MINING GEOLOGY

Part 1 - MINERAL EXPLORATION

MINING TERMINOLOGY

There are many terms and expressions unique to mining that characterize the field and identify the user of such terms as a ‘‘mining person.’’ The student of mining is thus advised to become familiar with all the terms used in mining, particularly those that are peculiar to either mines or minerals. Most of the mining terminology is introduced in the sections of this book where they are most applicable. Some general terms are best defined at the outset; these are outlined here:

Mining*:* the activity,occupation,and industry concerned with the extraction of minerals

Mining engineering*:* the practice of applying engineering principles to the development,planning, operation,closure, and reclamation of mines.

Adit: a mining passageway driven horizontally into a mountainside for the purpose of providing access to a mineral deposit.

Backfilling: the process whereby waste material is used to fill the void created by mining an orebody.

Ball mill: a steel cylinder loaded with steel balls into which crushed ore is fed. The ball mill is rotated, causing the balls to cascade and grind the ore.

Collar: the term applied to the timbering or concrete around the mouth of a shaft and the start of a drill hole.

Cut-and-fill: a method of underground mining in which ore is removed in slices or lifts, and then the excavation is filled with rock or other waste material (backfill) before the subsequent slice is mined.

Waste: the material associated with an ore deposit that must be mined to get at the ore and must then be discarded. Gangue is a particular type of waste.
EXTRACTION RATIO (mine recovery)

The proportion of the total in situ reserve that is actually extracted during stoping.

Development: to create access to an ore body and building of mine plant and equipments.

Development: underground work carried out for the purpose of opening up a mineral deposit. Includes shaft sinking, crosscutting, drifting and raising.

Drift: a horizontal tunnel driven alongside an orebody, from either an adit or shaft, to gain access to the ore.

Long-hole open stope: a method of mining involving the drilling of holes up to 90 feet long into an orebody and then blasting a slice of rock that falls into an open space. The broken rock is extracted and the resulting open chamber is not filled with supporting material.

Open pit: a mine that is entirely on the surface.

Shaft: a vertical passageway to an underground mine for moving personnel, equipment, supplies and material including ore and waste rock.

Ramp: an inclined underground tunnel that provides access for exploration or a connection between mining levels.

Stope: an area in an underground mine where ore is mined.

Stripping ratio: the ratio of the number of tons of waste material removed to the number of tons of ore removed, used in connection with open pit mining.

WASTE ROCK (dilution)

Valueless (but not necessarily useless) rock that must be removed in mining.
Autoclave system: an oxidation treatment in which high temperatures and pressures are applied to convert refractory gold-bearing sulfide materials into amenable oxide ore.

Mineral processing terms

By-product: a secondary metal or mineral product recovered in the milling process.

Carbon-in-leach: a recovery process in which a slurry of gold ore, carbon granules and cyanide are mixed together. The cyanide dissolves the gold content and the gold is adsorbed on the carbon. The carbon is subsequently separated from the slurry for further gold removal.

Carbon-in-pulp: similar to carbon-in-leach process, but initially the slurry is subjected to cyanide leaching in separate tanks followed by carbon-in-pulp. Carbonin-pulp is a sequential process whereas carbon-in-leach is a simultaneous process.

Contained ounces: represents ounces (generally referring to gold) in the ground without the reduction of ounces not recovered by the applicable metallurgical process.

Concentrate: a powdery product containing the valuable ore mineral from which most of the waste material has been eliminated.

Cyanidation: a method of extracting gold or silver by dissolving it in a weak solution of sodium cyanide.

Doré: unrefined gold and silver bullion bars usually consisting of approximately 90 percent precious metals which will be further refined to almost pure metal.

Flotation: a process by which some mineral particles are induced to become attached to bubbles and float, and other particles to sink, so that the valuable minerals are concentrated and separated from the worthless gangue or waste.

Gangue: Non-valuable materials associated with the ore minerals.

Heap leaching: a process whereby certain metals are extracted by "heaping" broken ore on sloping impermeable pads and repeatedly spraying the heaps with a solution that dissolves the valuable metal(s). The metal-laden solution is then collected for metal recovery.

Mill head grade: metal content of mined ore going into a mill for processing. Usually lower than reserve grade because of dilution by non-ore grade materials.

Recovered grade: actual metal content of ore determined after processing.

Reserve grade: estimated metal content of an orebody, based on reserve calculations.

Industrial minerals: a group of minerals that are important sources of raw materials for the chemical, metallurgical, construction, agricultural, and related industries.

Mill: a plant where ore is ground fine and the valuable minerals are recovered by physical and chemical processes.

Mineral deposit: any unusual mineral concentration, regardless of whether the valuable components can be extracted at a profit (see Ore and Orebody).

Ore: rock from which one or more valuable metallic or non-metallic minerals can be mined and processed at a profit.

Ore body: a sufficiently large amount of ore that can be mined economically.

Oxide ore: mineralized rock in which some of the original minerals have been oxidized. Oxidation tends to make the ore more porous which facilitates flow of solutions into the rock. This effect is particularly important for oxidized gold ore as it permits more complete permeation of cyanide solutions so that minute particles of gold in the interior of the mineral grains can be readily dissolved.

Reclamation: the process by which lands disturbed as a result of mining activity are reclaimed back to a beneficial land use. Reclamation activity includes the removal of buildings, equipment, machinery and other physical remnants of mining, closure of tailings impoundments, leach pads and other mine features, and contouring, covering and revegetation of waste rock piles and other disturbed areas.

Recovery rate: a term used in process metallurgy to indicate the proportion of valuable material obtained in the processing of an ore. It is generally stated as a percentage of the material recovered compared to the total material present.

Refractory material: gold-bearing rock in which the gold is not amenable to recovery by conventional cyanide methods without pre-treatment. The refractory nature can be either silica or sulfide encapsulation of the gold or the presence of naturally occurring carbons that reduce gold recovery.

Reserves: that part of a mineral deposit which could be economically and legally extracted or produced at the time of the reserve determination. Reserves are customarily stated in terms of ore when dealing with metallic minerals. There are two categories of reserves:

Proven ore: material for which tonnage and grade are computed from dimensions revealed in outcrops, trenches, underground workings or drill holes; grade is computed from the results of adequate sampling; and the sites for inspection, sampling and measurement are so spaced and the geological character so well-defined that size, shape and mineral content are established.

Probable ore: material for which tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance based on geological evidence; and for which the sites available for inspection, measurement and sampling are too widely or otherwise inappropriately spaced to outline the material completely or to establish its grade throughout.

Roasting: the treatment of ore by heat and air, or oxygen-enriched air, in order to remove sulfur, carbon, antimony and arsenic.

Semi-autogenous grinding (SAG): a method of grinding rock into fine powder in which the grinding media consist of larger chunks of rock and steel balls.

Smelting: a metallurgical process in which metal is separated from impurities by a process that includes fusion.

Solvent extraction (SXEW): a type of heap leaching and subsequent processing used for secondary copper ores whereby the oxidized copper minerals are taken into solution. The copper-bearing solution is processed to recover metallic copper from the solution electrolytically.

Sulfide ore: refers to any type of ore in which the ore minerals are in the form of metallic sulfides. Commonly used for a sub-group of refractory gold ore mineralized rock in which much of the gold is encapsulated in sulfides and is not readily amenable to dissolution by cyanide solutions associated with sulfide minerals (primarily pyrite) that have not been oxidized. Some sulfide ore may require autoclaving or roasting prior to milling.

Tailings: the material that remains after all valuable minerals have been removed from the ore during milling.

Troy ounce: the common measure of the precious metals. A troy ounce of a fineness of 999.9 parts per 1,000 parts, equal to 31.1034 grams.

Water management: process whereby the groundwater table in the mining area is lowered by pumping water from wells, and the water is conveyed and used or recharged to the groundwater system through infiltration, reinjection or irrigation return.

Reclamation: to make land where a mine had been suitable for future use

SPATIAL DATA

Spatial data is composed of data points with specific X, Y and Z coordinates and of corresponding data values representing any (geological) feature: grade, density, rocktype, etc.

TONNAGE FACTORS (bulk density)

Specific gravity is one of the standard petrophysical measurements for drill core samples. However, for large rock masses, specific gravity gives too high values. In rock there is void space, cavities, open fractures, porosity, etc., that reduces its overall density. Therefore, bulk density or tonnage factor should be estimated and used in resource/reserve calculations. Bulk density or tonnage factor is defined as 'mass per unit volume'. Geophysicists may make this revision automatically.

MINING GEOLOGY

PART 1 - MINERAL EXPLORATION

1. OBJECTIVES

The principal objective of mineral exploration is to find economic mineral deposits that will appreciably increase the value of a mining company's stock to the shareholders on a continuing basis, or to yield a profit to the explorer. For an established mining company this may entail discovery or acquisition of new ore reserves and mineral resources to prolong or increase production or life of the company, to create new assets and profit centers by product and/or geographic diversification. Or, in the case of individuals or exploration companies, an objective may be to seek a deposit for sale to, or joint venture with, a major operating company, or to serve as a basis for stock issue and formation of a new company. On occasion manufacturing companies will seek sources of critical metals to insure a supply. Each organization involved in exploration must define its own objectives in terms of mineral commodities, geographic locations, acceptable size, life, profitability, and acceptable risk. The exploration geologist must be aware of these limits.

Mineral prospecting

In the search for mineral deposits it is impossible to examine in details every square km of the area or country by, for example, drilling. This would be too expensive, time-consuming and in most cases pointless. An area where required mineral resources can be expected to occur is therefore delimited using prospecting criteria, that is , geological features which directly or indirectly suggest the presence of a given deposit.

Recognition (prospecting criterion)

Recognition of the environment and existence of potentially economic mineral deposits may be based upon a variety of geological criteria:

- stratigraphic (age) criteria (important in the search for sedimentary deposits e.g. coal , oil & gas, u, Fe, placer deposits etc.). Age of mineralization - e.g. banded iron formation deposits are characteristic of Precambrian age rocks.

- lithological criteria (different rock formations are characterized by deposits of definite lithollgical composition). Association with specific types of igneous rocks -- e.g., copper with quartz-monzonite porphyry, diamonds with kimberlite pipes, tin with granites, etc. . Host rock association -- e.g. lead and zinc with carbonate rocks.

- structural criteria. Structural controls -- e.g. laterite deposits associated with unconformities, replacement deposits associated with crests of anticlines.

- magmatogenic criteria (basic magma, granite magma and allkaline magma)

- metamorphic criteria (metamorphic facies are criterion for metamorphic deposits)

- geochemical criteria (the behavior of elements in the earth's crust is governed by certain laws, some are typical of basic rocks and others of acid igneous rocks sediment . Some elements never occur together in the same ore province(Cu and Sn), on the contrary, the presence of other).

- geomorphological criteria (mainly for placer deposits, direct criteria concerns the surface feature of the deposit, which can be either positive or negative, indirect criteria such as tectonic steps, hogbacks, cuestas, reveal the tectonic structure of the area.

- Paleoclimatic criteria (particularly important in prospecting for deposits related to weathering crust)

- Weathering effects -- e.g. oxidation of pyrite leaves a residue of iron oxide gossan marking possible underlying deposits.

- Wallrock alteration -- e.g. a concentric pattern of feldspathization, sericitization and propylitization around porphyry copper deposits, and dolomitization around lead-zinc replacement deposits.

- Gangue mineral association -- e.g. gold associated with quartz-ankerite veins.

- Trace metal association -- e.g. gold associated with arsenic and mercury in trace amounts.

- Ore and gangue mineral in fresh or oxidized states in outcrop of derived sediments may give surface evidence of underlying or adjacent deposits. - products of alteration zones from residual deposits like gossan

- the presence of pathfinders

- the presence of sulphide minerals in outcrops

- identification of suitable structures favourable for minerallization: major shear zone and contacts between various lithological units, volcano-sedimentary units, conglomerates

- presence of anomalies associated to structures and lithologies

- presence of electrical anomalies (the presence of conductive bodies)

Methods of mineral prospecting

- geological

- geochemical

- geophysical

- detailed follow–up

Geological prospecting include:

- studying documentation (archives , geological and topographical maps , aerial photo interpretation, bibliography and other information)
- choosing or selecting of an area
- definition of prospecting criteria
- inspecting of mining field (eg. Quarry) which have been abandoned , or even of fields still under operation
- even from scratch based on reports of minerals
- geological mapping
- from satellite images
- aerial photographs
- topo map
- field checking aided by ground investigation (gossan, rock alteration, sampling out crops etc.)

- Geochemical Methods

Geochemical methods involve the measurement of the chemistry of the rock, soil, stream sediments or plants to determine abnormal chemical patterns which may point to areas of mineralisation.

When a mineral deposit forms, the concentration of the ore "metals" and a number of other elements in the surrounding rocks is usually higher than normal. These patterns are known as primary chemical halos. When a mineral deposit is exposed to surface processes, such as weathering and erosion, these elements become further distributed in the soil, groundwater, stream sediments or plants and this pattern is called a secondary chemical halo. Secondary halos aid in the search for deposits as they normally cover a greater area and therefore the chance of a chemical survey selecting a sample from these areas is greater than from a primary halo area.

Exploration geochemistry, or geochemical prospecting, includes any method of mineral exploration based on a systematic measurement of one or more chemical, or chemically influenced, properties of naturally occurring material. The property measured is most commonly the trace concentration of some chemical element or group of elements. It may also include molecular and isotopic compositions and bacterial counts. The naturally occurring material may be rock, soil, stream sediment, glacial sediment, surface water, ground water, vegetation, micro-organisms, animal tissue, particulates, or gases including air.

Detailed follow up

- detailed work of geochemical, geophysical, geological (mapping, pitting, trenching) in selected promising area at a closer grid
- deep pits
- drilling
- mining works, underground workings (adit, cross-cuts, shaft , winze)

Stages of mineral prospecting

1. Strategically

Prospecting and exploration strategies vary widely depending upon the mineral commodity sought, the geologic and climatic environment, political and social restrictions, and the explorer's experience and available resources.

Possible strategies for the acquisition of mineral deposits: (1) acquire a producing mine, (2) acquire developed reserves, (3) develop a known deposit, (4) explore known deposits, and (5) explore for new deposits - (a) near known deposits, (b) in a mining district, (c) in a mineral belt, or (d) in a favorable virgin area.

Acquisition of land or ownership position may be by: staking claims , lease/option, joint venture, royalty or purchase, and will be determined by land ownership, local customs, and the level of confidence in economic feasibility.

Stages (phases) of mineral prospecting – exploration

1. *Reconnaissance (regional or general prospecting)*

RECONNAISSANCE (identification of mineralized areas or zones)

The process of narrowing down areas of enhanced mineral potential on a regional scale based primarily on airborne and indirect methods, preliminary field inspection as well as geological inference and extrapolation. The objective is to identify mineralized areas for further investigation towards prospect identification.

Purpose (aim)

- to determine prospecting criteria (such as lithological, structural, magmatic and others) and indications of mineralization
- to study superficial deposits from river , valleys, terraces, hill sides and residual deposits.

Methods

- geological mapping at a scale of 1: 200,000 to 1: 25,000
- interpretation of aerial photographs
- prospecting traverses
- geochemical survey (from stream, soil etc)
- geophysical (airborne geophysics)
- geological (pitting, trenching, test bore hole)
- sampling
- sampling space 500-1000 m

Results (outcome)

- determine the principal rock types and rock variability
- reveal major features of geological structures which may locate mineral deposits
- allow the classification of metallogenic districts

2. Prospection (prospecting)

PROSPECTION (target identification)

It is the systematic process of searching for an unknown deposit based on geologic inference and/or postulation of extensions of known deposits, by outcrop identification and indirect methods. The objective is the discovery of a prospect that will be the target for further exploration.

Most exploration programs focus progressively on areas of decreasing size, using methods increasing in cost per unit area, with declining risk of failure.

Purpose:

- to determine more details on rock characteristics and eventual mineral occurrences - to outline promising areas within the favorable geological structures revealed in the course of reconnaissance geological mapping

Methods

- geological (deep pits, trenching, drilling)
- geochemical (study of primary and secondary halo)
- geophysical (magnetic, resistivity, logging)

3. General exploration

General exploration (preliminary target investigation, screening)

It involves the initial delineation of an identified target mostly by surface mapping, loose-grid sampling (drilling), and limited interpolation based on indirect methods of investigation, to establish general geological features and to provide an initial estimate of size, shape and grade. Results are adequate for deciding whether detailed exploration is warranted.

Methods:

- Large scale geological mapping (1: 10,000 to 2000) depending upon the complexity and the direct interest of the area under study
- Intensive ground work comprising mapping, trenching, pitting, sampling, drilling

Outcome

- select target areas for the next phase detailed exploration)
- defining boundaries of ore fields and describing all the appearing characteristics of the existing and cropping out mineral deposits.

4. Detailed exploration (inventory drilling)

DETAILED EXPLORATION - This includes the three dimensional delineation and sampling of a known target from outcrops, trenches, a systematic set of boreholes, from shafts and tunnels, including bulk sampling (pilot mining) for processing tests (pilot tests). The sampling grid is spaced so closely that size, shape, grade and other relevant characteristics of the target are established with a high degree of accuracy and in sufficient detail for mine planning.

Methods

- Detail mapping on 1:200 or 1:1000 scale,

5. Exploratory underground work,

- drilling,
- Geophysical and technological sampling Purpose:
- To ascertain detail geological structure,
- To explore mineral deposits of irregular shape,
- Up grading of reserve categories,
- For testing and selecting exploitation methods,
- enable to inspect directly and study thoroughly the exposed rocks,
- Measure precise thickness, dip, strike of rocks and ores,
- To collect sufficient amount of representative samples for estimation of the deposit and to compare results from bore holes and other workings.

Outcome:

- Details of geological structures of the individual ore bodies (shape, dimension, position etc.), mode of occurrences, specific features of the host rock and the mineralised zones can be established,

- As a result of detailed mapping (1:1000 to 1:200) and sketch map (1:25 to 1:10). Geotechnical and hydrogeological conditions of the deposit are studied into detail ensuring the designing of mine planning,
- Bulk sampling from underground are taken to study technology and to compare results from bore holes and other workings.   Exploration during production (exploitation)

Objectives:

- to review the reserves of the deposit along with its exploration,
- to explore flanks and deep horizon of the deposit,
- in solving problems regarding dressing and treatment of the raw material

6. Surface and underground testing

Trenching, drilling and sampling program, and/or underground sampling by shafts, drifts and crosscuts, is essential. It is essential in the evaluation of a mineral deposit to have, as accurately as possible, a model of the mineralized zone geometry -- shape, size, quality, variability, and limits. Physical, chemical and geological characteristics may vary greatly within a single deposit and from deposit to deposit. Critical data can be collected in a variety of ways, including drilling, surface and/or underground mapping, geophysical or geochemical surveys, or studies of rock mechanics properties, mineralogical types and relations.

- testing: shallow pits, deep pits
- drilling: shallow bore holes, exploratory bore holes, deep bore holes
- Underground work: adit, cross-cuts, drifts, winze, shaft (inclined and vertical)

a. Pitting

- Shallow pits 5-10 m   Purpose:
- to check the presence of minerals in weathered and fresh material,
- for mapping purpose to expose fresh rock,
- to substitute trench where there exist thick overburden, - to explore placer deposits.

Deep pits 20-25 m

- normally done during detailed prospecting work,
- to check surface work (pits, trenches, geochemical survey and drilling,
- to take technological samples,
- pit diameter is 1 m2 for convenience

Underground geological data are costly to obtain but critical for proper evaluation and mining.

b. Trenching: - generally using a backhoe or bulldozer, enables shallow testing and sampling (bulk sampling or cut-channel samples) on a continuous basis across the mineralized zone. Most areas now require back-filling of the trenches, once the sample is taken.

Purpose:

- to find out the various surface parameters of the mineralized zones: length, width, thickness, structure and grade,
- the actual presence of mineralization can be proved on the surface from data collected by pitting and trenching,
- the data obtained from guide line in subsurface exploration, example, where to locate bore holes,
- Relatively cheap and data obtained are quick to estimate the surface configuration.

Methods

- normally done across the direction of mineralization,
- sampling is done from the bed rock by channeling normally every one meter,
- sampling also done from the wall by channeling ,
- the volume and number of trenches depend on :ore body morphology, dimension and degree of exposure, - data’s are used in reserve calculation

c. Drilling

Purpose:

- to explore ore bodies to a depth,
- to study internal structure of the ore bodies and rocks,
- to study the continuity of mineralization,
- to determine the thickness of the ore bodies ,
- data's are used in reserve calculation,
- the overall amount of drilling work and position of bore holes depend upon: geometry, type and extent of deposits
  Sampling the subsurface may involve one or more types of drilling, determined by the nature of the material to be sampled, rock conditions, and the objective of the sampling. Present exploration and development programs utilize diamond core drilling or rotary percussion drilling with reversed circulation (RC).

i. Rotary percussion
ii. Diamond core drilling
iii. Logging

e. Underground working

Objectives:

- ascertaining detailed geological structure of the area under study
- exploring and sampling of mineral deposits revealing their dimension and shape , mode of occurrence, composition of rocks and ascertaining mining technology and hydrological conditions,
- enabling to inspect directly and study thoroughly the exposed rocks, measure precise thickness, dip and strike of rocks and ore,
- they are useful to collect sufficient amount of representative sample to provide ideal data required for estimation of the deposit

Remark

Underground working is expensive and technically demanding. They are essential:

- in exploring mineral deposit of irregular shape such as (stockwork, nests, pipe-like bodies) and complicated structures,

- during exploration of mineral deposits within uneven distribution of minerals(e.g., gold)
- where drilling cannot provide a sufficiently precise picture, morphology and quality of the deposit,
- during detailed exploration of deposits with view of upgrading of reserve categories,
- for testing and selecting exploitation methods

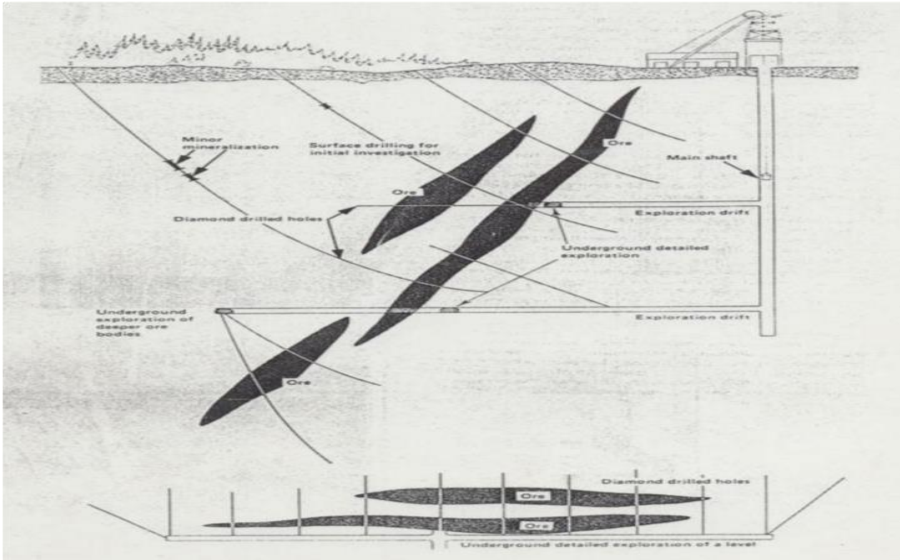


Figure 2. Exploration of an ore body by surface, core drilling and underground methods.

Sampling of ores and enclosing rocks

Sampling of mineral deposits is a very important step of the geological exploration. It is a process of obtaining a small quantity from material of a larger body so that the smaller quantity represents some characteristics or all characteristic of larger body.

Types , Time of sampling and purpose

Reconnaissance: during prospecting, for identifying mineral Occurrences, To obtain data to distinguish mineralised zones from other Zones, to identify the principal loci of Mineralization.

Thematic: during prospecting, for identifying specific characteristics.

Representative: during evaluation, for identifying quality and Quantity of mineral deposits and study of law of distribution.

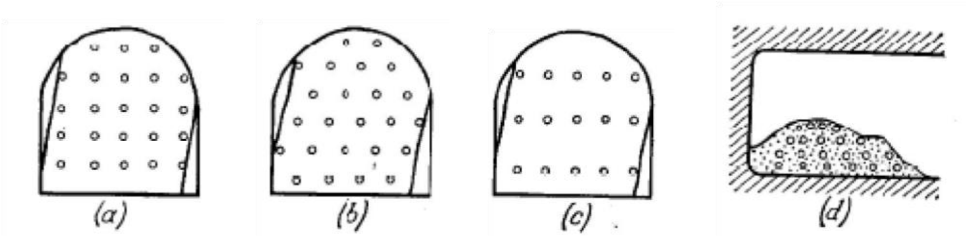
Bulk/Technological: during exploration and exploitation for pilot
Plant tests and mineral dressing check-up Methods of sampling: chip sampling, grab sampling, muck sampling, channel sampling, core sampling, bulk sampling.

Chip sampling – a sample consists of pieces taken on a grid from the working face, walls or roofs of an underground working (see below). A piece of material of the same size (approximately the size of a match-box) is taken from each point in the grid. The shape of the grid is adapted to the morphology and structure of the deposit. The advantage of chip sampling is its high productivity.

Grab sampling – A sample consists of several pieces of material, 0.5 – 2 kg in weight, which from visual observation represent the average composition of the deposit.

Muck sampling – is suitable for sampling of broken ore. A sample again consists of pieces taken on a regular grid. At each point of this grid a small pit is sunk through the whole layer of broken ore (see below). The basic principle is to take equal amounts of fine and coarse material. This procedure can be used only when the broken ore represents the whole thickness of the deposit. This sampling method is rapid and cheap.

Channel sampling – is the most frequently used for it is very accurate and universally applicable. It consists of cutting a continuous channel in the direction of the greatest variation of the deposit through its whole thickness (see below). Channel samples are usually collected by hand or small excavator. In deposits of complex structure, channel samples are taken from each band or layer separately. The following working procedure should be observed: the exposed rock surface is cleaned and projecting parts are removed; grooves are cut at the borders of a channel; the inner part is excavated keeping a constant



channel cross-section. All excavated material is collected and the sampling site is labeled. The cross-section of the channel is selected according to the variation in the mineralization quality. Channel distribution depends on the kind of underground working and on the deposition of the ore body. The bottom and walls of trenches are sampled.

Figure ---- a – chip sampling in the face based on square, b- rhombic and c – rectangular grids, d - sampling of ore in a pile of broken ore.

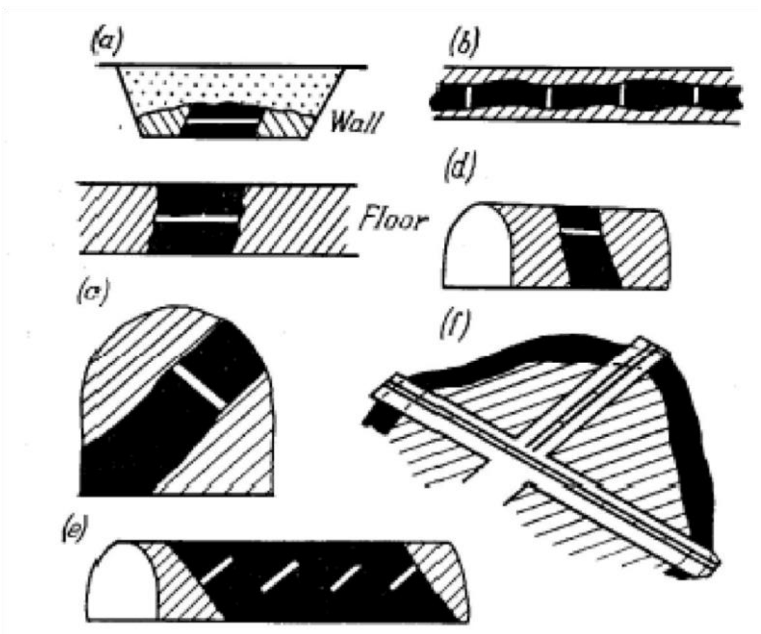


Figure ---- Disposition of channel samples: Sampling of cross-cuts: a – in ditches across the strike of the ore bodies, b – along the strike of ore bodies, c – in drifts pushed forward along the strike, (d and e) – in cross cuts and cross drifts, f – in workings crossing pipe-like bodies.

Sampling of Exploratory Boreholes

In the case of core drilling, the sampling material comes from the core, core and sludge, and sludge. To make sure of complete core recovery and obtain representative samples double core barrels are used.

*Core Recovery (C.R.) = l/L * 100%*

Where l = length of the core, and L = bore hole length.

Sludges are less valuable material than the core samples because of their being contaminated and incomplete catching. Therefore when the core recovery is as high as 70 to 80% no sludge samples are taken. If core recovery is incomplete or the core is lost entirely and a layer of the economic mineral is missed (which is established by logging), the bore hole is then artificially deflected for repeated drilling through a definite rock interval. In some cases, lateral projectile samplers are used in stead of artificial deflection of bore holes. The extracted cores are laid in their proper order into the core-sample containers. After that, core recovery is measured and the normal section of the deposit is recorded for kinds of rock, mineral, and structural features, and sketched. During sample taking the core is split longitudinally. One half of it goes to laboratory to assess grade and content of mineralization; and the other is stored.

Sample Spacing

The distance between the sampling sites is determined by the variability of mineralisation and the size of the deposit as well as by the objectives and detailed nature of the investigation.

Drill and Shot Hole Sampling: It is applied on ore deposits. This is employed in collecting samples for chemical as saying. The samples are taken from blast holes drilled in driving mine workings, or from special sampling bore holes. Drill holes intended for taking samples are disposed along the line of the greatest regularity or across the thickness of mineral body. The number of drill holes depends upon the degree of the irregularity: a uniform ore may be sampled from a single drill hole; with an extremely variable (irregular) ore samples are taken from 3 to 4 holes per each advance of the face. This type of sampling has the merit of a possible collection of specimens beyond the range of a mine opening, i.e. it enables thick ore bodies unexposed by the opening to be sample-tested. The method has, however, substantial disadvantages, such as: (1) it is not always possible to locate drill holes along the line of the maximum irregularity, (2) thin ore bodies cannot be test-sampled, (3) sectional sampling is lacking.

Bulk Sampling consists of taking large (up to 10,000 kg) sample, their volume not infrequently reaching scores of cubic metres. Bulk samples are collected for making technological laboratory and sampling mill and smelter tests, and also check tests on other types of sampling.

Sites of sampling

Surface

- surface outcrops of any possible rock types having ore indication,
- old working and old dumps,
- soil,
- broken ore,
- bottom or the walls of pits and trenches,

Underground :

- walls and /or roofs of adits, cross-cuts, drifts, raises, winzes and sometimes shafts.

In drill holes:

- either core or cuttings from bore holes During mining activities:
- they are taken as bulk samples from blasted material

Exploration during production

Objectives:

- to review the reserves of the deposit along with its exploration,
-to explore flanks and deep horizon of the deposit,
-in solving problems regarding dressing and treatment of the raw material

Part 2- mineral deposit evaluation

INTRODUCTION: MINERAL OCCURRENCE TO MINE

1.1 Mineral commodities

The title covers all marketable products except fuel minerals (coal, oil, uranium, etc.) of extractive industries like mining, quarrying, etc. The products may be dimension stones, ore (like iron ore or chrome ore), concentrates, or refined minerals or metals. Mineral-wise the number of commodity types exceeds 100. From an industrial point of view the most significant factors in the world of commodities are;

Commodity price
commodity consumption
commodity supply
commodity reserves/resourcs

Generally speaking, real prices of commodities have declined, even during the latest 20 years and, at the same time; consumption has increased. On the other hand, from commodity to commodity these factors may hugely vary. In addition to above factors some complementary ones like the strategic significance and criticality of a commodity is necessary.

The significance of mineral commodities as a foundation of industrial cultures (past, present and future) cannot be overestimated though, when evaluated in US dollars, this is not as obvious

1.2 Strategy of exploration

Mineral exploration covers the search for, and the discovery, identification, and evaluation of deposits but not their commercial development. The main purpose is success at reasonable cost of time, money, and human skill. Success in mineral exploration can be scientific, technical, commercial or, in an ideal case, all of them at the same time. Scientific success (on occurrence) results in a confirmation of scientific methodology (philosophy) effectively used in the course of exploration: exactly the type of deposit searched for was discovered. However, it may be noncommercial in grade or size. Technical success (on detection) means that technical arrangements were well designed: tools and methods, personnel, schedule, and financing were in balance, and the operation was skillfully done. If a deposit existed, it was certainly located.

Commercial success means, naturally, that the mineral deposit discovered meets all the criteria for a profitable operation.

Key words in exploration strategy are target definition, risk analysis, sequential approach, quantification of success and optimization

For target definition, expert knowledge of commodities, markets, regional geology and research and exploration methodology is needed as well as knowledge of risks.

Target definition is usually twofold: 1.Selection of commodities,

2. Selection of regions.

For the selection of commodities both the market situation on one hand and the processing from minerals (or rock) to commodities on the other hand must be considered.

An exploration project is always risky. No organization can live with scientific or technical successes alone, but everyone and then a commercial success is necessary. For this reason the exploration organization needs a good strategy to cope with scientific uncertainties and to optimize economic risks.
Risk analysis aims at foreseeing the possible effects of market risk (reflecting the sensitivity to the uncertainty with forecasts of trends in a commodity prices and of turbulences in currencies and interest rates).
project risk (Caused by the uncertainty with estimating ore reserves, recovery and dilution factors, capital and operating costs, time schedule, etc.)
Discovery risk (Reflecting the low probability (1 - 2%) of an economic deposit, given the discovery of a mineral occurrence)
geologic risk (Caused by the geologic variability in size, the grade, structure, etc. of mineral deposits that cannot be foreseen)
environmental risk (Caused by industrial construction or production as such or by their outbursts and tailings) and
political risk (Due to changing political situations in the home country, in neighboring countries or in the countries where the products should be sold to).

Sequential approach is considered in four aspects: chronologic sequentially, spatial sequentially, economic sequentially, and methodological sequentially. The idea is to detect economic ore deposits reducing the target area stepwise while increasing the expenditure of exploration. To succeed in this, realistic timing and use of resources, and good ability to quantify the success (or to evaluate the project after each sequence is necessary as well as the ability to choose appropriate methods.

Since all the good can seldom be achieved at the same time, optimization is the realistic way to control exploration budget. This means that you accept reasonable losses here if you can gain more there.
On the other hand optimization means rational planning so that you define both minimum and maximum objectives - in time, money, accuracy, probability, etc. As the grid spacing (upwards) increases or, conversely, as the coverage cost per unit of area decreases, the probability of detection gradually falls toward zero. As the grid spacing (downwards) diminishes and, conversely, as the coverage cost rapidly rises, the probability of detection improves only very slowly till it reaches the peak value. Here is a point for optimization: you select a grid spacing (unit price) and coverage (total price) according to your target definition (deposit type/ size, area outlined) and then you can estimate the probability of detection at a given cost.

It is seldom easy to estimate the precise price of a future exploration project. But it helps a lot if the range of prices can be given in terms of optimization degree.

Evaluation of an exploration project

Quantification of success means the calculation of the price of exploratory results. The cost of exploration is relatively easy to count or even to foresee. But the evaluation of results is much more difficult. We can say that quantifying has been well done, when we are able to sell our project with a reasonable profit. In other words, also projects have markets. It is one of the alternate economic strategies of mining companies to buy successful projects instead of starting new ones from the grassroots level.

Sequential approach makes above quantification easier. For each sequence targets have been defined on the basis of cumulated information. After completing a sequence, the expenditure is known. Target definition actually includes a rough estimate of the worth of deposits possibly detectable. With the help of analogy the value of results may be estimated: the value of anomalies, occurrences, mineral deposits and finally of an ore body. To the last point, however, selling a project is marketing images, illusions, potentialities that are not yet proved.

The first sequences end with screenings. Screenings or tentative feasibility studies or viability studies are based on indirect observations, extrapolations, analogies, and simulations and on general market and work pricing. The first economic appraisal resembling final feasibility study ends the detailed exploration phase. It is supposed to imitate feasibility study, but it is still an estimate of the potentiality of the deposit. It is only after detailed exploration that facts for a feasibility study are at hand. A feasibility study finally settles the expected value of the deposit. It may take several years and it may be expensive.

International frameworks for reserve/resource assessments

Most national classification systems in principle report mineral reserves/resources with respect to increasing geological assurance and diminishing economic potential. The variation between systems occurs in the terms and definitions used to delineate and classify reserve and resource categories. Since there are steadily growing international trade and investment in mineral commodities, a classification system to enhance communications between international mining companies, research institutes and national and local authorities have been considered necessary. United Nations Economic Commission for Europe initiated a program to bring experts from different countries together with the aim of establishing an internationally acceptable and market-economy-oriented classification system (Nötstaller et al. 1995, Riddler, 1995).

In this three-dimensional diagram the sequentiality of an exploration process has been abandoned to include Stage of geological assessment, Stage of mineability assessment (or: evaluation or quantification of success) and Degree of economic feasibility.

There has been plenty of confusion because of the varied usage of terminology. It seems now that the terms reserves and resources have been fixed:

Mineral resources are accumulations, occurrences or showings in such form and quantity that economic exploitation of a mineral or substance from the deposit may be currently or potentially feasible.

An ore (or mineral) reserve is that part of a mineral resource on which sufficient technical and economic studies have been carried out to demonstrate that it can justify exploitation under specified conditions.

The proposed new system appears to offer advantages over the national conventional systems. The numerous different terms describing categories of reserves/resources of increasing geological assurance are replaced by activity-related terminology. The same principle was applied to separate categories of increasing mineability assessment. Furthermore, this proposed new system may function as a platform or umbrella to national systems. However, its main emphasis is on the phasing and evaluation of exploration projects and mineral resources and not on the evaluation of detected mineral deposits and their ore reserves.

DEPOSIT TYPES

Deposit typification or modeling may be based on ore genetics (ore petrology), geological or analytical (grade) structures, relative or absolute age, chemistry, mineralogy, geometry, etc. Type recognition is important for exploration and for mine planning as well. Each international mining company has its own specialties as to deposit types, and the same holds with practically every geologist and mine engineer. It may bring significant savings if the general deposit type can be defined already in the target definition phase and if the typing can be sharpened toward the end of each exploration phase.

From a practical point of view deposit types can be classified as

Strategic deposit types for target definition and reconnaissance plans. The necessary type information includes genetic aspects to choose among geological environments (structural, age groups, etc.) and also concepts of the size class and expected grade of deposits to be located.

Tactical deposit types for prospection and general exploration phases. For the selection and application of indirect methods petrophysical information (conductivity, magnetic properties, density, etc.) as well and geometrical information (size, shape, grade structure) of the target type would be very useful.

Production (or process) deposit types: for detailed exploration and feasibility study. Useful type information includes physical properties like textural and structural characteristics of the ore, its host rock and country rock to estimate the mine ability of the deposit, and process mineralogical properties of the same to estimate the process technical treatment of the ore.

Introduction

In the field of mineral concentrations, the evaluation is developed according to three estimation levels:

evaluation of mineral indications

evaluation of mineral occurrences

evaluation of mineral deposits

The parameters which play a role in the evaluation process are essentially two: grade and tonnage.

The data to be processed derive from;

Geological and mineral exploration, from sampling (in different phases up to plant dressing) and analyses The data processing leads to the estimation levels from mineral indication to a mineral deposit.

The data processing gives or provides models which control all the decision making phases for the beneficiation of ore.

Basic data in the evaluation of a mineral deposit data derived from documentation, as aerial photos, cartography, scientific publications, archive, statistical information on mining activities, reports on old mining works etc. data derived from old mining works (quarries, old pits, dumps, relicts of old dressing and smelting plants, slag heaps etc.

data derived from geological mapping

lithology

structures

drainage pattern etc.

data derived from mineral exploration ,geochemical survey results geophysical results mining workings (trenches, pits bore holes and underground)

Factors controlling the evaluation of mineral deposits are

- information on the deposit
- information on general project economics
- mining method selection
- processing methods
- capital and operating estimate costs

1) Information on the deposit

Geology

- Mineralization (continuity, uniformity, type grade)
- Mineral paragenesis (economic minerals, by-products)
- Geological structures
- Country rocks: rock types, physical properties

- Geometry; Size, shape, attitude (affect the choice of exploration and exploitation methods)
- Continuity
- Depth
- Geography and climate:
- Location – proximity to towns
- Surface topography (accessibility)
- Climate conditions (affect the continuity of the activities of prospecting and exploitation)
- Surface conditions (vegetation, hydrography)
- Political boundaries

2) Information on general project economics

a) Market

- marketable form of product – concentrate, direct shipping ore, specifications market location expected price levels and trends – supply-demand, competitive cost levels, new sources of product, substitutions

b) Transportation

property access product transportation – methods, distance, costs
c) Utilities electric power – availabilities, location and costs natural gas - availabilities, location and costs - alternatives – on site generation

d) Land and mineral rights

- ownership – surface, mineral acreage requirements – concentrator site, waste dump location, tailings pond location, ecology

e) Water

- potable and process – source, quantity, quality, availability, costs

- mine water - source, quantity, quality, availability, costs, drainage method treatment

f) Labour

availability and type – skilled/unskilled in exploration and mining

rates and trends

degree of organization

3) Mining methods selection

- a) physical control
- - strength – ore, waste
- - uniformity – mineralization, blending requirements
- - continuity – mineralization
- - geology – structure
- - surface disturbance – subsidence
- - geometry
-
- b) selectivity (flexibility of methods)
-
- c) production requirements
- - relative production
- - development – methods, quantity, time requirements
- - capital requirements vs. availability

4) Processing methods

- - mineralogy (characteristics)
- - product quality vs. specification
- - recoveries
- 5) Capital and operating costs estimates
- a) Capital cost
- - exploration
- - mining
- - preparation development
- - site preparation
- - mine building
- - mine equipment's
- Mill
- - site preparation
- - mill building
- - mill equipments
- - tailing pond
- b) Operating costs
- - Mining
- - labour
- - maintenance and supplies
- - development
- - Milling
- - labour
- - Administrative and supervisory

Part 3 - Mining

Mining is the extraction of valuable minerals or other geological materials from the earth, usually (but not always) from an ore body, vein or (coal) seam. Basically all mining methods entail two fundamental tasks regardless of scale: breaking the ore, and transporting it to the beneficiation or processing plant.

Materials recovered by mining include bauxite, coal, copper, gold, silver, diamonds, iron, precious metals, lead, limestone, nickel, phosphate, oil shale, rock salt, tin, uranium and molybdenum.

The choice of mining methods weather by open pit or underground depends on the economic factors, setting the unit value of the deposit against the unit costs of extracting the ore.

The total cost of transforming one ton of ore in the ground into sealable commodity is termed the UNIT COST.

In a grossly simplified form, the unit cost (C) is made up of:

Co = the day-to-day cost of excavating and transporting one ton of ore;

Cw = the day-to-day cost of excavating of mass of waste (barren rock) associated with one ton of ore;

Cf = the overheads per ton of ore extracted per year = fixed costs;

Cp = the cost of processing one ton of ore to sealable products;

Therefore,

C = Co + Cw + Cf + Cp

The first two terms are made up of costs of explosives and fuel, maintenances costs of equipment, costs replacement, and wages.

The overheads, Cf, include: the cost of long-lived equipments, permanent constructions, land insurance, environmental restoration and road or rail access. The cost of processing, Cp, involves separation of ore minerals from waste, smelting and transport of refined metal.

There are two main economic differences between surface and underground mining. The first relates to the fixed costs, which are higher in underground mining partly because the permanent constructions and long lived equipment include fixed systems of access shafts and underground roadways and provision for ventilation and drainage. In surface mine, the access is part and parcel of ore excavation itself, and drainage, though necessary, requires only pumps and temporary pipes. Underground mining with all their requirements for safety and precision, require far more sophisticated designs and expensive equipment, with consequent addition to fixed costs.

Terms

Prospecting or Exploration to find and then define the extent and value of ore where it is located ("ore body")

Ore*:* a mineral deposit that has sufficient utility and value to be mined at a profit.

Gangue: the valueless mineral particles within an ore deposit that must be discarded. Waste: the material associated with an ore deposit that must be mined to get at the ore and must then be discarded. Gangue is a particular type of waste.

Mine: an excavation made in the earth to extract minerals

Mining*:* the activity, occupation, and industry concerned with the extraction of minerals.

Mining engineering*:* the practice of applying engineering principles to the development, planning, operation, closure, and reclamation of mines.

Conduct resource estimation to mathematically estimate the size and grade of the deposit.
Conduct a pre-feasibility study to determine the theoretical economics of the ore deposit. This identifies, early on, whether further investment in estimation and engineering studies is warranted and identifies key risks and areas for further work.
Conduct a feasibility study to evaluate the financial viability, technical and financial risks and robustness of the project and make a decision as whether to develop or walk away from a proposed mine project. This includes mine planning to evaluate the economically recoverable portion of the deposit, the metallurgy and ore recoverability, marketability and playability of the ore concentrates, engineering, milling and infrastructure costs, finance and equity requirements and a cradle to grave analysis of the possible mine, from the initial excavation all the way through to reclamation.

Development: to create access to an ore body and building of mine plant and equipment.

Reclamation: to make land where a mine had been suitable for future use

Mining techniques can be divided into two basic excavation types:

1. Surface mining
2. Sub-surface mining (underground mining)

Surface mining is a type of mining in which soil and rock overlying the mineral deposit (the overburden) are removed. It is the opposite of underground mining, in which the overlying rock is left in place, and the mineral removed through shafts or tunnels.

Surface mining is used when deposits of commercially useful minerals or rock are found near the surface; that is, where the overburden is relatively thin or the material of interest is structurally unsuitable for tunneling (as would usually be the case for sand, cinder, and gravel). Where minerals occur deep below the surface—where the overburden is thick or the mineral occurs as veins in hard rock— underground mining methods are used to extract the valued material. Surface mines are typically enlarged until either the mineral deposit is exhausted, or the cost of removing larger volumes of overburden makes further mining uneconomic.

Types of surface mining:

Open-pit mining

Strip mining

Quarrying

Placer mining

"**Open-pit mining**" refers to a method of extracting rock or minerals from the earth through their removal from an open pit.

Open-pit mines are used when deposits of commercially useful minerals or rock are found near the surface; that is, where the *overburden* (surface material covering the valuable deposit) is relatively thin or the material of interest is structurally unsuitable for tunneling (as would be the case for sand, cinder, and gravel).

Grade and tonnage of material available will determine pit limits and how much waste rock can be stripped. The ultimate limit to the pit is determined by the economics of removing overburden **(STRIPPING RATIO [ORE/WASTE]).**

For minerals that occur deep below the surface—where the overburden is thick or the mineral occurs as veins in hard rock— underground mining methods extract the valued material.

Open pit mining

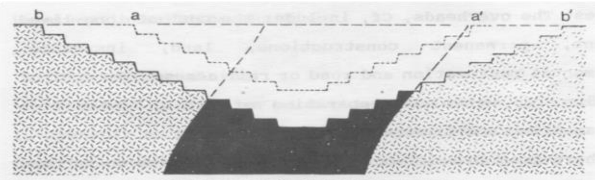


Figure 2 Development of an open pit. During the early stages (a–a'), more ore is removed than waste rock; as the pit becomes deeper, the ratio of waste to ore mined becomes greater until at stage b–b' it is about 1.6:1. At Bingham, the limiting waste-to-ore ratio is about 2:1.

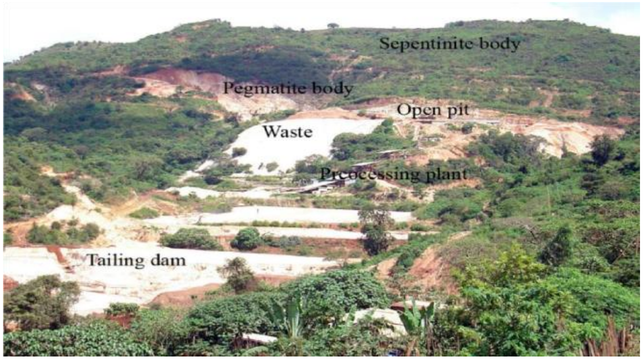


Figure 5. Map showing pit, waste and tailing dam in Kenticha Tantalite deposit, Adola (southern Ethiopia)

Figure 6. Tantalite mining by open pit in Kenticha, Adola, southern Ethiopia

Strip mining

"Strip mining" is the practice of mining a seam of mineral by first removing a long strip of overlying soil and rock (the overburden). It is most commonly used to mine coal or tar sand. Strip mining is only practical when the ore body to be excavated is relatively near the surface.

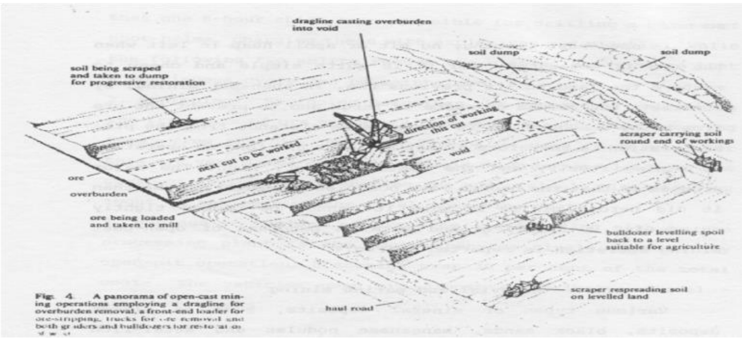


Figure 7. Strip Mining

QUARRYING or Quarry Mining is usually restricted to mining dimension stone - prismatic blocks of marble, granite, limestone, sandstone, slate, etc. that are used for primary construction of buildings or decorative facing materials for exterior and interior portions of buildings.

Figure 8. Marble Quarry

Underground mining (hard rock)

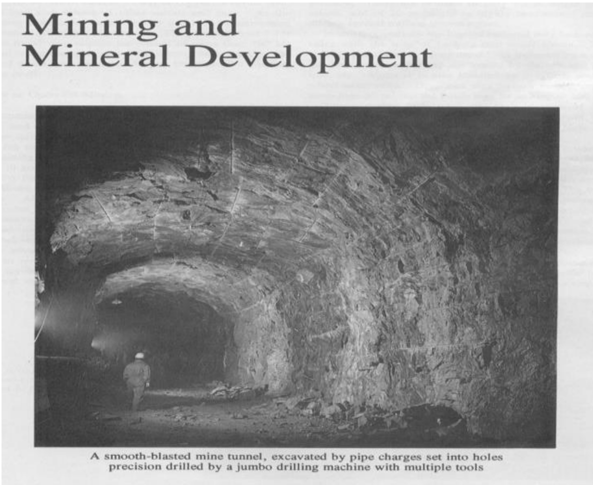


Figure 9. Underground Mining

Underground hard rock mining refers to various underground mining techniques used to excavate hard minerals, mainly those minerals containing metals such as ore containing gold, copper, zinc, nickel and lead, but also involves using the same techniques for excavating ores of gems such as diamonds.

Underground access

Development mining vs. production mining

There are two principal phases of underground mining: **DEVELOPMENT MINING** and **PRODUCTION MINING.**

Development: underground work carried out for the purpose of opening up a mineral deposit below the earth surface.

Four basic components of rock excavation are involved in normal mine developments and includes shaft sinking, ramp driving, drifting and raising.

Shaft: a vertical passageway to an underground mine for moving personnel, equipment, supplies and material including ore and waste rock, to ventilate the mine.

- the purpose is to provide access to underground workings
- the main shaft is usually vertical
- the profile can be rectangular, circular or elliptical
- a mine shaft is normally sunk to a depth that will ensure many years of production already in the initial stages of development
- shaft sinking in comparison with other development operations, a complex procedure
- the sinking requires a complete set of machinery, matched to the project
- shaft sinking is therefore treated as a special project and assigned to a contractor

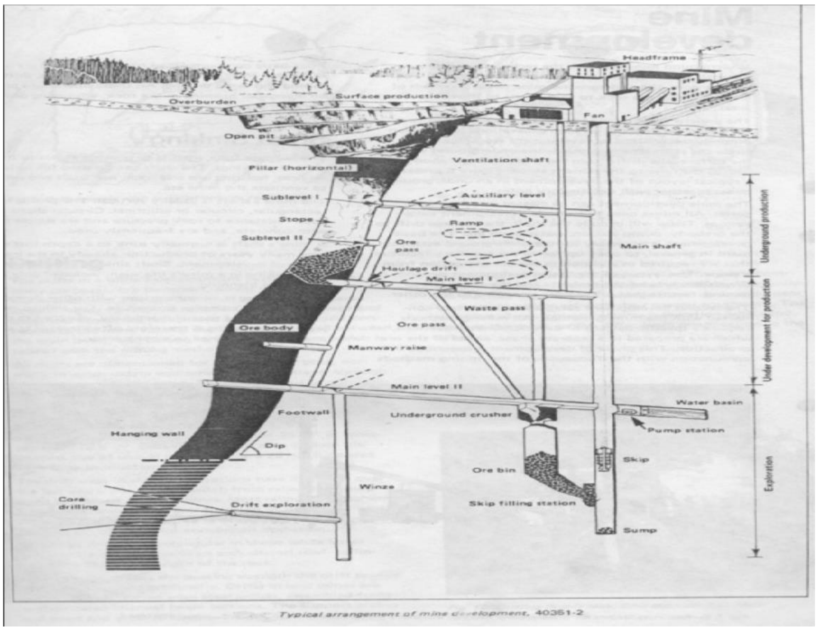


Figure 10. Typical arrangement of mine development

Drift: a horizontal tunnel driven alongside an ore body, from either an adit or shaft, to gain access to the ore, used for exploration.

Ramp: An inclined underground tunnel that provides access to an ore body for exploration, ventilation and/or mining purposes in an underground mine.

Raise - A vertical hole between mine levels used to move ore or waste rock or to provide ventilation.

Development mining is composed of excavation almost entirely in (non-valuable) waste rock in order to gain access to the ore body. There are six steps in development mining: remove previously blasted material (muck out round), Scaling (removing any unstable slabs of rock hanging from the roof and sidewalls to protect workers and equipment from damage), support excavation, drill rock face, load explosives, and blast explosives.

Production mining is further broken down into two methods, long hole and short hole.

Short hole mining is similar to development mining, except that it occurs in ore. There are several different methods of long hole mining. Typically long hole mining requires two excavations within the ore at different elevations below surface, (15 m – 30 m apart). Holes are drilled between the two excavations and loaded with explosives. The holes are blasted and the ore is removed from the bottom excavation.

Ventilation

One of the most important aspects of underground hard rock mining is ventilation. Ventilation is required to clear toxic fumes from blasting and removing exhaust fumes from diesel equipment. In deep hot mines ventilation is also required for cooling the workplace for miners. Ventilation raises are excavated to provide ventilation for the workplaces, and can be modified for use as emergency escape routes. The primary sources of heat in underground hard rock mines are virgin rock temperature, machinery, auto compression, and fissure water. Other small contributing factors are human body heat and blasting.

UNDERGROUND MINING METHODS

Cut-and-fill: a method of underground mining in which ore is removed in slices or lifts, and then the excavation is filled with rock or other waste material (backfill) before the subsequent slice is mined.

Drift and Fill is similar to cut and fill, except it is used in ore zones which are wider than the method of drifting will allow to be mined.

Shrinkage Stopping is a short hole mining method which is suitable for steeply dipping ore bodies. The method is similar to cut and fill mining with the exception that after being blasted, broken ore is left in the stope where it is used to support the surrounding rock and as a platform from which to work.

Room and Pillar mining : Room and pillar mining is commonly done in flat or gently dipping bedded ore bodies. Pillars are left in place in a regular pattern while the rooms are mined out.

Block Caving is used to mine massive steeply dipping ore bodies (typically low grade) with high friability.

Stopping is the removal of the wanted ore from an underground mine leaving behind an open space known as a stop. Stopping is used when the country rock is sufficiently strong not to cave into the stop, although in most cases artificial support is also provided.

A spoil tip is a pile built of accumulated *spoil*, which is a by-product of mining.

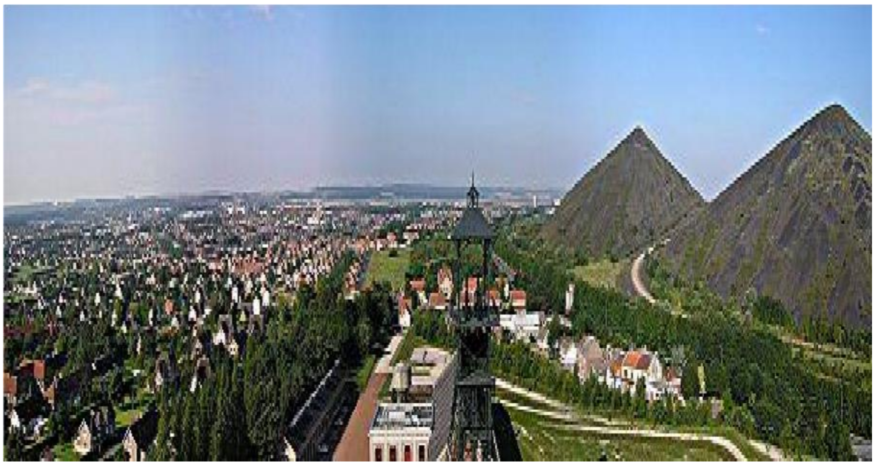


Figure 11. A spoil

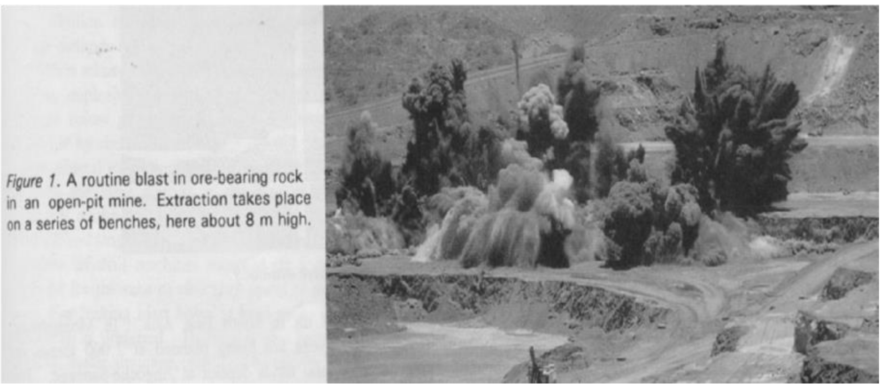


Figure 12. A routine blast in ore-bearing rock in an open-pit mine

PLACER MINING

Placer mining is the mining of alluvial deposits for minerals. This may be done by open-pit (also called open-cast mining) or by various forms of tunneling into ancient riverbeds. Excavation may be accomplished using water pressure (hydraulic mining), surface excavating equipment or tunneling equipment.

Methods

Panning: The traditional prospectors gold pan is an efficient device for washing and separating the heavy minerals in placer deposits and is commonly used as a prospecting and testing tool for evaluating placer deposits.

Sluicing: in sluicing placer gravel is shoveled, along with a stream of water, into the head of an inclined elongated sluice box with RIFFLES positioned across the bottom. These trap the heavy minerals and the lighter minerals are washed over the top and out as relatively barren waste. Sometimes fine gold is trapped as an amalgam when mercury is placed within the riffles or on a copper plate at the exit of the sluice box.

The gold in the amalgam is recovered by retorting off the mercury.

Figure 13. Ground sluicing for placer gold
Adola, southern Ethiopia

Figure 14. placer gold digger by free miners, Adola, southern Ethiopia

Figure 15. Placer gold panning by free miners, Adola, southern Ethiopia

TROMMEL

A trommel is composed of a slightly-inclined rotating metal tube (the 'scrubber section') with a screen at its discharge end.

The ore is fed into the elevated end of the trommel. Water, often under pressure, is provided to the scrubber and screen sections and the combination of water and mechanical action frees the valuable minerals from the ore.

DREDGING

"Dredging" is a method often used to bring up underwater mineral deposits. Although dredging is usually employed to clear or enlarge waterways for boats, it can also recover significant amounts of underwater minerals relatively efficiently and cheaply.

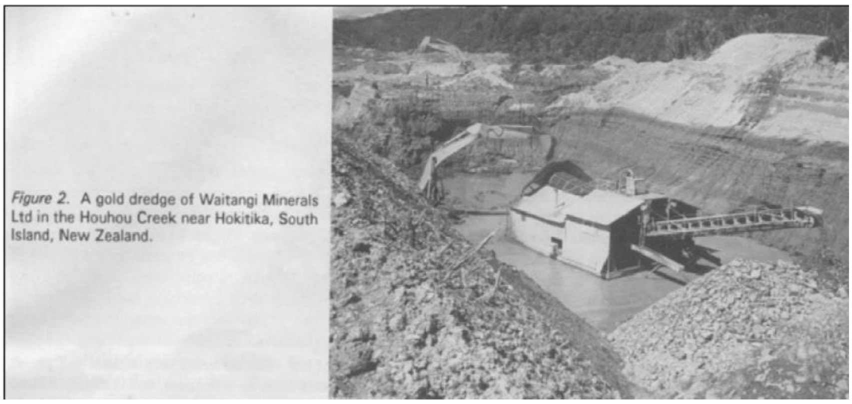


Figure 16. Dredging

HYDRAULIC MINING

Hydraulic mining, or hydraulicking, is a form of mining that uses high-pressure jets of water to dislodge rock material or move sediment. In the placer mining of gold or tin, the resulting water-sediment slurry is directed through sluice boxes to remove the metal.

Hydraulic mining - involves directing a high-pressure stream of water, via a **MONITOR or nozzle**, against the base of the placer bank. The water caves the bank, disintegrates the ground and washes the material to and through sluice boxes, and/or jigs, and/or tables situated down-slope. Hydraulic mining totally disturbs large areas and puts much debris into the drainage system. Presently, hydraulicking is used primarily in Third World countries.

Figure 17. Hydraulic platinum mining from laterite (Yubdo, western Ethiopia)

Figure 18. Hydraulic mining of placer gold (Adola area, southern Ethiopia)

Figure 19. placer gold mining by hydro monitor,
Adola, southern Ethiopia

Figure 20. A sluice box used in placer mining to recover gold,
Adola, southern Ethiopia.

In-situ leach is a particular mining technique that is used to mine minerals (potash, potassium chloride, sodium chloride, sodium sulphate and uranium oxide) which dissolve in water.

Environmental issues can include erosion, formation of sinkholes, loss of biodiversity, and contamination groundwater and surface water by chemicals from the mining process and products.

Acid mine drainage (AMD), or acid rock drainage (ARD), refers to the outflow of acidic water from (usually) abandoned metal mines or coal mines. However, other areas where the earth has been disturbed (e.g. construction sites, subdivisions, transportation corridors, etc.) may also contribute acid rock drainage to the environment.

Tailings piles or ponds may also be a source of acid rock drainage.

Metal mines may generate highly acidic discharges where the ore is a sulfide or is associated with pyrites. In these cases the predominant metal ion may not be iron but rather zinc, copper, or nickel.

TAILINGS

Tailings (also known as slimes, tailings pile, tails, leach residue, or slickens) are the materials left over after the process of separating the valuable fraction from the worthless fraction (gangue) of an ore.

PART 4 - MINERAL PROCESSING

Mineral processing, otherwise known as mineral dressing, is the practice of beneficiating valuable minerals from their ores. Industrial mineral treatment processes usually combine a number of unit operations in order to liberate and separate minerals by exploiting the differences in physical properties of the different minerals that make up an ore.

Mineral processing involves the use of physical processes to manipulate ore particle size, and concentrate valuable minerals using the processes of separation, based on such properties of the ore, as density, chemical composition, electrostatic, magnetic or fluorescence properties. A good example of a separation process is froth flotation. Also of interest to the mineral processor is the separation of mineral solids from water and aqueous solutions by thickening, filtering and drying.

BENEFICIATION

Success in any mining project cannot be achieved without a thorough knowledge of the characteristics of the ore to be treated. The geologist must establish close liaison with the metallurgist to correlate metallurgical behavior with detailed distribution patterns of the mineralogical, structural, textural and grade variations with the ore deposit. Plant design and production scheduling will be based upon this information.

The fundamental principle in mineral beneficiation is to reduce the crude ore to a size that will permit optimum liberation of the ore minerals and allow their subsequent separation from associated gangue minerals by gravity, magnetic, electrostatic, froth flotation, etc.

Information is gathered through chemical analyses, X-ray determinations, miner graphic examination, probe analyses, and geotechnical testing. Data sought will be: 1) tensional and uniaxial compressive strength of the ore/rock; 2) range of grain-sizes of ore and gangue minerals; 3) percentage of 'free' ore and gangue minerals at various size fractions; 4) states of oxidation, hydration, leaching and replacement in minerals; 5) presence of surface coatings which might influence flotation, cyanidization, etc.; 6) presence of exsolution phenomena and recognition of solid solution states; and 7) any special physical or chemical properties which might interfere with separation, or cause environmental problems. These characteristics may vary within the ore body and must be continuously monitored. This information will enable decisions to be made regarding separation methods or modification to existing procedures.

Mineralogical investigation is essential for determination of proper beneficiation methods. The most important factors for determination are: 1) identities of all minerals present in the ore and gangue: 2) observations on grain size, texture, alteration, coatings, etc.; and 3) nature of locking and liberation factor. Many plants also incorporate hydrometallurgical or pyrometallurgical processes as part of an extractive metallurgical operation.

Mineral processing involves four general types of operations: Commination or particle size reduction, Sizing or separation of particle sizes by screening or classification, Concentration by taking advantage of physical and surface chemical properties, and Dewatering or solid/liquid separation (Figure ------).

A number of auxiliary materials handling operations are also considered a branch of mineral processing such as storage (as in bin design), conveying, sampling, weighing, slurry transport, and pneumatic transport.

SIZE REDUCTION - CRUSHING AND GRINDING

Comminution

Comminution is particle size reduction of materials. Comminution may be carried out on either dry materials or slurries. Crushing and grinding are the two primary comminution processes. Crushing is normally carried out on "run-of-mine" ore, while grinding (normally carried out after crushing) may be conducted on dry or slurried material.

Crushing

FIRST STAGE CRUSHING is generally by JAW, GYRATORY or CONE

CRUSHERS, depending upon the tensional strength of the rock. Crushing capacity can be predicted from testing data from BRAZILIAN TESTS and UNIAXIAL COMPRESSIVE TESTS, or SCHMIDT HAMMER tests. It is important that all rock types that will be fed through the concentrator are tested. Many new beneficiation plants have found themselves to be short of crushing and grinding capacity because they tested an average grade ore and paid little attention to the rock type, or failed to recognize a siliceous cap that dominated production for the first several years.

SECOND STAGE GRINDING, a high energy input stage of processing, is limited to an optimum rather than a minimum size because: 1) cost increases rapidly as fineness increases; 2) grinding efficiency decreases with increasing fineness; and 3) production of slimes increases metallurgical losses. Resistance to grinding is a function of ore and gangue minerals properties, including hardness, cleavage, grain size, bonding, etc.

SCREENING AND/OR CLASSIFICATION entails removal of mineral grains from the grinding circuit as soon as they are reduced to an optimum size. Screens are generally used for making the separation when coarser sizes are involved, whereas CYCLONES and CLASSIFIERS are used when fine sizes are involved.

i. SCREENING, usually 20 mesh or coarser, may be dry or wet, stationary or vibrating. This sizing method is particularly effective when gravity methods of separation will be used, since the classification is purely on the basis of size.

ii. CLASSIFICATION uses water or air currents as the suspending medium in which particles settle at different rates. The settling rate is influenced not only by the size of the particle, but also by its specific gravity and grain shape.

Classifiers may be mechanical, usually classifying grains in the 100 to 400 mesh range. Sizes larger than the desired size settle out and are gathered by a rake or and returned to the mill for additional grinding. The finer sizes overflow from the classifier and pass on to the next stage of beneficiation.

Sizing is the general term for separation of particles according to size.

The simplest of sizing processes is screening, or passing the particles to be sized through a screen or number of screens. Screening equipment can include grizzlies, bar screens, and wire mesh screens. Screens can be static (typically the case for very coarse material), or they can incorporate mechanisms to shake or vibrate the screen.

Classification refers to sizing operations that exploits the differences in settling velocities exhibited by particles of different size. Classification equipment may include ore sorters, gas cyclones, hydro cyclones, rake classifiers, rotating trommels, or fluidized classifiers. When the feed material contains particles of different densities as well as particles of different size, a degree of concentration takes place during classification because settling velocities are also dependent on particle density.

Figure 21. Mill (grinding)

A grinding mill is a unit operation designed to break a solid material into smaller pieces. There are many different types of grinding mills and many types of materials processed in them. Historically mills were powered by hand (mortar and pestle), working animal, wind (windmill) or water (watermill). Today they are also powered by electricity.

The grinding of solid matters occurs under exposure of mechanical forces that trench the structure by overcoming of the interior bonding forces. After the grinding the state of the solid is changed: the grain size, the grain size disposition and the grain shape.

Grinding may serve the following purposes in engineering:

- increase of the surface area of a solid
- manufacturing of a solid with a desired grain size

- pulping of resources

Types of grinding (mill)

Ball mill

A typical type of fine grinder is the ball mill. A slightly inclined or horizontal rotating cylinder is partially filled with balls, usually stone or metal, which grinds material to the necessary fineness by friction and impact with the tumbling balls. The feed is at one end of the cylinder and the discharge is at the other. Ball mills are commonly used in the manufacture of Portland cement. These industrial ball mills are mainly big machines. Small versions of ball mills can be found in laboratories where they are used for grinding sample material for quality assurance.

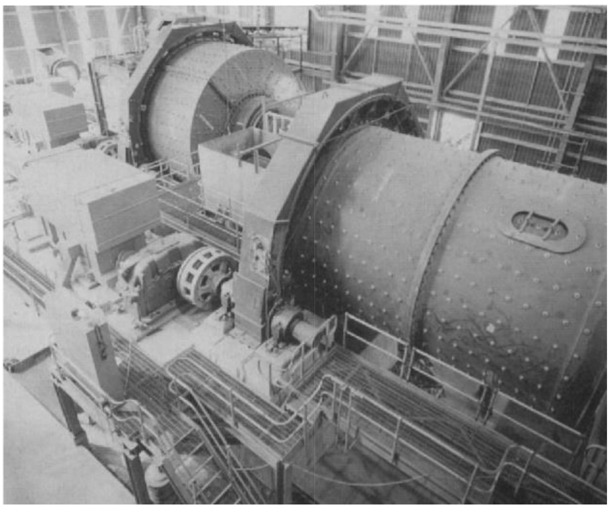


Figure 22. Ball mill in a processing plant

Rod mill

A rotating drum causes friction and attrition between steel rods and ore particles. But note that the term 'rod mill' is also used as a synonym for a slitting mill, which makes rods of iron or other metal.

A rotating drum throws large rocks and steel balls in a cataracting motion which causes impact breakage of larger rocks and compressive grinding of finer particles. Attrition in the charge causes grinding of finer particles. SAG mills are characterized by their large diameter and short length. The inside of the mill is lined with lifting plates to lift the material inside up and around the inside of the mill, where it then falls off the plates and falls back down. SAG mills are primarily used in the gold, copper and platinum industries with applications also in the lead, zinc, silver, alumina and nickel industries.

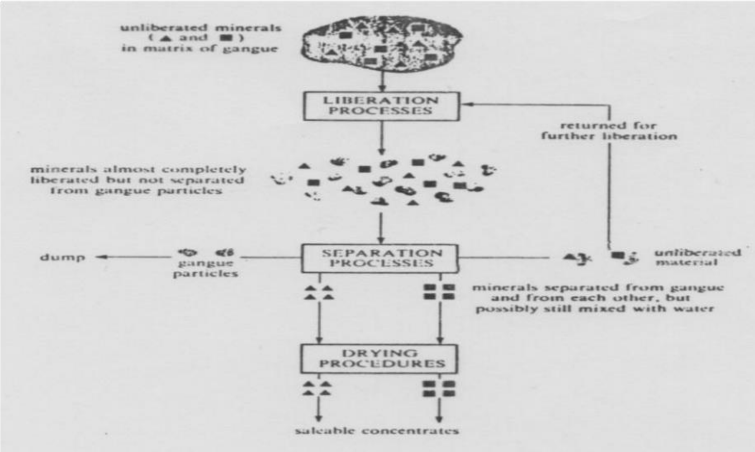


Figure 23. Schematic representation of mineral processing

MINERAL SEPARATION

- Mechanical sorting
- Float-sink method (Heavy media or dense media separation)
- Shaking tables
- Spirals (cyclone separator)
- Centrifugal bowl concentrator
- Jig concentrator
- Magnetic separation
- Electrostatic separation
- Froth flotation
- Carbon in pulp
- In-situ leach
- Cyanidation

Froth flotation

Froth flotation is achieved when particles are separated based on their surface potential. Hydrophobic particles are recovered to the froth, whereas hydrophilic particles are discharged with the tailings stream. Some mineral particles are naturally hydrophobic, whereas others require specific reagent additions to change their surface potentials.Oxide ores, such as spodumene and tantalite can be treated using oxalic acid based collectors. Sulfide ores can be recovered using xanthate or dithiophosphate type collectors.

Particles can be classified based on their specific gravity. Gravity concentration processes include:

Figure 2 4. Flotation cells in a processing plant

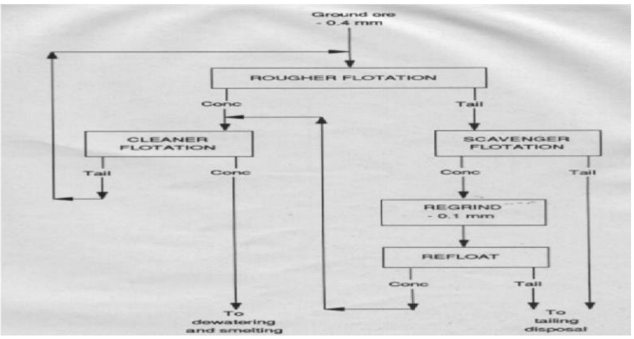


Figure 25. Simplified flow-sheet for flotation

In-situ leach

In-situ leaching (ISL), also called in-situ recovery (ISR) or solution mining, is a process of recovering minerals such as copper and uranium through boreholes drilled into the deposit. The process initially involves drilling of holes into the ore deposit. Explosive or hydraulic fracturing may be used to create open pathways in the deposit for solution to penetrate. Leaching solution is pumped into the deposit where it makes contact with the ore. The solution bearing the dissolved ore content is then pumped to the surface and processed. This process allows the extraction of metals and salts from

an ore body without the need for conventional mining involving drill-and-blast, opencut or underground mining.

Carbon in pulp

Carbon in Pulp (CIP) is an extraction technique for recovery of gold which has been liberated into a cyanide solution as part of the gold cyanidation process.

Introduced in the early 1980's, Carbon in Pulp is regarded as a simple and cheap process. As such it is used in most industrial applications where the presence of competing silver or copper does not prohibit its use.

Activated carbon acts like a sponge to aurocyanide and other complex ions in solution. Hard carbon particles (much larger than the ore particle sizes) can be mixed with the ore and cyanide solution mixture. The gold cyanide complex is adsorbed onto the carbon until it comes to an equilibrium with the gold in solution. Because the carbon particles are much larger than the ore particles, the coarse carbon can then be separated from the slurry by screening using a wire mesh.

Cyanidation

Cyanidation (also known as the cyanide process is a metallurgical technique for extracting gold from low-grade ore by converting the gold to water soluble aurocyanide metallic complex ions. It is the most commonly used process for gold extraction. Due to the highly poisonous nature of cyanide, the process is highly controversial and its usage is banned in a number of countries and territories.

Smelting

1. Pyrometallurgical

Smelting is the most important pyrometallurgical process by which metals are recovered from ore and concentrates to produce semi-refined metals. It entails high temperature processing during which gangue minerals are chemically altered - fluxed and reduced to form low-density molten slag, which separates from one or more heavier liquid metals or metallic compounds.

Feed to the smelting operation often goes through preliminary preparation, including drying, roasting, calcining, sintering, and agglomeration and/or pelletizing.

Because of the high energy input required, only relatively high-grade ores or concentrates can be economically smelted. This is usually by one of two processes:

- the smelting of metal oxide ores, concentrates and calcines, which involves reduction of the oxide to metal with coke or carbon monoxide, and less frequently iron, in blast furnaces or occasionally reverbatory or electric arc furnaces using a mixture of coarse ore, coke and fluxes and/or a sinter of these.

- matte smelting of sulfide ores and concentrates takes place in a neutral or slightly oxidizing condition to form a matte (an alloy of several metal sulfides) in a reverbatory furnace using concentrates and fluxes.

Products produced by either of the above methods require further treatment and refining:

- Pig iron (blast furnace) requires removal of carbon, sulfur and phosphorus by oxidation smelting with steel scrap, fluxes and air in reverbatory or basic oxygen furnaces;

- Lead bullion (blast furnace) must be drossed and softened. Impurities are removed by oxidation, sulfidization, alloying or electrolysis;

- Copper and Nickel Matte (reverbatory furnace) require oxidation of sulfur and slagging of iron with silica flux to produce Blister.

All pyrometallurgical operations produce large quantities of vaporized metals, dust and fumes.

2. Distillation

Because of their relatively high vapor pressure at elevated temperatures, some metals are recovered from ores, fumes and slags by distillation or fuming. Nearly all primary mercury is recovered and refined by relatively low temperature distillation of lowgrade cinnabar ores using rotary kilns, hearth furnaces and retorts. Zinc fuming or distillation in Imperial Smelting type furnaces is common. It entails sintering to remove sulfur, blast furnace smelting at high temperatures to volatilize the zinc and recover lead bullion, and condensation of the zinc in a spray of molten lead followed by cooling the zinc-saturated molten lead by skimming. Arsenic, antimony and cadmium can also be recovered by distillation techniques.

3. Liquation

Liquidation is a method by which metals or metallic compounds are separated on the basis of differences in melting points. For example, stibnite, which has a melting point of 550 degrees C., is recovered as pure Sb_2S_3 for subsequent reduction, by heating coarsely crushed stibnite ores. Liquation techniques are important in the refining of lead. The blast furnace produced lead contains copper, arsenic, antimony, tin, gold and silver that must be removed and refined to saleable products.

Copper, arsenic, antimony and tin are removed by cooling the lead bullion, adding elemental sulfur and blowing with air. When sulfidized and/or oxidized these impurities become insoluble in the molten lead and are skimmed off as DROSS floating on the molten lead. Gold and silver are removed by adding metallic zinc to form insoluble alloys that can be skimmed from the surface.

Liquation is also an important unit process utilized to separate copper-rich matte from heavier nickel-rich matte prior to subsequent processing.

D. Refining

Refining varies with the metal. Copper serves to illustrate. Fire-refined copper (BLISTER) in most instances still contains trace quantities of silver, gold and other metals. These are removed as ANODE RESIDUE and as slime on the bottom of electrolytic tanks. The copper precipitated on the cathodes is + 99.99% pure. This is then fabricated into wire, tubing, etc.

Reclamation

The final stage in the operation of most mines is *reclamation*, the process of closing a mine and recontouring, revegetating, and restoring the water and land values. The best time to begin the reclamation process of a mine is before the first excavations are initiated. In other words, mine planning engineers should plan the mine so that the reclamation process is considered and the overall cost of mining plus reclamation is minimized, not just the cost of mining itself. The new philosophy in the mining industry is *sustainability*, that is, the meeting of economic and environmental needs of the present while enhancing the ability of future generations to meet their own needs (National Mining Association, 1998).

In planning for the reclamation of any given mine, there are many concerns that must be addressed. The first of these is the safety of the mine site, particularly if the area is open to the general public. The removal of office buildings, processing facilities, transportation equipment, utilities, and other surface structures must generally be accomplished. The mining company is then required to seal all mine shafts, adits, and other openings that may present physical hazards. Any existing highwalls or other geologic structures may require mitigation to prevent injuries or death due to geologic failures.

The second major issue to be addressed during reclamation of a mine site is restoration of the land surface, the water quality, and the waste disposal areas so that long-term water pollution, soil erosion, dust generation, or vegetation problems do not occur. The restoration of native plants is often a very important part of this process, as the plants help build a stable soil structure and naturalize the area. It may be necessary to carefully place any rock or tailings with acid-producing properties in locations where rainfall has little effect on the material and acid production is minimized. The same may be true of certain of the heavy metals that pollute streams. Planning of the waste dumps, tailings ponds, and other disturbed areas will help prevent pollution problems, but remediation work may also be necessary to complete the reclamation stage of mining and satisfy the regulatory agencies.

The final concern of the mine planning engineer may be the subsequent use of the land after mining is completed. Old mine sites have been converted to wildlife refuges, shopping malls, golf courses, airports, lakes, underground storage facilities, real estate developments, solid waste disposal areas, and other uses that can benefit society. By planning the mine for a subsequent development, mine planners can enhance the value of the mined land and help convert it to a use that the public will consider favorable. The successful completion of the reclamation of a mine will enhance public opinion of the mining industry and keep the mining company in the good graces of the regulatory agencies.

The fifth stage of the mine is thus of paramount importance and should be planned at the earliest possible time in the life of the mine.

Terms and definitions

Evaluation terms

Conduct resource estimation to mathematically estimate the size and grade of the deposit

Conduct a pre-feasibility study to determine the theoretical economics of the ore deposit. This identifies, early on, whether further investment in estimation and engineering studies is warranted and identifies key risks and areas for further work. Conduct a feasibility study to evaluate the financial viability, technical and financial risks and robustness of the project and make a decision as whether to develop or walk away from a proposed mine project. This includes mine planning to evaluate the economically recoverable portion of the deposit, the metallurgy and ore recoverability, marketability and payability of the ore concentrates, engineering, milling and infrastructure costs, finance and equity requirements and a cradle to grave analysis of the possible mine, from the initial excavation all the way through to reclamation.

BLOCK ESTIMATE METHODS

They base on block models of a mineral deposit, either on bench by bench (2D) models or on real 3D models. The deposit space is subdivided into a matrix of blocks whose dimensions are governed by the mining method chosen as well as the geology and the sampling network of the deposit. If the blocks are similar in size and shape, any 2D spatial statistics can be used to interpolate blocks bench by bench while benches may be defined in three different directions (XY, XZ, YZ). Real 3D models demand, respectively, 3D statistics which is much more difficult to handle than the former. On the other hand, when properly applied, they give better results.

CUTTING FACTOR

Cutting factor is the highest metal assay accepted in resource/reserve estimates. Any individual assay value above the cutting factor is reduced to the latter. The cutting factor either base on the experience gained through the mining and processing of the same or similar type material, as is the target ore, or it is based on mathematical reasoning. Cutting factor is comparable to the 'nugget effect' and, similarly, used for gold ore estimates. There should not be anything like that but, due to inadequate sampling or sample preparation, measured values must be reduced.

CORE LOSS (/ core recovery)

Soft, non-coherent rock may flow out from the hole leaving empty spaces in between hard rock samples. These spaces are core loss. Core loss locations should be marked accurately as if they were samples. Core loss data may lead to important structural information. Statistical core loss is usually expressed in percentages per meter or per hole. Sometimes core recovery is used instead of core loss. It means the amount of core in percentages that has been collected.

MINERAL OCCURRENCE (mineral showing)

Mineral enrichment not quantified nor otherwise evaluated. Also: a minor mineral deposit of no or minimum value, though possibly prognostically interesting.

MINERAL RESOURCE (measured, indicated, inferred)

A mineral resource is an accumulation of material of intrinsic economic interest in such form and quantity that economic exploration of a mineral from the deposit may be feasible.

A measured mineral resource has been explored, sampled and tested (lab. scale) through appropriate techniques with observations and samples spaced closely enough to confirm geological continuity. The data should allow tonnage/volume, densities, size, shape, quality, mineral content and grades to be estimated with a high level of certainty.

An indicated mineral resource is defined like above except that samples are too widely spaced to confirm geological continuity but they are spaced closely enough to assume geological continuity.

An inferred mineral resource is indirectly or, without systematic sampling, assumed to be a part of a total mineral resource.

COUNTRY ROCK (wall rock, mother rock)

Country rock means the rock next to the ore and its host, or the rock enclosing or traversed by a mineral deposit. Data of country rock is valuable since most of the dilution comes from country rock.

CUTOFF GRADE (analytical cutoff, geological cutoff, economic cutoff, monetary cutoff*)*

Economic cutoff grade means the lowest grade of mineralized material that qualifies as ore. Analytical cutoff means the lowest grade accepted to be *processed or estimated.* In a mine there may be a general cutoff grade for an element but several subcutoffs for subprocesses like one for blasting, one for loading, one for transporting further than 1 500 m, etc. These are economic cutoffs. Simultaneously they are analytical cutoffs. However, in a broad sense of this term, analytical cutoff may be a lower grade limit on any other but economic ground as well.

Cutoff grades are normally expressed in percentages of metal for base metals and in grams per metric tons or ounces per short ton for precious metals. Cutoff grades may be simple or compound. In cases where the number one metal (or rather the refinery) is clearly defined, all other metals can be included in the compound cutoff grade. It is then called an equivalent grade, for example (Wrigglesworth, 1995):

%Eq.Ni = %Ni + {(Cu price)* %Cu/(Ni price)}
%Eq.Zn = 1.6*Cu% + 0.1*Pb% + Ag/55 g/t - 2.5%.

The latter formula obviously contains some 'experience factors' (1.6, 0.1, 55 and 2.5). Normally the metal price referred cannot be a market price since very few mines sell their product, the concentrate, anywhere else but to a certain smelter or refinery. The real price for the product will be negotiated with the buyer of concentrates.

Instead of grades, used in analytical cutoff expressions, other terms may be used. In some cases, the lithological or structural constraints of an ore body are so clear that cutoff grades may be replaced by geological definitions. Mining or process technical reasons may lead to similar solutions.

Instead of grades, monetary units may be used. However, simple cutoff grades for each valuable metal or mineral should be the basis of resource and reserve estimates.

DILUTION (waste rock dilution)

Dilution may come from internal waste, planned waste (intentional dilution), accidental waste or geologic waste. Internal waste, when detected, is usually included at assay grade. Planned waste is what belongs to the stopes to be mined. It can be foreseen and thus it can be added to the ore reserve estimation at the assayed grade; it usually varies from 10 % to 40 %. Accidental waste is a surprise caused by cavings, slough, etc. It may be caused by the incomplete control on the rock mechanics of a mine or by unrecognized zones of weakness. Geologic waste is caused by the incomplete knowledge on the shape of ore bodies. Contacts are usually interpolated from drill hole to drill hole. What happens between holes is not necessarily easy to predict: a problem with sampling density! Technical reasons may lead to faulty conclusions. For example the sample positions, due to the inadequate or badly documented hole orientation, may not be true. Waste dilution is normally expressed using the formula:

Waste dilution = the percentage of waste in the feed.

EFFECTIVE GRADE

The apparent grade averaged to a deposit may be true but misleading. The effective grade is generally lower than the apparent one, seldom higher. The former is counted on the basis of the material that will be really enriched. All calculations of ore loss, dilution and recovery derive from the known effective grade. Since we usually concentrate minerals and not metals, we should pay attention to the analytics (and sampling, of course). If the samples are representative, they contain real ore material in quantities and ratios that correspond to the material to be fed in the concentration plant. Respectively, analyzing methods should be relevant. For example, Ni should be analyzed by bromine methanol method to not include silicate nickel in the grade.

Exploration terms

RECONNAISSANCE (identification of mineralized areas or zones)

The process of narrowing down areas of enhanced mineral potential on a regional scale based primarily on airborne and indirect methods, preliminary field inspection as well as geological inference and extrapolation. The objective is to identify mineralized areas for further investigation towards prospect identification.

PROSPECTION (target identification)

It is the systematic process of searching for an unknown deposit based on geologic inference and/or postulation of extensions of known deposits, by outcrop identification and indirect methods. The objective is the discovery of a prospect that will be the target for further exploration.

GENERAL EXPLORATION (preliminary target investigation, screening)

It involves the initial delineation of an identified target mostly by surface mapping, loose-grid sampling (drilling), and limited interpolation based on indirect methods of investigation, to establish general geological features and to provide an initial estimate of size, shape and grade. Results are adequate for deciding whether detailed exploration is warranted.

DETAILED EXPLORATION (inventory drilling)

This includes the three dimensional delineation and sampling of a known target from outcrops, trenches, a systematic set of boreholes, from shafts and tunnels, including bulk sampling (pilot mining) for processing tests (pilot tests). The sampling grid is spaced so closely that size, shape, grade and other relevant characteristics of the target are established with a high degree of accuracy and in sufficient detail for mine planning.

EXPLORATION INFORMATION (mineral potential)

Information that results from activities designed to locate mineral deposits. This includes regional information and information of any non-minable mineral occurrences. It may be also called mineral potential if it is considered worthy of further investigation. Drilling-

Diamond: drilling with a hollow bit with a diamond cutting rim to produce a cylindrical core that is used for geological study and assays. Used in minerals exploration.

Infill: diamond drilling at shorter intervals between existing holes, used to provide greater geological detail and to help establish reserve estimates.

Reverse circulation: drilling that produces rock chips rather than core; the chips are forced by air to the surface and are collected for examination and analysis. Faster and cheaper than diamond drilling.

Exploration: prospecting, sampling, mapping, diamond drilling and other work involved in searching for ore.

Grade: the amount of valuable mineral in each ton of ore, expressed as troy ounces per ton or grams per tonne for precious metals and as a percentage for other metals.

Cut-off grade: the minimum metal grade at which an orebody can be economically mined.

Feed is the mined material that is transported to the concentration plant for enrichment. In practice an ore reserve estimate means a grade and tonnage estimate of the average feed(s). GANGUE (matrix)

The valueless rock in a ore body or in an ore sample.

HOST ROCK

The rock hosting an ore: especially with low-grade ores host rock and its properties are important to know and to control.

MINERAL DEPOSIT

A general name for an outlinable and quantifiable natural mineral enrichment possibly of economic value.

MINIMUM MINING DIMENSIONS (width, height)

Minimum dimensions depend on the mining technique chosen and they may vary from deposit to deposit or even from body to body in a single deposit. They are expressed as horizontal and vertical widths or heights. When expressing deposit dimensions geologists often use true dimensions. However, if a deposit is not horizontal or vertical but inclined, this may lead to different results in estimates. It usually means ore loss and waste rock dilution to change the reference system from that of the true deposit to the horizontal or vertical structures demanded by a mining operation.

NUGGET

Technically, nugget is the name for the departing of the modeled variogram curve from the origin (or the zero point). In practice it means a lowered reliability of sample analyses due to the uneven or sparse distribution and/or large grain size of minerals hosting assayed elements. Nugget was first recognized when analyzing gold samples - and it was explained to be caused by the nuggety appearance of gold in large and random grains. Nugget or 'the nugget effect' may give a measure to optimize geological sampling or sample preparation.

ORE

Economically valuable enrichment of mineral(s). Also: mineralized rock type that is typical to economic mineral deposits.

OREBODY

A three dimensional continuous mass of ore, either an ore deposit or an outlined part of an ore deposit. Also: a technically definable unit of an ore deposit.

ORE LOSS

The part of an orebody (in percentages) that is not blasted or loaded during a mining process. Usually this happens because of unexpected outlines of ore or as a consequence of unsuccessful blasting. Instead of ore loss, ore recovery may be used.

ORE MINERAL

The essential, and usually smallest constituent of ore to be enriched.

ORE RESERVE (proved, probable)

The economically minable part of a mineral resource, inclusive of diluting materials and allowing for losses.

A proved ore reserve is that part of measured mineral resource that can be exploited.

A probable ore reserve is that part of measured or indicated mineral resource that can be exploited under appropriate technical and economic conditions.

ORE VALUE

Ore value is the value of mineral concentrate per ore ton. The price or value of concentrate depends on the agreement between mine and refinery (smelter).

PARAMETER (factor, coefficient, 'experience factor')

'Quantity constant in case considered, but varying in different cases' (Fowler's, 1989). Other terms related to 'parameter' are 'factor' and 'coefficient'. Parameter is usually a mathematically derived number but in geology there are several 'experience factors'.

POLYGON ESTIMATE METHODS (triangulation)

The grade and thickness of each hole penetrating a plane can be assigned to an irregular polygon. These are assumed to remain constant throughout the area of the polygon that can be defined on the basis of perpendicular bisectors or angular bisectors.

RECOVERY (mining recovery, concentration recovery, metallurgical recovery)

The percentage of valuable minerals derived from an ore at a stage of mining: blasting R, loading R, concentration R, smelter R, etc. Mining recovery usually covers most of these phases and defines the recovery of a mineral derived into a concentrate.

RESOLUTION (GIS, graphic presentations)

The level of object detail or sharpness determined by how many picture elements compose an area of a display or corresponding raster. Ground resolution is the limit of detail clarity in an image of the earth's surface.

SECTIONAL ESTIMATE METHODS (linear and standard sectional methods)

Prospecting or Exploration to find and then define the extent and value of ore where it is located ("ore body")

Ore*:* a mineral deposit that has sufficient utility and value to be mined at a profit.

Gangue: the valueless mineral particles within an ore deposit that must be discarded.