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Methods used in the exploration of sediment-hosted, stratiform copper (SSC) deposits located in the SW Poland

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Presentation of the speaker and his professional experience related to the topic of the lecture

- MSc. Sławomir Zaczek
- KGHM Cuprum sp. z o.o. Research and Development Centre
- Professional experience related to the topic of the lecture:
  - exploration of Sediment-hosted Stratiform Copper (SSC) deposits from the terrain surface in the Fore-Sudetic Monocline, North-Sudetic Synclinorium and Mulkwitz Anticline,
  - to a lesser extent, exploration of SSC deposits from underground excavations in the area of the Fore-Sudetic Monocline and the North-Sudetic Synclinorium.

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Presentation content

- 1. Geological background
- 2. Exporation from ground surface
- 3. Underground excavations
- 4; Exploration from underground excavations
- 5. Conclusions
- 6 Used publications

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Part 1
Introduction

SSC deposits and prospective areas in SW Poland

the current state of knowledge

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Geological background

Age of deposits,

The rocks that build the deposits were formed in the **Permian** period.

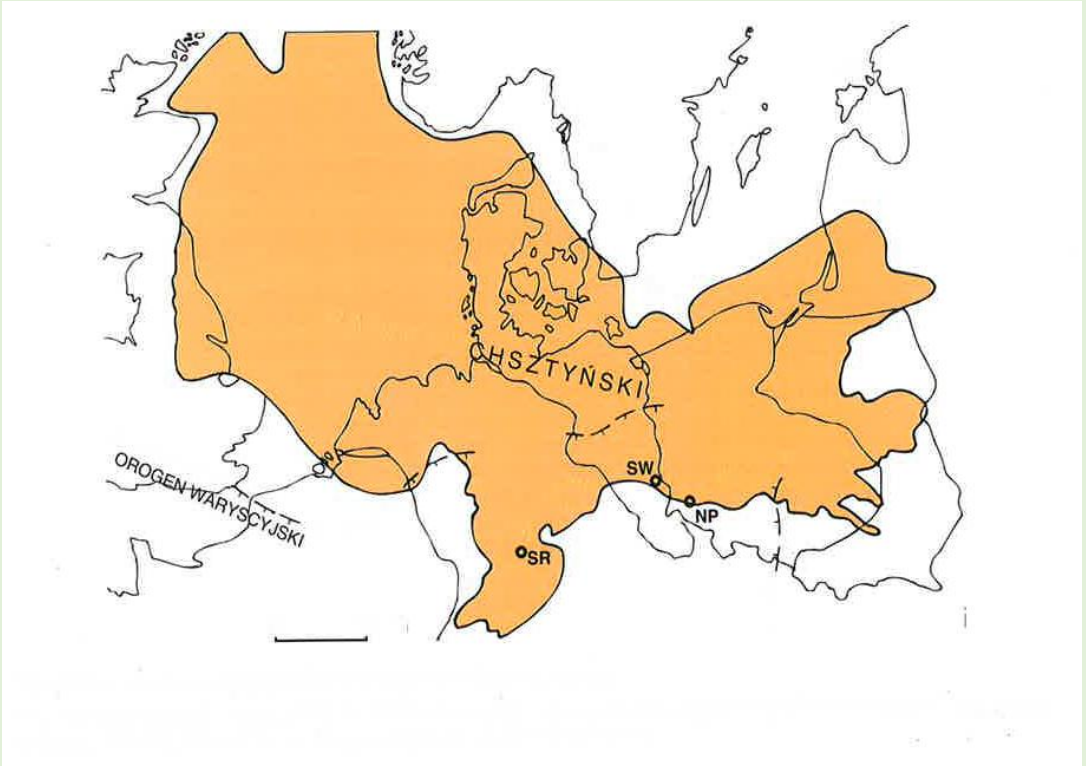
Paleogeography and stratygraphy

At the beginning of the Permian there was a desert here, with sand dunes several dozen meters high.

During the Permian period, about 258 million years ago, the desert was flooded by the sea.

Today we call the desert sediments Rotliegend and the sea sediments covering them Zechstein.

The Zechstein sedimentary basin of Europe – an area with preserved Zechstein sea sediments
(Piestrzyński et al., 2007)



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Stratigrafic position of copper-bearing series

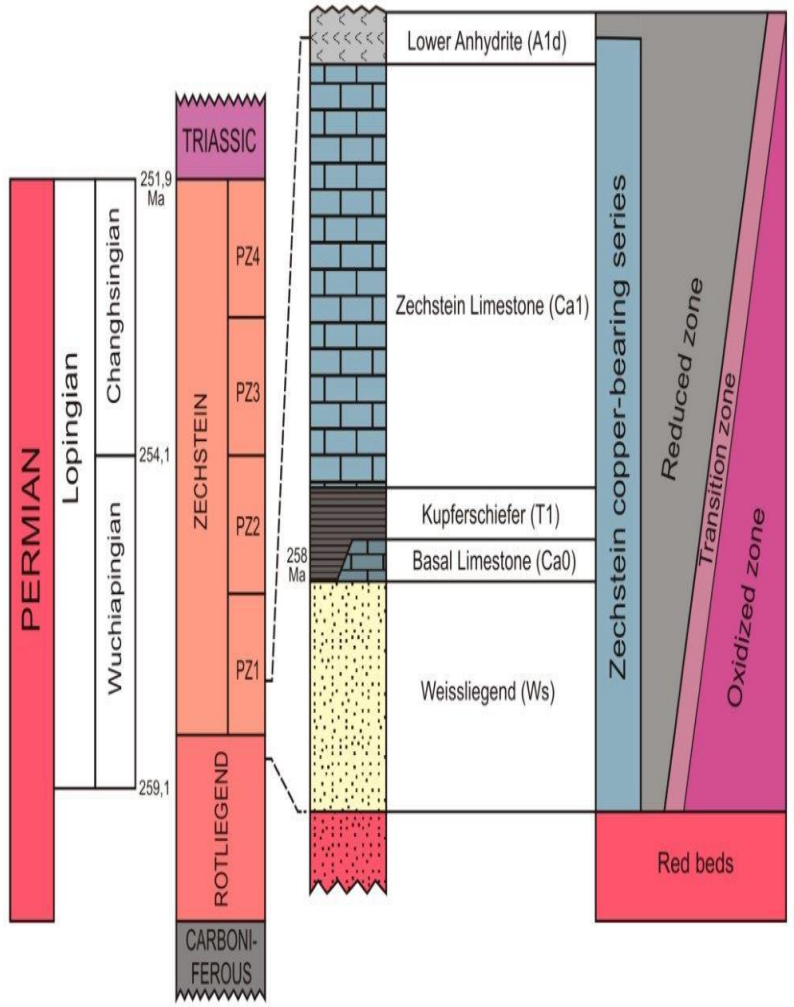
The copper deposits are located on the border between Rotliegend and Zechstein or not more than a few meters above it.

Lithology

Rotliegend- sandstones, mudstones, clay shales and conglomerates.

Zechstein - redeposited sandstones, clay shales, marls, limestones and dolomites.

Stratigraphic position
and lithology of copper-bearing series
(Oszczepalski at al., 2019)



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Characteristic features of copper-silver mineralization occurring in the Permian age deposits in SW Poland

Most often, copper-silver mineralization occurs as one layer above the oxidized zone.

Other forms of the deposit occur locally, e.g. double-decker or lenticular.

Cu-Ag mineralization lies at a depth of hundreds of meters to several thousand meters and is currently exploited almost exclusively at depths from 600 to1200 m.

The highest percentages of copper, silver and associated metals are found in shales.

SSC deposits thicknes is not more then 2-3 m in limestones and dolomites and up to more than 20 m in sandstones, in the white sandstone roof elevation areas, which are the remnants of desert dunes.

The average thickness of the deposits is 2-3 m, ranging from several dozen cm to over 20 m.

Under the copper mineralization, in the oxidized zone, Au-Pt-Pd mineralization occurs, however, it does not represent a great economic value.

Exploitation

SSC deposits in SW Poland are mined with the use of various variants of underground room-and-pillar method:

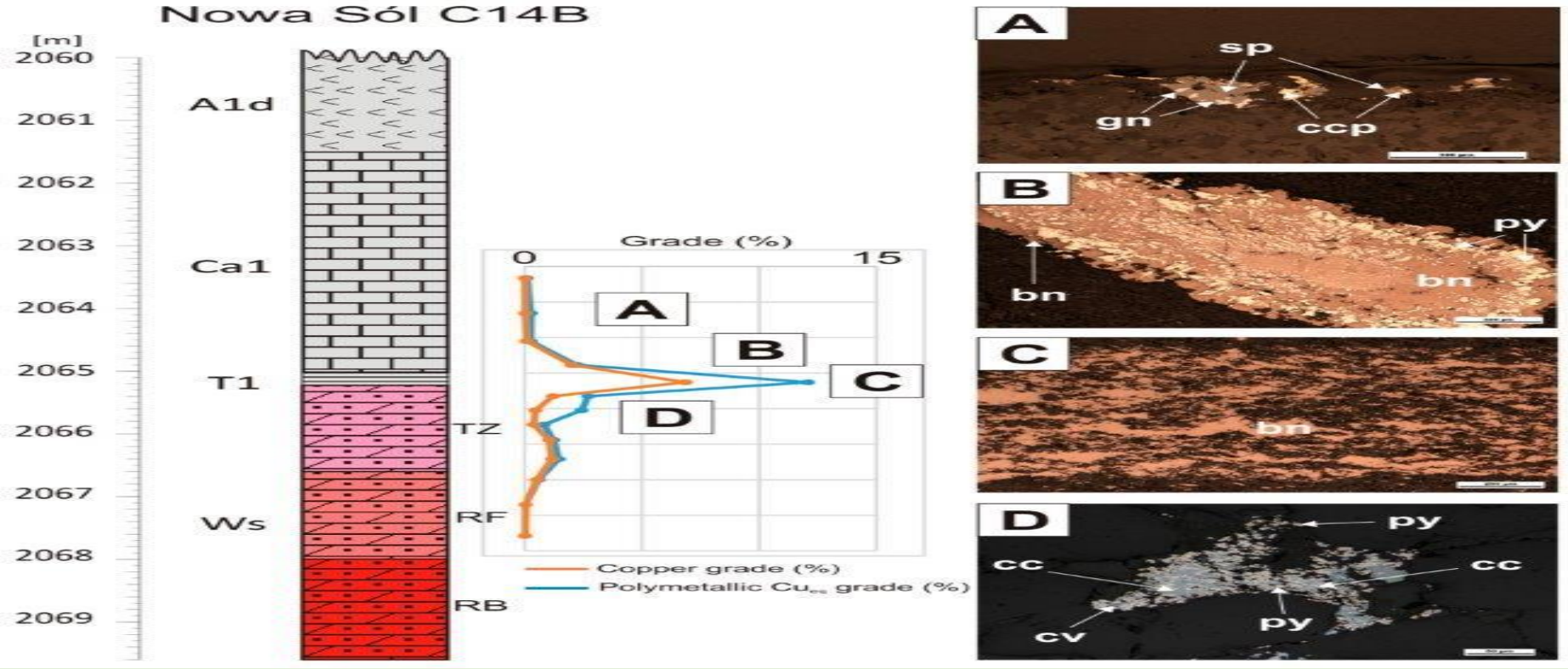
one- and two-stages,

single and multi-layer exploitation

using the following methods of roof control:

- flexible bending of the roof,
- intentional induced roof fall and
- hydraulic filling.

Typical Lower Zechstein profile from the borehole with results of chemical analysis and ore mineralogy. Orange line represents copper grade (Oszczepalski et al., 2019)



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Spatial distribution of SSC deposits and prospective areas in SW Poland

They are found in areas:

limited by the extent of Zechstein sediments,

within three tectonic units:

North Sudetic Synclinorium,

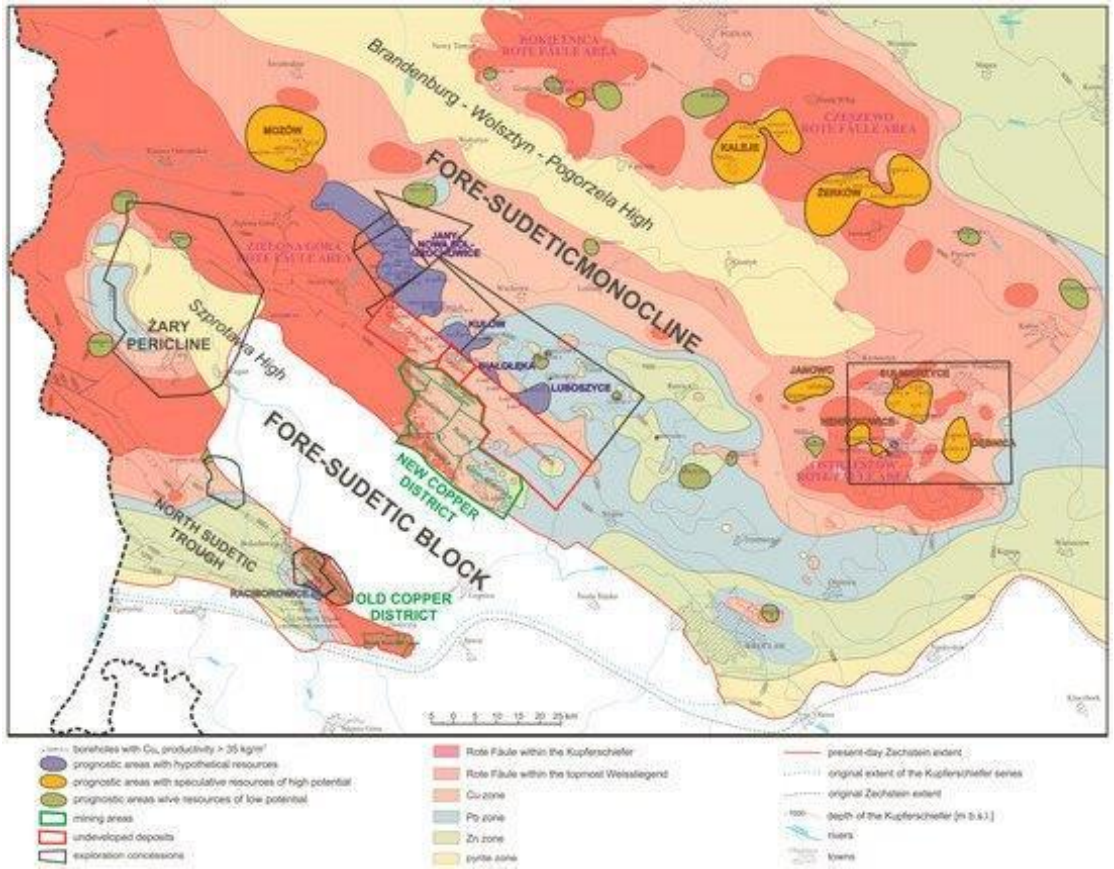
Żary Perycline and

Fore Sudetic Monocline,

near the contact between the oxidized and reducing Zechstein facies.

Distribution of SSC deposits and prospective areas of copper

(Oszczepalski et al., 2019 modified after Oszczepalski et al. 2016)



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Part 2

Methods
used in exploration SSC deposits
in SW Poland from the ground surface

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Study of archival materials and preparation of geological works designs

Before proceeding with exploration

archival material studies are conducted,

which include:

- familiarization with publications, documentation and other available unpublished documents,
- inventory and research of preserved drilling cores and rock samples,
- checking the compliance of information contained in publications and unpublished materials with the research of preserved cores and rock samples and
- drawing conclusions as to the legitimacy and methods of exploring or identifying a deposit in a given area.

designs are made for all planned works and individual openings.

Geophysical methods

Geophysical measurements taken from the ground surface:

- reflection seismic,
- gravimetric measurements,
- magnetic measurements,
- measurements of electric resistance of rocks,
- others.

Drilling and borehole geophysics

The hole is drilled in sections ranging from several dozen to several hundred meters.

Drilling without coreing (cheaper) and with coreing (giving more information) is used.

After drilling of the section, it is performed sequentially

- geophysical measurements in the borehole,
- running casing pipes,
- filling the space between the casing pipes and the rock with cement,
- breake for cement bond,
- drilling any cement remaining inside the casing and
- drilling the next section of the borehole.

After the last section has been drilled, the hole is filled with cement or a piezometer is made from it.

- A piezometer is a well that is used only to observe the water level and take water samples (water is not taken from it for utility purposes).

Core drilling - positioning the core barrel on the ramp

Borehole geophysics tasks

Control of hole parameters

- measurement of the diameter (Caliper Log) of the hole (among others to determine the amount of cement to fill the space between the casing pipes and the rock mass),
- measurement of the curvature (Inclination Log and Deviation Log) of the hole (large curvature may, make sinking casing pipes not possibile),
- acoustic measurement of the degree of cement filling (Cement Bond Log) the space outside the casing pipes (it is a control of the cementation effectiveness, which gives an assessment of the degree of isolation of various aquifers from each other, which ensures protection of drinking water against contamination and protection of the future mine against the penetration of waters from higher aquifers).

Borehole geophysics tasks - continued

Measurement of rock parameters in close proximity to the borehole

- measurement of natural gamma radiation of rocks,
- volumetric density measurement,
- porosity measurement,
- electrical resistance measurement, etc.

Measurement of the speed of seismic wave propagation in selected boreholes for the needs of surface measurements of seismic reflection.

In all wellbore geophysics measurements, a well probe is inserted and the measurements are made.

In the case of measuring the speed of propagation of seismic waves, additionally, at a distance of several dozen meters, a free-falling weight is set, which generates vibrations.

Geological supervision of drilling

Description of drill cores and cuttings.

Sampling the core for chemical analyzes

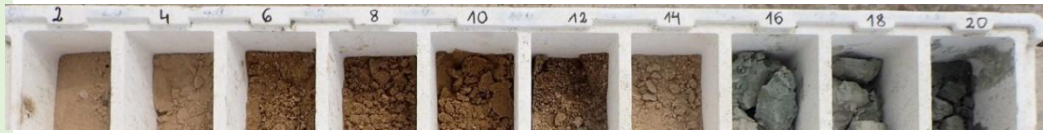
- sampling covers from a few to several meters of the core;
- the elementary sample is a quarter of the core, approx. 10 cm long,
- usually several dozen samples are taken from the hole,
- in the sample, several dozen elements and chemical compounds are determined by chemical analysis.

Reports are sent to the investor on a daily basis and data is collected as soon as possible prior to the completion of drilling.

Participation in making decisions regarding drilling technology

- determining the depth of completion of the drilling section,
- defining the procedure to be followed in the event of mud escape.

Box with samples of cuttings



Drill core in boxes

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Changes in exploration methodology (examples)

Changes in the methodology result from three main factors:

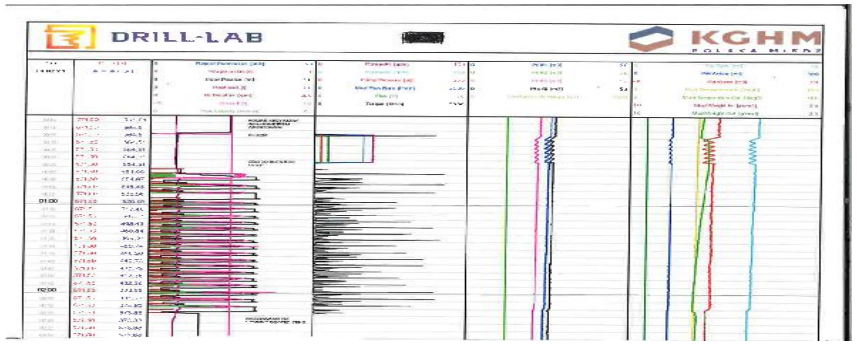
1 Scientific and technical progress

measurement of drilling parameters, especially drilling progress, is a valuable source of information about drilled rocks,

the introduction of portable x-ray analyzers for the initial determination of the interval that should be tested for metal content,

the expansion to several dozen elements and chemical compounds determined during laboratory analyzes increases the amount of geological data, only slightly increasing drilling costs.

Drilling parameters charts



Measurement of copper content in the core with an X-ray analyzer

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Changes in exploration methodology (examples) - continuation

2. Entering with exploration into new areas, where the deposits usually are in more difficult geological and mining conditions, this causes

an increase in the scope of research related to gas hazards, including

drill stem test - the sampler is lowered on the drill pipe string and two rubber packers are used to isolate the tested layer from the bottom and top. If the tested layer is at the bottom of the hole, only one packer is needed. Due to the isolation, the hydrostatic pressure of the drilling mud ceases to act on the tested layer. Under the influence of the pressure of hydrocarbons and water in the tested layer, mixture flows out of the drill string, the chemical composition of which is determined and the pressure at which it flows out is noted. On this basis, the amount of hydrocarbons that can flow out of the tested layer is inferred,

tests of the drill core for degassing - laboratory determination of the amount and chemical composition of the gas contained in the rock.

3. Legal changes

data and rock samples protection.

Container for the core sample for degassing

Part 3

Mining excavations, from which SSC deposits in SW Poland are explored

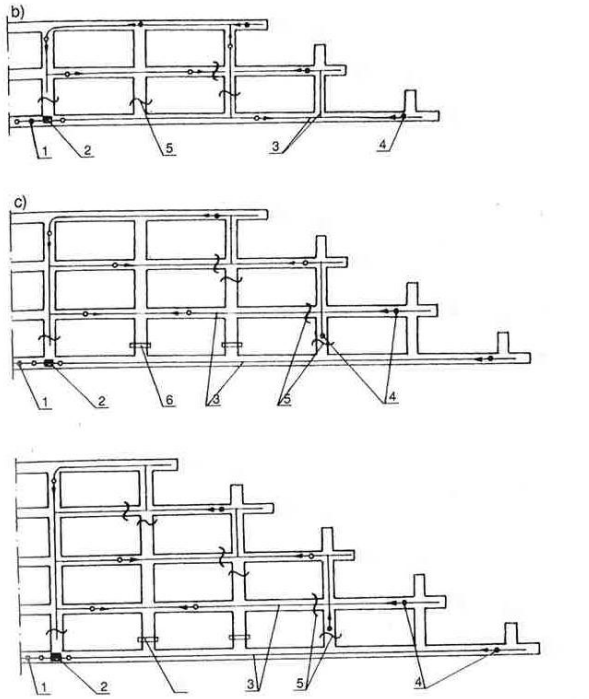
Spatial distribution of mining excavations exploring the deposit

Exavations, which explore the deposit, are made in the deposit.

Bundles of 3-5 parallel excavations. Distance beetwen them approx. 30 m.They are connected every 60 m.

In 2019, in the mines of KGHM Polska Miedź S.A. 61 km of excavations exploring the deposits were made in SW Poland.

Bundles of excavations exploring the deposit
(Piestrzyński et al., 1996)



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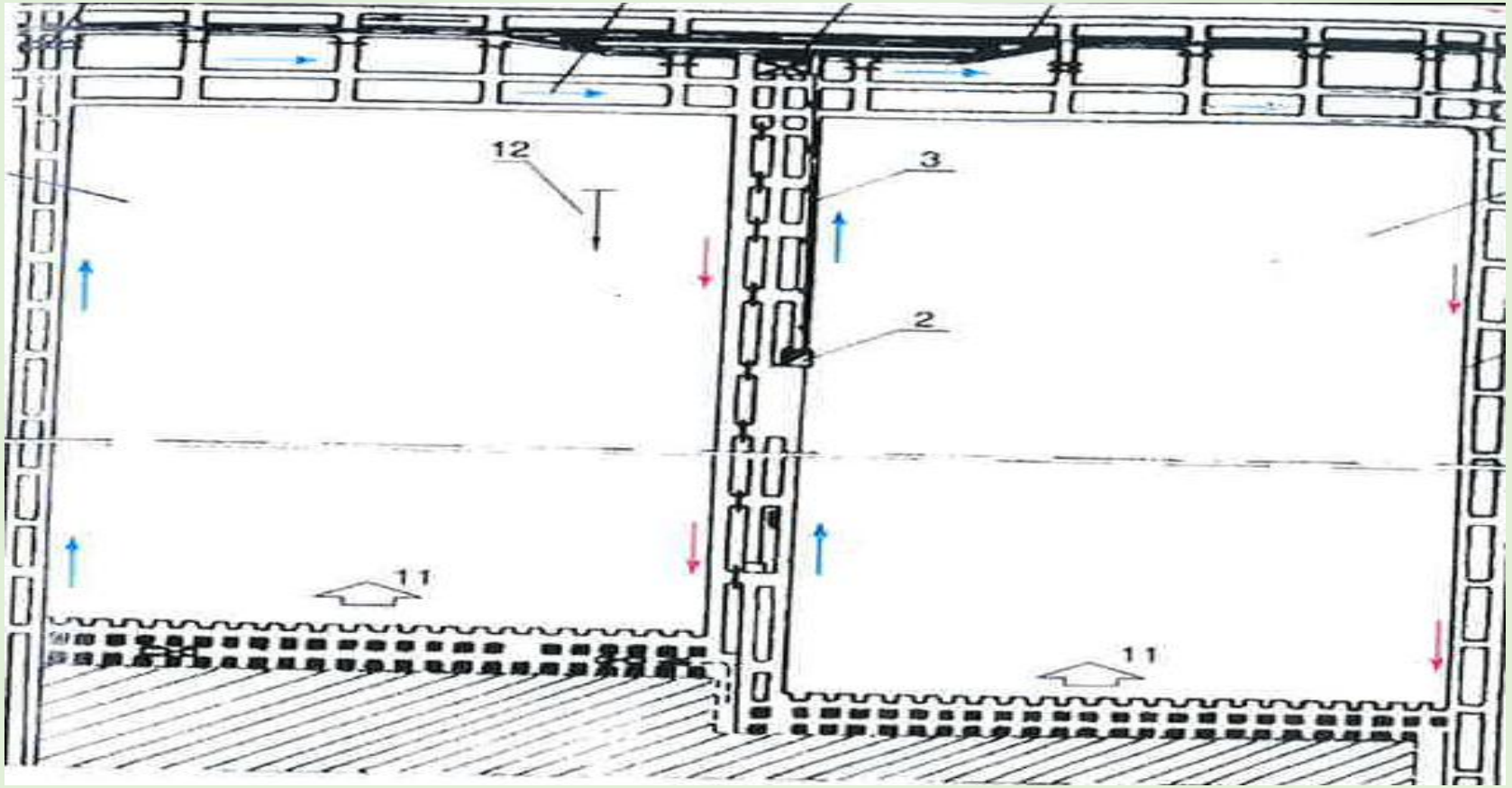
Contoured mining fields - at this stage it is possible to estimate the parameters of the deposit in the mining field with great accuracy (Piestrzyński et al., 1996)



Shape and dimensions of mining excavations

The cross-section of excavations are trapezoidal (wider at the top).

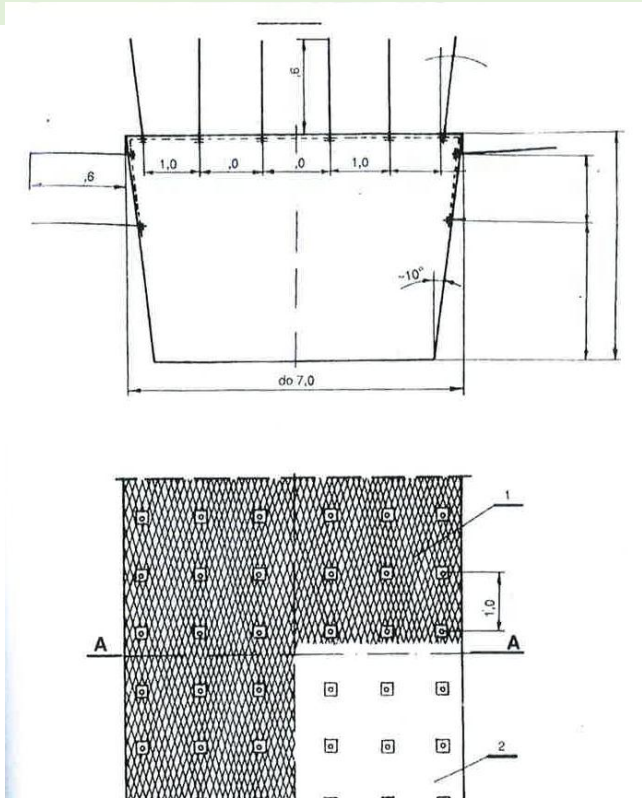
Height up to 4.5 m.

Width (measured at the roof) 5-7 m.

Support of mining excavations

The most commonly used is an anchor support.

In the case of weak rocks in the side walls and/or in the roof. Ancor support is supplemented with metal mesh and sprayed concrete - in this case, the deposit must be described and sampled before the complete support is made.



Anchor support supplemented with a metal mesh
(Piestrzyński et al., 1996)

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Part 4

Methods used for exploration SSC deposits in SW Poland from mining excavations

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Geological description of the deposit made from mining excavations

Geological description includes the term

- types of rocks in the roof, sides and floor of the excavation,
- thickness of layers and parameters of their spatial positions,
- tectonic disturbances,
- macroscopically visible ore mineralization,
- water outflows, manifestations of rock mass pressure and gas phenomena.

Sampling of rocks in mining excavations in order to determine the content of metals

Vertical furrows are made in the side walls at a distance not greater than 40 m.

The obtained rock material is divided into partial samples with a length of no more than 20 cm.

In areas where analysis shows that the mineralization may extend above or below the excavation, sampling may be supplemented by samples of core from drilling made form the excavation.

In the mines of KGHM Polska Miedź S.A. in SW Poland hundreds of thousands of samples are taken annually and their copper content is measured. In half of them, the content of silver is also measured.

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Drilling from mining excavations

2. Vertical drilling, the so-called Vet-hole explore the roof and bottom of the deposit (approx. 25 m above the head of the excavation and approx. 5 m below the floor of the excavation) are carried out in order to determine the properties of the roof and floor rocks, especially their tendency to rock bursts.

3. Gas drillings recognizing the deposit as well as the roof and floor rocks. They are made in the plane of the deposit and about 15 degrees up and 15 degrees down. All three holes are made in the direction of the axis of the excavation. Gas drillings purpose is to detect and neutralize gas accumulations.

Changes in the methodology of exploration from mining excavations (examples)

Changes in the methodology result from three main factors.

1. Scientific and technical progress

   the introduction of portable x-ray analyzers for the initial determination of the interval that should be tested is also important in order to quickly correct the position of the excavation according to the vertical extent of mineralization.

2. Entering with exploration into new areas, where are others conditions

   increasing the scope of research carried out in order to identify gas hazards (gas drillings).

3. Legal changes

   geological data and rock samples protection.

Part 5

Conclusions

Despite the decades of exploration of SSC deposits in the SW Poland, there is still a need to continue these activities.

Due to the generally greater depth of the explored ore bodies, these studies are more and more difficult and require the expenditure of more and more money.

Publications used in the presentation

c

Cierzniak M. i Niedbał M., 2018 – Methods of exploration of stratified deposits based of Lubin-Głogów deposit in Polanad

Presentation is on the Internet at

https://www.openyourmine/up-content/uploads/2020/06/WP2-SRATYFIELD-COPPER-DEPOSITS-MODEL-EXPLORATION.pdf

: Konstantynowicz E. i in., 1971 – Monografia przemysłu miedziowego w Polsce Wydawnictwa geologiczne. Warszawa

Oszczepalski S., Chmielewski A. 2015 – Zasoby przewidywalne surowców metalicznych Polski na mapie w skali 1:200 000 – miedź, srebro, złoto, platyna i pallad w utworach cechsztyńskiej serii miedzionośnej. Prz. Geol. 63: 534 – 539. (w języku polskim, pełnego tekstu w Internecie nie znaleziono)

Oszczepalski S., Speczik S., Zieliński K., Chmielewski A., 2019 – The Kupferschiefer Deposits and Prospects in SW Poland: Past, Present and Future

Especially worth recommending publication for participants of the OpenYourMine program. It contains the most up-to-date knowledge about SSC deposits and prospective areas in SW Poland . It includes information from large number of mining and prospective areas in Poland. It is available in English. The full text is on the Internet at

https://www.researchgate.net/publication/336133754_The_Kupferschiefer_Deposits_and_Prospects_in_SW_Poland_Past_Present_and_Future

Publications used in the presentation - continued

Oszczepalski, S.; Speczik, S.; Małecka, K.; Chmielewski, A. Prospective copper resources in Poland. Miner. Res. Manag. **2016**, 32, 5–30

Piestrzyński A. i in., 1996 - Monografia KGHM Polska Miedź SA , wydawca CBPM Cuprum na zlecenie KGHM Polska Miedź S.A.

In Polish, very extensive.

Piestrzyński Adam i in., 2007 - Monografia KGHM Polska Miedź S.A., wydawca KGHM Cuprum sp. z o.o. Centrum Badawczo-Rozwojowe na zlecenie KGHM Polska Miedź S.A.

In Polish, even more extensive than the monograph from 1996, but generally the scope of content these two publications are similar to each other.

The End

Thank you for your attention