1. Rock Mechanics and mining engineering

1.1 General concepts

- Rock mechanics is

  the theoretical and applied science of the mechanical behavior of rock and rock masses; it is that branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment.

By US National Committee on Rock Mechanics (1964 & 1974)

1.1 General concepts

- Geomechanics is

  the application of engineering and geological principles to the behavior of the ground and ground water and the use of these principles in civil, mining, offshore and environmental engineering in the widest sense.

By the Australian Geomechanics Society

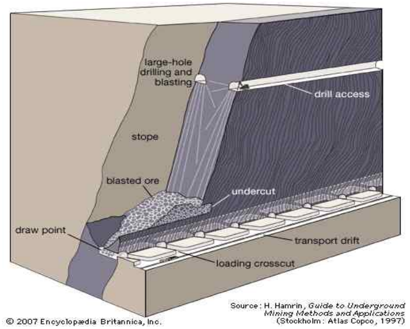
1.1 General concepts

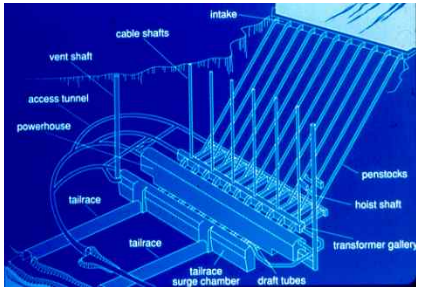
- Geotechnical engineering is

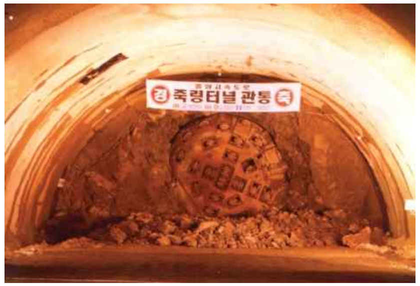
  the application of the sciences of soil mechanics and rock mechanics, engineering geology and other related disciplines to civil engineering construction, the extractive industries and the preservation and enhancement of the environment.

By Anon (1999)

Application of rock mechanics







응용 분야	활용 시설 유형과 세부 분야
자원개발	지하채광 : 수갱, 사갱, 수평갱도, 주운반 갱도 설계 각종 채굴법 설계(주방식, 장벽식, 붕락식) 노천채광 : 사면의 안정 우주개발 (NASA Project)
석유개발	시추공정, 수압파쇄(2차 채유), 오일 셰일 채광
수자원 및 에너지 저장, 개발	댐, 지하 발전소(수력, 양수, 원자력), 원유와 액화가스의 지하저장, 압축공기, 방사능 폐기물 지하 보관, 지열 개발, 열저장 및 지역 냉난방
교통, 수송	고속도로(도로) 터널, 고속철도(철도) 터널 도시지하철 및 정거장, 지하 주차장
사회 공공시설	용수로 터널, 폐.하수로 터널 및 지하 폐.하수 처리장 송배전 및 통신 케이블 터널, 산업 폐기물 처리장
식품.농수산	지하 냉동. 냉장 저장소, 지하 저온 저장소
군사시설	전략 미사일 지하기지, 지하방어(지휘, 통신, 대피)시설
주거.문화	지하 또는 반지하 주택, 지하상가, 사무실, 창고, 음악당 박물관, 스포츠센터

1.1 General concepts

- Application of rock mechanics to (underground) mine engineering : premises

1) a rock mass can be ascribed a set of mechanical properties which can be measured in standard test or estimated using well-established techniques.

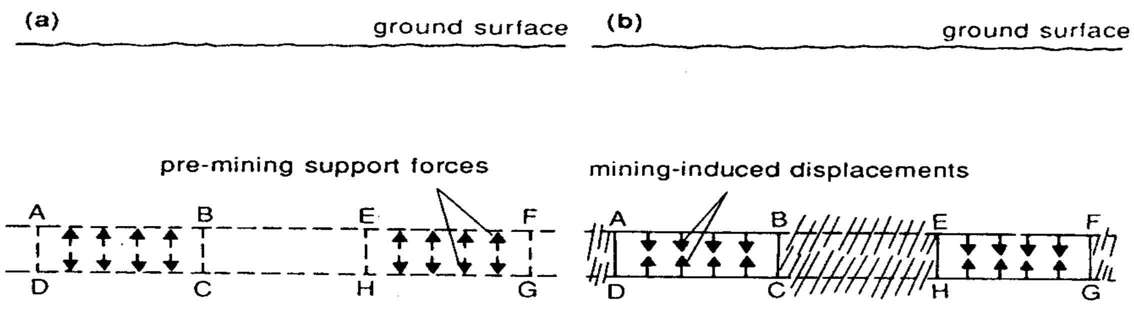
2) the process of underground mining generates a rock structure consisting of voids, support elements and abutment; mechanical performance of the structure is amenable to analysis using the principles of classical mechanics.

1.1 General concepts

3) the capacity to predict and control the mechanical performance of the host rock mass in which mining proceeds can assure or enhance the safe and economic performance of the mine.

1.1 General concepts

- Mechanical process during underground mining



- Before excavation: in-situ/initial state stress
- Excavation: perturbation/concentration of stress in pillars
- Deformation: strain energy = stress × strain
- Displacement/fracture/slip/collapse (sudden release of potential energy)

1.1 General concepts

- Ultimate objective in the design of a mine structure in a geomechanical point of view is to control rock displacements into and around mine excavations.

- To achieve such objective we should know about

- Strength and deformation properties of orebody and adjacent rock
- Geological structure of rock mass: geometrical and mechanical properties
- Groundwater pressure distribution
- Analytical techniques to evaluate the response of rock mass

…..recently available (from about 40 years ago)

1.1 General concepts

- Factors contributed to the recent emergence of rock mechanics as a mining science are

- Increased dimension of mines: increased possibility of failure
- Requirement for improved profitability
- Unfavorable mining environments: increasing depth
- Resource conservation and industrial safety: maximizing the recovery from mines

- Difference between rock mechanics and soil mechanics

- Failure process of materials: fracture (crack) generation
- Stress condition: relatively high/low
- Mechanical properties: strength, deformation modulus, permeability, etc.

…. should be regarded as complementary rather than mutually inclusive

1.2 Inherent complexities in rock mechanics

1) Rock fracture

- Fractures occur in a tensile stress field.
- Stress fields are pervasively compressive.
- Friction intervenes in failure process.
- Strength of rock is highly sensitive to confining pressure.

2) Scale effect

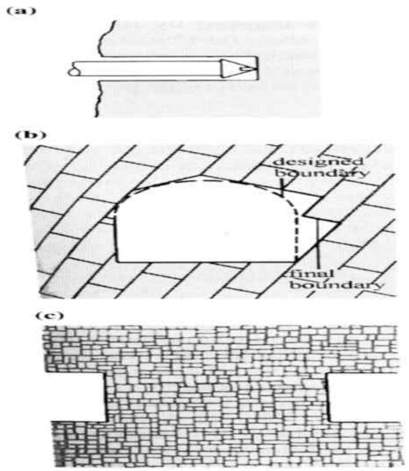
- Response of rock mass to imposed load is affected by the scale (size) of the loaded volume:

  Drilling – intact rock;

  Tunnel in a jointed rock mass – joint surface;

  Large mine pillar – rock + joint

  (pseudo-continuum)



1.2 Inherent complexities in rock mechanics

3) Tensile strength

- Lower tensile strength than all other engineering materials except concrete.
- Joints or fractures have very little or no tensile strength.
- Tensile stress zone identified by analysis means a de-stressed zone where detachment of rock units from host mass takes place.

4) Effect of groundwater

- Normal effective stress is reduced by water in joints and pore, and therefore strength of the mass decreases.
- Argillaceous rock shows marked reduction in material strength following infusion with water.

1.2 Inherent complexities in rock mechanics

5) Weathering

- Chemical or physical alteration of rock at its surface by its reaction with atmospheric gas or aqueous solutions.
- Physical processes such as thermal cycling and insolation are important in surface mining while underground weathering processes are chiefly chemical: dissolution, ion exchange, oxidation, and hydration.
- Dissolution of limestone, softening of marl (이회,泥灰) due to sulfate removal, oxidation of pyrrhotite (자황철광,磁黃鐵鑛), etc.

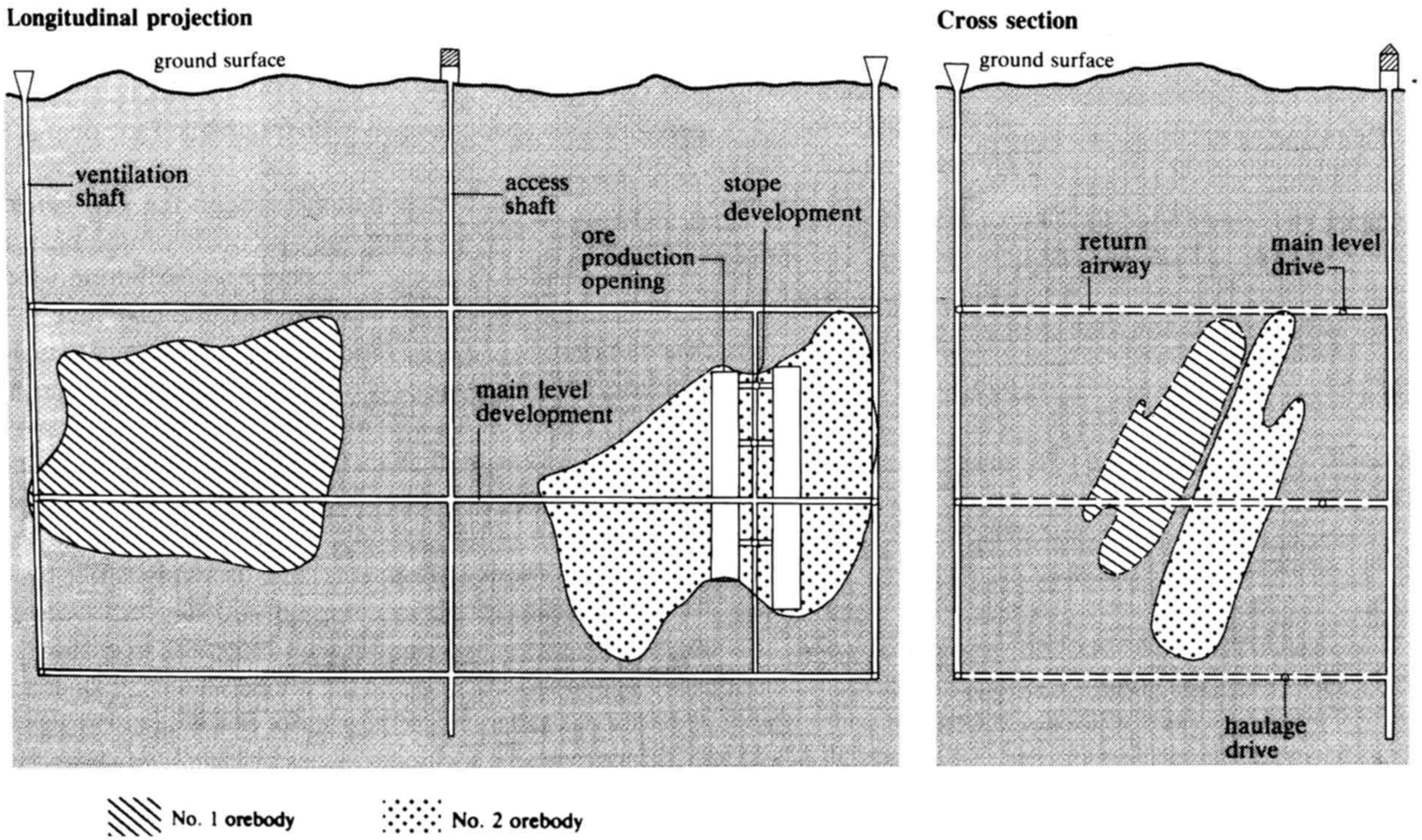


1.3 Underground mining

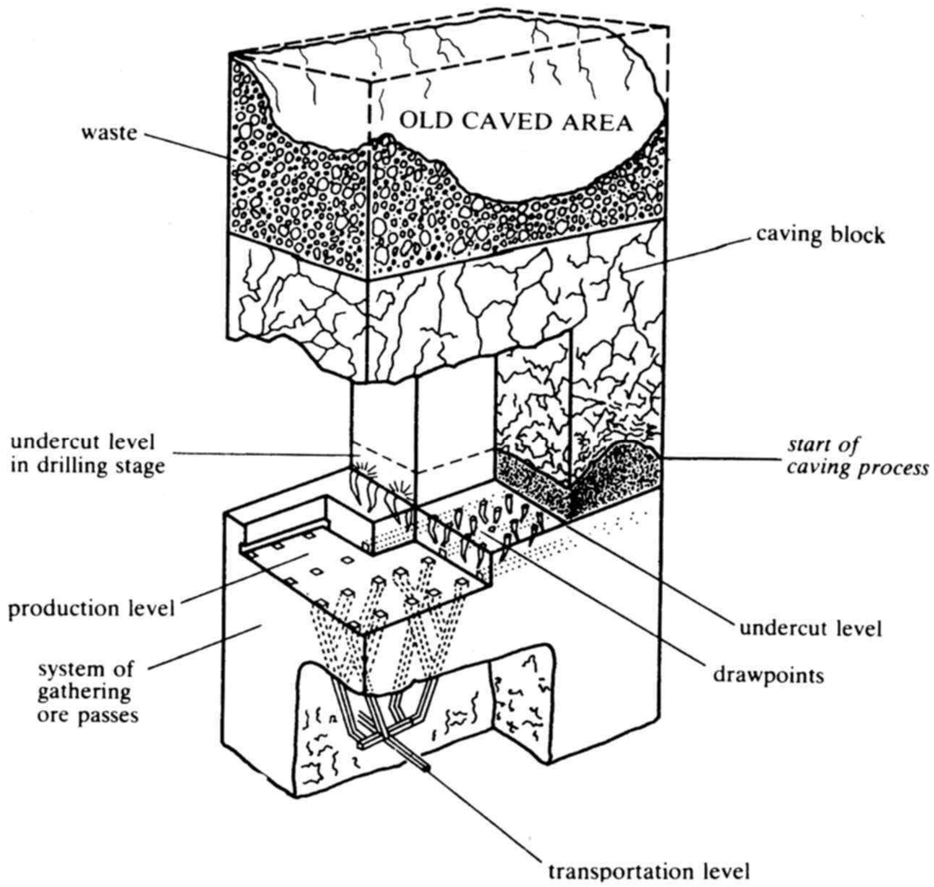
1) Types of openings

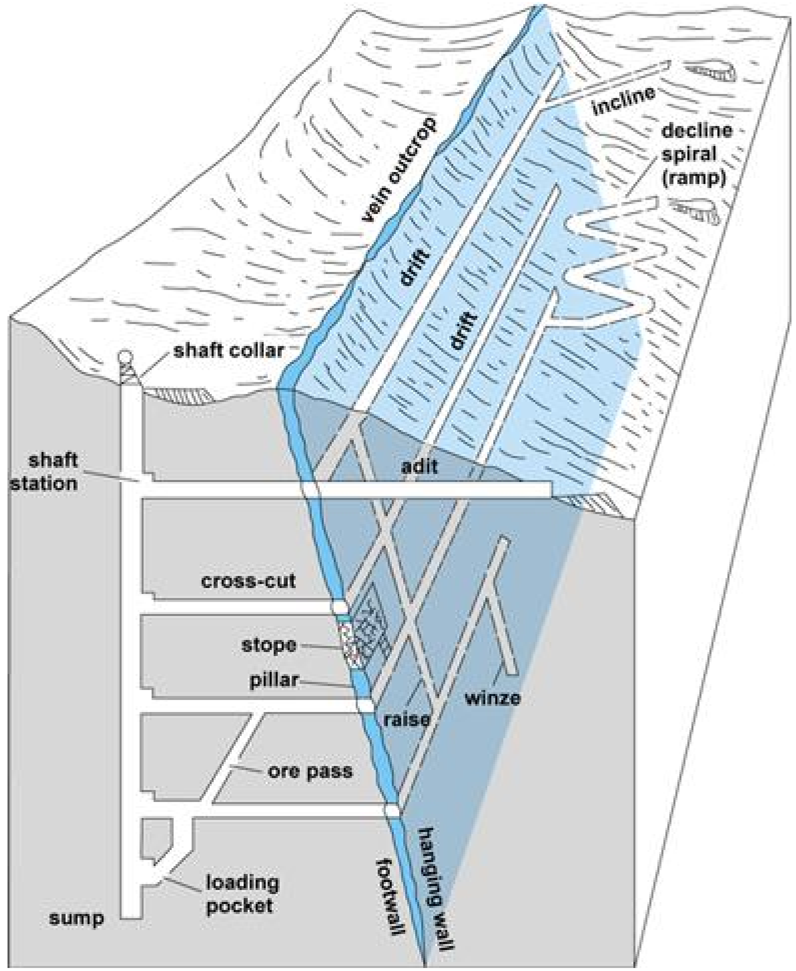
- Operating (mine access) opening / service opening/ ore source: main shaft, level drive, cross cut, ore haulage, ventilation shaft, airway, drill heading, access raise, extraction heading, ore pass, etc. Refer to Fig.1.3 & Mine terminology.
- Duty life of the openings: equal to or longer than mining life.

1.3 Underground mining



1.3 Underground mining





1.3 Underground mining

2) Mining methods

- Unsupported (naturally supported) mining:

  room-and-pillar, stope-and-pillar, shrinkage stoping, sublevel stoping

- Supported mining (artificially supported):

  cut-and-fill stoping, stull stoping, square-set stoping

- Caving (longwall and caving) methods:

  longwall mining, sublevel caving, block caving

3) Choosing of mining methods

- Consider ore size, shape, geometric disposition, distribution of values, and geotechnical environments.
- The geotechnical environments include: mechanical properties of ore and rock, geological structures, state of stress, geohydrological conditions.

1.3 Underground mining

4) Rock mechanics objectives for the performance of mine structure

- to ensure the overall stability of the mine structures including the main ore sources, mined voids, ore remnants and adjacent rock.
- to protect the major service openings throughout their duty life.
- to provide secure access to safe working places
- to preserve the mineable condition of unmined ore reserves.

1.3 Underground mining

5) Difference with civil excavations

- Use of any opening is entirely in the control of mine operators.
- Duty life is significantly less than those of civil excavations.
- Mine structures continue to develop throughout the life of mine.

1.4 Functional interactions in mine engineering

- Activities in planning and design of mining

  - Refer to Fig. 1.5

- Interaction between technical groups

  - Refer to Fig. 1.6

  - Key point is the mutual dependence of each functional group on information provided by the others: close working relationship between geology, planning, rock mechanics and production group is required.

1.4 Functional interactions in mine engineering

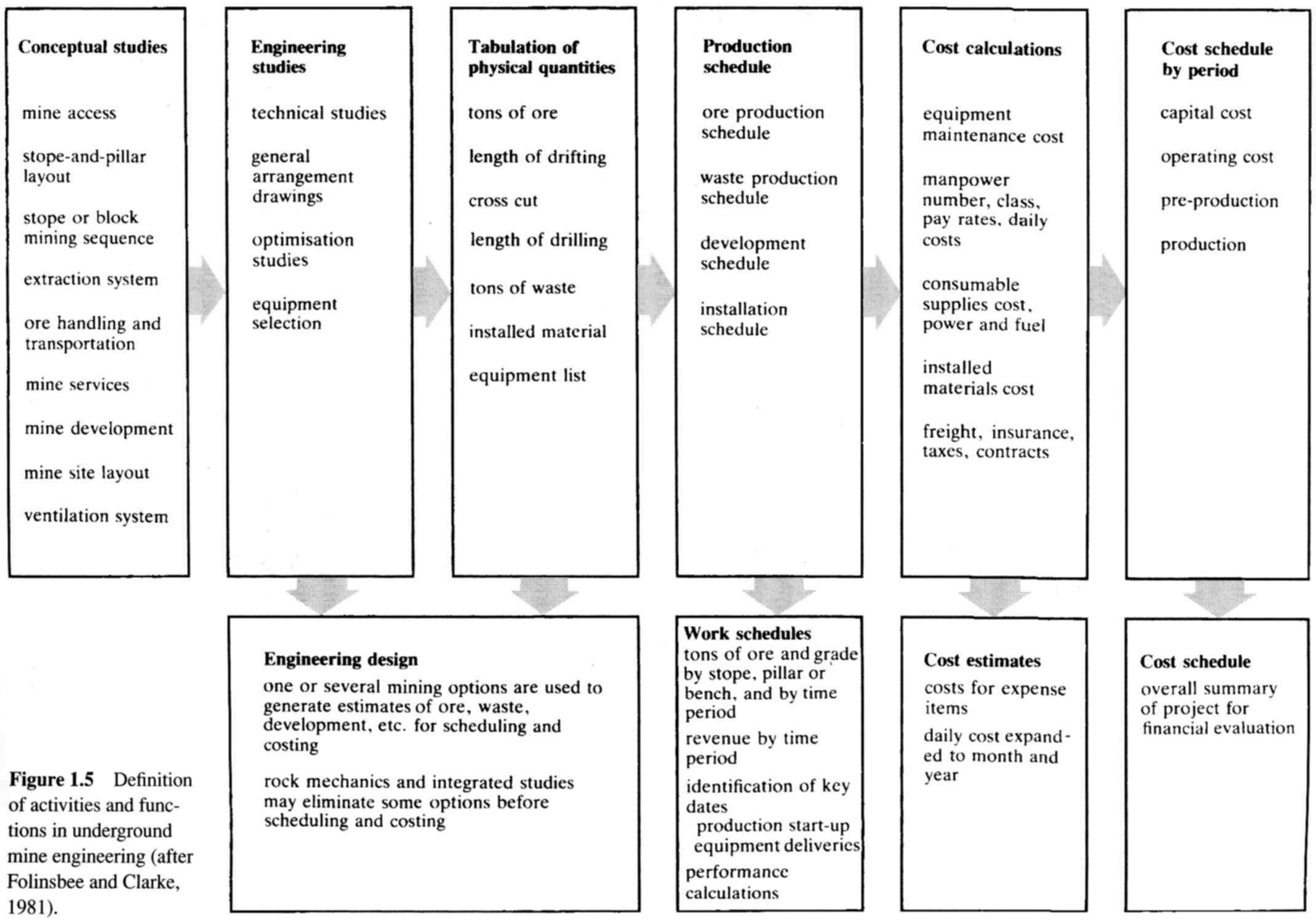


Figure 1.5 Definition of activities and functions in underground mine engineering (after Folinsbee and Clarke, 1981).

1.4 Functional interactions in mine engineering

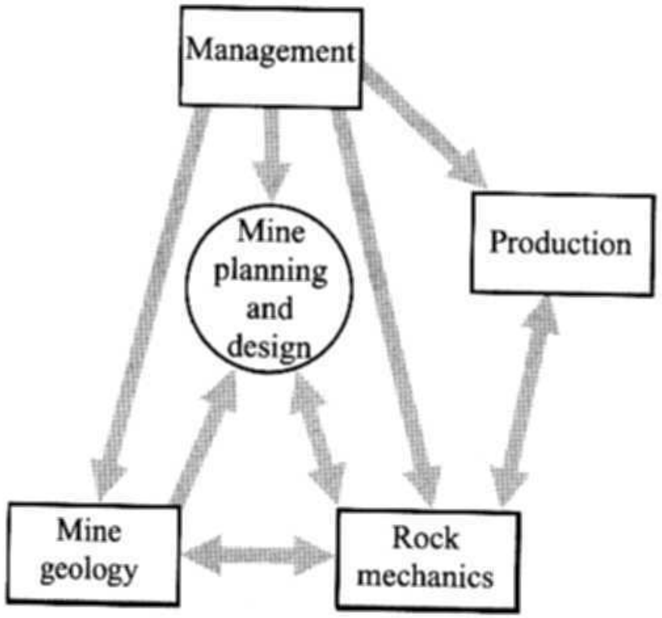


Figure 1.6 Interaction between technical groups involved in mine engineering.

1.4 Functional interactions in mine engineering

1) Management

- Should define explicitly management policy and objectives for the mining such as
- orebody extraction ratio and its change in response to product prices, company investment strategy, constraints on mining technique, restrictions on geohydrological disturbance, restriction on operating practices, etc.

2) Geology

- Structural (geological) and geohydrological data should be logged and processed.
- Comprehensive geological description should be given: distribution of lithologies, distribution of values throughout the orebody, etc.

1.4 Functional interactions in mine engineering

3) Planning

- Mine planning and design engineers' role is initiative as well as integrative.
- Gives information useful to delineate the scope of geomechanical analysis.
- Defines the general mining strategy: whether to extract pillars, extent of mine structures, use of backfills, constraints on future mining by current situation, etc.

4) Rock mechanics

- Relevant role in design: mine layout and sequencing, extraction design, support and reinforcement design, siting of service and ventilation shaft, etc.
- Majority of rock mechanics activity: dimensioning, layout, and sequencing (of extraction) of stopes and pillars, blasting design, monitoring of excavations and providing remedial actions to manage unforeseen events, etc.

1.5 Implementation of a rock mechanics program

- Rock mechanics program

- Refer to Fig. 1.7
- Multi-pass loop: repeated site characterization is required and mine design is a evolutionary process.

1) Site characterization

- Define mechanical properties and state of medium: strength and deformation (modulus), geometric and mechanical properties of joints and faults, in situ stress, hydrogeology etc.
- First-pass site characterization is deficient due to limited physical access.

1.5 Implementation of a rock mechanics program

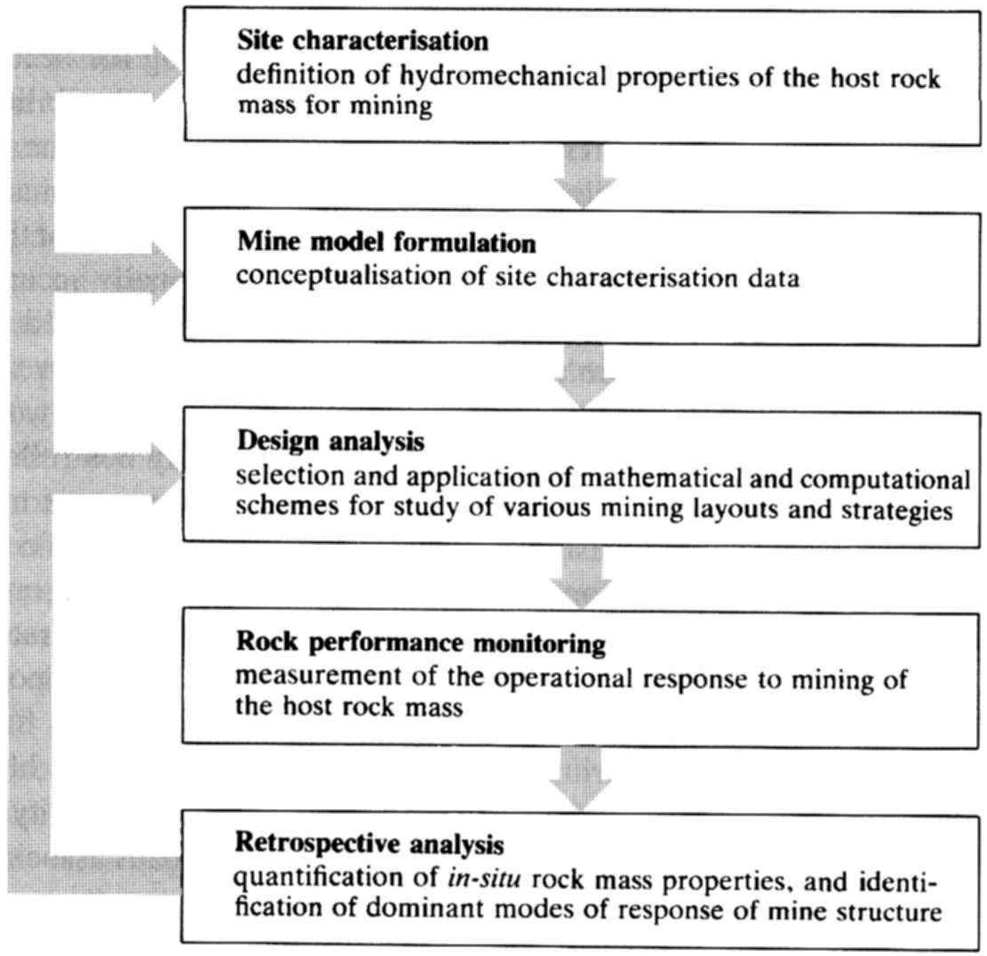


Figure 1.7 Components and logic of a rock mechanics programme.

1.5 Implementation of a rock mechanics program

2) Mine model formulation

- To account for principal geomechanical features of a mine such as deformational behavior based on simplified and rationalized data of site characterization.
- Use of representative/average/regular properties of rocks/joints/faults/stress.
- Significant discrepancies may be introduced by failure to recognize particular features of the mine site.

1.5 Implementation of a rock mechanics program

3) Design analysis

- Mechanical performance of selected mining configuration can be predicted by mathematical or numerical techniques.
- It shows the core of rock mechanics practice.

4) Rock performance monitoring

- The objective is to characterize the operational response of rock mass to mining activity.
- Measurements are for displacement, stress, slip on faults, etc at key locations.
- Visual inspection should be undertaken regularly for structurally controlled failures and area of anomalous response, and should be mapped routinely.

1.5 Implementation of a rock mechanics program

5) Retrospective analysis

- Quantitative analysis of data obtained by monitoring is useful to improve knowledge of the in situ mechanical properties of rock mass and to review the adequacy of the postulated mine model.
- Analysis of local failure is practically valuable for this purpose.
- This enables us to establish the rules specifying stope shape, stope blasting practice, and drawpoint layouts.