WP-B Training 20 Nov. – 1 Dec. 2022

Lubango, Angola

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Pan-African Support
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Appui panafricain aux géosciences
du partenariat Afrique-UE

Apoio pan-africano às geociências
da parceria África-UE

PanAfGeo -2 WP-B Avaliação do Potencial em Recursos Minerais:

Valorisation of mining and post-processing waste

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Polish Geological Institute

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Circular economy

- One the offical political and economic targets of the European Union (EU) has become the transition to a circular economy model. This system assumes minimising the use of raw materials and the amount of waste produced, and reducing energy emissions by creating closed processes (loops) in which the waste from one process becomes the raw material for other processes.

Fig. 1 Circular economy as a way of responsible development.

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Exploration, mining and processing

- Economic growth, especially in emerging and developing countries increases the demand for mineral resources and energy. According to forecasts, the global consumption of mineral resources by 2060 will increase to 167 Gt from the current 79 Gt.
- As a result of increased exploitation and processing of mineral raw materials, the volume of anthropogenic waste (**mine waste-rock, tailing, and slags**), **G**reenhouse **g**as **e**mission (**GHG**), leaching of **a**cid **m**ine **d**rainage (water) (**AMD**), pollution of soil and surface and underground waters, among other things, through the failure of tailing ponds, will increase.
- However, anthropogenic waste can be a valuable source of many metals, including **rare metals, rare earth elements (REEs); Nb, Ta, Co and non-metallic minerals**. Post-mining waste can also be used for the **production of aggregate.**

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Exploration, mining and processing

- Mine waste rock – is bedrock that has been mined and transported out of the pit but does not have metal concentrations of economic interest.
- Tailing – consist of ground rock and process effluents that are generated in a mine processing plant. The unrecoverable and uneconomic metals, minerals, chemicals, organics and process water are discharged, normally as slurry, to a final storage area commonly known as a Tailings Management Facility (TMF) or Tailings Storage Facility (TSF).
- Slags – waste matter separated from metals during the smelting or refining of ore.

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Valorisation of mining and post-processing waste PGI National Programme

- PGI national programme: Geobaza Hałdy (a using GIS system for the dump location);
- https://cbdgportal.pgi.gov.pl/haldy/
- Approx. 1.000 dumps were inventoried;
- Details description:

- source of waste, petrology, geochemistry, landscaping, local infrastructure and other

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The dumps in Poland

We have 3 groups of dumps:

- Historical (medieval and later); (old mining of coal, metals – Ag, Au);
- Modern – 20th century (effect of coal mining, Cu, Pb-Zn, U and others);
- The current waste stream; (e.g. Żelazny Most (Iron Bridge) Reservoir – the largest dump reservoir of froth (copper mining tailings dam) in Europe.

Żelazny Most (=Iron Bridge) Reservoir
(Likely, the biggest landfill of post-treatment wastes in the world)

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Mineral resources of Poland

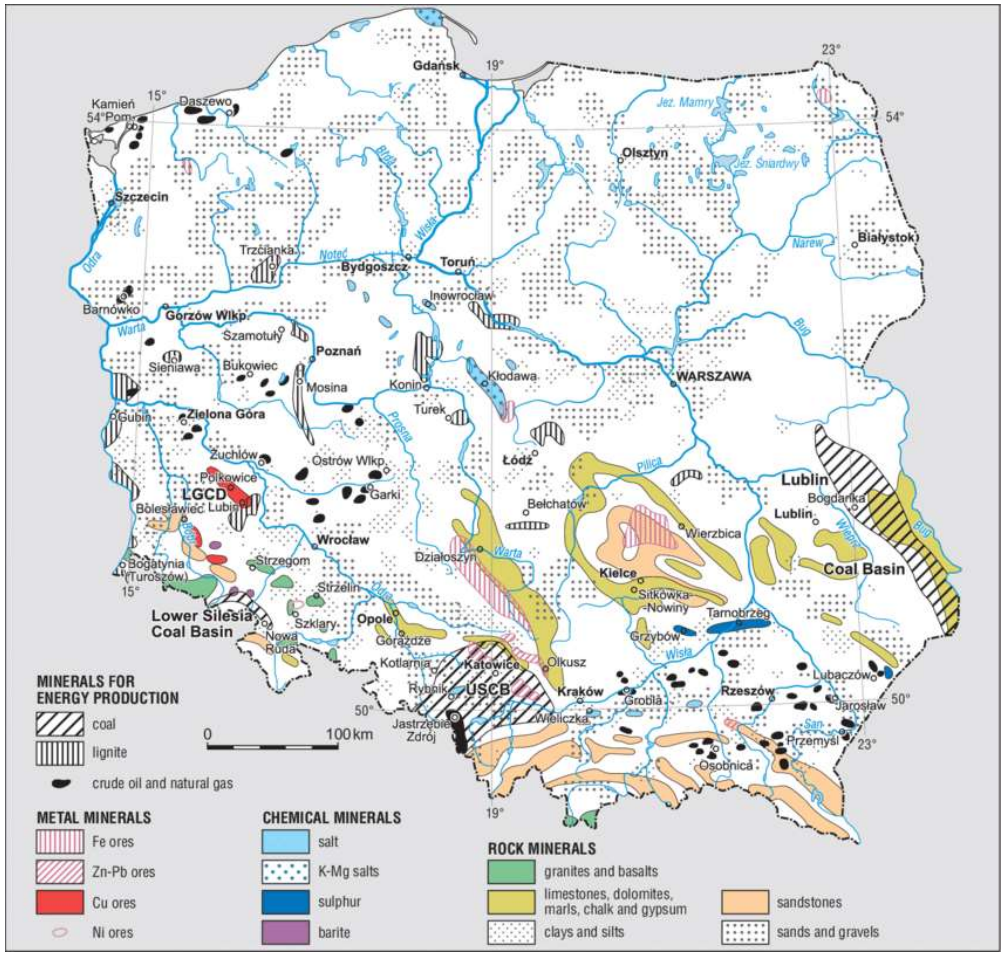

Fig. 2 Mineral resources of Poland.

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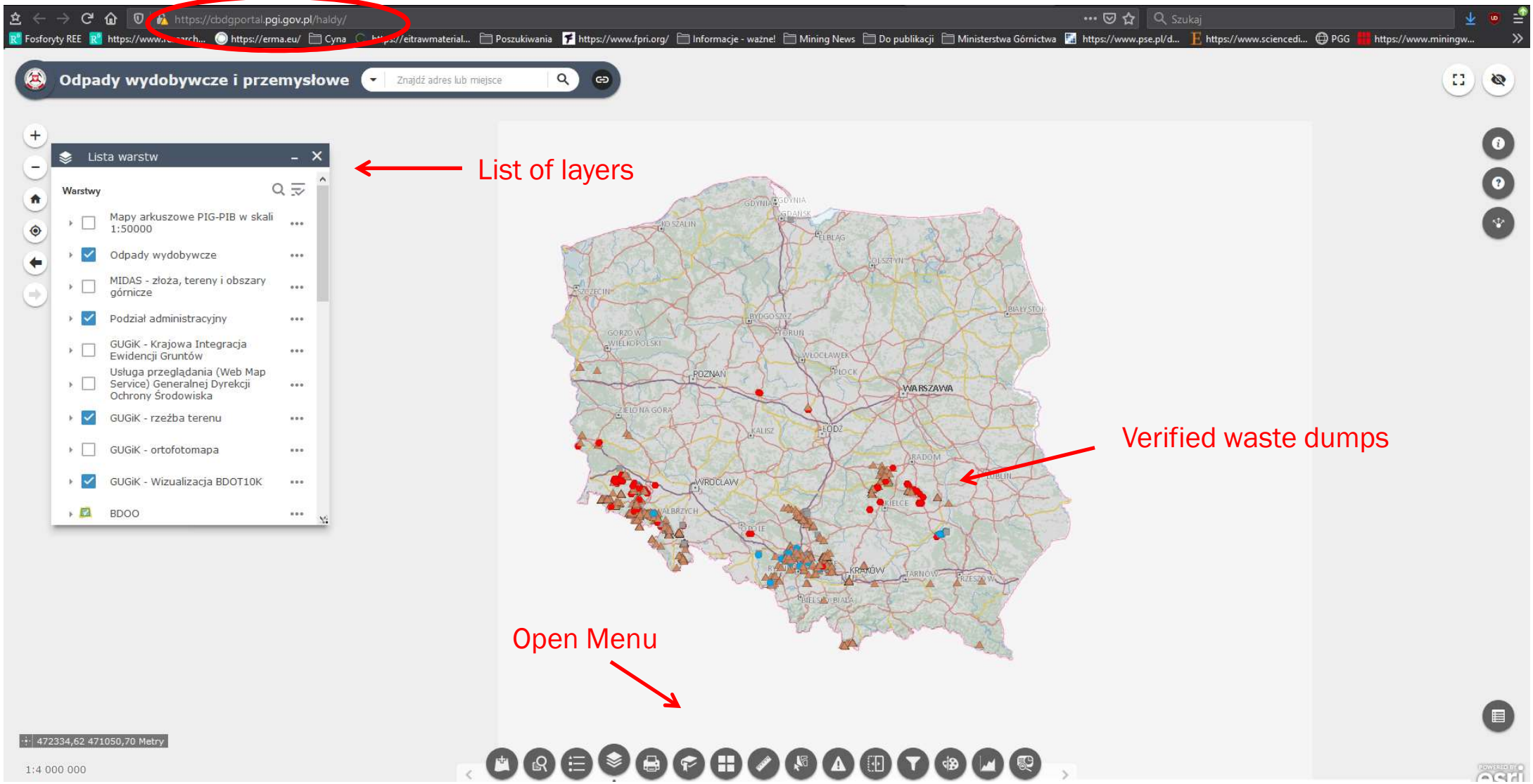
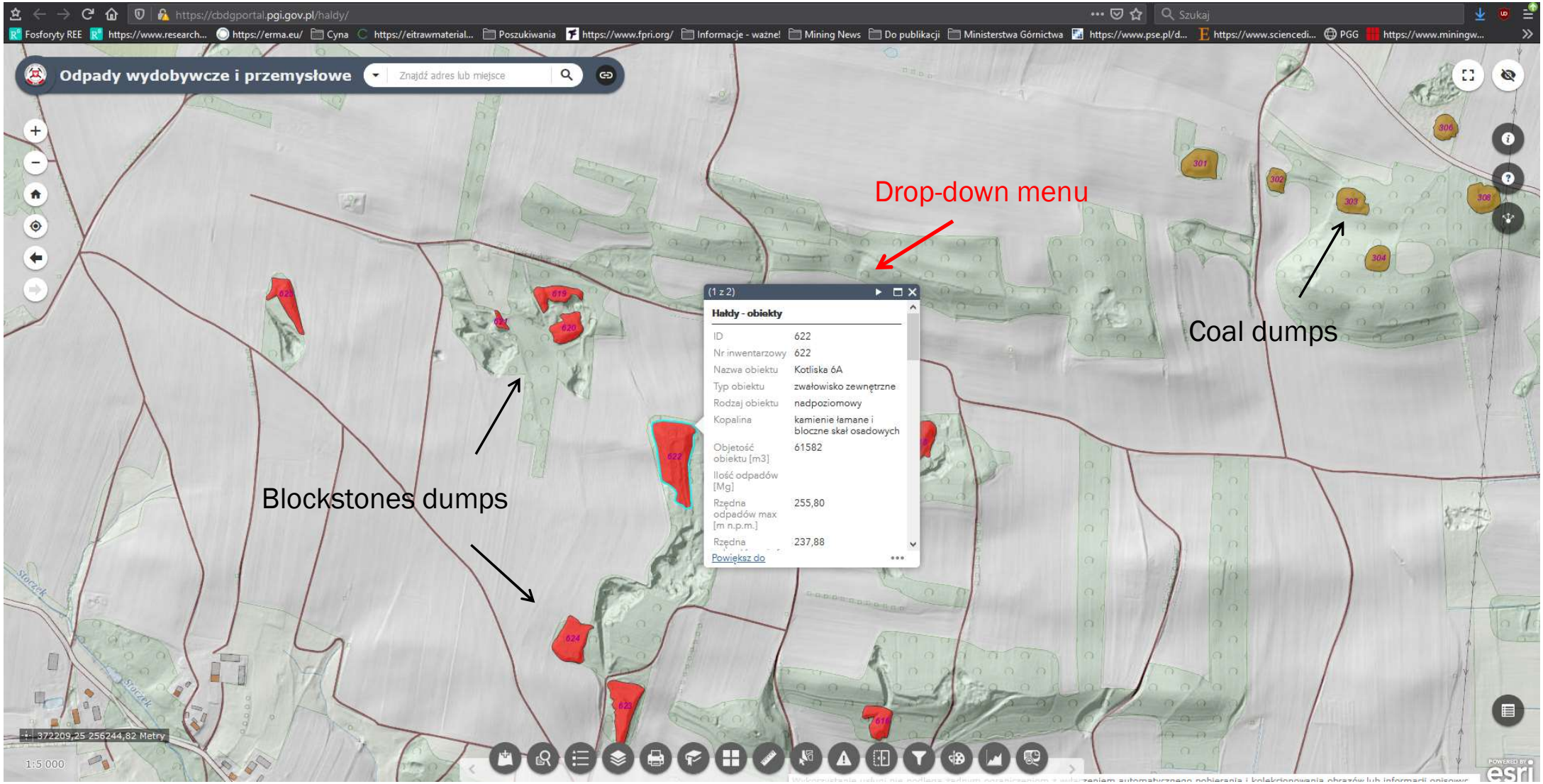
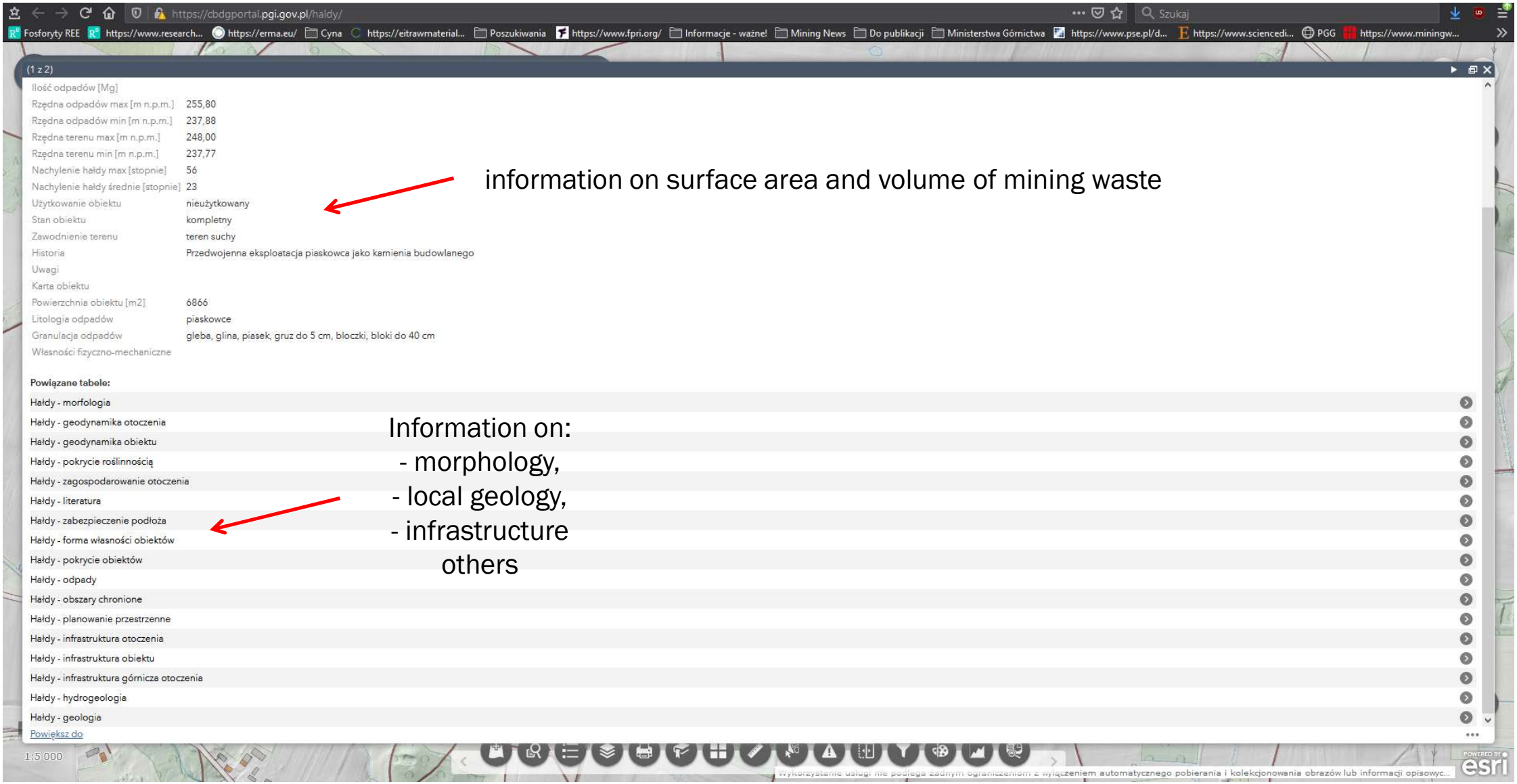
Source


https://cbdgportal.pgi.gov.pl/haldy/
Odpady wydobywcze i przemysłowe
Znajdź adres lub miejsce
Lista warstw
Warstwy
Mapy arkuszowe PIG-PIB w skali 1:50000
Odpady wydobywcze
MIDAS - złoża, tereny i obszary górnicze
Podział administracyjny
GUGiK - Krajowa Integracja Ewidencji Gruntów
Usługa przeglądania (Web Map Service) Generalnej Dyrekcji Ochrony Środowiska
GUGiK - rzeźba terenu
GUGiK - ortofotomapa
GUGiK - Wizualizacja BDOT10K
BDOO
List of layers
Verified waste dumps
Open Menu
472334,62 471050,70 Metry
1:4 000 000


Odpady wydobywcze i przemysłowe
Znajdź adres lub miejsce
Drop-down menu
Coal dumps
Blockstones dumps
(1 z 2)
Hałdy - obiekty
ID 622
Nr inwentarzowy 622
Nazwa obiektu Kotliska 6A
Typ obiektu zwałowisko zewnętrzne
Rodzaj obiektu nadpoziomowy
Kopalina kamienie łamane i bloczne skał osadowych
Objętość obiektu [m3] 61582
Ilość odpadów [Mg]
Rzędna odpadów max [m n.p.m.] 255,80
Rzędna 237,88
Powiększ do
372209,25 256244,82 Metry
1:5 000



information on surface area and volume of mining waste

Information on:
- morphology,
- local geology,
- infrastructure
others

How we search for old dumps? – PGI National Programme

- Historical (medieval and later) mining (e.g. The Sudetes Mountains)

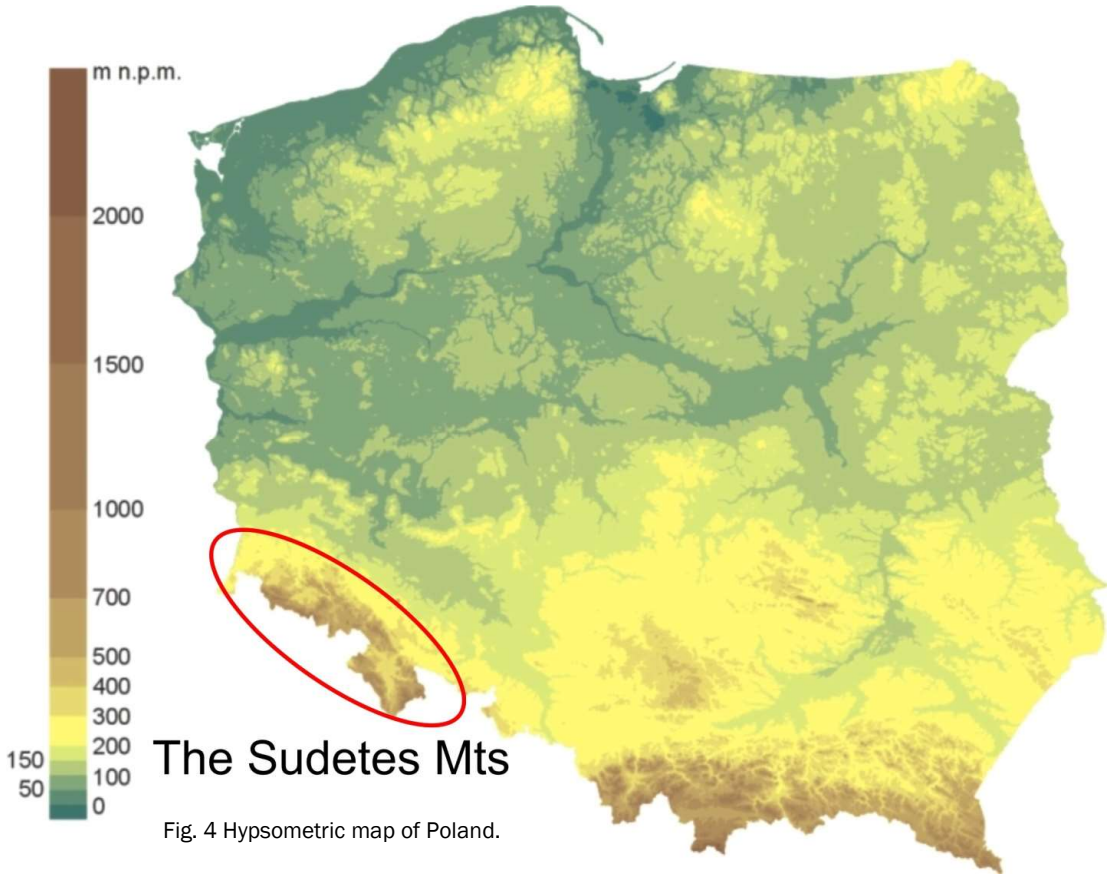


Fig. 4 Hypsometric map of Poland.

Fig. 5 The dump of polymetallic ore mine "Cons. Gut Glück" (1858-1864) and uranium ore mine "Dziećmorowice" (1949-1952).

How we search for old dumps? – PGI National Programme

We use the sources:

- old maps, old notes;
- mining traces (e.g. shafts, exploratory drift and others);
- Landstat imaging;
- searching a sinkholes;
- research articles;
- Internet forums of old mining enthusiasts;
- fieldwork;

Fig. 6 Extract from the Fr. Holsche map dated 1777.

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The Landsat Data

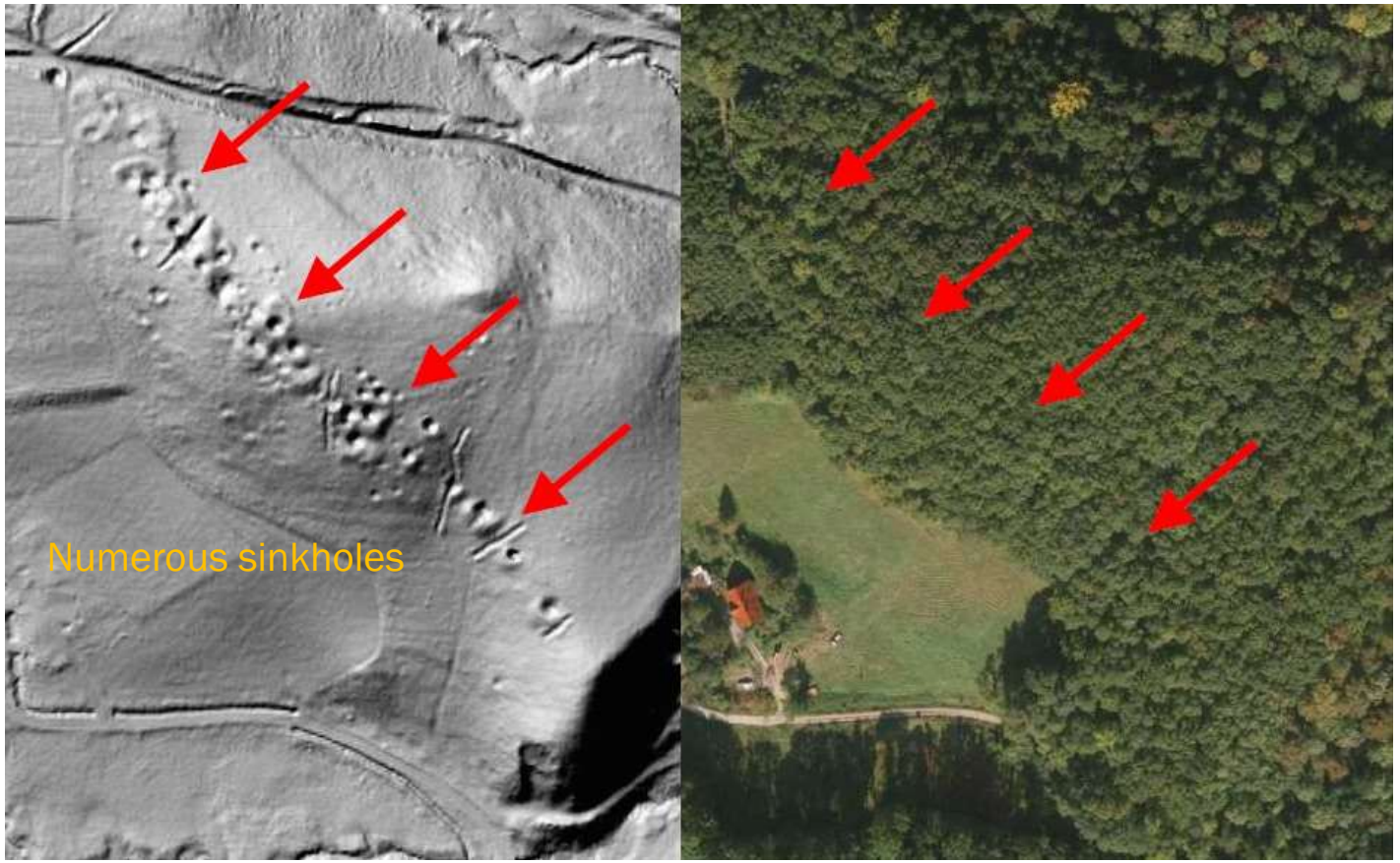

Fig. 7 Landstat image.

Fieldwork

The dump of polymetallic ore mine.

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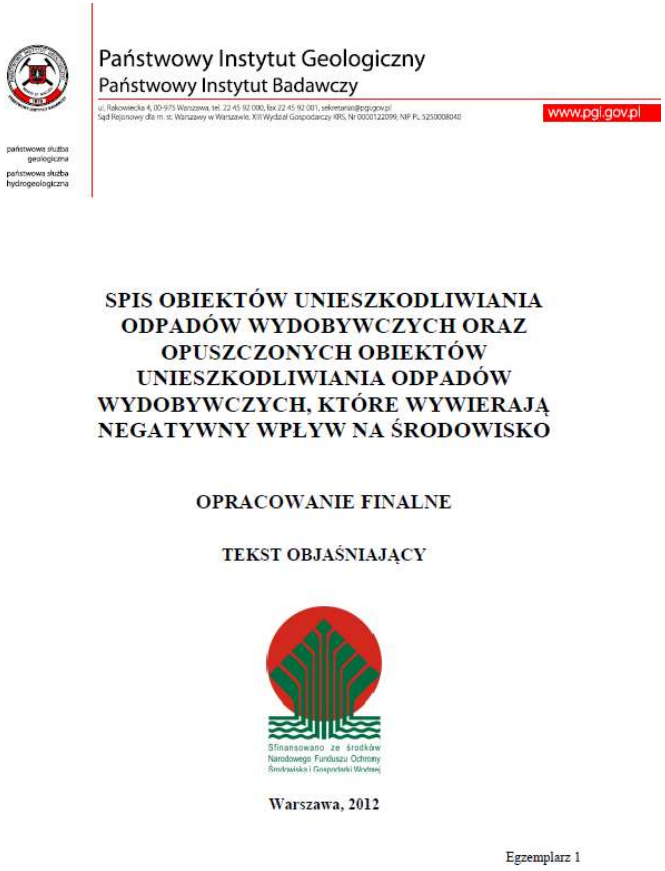
Historical dumps in Poland – research PGI-NRI



Państwowy Instytut Geologiczny
Państwowy Instytut Badawczy
www.pgi.gov.pl

państwowa służba geologiczna
państwowa służba hydrogeologiczna

SPIS OBIEKTÓW UNIESZKODLIWIANIA ODPADÓW WYDOBYWCZYCH ORAZ OPUSZCZONYCH OBIEKTÓW UNIESZKODLIWIANIA ODPADÓW WYDOBYWCZYCH, KTÓRE WYWIERAJĄ NEGATYWNY WPŁYW NA ŚRODOWISKO

OPRACOWANIE FINALNE

TEKST OBJAŚNIAJĄCY

Sfinansowano ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej

Warszawa, 2012

Egzemplarz 1

- In 2012, at the request of the Chief Inspectorate of Environmental Protection, Polish Geological Institute - National Research Institute made „List of closed mining waste facilities and abandoned mining waste facilities that have a negative impact on the environment”,
- 368 mining waste facilities, stockpiles, dumps and floatation clarifiers where the waste of exploitation and processing of minerals was disposed, have been cataloged,
- The wastes facilities were assessed in terms of their negative impact on environment including soils, air, surface and underground waters,
- As a result of analysis, none of the studied wastes facilities **is not classified in Class I (significant impact)**, in **Class II classified 17 wastes facilities** (without significant impact) and in **Class III – 351 (lack of impact)**.

Types of closed mining and tailings storage facilities

Closed facilities

- Historical objects
  - rehabilitated
    - in the special direction
    - in the forest direction
    - towards the communal
- Recent objects
  - not rehabilitated

Źródło: https://eksploratorzy.com.pl/viewtopic.php?t=4006; Lizęga J., 1970: „Ziemia rybnicko-wodzisławska", Śląski Instytut Naukowy
Hałda byłej kopalni „Rymer" w Niedobrzycach

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Orchid Dump (Ząbkowice County)

Ecological site The Orchid Dump is an **ecological site**. This Dump consists mainly of mining waste accumulated over seven centuries of use of the surrounding mines. It consists of waste rock and low grade polymetallic ore.




Dump of Bolesław (Olkusz County)

Currently, it is an ecological site, which was created in 1997 on the site of the "Bolesław" dump in order to protect a rare plant species found there.


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Staszic Dump (Town Wałbrzych)

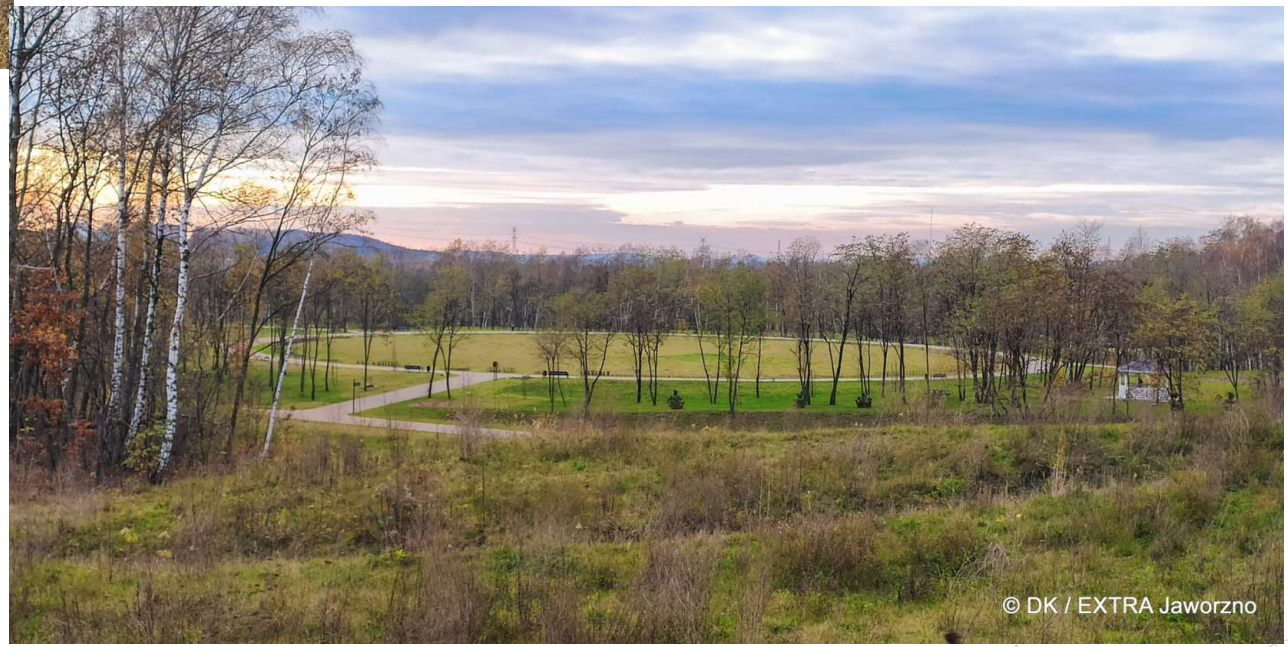
The dump with an area of 9 hectares and a volume of about 2.4 million m^3 was created as a result of collecting waste from the nearby hard coal mine "Wałbrzych", which is mainly shale and sandstone with an admixture of coal and combustion slag. As part of the reclamation works, drainage ditches and technological roads, erosion of escarpments in the area of 3.3 ha, planting over 10,000 trees and shrubs.

Dump Kostuchno (Katowice City)

The slag dump in Kostuchno, i.e. a dumping ground next to the "Boże Dary" coal mine, is the second highest hill in Katowice. The dump with an area of 32 ha, at its highest point reaches a height of 339 m above sea level. At the foot of the heap there are forests, while shrubs have been planted on the slopes. The peak, in turn, is a huge flat clearing, from which there is a wonderful panorama of the surrounding forests and a large part of the Upper Silesian agglomeration.

The areas of the former Piłsudski dump in the Stara Huta district in Jaworzno have been transformed into an English-style park. The creation of the park made it possible to develop a degraded post-industrial area for natural purposes and to improve the quality of the urban environment. The park has an educational function and is a place of rest, relaxation and recreation for the inhabitants of the city

Piłsudski Dump (Town Jaworzno)



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Wieściszowice (former mines for pyrite 1785-1925)

The place is now known as the Colored Lakes and is a local tourist attraction

But many old dumps of post-mining waste still require development, use of deposited waste and recultivation...

Dump at the adit of the arsenic ore mine in Czarnów (Sudetes)

Iron ore mine dump in Wręczyca Wielka

Dump of the polymetallic ore mine „Stara Góra” (Radzimowice)

Modern dumps (Phosphorite mine in Chałupki)

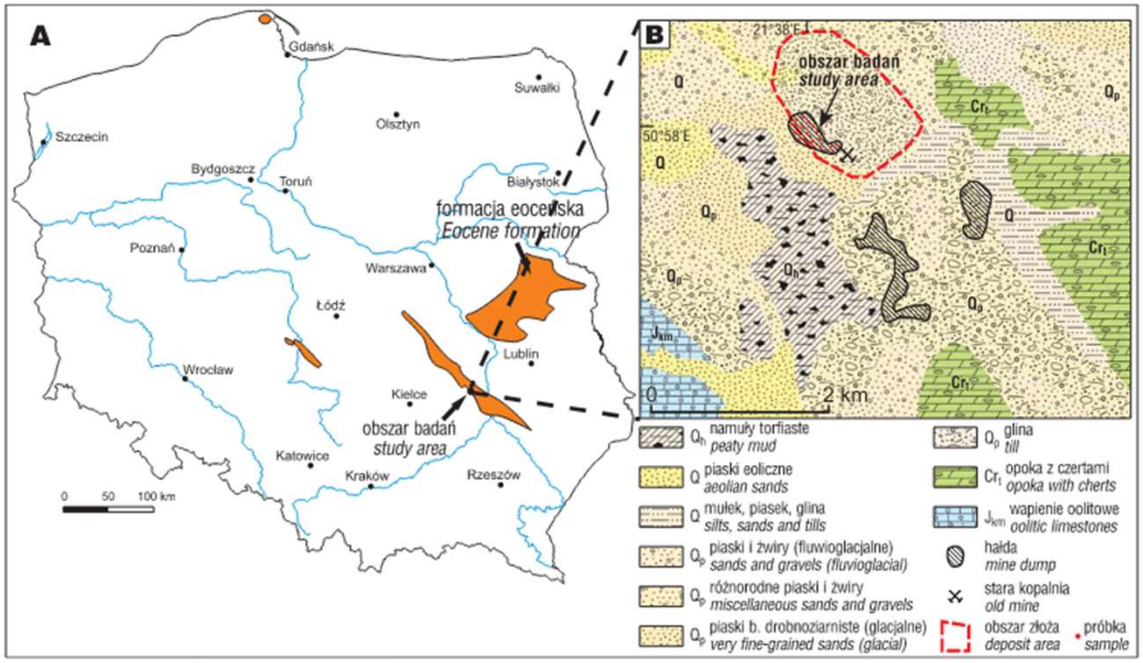
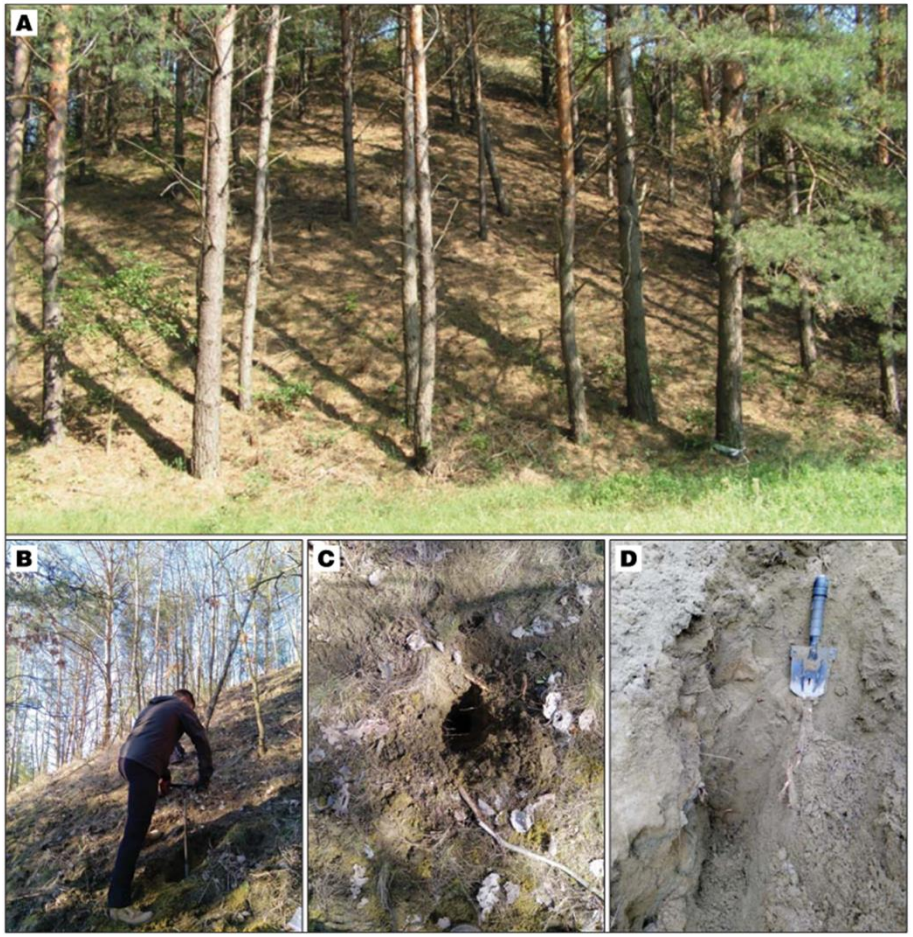


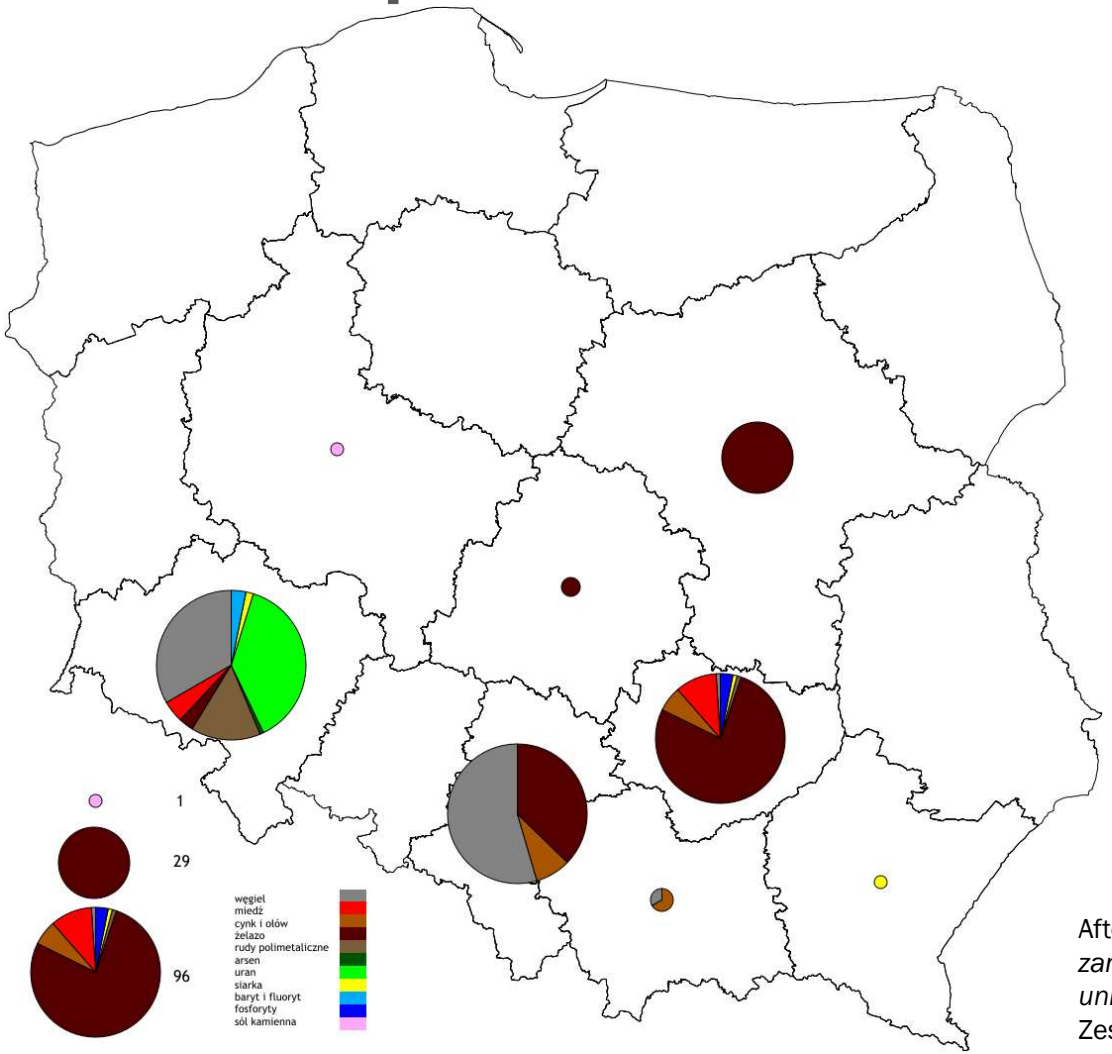
Fig. 12 Areas of potential occurrence of phosphorites in Poland.

The PGI-NRI conducts geological research on the documentation of occurrence of REE deposits in Poland. The deposit potential may be related to the formation of Lower Cretaceous phosphorites from the NE margin of the Holy Cross Mountains.



The old dump from the Chałupki mine. A – the view of afforested dump, B – sampling site, C – drilling hole with a probe, D – scrap sampling from the dump

Historical dumps in Poland – research PGI-NRI



After: Kostrz-Sikora et al., 2013: *Inwentaryzacja zamkniętych i opuszczonych obiektów unieszkodliwiania odpadów wydobywczych* [w]: Zeszyty Naukowe IGSMiE PAN Nr 85.

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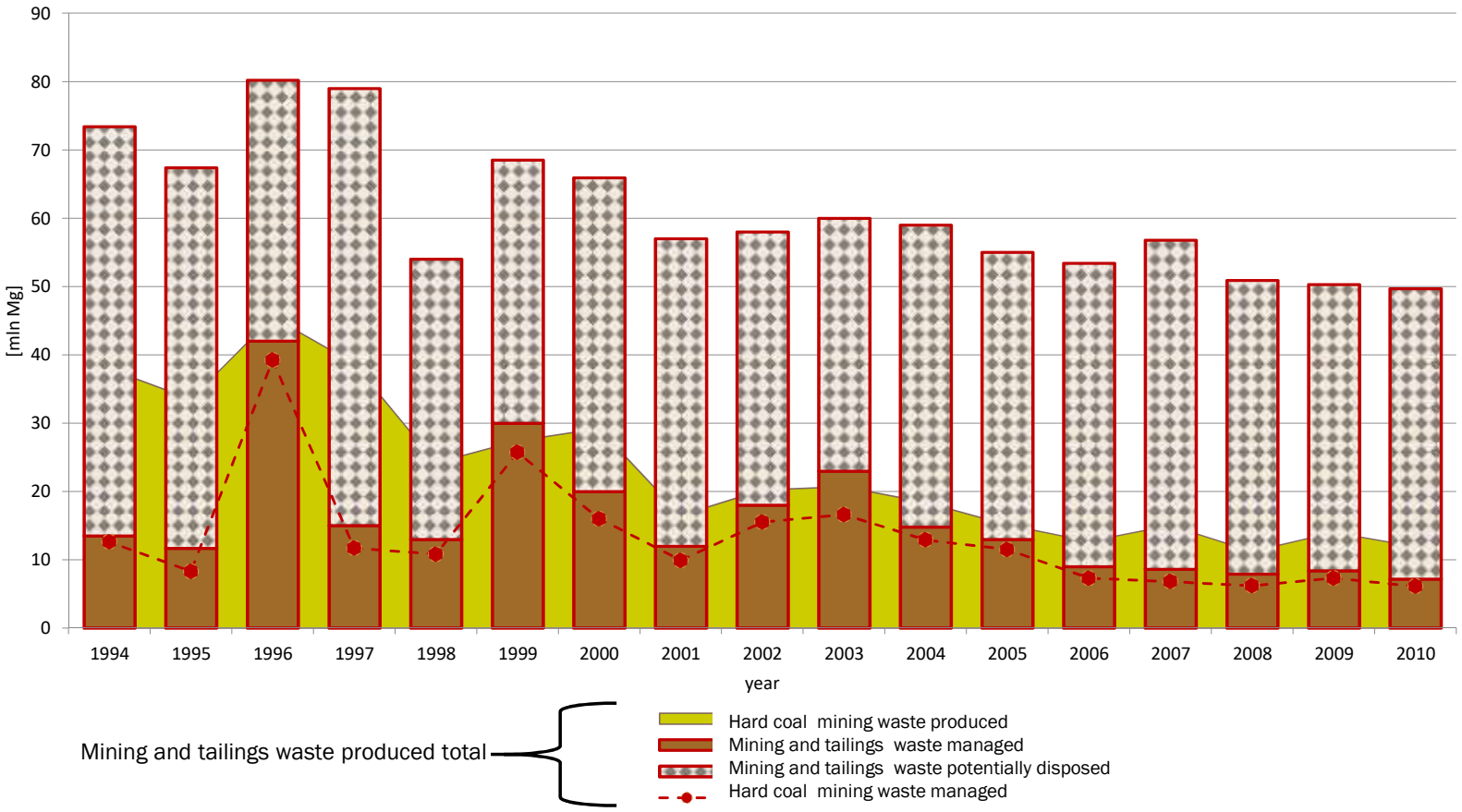
Mining waste – the quantities produced and managed in the years 1994-2010

After yearly prepared Balance of mineral resouces.



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Mining waste management in Poland in 2011 and 2020 [in millions of Mg]

Industry	Waste generated		Recycled waste		Neutralized waste				Waste accumulated	
					Total		Including stored			
	2011 r.	2020 r.	2011 r.	2020 r.	2011 r.	2020 r.	2011 r.	2020 r.	2011 r.	2020 r.
Mining and quarrying, including:	**60.9**	**60.8**	**45.5**	**24.4**	**14 .8**	**36.1**	**14.8**	**35.9**	**809.5**	**828.3**
Hard coal mining	*30.3*	*27.8*	*24.4*	*21.4*	*5.4*	*6.3*	*5.4*	*6.3*	*480.1*	*430.1*
Mining of non-ferrous metal ores	*28 .2*	*28.0*	*18.9*	*0.06*	*9.3*	*27.9*	*9.3*	*27.9*	*314.4*	*317.1*
Extraction of aggregate, sand and clay	*1.7*	*4.5*	*1.4*	*2.9*	*0.08*	*1 .4*	*0.09*	*1.1*	*14.4*	*39.4*
Mining and quarrying not elsewhere classified	*0.7*	*0.5*	*0.7*	*0.001*	*0.0001*	*0.5*	*0.0002*	*0.5*	*0.6*	*8.7*
Other groups	62.6	48.6	43.2	32.2	16.7	16.3	33.6	10.5	844.6	959.5
TOTAL	**123.5**	**109.5**	**88.6**	**56.6**	**31.4**	**52.4**	**48.4**	**46.3**	**1 654.0**	**1 787.8**

Data from the Central Statistical Office, reproduced by the Authors

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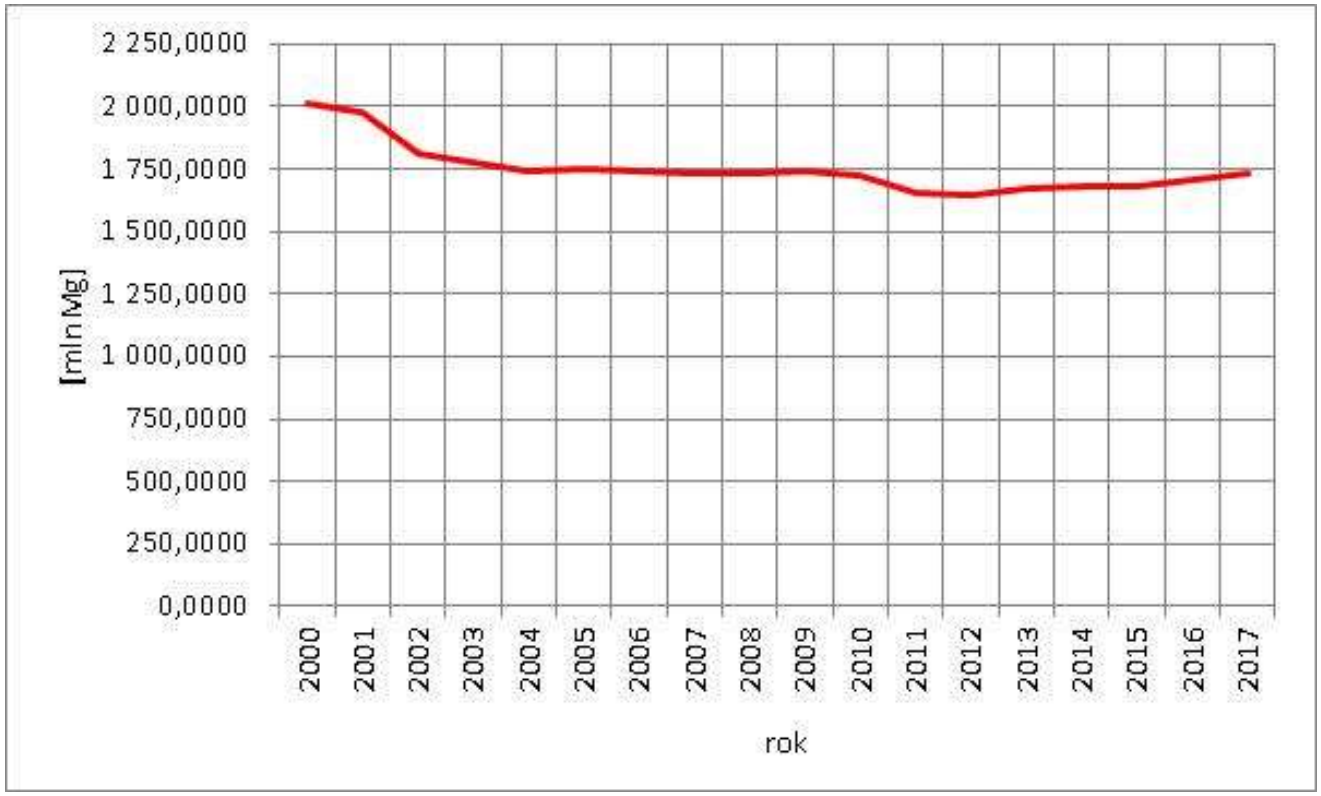
The current waste stream of mining waste in Poland –waste accumlated

Waste accumulated in own waste facilities (including heaps, sedimentation ponds)



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Recovery of mining waste - main directions of use:

Construction and building materials:	Road engineering and engineering works:	Mining:	Agriculture:	Recovery of raw material from heaps:
• aggregate production, including burnt shale; • production of building materials.	• construction of road surfaces; • construction of road embankments; • improved substrates with frost protection layer; • foundations stabilized with binders, mechanical, of lean concrete.	• component of backfill mixtures; • sealing old goafs in fire prevention; • liquidation of redundant excavations, including shafts; • reinforcement and stabilization of mining excavations.	• improvement of soil properties by enriching them, e.g. in calcium, potassium and magnesium; • production of granules supporting the cultivation of plants.	• coal recovery from mining waste from mining and coal processing.

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Evaluation of the raw material potential and the possibility of using waste as substitutes for natural resources from reclaimed objects

- Identification of formal and legal aspects,
- Determination of the physical and chemical composition of the accumulated mining waste,
- Identification of types of deposited mining waste,
- Estimating the amount of accumulated waste,
- Compliance with environmental standards,
- Compliance with technical standards,
- Analysis of the condition of economic profitability,
- Social acceptance for the planned activities.

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SWOT analysis of the effective use of accumulated waste on closed facilities

STRENGTHS	WEAKNESSES
– high raw material potential of the facilities, – operating technologies for the extraction and processing of waste, – increasing demand of various industries for natural resources, – the possibility of substituting natural resources with secondary raw materials from waste, – reduction / limitation the extraction of natural resources.	– lack of inventory and raw material evaluation of accumulated waste at closed landfills, – high quality diversification of waste within one facility, – non-selective storage of waste in historical closed facilities, – unregulated legal status of historical closed buildings, – risk of lack of economic profitability.
CHANCES	**THREATS**
– implementation of the circular economy concept, – development of national strategic documents focused on the implementation of the circular economy concept - Road Map of Transformation towards a circular economy, – recovery of waste accumulated on closed facilities, – reduction/limitation/elimination the impact of closed facilities on the environment, – recovery of areas occupied by facilities and the possibility of their re-development.	– change in the economic situation, – administrative procedures, – lack of consent of the society to the liquidation of developed objects from the spatial landscape.

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Program related to the construction of the first nuclear power plant in Poland:

Can post-uranium dumps in the Sudetes be treated as anthropogenic uranium deposits?

Scope of works performed:

- **Field verification of dumps - 74 dumps in 31 regions were penetrated,**
- **Measurements of dumps in the field and analysis using GIS,**
- **Sampling (175 multipoint samples),**
- **Chemical analyzes for the content of uranium and other trace elements,**
- **Estimation of the amount of uranium in the dumps.**

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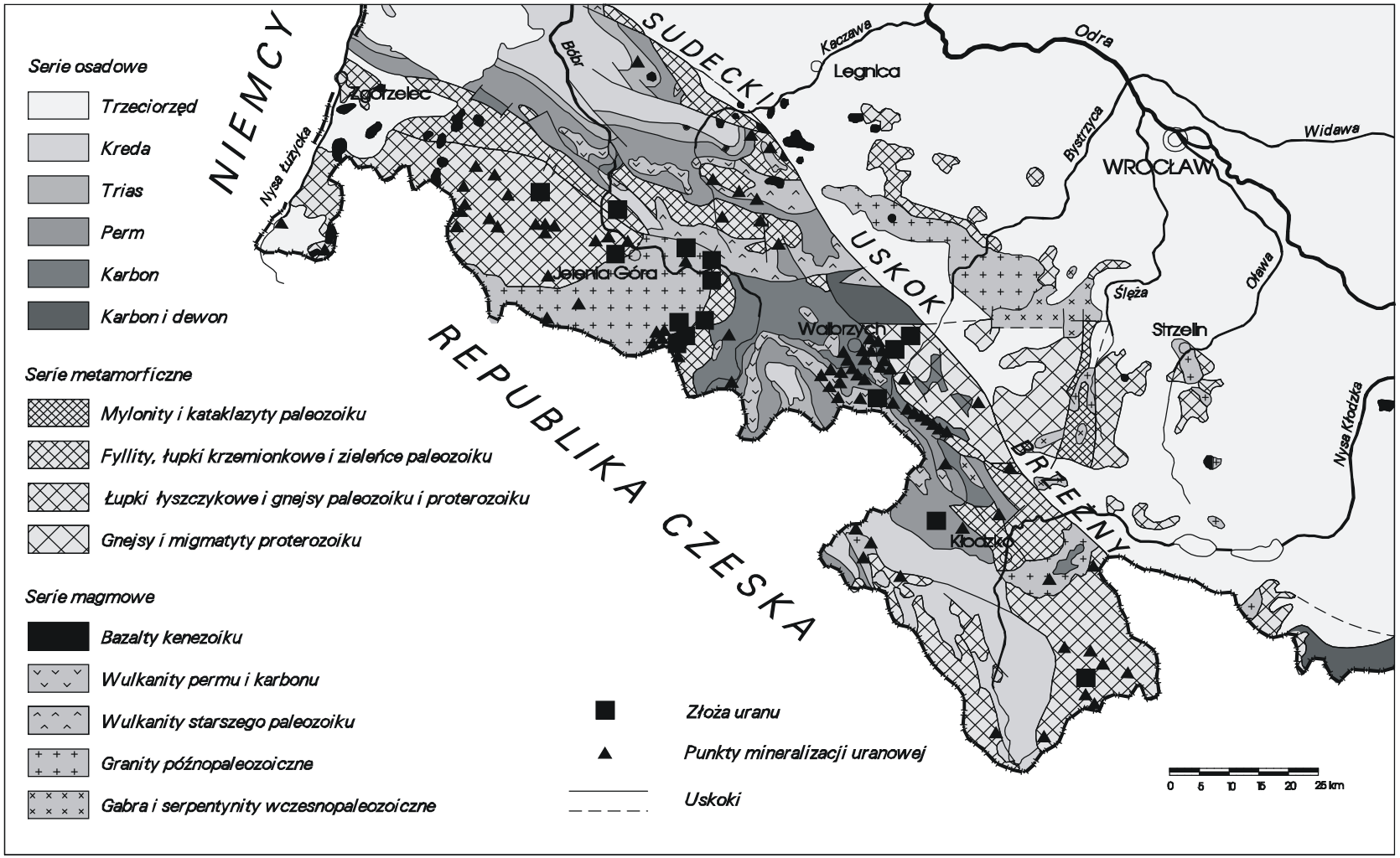
Deposits and selected major points of uranium mineralization in the Sudetes



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The current state of post-uranium dumps in the Sudetes: some have undergone recultivation, others are a source of natural aggregate, often devastate the landscape...

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Results and conclusions from the research:

- On 54 sites with a total area of approximately 113 ha there are about **440,000 m^3** of rock material. The other objects are very small,
- **Estimated uranium resources are around 11 - 15 tonnes**, therefore, post-uranium dumps in the Sudetes cannot be considered as anthropogenic uranium deposits due to their small resources and low contents,
- Measurements of **gamma radioactivity** on the dumps and their surroundings showed their very limited range of impact,
- Detailed studies carried out by the Central Laboratory for Radiological Protection have shown that the **stored waste is not hazardous to the environment and can be used as aggregate**,
- **The emotions associated with uranium mining in the Sudetes have made these objects relatively the best described and studied, and yet they still raise concerns.**

The international contex;
The current waste stream; an example the Bangka Island (Indonesia)

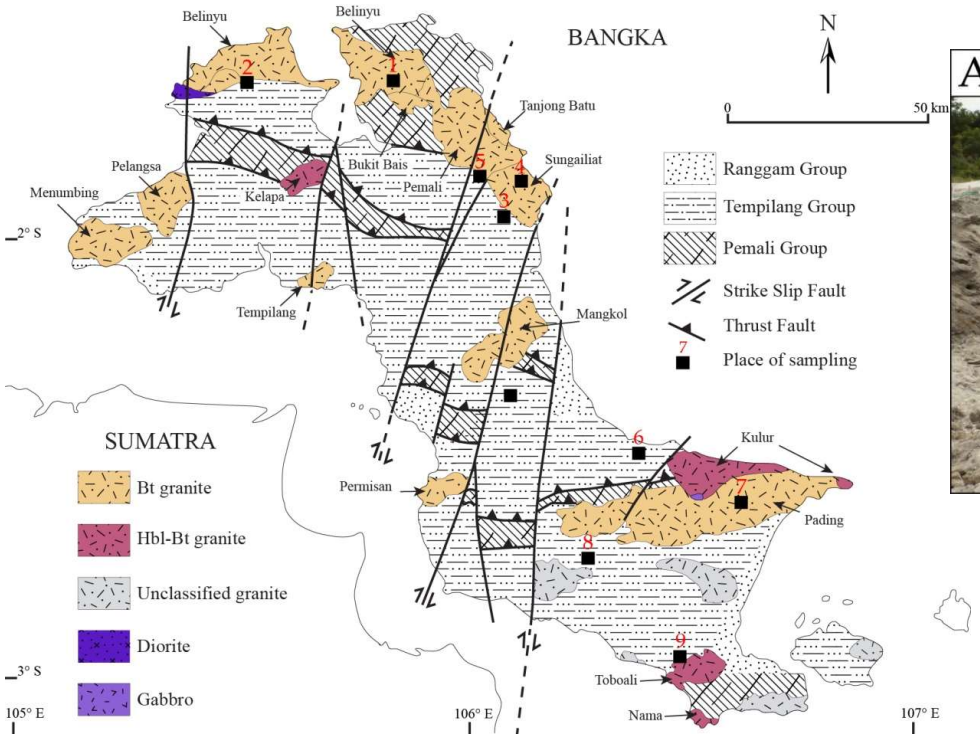

Fig. 14 Geological map of Bangka Island

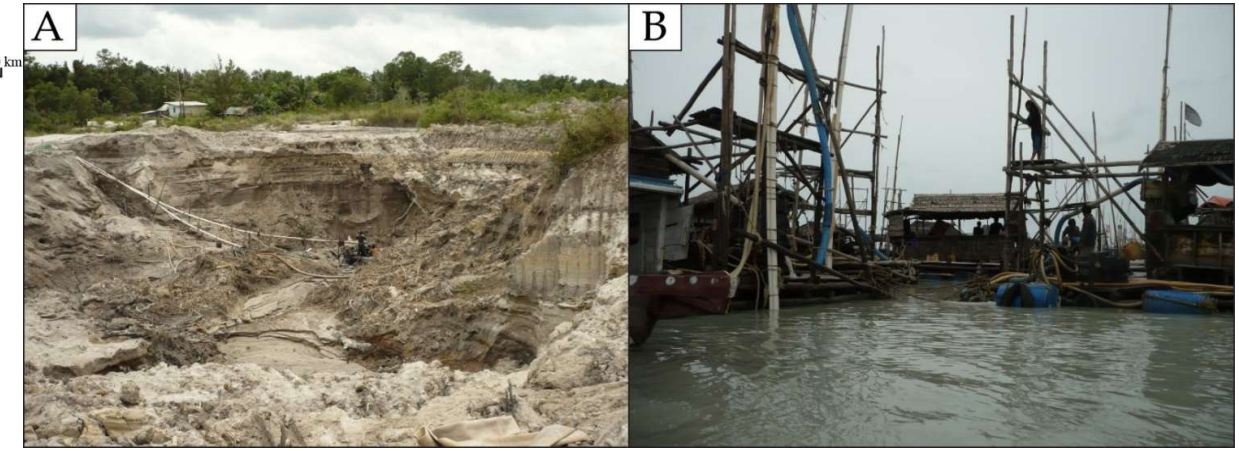

Fig. 15 Mining on Bangka Island: (A) open-pit cassiterite mining; (B) marine cassiterite extraction using primitive mining platforms.

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Tailings may be of particular importance for obtaining metals. Each year, about 8–10 billion tons of tailings are produced in the world, which can be a source of many metals.

On the basis of the predominating mineral constituent (more than 50 wt%), four types of tailings were distinguished:
(1) zircon;
(2) ilmenite-rutile;
(3) monazite;
(4) monazite-xenotime mixture.

Tailings on Bangka Island; (A) state-owned tailings dump with warnings indicating radiation hazard; (B) illegal mining pit with pumps and tubs for washing cassiterite-enriched clastic sediments; (C) tailing resulting from processing and washing of cassiterite sands. By-product used to fill the pit; (D) jute bags of tailing in a domestic dump at a mineral broker/seller (compradores).

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Tailings contain elevated amounts of the following critical raw materials: Ga (to 0.03 wt%); Hf (to 0.64 wt%); Ta (to 0.08 wt%); W (to 0.14 wt%); Zr (>5.0 wt%); and Sc (up to 0.01 wt%).

The high contents of LREE (up to 3.18 wt%) and HREE+Y (up to 1.93 wt%) also include very high concentrations of the “most critical” HREE: Dy (to 0.18 wt%), Tb (to 0.03 wt%), Eu (to 8.4 ppm), Nd (to 0.58 wt%), and Y (to 1.20 wt%).

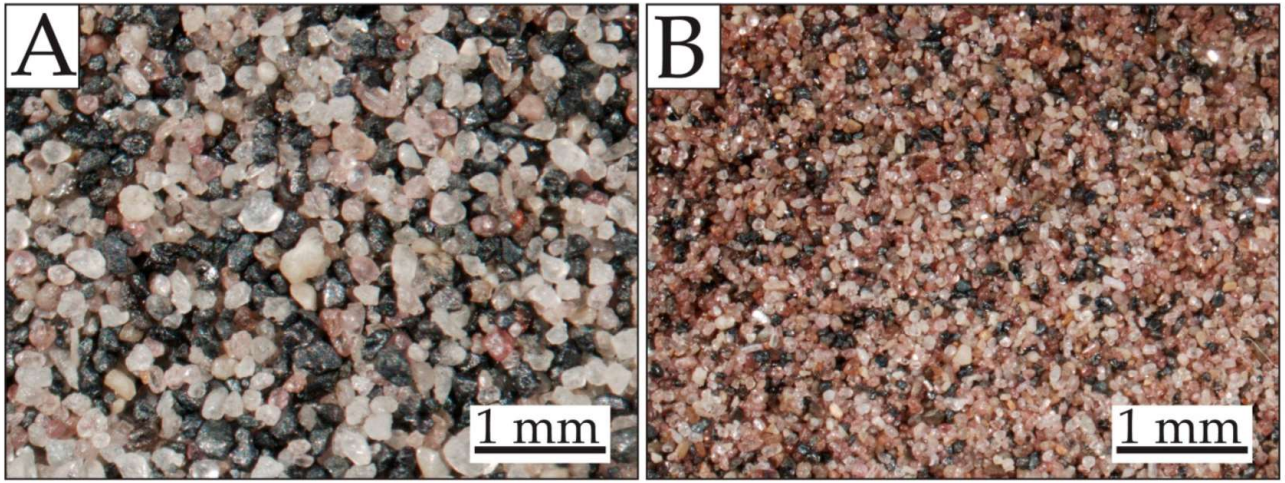

Fig. 17 Tailing after the post-processing of cassiterite-bearing sands: (A) tailing from Nyelanding, sample Bngk 4; (B) tailing from Pemali–Bngk 16. Stereoscopic image magn. ×2.

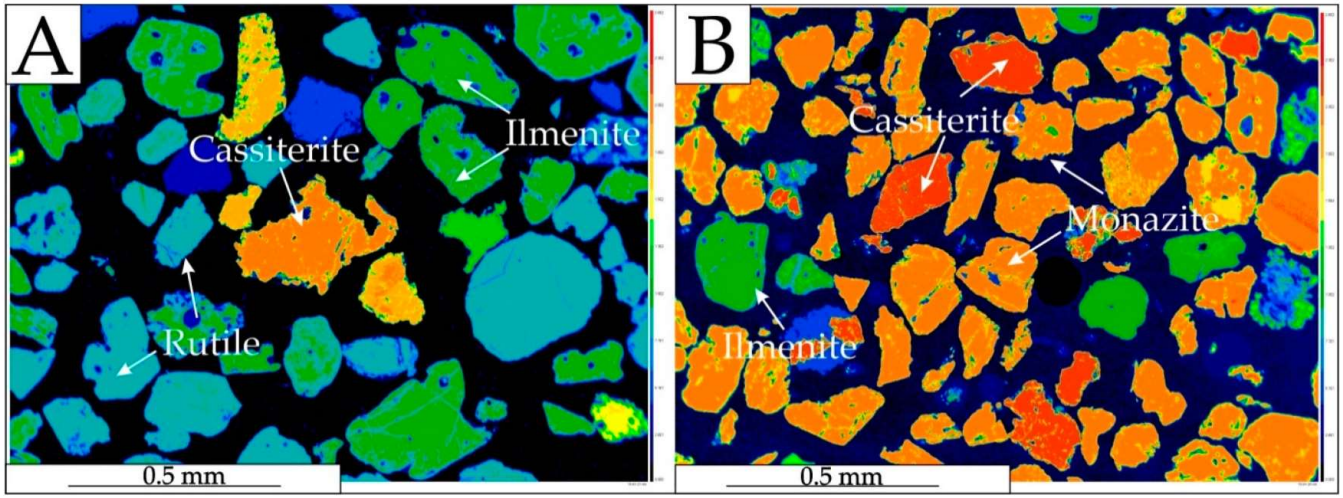

Fig. 18 Mapping of minerals using SEM-BSE: (A) Ilmenite-rutile tailing (Sample Bngk 27); (B) monazite tailing (Sample Bngk 21).

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- The example of the Bankga Island tailings highlights the extent and significance of such a **potential REE resource base.** The development of a technology based on a circular economy and zero-waste principle can contribute to the acquisition of rich mineral concentrates. **Improving the efficiency of the technological process will improve environmental safety by reducing emissions of radioactive substances and will reduce the poverty level of the local mining community.** The diversification of critical metals sources is one of the goals of the Green Deal and of the energy transition of Europe. EU–Indonesian bilateral cooperation can bring mutual benefits by ensuring the security of raw materials, increasing awareness **among local communities of radiogenic risks and environmental protection, increasing the supply of metals on the world market and boosting Bangka's GDP.**

Co-funded by the European Union
Cofinancé par l'Union Européenne
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Some examples from Africa:

Zambia – Kabwe (Broken Hill) - it was founded when Pb-Zn deposits were discovered in 1902



One of the most polluted places in the world…….

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Zambian Cooperbelt - Kitwe



Mopani Copper Mines Plc considers old tailings dumps as potential anthropogenic deposits that can be economically re-used for metal recovery. The rocks are already extracted, ground, and modern technologies are much more effective than those used in the past.

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