

GGY 4119 – MINING GEOLOGY

GEOTECHNICAL, DE-WATERING AND ENVIRONMENTAL ISSUES IN MINING

Objective

- The student should be able to understand the various ground conditions arising from geological phenomenon
- Be able to remediate any hazards arising from such conditions, and ensure the safety of workers as well as machinery.

Acknowledgements

The contents of this presentation are mostly taken from articles published by the following scholars;

- Swart, A H (2005)
- Stacey (1968)

Introduction

- In any major mining operation, Geotechnics and De-watering are of prime importance.
- It is therefore crucial that detailed studies and understanding of these parameters is undertaken before any mining works are commenced.
- The Primary aim of understanding these parameters is to prevent Fall of Ground (FOG), which could potentially damage machinery and in worst case scenarios, be fatal.

Exploration

Resource Estimation

Mining

Closure

Geology



Laboratory



Survey



Geotech/Vent



Mining Eng



Metallurgy



Environmental



Ground conditions in mines

- In underground excavations and open pits, FOG is largely and frequently controlled by the presences of discontinuities
- The intersection of these structural features can trigger the release of rock blocks which can fall or slide from the surface of the excavation.
- Other factors controlling FOG are, but not limited to the following;

Factors governing ground conditions

- Geological Structure
- Groundwater conditions
- Strength of Discontinuities and Intact rock
- Rock stresses
- Pit Geometry including both slope angles and slope curvature
- Vibrations from blasting or seismic events
- Climatic conditions
- Time

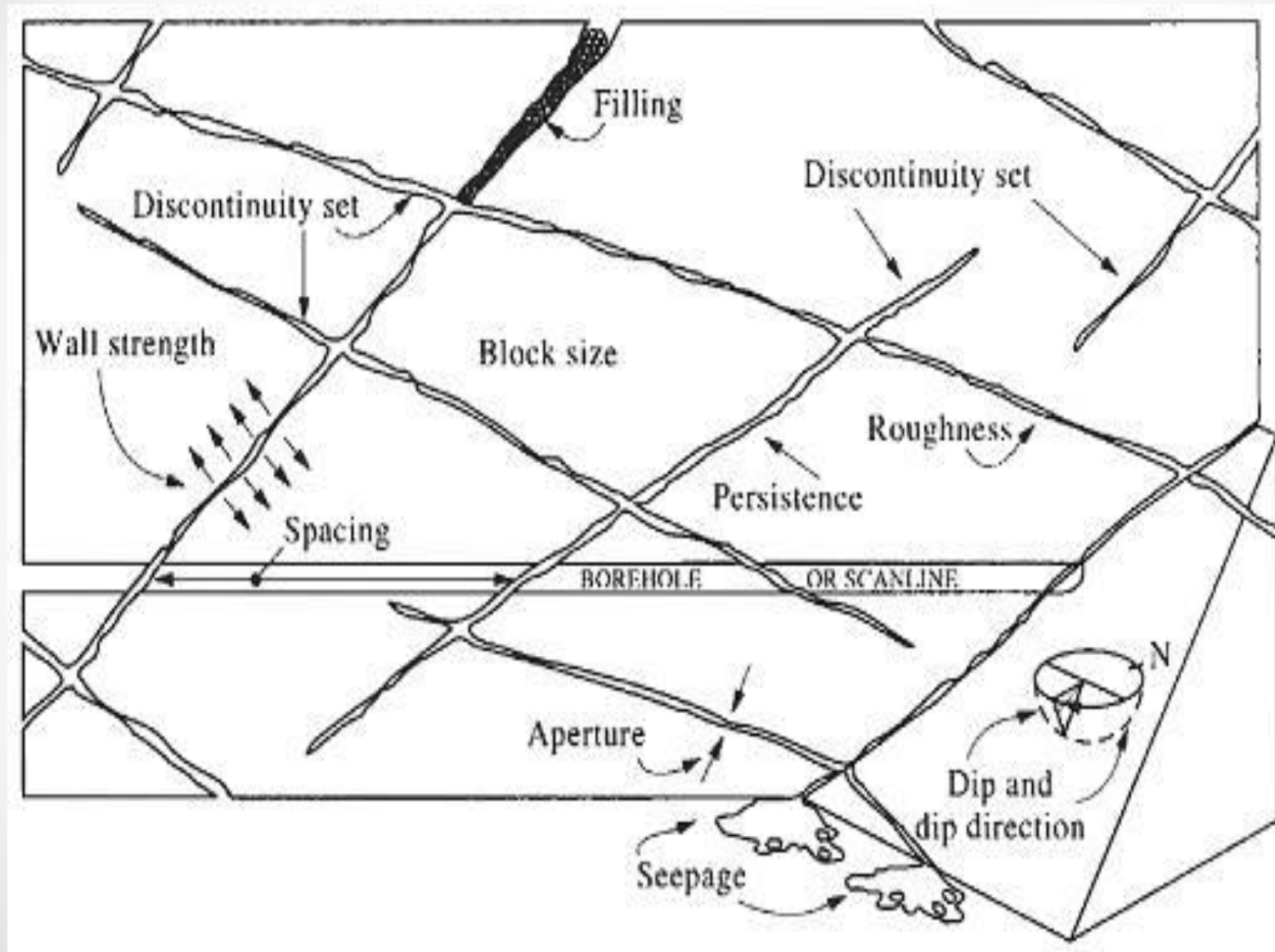
- In mining, there is greater scope for slope design variations, especially open-pit mining of large orebodies, because the whole mine geometry can be arranged to optimize the extraction conditions.
- Furthermore, mining slopes only have to be stable in so far as any instabilities do not inhibit the mining operations - which means that some forms of minor instabilities are acceptable

Geological structures

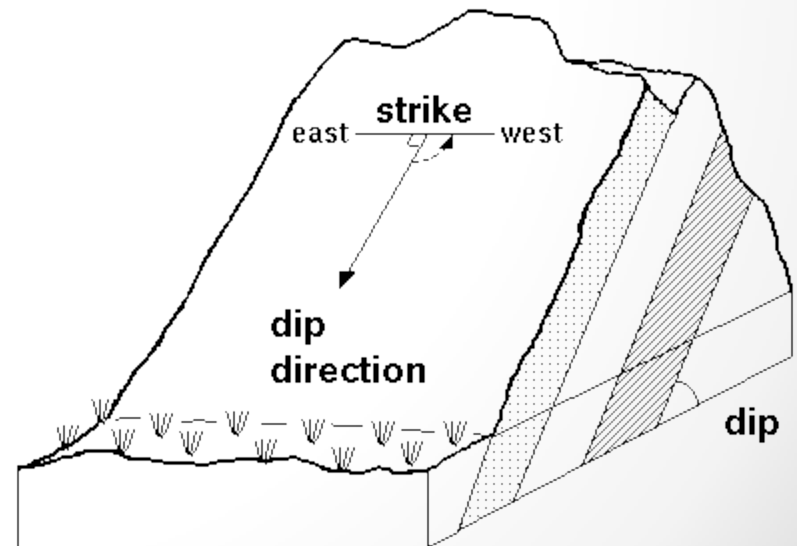
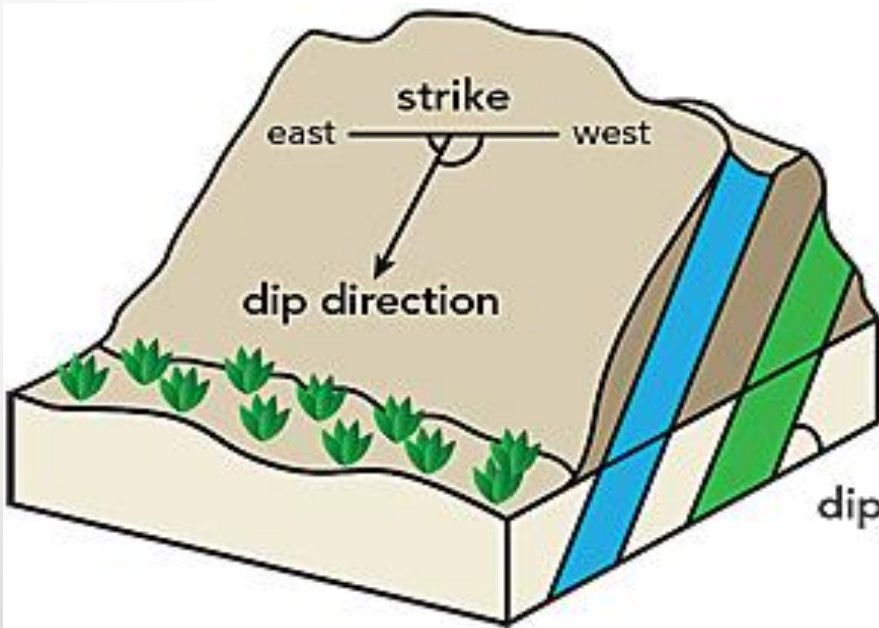
- It is obviously one the most important factors governing slope stability
- The term ‘Geological structures’ includes both rock type and the discontinuities which form the rock mass
- Discontinuities are present on virtually all scales, from microcracks (<10mm) to plate boundaries of the earths crust.
- Geological structure is dependent on rock type e.g. Parallel bedding in sedimentary rocks, schistosity and foliation in metamorphic rocks

- Geological structures have a range of characteristics including;
- Orientation – usually specified by dip angle and direction
- Spacing
- Persistence or continuity
- Roughness
- Wall strength
- Aperture
- Filling
- Seepage and
- Number of sets

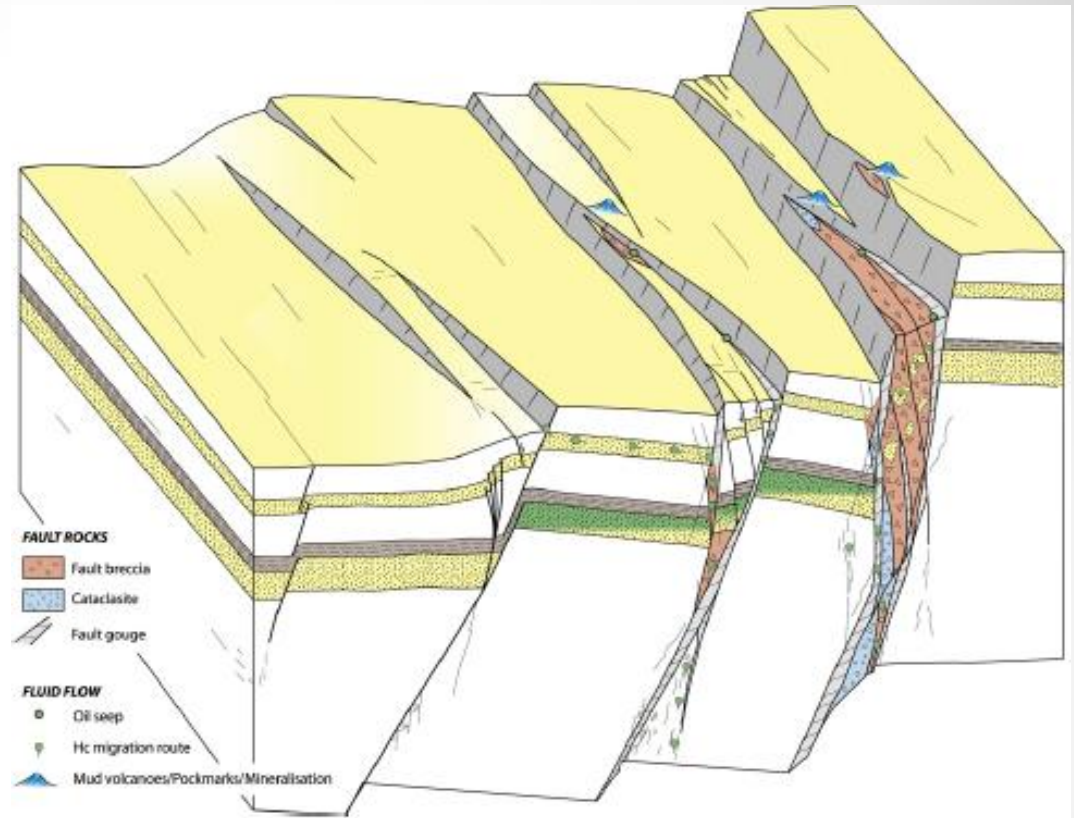
Structural characteristics



- **Orientation** – usually specified by strike, dip angle and direction.
- Strike is the direction of the imaginary line which would represent the intersection between the plane and a horizontal surface
- Dip angle (Dip) is the angle of inclination of the plane.
- Dip direction is just the direction toward which the plane is inclined.



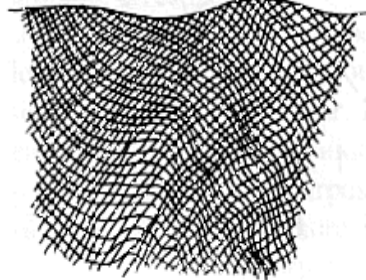
- *Spacing*
- This has to do with the relative distance between respective structures



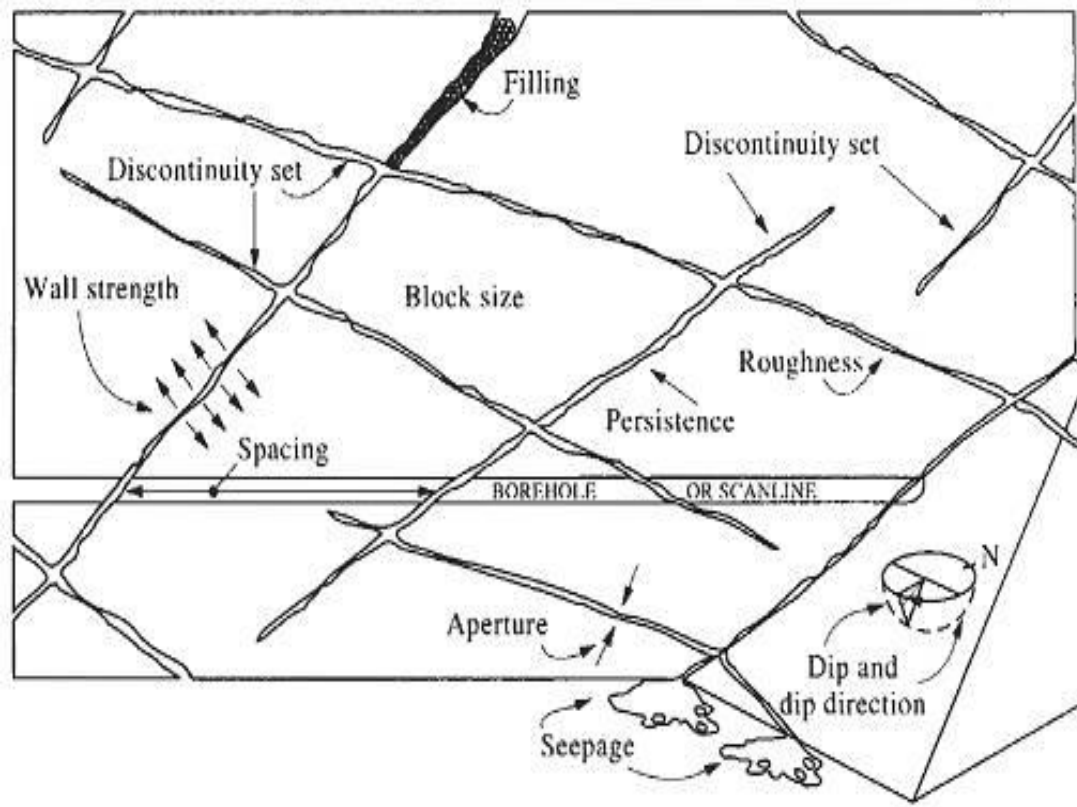
WIDELY SPACED JOINTS



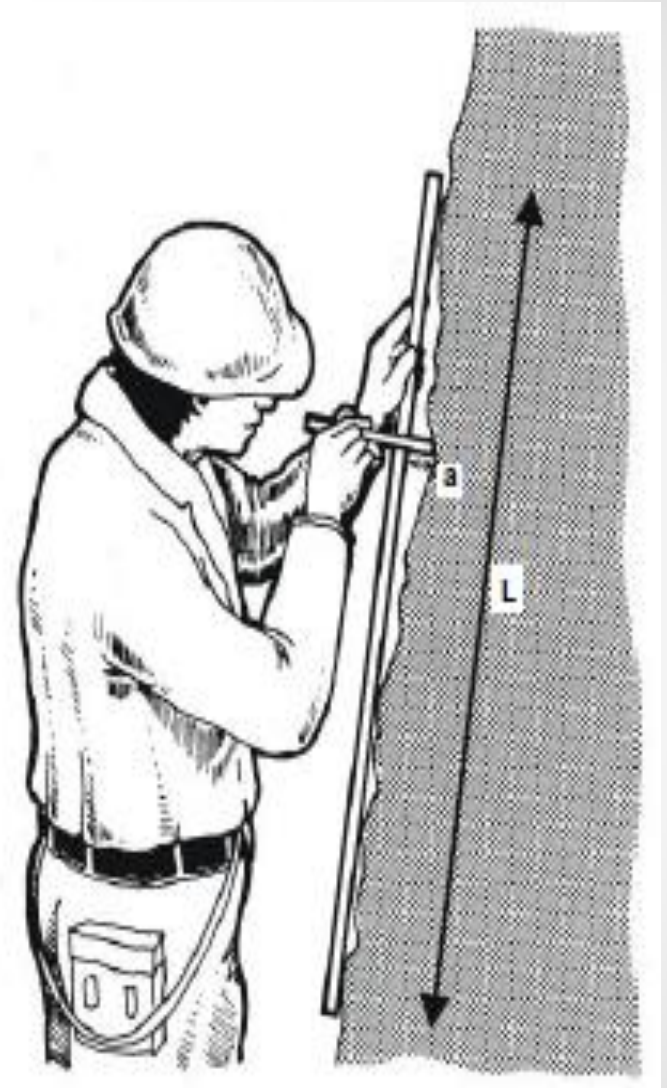
CLOSELY SPACED JOINTS



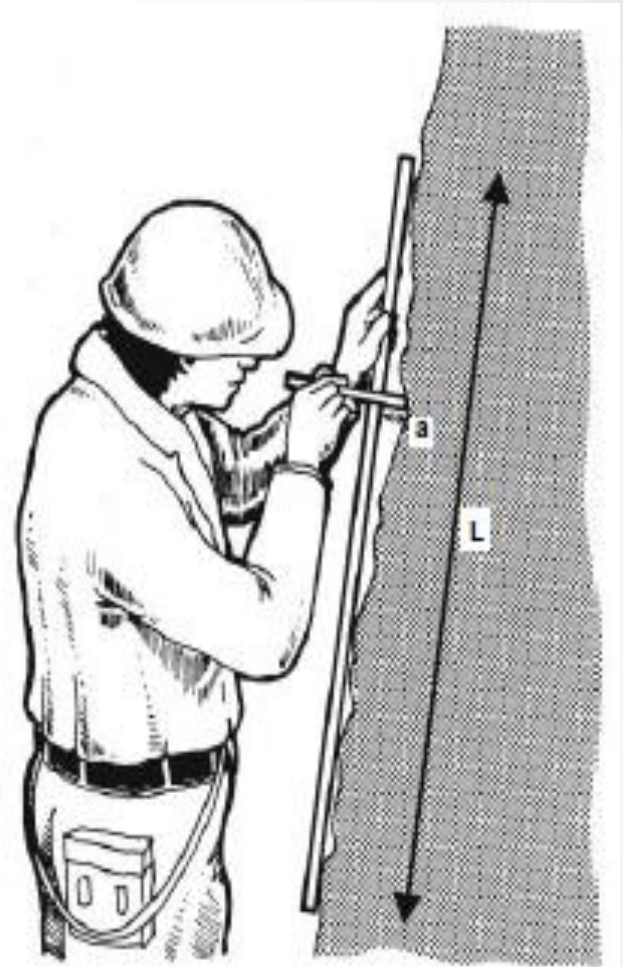
- *Persistence or continuity*
- Joint continuity is divided into two main groups:
 - continuous or persistent joints that terminate against other joints
 - discontinuous joints that terminate in massive rock.



- ***Roughness***
- Roughness is a measurement of the inherent surface unevenness and waviness of the discontinuity related to its mean plane
- It includes the condition of the joint wall surface both for filled and unfilled (clean) joints.

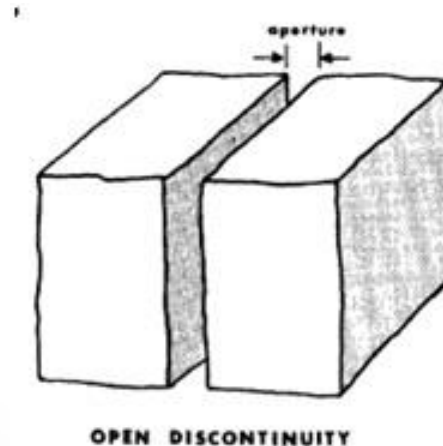


- *Wall strength*
- In case where the roughness coefficient is low the compressive wall strength has greater role in the stability of geological structures while a higher roughness coefficient implies the compressive wall strength has greater role in destabilising the structures.

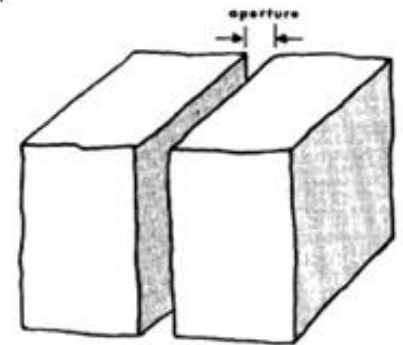


- ***Aperture***

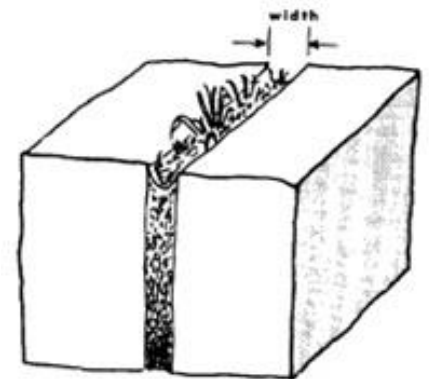
- The aperture of a joint is the space between its two walls measured perpendicularly to the mean plane.
- Apertures can be open (resulting in permeability enhancement) or occluded by mineral cement (resulting in permeability reduction).
- Aperture is an important parameter for estimating the *hydraulic conductivity* of the rock mass and the shear strength of the discontinuities



- ***Filling***
- All materials occurring between the fracture walls are referred to as filling. The term includes in-situ weathered materials, fault zone materials (gouge) and foreign materials either deposited or intruded between the structure surfaces.
- A filling can consist of several different minerals and materials. The main groups are:
 - Hard and resistant minerals (quartz, epidote and serpentine)
 - Soft minerals (clay, chlorite, talc and graphite)
 - Soluble minerals (calcite, gypsum)
 - Swelling minerals (swelling clays (smectites), anhydrite)
 - Loose materials (silt, sand and gravel)



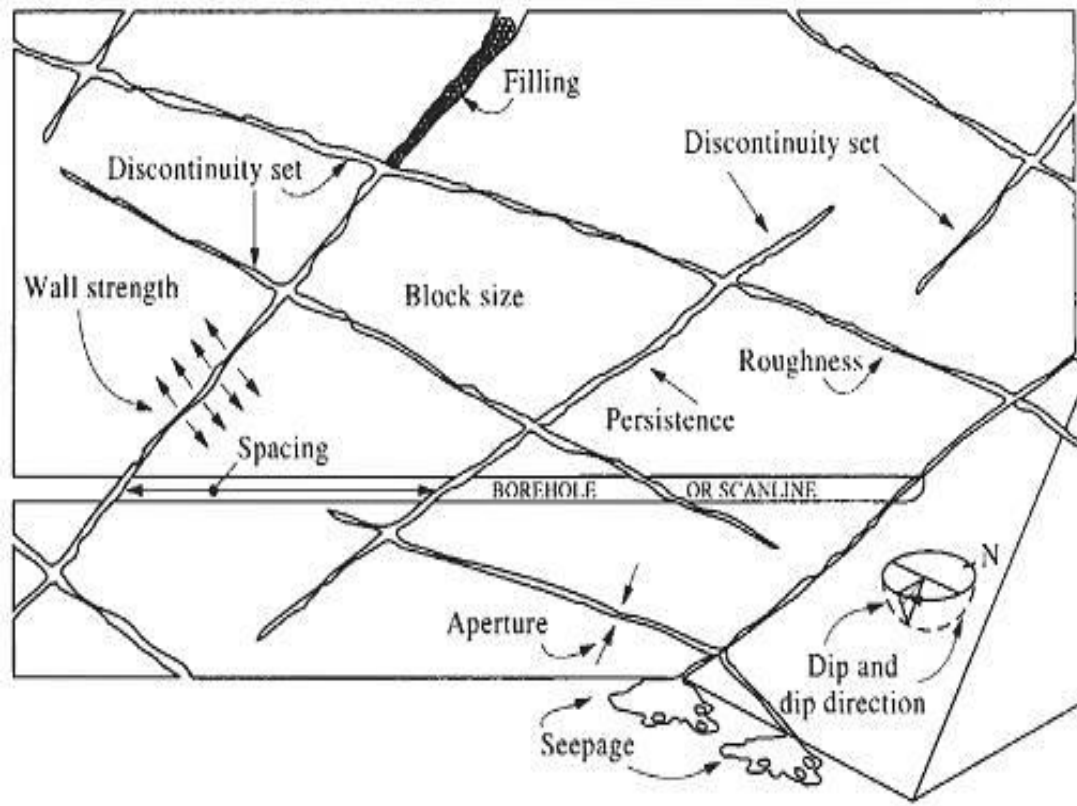
OPEN DISCONTINUITY



FILLED DISCONTINUITY

- Seepage

- *Number of sets*
- A set is a group of structures (joints) with similar orientation and morphology.
- Two or more sets of joints present together in an exposure compose a joint system



- Discontinuities are defined by such features as Bedding planes , Joints , Faults , Foliation , Fractures etc.
- These affect geotechnics in that they affect the rock quality designation.
- Mathematically the RQD is got as follows:
- $RQD = \text{length of core sticks} > 10\text{cm} / \text{length of core run}$

Examples – u know them, u r geos

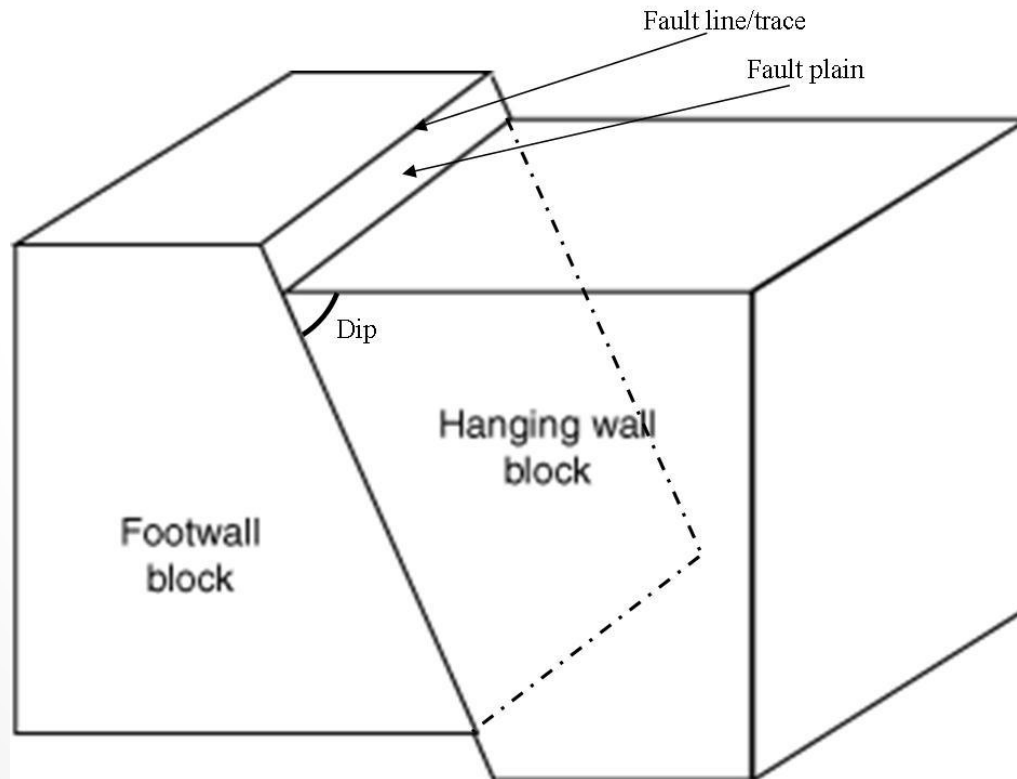
- JOINTS - A break (fracture) of natural origin in the continuity of a mass of rock that lacks any visible measurable movement.



- Joints result from the brittle fracture of a rock as the result of tensile stresses
- Tensile stress is either induced or imposed from outside
- Or from internal stresses induced by the shrinkage
- Joints often form discontinuities that may have a large influence on the mechanical behaviour of rock masses in mine constructions (underground excavations and slope construction), and as a result are an important part of geotechnical engineering.

Examples

- **FAULTS** - Faults are raptures in the earth's crust along which the opposite walls have moved relative to each other.



Groundwater conditions

- The stability of a slope/excavation is also dependent upon the groundwater conditions - water below the surface
- The hydrogeological environment of a mine should be understood to an appropriate level of detail
- The presence of groundwater in rock slopes results in varying groundwater pressure distribution throughout the slope
- The stress state at a point in the rock mass is governed by;
Principle stress + Water pressure
- Since the water pressure is equal in all directions, it acts to reduce the effective stress at a point in a rock mass

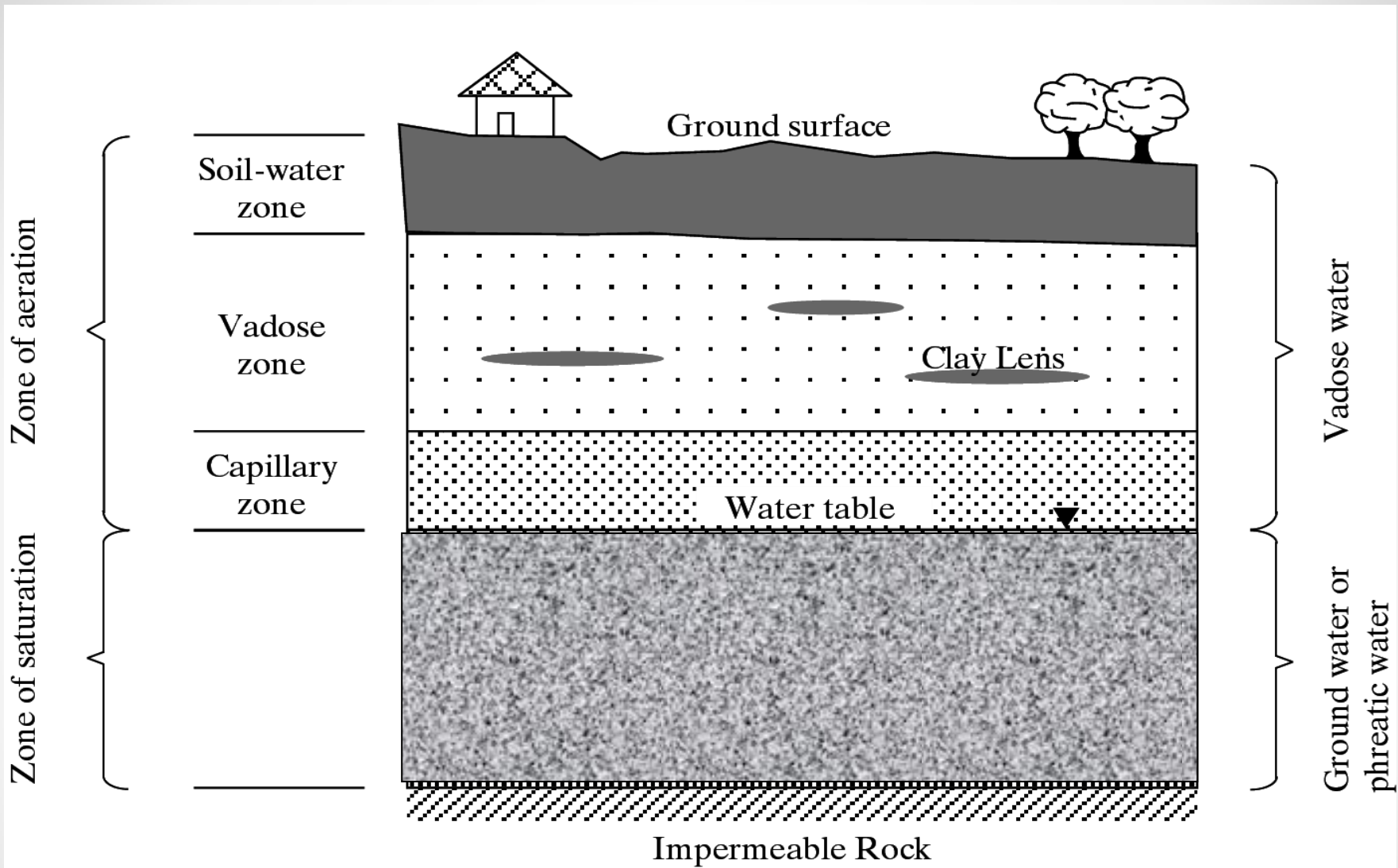
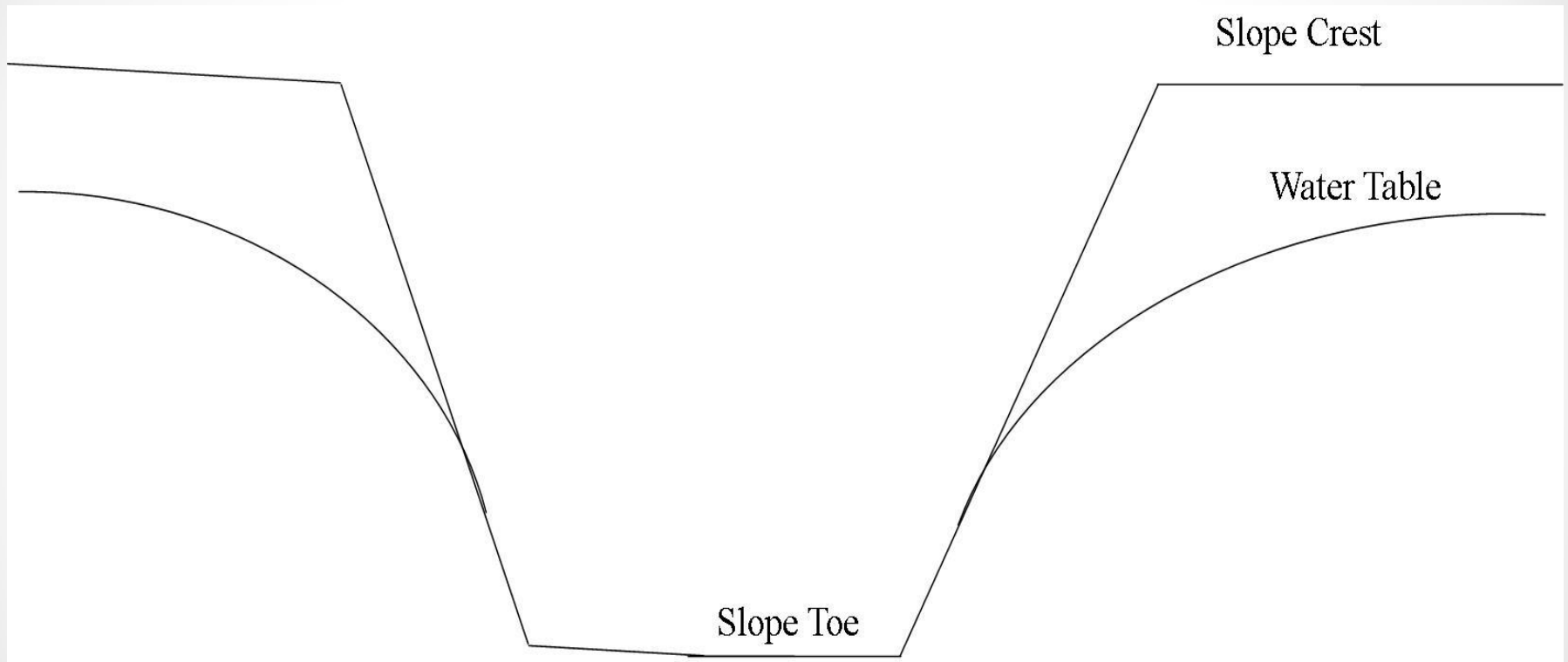


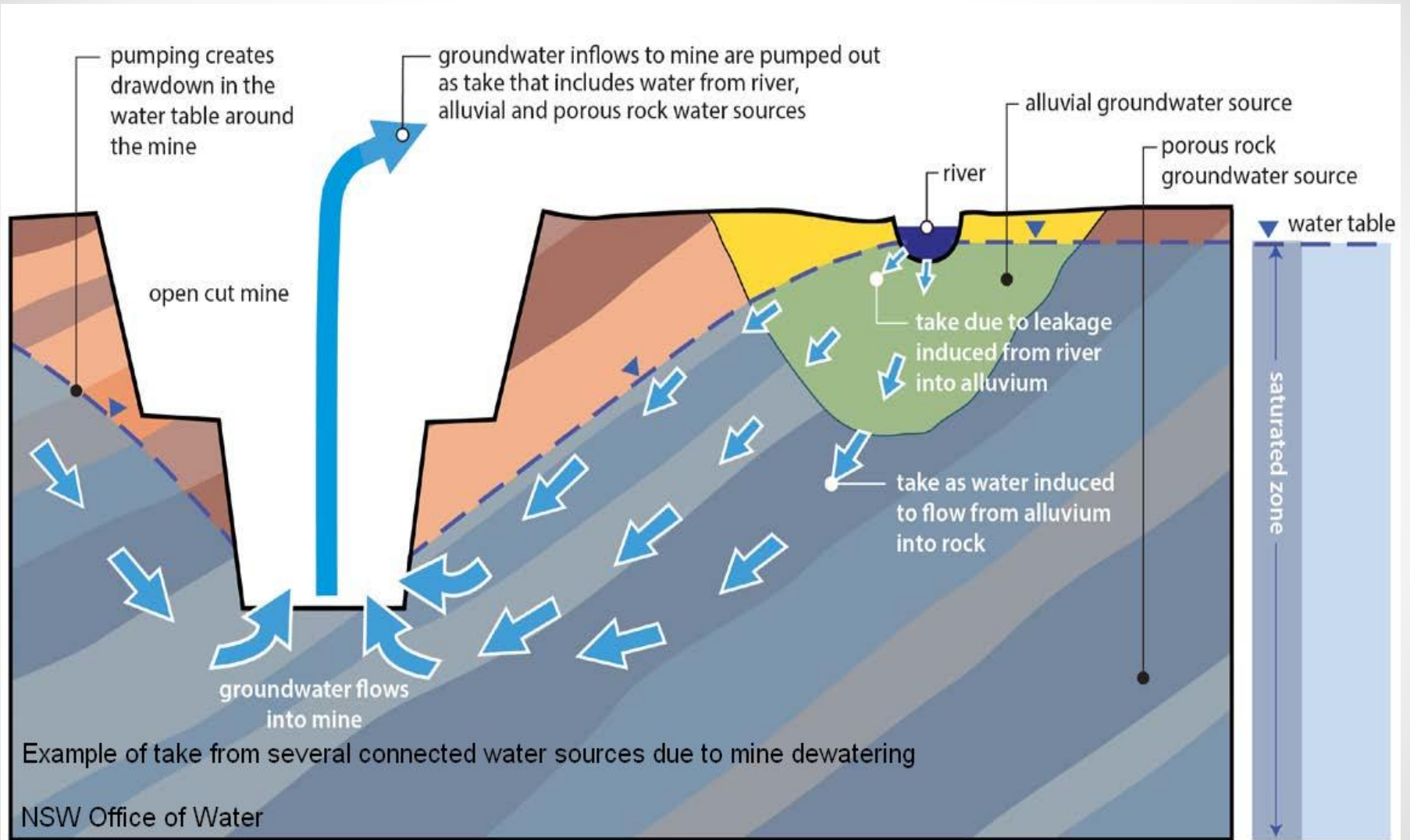
Figure 8.3

Vertical zones of subsurface water.

Groundwater conditions



Drawdown due to mining of an open pit



JTN 12268-3

You don't want to be fired for this



This is acceptable



DE-WATERING

- De-watering involves removal of water from mine operation sites for continuity of production.
- It involves studying in-pit water inflows and their sources.
- After these studies , a suitable de-watering method is suggested and used.

Open pit/Underground water inflows

- Mining activities are usually done below the water table hence groundwater flows into the production areas
- Rain water also contributes to flooding in the mines
- Rivers near the mine also contribute as water from the river seeps through the fractures and other discontinuities to the production site

So...how do you deal with this problem??..Strategies

- Map all aquifers both in the pit and outside
- Undertake aquifer pump test
- Undertake geophysical investigations to delineate fractures/discontinuity zones; possible flow routes of water
- Design dewatering and water management plan
- Hydrogeological conceptual model

Analysis and remediation

- The ultimate aim is to prevent any accidents that could arise from FOG.
- The analysis of ground stability depends on;
- Correct interpretation of structural geology (discontinuities)
- Thorough investigation and analysis of geological structure is vital to a good understanding of the major influence that geological structure exert in determining the ground conditions in mining.
- Identification of potential unstable blocks or wedges
- Analysis of the stability of the blocks and wedges which can be released by the creation of the excavation

- Analysis of the reinforcements required to stabilise these blocks and wedges.
- Ground control may be considered to be made up of three main components;
- Ground conditions
- Mine planning and design; and
- Ground support and reinforcement.
- Put simply;

Ground Control = Ground Conditions + Mine planning and design + Ground support and reinforcement

ENVIRONMENT

- Environmental protection is extremely important to as all mining activities produce waste
- This starts with planning of mine waste disposal in the very early stages of mine development
- Before any mining activity commences, an EIA (environmental impact assessment) is done
- This is done in order to plan ahead in terms of mine waste disposal and environmental protection in general

- The waste produced by the mines is in form of overburden , toxic gas emissions such as SO_2 , fluid emissions into rivers and dust emissions .
- Mine dumps have to be located away from the production areas where exploration has already been done and no economic minerals found in that area.
- Air or gaseous emissions have to be screened and purified before release to the atmosphere.
- Fluid emissions from the Metallurgical plants have also to be screened and treated before release to streams.

- Fluid emissions from underground and open pit operations(mud) are pumped out and directed into the tailings dams located far away from the plant area on Mineralogically uneconomic land
- Soil contamination has to be kept at its minimal so that the land can be used for other purposes such as Agriculture.
- Land reclamation after mining activities have ceased has to be done to make the land productive .
- Cave-in areas have to be cordoned to prevent people using these areas