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MINERALOGICAL CHARACTERISTICS OF ACCESSORY MINERALS FROM OSIECZNICA DEPOSIT, SW POLAND

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The composition of the heavy mineral fraction from the glass sand in Osiecznica (Lower Silesia, SW Poland) was described. Accessory minerals are present in the gravity concentrate mainly as individual grains, whereas lower amounts occur as vein rocks debris, inclusions in quartz grains and heavy minerals. The sample under study contained the following minerals: rutile, anatase, hematite-goethite, ilmenite-leucoxene, zircon, monazite, xenotime, kyanite, pyroxenes, and quartz with inclusions of chalcopyrite, pyrite, pyrrhotite, sphalerite, pentlandite, arsenopyrite, and tetrahedrite-tennantite. Moreover, the presence of native gold and silver was determined. Major components of the concentrate are rutile, anatase, quartz with inclusions of ore minerals, zircon, and goethitized hematite. The other minerals occur in the amount below 2-3 vol. %. The content of native gold in the concentrate sample (0.11%) may be indicative of a significant concentration (around 1.5 g/Mg) of this metal in the Osiecznica deposit.

Key words: glass sand, heavy minerals, gravity concentration

INTRODUCTION

Deposits of glass sands (sandstones) near Osiecznica belong to the largest in Poland. According to the new Resources Balance (2005) the resources of the currently exploited deposit Osiecznica II amount to 22.43 Tg. The sandstones in this area belong to the northern part of the North-Sudetic Basin, the so called Bolesławiec syncline (Fig. 1). The basin comprises Cretaceous sediments overlain with sedimentary rocks of the Neogene. Cretaceous sandstones outcrops are very sparse (Milewicz 1967).

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The raw materials for glass production are Cretaceous sandstones of the Coniacian age and certain parts of the Santonian sandstones. Coniacian and Santonian beds are stretched along the axis of the basin from the NW to the SE and dip in the direction of its centre at 20–45° to the SW. The sandstones were subject to weathering (weakening) and parting in the zones of tectonical engagement. The Coniacian sandstones and some parts of the Santonian sandstones are characterized by expressed homogeneity. These are most of all fine-grained quartz sandstones in which the basic grain fraction (0.100 to 0.315 mm) prevails. The average amount of this fraction is around 80% (Milewicz 1967; Błaszak and Grodzicki 1979). The sandstones contain only trace amounts of heavy minerals.

Accessory minerals (heavy minerals) in the glass sands form a significant impurity (they may colour industrial semi-products). On the basis of the accessory minerals content a classification of deposits of sands (sandstones) has been prepared and a purity class of these sediments has been determined (classes from 1 to 6, and the best class S).

Glass sandstones (quartz well-sorted sandstones) contain no traces of micro- or macro-fossils. Such deposits are very difficult to correlate stratigraphically. The main aim of the investigations consisted of checking whether these stratigraphically ‘silent’ beds may contain some components that would allow lithostratigraphical correlation. Moreover, the authors decided to take an attempt and apply a technique called ore minerals analysis in the study of very well sorted quartz sandstones. The authors’ idea was also to check whether it is possible to determine a possible source area of the rocks in question on the basis of accessory minerals.

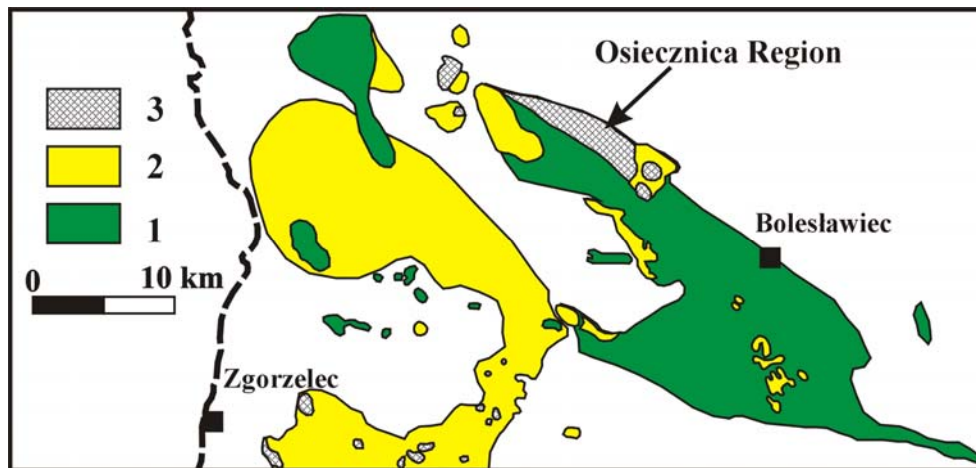


Fig. 1. Cretaceous and Neogene glass sandstones occurrence near Bolesławiec. 1 – Cretaceous sediments: sands and sandstones, clays and marls; 2 – Neogene sediments: sands and clays with lignite beds; 3 – areas of glass sand deposits

DEPOSIT DESCRIPTION

The deposit series is characterised by high homogeneity of mineral and chemical composition. The content of silica in the deposit reaches up to 98.0 wt. % and no more than 0.02 wt. % of iron oxides. After washing and removing clay matrix silica content reach up to 99.8 wt. % (Kozłowski 1986). The moist sand is grey, and after drying it is mainly white and in some cases yellow. The dominant mineral is quartz, and such components like feldspars, glauconite, heavy minerals and vein rocks debris are sparsely present. Heavy minerals have the form of individual grains and occur also as veinlets and inclusions in quartz and in other heavy minerals.

The deposit series is characterised by high homogeneity of chemical composition. A relatively low concentration of iron compounds in the sands (max. 0.02 Fe₂O₃) makes it possible to regard them as one of the best quality glass sands in Poland and Europe (Kozłowski 1986). The sands (sandstones) in question meet requirements of class 2, 3, 4 and 5 from which after adequate processing material of class 1, 2 and 3 is obtained (Poręba 1968).

An average thickness of the deposit is around 38 m (Osiecznica II). The overburden contains Cretaceous sediments younger than the Coniacian (clays, clay-shales and some sandstones), Miocene (sands, quartzites, and in some parts also gravels) and Pliocene-Holocene sediments (clayey sands and muds). An average thickness of the overburden is varied and ranges from 1.25 to 21 m (Błaszczak 1973).

METHODS

Fifty kilograms of preliminary purified glass sand from the Osiecznica II deposit were collected for the study. This sand was concentrated with the use of a concentration table of the Wilfey type (made by the British company Denver) at the Institute of Mining Engineering of the Wrocław University of Technology (Fig. 2). The resulting mass balance of this operation is shown in Table 1. Tailing 1 presented in this table as the purified glass sand was separated earlier on a commercial scale in a spiral separator at the Osiecznica Plant.

Table 1. Mass balance of heavy mineral fraction (HMF) of tabling of the glass sand

#	Product	Yield, %	HMF content, %	HMF recovery, %
1.	Concentrate 1	0.28	29.12	54.89
2.	Concentrate 2	0.45	8.15	24.41
3.	Middlings 1	1.09	0.63	4.61
4.	Tailings 2	3.34	0.12	2.69
5.	Tailings 1	94.85	0.02	13.39
6.	Calculated feed	100.00	0.15	100.00
7.	Feed assay		0.13	

In the products separated the contents of heavy mineral fraction was determined with the use of tetrabromoethane (heavy liquid $\rho=2950 \text{ kg/m}^3$). The heavy mineral fraction obtained from concentrate 1 (Table 1) was divided in the magnetic field of a permanent magnet into two fractions: magnetic and non-magnetic. Polished sections for reflected light microscopic studies and microchemical analyses were prepared from the heavy mineral fraction samples of the both concentrates. The polished sections were prepared with the use of a standard technique for metal ore samples (Muszer 2000). Polishing of the study material was performed on polishing cloths Struers DP-Mol, DP-Dur and DP-Nap while applying strictly defined grain sizes of diamond polishing pastes. The polished sections were investigated under the microscope in the Laboratory of Mineral Raw Materials at the Institute of Geologic Studies of the Wrocław University. The studies of samples were performed with Nikon binocular and investigated in reflected light with the use of Nikon Optiphot 2-Pol microscope.

Planimetric analysis and the Lucia M programme were used in the quantitative analysis of heavy minerals. The distribution of metals in sulphides was determined with the use of microchemical analysis. The elemental composition of minerals was studied with the use of scanning microscope SEM 515 (Philips) equipped with an X-ray spectrum analysis attachment. These investigations were carried out at the Institute of Low Temperature and Structure Research (Polish Academy of Sciences) in Wrocław.

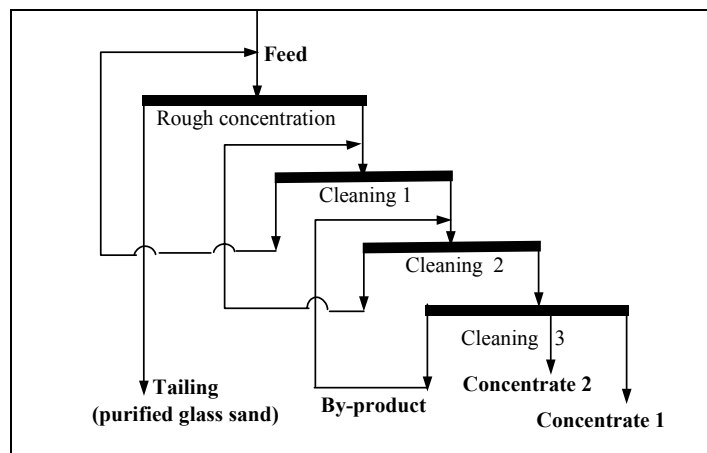


Fig. 2. Flowsheet of gravity separation with the use of a laboratory concentrating table

DESCRIPTION OF HEAVY MINERAL FRACTION

The concentration of heavy minerals in the Osiecznica deposit varies from 0.2 to 2.5 vol. % depending on the part of the deposit (Błaszak and Grodzicki 1979; Łuszczkiewicz 1987, 2002). The investigations revealed the presence of the following minerals in the sample: oxides, represented by rutile, anatase, magnetite, hematite-

goethite, ilmenite-leucoxene; quartz with inclusions of sulphides and oxides; phosphates (monazite, xenotime); silicates (zircon, disthene, pyroxenes) and sulphides (chalcopyrite, pyrite, pyrrhotite, sphalerite, pentlandite), sulphoarsenides and sulphoantimonides (arsenopyrite, tetrahedrite-tennantite). Moreover, native gold and silver were determined in the sample.

During the process of purification of glass sands (sandstones) heavy mineral fraction is concentrated mostly in the finest grain size fraction. In the Osiecznica deposit heavy mineral fraction is concentrated mainly in the fraction below 0.071 mm (Table 2). According to the investigations' results, the heavy mineral fraction concentration in the grain size fraction <0.1 mm is 3-4-fold greater than in the fraction >0.1 mm (Łuszczkiewicz 1987, 2002).

Table 2. Particle size composition and the distribution of heavy mineral fraction (HMF) in gravitational tailing from the purification of glass sands of the Osiecznica Plant (Łuszczkiewicz 1987, 2002)

Particle size, mm	Yield, %	Concentration of HMF, %	Recovery of HMF, %
+0.5	7.50	0.00	0.00
0.5 – 0.2	19.80	0.022	1.79
0.2 – 0.071	47.10	2.55	49.28
- 0.071	25.60	4.66	48.93
Calculated feed	100.00	2.44	100.00
Assay feed		2.35	

The main component of the heavy mineral fraction is rutile with anatase (TiO₂). These two minerals of titanium make up for 50.1 % of the concentration of all heavy minerals. Rutile and anatase grains are medium or poorly rounded. It is possible to observe columnar or acicular crystals which are frequently crushed. Rutile is characterised by red, brown and yellow internal reflexes, while the typical reflexes of anatase are white-yellowish. These both minerals are easy to polish. The most widespread rutile crystals are those with red - brown internal reflexes. Rutile grains contain inclusions of pyrrhotite and pyrrhotite-chalcopyrite aggregates. The inclusions may reach 25 µm in diameter.

An important component of the volumetric composition of the heavy mineral fraction separated from the gravitational concentrate is quartz. Its concentration amounts to around 18 % of all minerals in the heavy mineral fraction (Table 3). This quartz was separated from the sample with a permanent magnet. Macroscopic investigation of the magnetic fraction under reflected light revealed that individual quartz grains contain numerous inclusions of magnetite or magnetite with hematite, as well as inclusions of pyrrhotite with other ore minerals (Fig. 3). Quartz grains are colourless and have strong lustre, whereas in certain cases may be matted. The majority of quartz grains are semi-rounded or angular. The product under study contained very few well-rounded grains. The surface of individual grains is scratched and rough which implies rapid transport of these grains.

Table 3. The composition of the heavy mineral fraction from the Osiecznica deposit

Mineral	Concentration in % vol.
Rutile, anatase	50.10
Zircon	16.65
Monazite	1.99
Xenotime	0.56
Quartz	18.38
Magnetite	0.20
Hematite (goethite)	9.30
Ilmenite-leucoxene	2.30
Kyanite	0.10
Pyroxenes	0.10
Native gold	0.11
Pyrrhotite, pyrite, arsenopyrite, chalcopyrite, sphalerite	0.21
Total	100.00

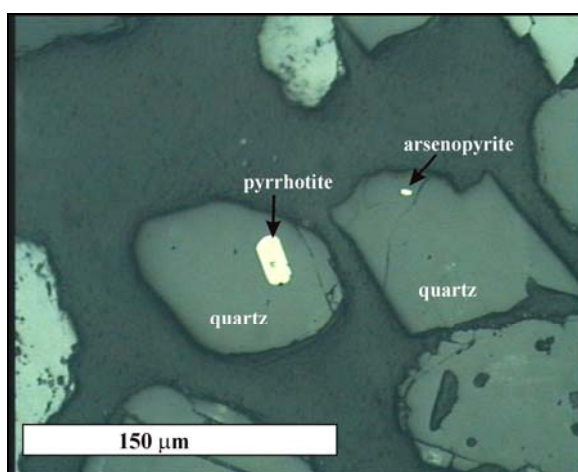


Fig. 3. Ore minerals (pyrrhotite, arsenopyrite) in quartz grains from Osiecznica. Reflected light, plane polarized light

The third most important component of the heavy mineral fraction is zircon. Its quantity is almost 3-fold lower than the amount of rutile-anatase (Tab. 3). The diameter of zircon crystals ranges from 50 to 200 μm . The concentrate contains two zircon varieties, i.e. zonal zircon and zircon without the zonal structure. Individual zircon grains are very well or poorly rounded. Zircons have a well defined structure of the tetragonal prism. Zircon crystals contain inclusions of pyrrhotite, chalcopyrite, pyrite and magnetite (Fig. 4). The diameter of inclusions ranges from 1 to 25 μm . The inclusions are idiomorphic and xenomorphic.

Hematite occurs in the concentrate in the form of separate grains. The diameter of grains ranges from 60 to 150 μm . This mineral reveals strong anisotropy and red internal reflexes. The majority of hematite grains contain substitution structures. Along cracks and from the boundaries of grains hematite was subjected to goethitization (substitution by goethite).

The concentration of other minerals in the heavy mineral fraction ranges from 0.1 % (kyanite) to 2.3 % (ilmenite-leucoxene). Ilmenite, monazite, xenotime, magnetite, kyanite, pyroxenes, native silver, and native gold are present in the concentrate as individual grains. The other minerals, i.e. sulphides (chalcopyrite, pyrite, pyrrhotite, pentlandite, sphalerite), arsenopyrite and tetrahedrite-tennantite form tiny inclusions in silicate or phosphate minerals.

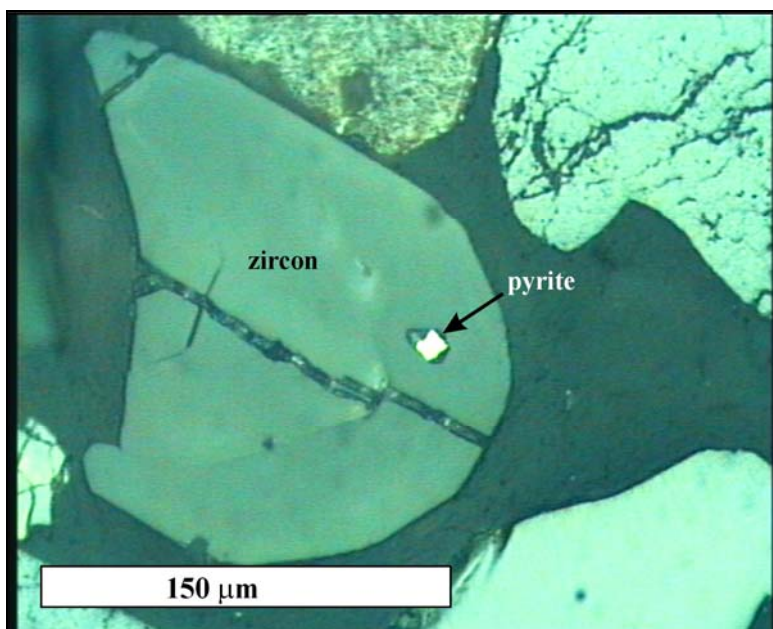


Fig. 4. Pyrite in a zircon grain from Osiecznica. Reflected light; plane polarized light

Ilmenite (ilmenite-leucoxene) forms grains from 70 μm to 0.2 mm in diameter. Most ilmenite grains contain substitution structures, i.e. traces of leucoxenization. Ilmenite grains are tabular with rounded corners. Their optical features are typical of this mineral. Ilmenite may form individual grains and was observed also in structures from the decomposition of solid solution in several magnetite grains. These structures univocally point to magmatic origin of these magnetite grains.

Monazite and xenotime are distinct from other grains in the concentrate. Monazite has white-yellow-brown internal reflexions and xenotime has yellow-brown internal reflexions. Monazite shows poor cleavage when compared with xenotime and is difficult to polish when compared with zircon.

Magnetite present in the concentrate very rarely forms grains. Most of these grains are martitized. Their characteristic feature is a magnetite-hematite grid structure typical of the process of substitution of magnetite by hematite. Most of magnetite grains occur as inclusions in quartz and are responsible for its magnetic properties. Quartz with magnetite inclusions is poorly rounded. Magnetite in quartz has the form of cubic crystals or oval-shaped exsolutions. Oval inclusions of magnetite are frequently accompanied by hematite inclusions of identical shape.

Pyrrhotite was observed in poorly rounded quartz grains, and in zircons and monazite. Pyrrhotite is present in the form of xenomorphic grains, oval shaped forms or as crystals. All zircons containing pyrrhotite inclusions are very well rounded and do not have zonal structure. The well rounded grains of quartz contain pyrite-pyrrhotite inclusions. These aggregates have xenomorphic structure and their diameter does not exceed 10 μm . Several zircon grains contain pyrrhotite with flame structures of pentlandite (structures from the decomposition of a solid solution). Moreover, hexagonal-monoclinical structures observed in pyrrhotite point to high temperature of its crystallization.

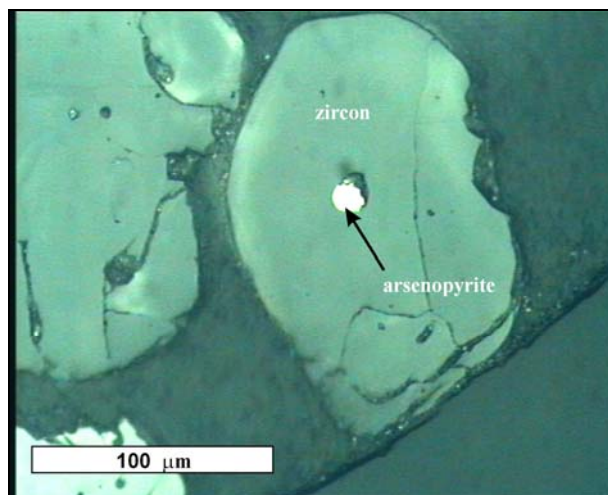


Fig. 5. Arsenopyrite in zircon grain from Osiecznica. Reflected light; plane polarized light

Chalcopyrite was observed in poorly rounded quartz grains and in a grain of a vein aggregate. In quartz grains chalcopyrite occurs in intergrowths with pyrrhotite, forming a shapeless xenomorphic aggregate. Chalcopyrite grains do not exceed 5 μm in diameter. Chalcopyrite grain is always smaller than pyrrhotite grain attached to it.

Arsenopyrite was observed as inclusions or veinlets in quartz or zircon. In quartz grains this mineral occurs as individual inclusions up to 10 μm in diameter or is intergrown to form pyrrhotite-arsenopyrite aggregates or aggregates of pyrrhotite-arsenopyrite-chalcopyrite. The diameter of these aggregates does not exceed 15 μm . The diameter of arsenopyrite in zircon grains does not exceed 15 μm (Fig. 5). The

microchemical analysis of elemental composition did not reveal the presence of any additions in this mineral. Both native gold and native silver are very rare in the concentrate. The concentration of native gold amounts to 0.11 vol. % of the heavy mineral fraction. This mineral is frequently intergrown with hematite. Native gold was also determined in the magnetic fraction separated from the heavy mineral fraction. Gold occurs in the form of scales and irregular clusters. The scales are up to 150 μm long and 25 μm thick (Fig. 6). Gold has distinct golden-yellow colour. In gold grains analysed microchemically an addition of Ag was determined in the amount ranging from 0.1 to 2.5 wt. %.

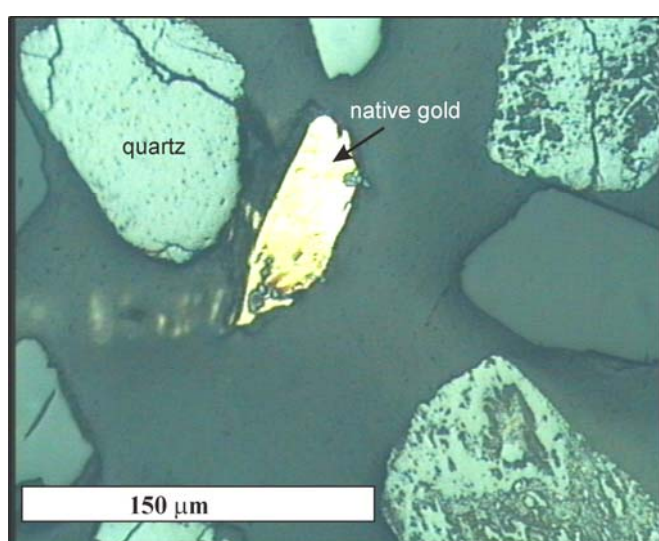


Fig. 6. Native gold with hematite from Osiecznica. Reflected light; plane polarized light

Pyrite is present in the heavy mineral fraction in the form of inclusions in grains of quartz and zircon (zonal zircon and zircon without the zonal structure). Quartz grains containing pyrite are poorly rounded. Grains of non-zonal zircon with pyrite are also poorly rounded. Grains of zonal zircons are on the other hand very well rounded and pyrite occurs in the external rim of zircon growth. Its diameter ranges from 1 to 5 μm .

Tetrahedrite-tennantite in the material from Osiecznica is very rare (Fig. 7). It was observed in two grains of the concentrate which consisted of quartz-calcite aggregates with sulphides and also in three inclusions in quartz grains. In the first example tetrahedrite-tennantite occurs in the concentrate grains in the form of intergrowths with chalcopyrite (Fig. 7).

This grain is a product of mechanical destruction of a hydrothermal vein. Apart from these two sulphides the aggregate from the vein contains also pyrite and sphalerite. In the second example tetrahedrite-tennantite has a form of an inclusion

intergrown with chalcopyrite inside quartz grains. The diameter of the tetrahedrite-tennantite-chalcopyrite ranges from 10 to 15 μm . The same quartz grains contain small inclusions of sphalerite (5 μm in diameter) intergrown with chalcopyrite.

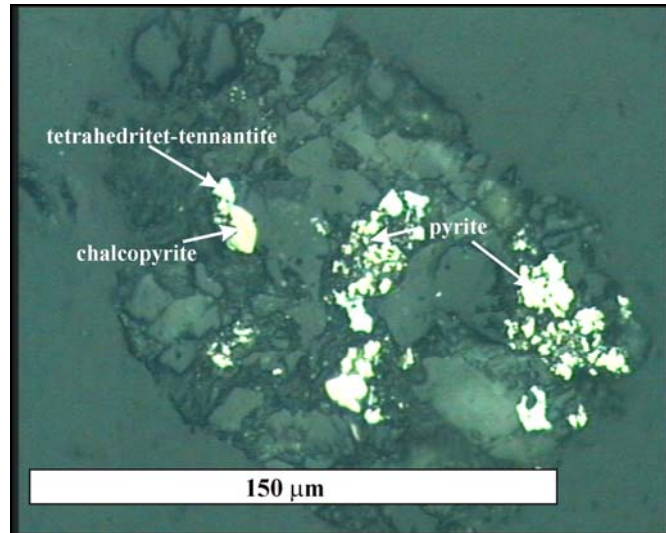


Fig. 7. A grain from a quartz-calcite vein (grey minerals) containing sulphide minerals from Osiecznica. Reflected light, plane polarized light

CONCLUSIONS

Although the glass sands from Osiecznica are very well sorted, they contain abundant ore minerals which have not been described earlier from this deposit. The minerals are simple sulphides of Cu, Fe and Zn, i.e. chalcopyrite, pyrite, pyrrhotite, sphalerite, pentlandite, and complex sulphides, i.e. arsenopyrite and tetrahedrite-tennantite. The sulphides may be a source of increased content of unwanted elements such as Zn, Cu, Ni, As, Sb in products and half-products, in industries in which purity of material is of utmost importance (e.g. glass production, pharmaceutical and chemical industry).

The sample contains also native gold and silver. Native gold concentration in the concentrate sample reaching 0.11 vol. % may be indicative of a high content of this metal in the Osiecznica deposit (around 1.5 g/Mg).

Accessory minerals described from Osiecznica glass sands point to the Sudetic area (S or SE of Osiecznica) as the source area. The composition of the main minerals in the heavy mineral fraction is different in relation to other occurrences of such sands in Poland (e.g. Biała Góra (Łuszczkiewicz 1987, 2002)). On the basis of major components in the heavy mineral fraction it is very difficult to define the source area of the glass sands under study. Accessory minerals, i.e. rutile, anatase, quartz, zircon

or monazite with xenotime occur in various magmatic or metamorphic rocks. Most mountain massifs in the Sudetes Mts are composed of such rock types. However, ore minerals present in the minerals mentioned earlier provide a source of univocal information regarding the origin of these ore minerals and at the same time information on the origin of the host mineral.

All of the ore minerals mentioned earlier (sulphides, sulphide analogues) observed as grown together or intergrown are a result of crystallisation in mesothermal conditions or under boundary conditions between mesothermal and catathedral. The presence of these minerals and the presence of the eroded hydrothermal vein point to the origin of the material from eroded rock massifs which contained hydrothermal quartz and quartz-feldspar veins. The rocks of such type are common in the Góry Kaczawskie Mts and the Pogórze Kaczawskie Foreland in the area between Zagrodno and Wojcieszów. It is plausible that gold and the main component of the glass sand, i.e. quartz did not originate from the region of Karkonosze Mts - Góry Izerskie Mts, which is indicated by the geographical position, but from an area located farther to the SE, i.e. the Kaczawskie Góry Mts.

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Scharakteryzowano skład minerałów ciężkich w złożu piasków szklarskich z Osiecznicy na Dolnym Śląsku. W wydzielonym koncentracie grawitacyjnym minerały akcesoryczne występują głównie jako samodzielne ziarna, w mniejszej ilości jako okruchy skał żyłowych oraz w postaci wrostków w ziarnach kwarcu i w samych minerałach ciężkich. W badanej próbce stwierdzono obecność rutylu, anatazu,

magnetytu, hematytu-goethytu, ilmenitu-leukoksenu, cyrkonu, monacytu, ksenotymu, cyanitu, piroksenów oraz kwarcu z wrostkami chalkopirytu, pirytu, pirotynu, sfalerytu, pentlandytu, arsenopirytu i tetraedrytu-tennantytu. Ponadto w badanej próbce stwierdzono obecność złota i srebra rodzimego. Głównymi składnikami w badanym koncentracie są rutil, anataz, kwarc z wrostkami kruszców, cyrkon oraz zgoethytizowany hematyt. Pozostałe minerały występują w ilości mniejszej niż 2-3 % objętościowych. Zawartość złota rodzimego w badanej próbce koncentratu (0,11 %) może świadczyć o znaczącej zawartości tego metalu w złożu w Osiecznicy w ilości rzędu 1,5 g/Mg.