The main stages of mining project

First stage is to inspect the locations to find the type of minerals present at that location which is called **prospecting**.

Once the minerals are found, the quantity of the minerals, depth of the deposit and the surroundings of the mineral can be investigated which is known as **exploration**.

To reach the deposit, a pathway needs to be prepared which can be removal of overburden or declines or shafts and crosscuts which is known as **development**.

The most important stage of the mine life is **exploitation** of the mineral i.e. extraction of the mineral which can be done by several methods.

While the cooking has only four stages, mining has fifth stage known as **reclamation** that is to fill up the area with other material such that there are no pot holes created or to make that useful.
<table>
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<tr>
<th>Stage (Project Name)</th>
<th>Procedure</th>
<th>Cost Unit Cost</th>
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| Prospecting (Mineral deposit) | 1 - 3 years | Search for ore  
a. Prospecting methods:  
  • Direct: physical, geologic  
  • Indirect: geophysical, geochemical  
b. Locate favorable loci (Maps, literature, old mines)  
c. Air: aerial photography, airborne geophysics,  
d. Surface: ground geophysics, geology  
e. Spot anomaly, analyze, Evaluate | $0.2 to 10 million  
Or  
$0.05 - 1.00 per ton |
| Exploration (Ore body) | 2 - 5 years | Defining extent and value of ore  
(examination/evaluation)  
a. Sample (drilling / excavation), assay, test  
b. Estimate tonnage and grade  
c. Valuate deposit (Hoskold formula or discount method)  
  Present value = income – cost  
  Feasibility study: Make decision to abandon or develop. | $1 to 15 million  
Or  
$0.20 - 1.50 per ton |
| Development | 2 - 5 years | Opening up ore deposit for production  
a. Acquire mining rights (purchase or lease)  
b. File environmental impact statement (EIS), technology assessment, permit  
c. Construct access roads, transport system  
d. Locate surface plant, construct facilities  
e. Excavate deposit (strip or sink shaft) | $10 to 500 million  
Or  
$0.25 - 10 per ton |
| Exploitation (Mine) | 10 - 30 years | Large-scale production of ore  
a. Factors in choice of method: geologic, geographic, economic, environmental, societal safety  
b. Types of mining methods: Surface: open pit, open cast, etc. Underground: room and pillar, block caving, etc.  
c. Monitor costs and economic payback (3 – 10 years) | $5 to 75 million per year  
Or  
$ 2 - 150 per ton |
| Reclamation (closure) | 1 - 10 years | Restoration of site  
a. Removal of plant and buildings  
b. Reclamation of waste and tailings dumps  
c. Monitoring of discharges | $1 to 20 million  
Or  
$ 0.2 - 4 per ton |
Prospecting:
It is the first stage in the utilization of a mineral deposit; it is the search for ores or other valuable minerals (coal or nonmetallic). Because mineral deposits may be located either at or below the surface of the earth. Both direct and indirect prospecting techniques are employed. It is general to find signs of the minerals in the locality or general indications by:

- Exposure of the mineral at the ground surface
- The topography relief
- Fragments of the mineral at the ground surface
- Traces of the ancient mine workings
- Vegetation
- Egress of underground water.

Direct method
The direct method of discovery, normally limited to surface deposits, consists of visual examination of either the exposure (outcrop) of the
deposit or the loose fragments (float) that have weathered away from the outcrop. Geologic studies of the entire area extend this simple, direct technique. By using of aerial photography, geologic maps, and structural assessment of an area, the geologist gathers evidence by direct methods to locate mineral deposits. Detailed mapping and structural analysis plus microscopic studies of samples also enable the geologist to locate the hidden as well as surface mineralization.

**Indirect method**

**Geophysics** is the most scientific search tool for hidden mineral deposits, the science of detecting anomalies using physical measurements of gravitational, seismic, magnetic, electrical, electromagnetic, and radiometric variables of the earth. The methods are applied as following:

- from the air, using aircraft and satellites;
- on the surface of the earth; and
- beneath the earth, using methods that probe below the topography.

**Geochemistry**, the quantitative analysis of soil, rock, and water samples, and geobotany, the analysis of plant growth patterns, can also be employed as prospecting tools.

**Remote sensing:** this includes aerial photography, side looking airborne radar (SLAR), false color infrared (IR) photography, thermal IR photography, and multi special scanning from satellites or high altitude aircraft. The use of such imagery is mainly to locate lineaments (distinct features) and their lengths and orientations. The lineaments located by means of such techniques should be always checked on ground, as there are many reasons for lineaments other than those associated with rock structure.
Geophysics is the branch of science which studies the physical properties of the Earth. In a typical geophysical survey, a physical property like the gravitational or magnetic field is measured on a grid of locations over the survey area. The value found at each grid position is plotted on a plan view or section views of the property and contour maps created. Geophysical exploration techniques involve many methods such as Resistivity, Induced polarization, Self-potential, Seismic, Magnetic, Electro magnetic, Gravity, Nuclear, Geothermal and Magneto-telluric.

In magnetic surveying, for example, the geophysicist measures the strength of the earth's magnetic field, which will vary locally depending on the amount of magnetic material in the underlying rocks. Where the rocks have high magnetic susceptibility the local magnetic field will be strong; where they have low magnetic susceptibility it will be weaker. Deposits with magnetic minerals – iron, pyrrhotite bearing nickel, and skarns – can be detected directly. Magnetic surveying can be used as an aid to geological mapping; units with higher susceptibility will show up as areas of high magnetic field strength.

In the method of resistivity, an electric current is generated and forced into the ground from widely spaced electrodes. The current flows through the earth to complete the circuit, and the amount of current that flows depends on the resistance the rock offers. This can be measured by probing the ground with pairs of electrodes connected to sensitive voltmeters. A conductive orebody containing economic metallic sulphides will cause an anomalously low resistance. So, too, will a fault lane lined with graphitic material, a barren sulphide, or a watercourse containing brackish solution. So results from this method must be interpreted using geological evidence.
The force of gravity, as other method, is not uniform over the whole surface of the earth; it is actually slightly stronger where the underlying rocks are denser, and slightly weaker where they are less dense. The difference is tiny, but it can be measured and mapped.

Gravity surveys use extremely sensitive balances to detect the variations in density of the underlying rocks. They can be useful in conducting a rapid reconnaissance survey of an area to delineate major rock types. This information can help to indicate areas favorable to exploration by other methods. They can also be used in more detailed exploration to detect mineral deposits, which are commonly denser than the rocks that surround them.
Exploration is the second stage in the life of a mine, determines as accurately as possible the size and value of a mineral deposit, utilizing techniques similar to but more refined than those used in prospecting. The line of demarcation between prospecting and exploration is not sharp. Exploration generally shifts to surface and subsurface locations, using a variety of measurements to obtain a more positive picture of the extent and grade of the ore body.

During this stage an attempt is made to establish some of these parameters:

- Area/location of the deposits and its shape
- Depth of deposits, dip and strike directions
- Thickness details
- Type of surrounding rocks i.e. as over burden, h/w, f/w.
- Grade, mineralogical and chemical composition
- Quantity and variation with respect to depth etc.

**Sampling:** Representative samples may be subjected to chemical, metallurgical, X ray, spectrographic, or radiometric evaluation techniques that enhance investigation of the mineral deposit. Samples are obtained by chipping outcrops, trenching, tunneling, and drilling; in addition, borehole logs may be provided to study the geologic and structural makeup of the deposit.

**Drilling:** Rotary, percussion, or diamond drills can be used for exploration purposes. However, diamond drills are favored because the cores they yield provide knowledge of the geologic structure. The core is normally split along its axis; one half is analyzed, and the other half is retained intact for further geologic study.

Core drilling is among the routine methods for subsurface exploration. The drilling often has multiple purposes, of which the following are in most cases the most important:

- Verification of the geological interpretation.
- To obtain more information on rock type boundaries and degree of weathering.
- To supplement information on orientation and character of weakness zones.
- To provide samples for laboratory analyses.
- Hydrogeological and/or geophysical testing.

In case of tunneling projects, the drilling often is carried out with the prime purpose to investigate major faults or weakness zones and ground water conditions of the opening.
**Analysis:** An evaluation of the samples enables the geologist or mining engineer to calculate the tonnage and grade, or richness, of the mineral deposit. They estimate the mining costs, evaluates the recovery of the valuable minerals, determine the environmental costs, and assess other foreseeable factors in an effort to reach a conclusion about the profitability of the mineral deposit. For an ore deposit, the overall process is called reserve estimation, that is, the examination and valuation of the ore body. At the conclusion of this stage, the project is developed, traded to another party, or abandoned.

In general exploration is collecting and generating information about grade, ore deposits, type of deposit and its size (tonnage). It helps to determine the promising ore deposits (by size) at present prevailing condition (size in millions of tons or in a fraction of million ton). Also it includes a Full detailed feasibility study ($1 – 10 M) contains full plan to mine, process and market the ore.

![Exploration Results Diagram]

**Exploration Results**

**Mineral Resource**
(classified on geological confidence)

- **Inferred**
  Limited sampling, low confidence about what's really there

- **Indicated**
  More sampling, more confidence, but still an estimate

- **Measured**
  Additional sampling, high confidence, estimate is accurate

**Ore Reserve**
(classified on geological confidence + certainty of modifying factors)

- **Probable**
  Some confidence in ore + some uncertainty in modifying factors

- **Proved**
  High confidence in ore + little uncertainty in modifying factors

**Increasing Economic Favorability**

Based on analysis of "modifying factors" including mining, metallurgical, economic, environmental, marketing, legal, political, and social considerations
In the third stage, development, the work of opening a mineral deposit for exploitation is performed. With it begins the actual mining of the deposit, now called the ore. Access to the deposit must be gained either (1) by stripping the overburden, which is the soil and/or rock covering the deposit, to expose the near-surface ore for mining or (2) by excavating openings from the surface to access more deeply buried deposits to prepare for underground mining.

In each case, certain preliminary development work, such as acquiring water and mineral rights, buying surface lands, arranging for financing, and preparing permit applications and an environmental impact statement (EIS), will generally be required before any development takes place.

When these steps have been achieved, the provision of a number of requirements (access roads, power sources, mineral transportation systems, mineral processing facilities, waste disposal areas, offices, and other support facilities) must precede actual mining in most cases.
Stripping of the overburden will then proceed if the minerals are to be mined at the surface. Economic considerations determine the stripping ratio, the ratio of waste removed to ore recovered; it may range from as high as 38 m/tonne for coal mines to as low as 0.8 m/tonne in metal mines. Some nonmetallic mines have no overburden to remove; the mineral is simply excavated at the surface.

Development for underground mining is generally more complex and expensive. It requires careful planning and layout of access openings for efficient mining, safety, and permanence.

The principal openings may be shafts, slopes, or adits; each must be planned to allow passage of workers, machines, ore, waste, air, water, and utilities.

Many metal mines are located along steeply dipping deposits and thus are opened from shafts, while drifts, winzes, and raises serve the production areas. Many coal and nonmetallic mines are found in nearly horizontal deposits. Their primary openings may be drifts or entries, which may be distinctly different from those of metal mines.
Exploitation

Exploitation is the fourth stage of mining; it is associated with the actual recovery of minerals from the earth in quantity. Although development may continue, the emphasis in the production stage is on production. Usually only enough development is done prior to exploitation to ensure that production, once started, can continue uninterrupted throughout the life of the mine.

The mining method selected for exploitation is determined mainly by the characteristics of the mineral deposit and the limits imposed by safety, technology, environmental concerns, and economics. Geologic conditions, such as the dip, shape, and strength of the ore and the surrounding rock, play a key role in selecting the method.

Traditional exploitation methods fall into two broad categories based on locale: surface or underground methods.
**Surface mining** includes mechanical excavation methods such as open pit and open cast (strip mining), and aqueous methods such as placer and solution mining.

**Underground mining** is usually classified in three categories of methods: unsupported, supported, and caving.
Blasting is an essential part of the mining cycle. In virtually all forms of mining, rock is broken by drilling and blasting the rock. Blasting technology is the process of fracturing material by the use of a calculated amount of explosive so that a predetermined volume of material is broken. From the earliest days of blasting with black powder, there have been steady developments in explosives, detonating and delaying techniques and in the understanding of the mechanics of rock breakage by explosives.

Good blast design and execution are essential to successful mining operations. Improper or poor practices in blasting can have a severely
negative impact on the economics of a mine. The use of excessive explosives at a mine site can result in damages to the rock structures and cause unwanted caving and large increases in support costs.

There are many different types of explosives used today. Many factors are taken into account when determining what type of blast design or explosive will be used. Rock type, density, and strength are all important factors, as well as fracture condition of the rock, and water conditions.

In underground mining, the truck-loader haulage system involves mucking of the material from the working face and transporting it to the dumping point where it is reloaded into trucks for further transportation. In some cases, trucks can be loaded directly at the working face or at a dumping point. Due to a limited size of the drifts and the ramps used in transporting material, the size of the haulage equipment is an important factor to consider when seeking to optimize the haulage system.

The transport system must be designed, considering the many other elements of the mining operation, and we must take into account the number of possible steps from the extraction site (stope/face) to the shaft or ramp portal.

Important factors that affect the selection of the materials and equipment transport system are as follows:

1. Quantity (volume, weight.) and size of materials and equipment.
2. Access method to the destination.
3. Transport roadway size (height and width).
4. Transport distance and transloading points.
5. Roadway conditions (gradient, undulation, soft floor...).
6. Relation to the personnel transport system.
Mineral processing (mineral dressing, mineral beneficiation)

Mineral processing is the art of treating crude ores and mineral products in order to separate the valuable minerals from the waste rock, or gangue. It is the first process that most ores undergo after mining in order to provide a more concentrated material for the procedures of extractive metallurgy. The primary operations are comminution (liberation) and concentration, but there are other important operations in a modern mineral processing plant, including sampling and analysis and dewatering.

Ore is an aggregate of minerals and contains valuable and gangue minerals. The mineral beneficiation involves separation of gangue minerals from ore. It has three steps, which are:

1. Liberation of valuable mineral by size reduction.
   Communion: crushing and grinding
2. Separation of coarse and fine particles.
3. Concentration to separate the gangue minerals to increase the metal grade.
Reclamation (closure)

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. Mine planning engineers should plan the mine so that the reclamation process is considered and the overall cost of mining plus reclamation is minimized.

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. Therefore, 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.

**Resorting is the second major issue** to be addressed during reclamation of a mine site. It includes:

- 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.
- 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.