broeggerite were reported by Kucha & Sylwestrzak (1978), from a drill core (Karkonosze IG-1 well, Szklarska Poręba area) (Szklarska Poręba I, Figs 1–3, Tab. 1). Here, a zone in the Karkonosze Granite is regionally enriched in uranium at the level of about 90 ppm (Lis & Sylwestrzak, 1977). Pyrite is the only accompanying mineral. Broggerite is syngenetic with the granite and its U-Pb age is 299.8 Ma (Kucha *et al.*, 1986).

1.2. U minerals filling cracks in granite

1.2.1. In the tectonic zone near Maciejowa (Majewo) cracks filled with sooty pitchblende were noted (L. Kaczmarek, 1959). Accompanying minerals are: marcasite and autunite with small amounts of molybdenite, quartz and calcite (Tab. 1). The host rock is the Karkonosze Granite cut with lamprophyres.

1.2.2 and 1.2.3 The two other localities (Bobrów near Miedzianka and Trzcińsko near Jelenia Góra) show geological settings similar to the locality 1.2.1. Torbernite and autunite were reported by L. Kaczmarek (1959) from Bobrów and by Lis & Sylwestrzak (1986) from Trzcińsko. Mineralized zones are accompanied by typical alterations, which were described by Lis & Sylwestrzak (1979) as episyenitization and which can be important guides for exploration.

1.3. Disseminated U and Th minerals in the pegmatites

1.3.1. The Nb, Ta and Li-pegmatites known from Szklarska Poręba (Szklarska Poręba II, Figs 1–3, Tab. 1) contain diversified U-Th-REE assemblage (Gajda, 1960a; 1960b). Magnetite and hematite are accompanied by accessory uraninite, thorite, autunite, fergusonite and others (Tab. 1).

1.3.2. Similar occurrences were reported from pegmatites near Karpacz. Uraninite crystals rimmed by gummite and U-ochres were intergrown with feldspar. Pitchblende and uranocircite were also identified (Berg, 1923; Lis & Sylwetrzak, 1986).

2. Mineralization in the metamorphic cover

2.1. U and Th in nests

2.1.1. Ore mineralization is hosted in andalusite-cordierite hornfelses formed in the vicinity of Szklarska Poręba, at the contact of the Karkonosze Granite and its northern metamorphic cover (Szklarska Poręba III, Figs 1–3, Tab. 1) (Bareja *et al.*, 1982). Exploration revealed the lensoidal bodies up to 100 meters long, containing thorite, monazite, xenotime and zircon, the two latter enriched in REE. According to Kanasiewicz (1988), alkaline metasomatism affected not only the Karkonosze Granite but also the hornfelses and supplied the REE (1836 ppm), Zr (9000 ppm), Th (576 ppm), U (63 ppm), P (10500 ppm) and Nb (100 ppm) (all contents are average values).

2.1.2. Mineralization in leucogranites and tourmaline gneisses was described by Lis *et al.* (1965) and L. Kaczmarek (1959) from Wołowa Góra near Kowary. Leucogranite zones in gneisses of the Kowary Gneiss Group are cut by quartz veins with brannerite and other high-temperature minerals (Tab. 1). Similarly, the Ti-Ta-Nb mineralization with uranium is connected with one of tourmaline veins cutting the tourmaline gneisses in Wołowa Góra (L. Kaczmarek, 1959). Spatial relationships between the mineralization occurrences and the Karkonosze Granite suggest the genetic link to the Variscan hydrothermal activity (Lis *et al.*, 1965).

2.1.3. Several small localities were traced in Budniki near Kowary. Gneisses and biotite-amphibole schists cut by lamprophyre dykes (L. Kaczmarek, 1959) are enriched in sulphides (chalcopyrite, pyrite, pyrrhotite, arsenopyrite, marcasite). Uranothorite, sooty pitchblende with chalcopyrite and fluorite occur in tectonic fissures and breccias, and at the intersections of tectonic fissures with lamprophyres or biotite-amphibolite schists (L. Kaczmarek, 1959), (Tab. 1).

2.1.4. The most interesting Th-bearing zone in the KIB is located south from Markocice, near Bogatynia (Fig. 1). Remarkable anomalies (200–300 em) and further detailed exploration proved a nest-like orebody at depth 1.5–2.4 meters below the surface.

Ore mineralization occurs in high-potassium granitoids (Rumburk Granites) and is related to the NNE–SSW-trending tectonic zone accompanied by parallel veins and irregular bodies of a rock macroscopically described as Th-bearing pegmates (Banaś & Kucha, 1984). Detailed petrographic studies (Jęczmyk & Juskowiakowa, 1989) allowed to identify these rocks as metasomatic syenitoids. The rock is almost monomineral and composed of highly altered K-feldspar. Brecciation, mylonitization and infiltration with iron and manganese hydroxides as well as the presence of illite-beidellite and illite-montmorillonite clays are typical features.

Local radiation of the ore bodies is up to 2000–12000 μR/h. Their mineralogy includes feldspar xenoblasts which are overgrown, penetrated and locally replaced by Th-phosphates (monacite, rabdophane and ferrothorite?) (Banaś & Kucha, 1975; 1984; Kucha, 1979, Kucha & Wieczorek, 1980; Kucha, 1989). The four identified Th-phosphates are the new phases. The Nb-enriched minerals, Fe-mossite, Nb-ilmenorutile, Nb-rutile and accessory ore minerals: native copper, native gold and native silver, cuprite, malachite, chalcocite and Ni-arsenides were also reported by these authors. Among other noticed minerals there are: anatase, psylomelane, xenotime, fluorite and Fe, Cu, Pb and Zn sulphides (Jęczmyk & Juskowiakowa, 1989), goyasite (Jęczmykowa, 1988), pyrrhotite, chalcopyrite, tetrahedrite-tennantite, pyrite, marcasite, bismuthinite, hematite and magnetite (Marcinkowski, 1985). High cerium contents as well as X-ray powder patterns indicate the presence of cerianite. PGEs are connected with Th minerals. The asset of ore includes (in average): 42.56 wt.% ThO, 1.86 wt.% REEO (Mikuszewski, 1974) and 880 ppm U.

Mineralization in the Markocice area can be connected with the activity of high-temperature hydrothermal solutions. However, Jęczmyk & Juskowiakowa (1989) proposed the Fe-Nb-Th-RRE-PO_4 as well as Fe-Cu-Pb-Zn-sulphide mineralization to result from the Tertiary volcanic activity. Despite the source of ore forming solutions, their penetration was undoubtly facilitated by intense tectonic processes.

2.2. Pitchblende-fluorite mineralization in veins and nests

2.2.1. Typical example of this type of mineralization is the Radoniów deposit – one of the largest uranium accumulations in the KIB (Jaskólski, 1967a; 1967b). The host rocks are gneisses and pink granitic gneisses, both belonging to the Izera Gneiss group. Radiometric anomaly of the size 700x100 meters yielded 880 em. The deposit is located in the vicinity of two large faults. Ore nests of various size and veinlets occur in tectonic breccia which truncates pinkish granitic gneisses. Ore zones grading 0.2 wt. % U form three stocks (relics of the fourth one have also been found) which continue down to the depth 355 meters and are surrounded by aureoles of disseminated mineralization. According to Jaskólski (1967), the primary mineralization consisted of pitchblende with fluorite and traces of pyrite and galena. Secondary zone is well developed (Tab. 1).

2.2.2. The Podgórze (Ruebezahl) Mine deposit is an example of fluorite-dominated uranium accumulation. Fluorite vein accompanied by breccia occurs in a tectonic zone, which cuts mica, quartz-chlorite and chlorite schists with interbeds of graphitic schists, gneisses and marbles. Host rocks belong to the Czarnów Schist Formation. Pitchblende with chalcopyrite and pyrite (Tab. 1) are accumulated in calcite veinlets cutting fluorite and quartz-carbonate rock (L. Kaczmarek, 1959). The coexistence of uranium and fluorite is only spatial as the former appears to be younger.

2.3 Pitchblende mineralization in veins and nests

Sulphide-depleted uranium mineralization is represented by the Podgórze deposit near Kowary. The wall rocks are monoclinally dipping granitic gneisses, gneisses, mica schists and rare amphibolites. Ore zone is located within the metamorphic cover, about 2.5 kilometers south of its contact with the Karkonosze Granite and is related to the intersections of NW–SE-trending joint system with schists interbeds. The ore-bearing breccia consists of barite-fluorite and calcite, and contains elongated pitchblende lenses up to 3 centimeters long. Moreover, the schists altered strongly by carbonatization, chloritization and/or haematitization are also mineralized. Mineralization (Tab. 1) was proved down to the 660 meters level. Weathering zone extends to about 200 meters below the surface and is followed by cementation zone (down to 280 meters). Beneath, the primary mineralization occurs. The ore contained 0.2 wt.% U, in average (L. Kaczmarek, 1959). The Podgórze deposit was one of the largest uranium accumulations in Poland.

2.4 Pitchblende-polymetallic mineralization in veins and nests

2.4.1 Vein-type polymetallic-uranium mineralization belonging to the "five metals" formation is hosted in the Kowary deposit (Mochnacka, 1966; 1967; Banaś & Mochnacka, 1986). Typical feature of this locality is the coexistence of magnetite orebody and polymetallic uranium veins (Zimnoch, 1961; Mochnacka, 1966). The typically lensoidal "Podgórze Ore-bearing Formation" comprises marbles, erlans, schists and skarns enclosed within gneisses of the Kowary Gneiss Group. Numerous longitudinal and transversal faults cut the ore-bearing formation. Uranium-bearing zones are tectonically controlled. The so-called

"Main Fault" is of special importance for the mineralization. The majority of ores is located in western part of the ore-bearing formation, close to the Main Fault. Mineralization was proved down to 650 meters level but the highest-grade parts were found in the interval 150–250 meters below the surface. Commonly, the mineralization occurred at the contacts of various rock types.

Two forms of mineralization were distinguished:

– pipe-shaped, almost vertical stockworks continuing down to several hundreds of meters,

– veins up to several tens of centimeters thick.

Stockworks host tectonic breccias cemented with quartz and calcite with minor barite and traces of fluorite or a network of quartz-calcite veinlets. Uranium-polymetallic mineralization forms nests in the breccia cement. Veins are more common forms of mineralization. Typical gangues are calcite and dolomite.

Pitchblende is usually main ore mineral and is accompanied by a diversified association of more than 40 minerals including As, Co, Ni, Bi, Ag and Se phases (Tab. 1).

Three stage of ore formation were distinguished (Mochnacka, 1966):

– formation of magnetite bodies connected with regional metamorphism (Zimnoch, 1961),

– formation of minor sulphides in skarns as a result of contact metamorphism,

– formation of polymetallic uranium mineralization as an effect of hydrothermal activity. This stage included the four succeeding substages: As-Co-Ni, pyrite-pitchblende, sulphide-selenide and carbonate. For the pitchblende from Kowary Mine the Pb-U ages: 265 and 70Ma were obtained (Lis *et al.*, 1971).

2.4.2. In the Kowary region a small uranium deposit is known from Ogorzelec (Victoria Mine), (Fig. 1, 2.4.2). A tectonic zone at the contact between mica schists and gneisses contained pitchblende and secondary U minerals accompanied by fluorite, quartz and calcite. The richest, lensoidal zone was found close to the surface. Downward, it graded into a network of veinlets containing hematite, pyrite and chalcopyrite (L. Kaczmarek, 1959).

2.4.3. Uranium mineralization found in the vicinity of Miedzianka (Fig. 1, 1.2.4.) can be included into the vein-and-nest group. The Miedzianka deposit is located in the eastern part of the metamorphic cover, close to the contact with the Karkonosze Granite (Fig. 1). The wall-rocks: amphibolite schists and lenses of marbles along with quartz and mica schists belong to the Czarnów Schists Formation and partly to the Leszczyniec Volcanic Formation. Intense faulting and acid magmatic veins are typical of this area (L. Kaczmarek, 1959; Teisseyre, 1973). The U-bearing veins interfere with typical vein-type copper deposit. Three types of ore mineralization were distinguished (Zimnoch, 1978):

– contact-metasomatic magnetite bodies,

– multi-directional veins containing copper and accessory mineralization,

– U-bearing veins.

Lenses containing pitchblende and secondary uranium minerals were excavated from tectonic fissures (L. Kaczmarek, 1959).

2.4.4. The Mniszków deposit (Fig 1, 2.4.4) bordering the Miedzianka Mine from the south is located 500 meters from the contact of the metamorphic cover with the Karkonosze Granite. Fissure veins containing U minerals were observed in marbles, schists, phyllites, and andalusite/andalusite-cordierite schists (L. Kaczmarek, 1959). The richest zones accompanied the intersections of fissures with contacts between amphibolites and quartzites. Pitchblende and secondary uranium minerals were associated with arsenopyrite, chalcopyrite and hematite (Tab. 1). Typical feature of this deposit is almost complete absence of gangue minerals except of traces of quartz and calcite.

2.5. Secondary vein- and nest-type uranium mineralization
2.5.1. Secondary accumulations with traces of primary mineralization

2.5.1.1. In the northern part of the metamorphic cover a few uranium localities are known. The Kopaniec-Mała Kamienica area (Fig 1, 2.5.1.1) is the most typical example. This uranium mineralization is quite different from the localities described above (Banaś, 1969; Mochnacka, 1976; 1978; Banaś *et al.*, 1978). Ore zones are situated about 1.5 kilometer south from the Kamienica Schists Belt. The host rocks are gneisses, Izera Granites, leucogranites, mica schists and amphibolites. These rocks were cut by NW–SE-trending fault and the zone of silicified tectonic breccia was formed in the vicinity of the fault plane. Numerous fractures filled with quartz and fluorite veinlets accompany the fault. Uranium ore occurs usually at shallow depths. The ore minerals are uranium silicates, phosphates and arsenates – an assemblage typical of weathering zone (Tab. 1). Archival data (A. Kaczmarek, 1959) reported traces of uranothorite and pitchblende. Pyrite and chalcopyrite were also noted. Uranium concentrations formed lenticular zones of impregnations or fillings of small cracks in host-rocks. Mineralized zones are parallel to the fault plane or located at the contacts of various host rocks. Sulphides occurring in the same area (pyrite, pyrrhotite, arsenopyrite, chalcopyrite) do not indicate any spatial or genetic relationships to the uranium mineralization.

Petrographic studies of the Kopaniec-Mała Kamienica ore zones revealed the presence of the two stages of ore formation (Mochnacka, 1975). The first stage is probably related to the hydrothermal activity which seems to be the continuation of regional metasomatic processes (K and Na-metasomatism). The second stage of mineralization results from weathering of the primary deposit and the enrichment of surrounding rocks in uranium during the circulation of groundwaters.

2.5.1.2. Similar U mineralization depleted in sulphides occurs in the Wojcieszyce deposit (Fig 1, 2.5.1.2). The ore zone is located in the vicinity of the Stara Kamienica Shists Belt, 200–700 meters south from its contact with the Karkonosze Granite. Wall-rocks – granitic gneises and gneisses with mica schists, amphiblites and lamprophyre dykes are cut by tectonic fissures and breccia zones. Mineralization is confined to the breccia, biotite-chlorite schist interbeds and schists-granite contact zone. Sooty pitchblende with small amounts of pitchblende and secondary U minerals assemblage were observed (Tab. 1), (A. Kaczmarek 1959).

2.5.2. Secondary accumulations without traces of primary mineralization

2.5.2.1. and 2.5.2.2. The two occurrences in the vicinity of the Stara Kamienica Schist Belt (Kromnów and Czerniawa), contain secondary, disseminated uranium mineralization but lack primary minerals (Tab. 1). In Czerniawa the radiometric anomaly follows a tectonic fissure close to the contact between gneisses and schists. In Kromnów the mineralization occurs in tectonic fissures within schists embedded in gneisses, about 0.5 km south of the Stara Kamienica Schist Belt (A. Kaczmarek, 1959).

CONCLUDING REMARKS

The distribution of uranium and thorium deposits and occurrences in the Karkonosze–Izera Block led to the distinguishing of three areas in which these metals are especially abundant:

– Kowary area (southeastern part of the metamorphic cover),

– Miedzianka area (northeastern part of the metamorphic cover),

– Stara Kamienica Schist Belt area (northern part of the metamorphic cover).

In the remaining part of the KIB only single deposits and/or occurrences of U and Th are known.

The Kowary area includes wide range of deposits and ocurrences: from uranium and thorium mineralization in pegmatites (Karpacz), through high-temperature, U-Th mineralization (Wołowa Góra, Budniki), polymetallic-uranium mineralization (Kowary and Victoria Mines), fluorite deposit with uranium (Podgórze-Ruebezahl Mine) up to pitchblende deposit (Pogórze Mine). The spatial relationship of these localities to the Karkonosze Granite is undoubtful.

The Miedzianka area is generally similar to the former but lacks the paragenetic assemblage known from the Kowary Mine. The mineral assemblages accompanying uranium ores are much less diversified and abundant in the Miedzianka as well as in the neighbouring Mniszków. Rich sulphide accumulation in Miedzianka forms a vein-type copper deposit. The relation of this mineralization to the mineral assemblage accompanying the uranium ore is unknown. In the close vicinity of Miedzianka the uranium occurrences (mostly secondary) were found in two localities within the Karkonosze Granite (Maciejowa/Majewo and Bobrów). As in the case of the Kowary area, the spatial relationship of uranium mineralization to the Karkonosze Granite is obvious.

In the Kamienica Schists Belt area the character of uranium mineralization appears to be different. Four remarkable localities are known (Kopaniec, Wojcieszyce and Kromnów deposits, and Czerniawa occurrences), accompanied by several small anomalies (the latter were not marked in Fig. 1). The shallow ore zones (maximum depth of 170 meters) discovered at the Kopaniec Mine are dominated by uranium phosphates, typical of weathering zone. Only the two localities contained also pitchblende (Wojcieszyce and Kopaniec) and traces of uranothorianit (Kopaniec). The three uranium deposits are located within gneisses, south of the Stara Kamienica Schist Belt and seem to be related to the southern contact of schists and gneisses (leucogneisses or leucogranites). All the localities described above are controlled by the tectonic zones. Their spatial relationship to the Karkonosze Granite is disputable.

The Pb-U isotopic age of pitchblende from Kowary (265 Ma, Lis *et al.*, 1971) indicates that uranium mineralization is about 35 Ma younger than the emplacement of Karkonosze Granite (see Fig. 2). Therefore, the uranium occurrences and deposits spatially related to the granite might have resulted directly from the Variscan hydrothermal activity. The second isotopic result obtained for the pitchblende from Kowary (70 Ma, op.cit.) may be connected with the Alpine rejuvenation.

The origin of uranium mineralization in northern part of the metamorphic cover appears to be a more complicated problem. The spatial relationship to the schist/gneiss contact as well as the presence of leucogranites as host-rocks in some localities allow to suggest that mineralizing solutions were not directly related to the Karkonosze Granite. Taking into consideration metasomatic origin of leucogranites, these solutions could be connected with the final, stage of metasomatic activity. The fissures and cracks hosting the mineralization can be related to the D3 stage deformations distinguished by Oberc-Dziedzic (1988) (Fig. 2).

The importance of leucocratization for the formation of uranium deposits in the Sudety Mts has been emphasized by Depciuch *et al.* (1976). According to their opinion, alkaline metasomatism caused leaching of uranium from the surrounding rocks whereas the schists acted as "lithogeochemical barriers".

As shown in previous chapters, the age of leucocratization is doubtful. Consequently, the age of related uranium mineralization cannot be precisely determined.

Considering the studies of Borkowska *et al.* (1980), the hypothesis on the origin of uranium mineralization in northern part of the metamorphic cover must be revised. Hydrothermal activity should be related to the intrusions of leucogranites, Isera Granites and/or Rumburk Granites. Consequently, Early Palaeozoic age is proposed for this mineralization.

The largest uranium deposit known from northern part of the metamorphic cover (Radoniów) is located far north of the Stara Kamienica Schist Belt (Fig. 1). It is hosted in the vicinity of the Złotniki Lubańskie schist belt, in NE–SW-trending tectonic zone cutting the gneisses. According to Jaskólski (1967), the Radoniów deposit resembles the Kowary one but lower temperature of crystallization caused the absence of five-metals formation. After the opinion of this author it is related to the Karkonosze granite.

The comparison of parageneses from the uranium localities in northern and eastern parts of the metamorphic cover reveals significant differences (Fig. 3, Tab. 1). In the eastern part the predominating pitchblende is accompanied by diversified assemblages of sulphides, selenides, sulphosalts etc. In the northern part phosphates and silicates dominate, pitchblende is rare, uranothorite was reported only from one of the localities and sulphides are almost absent. Accumulations of phosphates do not reveal pseudomor-

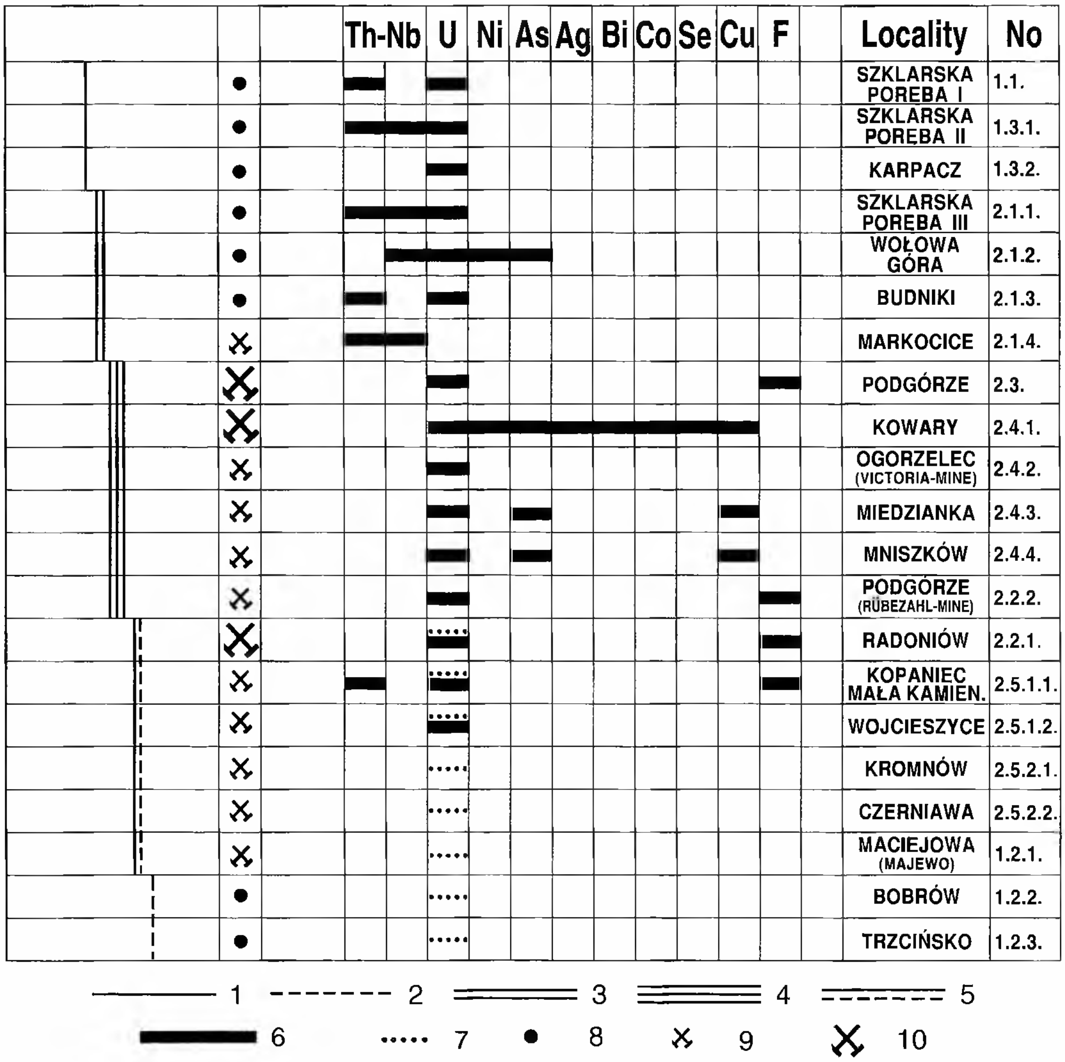

Fig. 3. Comparison of the mineral parageneses. *1* – mineralization in the Karkonosze granite and its pegmatites, (syngenetic), (U,Th); *2* – mineralization in the Karkonosze granite, (epigenetic), (U); *3* – mineralization in the metamorphic cover, (epigenetic), (U,Th); *4* – mineralization in the metamorphic cover, (epegenetic), mainly primary, (U); *5* – mineralization in the metamorphic cover (epigenetic), mainly secondary, sometimes with traces primary one; *6* – oxides, sulphides, arsenides, selenides and/or sulphosalts of U, Th, Cu, Ag, Bi, Ni, Co, As; *7* – phosphates, arsenates, silicates of uranium; *8* – occurrences of U-Th mineralization; *9* – smaller deposits; *10* – larger deposits

phoses after pitchblende – a feature typical of weathering zone.

The observed mineral parageneses allow to suggest the basic differences in the chemistry of mineralizing solutions and in precipitation conditions. It seems that uranium mineralization in northern part of the metamorphic cover was precipitated mainly from low-temperature hydrothermal solutions whereas that in eastern part of the metamorphic belongs to high- to medium-temperature range.

The Th-REE-Nb-P and Fe-Cu-Pb-Zn mineralizations known from the area of Bogatynia do not reveal any genetic relationships to the occurrences described above. Apart from Szklarska Poręba (Fig. 1, 2.1.1), where Th-Nb mineralization has also been reported, in the remaining parts of the KIB such associations are lacking. Studies on the occurrence in the Bogatynia area did not provide proofs indicating a genetic link of mineralization to the ore-bearing syenitoids. Current ideas (Jęczmyk & Juskowiakowa, 1989) relate this mineralization to Tertiary basic volcanism. In the present author's opinion the basaltic volcanism might have been rather the energy source for solution circulation system than the source of REE, Nb and P.

Broeggerite mineralization known from the Karkonosze Granite also appears to be completely different from those in the localities mentioned above. Isotopic age of this mineral corresponds to the age of granite itself. Hence, its origin syngenetic with the granite emplacement is proposed.

The occurrences of torbernite and autunite within the Karkonosze Granite were regarded as infiltrational. However, episyenite zones found by Lis & Sylwestrzak (1979) imply the participation of alkaline metasomatism.

Instead of some disputable genetic relationships of uranium occurrences in the KIB and in the Karkonosze Granite, the largest uranium deposits in this region seem to belong to the province associated with S-type, collisional granites of Variscan age in western Europe (Sawkins 1990).

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Streszczenie

WYSTĄPIENIA MINERALIZACJI URANOWEJ I TOROWEJ W BLOKU KARKONOSKO-IZERSKIM I ICH RELACJE GENETYCZNE (SUDETY, POLSKA)

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W bloku Karkonosko-Izerskim na terenie Polski znanych jest kilka wyeksploatowanych, lub bez ekonomicznego znaczenia złóż uranu oraz szereg drobnych wystąpień mineralizacji uranowej i torowej. Ich rozmieszczenie przedstawiono na Fig 1. Wystąpienia te zlokalizowane są w metamorficznej osłonie granitu, bądź też w samym granicie. Celem pracy było przedstawienie powyższych złóż i przejawów okruszcowania na tle geologicznego rozwoju KIB oraz dyskusja nad ich powstawaniem.

Opierając się na klasyfikacji Dalkamp'a (1979), omawiane złoża i wystąpienia można zaliczyć do dwu grup: do złóż lub wystąpień typu żyłowego oraz do mineralizacji śródintruzywnej.

Niektóre ze złóż doczekały się szczegółowych opisów, jak na przykład złoże Radoniów (Jaskólski 1967, 1967a,), złoże w Kowarach (Hoehne 1936. Zimnoch 1961, Mochnacka 1966, 1967), Kopaniec-Mała Kamienica (Krawczyk & Mochnacka 1973, Mochnacka 1975, 1978; Banaś *et al.* 1978), wysokotemperaturowa mineralizacja na Wołowej Górze koło Kowar (Lis *et al.* 1965), wystąpienia Th-Nb w "pegmatytach" (Banaś & Kucha 1984), wystąpienia broeggerytu w granicie Karkonoszy, w rejonie Jagniątkowa (Lis & Sylwestrzak 1977, Kucha *et al.*, 1978). Pozostałe oparte są w większości na materiałach niepublikowanych, zestawionych przez L. Kaczmarka (1959) i A. Kaczmarka (1959).

Większość punktów jest zlokalizowana w metamorficznej osłonie granitu Karkonoszy, kilka raczej drobnych wystąpień znajduje się w granicie lub w pegmatytach. Omawiane wystąpienia można w oparciu o zamieszczoną w spisie literaturę uszeregować w zależności od środowiska w którym występują, w sposób następujący:

1. Mineralizacja w granicie Karkonoszy i w pegmatytach
   1.1. broeggeryt rozproszony w granicie
   1.2. mineralizacja uranowa wypełniająca szczeliny w granicie
   1.3. mineralizacja uranowa i uranowo-torowa w pegmatytach
2. Mineralizacja w osłonie metamorficznej:
   2.1. mineralizacja uranowa i torowa w postaci gniazd
   2.2. smółkowo-fluorytowa mineralizacja w formie żył i gniazd
   2.3. smółkowa mineralizacja w formie żył i gniazd
   2.4. smółkowo-polimetaliczna mineralizacja w formie żył i gniazd
   2.5. wtórna mineralizacja uranowa w formie żył i gniazd
      2.5.1 ze śladami mineralizacji pierwotnej
      2.5.2. bez mineralizacji pierwotnej

KIB jest częścią zachodnich Sudetów (Fig 1.). W jego skład wchodzi waryscyjski granit Karkonoszy oraz jego metamorficzna osłona. Północna i wschodnia osłona znajdują się prawie w całości na obszarze Polski. W oparciu o cytowane w spisie literatury prace na Fig. 2 przedstawiono w sposób schematyczny następstwo skał w północnej i wschodniej części KIB, kolejność ich tworzenie się w procesach metamorficznych. Na tym tle przedstawiono omawiane złoża i wystąpienia okruszcowania. W tabeli 1 podano zespoły minerałów oraz formy okruszcowania w omawianych wystąpieniach, zaś Fig. 3 przedstawia porównanie paragenez mineralnych.

Rozmieszczenie wystąpień uranu i toru w KIB pozwala na wyróżnienie trzech, szczególnie bogatych obszarów. Są nimi:

– obszar Kowar w SE części metamorficznej osłony Karkonoszy
– obszar Miedzianki w NE części osłony metamorficznej
– otoczenie łupkowego Pama Kamienickiego.

W pozostałych obszarach są tylko pojedyncze złoża (np. Radoniów) lub drobne wystapienia mineralizacji U lub Th.

Obszar Kowar obejmuje szeroki wachlarz złóż i wystąpień mineralizacji U i Th, począwszy od wystąpień w pegmatytach (Karpacz), poprzez wysokotemperaturowe wystąpienia U-Th (Wołowa Góra, Budniki), złoża polimetaliczno-uranowe (Kowary i Ogorzelec – kopalnia Victoria), złoża fluorytowo uranowe (Podgórze-Ruebezahl), aż do złoża smółkowego (Podgórze). Przestrzenny związek tych złóż z granitem Karkonoszy jest niewątpliwy.

Obszar Miedzianki jest generalnie podobny do poprzednio opisanego, brak tu jednak paragenez mineralnych typowych dla Kowar. Zespół minerałów jest mniej urozmaicony w porównaniu z Kowarami. Bogata siarczkowa mineralizacja regionu Miedzianki to żyłowe złoża miedzi których stosunek do okruszcowania uranowego nie jest znany. W bliskim sąsiedztwie omawianego złoża znajdują się dwa wystąpienia mineralizacji uranowej w granicie Karkonoszy (Maciejów i Bobrów). Podobnie jak w przypadku regionu Kowar, tak i w rejonie Miedzianki przestrzenny związek z granitem jest niewąpliwy.

Mineralizacja uranowa z obszaru Pasma Kamienickiego ma odmienny charakter. Znane są tu trzy wystąpienia złóż: w Kopańcu, Wojcieszycach, Kromnowie oraz przejaw mineralizacji w Czerniawie, którym towarzyszy szereg anomalii radiometrycznych. Płytko usytuowane strefy rudne są zbudowane głównie z fosforanów. Jedynie dwa wystąpienia (według informacji zawartych w materiałach niepublikowanych) zawierają smółkę uranową (Wojcieszyce i Kopaniec) oraz ślady uranothorytu (Kopaniec). Trzy spośród wymienionych wystąpień znajdują się w gnejsach na południe od pasa łupkowego, w sasiedztwie południowego kontaktu łupków i gnejsów (leukognejsów lub leukogranitów). Wszystkie są związane ze strefami tektonicznymi.

Oznaczenia wieku bezwzględnego smółki z Kowar (265 Ma, Lis *et al.*, 1971) wskazują, że jest ona tylko nieznacznie młodsza od granitu (Fig. 2), zatem złoża przestrzennie związane z granitem

powstały w wyniku waryscyjskiej działalności hydrotermalnej. Drugi wiek (70 Ma, Lis *et al.*1971) według wspomnianych autorów świadczy o alpejskiej rejuvenacji.

Pochodzenie mineralizacji uranowej w północnej osłonie metamorficznej KIB jest problemem bardziej skomplikowanym. Mając na uwadze przestrzenny związek złóż i wystąpień okruszcowania z kontaktem łupkow i gnejsów oraz fakt występowania w niektórych przypadkach złóż i wystąpień okruszcowania uranem w leukogranitach, można sugerować, że brak jest tu bezpośredniego związku genetycznego z granitem Karkonoszy. Uwzględniając natomiast udział procesów leukokratyzacji, można przypuszczać, że uranonośne roztwory mogły być związane z ostatnim, hydrotermalnym etapem działalności metasomatycznej. Szczeliny i pęknięcia zawierające obecnie okruszcowanie powstały w trzecim stadium deformacji (Fig.2), wyróżnionym przez Oberc-Dziedzic (1988).

Znaczenie leukokratyzacji dla powstawania złóż uranu na terenie Sudetów podkreślane było przez Depciucha i in. (1976). Zgodnie z koncepcją tych autorów metasomatoza alkaliczna powodowała ługowanie uranu ze skał otaczających, zaś łupki działały jako "bariera litogeochemiczna". Wiek leukokratyzacje jest przedmiotem szerokiej dyskusji.

W świetle prac Borkowskiej i inn. (1980) hipoteza odnośnie genezy mineralizacji w północnej osłonie winna ulec rewizji. Działalność hydrotermalna powinna być wiązana z intruzją leukogranitów, granitami izerskimi bądź rumburskimi wieku wczesnopaleozoicznego.

Największe złoże uranu w północnej osłonie (Radoniów) znajduje się w sąsiedztwie łupków Złotnik Lubańskich, w obrębie strefy tektonicznej przecinającej gnejsy. Według Jaskólskiego (1967) jest ono podobne do złoża Kowary, lecz niżej temperaturowe i dlatego pozbawione zespołu typowego dla formacji pięciometalicznej. Wykazuje ono czasowy i przestrzenny związek z granitem Karkonoszy.

Porównując paragenezy mineralne złóż północnej osłony metamorficznej i wschodniej dostrzegamy wyraźne różnice (Fig. 3, Tab. 1). We wschodniej osłonie dominuje smółka uranowa, której towarzyszy bogaty i zróżnicowany zespół siarczków, siarkosoli, selenków, itp. W złożach północnej osłony dominują fosforany i krzemiany, smółka jest rzadka, a ślady uranothorytu były notowane tylko w jednym wystąpieniu. Również siarczki występują śladowo. Akumulacje fosforanów nie ujawniają pseudomorfoz po smółce, typowych dla strefy wietrzenia. Porównanie powyższe pozwala na sugestie, że podstawowe różnice tkwią w chemiźmie roztworów i warunkach precypitacji. Mineralizacja północnej osłony KIB tworzyła się z roztworów niskotemperaturowych, w przeciwieństwie do okruszcowania wschodniej osłony, utworzonego z roztworów średnio- i wysokotemperaturowych.

Okruszcowanie Th-REE-Nb-P i Fe-Cu-Pb-Zn, znane z obszaru Bogatyni nie wykazuje powiązania genetycznego z omawinymi wystąpieniami uranu. Nie stwierdzono tu dowodów na istnienie genetycznego związku tej mineralizacji ze syenitodami. Według Jęczmyk i Juskowiakowa (1989), okruszcowanie to należy wiązać z trzeciorzędowym wulkanizmem bazytowym.

Okruszcowanie broggerytem jest całkowicie odmienne od opisanych, jest to mineralizacja sygnenetyczna z granitem Karkonoszy, zaś wystąpienia autunitu i torbernitu wydają się być infiltracyjne. W tym ostatnim przypadku stwierdzone przez Lisa i Sylwestrzaka (1979) strefy episyenitów sugerują również metasomatozę alkaliczną.

Generalnie, pomimo niekiedy dyskusyjnego związku genetycznego mineralizacji uranowej z granitem Karkonoszy, złoża i wystąpienia okruszcowania w obrębie KIB stanowią najbardziej wschodni fragment dużej grupy złóż uranu o genetycznym związku ze środkowoeuropejskimi, waryscyjskimi intruzjami granitowymi typu "S", towarzyszącymi zjawiskom kolizji kontynentów (Sawkins 1992).