Mineral raw materials and commodities of Poland

Marcin Piwocki*, Stanisław Przeniosło*

A b s t r a c t. Mineral resources of Poland are presented in a historical view, from the prehistoric beginnings till the present day. Some of the mineral resources in Poland have been exploited constantly since the 11th–12th century — these resources are zinc and lead ores and rock salt. One of the important Polish mining traditions concers of hard coal. Noteworthy is the world earliest crude oil mining industry in the Carpathians region. In the present day, the main achievements of Polish economic geology are: the discovery of copper and silver ores in the Fore-Sudetic monocline; documentation of a new major coal basin in Europe, in the Lublin region, and lignite deposits in the central and western Poland; the discovery of the worlds biggest native sulphur deposits in the Carpathian Foredeep; and also the discovery of the gas fields in the Carpathian Foredeep and in the Polish Lowland. Within the last fifty years some of the mineral raw materials, like iron ores and native sulphur deposits, have lost their economic value.

Key words: *Poland; mineral resources, deposits, resources, history of investigations*

Poland has resources of various useful minerals. Many of them have been mined for ages and were traditionally regarded as typical for the country. Some gained importance only in recent decades, while others lost their value.

Among major economic minerals with long mining tradition spanning several historical epochs are ores of zinc and lead with silver, as well as black coal in the Upper and Lower Silesia, though in the latter area it is merely of historical importance now. An important Polish raw material is rock salt, exploited in the Fore-Carpathian area since more than nine hundred years. For centuries, another valuable mineral resource, now obsolete, were bog iron ores. In the early 20th century, a substantial part of the world oil production came from the area of Poland. Nowadays, only about 4 percent of the national demand is satisfied by local oil exploitation. During the last half century, after the discovery of large copper deposits near Legnica and Głogów, Poland has become a major producer of copper and silver. In the second half of the 20th century, following the discovery of large deposits of native sulphur in the Fore-Carpathian zone, Poland was also a major sulphur exporter. However, the prosperity dwindled with the development of cheap methods of sulphur recuperation from oil and gas. Besides these basic mineral resources we have substantial quantities of such mineral resources as building stones, ceramic clays and raw materials for cement production.

This paper outlines the development of knowledge about the distribution of mineral resources in Poland through the ages, as well as a brief history of their use.

Prehistoric beginnings

The progress of civilization correlates with the development of human usage of tools and resources, including the mineral resources. It is reflected in the division of human history into the Stone Age, Chalcolithic Age, Bronze Age and Iron Age. Already the early humans knew the properties of many stones and the best ways to use them. Then metal ores were employed to provide raw material for weapons and tools manufacturing. People started to search for these resources, to exploit and process them. The development of mining and metallurgy began. Geological knowledge about the presence of rocks and useful mineral resources, such as metals, was the domain of practics, the prospectors and "treasure hunters". Thus, from mining and mineralogy a new discpline emerged, called first geognosy, then geology — a new science with its own research methods and goals. One of the principal goals was expanding the knowledge on mineral deposits.

The oldest traces of mineral exploitation within the present teritory of Poland date back to the Palaeolithic and Neolithic. Local flint served to produce primitive Palaeolithic tools found in many localities, especially in southern Poland. Prehistoric open pits to dig flint are known along the northern rim of the Holy Cross Mountains, e.g., from Orońsko and Wierzbica. An underground mine of world-wide fame is preserved in Krzemionki Opatowskie, where banded Jurassic flints were exploited in 2300–1800 BC. Also during the Neolithic, basalt, amphibolite, serpentinite and nefrite were mined in the Lower Silesia (e.g., Pazdur, 1960; Kozłowski, 1986). Pottery clays, abundant in Poland, were exploited as well, quern stones were manufactured and salt was obtained from brines.

There is still no reliable evidence of metal ores being exploited within the area of Poland during the Bronze Age. During the Halstatt Period of the Iron Age, since about 500 BC, bog ores were dug and processed in numerous primitive smelting furnaces. The extensive metallurgy involved thousands of such furnaces; in Roman times, most of European production of iron concentrated in Poland (e.g., near Warsaw). Traces of technologically more advanced underground exploitation of hematite and siderite from Roman times (2nd and 3rd century AD) were found in Rudki in the Holy Cross Mountains (Pazdur, 1969; Adamski, 1994).

Until the 13th century, salt was produced in Poland using brines. Since 7th century AD, a major salt-making centre existed in Kołobrzeg on the Baltic shore (Pazdur, 1960).

Later Middle Ages, till 15th century

In historical times, by the end of early medieval period, especially during the formation of the Polish state since the 10th century, began exploitation of building stones for the construction of defensive and monumental, mainly sacral, structures. Building stones were quarried in the 9th and 10th centuries, e.g., in Brzeźno (Wielkopolska), Pińczów (Małopolska) and near Lwówek Śląski (Lower Silesia). Early medieval archaeological sites yielded also stone utensils (such as whetstones, spindle whorls, fishnet weights) made of local material (Pazdur, 1960; Skoczylas,

*Polish Geological Institute, Rakowiecka 4, 00-975 Warsaw, Poland

1994). Archaeological data indicate very early commencement of exploitation of gold from the Lower Silesian placer deposits (Legnica, Bolesławiec, Złotoryja). The exploitation continued during the rule of the first Polish dynasty in the 10th–12th centuries.

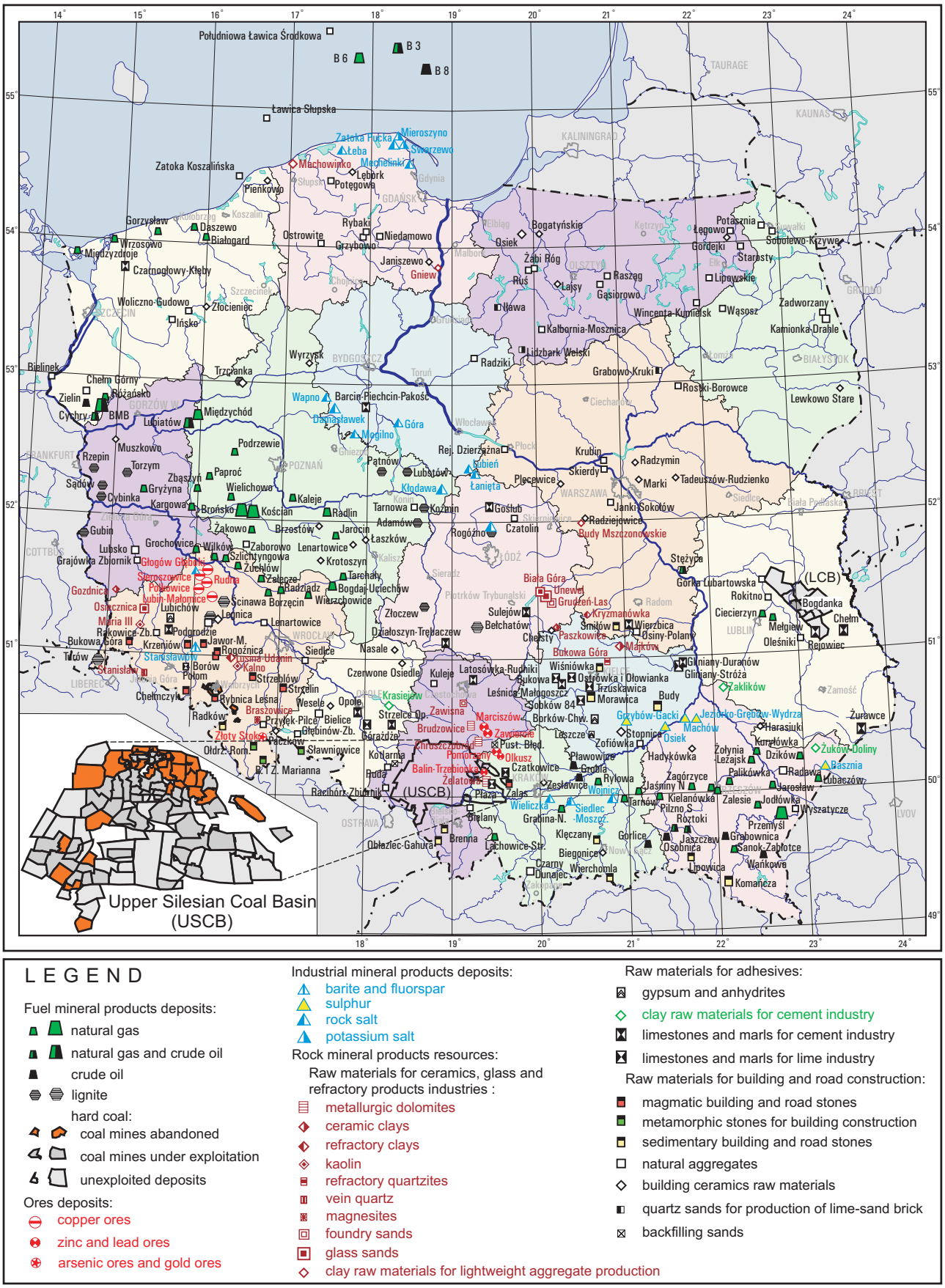


Fig. 1. Map of Occurrence of the main Deposits of Mineral Products in Poland (as of 2004)

There are reliable data on presence and exploitation of various mineral resources in Poland in the 11th–14th centuries. They concern salt deposits in Wieliczka and Bochnia, saltworks in Kołobrzeg and SE Poland, silver-bearing lead ores as well as iron ores in the Silesia–Cracow area near Olkusz and Bytom, and metals, including gold, in the Lower Silesia, especially near Legnica, Złotoryja, Świdnica, Kowary and Złoty Stok. It is estimated that during the 12th–4th centuries, about 750 kg of gold was mined near Złotoryja. In the 14th and 15th centuries, mining of copper and silver ores developed also in the Carpathians, including the Tatra Mountains. In the Holy Cross Mountains near Chęciny and Kielce, copper ores and silver–bearing galena were mined, and the "Kielce marbles" (dense limestones) were first quarried. In Swoszowice near Kraków sulphur exploitation began, necessary for gunpowder manufacturing (see, e.g., Łabęcki, 1841; Czarnocki, 1958; Pazdur, 1960; Fischer, 1962; Jost, 1962; Osmólski, 1969; Skoczylas, 1994). Even though the bog ores were still used, siderite and oxide iron ores began to be exploited in the Upper Silesia and near Częstochowa and Tychów Kielce–Sandomierz region (Adamski, 1994; Krajewski, 1960). Also exploited were clay minerals for pottery and brick-making, that became popular technology in Poland, especially northern and central, since the 13th century (Kozłowski, 1986).

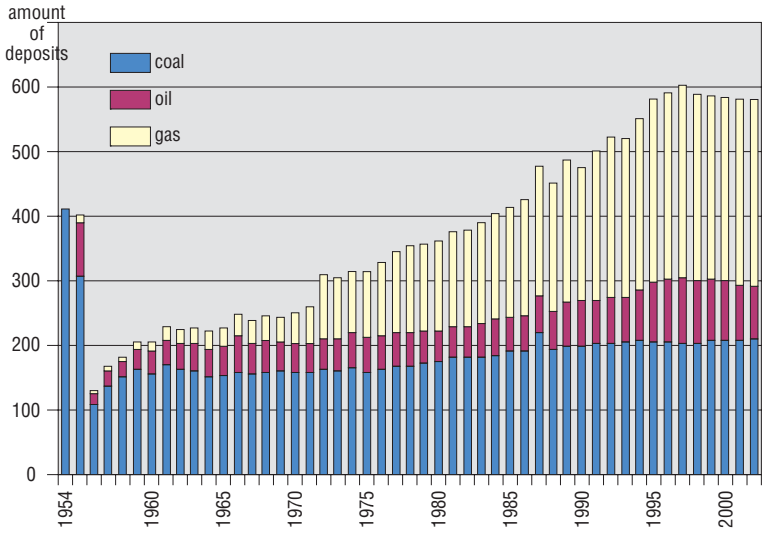


Fig. 2. The amount of fuel mineral products deposits in Polish balance of raw material in 1954–2002

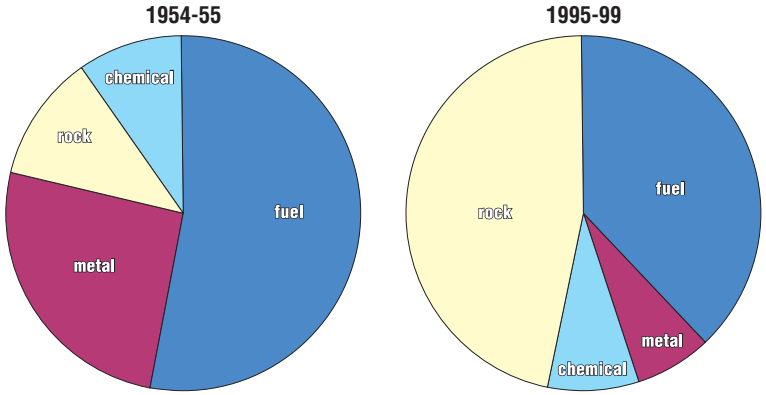


Fig. 3. Shares of the main mineral products groups in deposits proven in 1954–1955 and 1995–1999

Early modern times since the 16th to the 18th century

This period includes the heyday of the Polish–Lithuanian Commonwealth and its decline culminating in the successive partitions of Poland among Russia, Austria, and Prussia in 1772, 1793, and 1795.

The known and rich deposits of salt, metal ores, and building stones are were traditionally exploited. Underground mining of salt for consumption in large rock salt deposits in Wieliczka and Bochnia, as well as its production in numerous saltworks, especially in the southeast of the Polish state ("Cis–Carpathian Ruthenia", now western Ukraine) near Kałusz, Stebnik, Drohobycz and Kołomyja. The mines in Bochnia and Wieliczka yielded up to 42 thousand tonnes per year in the 17th century, and the Ruthenian salines produced up to 6 thousand tonnes of salt per year in the second half of the 18th century (Pazdur, 1960).

Prospecting around the already known occurrences of metal ores near Olkusz and Bytom in the Silesia–Cracow area resulted in opening new mines in Tarnowskie Góry and near Chrzanów and Trzebinia. However, already in the 17th century local ore mining began its slow decline, due to diminishing resources exploitable with mining technology available at that time. To face the crisis, besides introducing technological innovations, new deposits with better geologic-mining conditions were needed. Similar crisis hit the metal mining near Kielce and Chęciny and in the Lower Silesia, that reached its peak in the 16th century, but then gradually declined. The decline in mining is also related to the country's destruction during wars with Sweden. Also the import of gold and silver from the Central and South American Spanish colonies undoubtedly accelerated the end of their traditional mining in Europe.

Iron ore mining developed, which since the 16th century supplied not only the traditional bog ores, but also the richer and more easily processed siderite and limonitic ores occurring in shallow deposits from Zawiercie to Wieluń in southern Poland, as well as around the Holy Cross Mountains, in the Upper and Lower Silesia, and patchily in the Tatras. It is estimated that before the partitions of Poland, about 20 thousand tonnes of iron ores were mined per year nationwide (Pazdur, 1960).

Since the 16th century the resources of building stones are more extensively exploited, not only ashlar for basic construction purposes, but also for facing and decorative purposes, in Lower Silesia (Sławniowice), Cracow area (Dębnik) and Chęciny and Kielce quarries. Finished masonry and raw cut blocks were delivered to many places in Poland and even abroad. Near Halicz on Dniester, alabaster was quarried in minor quantities from the Żurawno deposit.

The only Polish sulphur deposit known at that time, in Swoszowice, was still exploited, yielding several hundred tonnes per year. All over the country small shallow deposits yielded ceramic clays, bleaching earths and dyeing clays. Quartzose sands and quartz were used for glass manufacturing. Previously unused calamines began to be roasted to

obtain zinc white needed in brass production. Alum earths were leached to produce alum for tanning purposes, especially in the Lower Silesia and Wielkopolska (Great Poland).

The Dutch settlers, immigrating since the 16th century, began using peat at fuel (Maksimow, 1959). The presence of petroleum and ozokerite (paraffin) in the Carpathians was long known but these mineral resources had hardly any economic value. Petroleum was used in folk medicine and as grease in wagons, while the paraffin served to produce candles (Pazdur, 1961).

The partitioned Poland (1772–1918)

After Poland had lost independence, Polish mineral resources and mining centres were annexed by the partitioning powers: Prussia, Russia and Austria. Each of these countries had its own policy on raw materials and mining, so the economic development of the divided Polish territories could not have been harmonious. Characteristic for that period was general scientific progress and technological advances in exploiting mineral resources and their utilization as a result of the industrial revolution in Europe, proceeding since the mid-1700s, and spread of capitalist methods and organization of production.

A major element of this historical stage in the area of Poland was a dynamic growth of coal mining in the Lower and Upper Silesia. The rich coal deposits were known there since 15th–16th century. In the Lower Silesia, the first mine near Wałbrzych was established in 1561, but the mining boom started only after the Seven Years War (which ended in 1763). The exploitation of the Upper Silesian coal dates back to 1657, but its major development started in the mid-18th century. It was related to a general progress in mining technology and transportation, and especially was due to the use of coke in metallurgy. The annual output of the aforementioned coal basins steadily grew: in 1769 equalled 3.6 thousand tonnes, in 1800 — 188.8 thousand tonnes, in 1900 — 34,872.4 thousand tonnes, in 1913 — 58,118.9 thousand tonnes and in 1918 — 50,701.5 thousand tonnes (Pazdur, 1961; Jaros, 1975). By the end of 18th century, brown coal mining began in the Miocene deposits of Lower Silesia and Wielkopolska. Less important were the Mesozoic deposits near Zawiercie and Miocene deposits in the fore-Carpathian area and in the Carpathians (Ciuk, 1991; Jaros, 1984). Exploitation, mainly for local needs, developed since the second half of the 19th century. Gradually, the concentration of production led to demise of small mines, because of the competition of hard coal supply. Of major importance was the production of brown coal in the Lower Silesia and Wielkopolska, with yield in 1870 of about 372 thousand tonnes, in 1900 — 865.5 thousand tonnes and in 1913 — about 1960.3 thousand tonnes, including about 28.4 thousand tonnes in the Poznań area. In the eastern territories of former Poland, in 1913 about 37.4 thousand tonnes of brown coal were mined (Bohdanowicz, 1927; Jaros, 1975; Stawiarski, 1988). Peat was still exploited as fuel and since mid-19th century also for farming.

Another important feature marking this period was a fast development of the oil industry and geological prospecting for oil deposits in the Carpathians, especially near Gorlice, Bóbrka, Borysław, Bitków and Słoboda Rungurska. It started already in the first half of the 18th century, but officially the starting date is 1853, when kerosene lamps were used to lit a hospital room in Lwów (Lviv) (Pazdur, 1961; Karnkowski, 2004). This was the beginning not only of the Polish oil industry, but also of the worldwide oil mining. Initially, shallow dug wells were exploited, then deeper and deeper shafts (up to 200 m deep), and since 1861, boreholes started to be used. Discovery of rich Borysław oil fields in 1896 accelerated the development of the industry. The yield steadily grew, from 271 tonnes in 1840, through 65 thousand tonnes in 1885, 326.3 thousand tonnes in 1900, 1071 thousand tonnes in 1913 to 822.9 thousand tonnes in 1918. In 1909, Austro–Hungarian province Galicia (former south–eastern Poland) producing 2.1 million tonnes annually was the third largest oil supplier worldwide. Ozokerite deposits near Borysław, Starunia and Dźwiniacz yielded annually about 6.5 thousand tonnes in 1842–1892 but dropped significantly after 1872, since paraffin became widely available as a by-product of oil refining (Bohdanowicz, 1919). About 1880 natural gas started to be used for heating purposes and to produce gasoline. Its energetic use started for good only in 1908, with the construction of gas pipelines that in 1913–1914 transported about 2 million m^3 of gas (Tołłoczko, 1919; Pazdur, 1961).

Rock salt mining still developed, especially in the Austrian part, in Wieliczka and Bochnia deposits, as well as salt production from brines in the eastern Galicia. In the Lack, Kałusz and Stebnik mines, salt was dissolved with water in underground chamber since 1814. Salt production in this region in 1848 was 106 thousand tonnes, in 1900 — 145.8 thousand tonnes, and in 1913 — 151.8 thousand tonnes. In Kałusz since 1867 potassium salts were exploited. In the Prussian partition, the Inowrocław salt deposit was discovered in 1870 and in 1889 its exploitation began by underground leaching. A nearby Wapno deposit was also recognised, where gypsum was quarried since 1828, and salt mining began in 1911. In the Upper Silesia, a salt deposit was discovered near Rybnik in 1900. Salt production in the Prussian partition slowly increased: 21.5 thousand tonnes in 1880, 52.4 thousand tonnes in 1900, 56.1 thousand tonnes in 1913 and 31.8 thousand tonnes in 1918. Extensive prospecting for salt in the Russian partition remained futile. Since 1829, minor quantities of salt were produced using brine in the Ciechocinek saltworks (up to 9 thousand

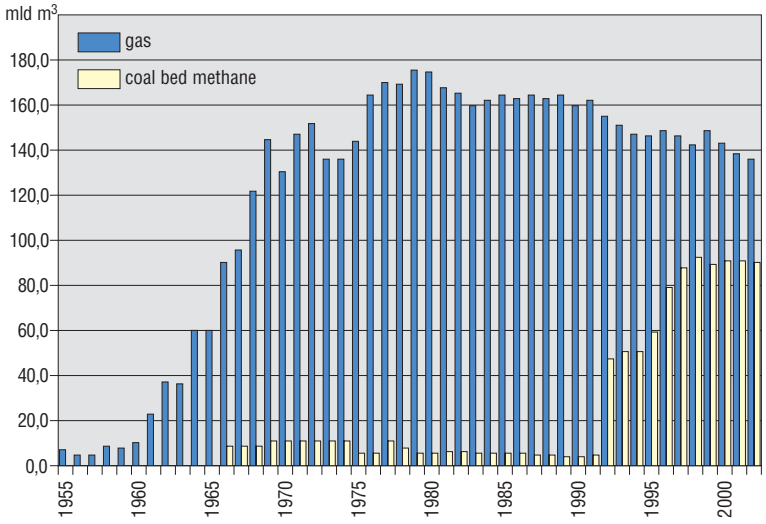


Fig. 4. Natural gas and coal bed methane resources in 1995–2002

tonnes annually) and in a few other places. The increased production of salt in the Polish territories in late 19th century resulted from ine growing demand of the fast-developing soda industry (Pazdur, 1961).

Steam pumps were used for dewatering mines, and many tasks were mechanised, thus saving from complete collapse the ore mining in the Upper Silesia, especially in Tarnowskie Góry. Its development continued after 1870 due to growing demand for zinc ores and increased production of silver–bearing lead ores in the process. Upper Silesian output of zinc ores in 1820 was a mere 2.7 thousand tonnes, but in 1850 increased to 136.9 thousand tonnes. Early 20th century brought further development of this industry, with a peak of zinc mining in 1910, with the annual yield of 250 thousand tonnes of metallic Zn (Bogdanowicz, 1919). A similar level was reached again in 1992 (Przeniosło, 1999).

In the first half of the 18th century, some attempts at reviving the metal ore mining near Chęciny and Kielce, like those of mid-19th century were quite ineffective, even though the total production of copper ores in 1820–1840 was 17.6 thousand tonnes. During the World War I (in 1914–1915) the Miedzianka deposit yielded 1360 tonnes of copper ore (Czarnocki, 1958). Better results were obtained in the Lower Silesian ore deposits. In Złota Góra, Radzimowice and Klecza gold-bearing arsenopyrite was mined. Deposits near Gierczyn provided small amounts of tin, while near Grochowa and Tąpadła chromium was produced. Since 1888, deposits near Szklary were exploited for nickel; its production was intensified due to increased demand during the war (1914–1918). Besides, minor amounts of copper ores were produced in the Lower Silesia near Bolesławiec and in Miedzianka.

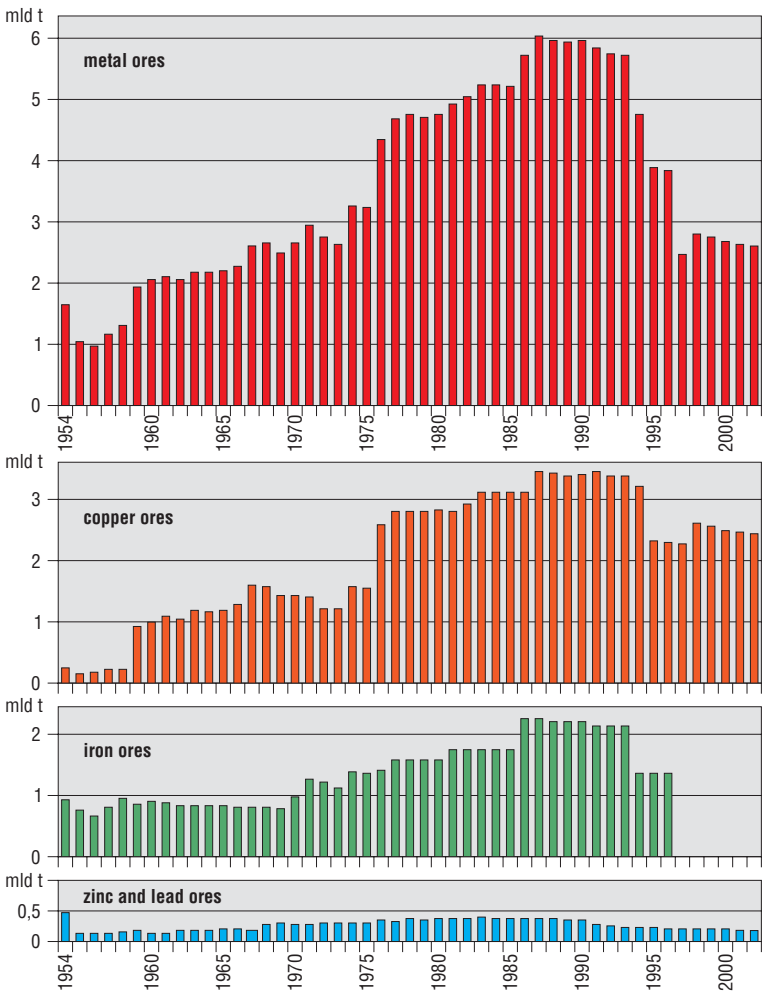


Fig. 5. Ores deposits resources in 1954–2002

In this period the iron ores were successfully mined in the Upper–Silesia, in the Kraków–Wieluń area, in the Holy Cross Mountains region, and on lesser scale in the Carpathians. Fast progress of metallurgical technology prompted increased ore supply. In the Holy Cross Mountains region, annual iron ore output was about 570 thousand tonnes in the second half of the 19th century, 463.8 thousand tonnes in 1900, and dropped to 171.6 thousand tonnes in 1910. Such dramatic drop in production has been caused by the supply of high quality Ukrainian ores from the Kryvyj Rih basin. Similar was the situation in the Częstochowa region, where in 1891 the production was as much as 451.3 thousand tonnes of ore, while in the early 20th century the mining output decreased dramatically to 178.7 thousand tonnes in 1900 and as little as 66.7 thousand tonnes in 1909 (Pazdur, 1961; Adamski, 1994). Small deposits were exploited also in the Upper Silesia near Bytom and in the Lower Silesia, e.g., near Kowary. Total Silesian production is estimated at 182 thousand tonnes in 1851, 660 thousand tonnes in 1881, 457.2 thousand tonnes in 1901 and 134.5 thousand tonnes in 1913. The decrease was partly due to diminishing resources, but mainly to cheap import of iron-rich ores, mainly from Russia and Sweden (Pazdur, 1961). In the Austrian partition of Poland, small deposits yielded some production of ores, including those in the Tatra Mountains, exploited until 1880. Processing of ore from Slovakia continued till 1890, resulting in major damage to the mountain forests (Fabijanowski, 1955; Jost, 1962).

The sulphur deposit in Swoszowice was exploited until 1884 and yielded up to 10.9 thousand tonnes annually, but was abandoned due to deplenished resources and competition from the Sicilian sulphur. On a small shallow deposit in Czarkowy on Vistula River a sulphur mine was created in 1795, operating intermittently until 1918. In 1901, it yielded 17.1 thousand tonnes of ore (2407 tonnes of sulphur). Sulphur for production of sulphuric acid was also obtained during processing zinc and lead ores, as well as from pyrite, occurring as a by-product in the coal washers in the Upper Silesia and mined locally in the Lower Silesia (Pazdur, 1961; Osmólski, 1969).

Quarrying building and decorative stones suffered a collapse in late 18th century, but was markedly revived in the early 19th century, because of construction boom and railrod expansion. Masonry basing on the Kielce and Dębnik "marbles" and on Lower Silesian deposits blossomed. Sandstones and limestones were quarried in the Holy Cross Mountains, Lower Silesia and the Carpathians, as were the igneous rocks near Kraków, in the Pieniny Mountains and in the Lower Silesia. Limestones, marls and dolomites were widely used for producing cement, quicklime and fluxes for metallurgy. One of the first cement plants in the world was built in Grodziec near Będzin in 1857. Quickly

increased the production of gypsum, clays and stone agglomerate (Pazdur, 1961; Kozłowski, 1986).

Independence period (1918–1939)

After World War I, Poland regained independence, but as a result of the war the national economy, including its mining sector was ruined. It is demonstrated also in the post-war drop of production in all branches of the mining industry. Moreover, the economic conditions and transportation networks in the reunited parts of Poland were quite different. Geological research for the economic needs of the independent state were then commenced mainly by geologists employed by the Polish Geological Institute, established in May, 1919.

The existing knowledge on major mineral resources of Poland at the dawn of independence, together with their geology, utilisation and perspective occurrences was summarized, among others, by Bohdanowicz (1919; 1927). The data including results of the geological research in the first post-war decade were summarized in a map of mineral resources of Poland published by the Polish Geological Institute (Czarnocki, 1931). A detailed study of coal beds, including also abundant data on zinc-lead and iron ores in the Upper Silesian Coal Basin was presented by S. Czarnocki (1935). Most of the rich Upper Silesian Coal Basin (72%, 3880 km^2) was in 1922 alloted to Poland. In 1927, total resources of coal in seams thicker than 0.61 m down to 1000 m below ground level were estimated at about 63.9 billion tonnes. Further calculations revised the estimates for the Polish part of the coal basin to 58.7 billion tonnes (Czarnocki, 1935). The total production of coal in Poland in 1919 was 25.3 million tonnes, in 1929 — 46.2 million tonnes, and in 1938 — 38.1 million tonnes. In 1937, prospecting for coal began in Wołyń (Volhynia), where coal intercalations were found in several boreholes (Porzycki, 1988), but the World War II intervened with the studies.

The brown coal resources in the Mesozoic strata near Zawiercie were estimated at about 63 million tonnes, while the Miocene brown coal resources in Wielkopolska at 2 billion tonnes. The Forecarpathian resources were not quantified. During 1918–1939, little prospecting for brown coal was conducted, but an inventory of its known occurrences and deposits was made (Ciuk, 1960). The maximum production was noted in 1921 — 270.4 thousand tonnes, but after incorpoation of the Upper Silesia to Poland in 1922, the hard coal competition caused a dramatic drop in brown coal mining, down to mere 10 thousand tonnes in 1938. The peat bogs area in Poland was estimated in 1919 at about 777.3 thousand hectares, and the resources of peat at an average thickness of 1 m were estimated at about 1.2 billion tonnes (Tołłoczko, 1919). Later estimates (Czarnocki, 1931) list resources of 2.29 billion tonnes of peat within peat bogs covering an area of 1,832.2 thousand hectares.

The Carpathian oil mining suffered heavy devastation during the World War I. The drop in production was caused by damages and war economy, as well as by diminishing resources. Geological perspectives of oil resources in Poland were variously estimated by the post-war authors at 37.5 to 160 million tonnes (Bohdanowicz, 1927). Later estimates were even more pessimistic, especially given the depletion of Borysław oil fields. Prospecting in the Carpathians continued with varying intensity, and by 1939 several new oil reservoirs were found, e.g., in Turoszówka (1930), Tyrawa Solna (1931) and Dolina (1937). Nevertheless, Polish oil mining, extracting about 500–600 thousand tonnes per year during 1930–1938, never regained its peak yields of 1909–1910. Before 1939, several gas reservoirs were also discovered, e.g., in Daszawa (1920), Strachocin (1928), Roztoki (1931) and Opary (1937). Annual natural gas production during the years 1925–1936 reached up to 500 million m^3 and in 1938 was 584.5 million m^3 (Czarnocki, 1931; Pazdur, 1961; Karnkowski, 2004). About 700–900 tonnes of ozokerite was exploited in the Borysław, Starunia and Dźwiniacz, while the Truskawiec deposits were explored. Feasibility of exploitation of large amounts of bituminous shales, especially in the Carpathians, was considered. Prospecting for oil and gas in the Polish Lowlands was planned to locate hydrocarbon reservoirs in Mesozoic and Permian strata. As a part of this project, E. Janczewski began gravimetric research in the Kujawy region (Wdowiarz, 1960).

Good perspectives for expanding geologically documented resources opened for the rock salt mining in the Fore-Carpathian area and in the Wielkopolsce province, where besides the previously known Inowrocław structure, a mine was established on a salt diapir in Góra. Near an existing potassium salts mine in Kałusz (Fore-Carpathians), new such mines opened in Stebnik (1923) and Hołyń (1930). At the same time prospecting for these salts continued nearby in the vicinity of Turza and Morszyn. Total reserves of rock salt were estimated in 1927 at around 12.5 billion tonnes, while later, in 1931 the estimate dwindled to 6 billion tonnes. An urgent task was to prospect for potassium salts, especially in Wielkopolska. Gravimetric methods were already recommended for prospecting in this area (Bohdanowicz, 1927), and successfully employed since 1929. Intense prospecting for salt in Kujawy with gravimetry and drilling methods, directed by E. Janczewski, led to discovery of the salt structure of Izbica Kujawska (Werner, 1960). Rock salt mining in Poland systematically grew: in 1921 it was 327 thousand tonnes, in 1930 — 534 thousand tonnes, and in 1938 — 643 thousand tonnes. Potassium salt production also increased, from 15,5 thousand tonnes in 1921 to 300 thousand tonnes in 1934.

Future development of mining and iron metallurgy had good prospects, especially given abundant coke supply and favourable geological conditions of iron ores. Their earliest estimates ranged from 197 to even 388 million tonnes (Bohdanowicz, 1927), while more detailed assessments showed about 60 million tonnes (Pazdur, 1961). They were expected to last for 40 years, given the calculated industrial demand. In 1937, the threat of coming war spurred prospecting for new deposits, e.g., in the Holy Cross area and in the Carpathians, and wider use of bog ores was planned (Krajewski, 1960). The extraction of iron ores was 469.7 thousand tonnes in 1923, then fell during the Great Depression to 77 thousand tonnes in 1932, but subsequently quickly intensified, reaching 872 thousand tonnes in 1938.

The zinc and lead ores in Poland were estimated by C. Kuźniar at 20 million tonnes, while their average annual production was about 1.1 million tonnes (Czarnocki, 1931, 1935). The situation of zinc metallurgy was then recognized as disadvantageous due to lack of ore resources, because 90% of zinc and lead deposits were situated in the German part of the Upper Silesia, while the non-ferrous metallurgy was mostly concentrated in the Polish part of that industrial region (Bohdanowicz, 1919, 1927). Poland was then among the world top producers of zinc and lead, but depended on supply of ore and concentrate from Ger-

many. In 1938, the national production of zinc and lead ores was only about 500 thousand tonnes. Thus, intense prospecting for new deposits of zinc and lead ores was being conducted in the Upper Silesia and near Olkusz and Jaworzno, applying state-of-the-art geophysical methods.

During 1926–1929, copper ores were prospected for in the Holy Cross Mountains area, near Chęciny and Kielce. Geoelectrical prospecting methods were first applied there. The exploitation of copper ores in Miedzianka and Miedziana Góra ceased in 1920 and 1922, respectively, as economically unprofitable. Prospecting for copper ore was also done in Wołyń (Volhynia) and Podole (Podolia). Exploitation attempts of native copper in Mydzko yielded no positive results. Lead and zinc ores were also prospected for near Chęciny, Kielce and Łagów, where small-scale exploitation of galena was even started (Krajewski, 1960). Minor occurrences of manganese were described near Pińczów, and in the Carpathians, near Sanok and Czywczyn. In 1934, bauxite clays were also located in the Upper Silesia.

Long known poor deposits of sulphur in Swoszowice and Czarkowy were depleted and uneconomical. Basically their exploitation ended by the end of 19th century. After World Ward I, sulphur was mined only in Posądza, until 1921. In 1929–1934, R. Krajewski and A. Bolewski conducted detailed studies in the area, to elucidate their origin (Osmólski, 1969). In 1922, the pyrite, hematite and siderite deposit in Rudki was documented, and in 1925 iron ore extraction began; in 1932 started mining of pyrite (Krajewski, 1960), and after the World War II, even uranium ores were exploited there.

The largest phosphate deposits, estimated at about 16 million tonnes were found on the Dniester River. They occur between Niżniów and Niezwiska where they were shortly exploited in 1923–1925, and near Horodenka (Czarnocki, 1931). In central Poland, phosphates were located near Rachów (1923–1924), Chwałowice (1936) and Chałupki (1937). The Rachów deposit was exploited since 1924, and also in Chałupki exploitation began. Phosphate-bearing areas near Grodno and Mielnik, and in the Palaeozoic of the Holy Cross Mountains were studied. Also studied were barite occurrences in the Holy Cross Mountains (e.g., Hucisko, Strawczynek), and some deposits were periodically exploited.

In the inter-war period much attention was paid to rock resources, especially kaolin, dyeing and refractory clays, building stones and raw materials for the cement industry. Poland in its pre-1939 borders had large resources of these minerals in the Holy Cross Mountains and their surroundings, in the Upper Silesia, near Cracow, in the Carpathians, and in Volhynia and Podolia (Pazdur, 1961).

Second World War 1939–1945

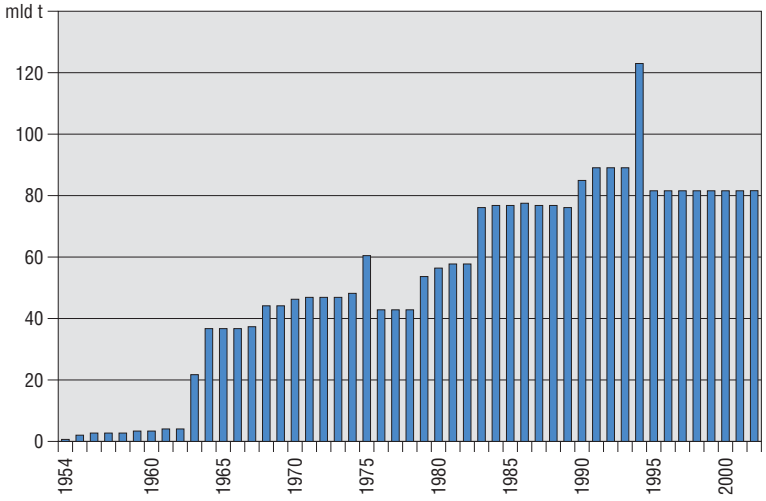
During the war, geological research and prospecting on largely ceased. Areas occupied by the Nazi Germany and transitionally (1939–1941) by the Soviet Union, were subject to military economy. The extraction of mineral resources proceeded in a quick-and-dirty way, without rational perspective planning, and the output of industrially important fuels increased markedly, e.g., hard coal production in the pre-war area of Poland reached 57.5 million tonnes. At the same time, documentation and inventory was performed for some deposits, especially of brown coal, peat and phosphates. In 1940–1941, the Soviet authorities in Volhynia continued prospecting for coal (Porzycki, 1988). In Wielkopolska (incorporated to the Third Reich as Warthegau), brown coal resources were explored, and exploitation of its deposits in Konin and Wronki began in 1941 (Jaros, 1984). As for the oil and gas fields, the occupation authorities tried to maximise the exploitation, and this policy led to subsequent major drop in the hydrocarbons' yields in 1942–1943 (Wdowiarz, 1960; Pazdur, 1961).

Recent times 1945–2004

The Polish economy was mostly ruined during the war. Many mineral deposits were depleted, and the mining industry suffered heavy losses. In the post-war Europe, Poland reappeared in a changed geopolitical situation, with new territorial extent, meaning also new natural and communication conditions, as well as in a new economic and social system. For the second time within 25 years the nation faced great challenges. For geology of useful mineral resources this meant the necessity to recognize the geological structure of the territories incorporated into Poland, both with regard to mapping and estimating the resource potential. Existing deposits had to be inventoried, the mining needs estimated, and the geological materials revindicated. These tasks became the responsibility of the geological survey, represented by the Polish Geological Institute, reactivated in 1945.

First operations were closely coordinated with the mining industry. The resource research were mostly concentrated in existing mining areas, to document their structure and abundance of the deposits, especially in the new western and northern territories of the country (Lower and Upper Sielsia, Lubuskie region, Sudetes, Pomerania, East Prussia), assigned to Poland after the Potsdam Conference. Prospecting and exploration activities in areas with perspective mineral resources intensified after 1952, due to the establishing of the Central Office for Geology, and reorganisation of the national geological survey. Geological research, including resource studies, were abundantly financed by the state budget. Besides drilling, modern geophysical and remote sensing methods were widely applied.

It should be noted that the first post-war estimates concerned total geological resources, thus lumping together



Ryc. 6. Industrial mineral products resources in 1954–2002

both documented and perspective resources in current terminology (Piwocki & Przeniosło, 1997). These data were successively verified after 1955, using formalised rules and criteria of resource balancing. For example, in 1954–1955 the hard coal resources were estimated at about 80 billion tonnes, and brown coal at about 38 billion tonnes. After the verification in 1956, the estimates were reduced to 18 and 1 billion tonnes, respectively (Przeniosło, 2003a). According to recent data (2002), documented hard coal resources are about 44 billion tonnes, and brown coal about 13.9 billion tonnes (Przeniosło, 2003a). During that time, numerous detailed and overview geological-resource maps were made, and many extensive synthetic studies on mineral resources were completed. Prospecting and exploration resulted in 6925 sets of deposit documentations (Przeniosło, 2003a) and thousands of prognostic resource studies.

Major successes were achieved in prospecting for energy resources: hard and brown coal, oil and gas. An important step was working out the nomenclature and corellation of coal beds in the Upper Silesian Coal Basin. Besides continued exploration of known parts of the basin, since 1959 geological research developed in the southern, poorly studied part; this led to the discovery and documentation of further coal deposits (e.g., Zebrzydowice, Żory–Suszec, Kobiór–Pszczyna, Międzyrzecze). Extensive search for new resources in the Lower Silesian Coal Basin were less successful. After their in-depth analysis of geological data, J. Porzycki and Z. Dembowski proposed a project of prospecting for coal in the Lublin area. By 1966, a completely new European coal deposit was found: the Lublin Coal Basin. During 1971–1974, coal resources in the Łęczna and Chełm deposits were documented. Construction of the Bogdanka coal mine began in 1975. These successes crowned the research started in this region already in 1937, thus dating back to pre-war times (Porzycki, 1988). Current estimates of the Lublin Coal Basin resources are about 9.2 billion tonnes, while current local coal production is about 3.8 million tonnes per year (Przeniosło, 2003b).

During 1948–2004, in western and central Poland more than 180 deposits of brown coal were found, including 83 documented deposits. Many of these newly discovered deposits (e.g., Bełchatów, Legnica, Ścinawa, Gubin) exceed 1 billion tonnes in resources. Modern strip mines were built there, yielding about 60 million tonnes of brown coal per year (in 1938, only 10 thousand tonnes). Peat almost ceased to be used as fuel, and its limited exploitation continues only for agricultural purposes. In many regions of Poland, uranium deposits were prospected for, but the deposits found are not economically important.

Post-war borders left Poland with few its former known oil and gas resources (with only about 5 million tonnes of oil and about 5 billion m^3 of gas). Thus, after 1945 prospecting for these energy resources gained momentum. New deposits, especially of natural gas, were found not only in the traditional oil-and-gas-bearing areas in the Carpathians and in the Carpathian Foredeep (e.g., Przemyśl, Lubaczów, Tarnów, Kielanówka–Rzeszów, Grobla, Pilzno, Zalesie, Żołynia), where by 1997 about 164 billion m^3 of gas and several million tonnes of oil were documented (Karnkowski, 2004).

Previously unknown oil and gas deposits in the Polish Lowland were found, as one of the major achievements of the resource geology of the post-war period. Systematic geological and geophysical research, especially seismic studies conducted by the mining industry, led to discovery of the first oil reservoir (Rybaki) in 1961, and first gas reservoir (Bogdaj–Uciechów) in 1964. The following decades brought new important finds in the Fore-Sudetic Monocline (e.g., Załęcze, Żuchlów, Radlin, Górzyca) and in the Gorzów block (BMB — Barnówko–Mostno–Buszewo), within the Łeba Elevation and in the Polish zone of the Baltic, as well as in Pomerania (e.g., Kamień Pomorski, Daszewo, Gorzysław) and Lublin area (e.g., Ciecierzyn, Mełgiew). As a result of these work, Polish Lowlands has become a major gas- and oil bearing area in the country (Karnkowski, 2004). Even though the production markedly increased, it does not satisfy the national demand. It should be noted, that in the coal beds of the Upper Silesian Coal Basin, presence of about 80 billion m^3 of methane was documented.

The post-war period also greatly expanded the known resources of rock salt, mainly due to geological research performed since 1947 in the Polish Lowlands, where numerous new Permian diapiric and bed deposits (e.g.. Kłodawa, Rogóźno, Damasławek, Lubień, Zatoka Pucka, Łeba) were found. In traditionally salt-bearing Forecarpathian and Upper Silesian areas further Miocene salt deposits were documented (Rybnik–Żory, Wojnicz). Currently, the total resources of 20 salt deposits are estimated at 80 billion tonnes, and the annual yield is about 3 million tonnes. Potassium-magnesium salts in the present territory of Poland were known before 1939 in salt diapirs in the Kujawy. After 1945, minor amounts of potassium salts were documented in Kłodawa (about 72 million tonnes) in that area, and prospecting during 1964–1972 in the Puck Bay area, new potassium-magnesium deposits were found (Chłapowo, Mieroszyno, Swarzewo) with total resources of about 597 million tonnes (Przeniosło, 2003b).

Fore-Carpathian exploration works were also important, which besides expanding the knowledge on oil and gas resources led in 1952–1987 to the discovery and study of one the world's greatest deposits of native sulphur. The deposits were first exploited with strip-mining method since 1957, and since 1966 with the underground melting method, applied for the first time in Europe in the Grzybów deposit (Kubica, 1994). Total resources of sulphur in 13 deposits are currently estimated at 470.6 million tonnes (Przeniosło, 2003b). Due to trends in global markets and large forced production of sulphur as a by-product of desulphurisation of oil, gas and exhausts of metallurgy based on sulphide ores, annual production of native sulphur in Poland dropped dramatically from about 5 million tonnes around 20 years ago to mere 761 thousand tonnes in 2002 (Przeniosło, 2003b).

Since 1952, extensive prospecting began for sedimentary iron ores, mostly in the Middle Jurassic and Lower Cretaceous deposits. In 1954 a siderite deposit in Łęczyca (Kujawy region) was discovered, and mining began already in 1955. Also the iron ore production in the Częstochowa area increased to about 2.5 million tonnes in 1967. Systematic geomagnetic and drilling work led to the discovery of vanadium-rich magnetite-ilmenite iron ores near Suwałki in 1964. According to current criteria, they are regarded as of no industrial value (Nieć, 2003). In the national resource balance, the iron ores are not listed since 1994, because they do not meet the balancing criteria. Iron ore mining, yielding about 500 thousand tonnes of ore shortly after the war, and about 3.1 million tonnes in 1967, was liquidated in 1982 (Adamski, 1994). Currently, Polish iron metallurgy is based on import of ores and concentrates.

Already since 1950, geological research were expanded on centuries-old zinc and lead ore mining areas, first near Bytom and Olkusz, and then near Siewierz, Zawiercie and Żarki. During the period 1958–1980, several new deposits around Zawiercie were studied, with total resources of about 109.8 million tonnes. Total resources of zinc and lead ores in the Silesia–Cracow area are currently estimated at about 179.9 million tonnes, while the amount mined annually is about 4.7 million tonnes (Przeniosło, 2003b). Poland is still among European exporters of zinc and lead, but to cover full demand of its processing industry it relies on import of ore concentrates.

After 1945, Poland, for the first time in its history, got major copper deposits in the Lower Silesia near Bolesławiec and Nowy Kościół. Mines constructed there by the Germans since 1936, destroyed during the war, resumed operation in 1950. Peak production of copper ores in this region exceeded 2 million tonnes in 1970, but by 1989 the mines were liquidated (Paździora, 1996). Geological prospecting conducted since 1952 in new perspective areas near Legnica and Głogów led to dicovery of huge sedimentary deposits of copper ores in the Fore-Sudetic Monocline in 1957–1959. Beginning in 1963, modern copper industry was build here from scratch, and Poland became a globally important producer of copper and associated silver. Total resources of this great copper-rich area are about 2.2 billion tonnes of ore, containing about 45.5 million tonnes of copper and 131.7 thousand tonnes of silver. In 2002, about 28.5 thousand tonnes of ore were mined, making Poland one of the leading copper producing countries in the world (Paździora, 1996; Przeniosło, 2003b).

In Złoty Stok in the Lower Silesia the gold-bearing arsenic ores known since the 13th century were exploited in the post-war Poland until 1960. The deposit still contains about 0.5 million tonnes of ore, with about 1900 kg of gold.

Other metallic mineral resources were also researched after the war, e.g., bauxites and tin ores in the Sudetes, molybdenum-tungsten-copper ores near Myszków, as were chemical deposits such as pyrite, barite and fluorite in the Lower Silesia and the Holy Cross Mountains.

During the second half of the 20th century, also many new deposits of rock mineral raw materials were discovered and documented, such as refractive clays, magnesite, dolomite, kaolin, moulding and glass sands, natural aggregate, quartzites, building stones, raw materials for the cement industry, gypsum and various pottery minerals. There are more than 7 thousand deposits, containing over 52 billion tonnes of these mineral resources (Przeniosło, 2003b).

Conclusion

After the World War II, traditional Polish resources of hard coal, rock salt, iron, zinc, and lead were augmented by discoveries of large deposits of brown coal, sulphur, and copper. The gas balance improved. Meantime, the resources of zinc and lead ores were depleted, the exploitation of low-iron bog ores is no longer economically viable, and sulphur deposits lost their importance. Poland still remains, however, an important producer of many mineral resources. The negative balance of foreign trade in mineral resources is mostly due to the necessity of importing large quantities of oil and gas, as well as iron and aluminum ores.

References

ADAMSKI A. 1994 — Górnictwo rud żelaza w regionie częstochowskim: 299, Częstochowa.

BOHDANOWICZ K. 1919 — Złoża mineralne ziem polskich. [In:] Gieysztor J. (ed.) — Pr. Pol. Narady Ekonom. w Petersburgu. T. 1: 3–38, Biuro Prac Kongresowych, Warszawa.

BOHDANOWICZ K. 1927 — Zasoby mineralnych surowców w Polsce i wynikające z zależności od nich zagadnienia gospodarki narodowej. Dąbrowa Górnicza.

CIUK E. 1960 — Badania złóż węgla brunatnego. Inst. Geol. Pr., 10: 249–257.

CIUK E. 1991 — Zarys historii poszukiwań, badań i górnictwa węgla brunatnego w Polsce oraz udział w niej Państwowego Instytutu Geologicznego. Kwart. Geol., 35: 207–220.

CZARNOCKI S. 1931 — Mapa Bogactw Kopalnych Rzeczypospolitej Polskiej 1:750 000. Objaśnienia do Mapy Bogactw Kopalnych Polski: 1–136. Państw. Inst. Geol., Warszawa.

CZARNOCKI S. 1935 — Polskie Zagłębie Węglowe w świetle badań geologicznych ostatnich lat dwudziestu (1914–1934): 1–276, Państw. Inst. Geol.

CZARNOCKI J. 1958 — O bogactwach kopalnych Gór Świętokrzyskich. Inst. Geol. Pr. V: 176–185, Warszawa.

FABIJANOWSKI J. 1955 — Lasy tatrzańskie. [In:] Szafer W. (ed.) — Tatrzański Park Narodowy, PAN, Zakł. Ochr. Przyr., Wyd. Popularnonaukowe, Kraków, 10: 73–131.

FISCHER S. 1962 — Dzieje bocheńskiej żupy solnej. Państw. Rada Górn, Mat. Z Prac Rady, z. 36, ser. E (3) — Historyczna: 162, Warszawa.

JAROS J. 1975 — Zarys dziejów górnictwa węglowego. PWN.

JAROS J. 1984 — Słownik historyczny kopalń węgla na ziemiach polskich. 2nd ed., Śl. Inst. Nauk.: 1–200, Katowice.

JOST H. 1962 — O górnictwie i hutnictwie w Tatrach Polskich, WNT.

KARNKOWSKI P. 2004 — Przegląd historyczny odkryć złóż ropy naftowej i gazu ziemnego w Polsce. Prz. Geol., 52: 120–128.

KOZŁOWSKI S. 1986 — Surowce skalne Polski. Wyd. Geol.

KRAJEWSKI R. (ed.) 1960 — Geologia złóż surowców mineralnych Polski. Surowce metaliczne. Inst. Geol. Biul.: 1–389.

KUBICA B. 1994 — The discovery of new sulphur deposits between the Vistula and San rivers (the Carpathian Foredeep, southern Poland) — a historical review. Geo. Quart., 38: 341–352.

ŁĄBĘCKI H. 1841 — Górnictwo w Polsce. Opis kopalnictwa i hutnictwa pod względem technicznym, historyczno-statystycznym i prawnym. T. I: XIII, 538, T. II:XX, 551, Warszawa.

MAKSIMOW A. 1959 — Torf i użytkowanie surowca torfowego w rolnictwie. PWRiL: 353, Warszawa.

NIEĆ M. 2003 — Ocena geologiczno-gospodarcza złóż wanadonośnych rud tytanomagnetytowych masywu suwalskiego. Gosp. Sur. Miner. 19, 2: 5–28. Wyd. IGSMiE PAN Kraków

OSMÓLSKI T. 1969 — Siarka w zapadlisku przedkarpackim w latach 1415–1921. Kwart. Geol., 13, 1: 233–252.

PAZDUR J. (ed.) 1960 — Zarys dziejów górnictwa na ziemiach polskich. T. I: 210, SITG, Wyd. Górn.-Hutn, Katowice.

PAZDUR J. (ed.) 1961 — Zarys dziejów górnictwa na ziemiach polskich. T. II: 276, SITG, Wyd.Górn.-Hutn., Katowice.

PAŹDZIORA J. 1996 — Polskie Zagłębia Miedziowe. Cuprum, 1/96: 1–71, Wrocław.

PORZYCKI J. 1988 — Historia badań geologicznych i odkrycia Lubelskiego Zagłębia Węglowego. [In:] Dembowski Z. & Porzycki J. (eds) — Karbon Lubelskiego Zagłębia Węglowego, Pr. Inst. Geol., 72: 9–18.

PIWOCKI M. & PRZENIOSŁO S. 1997 — Propozycje stosowania nowej międzynarodowej klasyfikacji zasobów w Polsce. Prz. Geol., 45: 761–767.

PRZENIOSŁO S. 1999 — Baza zasobowa rud cynku i ołowiu w Polsce. Mat. Konf. „Stan aktualny i perspektywy górnictwa rud Zn i Pb w Polsce". 5–12. Olkusz 29–30.09.1999.

PRZENIOSŁO S. 2003a — Rola Komisji Zasobów Kopalin w kształtowaniu bazy zasobowej kraju. Prz. Geol., 51: 858–861.

PRZENIOSŁO S. (ed.) 2003b — Bilans Zasobów Kopalin i Wód Podziemnych w Polsce wg stanu na 31.XII.2002. Wyd. Min. Środ., Państw. Inst. Geol., Warszawa.

SKOCZYLAS J. (ed.) 1994 — Użytkowanie surowców skalnych w początkach państwa polskiego. VI Konf. Sozol. i Seminarium Petroarcheologiczne, Poznań, 29.IX.1994: 90.

STAWIARSKI J. 1988 — Historia górnictwa węgla brunatnego na ziemiach polskich. [In:] Matl K. — Problematyka wykorzystania małych powierzchniowych złóż węgla brunatnego dla potrzeb gospodarki lokalnej. AGH, Inst. Sur. Energet.: 65–76, Kraków.

TOŁŁOCZKO L. 1919 — Źródła energji na ziemiach polskich i sposoby ich wykorzystania. [In:] Pr. Pol. Narady Ekonom. w Petersburgu, Gieysztor J. ed., T. 1: 39–95, Biuro Prac Kongresowych, Warszawa.

WDOWIARZ S. 1960 — Badania złóż ropy naftowej i gazu. Inst. Geol. Pr., 10: 267–281, Warszawa.

WERNER Z. 1960 — Badania złóż soli. Inst. Geol., Pr. 10: 317–324, Warszawa.