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General characteristics of the Olkusz region

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Location

The Olkusz region is one of the three areas in the Silesia-Cracow Upland where zinc and lead (Zn-Pb) deposits occur; the other two are the Chrzanów and Bytom regions (Molenda 1963). According to Kondracki's (2009) physiographic division, this deposit-rich area (Niedzielski and Szostek 1980) is located in the eastern part of the Garb Tarnogórski mesoregion. It is a part of the Silesian Upland macroregion, which is separated from the Kraków-Częstochowa Upland by the escarpment face of a cuesta that runs from Żurada across Olkusz and reaches Klucze (Dziechciarz 2001) (Fig. 1). The area is characterised by gentle but varied land relief; elevation ranges from 270 m a.s.l. in the Dolina Białej Przemszy valley up to 500 m a.s.l. Wysokie Przymiarki is the highest elevation of the Olkusz Region (482.6 m a.s.l.). The hills of the Olkusz area (called Grzędy Olkuskie perches), at 50–100 m a.s.l., are flattened at the top. Numerous monadnocks and caves can also be found there. Jaskinia Wierzchowska Górna cave is the cave closest to Olkusz. The Pustynia Błędowska desert, the so-called "Polish Sahara", is in the eastern part of the Silesian Upland. In the northwestern part of the region (Krzykawa area) there are loess deposits cut by numerous gorges and ravines resulting from denudation processes (Szczypek *et al*. 1995; Dziechciarz 2002; Nowak *et al*. 2011).

Zn-Pb ore mining and processing has left its mark on the landscape. The natural relief

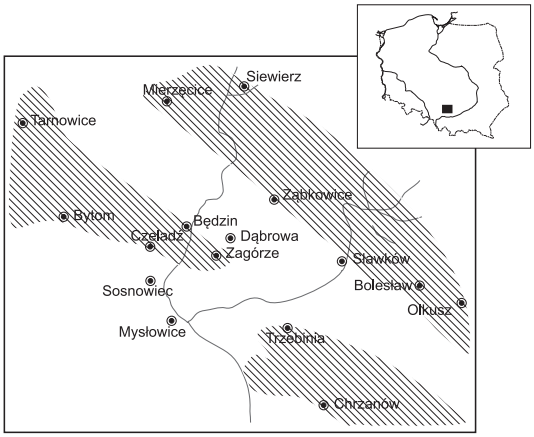

Fig. 1. Areas of zinc-lead (Zn-Pb) deposits in the Silesia-Cracow Upland (Chrzanów, Bytom and Olkusz regions) (U. Korzeniak)

Ryc. 1. Obszary występowania złóż cynkowo-ołowiowych (Zn-Pb) na Wyżynie Śląsko-Krakowskiej (region chrzanowski, bytomski i olkuski) (U. Korzeniak)

has been deformed by centuries of mining. There are many post-exploitation pits, excavations and sinkholes, and it is dominated by artificial elevations in the form of slag heaps composed of mining and metallurgical waste, and humps made of discarded gangue material (Wierzbicka 2002; Godzik and Woch – Chapter 3 and Woch – Chapter 4, this volume). The waste landfills are of different sizes and shapes; they vary from small mounds and cones to long, often irregular berms elevated up to 25 metres. Exploitation of fill sand for mining purposes and aggregate mines also deformed the landscape, creating many wide and deep pits around the whole area. They are forested or filled with water and have become recreational areas (Kotlicka 1978). All of these land forms are now integral though unnatural parts of the landscape. The numerous transport routes are another artificial element of the landscape, including national road 94 running from Kraków to Wrocław, the Katowice-Kielce railway and the broad-gauge rail line for transporting sulphur. A part of the Olkusz Ore-bearing Region (OOR), a 48 km^2 mining area situated between the towns of Laski, Olkusz and Bukowno (Fig. 2), was included in the studies carried out within the "Vegetation of calamine soils and its importance for biodiversity

Fig. 2. The area of project EEA FM PL0265. 1 – settling ponds, 2 – industrial areas, 3 – built-up areas, 4 – forests, 5 – main roads, 6 – railway line, 7 – watercourses, 8 – ZGH Bolesław zinc smelter, 9 – flotation fascility, 10 – flotation tailings heap (P. Kapusta)

Ryc. 2. Teren objęty badaniami wykonywanymi w ramach projektu MF EOG PL0265. 1 – stawy osadowe, 2 – tereny przemysłowe, 3 – tereny zabudowane, 4 – lasy, 5 – główne drogi, 6 – linia kolejowa, 7 – cieki wodne, 8 – huta cynku ZGH Bolesław, 9 – zakład flotacji, 10 – hałda odpadów poflotacyjnych (P. Kapusta)

and landscape conservation in post-mining areas" project (EEA FM PL0265). It is a rectangular area measuring 8 × 6 km (19°25′–19°32′E, 50°15′–50°19′N). The OOR lies in Olkusz County in the northwestern part of Małopolska Province, and includes all of Bolesław municipality, the northern part of Bukowno municipality and the western edge of Olkusz municipality. The central part of the OOR is an area of previous and current activity related to lead and zinc ore extraction and processing, and on its outskirts are pine forests, fill sand mines (on the eastern and southern sides) and agricultural land (on the western and northern sides). A number of publications further describe the area (e.g. Stefanowicz *et al*. 2010; Kapusta *et al*. 2011; Nowak *et al*. 2011; Wierzbicka 2015).

Climate

According to Romer's (1949) climate regionalisation, the Olkusz area is under Central Highlands climate in the Silesia-Cracow region. Weather conditions are the result of the influx of arctic, subtropical, strong oceanic and strong continental air masses (Lazar 1962; Jędrzejczyk 2004). Average annual temperature is 8°C and varies depending on the relief; valleys and higher elevations have lower temperatures. The lowest temperature reaches –31°C and the highest 35°C (Szczypek 1997). The whole area is dominated mostly by weak and moderate westerly winds, but southwesterly and northwesterly winds also play a role (Jędrzejczyk 2004). Annual precipitation in Olkusz municipality is 700–800 mm, highest in June and September and lowest in February, March and October (Dziechciarz 2002). The growing season lasts 200–210 days (Anonymous 2004).

Low wind velocity and the large number of calms (24% of the year), occurring most frequently in August and September, prevent air pollution from dispersing. High levels of particulate pollution block solar radiation, increasing the annual count of overcast days (Nowak 1978; Kruczała 2000; Baic *et al*. 2004; Lorenc 2005).

Hydrological conditions

The Olkusz area is entirely within the Vistula River Basin. The hydrological system is very poor, due to the particular geological structure (permeable sands and Quaternary loess, weathering, and tectonic cracks in Mesozoic rock) and to hydrogeological conditions that allow water to seep into the ground. The Biała Przemsza river is the main watercourse draining the northern part of the region. The Sztoła river discharges water from the south. Bolesław municipality is in the basin of the Biała Przemsza river, mainly its left bank tributaries, the Biała river and Warwas and Struga creeks. The Biała river carries mine water and around Krzykawka and Laski it forms picturesque meanders, backwaters and swamps. The ponds in Krążek, Małobądz and Stara Wieś are some of the few waterbodies of the region. Surface waters cover less than 1% of Bolesław municipality (Anonymous 2005).

Some of the minor surface watercourses are artificial. Regulated canals such as the Dąbrówka and Baba and the partially regulated Sztolnia drain the ore mines. Sztolnia Ponikowska, another artificial watercourse, has dried up almost entirely. Exploitation and mining, together with water consumption, have profoundly altered the hydrological conditions (Baic *et al*. 2004; Anonymous 2004). Some of the surface watercourses may be contaminated due to weathering and leaching of metalliferous waste by acidic mine water (Bauerek *et al*. 2009).

Geological structure

In terms of geology the Olkusz region belongs to the Silesia-Cracow Monocline (Sokołowski 1990; Wika and Szczypek 1990; Jędrzejczyk 2004), where three structural levels can be distinguished: folded Palaeozoic forms, Mesozoic forms that create a monocline, and Cenozoic cover forms (Nowak 1978). The sediments of the Paleozoic structural layer are thick. They emerge to the surface between Bukowno and Sławków and form Upper Carboniferous sedimentary rocks consisting of sandstones and slates (Stupnicka 2007). The zinc and lead ores are locally associated with Triassic forms and occur as veins in conchoidal limestone and dolomite (Książkiewicz *et al*. 1965; Smakowski 1992; Cabała 2009). The Quaternary forms are lithologically varied, they do not form a continuous layer, and they range in thickness from a few to tens of metres, exceeding 60 metres in the Przemsza Basin (Cabała and Konstantynowicz 1999; Stupnicka 2007). They occur in the Mesozoic layers as fluvioglacial and aeolian sediments of the Pleistocene and Holocene (Cabała 2009).

The Olkusz deposits are one of Poland's three richest lodes of Zn-Pb ore. The deposits near Bytom and Tarnowskie Góry are furthest to the west. On the edge of the Silesia-Cracow Monocline they occur in the vicinity of Zawiercie, Olkusz and Chrzanów (Ney 1997; Szulc 2008). The exploited ore deposits in the Olkusz region are spread over large areas. Within the ore-bearing dolomites they form point bars and pockets, and fill karstic pockets (Sylwestrzak 1998). On the edges they form lenticular nest-like bodies (*Pomorzany* mine, Zawiercie-Siewierz deposits). Nest-like ore bodies also occur in dolomites of bunter sandstone in the area of the *Bolesław* placer (Cabała 2009).

The mineral composition of Zn-Pb ores in the placer varies in a manner reflecting the history of their formation (Ney 1997). The basic exploitable ores are usually built of zinc sulphides (sphalerite, wurtzite β) and lead sulphide (galena) with high silver content, accompanied by iron sulphides (marcasite, pyrite), cadmium (greenockite), calcite (calcium carbonate) and baryte (barium sulphate) (Cabała 2009). In the weathering zone, sulphides are easily oxidised and form secondary carbonates, zinc silicates (calamine) and lead silicates (cerussite) (Rybak and Wójcik 2009). This type of deposit was surface-mined in Bolesław, Ujków Stary and Krążek (Cabała and Konstantynowicz 1999).

Soils

The soils of Olkusz are highly diverse. Among the most common are regosols, poorly developed quartz-silicate soils, carbonate-free soils, podzols, hydrogenic soils, alluvial and industrial soils (Gruszczyński *et al*. 1990). The most common soils are formed on Quaternary sands, clays and loess (Cabała 2009). The entire area also has small patches of skeletal soils formed from limestone (Kiryk and Kołodziejczyk 1978). Also very diverse is the mechanical composition of the soil, including sand, loam, clayey and dust soils (Lazar 1962; Cabała 2009). The prevailing soils are dry, low-sorption and nutrient-poor (low nitrogen and phosphorus), and of little utility (Cabała 1990; Jędrzejczyk 2004). The OOR soils have exceptionally high concentrations of heavy metals, significantly deviating from the natural levels found in Polish soils (Anonymous 2004; Niklińska *et al*. 2005; Trafas *et al*. 2006; Pasieczna and Lis 2008; Kicińska 2009; Kapusta *et al*. 2011; Kapusta *et al*. – Chapter 13, this volume). Their sources are natural and anthropogenic. Soils developed on weathered, shallowly buried ore-bearing

dolomites are naturally enriched in metals, and centuries of exploitation and processing of metal-rich ores constitute the anthropogenic source. Contemporary processing of ores produced high emissions of pollutants and contaminated the soil over a wide area. Disposal of flotation tailings in settling ponds, consisting mostly of fine-grained fractions easily carried by the wind, are a secondary source of soil contamination (Bauerek *et al*. 2009; Cabała 2009). In the Olkusz region the soils richest in zinc, lead and cadmium (calamine soils) are found at sites of historical and modern ore extraction and processing: Bolesław, Ujków Stary, Bukowno, Stary Olkusz, and the vincinity of the *Bolesław* smelter and the *Pomorzany* mine (Pasieczna and Lis 2008).

Flora and fauna

The Olkusz region is used for agricultural purposes to a large extent, much of the area is covered by forests, and the remaining parts are built-up areas and wastelands. Mostly cereals, potatoes and forage are cultivated. Meadows and pastures occupy part of the fields. Some of the arable land is abandoned or is undergoing planned or natural afforestation.

The huge impact of mining and ore processing on the Olkusz region has shaped its contemporary flora. The landscape and the functioning of aquatic and terrestrial ecosystems have been altered drastically in areas where Zn-Pb ore has been mined (Woźniak and Kompała 2001; Zawada 2007). Old forests have been replaced by young species-poor greenwoods whose presence is due to remediation of parts of this area. The young age of forests is also related to the history of fires, sand quarrying, and afforestation of inactive gravel pits. On the other hand, human-caused changes of the natural environment in the Olkusz area have also promoted the development of the flora of this region. The opening of new habitats, the diversification of substrate chemistry and the formation of artificial terrain (various kinds of slag heaps) have enriched the species composition of the region. There are many legally protected species; the abundance of some of them is attributable to the presence of large wasteland areas where they can freely spread (Nowak *et al*. 2011; Nowak *et al*. – Chapter 8, this volume). At sites where calamine waste is deposited the only Polish calamine turfs have developed; species tolerant of high levels of metals in the soil occur there (Grodzińska and Szarek-Łukaszewska 2002; Jędrzejczyk-Korycińska 2006; Szarek-Łukaszewska and Grodzińska 2008, 2011; Kapusta *et al*. 2010; Kowolik *et al*. 2010). The value of those sites has been recognised: two sites particularly rich in calamine species have been placed under protection as Natura 2000 areas (Szarek-Łukaszewska and Grodzińska 2008; Kapusta *et al*. 2010; Jędrzejczyk-Korycińska – Chapter 15, this volume).

Bibliographic data on the flora of this area were included in the monograph *The vascular plants of the Olkusz Ore-bearing Region* (Nowak *et al*. 2011) and are also given in several chapters of this book.

The varied environmental conditions of the region create favourable conditions for animals. There are wild boar, deer, hares, and even some moose and beavers. There are also voles, squirrels, muskrats, raccoon dogs and a few ermines. Nineteen of the 21 bat species recorded from Poland can be found there. There is a rich bird fauna, including owls and eagle-owls, and a station of the black stork in the vicinity of Laski. Amphibians (e.g. salamanders) and reptiles (e.g. common European viper) have also been noted in the area (Dziechciarz 2002; Sawicki and Szlęzak 2012).

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