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Massive Open Online Course (MOOC)

LECTURE 9 - MINING TECHNOLOGIES

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Photo Boliden

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Modern mining

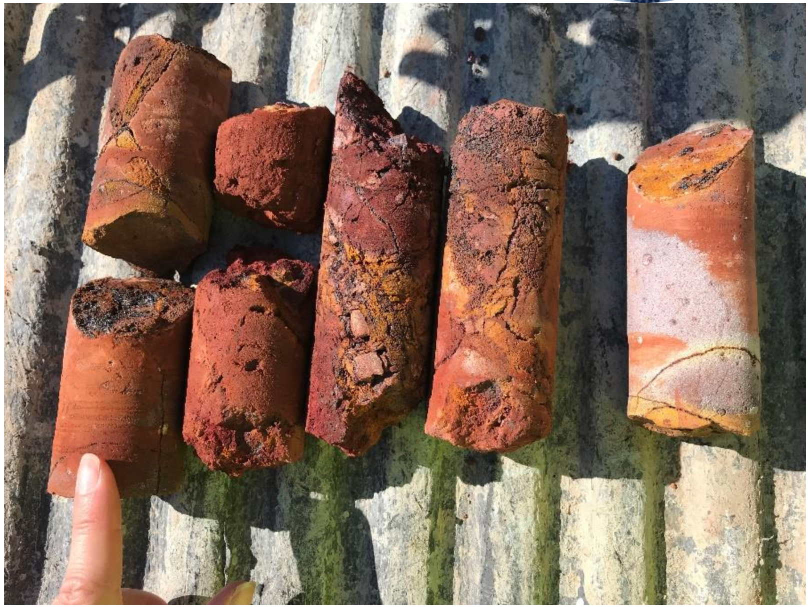
The process to establish a mine go through exploration to permitting to starting a mine.

The mine itself consist of:

- The extraction site/area at surface or depth
- The processing plant containing crushing/milling and processing of the ore for the recovery of metals
- The waste site

In, general, modern mining have at least three paths along which large improvements have been made in terms of environmental impact, health and safety and energy efficiency compared to say only the last 30-40 years.

Optimisation of mine
Decrease in emissions
Decrease footprint



Mineralized drill cores. Copper from Cyprus. Photo Ronald Arvidsson

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Economical viability in mining industry

Profitability is a fundamental business principle for any industry project. Viability depends on a complex balance of factors.

Key Economic Considerations if mioneral deposit is economically viable:

- **Ore Grade & Deposit Size:** The concentration and total amount of the valuable mineral directly impact potential revenue.
- **Commodity Prices:** World market prices for the final product can fluctuate. Rising prices can make lower-grade deposits viable and secure investment returns.
- **Upfront Investment:** Mining requires substantial initial investment in exploration, permitting process, technology, equipment, and infrastructure.
- **Operational Costs:** These include factors such as energy consumption, labour, maintenance and waste water treatment. Deeper or more complex underground mines usually have significantly higher operational costs. The deposit type, its geological setting and structure may directly affect operational costs.

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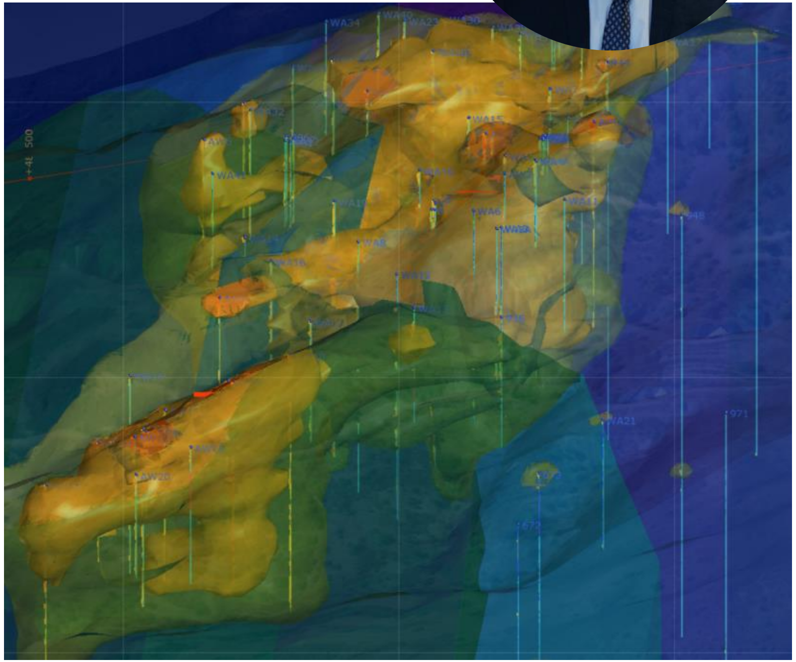
Exploration

The exploration process is often time consuming and often five to ten years or more. The main components are:

- Geologist makes prospecting on the surface and sample the rock (usually not large then a few kg/sample)
- Geochemical investigation through analysis of rock and soil samples
- Geophysical surveys
- Drilling and sampling rock at depth

From an environmental perspective it may be important to choose time of the year when important sensitive wildlife is not(less) impacted. Certain investigations are though necessary to be done when there is e.g., no snow cover (rock sampling) or temperatures are such that they cause no Hazard for the geologist.

The end product of exploration is a geological 3D ore-body model of the ore body with an accurate estimate of its resources in concentration and tonnage



Model of copper deposit, Apliki, Cyprus. Picture Ronald Arvidsson.

Exploration

Geophysical surveys can be done through:
Aerial/drone measurements
Ground measurements

A range of physical properties are being measured and modelled. Choice of parameters depends upon properties of the ore and surrounding rock. A wide range of methods exists to measure:

- Gravity
- Earth's magnetic field
- Induced electromagnetic fields
- Frequency dependent natural and induced magnetic fields
- Seismic measurements

Geophysical surveys leave no lasting footprint and are non-invasive.

Aerial geomagnetic geophysical survey – magnetic and VLF sensor in the tail. Gammaspectrometer in the hold.
Photo SGU

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Main concepts in mining

Mining is about excavating valuable raw materials from the Earth.

A mine can be either constructed as
- Open pit mine
- Underground mine

The extraction is usually done by
- Blasting out the valuables
- Transportation
- Crushing and milling – called **comminution**
- Processing – called **beneficiation**
- Remaining waste onto tailings and waste rock dumps

The valuable raw materials are then separated, liberated, from the rock through one or several methods below
- Gravity separation
- Flotation – i.e. chemical separation in a series of baths
- Leaching – chemical or biological separation through agents seaping through the rock which can be crushed and ginded

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Main concepts in mining

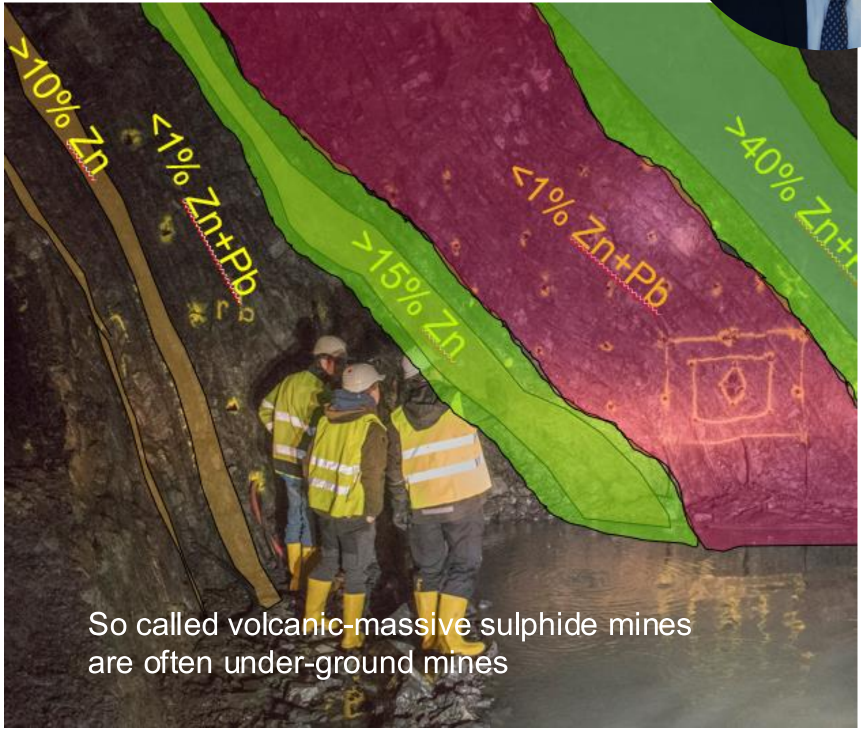
The type of deposit, its extent and depth governs the mine design.

Open Pit Mining:

- Involves excavating from the surface downwards, creating a large, open pit.
- Has a significantly larger surface footprint compared to underground mining.
- Typically used for large, near-surface ore deposits and bulk materials such as limestone.

Underground Mining:

- Involves accessing the ore deposit through tunnels and shafts, with most of the activity occurring below the surface.
- Has a much smaller surface footprint.
- As near-surface, easily extractable resources are depleted, there is an expected trajectory towards more underground mining to access deeper deposits



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Main costs in mining

Some Key factors determining the cost and economic viability of a mine

- **Commodity price** – the price of the mined raw material
- **Operational costs**
  - Extraction
  - Transportation
  - Sorting, crushing and milling
  - Processing: flotation, leaching, gravity, magnetic
  - Cost for storage of waste – tailings and waste rock sit
- **Investment costs** into the industrial site – mine, processing plant, waste storage (tailings, waste rock)
- **Remediation** of the waste sites (tailings), mine and its industrial site

Some key facts about mining costs

- Transportation costs about 20 EUR/100 km
- Remediation in N Sweden 10 EUR/tonne
- Flotation of copper 7 EU/tonne

This part of the costs equals to about .6% Cu. If processing plant nearby transportation costs improves a lot on potential economic viability. We have not mentioned extraction costs or crushing and milling and other costs.

Modern mining strive after recovering as many raw materials as possible. Improves the economic viability of the mine.

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The Future of Mining: Digitalization and Automation

The mining industry is in the midst of a digital revolution and transformation process.

Smart Mining Technologies:

- Operations are monitored and steered from a operational room that can be either underground or on the surface. Benefits are a much safer working environment and minimizing time for transport of personnel.
- Internet of Things (IoT): A network of sensors on equipment provides real-time data for a complete operational overview. Uses modern 5G technology.
- Drones & Robotics: Used for exploration, surveillance, risk monitoring and increasing efficiency and also for performing tasks in hazardous areas.

Foot print

The foot print in modern mines is decreasing. Some measures are:

- To move large parts of the remaining waste to fill in and secure the underground caverns decreasing amount of waste left on the surface
- Underground access beneath the surface of e.g. protected nature
    - Mittersill to avoid impact on protected nature
    - Rävliden, Sweden, underground access from nearby mine to avoid surface impact. Reuse existing infrastructure in nearby mine.
    - Sakatti to avoid impact on protected nature
- If nearby processing plant exist and transport not too costly, leaving room for profit. The ore may be transported for comminution and/or beneficiation from the mine to the plant. Examples - Stekkenjokk Sweden (planning), Boliden area

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Mining waste - backfilling

Backfilling is the process of refilling voids left by underground mining.

Key Benefits of Backfilling:

- Reduces Surface Waste: Uses tailings or waste rock as the fill material, which significantly minimizes the need for surface storage area and reduces the mine's footprint.
- Improves Geotechnical Stability: Provides ground support, prevents surface subsidence above the mine, and allows for safer and more complete extraction of the ore body.
- Promotes a Circular Economy: Reuses a waste product for a valuable engineering purpose.

Limitations:

- Orebody geometry, grade and type, selected beneficiation process (refining and processing the mined ore), as well as the choice of mine design layout may limit technical possibilities to use backfilling in the mining operation.
- Economic viability may also be affected by available surface area, specific conditions in the mine's permitting and the cost for backfilling vs. surface storage of tailings.
- Significant volume increase in crushed and milled rock, compared to solid rock. Therefore, not all remaining waste/tailings material will fit into the voids of the mine.

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Mining waste – tailings safety

Managing tailings (the waste material from ore processing) is one of mining's biggest environmental challenges.

Tailings Dam Safety:

- Profound geotechnical knowledge of dam construction, subsoil characteristics/layering, as well as technical understanding of the tailings material and its behaviour is essential.
- *Autonomous, real-time monitoring* is a key innovation for preventing dam failures.
- Technologies used include seismic sensors, geotechnical sensors, and satellite-based radar (DInSAR) to detect ground movement at a millimetre scale. Preventive measure can be done in order to avoid any break in the dam structure.

Reducing Waste Generation:

- Improved technologies for ore sorting separating valuable ore from country rock before processing may significantly reduce the volume in tailings. It however increases amount of waste rock.
- Use of mined country rock in infrastructure & construction in- and outside a mine reduce need for waste rock piles and lessen the surface footprint.
- Use of mining waste, both waste rock and tailings material in backfilling.

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Health and safety

- Health and safety well regulated within the legislation
- Modern mines have to keep high standards of health and safety for the miners
- Under ground mines often machinery operated from terminals in safe location
- Air must be ventilated to keep gases and dust within stipulated safe limits for humans. E.g., quartz dust, other toxic dust, gases like radon,
- Conditions for mining have to be such that miners do not get silicosis or other health related illnesses due to toxic substances or gases
- The drifts and shaft in the mine are properly secured and controlled
- A well kept mine do not have any higher caualties then any other well kept industry
- The extraction technology including securing and filling the voids left from the mining to avoid risk of mine collapse

Electrification of vehicles and equipment underground has:

- Reduced combustion gase
- Improved air underground significantly
- Lower noise and vibrations

Photo Boliden: hybrid truck

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Remediation

Remediation is the process through which the mining area and waste is secured from toxic release to the surrounding area. It also includes long-term monitoring in order to control the continued safety of the site.

The end product should be new land use for the mining area. This can be e.g.:

- grazing land
- forest
- recreational area
- Habitation

The remediation often includes landscaping the old mine area to fit into the surroundings.
Remediation is mandatory from legislative view and is connected to the environmental directive. Remediation starts in the mine plan when constructing the mine.

Tailings that have been remediated. New land use, woods and husbandry. Photo Ronald Arvidsson

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Quiz

Name four factors that influence the economic viability of a mining project.

Mention two improvements due electrification of vehicles underground.

What is the purpose of using autonomus sensors & satellite monitoring on tailings dams?

What are the three main stages of the mine life cycle?

Name two environmental benefits of using electric vehicles (EVs) in mining.

In mning - what is backfilling?

What is the purpose of remediation?

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Thank you

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