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The history of the Olkusz mining area of zinc and lead ores, and of the area of occurrence of *Biscutella laevigata* L.

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Introduction

Advances in metal production and processing were a 'technological acceleration' that opened a new chapter in the field of mining of natural resources. At the same time, these new abilities allowed the production of goods. Fundamental discoveries and inventions in the field of metallurgy are likely to have been attributed to people associated with making ornaments and broadly-defined decorative arts. They influenced the development of many more mining, processing, and metallurgy centers by prospecting vast territories. The primary location of such centers was in today's borderland between Iran and Turkey (Łęczycki 2010). By the 4th millennium BC, this region was developing a complex production infrastructure which needed organizing and protecting. There were organized centers of power and city fortifications on the Upper Euphrates. In successive millennia, a vast state-controlled structure was set up around the Black Sea, which was able to spread its influence further north, possibly also beyond the Carpathians.

The first metal discovered by humans was native gold found as nuggets, veins, wires, etc. In natural conditions, native silver and copper were also found upon crushing rocks. The origins of technology for processing native gold and copper into everyday objects through forging date back to around 7,000 BC (Łęczycki 2010). However, lead metallurgy taking place circa 6,000 BC is deemed to have been the oldest. While roasting an ore, lead oxide was obtained at a temperature of only 327°C and successively converted into metallic lead due to a reaction with charcoal. This lead technology was followed by copper metallurgy, whose origins date back to the 5th millennium BC. Initially, copper metallurgy was based upon oxide ores, but in the 2nd millennium BC, the interest was shifted to copper sulfide ores, which were more available. After circa 4,000 BC, various metals co-occurring in the extracted copper ore were mixed in the metallurgical process performed in the metallurgical centers. The alloys obtained exhibited better mechanical and functional properties, for example, bronze produced circa 3,500 BC, which was a 9 : 1 mixture of copper and tin (in Hungary, lead or antimony was used instead of tin). The production and casting technology for 'ancient bronze' (brass) was mastered circa 1,000 BC. Brass was a by-product in the copper smelting process from ore containing oxidized zinc minerals. The technology for producing and casting copper alloys was invented in Ancient Greece and taken over by the Romans, who propagated it all over their empire (Gurlt 1883).

Products made of non-ferrous metals and their alloys changed our way of life, especially at the start of the Bronze Age. In Southeastern Europe, this phenomenon took place in the early 2nd millennium BC, since the Bronze Age started around 1,800 BC. Smelting was only mastered considerably later and allowed the use of other metals. Pure metallic zinc was first obtained in China circa 600 BC (Pater 2011). From there, zinc smelting technology reached Persia and was developed in the years 1,100–1,200 AC. This knowledge only arrived in Europe in the 17th century. The main reason for such late mastering of zinc production was that, despite its relatively low boiling point of 907°C, zinc did not precipitate as a liquid and was instead released as vapor (like cadmium and mercury).

The oldest documentation of the mining and processing of lead and silver ore in the Silesian-Cracow Upland is the Papal Bull of Innocent II, 1136. However, some archaeological discoveries indicate that silver mining and metallurgy existed as early as the 9th century (Anonymus 2007). The Polish center of lead and silver ore mining and metallurgy was among the most important European mining centers in the early Middle Ages (Cabała et al. 2020).

In the long history of mining, lead and silver ores were often discovered by sheer coincidence. There were some ore-bearing rocks appearing directly on the surface or covered only by a thin layer of fertile soil. Such ores were found by inhabitants attracted by the silvery shine of lead glance (lead sulfide), which may have also contained silver nuggets. In the distant past, people also used a dowsing rod (Fig. 1). Skillful prospectors would find ore primarily by following field traces, such as the presence of a particular mineral in stream and riverbeds, fragments of veins in surrounding weathered rock, or relicts of the sea fauna and flora. They also observed the vegetation and may have known of plants which were associated with metals. In his work about mining and metallurgy, Georgius Agricola wrote that '…ore veins are grown over by herbaceous plants and mushrooms which do not occur in the neighborhood. Veins can be discovered due to those signs of nature.' (Agricola 1556). The significance of those signs reached the turn of the 20th century, when prospecting for deposits of useful minerals was based upon the knowledge of the geological structure. The use of field indications increased the probability of successful prospecting with expensive mining methods, which consisted of laying bare deposits by means of exposing shallow trenches and test pits, deeper drilling and adits (underground exploratory headings).

In the first centuries, the exploitation of silver-bearing lead glance did not require huge expenditure; many people were tempted by the profit. Miners deprived of sunlight and cut off from the outside world encountered subterranean elements, worked hard day and night, and firmly believed that their patience would be rewarded. Eventually they would come across 'the bullion'. The miner's profession entailed years of practice, in conjunction with a continuous improvement of mining

Fig. 1. Ore prospecting by Agricola (1556). A – dowsing rod, B – prospecting trench
Ryc. 1. Poszukiwanie złoża rudy według Agricola (1556). A – różdżka, B – rów poszukiwawczy

techniques and technology, because it was said that '…it's easier to plough than to mine in the hills…' (Agricola 1556).

Nevertheless, as the time went by, the costs of prospecting for ore deposits, opening them up, draining them using adits, and pumping out subterranean water was increasing. At the same time, these underground mining operations were becoming more and more risky. The implementation of mining projects entailed considerable funds and stable sources of financing. In order to meet such challenges, miners' guilds (joint stock mining companies of the time), were set up. However, there was a free enterprise system: irrespective of family background, nationality, social status, or sex, everybody had the right to open mines (called 'mountains') after obtaining a license, which was never refused (Molenda 1972).

For a long time, the art of mining was based upon the power of human strength and simple tools. Mining was extremely strenuous, dangerous, and time-consuming. Gunpowder is likely to have been used for rock blasting in Hungarian mining in the 16th century. Due to the use of gunpowder for deposit mining, mining productivity increased by 100 times (Gurlt 1883). In Poland, gunpowder was used only in the early 19th century in zinc ore (calamine) mines. Towards the end of the century, it was replaced with dynamite, and for drilling blast holes (to place blowing charges) adequate drilling machinery supplied with compressed air was implemented.

Under the ground, the ore was initially transported using wooden troughs, wheelbarrows, and three or four-wheeled carts. At the turn of the 20th century, manual rail transport in self-tipping cars (rocker dump cars) was introduced. Complete sets of cars were drawn by pulleys or horses. The ore, first supplied to the pit bottom, was loaded into baskets, iron-banded barrels, pails, or skin sacks, and then dragged up to the surface by pullers operated by at least two workers who rotated a shaft with a rope wound on it. In the second half of 19th century, winding gears were introduced in vertical transport, initially with steam and later with an electric motor.

The importance of mining silver-bearing lead glance and oxidized and sulfide zinc ores for the Polish state as the driving force for national, social, technological, and economic development is unmeasurable. To this day, the bold planning of mining and the historical and contemporary work conducted in difficult geological mining conditions is impressive. New ore deposits of lead, silver and zinc lying in carbonate Triassic formations were opened out into an area of around 2,000 km^2 within the 'Polish ore basin' in the Silesian-Cracow Upland, in two strips, each approx. 80 km long, extending from the north-west towards the south-east. The first of them covered an area from Siewierz, through Sławków, Olkusz, Lgota, Nowa Góra to Czerna. The other, an area from Bibiela, through Miasteczko Śląskie, Tarnowskie Góry, Bobrowniki, Czeladź, Będzin, Chrzanów, Trzebinia to Alwernia (Molenda 1972).

Zinc and lead mineralization of industrial importance occurred in the dolomitized parts dating back to the Middle Triassic. Ore-bearing dolomites which were metal carriers contained ore accumulations in the form of pseudo-beds and lens with various horizontal distribution patterns, as well as in the form of nest filling at variable vertical and horizontal intervals. Their

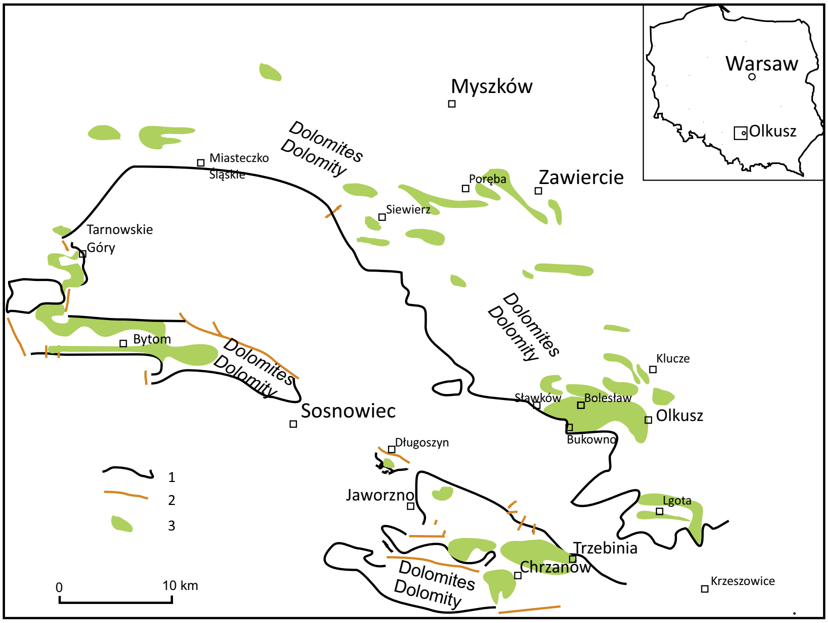

Fig. 2. A layout of deposit areas in the Silesian-Cracow region. 1 – erosion margin, 2 – fault, 3 – zone mineralized by zinc and lead ores (base on Cabała 2009, modified)

Ryc. 2. Rozmieszczenie obszarów złożowych w regionie śląsko-krakowskim. 1 – krawędź erozyjna, 2 – uskok, 3 – strefy zmineralizowane kruszcami cynku i ołowiu (za Cabała 2009, zmienione)

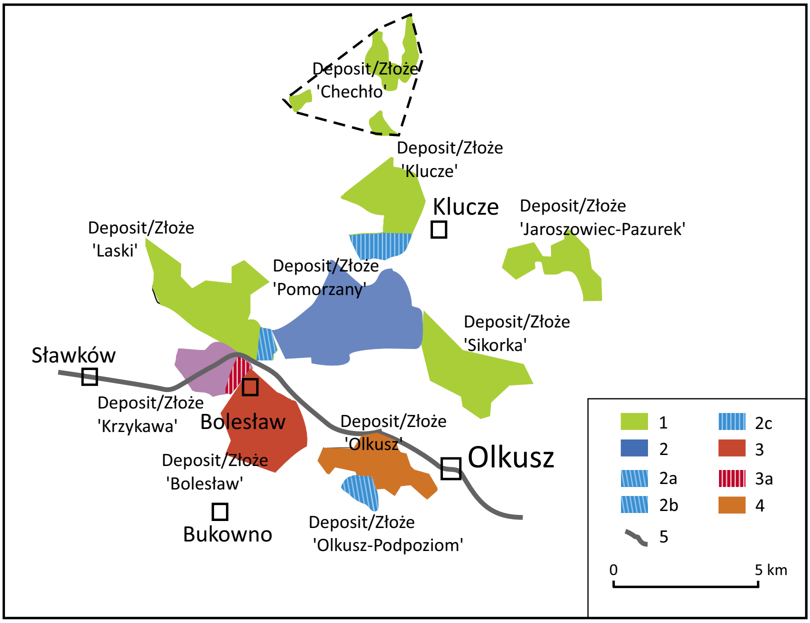

Fig. 3. Documented zinc and lead deposits in the Olkusz region (as of 1972) (base on Liszka and Świć 2013, modified). 1 – undeveloped deposits, 2 – 'Pomorzany' deposit developed on a level 175 m a.s.l., 2a – a portion of 'Laski' deposit depleted in the Pomorzany region of the 'Olkusz-Pomorzany' Mine, 2b – 'Olkusz-Podpoziom' deposit depleted by the Pomorzany region of the 'Olkusz-Pomorzany' Mine, 2c – a portion of 'Klucze' deposit mined by the Pomorzany region of the 'Olkusz-Pomorzany' Mine, 3 – 'Bolesław' deposit opened out on levels 264 and 245 m a.s.l., 3a – a portion of 'Krzykawa' deposit exploited by the 'Bolesław' Mine, 4 – 'Olkusz' deposit developed on a level 238 m a.s.l., 5 – trunk road 94 (Cracow–Katowice)

Ryc. 3. Udokumentowane złoża rudy cynku i ołowiu w rejonie olkuskim (stan na 1972 r.) (za Liszka i Świć 2013, zmienione). 1 – złoża nie udostępnione do eksploatacji, 2 – Złoże „Pomorzany" udostępnione na poziomie 175 m n.p.m., 2a – fragment złoża „Laski" wyeksploatowany przez rejon Pomorzany kopalni „Olkusz-Pomorzany, 2b – złoże „Olkusz-Podpoziom" wybrane przez rejon Pomorzany kopalni „Olkusz-Pomorzany", 2c – fragment złoża „Klucze" eksploatowany przez rejon Pomorzany kopalni „Olkusz-Pomorzany", 3 – złoże „Bolesław" udostępnione na poziomach 264 oraz 245 m n.p.m., 3a – fragment złoża „Krzykawa" wybrany przez kopalnię „Bolesław", 4 – Złoże „Olkusz" udostępnione na poziomie 238 m n.p.m., 5 – trasa przebiegu drogi krajowej 94 (Kraków–Katowice)

compact structure guaranteed safety for mining activities. For successful mining activities management, the structure of the area where ore-bearing deposits occurred, which was related to tectonics, was of the utmost importance. Faults with thrusts of a few dozen of meters or so gave rise to rift valleys and horsts. In the uplifted horst areas, the youngest Triassic (Keuper and Diplopora dolomites) and Jurassic deposits eroded. Shallow beds, for their ease of accessibility, were the first to be subjected to mining. In the early stages of the development of ore deposits, portions of zinc and lead ore containing oxide materials that were close to the surface were extracted. These were produced during the oxidation of sulfide minerals. Of particular importance was the extraction of lead glance (galena, lead sulfide) from which lead and silver were obtained. Then, oxidized ores dominated by zinc carbonates and silicates (calamine), lead carbonate (cerussite) and iron oxides (limonite) were extracted as well. The resources of zinc and lead sulfide ores in the depth of troughs and sink holes of monocline slabs were documented in the 20th century. Many elements and minerals were found there, but only zinc sulfide ore (blende) and lead sulfide ore (galena) were economically useful, with the total contents of metallic zinc and lead being 5–6%.

Within the Silesian-Cracow area of occurrence of Triassic deposits, a few important mining centers corresponding with the areas of occurrence of the richest deposits were established (Fig. 2). Those regions were as follows: Bytom, Tarnowskie Góry, Siewierz-Zawiercie, Chrzanów and Olkusz (Molenda 1972, Szuwarzyński 2000). The Olkusz region was best recognized and rich in ore (Fig. 3).

Mining in the Olkusz region

In the Olkusz region, zinc and lead ore deposits occurred in the lower shell limestone formed in the Triassic period as wavy limestone, which is characteristic of the time (Table 1). The upper level of wavy limestone was represented by ore-bearing dolomite containing zinc, lead and iron minerals (Fig. 4). The lower level is a typical, fine-grained, wavy and chalk rock, impermeable to water, known as 'basic limestone'. In the upper layers of shell limestone, Gangue and Diplopora dolomites covered by marly dolomites were accumulated on the ore-bearing dolomites. In the Mesozoic and Cenozoic eras, due to Alpine Orogeny, the formation of Triassic rocks was subject to strong tectonic rebuilding. Numerous rifts and fissures paved the way for mineralizing solutions, which favored the formation of ore-bearing bodies (nests, caves, troughs, pits, and fissure filling), with variable volumes, ranges, and locations. This impeded rational subterranean and open-pit mining. A continuous problem was the pervasive presence of water which often excluded mining works.

Initially, mining activities were conducted in areas where ore-bearing dolomites were on

Fig. 4. Zinc and lead ores (photo K. Boniecki)

Ryc. 4. Minerały rud cynku i ołowiu (fot. K. Boniecki)

Fig. 5. Excavation in the Pomorzany region of the 'Olkusz-Pomorzany' mine (photo K. Boniecki)
Ryc. 5. Wyrobisko eksploatacyjne rejonu Pomorzany kopalni „Olkusz-Pomorzany" (fot. K. Boniecki)

the surface, and a deposit strip spread over the natural table of subterranean waters. Outcrops of ore-bearing dolomites were usually local uplifts, hills or eminences surrounded by deep-cut valleys with flowing water. In the Olkusz region, the average depth of the table of subterranean water was around 10 m, but in some uplifts, it amounted to 20 m.

'Mountains', mines of silver-bearing lead glance, were primitive shafts subject to deepening as the rock mass was being dried. Upon obtaining a license, a main draining shaft was dug, with 3–4 smaller peripheral shafts to ventilate and to extract the ore, sludge, and gangue. The shafts were possibly connected with each other by possibly small headings, gradually widened according to the sizes of ore nests (hotbeds) discovered. When the resources had been depleted, the wooden framework of the shafts was disassembled, and miners moved to a new mining field (Łabęcki 1858).

In the age of shafts, the mines had to be drained continuously. Taking into consideration the water hazard, in 1473, the Cracowian bishop allowed working in mines on feast days (Kozłowski 1889). Since the drain machinery was insufficient to control the water, the workers resorted to drainage adits, already successfully implemented in Slovakian and Hungarian mining. The exploitation of silver-bearing lead glance, based upon adit drainage, ceased in the second decade of the 18th century. The map of the Olkusz and surrounding areas, created by Maciej Deutsch in 1761, shows an area riddled with skylights of drain adits and mine shafts, with respective densities of 120 and 456 per 10 km^2.

In the next century, mining activities in the Olkusz region completely disappeared. They resumed in the second decade of the 19th century, when a series of government-controlled calamine mines were established in the area from Czerna, through Olkusz and Bolesław, and up to Sławków, under the management of the administration of the Kingdom of Poland. Among the most important mines

Table 1. Stratigraphy of the Olkusz region

Tabela 1. Stratygrafia rejonu olkuskiego

<table>
<tr><th>Period
Okres</th><th>Epoch
Epoka</th><th>Stage
Piętro</th><th>Strata
Warstwy</th><th colspan="2">Deposition
Zaleganie</th><th>Lithology
Wykształcenie litologiczne</th><th>Mineralization
Okruszcowanie</th><th>Aquifer Horizon
Poziom
wodonośny</th></tr>
<tr><td>Quaternary
Czwartorzęd</td><td>……</td><td>……</td><td>……</td><td colspan="2">Q</td><td>Fine-grained sands, thickness: up to 80 m
Drobnoziarniste piaski o miąższości
do 80 m</td><td>……</td><td rowspan="3">I Aquifer
horizon
I poziom
wodonośny</td></tr>
<tr><td rowspan="2">Jurassic
Jura</td><td>Upper (Malm)
Górna (Malm)</td><td>……</td><td>……</td><td>J_3</td><td rowspan="9">Q</td><td>Platy limestone, marls, at the bottom,
thickness: up to 60 m
Wapienie płytowe, w spągu margle do
60 m miąższości</td><td>……</td></tr>
<tr><td>Middle
(Dogger)
Środkowa
(Dogger)</td><td>……</td><td>……</td><td>J_2</td><td>Platy marls, conglomerates at the
bottom, thickness: up to 13 m
Margle płytowe, w spągu zlepieńce
miąższości 13 m</td><td>……</td></tr>
<tr><td rowspan="7">Triassic
Trias</td><td>Keuper
Kajper</td><td>……</td><td>……</td><td>T_3</td><td>Green and red mottled clays, thickness:
up to 90 m
Iły pstre zielone i czerwone o miąższości
do 90 m</td><td>……</td><td>Isolation
Izolacja</td></tr>
<tr><td rowspan="6">Shell limestone
Wapień
muszlowy</td><td rowspan="2">Upper
Górny</td><td>Wilkowice
Wilkowickie</td><td rowspan="2">$T_2 3$</td><td>Conglomerates, up to 4 m
Zlepieńce do 4 m</td><td>……</td><td rowspan="6">II Aquifer
horizon
II poziom
wodonośny</td></tr>
<tr><td>Tarnowice
Tarnowickie</td><td>Marly dolomites, up to 20 m
Dolomity margliste do 20 m</td><td>……</td></tr>
<tr><td>Middle
Środkowy</td><td>Diplopora
dolomites
Dolomity
diploporowe</td><td>$T_2 2$</td><td>Granular dolomites, thickness:
up to 40 m
Dolomity ziarniste o miąższości
do 40 m</td><td>……</td></tr>
<tr><td rowspan="3">Lower
Dolny</td><td>Karchowice
Karchowickie</td><td rowspan="3">$T_2 1$</td><td>Crystalline limestones, thickness:
up to 12 m
Wapienie krystaliczne 12 m</td><td>……</td></tr>
<tr><td>Terebratula
Terebratulowe</td><td rowspan="2">Crystalline limestones, thickness:
up to 20 m
Wapienie krystaliczne o miąższości
do 20 m</td><td rowspan="2">Grey, hard,
crystalline ore-
bearing dolomites</td></tr>
<tr><td>Górażdża
Górażdżańskie</td></tr>
</table>

Triassic Trias			Gogol Gogolińskie		Q	Light grey limestone, thickness: up to 30 m Wapień jasno-szary o miąższości 30 m	Szare, twarde, krystaliczne dolomity kruszconośne	Isolation Izolacja
	Bunter sanstone Pstry piaskowiec	Upper Górny (Ret)	......	T_13		Grey, dolomites, thickness: up to 30 m Dolomity szare, o miąższości do 30 m	Rhaetian dolomites Dolomity retu	III Aquifer horizon III poziom wodonośny
		Lower Dolny	......	T_12		Sandstones, sands or silts, thickness: up to 3 m Piaskowce, piaski lub iły o miąższości do 3 m	......	
Permian Perm	Rotliegend Czerwony spagowiec	......	......	P_1		Pebbles of limestone, quartz, dolomite, porphyry and melaphyre with tufa and marly binder, thickness: 200 m Otoczaki wapienia, kwarcu, dolomitu, porfiru i melafiru z lepiszczem tufowo-ilastym o miąższości do 200 m	......	Isolation Izolacja

were 'Józef', 'Ulisses', 'Jerzy' and 'Bolesław'. The initially chaotic extraction of calamine from abandoned former works, dating back to the age of silver and lead, evolved into systematic subterranean mining activity, which in the Olkusz region lasted until 1908. In the area surrounding Bolesław, mining activities ceased in 1931 and resumed in 1940. In the post-war period, based upon investigative drilling, geological documentation of zinc and lead deposits was compiled from Bolesław (1953), Olkusz (1959), Klucze (1964), Pomorzany (1969), Chechło (1969), Sikorka (1970), Laski (1971), Krzykawa (1971) and Jaroszowiec-Pazurek (1972). Among them, only the deposits in Bolesław, Olkusz and Pomorzany were made available. Today, the extraction of the remaining deposits in the Olkusz region is deemed unprofitable.

In the 20th century, the extraction of zinc and lead ore in the Olkusz region was continued by the Bolesław Mining and Metallurgical Plant (Zakłady Górniczo-Hutnicze 'Bolesław' known as ZGH Bolesław) in Bukowno established in 1958. The company had three mining plants, 'Bolesław' Mine (successor of combined 'Bolesław' and 'Ulisses' calamine mines), 'Olkusz' Mine (established in 1968) and 'Pomorzany' Mine (in operation since 1974). Those mines mainly extracted zinc and lead sulfide ores. A ZGH Bolesław mining area of 56 km^2 was established on the surface and covered the area of the former historical mining industry of lead, silver and zinc, situated around the localities of Bolesław and Olkusz, as well as the previous iron mining area at Krzykawa.

Continuous mining activities, performed for more than 70 years, led to the depletion of the deposits in the Olkusz region. Both the 'Bolesław' Mine and part of the 'Olkusz-Pomorzany' Mine were put under liquidation, on 1 July 1992 and 1 January 1998 respectively

(Włodarz 2003). Given that it is impossible to open up new deposits in the Olkusz region, the extraction in the mines will inevitably cease and the excavations will be destroyed. This is scheduled for the 2020s. So far, zinc and lead ores have been extracted in the region of the Pomorzany rift and in part near the Biała horst (a part of Kucze deposit) in the 'Olkusz-Pomorzany' Mine (Fig. 5).

Detailed history of ore mining in the selected parts of the Olkusz region

The Olkusz region is situated in the borderland of the Cracow-Częstochowa Upland (vertical datum from 400 to 480 m above sea level) and the Silesian Upland (vertical datum from 300 to 330 m above sea level), in a vast Triassic valley surrounded by limestone diapirs of Polish Jurassic Highland. Its edge, the so-called 'questa', runs from the south eminence ('Black Mount' hill), skirts the eastern part of Olkusz ('Jurassic hills in Olewin'), then stretches northwards ('Jurassic hills in Pomorzany') and northwestwards ('Jurassic hills in Klucze'). Extending westwards of the valley lies the area of the Starczynowska Desert field with Quaternary postglacial sands, extending southwards from Starczynów, and the area of the Błędowska Desert situated westwards. Both the sandy areas are united by the marginal stream valley of the Przemsza River, skirting along the western side of the locality of Pomorzany. The northern part of the valley is an area with dolomitized formations, from the Middle Triassic period, which have been raised to the surface (the Olkusz-Bolesław horst). In the eastern part, this area covers the city of Olkusz with the localities of Stary Olkusz and Pomorzany, and in the west the localities of Starczynów, Ujków, Bolesław, Krążek and Tłukienka. On the southern side, those dolomites were cut with faults and tectonically downthrown. In that area, they were covered by post-glacial sandy deposits within the Baba riverbed. The southern boundary of dolomite deposits runs in the Niesułowice-Starczynów line, the western one from Bukowno, through Krążek and Bolesław, towards Klucze.

Mineralization with silver-bearing lead glance and zinc blende is related to a shallow deposit of ore-bearing dolomite. In rift valleys, deposits occurred considerably deeper: under argillaceous Keuper formations and Jurassic limestones. Fine-crystalline and compact ores bearing dolomites of yellowish, dark brown or dark grey color are made of various formations with ferruginous dolomites and numerous limestone relics. Their mineralization with zinc and lead is related to tectonic disturbances, namely faults and rift valleys. The sulfide ore was a mix of sphalerite, marcasite, and calamine.

Scientific investigations confirm unambiguously that the production of lead and silver took place from as early as the 12th century. Even earlier production is probable based on the Olkusz deposits. From the 12th century onwards, in the region from Olkusz to Łosien and Sosnowiec, there were centers of lead and silver metallurgy which have left slags and numerous artifacts all over the surface (Cabała et al 2020). In the Olkusz region, the mining industry in the lead and silver period (14th–18th century) was based upon shallow resources of silver-bearing galena lying on the outcrop of ore-bearing dolomites. The metals were extracted from foreshafts, drilling down to the level of underground water, and from where the exploratory drifts followed ore veins. Localised well-like draining systems did not permit one to descend permanently below the level of subterranean waters. Instead, this was

Fig. 6. A satellite picture of the mining area of the Bolesław Mining and Metallurgical Plant in 2019 with marked locations of reclaimed open-pit mines: 'Bolesław' (1), 'Krążek' (2), 'Hałda Michalska' (3), 'Ujków Stary' (4), 'Dąbrówka' and the underground mine 'Olkusz-Pomorzany' (5). A – ZGH Bolesław zinc smelter, B – ZGH Bolesław settling ponds [Orthophotomap originate from the National Geodetic and Cartographic Resources (PZGiK)]

Ryc. 6. Obraz satelitarny obszaru górniczego Zakładów Górniczo-Hutniczych „Bolesław" z 2019 roku z zaznaczonym położeniem zrekultywowanych odkrywek górniczych: „Bolesław" (1), „Krążek" (2), „Hałda Michalska" (3), „Ujków Stary" (4), „Dąbrówka" i kopalnią podziemną „Olkusz-Pomorzany" (5). A – huta cynku ZGH „Bolesław", B – stawy osadowe odpadów flotacyjnych ZGH „Bolesław" [Ortofotomapa pochodzi z Państwowego Zasobu Geodezyjnego i Kartograficznego (PZGiK)]

achieved using subterranean drain adits, whose surrounding excavations were also explored for lead glance. Mining activities ceased completely after the total depletion of ore down to the level of drain adits.

In the early 19th century, workers returned to the areas of the old medieval mines where oxidized zinc ore was once extracted and is now abandoned as gangue. Since calamine occurred as nests limited in size, its extraction continued using many drawing and upcast shafts, connected by passages.

The extraction of calamine gave rise to an unprecedented development of open cast mining in the 'Bolesław' Mine, making it the longest operating ore mine (1821–1996) in Poland. The mine extracted calamine existing in the roof of ore-bearing dolomites, in the form of nests and lenses of various sizes, often connected with each other, with the vertical datum ranging from 285 to 305 m above sea level. The nearby faults' depth reached up to 30 m, and the width reached up to 100 m. Calamine open cast mining down to 30 m covered an area of around 30 ha, and comprises the following strip pits: 'Bolesław', 'Hałda Michalska', 'Ujków Stary', 'Dąbrówka'. There were arranged dumping grounds (heaps) for overburden and gangue near the open-pits.

Before 1931, the richest ore nests, containing more than 13% zinc, were depleted. In the post-war period, the exploitation of the remaining and poorer deposits through open-pits was planned. The ore from open-pit mines was washed with slurry and material from heaps and dumping grounds containing poor calamine. Intensive open-pit mining started in 1957, but was abandoned in 1981 when proven unprofitable, and these materials were deemed economically unviable.

'Bolesław' open-pit

The 'Bolesław' open-pit was established on a calamine nest situated within the Kuklinki hill, which was described by Dr Löwe as follows: 'The entire hill appears to be one great depot which, from the bottom to the top, could be reconstructed in an open cast. Dolomite is so strongly bound with chips of zinc spar that it looks like a true calamine breccia. With a careful manual stripping one can obtain calamine containing 10–15% zinc'. In the entire mass, lead glance was found among the calamine in a concentrated form. The calamine deposit was in 40–70 m thick ore-bearing dolomite, of which the lower part was grey, crystalline, hard, and roughly broken, with numerous caverns. The upper portions were brown, or greyish brown, because they had lost their primary crystalline structure due to weathering. In the fissures, both limonite and calamine were present. Near the faults, rich nests of zinc and lead ore were also present. Calamine was dispersed irregularly in brown, brittle and weathered dolomite, or it occurred as tenuous veins in compact dolomite. It was formed into irregular-shaped nests, measuring 50–80 m. Calamine was accompanied by irregular glance veins, with an average diameter of 3 cm, filling the fissures in the dolomite.

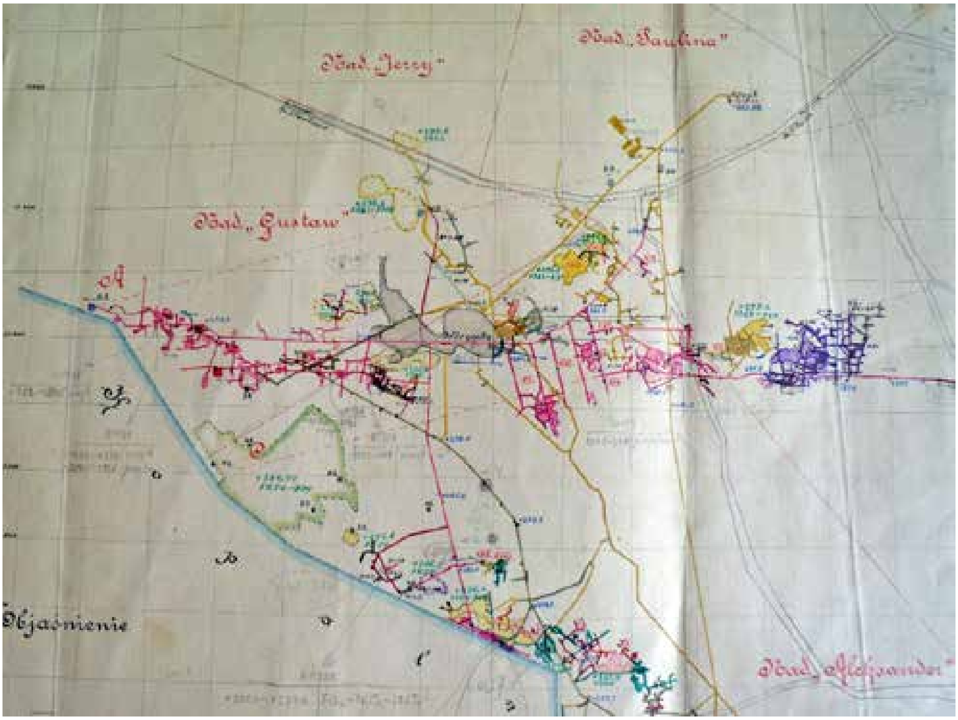

Fig. 7. 'Bolesław' open-pit mine – a map showing excavations of 'Bolesław' mine, 1931. Grey color indicates an open-pit mine, other colors mark the respective deposit mining levels. Scale 1 : 5,000

Ryc. 7. Odkrywka „Bolesław" – lokalizacja na mapie wyrobisk górniczych kopalni „Bolesław" z 1931 r. Kolorem szarym oznaczono odkrywkę, pozostałymi poszczególne poziomy eksploatacji złoża. Skala 1 : 5000

Fig. 8. 'Bolesław' open-pit mine during technical reclamation, 2002 – a view from the south (photo B. Włodarz)
Ryc. 8. Odkrywka „Bolesław" w trakcie rekultywacji technicznej, rok 2002 – widok od strony południowej (fot. B. Włodarz)

In the early Middle Ages, the Kuklinki hill was where lead glance was mined. There were not superficial water courses or water bodies. The drifts created in the 16th century drained the rock mass as far as Ujków, removing water within a radius of approximately 1 km. This enabled open cast mining on a massive scale from 1900–1930, which resulted in an excavation volume of around 3 million m^3. Old side drift works formed a labyrinth of crisscrossed passages and chambers situated on various levels. When calamine extraction resumed in the old works, it turned out that in the pillars left among the passages and chambers still contained about 50% of primary ore resources. In 1931, after abandoning the mining activities started 60 years earlier, the 'Bolesław' open-pit excavation was an oblong, irregular elliptical shape, approximately 250 m wide and 650 m long (Fig. 8). Its area exceeded 12 ha, at a depth of 30 m.

After World War II, the calamine deposit in the region of the 'Bolesław' open-pit was estimated to reach 1,000 m eastwards and 500 m northwards, and the zinc contents in the ore was 8–8.5%. However, the extraction from this part of the open-pit deposit was not resumed.

In the early 1980s, in the western part of the excavation, a municipal landfill was sited. Because of a fire, the waste already dumped there was covered by a layer of gangue and, in part, rehabilitated by means of reforesting. Eventually, the open-pit excavation was approximately 450 m long east to west, and about 220 m long north to south. Along the southeastern side boundaries of the 'Bolesław' open-pit on the mine waste heap, the 'Pleszczotka' Natura 2000 area (PLH120092) was established and constitutes a habitat of calaminarian grasslands with the buckler mustard (*Biscutella laevigata* L.) (Jędrzejczyk-Korycińska and Szarek-Łukaszewska – Chapter 10 of this volume).

‘Hałda Michalska’ open-pit

The ‘Hałda Michalska’ calamine nest was located between Ujków Stary (north) and Starczynów (south), on an uplift of ore-bearing dolomites, entirely surrounded by faults beyond which lies Diplopora dolomites and Tarnowitz layers. The vertical datums of the surface in the surrounding area oscillated from 325 to 334 m above sea level. Calamine stretching up to the vertical datum of 316 m a.s.l. contained 4–8% zinc, and exiguous quantities of lead. Calamine mining dates back to the early 20th century. It continued until 1931, and calamine containing more than 7% of zinc, was sent off to metallurgical plants. The ‘Hałda Michalska’ open-pit was reopened, and mining continued between 1953–1969, which gave rise to a 2.9 ha excavation with a depth reaching 15 m, the total volume being 270,000 m^3. After the open-pit was decommissioned, the excavation was backfilled and reclaimed, with the aim of reforestation (Fig. 9). The second Natura 2000 area (PLH120091 ‘Armeria’) was established to protect calaminarian grassland, measuring 7.4 ha (Jędrzejczyk-Korycińska and Szarek-Łukaszewska – Chapter 10 of this volume).

‘Krążek’ open-pit

A calamine nest was found in the roof of ore-bearing dolomites, on the southern side of the fault of the Bolesław rift valley near

Fig. 9. A view of the ‘Hałda Michalska’ open-pit, rehabilitated through planting pines, 2019. Along the line of birches, an embankment for the narrow-gauge railway leading to the open-pit mine is still visible (photo B. Włodarz)

Ryc. 9. Widok na zrekultywowaną poprzez nasadzenia sosny odkrywkę „Hałda Michalska”, rok 2019. Na linii brzóz nadal widoczny nasyp kolejki do odkrywki (fot. B. Włodarz)

Fig. 10. A view inside the ‘Krążek’ open-pit mine, 1995 (photo B. Włodarz)
Ryc. 10. Widok wnętrza odkrywki „Krążek", rok 1995 (fot. B. Włodarz)

Krążek. The nest was mined until 1931 by the ‘Ulisses’ mine, down to the vertical datum 321 m a.s.l. In this deposit, calamine occurred in small quantities as little crystalline aggregates in the zinc ore. The extraction intensified in the open-pit when the government-owned ‘Ulisses’ calamine mine was taken over by the Polish-Russian Society in the 1890s. Between 1956–1968 and 1979–1981 the ‘Bolesław’ mine resumed the extraction of oxide ore in the ‘Ulisses’ open-pit, renamed to ‘Krążek’ (Fig. 10). The open-pit was rehabilitated by backfilling and the planting of trees during 1997–2003.

‘Ujków Stary’ open-pit

The ‘Ujków’ nest, situated southeast of the Ujków locality, was drained and developed through mining in the existing ditch with a vertical datum from 297 to 298 m above sea level. At the end of the 19th century, extracting minerals with foreshafts was attempted. In order to lower the table of water along the narrow-gauge railway leading to Bolesław, a drainage ditch was prepared. In the village of Ujków Stary, two wells with calamine lead glance were found. Even earlier, in the 1880s, on the western side of Ujków Stary, calamine containing lead glance was extracted with the foreshaft technique. On that site, at a vertical datum of 306 m a.s.l., were old 16th/17th century preserved chamber excavations from which lead glance had been extracted, and calamine was left as a floor.

The ‘Ujków’ calamine nest was developed for mining purposes at the turn of the 20th century. Around the year 1900, a small, separate mine with its own drawing shaft and subterranean drainage system was established and operated successfully for some time. At the vertical datum 308 m a.s.l., the rock mass was cut open with a series of exploratory drifts. As early as 1905, mining was interrupted due to the expanding tributaries of subterranean water. In

Fig. 11. Reclamation of the 'Ujków Stary' open-pit in 1995 – a view from the north, from the top of settling ponds (photo B. Włodarz)

Ryc. 11. Rekultywacja odkrywki „Ujków Stary" – widok od strony północnej, ze szczytu stawów osadowych, rok 1995 (fot. B. Włodarz)

1924, a crosscut was made at a vertical datum 298 m a.s.l. and leading from the center of 'Bolesław' mine in coherent grey dolomite, the area was drained. When the presence of calamine had been confirmed, 20 shallow manual holes were drilled in the floor of those drifts, and a calamine deposit was documented in the floor of existing excavations down to a depth of 1.5–5.0 m. According to that evaluation, the 'Ujków' nest area could be mined in an open-pit extending to an area of approximately 3 ha, with a calamine bed containing 15% zinc and 1% lead.

After stripping the blanket rock in 1926, open-pit mining started to reach a depth with a vertical datum of 306 m a.s.l. The extracted mineral was calamine, and simultaneously a crosscut was hollowed out to the level of 298 m a.s.l. When the crosscut passed through the open-pit, it entered a zone of cracked, bright yellow dolomites, locally mineralized with calamine in the presence of the expanding tributaries of underground waters. As soon as the flow of water coming from the marginal stream valley of the Przemsza River had reached a rate of 4 m^3/min, the crosscutting was stopped. A dam was built in the cohesive dolomite and the water inflow was cut off. In 1931, the mining activity in that region was ended.

In the 1950s, the Ujków deposit was developed and drained, with drifts made at a vertical datum of 290 and 280 m a.s.l., which made it suitable for open-pit mining. On average, the vertical datum was 322 m a.s.l., and the vertical datum of the deposit roof was 310 m a.s.l. The deposit depth was estimated at 6 m. The Ujków open-pit was reopened in 1957.

Calamine was extracted until 1981, and the depletion reached a depth of 30 m in an area of 26.1 ha. The volume of the resulting open-pit excavation totaled 6.2 million m^3.

The open-pit was reclaimed between 1993–1996 through backfilling (Fig. 11), with the view of reforestation. On the small non-forested areas, buckler mustard and other species of calaminarian grasslands grow. These species are also occasionally found in loose woodlands (Jędrzejczyk and Szarek-Łukaszewska – Chapter 10 of this volume).

'Dąbrówka' open-pit

In this area, ore-bearing dolomite contained a calamine deposit with traces of shallow underground mining at the turn of the 20th century. The 'Dąbrówka' uplift was drained by a short drain adit and an open channel. The water drained from excavations was transported using this channel and was used for watering the manor meadows in the Bolesław estate.

The 'Dąbrówka' area was subject to open-pit mining in the last decade of the 20th century. Cracked dolomite containing lead sulfide sheets and grains, and infiltrations of iron ore or calamine occurred in the open pit. Underground and open-pit mining was conducted in a separate calamine mine and drained by steam engine-driven pumps. Next to the mine, a calamine washer (Fig. 12) was installed and pools of leftover sludge still exist to this day. The open-pit was still mined at intervals during the early 20th century. There were two

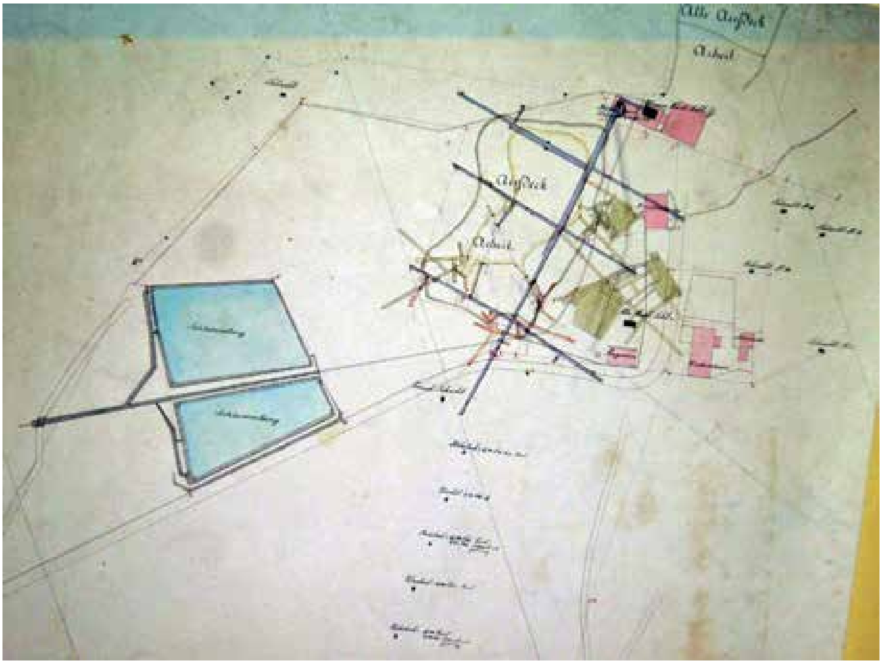

Fig. 12. A fragment of the map with the location of 'Dąbrówka' mine, 1872. The color violet indicates the main excavations to open out calamine deposits. The color yellow refers to excavations. The color blue indicates settling ponds of slurry. Building structures are marked red. Scale 1 : 5,000

Ryc. 12. Wycinek mapy z lokalizacją kopalni „Dąbrówka" z 1872 r. Kolorem fioletowym oznaczono główne wyrobiska udostępniające złoże galmanu. Kolor żółty nadany został wyrobiskom eksploatacyjnym. Na niebiesko wyróżnione zostały stawy osadowe szlamów popłuczkowych. Obiekty budowlane posiadają czerwone zabarwienie. Skala 1 : 5000 excavations, one oblong shape of 300 × 50 m, and the other with a diameter of approx. 50 m. The total area of open-pits was around 1.5 ha, and its depth did not exceed 10 m. In the 1920s, in the Dąbrówka region, 10 exploratory holes were drilled, and a 5–18 m thick calamine bed was documented, with 8% zinc and 1% lead situated at datums between 292 and 308 m a.s.l. However, further open-pit extraction of these resources did not continue.

When work began on the 'Pomorzany' deposit, the abandoned 'Dąbrowka' open-pit excavations were filled with the extracted gangue. In the 1970s, the Trunk Road no. 94 was built through the pools of leftover sludge. In 1900, remnants of metallurgical furnaces were still visible next to the Dąbrówka area, in the village of Hutki. Dumps of metallurgical slags contained on average approximately 7% zinc and 7% lead.

Transformation of the landscape and terrain caused by the extraction of zinc and lead ores

As mentioned before, the Olkusz region has a specific geological structure and topographic morphology. Its specificity results from the occurrence of oxidized and sulfide zinc and lead ore in Triassic strata. One peculiar morphological feature is the huge accumulations of Quaternary sand from the Starczynowska and Błędowska Deserts associated with the sand-filled marginal stream valley of the Przemsza River. The Olkusz region lies in the river basin of the White Przemsza. Natural water courses in the river basin disappeared due to draining of the rock mass during mining. Pumped mine waters in sealed beds were transported out by artificial streams. Drained deposits of zinc and lead ores, Triassic and Devonian dolomites, and Quaternary sand became subject to intensive mining conducted by open-pit and underground methods.

The extraction of those raw materials heavily interfered with the environment of the Olkusz region. Both open-pit and underground mining brought about numerous surface deformations. Open-pit mining was preceded by the removal of overburden (soil layers and useless gangue), which was dumped on the surface. The heaps that emerged about open-pit excavations were a few meters high and vastly extended around open mines. Their material was ground up to various degrees, from gravel to bigger rock lumps, and it contained residual ores. Today, most heaps are covered by vegetation, as a result of both natural causes and reclamation.

Now, in the regional landscape there are no visible giant 'holes' after the contemporary open-pit post-mining because they have all been reclaimed (Włodarz 2003). The overwhelming majority have been backfilled with above-ground overburden heaps, the material coming from gangue dumping areas, and sometimes with waste from ore flotation. Eventually, new land surfaces emerged, and the soil was restored by technical reclamation and by the dumping of foreign material. As part of biological reclamation, a layer of vegetation was planted, and the composition of species depended on whether it was targeted at forestation, meadows, parks, etc. All of this was essential for transforming the regional environment.

The region of Olkusz was characterized by strong waterlogging of the strata, and constantly renewing water reserves which were in the state of dynamic equilibrium. The several hundred years of mining activity resulted in changes in hydrographic conditions, at first due to drainage by wells, and then by the system of adits, and now by underground drainage using the system of pump chambers.

The biggest inflows of underground water (373.50 m^3/min) to underground mining sites occurred in the 'Olkusz-Pomorzany' mine in 1998. Drainage of the strata to the depth of 150 m below ground level in the central part of the 'Pomorzany' deposit and to around 60 m below ground level in the outlying areas of the Olkusz region created suitable conditions for underground and open cast mining. At the same time, many springs, surface watercourses and wells waned, and water from existing natural reservoirs infiltrated the strata. It has been estimated that the depression sink, formed by draining the strata for many years, is around 485 km^2, including 250 km^2 of the depression sink directly associated with mining operations.

Contemporary underground mining has also had a fundamental impact on the extent of changes in the land morphology and hydrographic conditions. For example, land subsidence occurred. The resulting caving and cracks in the blanket rock over the mining fields directly sped up the infiltration of precipitation into the rock, and a connection of previously isolated Quaternary and Tertiary multi-aquifer systems. The related phenomena of subterranean suffosion and erosion led to deformation of the land surface; either the existing marshland or overflow lands were dried, or new ones came into existence. These factors indirectly caused changes to the vegetation and reduced the productivity of arable and forest crops.

When the silver and lead mining industry started to take shape, nature was subject to considerable changes in the surrounding area. A useful tool for studying the history of nature in a particular area are peat bogs, which reflect natural changes and economic transformations over time. In strata containing organic, non-decaying matter, peat bogs store organic and mineral dust as well as industrial pollutions, deposited thereupon. A peat swamp near Wolbrom is found in the direction that air pollution travels from the Silesian-Cracow area. After investigation of the peat swamp, it was determined that there was a rapid development of lead and silver metallurgy in the years 800–860 AC, as well as its slow decline circa 1,500 AC despite an obvious increase in lead glance exploitation in the Olkusz region (Anonymous 2007). This may imply that lead smelting in the Olkusz region was limited due to a lack of firewood. The felling of royal woodlands to get fuel for local mining and metallurgy gave rise to shifting sands, and this area is now referred to as the Błędowska Desert. While investigating the peat swamps near Tarnowskie Góry, it was determined that from approximately 1570 onwards, the extraction of lead glance gradually diminished. Even so, there was a continuous increase recorded in lead fall until 1825. The results of the investigation suggest that wood from the Tarnowskie Góry and Lubliniec woodlands was used for lead smelting from Olkusz ores near Tarnowskie Góry.

Changes to the landscape and nature in the Olkusz region are also related to the processing of the extracted zinc and lead ore, subject to ore dressing and treatment. Oxidized ores were washed, which meant producing big quantities of slurry. The slurry was stored in various places in the Olkusz region, and this has now been reclaimed through levelling, covering with fertile soil, and restoration of vegetation. Slurry was also used as a batch in the zinc oxide production of rolldown-type furnaces.

Sulfide ores are subject to heavy mineral separation using dense liquid, which leads to a 35% recovery of dolomite in the feed material. In turn, during the flotation process, zinc and lead concentrates (8% of feed) and flotation waste (57% of feed) are obtained. Flotation wastes are collected in settling ponds, spanning an area of about 112 ha. The waste heaps, up to 50 m tall, dominate the regional landscape. As a result of the development of processing technologies for zinc and lead sulfide ores, secondary processing of the material collected in the ponds is possible.

Reclamation of open-pit mine excavations in the Olkusz region

Effective environmental protection standards ensure that mining technologies do not completely destroy the natural environment. They take into consideration natural conditions, land development methods, protection of cultural assets, historical buildings and monuments, as well as protection procedures for urbanized and industrial landscapes. The open cast mining of the 19th and 20th centuries left areas in the region of Olkusz degraded and devastated. Over time, the development of plant communities occurred by ecological succession on the abandoned land, or the land was deliberately reclaimed, which resulted in the development of new man-made landscapes. Ecological succession leads to the establishment of grasslands and then of scrub and woodlands on the bare ground of mine waste heaps, escarpments, and the bottom of opencast mining excavations. Reclamation creates both new habitats and a layer of vegetation.

The first reclamation techniques for open-pit excavations in the Olkusz region were for practical reasons. The rapidly developing city of Olkusz adopted an excavation in an open-pit mine of oxidized zinc ore, as well as a quarry in the municipal area, to serve as landfills. Municipal, industrial, and hospital waste backfilled the open-pit in one of Olkusz's quarters where ore was once extracted. The area was then covered by a layer of fertile soil, and soon became the town market. The flat top of the landfill in the quarry in Pomorzany was reclaimed with earth taken

Fig. 13. A landfill at the central part of the 'Ujków' open-pit, 2008 (photo B. Włodarz)

Ryc. 13. Wysypisko odpadów w środkowej części odkrywki „Ujków", rok 2008 (fot. B. Włodarz)

Fig. 14. Reclamation of an open-pit performed by backfilling with slags, 2002 (photo B. Włodarz)
Ryc. 14. Rekultywacja odkrywki górniczej przez zasypanie żużlami pokutniczymi, rok 2002 (fot. B. Włodarz)

from foundation trenches prepared for multi-storey buildings. An expansion of the mines in the Olkusz region, in conjunction with the development of other branches in the industries of trade, services and small-scale production, caused a considerable increase in the local population. An attempt to develop the 'Bolesław' open-pit mine into another municipal landfill resulted in a huge fire with fumes reaching the underground excavations in the 'Bolesław' mine. The firefighting and rescue operation lasted for two weeks in June and July of 1984 (Liszka and Świć 2013). When the fire was extinguished, the existing landfill in the 'Bolesław' open-pit was reclaimed, which included steep slope levelling. In the 1990s, the area was planted with pines, larches, and some deciduous trees for afforestation, however there was little success.

The subsequent absence of a municipal landfill for the Olkusz region was resolved by repurposing the southern part of the 'Ujków Stary' open-pit, which had an area of approximately 3.8 ha and a volume of 500,000 m^3 (Włodarz 2014). This landfill was used until 1998, and its reclamation, aimed at reforesting, was carried out in stages between 1995 and 1998 by covering its flat top with a 0.5 m thick layer of fertile soil with successive tree planting. The reclamation also covered the central part of 'Ujków Stary' open-pit, measuring 13.1 ha with a volume of 3.2 million m^3. Here, the landfill, in operation since 1995, has foil insulation, a leachate treatment plant, as well as a degassing and pest control system, etc. (Fig. 13).

Reclamation through backfilling with metallurgical waste was applied in the 'Hałda Michalska' open-pit. In this excavation with a volume of almost 270,000 m^3, metallurgical slags produced in the pyrometallurgy of zinc-bearing waste were placed in rolldown-type

Fig. 15. Reclamation of an open-pit performed by backfilling with flotation tailings, 2002 (photo B. Włodarz)
Ryc. 15. Rekultywacja odkrywki górniczej przez zasypanie odpadami poflotacyjnymi, rok 2002 (fot. B. Włodarz)

furnaces (Fig. 14). Upon backfilling the open-pit, its flat top was covered with a 1.0 m thick layer of subsoil consisting of gangue and overburden stored near the open-pit excavation. The subsoil was leveled mechanically, and then covered by another layer of fertile soil in an attempt at reforestation.

In the early 1990s, the process of reclamation of open-pit excavations was initiated by backfilling with flotation waste, deposited in ZGH Bolesław settling ponds from 1957. The waste from mechanical cleaning and flotation mostly consisted of dolomite (75%), as well as marcasite, quartz, calcite, sphalerite, cerussite, anglesite, calamine and marly minerals (Cabała 2009). During backfilling with flotation waste, the slope was sealed. The bottom of open-pit excavations was sealed layer by layer with insulation materials consisting of clay, Keuper marls, and deposits from the Permian period at least 0.2 mm thick (Fig. 15). The flat top of the reclaimed excavation was covered by a 0.2 m thick insulation material, a 0.5 m thick subsoil layer made from available waste rock and overburden, and was eventually restored to a 0.2 m thick soil layer. The last stage of reclamation was the planting of vegetation in an attempt at reforestation. The 'Ujków Stary', 'Krążek', and 'Bolesław' open-pits were reclaimed in the same way.

Summary

The first lead ores to be extracted and selectively mined were very rich and contained as much as 50% lead. However, their utilization, mainly in regards to metallurgical technologies, left much to be desired. The recovery rate was about 33% for pure lead, and around 20% for its oxide (litharge), and the remaining 47% either evaporated or passed into the slag (Żukowski 1946). Due to high lead and zinc

content (up to about 9%), metallurgical slags were subject to secondary mining at the turn of the 20th century. Their remnants constituted rolldown-type furnace feed in zinc metallurgical plants in the 1950s.

During the reign of Sigismund II Augustus, approximately 12,000–20,000 cwt of lead (780–1,300 tonnes) was obtained from smelted ore, and 1,500–3,000 *grzywna* of silver (*grzywna* – an old Polish and Bohemian weight unit, where the equivalent weight is 300–600 kg) was detracted (Łabęcki 1858). The value of production in the Olkusz region reached 1.25 million Polish Zloty (exchange rate from 1840).

According to another estimate (Żukowski 1946), during 120 years of intensive calamine extraction until the depletion of the resources, the Olkusz mines produced approximately 17,000 tonnes of lead, 10,000 tonnes of its oxide, and around 15 tonnes of silver. The value of production was estimated at around 60 million Polish Zloty or 90 million Francs, according to the rate of 1840. In turn, in the Olkusz region from 1814–1931, the total quantity of extracted oxidized ore (on an average 16% zinc) totaled approximately 4 million tonnes, and 450,000 tonnes of metallic zinc was obtained. At the same time, 150,000 tonnes of calamine ore containing 30–45% lead was also extracted (Żukowski 1946). Since the beginning of the 20th century, the volume of extracted zinc ore (mainly blende) reached 400,000 tonnes, the ore contained 13–23% zinc, and 150,000 tonnes of concomitant calamine ore containing 30–45% lead was also extracted. To obtain this scale of production, it was necessary to perform more than 250 km of excavations, and the related expenditure was around 75 million Polish Zloty (zł). The labor cost was 50 zł/t of extracted calamine, and the total labor costs amounted to approximately 200 million zł. The value of smelted zinc was around 405 million zł (Żukowski 1946).

The scale and the value of production imply that the Olkusz mining was an important business venture aimed at obtaining silver, which was indispensable for issuing money. Therefore, successive rulers took great care of the mining industry in the Olkusz region. Firstly, they created favorable conditions for the development of mining by bringing together human and material resources, as well as securing funds from the royal city of Olkusz. Rulers also offered other land (except from the royal district of Rabsztyn) for the mining of silver-bearing lead glance.

A similar situation arose in the Olkusz region in the early 19th century when, on the initiative of the government of the Kingdom of Poland, zinc mining was established on land owned by the city of Olkusz and in the nationalized areas belonging to the Cracowian bishopric. At the beginning of the 19th century, crops and zinc were the predominant exports of the Kingdom of Poland. At the government level, decisions were made about building further calamine mines and, after some time, also about the reconstruction of drain adits. In the last decade of the 19th century, leases on calamine mines in the Olkusz region were taken over by private investors. A long-term decline in the world zinc market brought them to a stop. After water drainage, they continued exploiting calamine, blende and pyrite. Then after 1948, the mines were subject to thorough upgrading and expansion, again as government-controlled entities.

When further deposits of zinc and lead sulfide ore were discovered in the second half of the 20th century, mining in the Olkusz region was resumed again. Mines were established with an integrated rock mass drainage system, equipped with modern machinery and devices, new processing technologies, and ore dressing facilities. Mass extraction, in conjunction with high labor efficiency, guaranteed the profitability of the production of zinc and lead concentrates from ore disregarded in the past, which only contained small deposits of those metals. After years of extraction, zinc and lead ore reserves in existing deposits in the Olkusz region have been depleted, and the development of new sites is now impossible. Thus, the final stage of mining activities in the Olkusz region is gradually approaching its end.

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