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Lectures on Rock Mechanics

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ROCK MECHANICS

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INTRODUCTION

- **What is Rock Mechanics?**

Rock mechanics is a discipline that uses the principles of *mechanics* to describe the behaviour of *rock* of engineering scale.

SCOPE OF ROCK MECHANICS

- CIVIL ENGINEERING
- MINING ENGINEERING
- PETROLEUM ENGINEERING
- GEOLOGY
- GEOPHYSICS

SCOPE OF ROCK MECHANICS

- Evaluation of GEOLOGICAL HAZARDS .. landslides, seismic etc.
- Selection of CONSTRUCTION MATERIALS
- Selection and layout of CONSTRUCTION SITES
- Analysis of STABILITY
- Design of BLASTING OPERATIONS
- Design of SUPPORT SYSTEMS
- Design of HYDRAULIC FRACTURING PROGRAMS
- Design of INSTRUMENTATION PROGRAMS
- Evaluation of EXCAVATION CHARACTERISTICS
- Studies of rock deformation at high temperatures and pressures (STRUCTURAL GEOLOGY)

APPLICATION OF ROCK MECHANICS

- **DEEP EXCAVATIONS**
  - **Mines (Temporary and Permanent)**
  - **Tunnels (Roads, H.E.P.)**
  - **Underground chambers (Power stations, storage, recreational)**
- **ENERGY DEVELOPMENT**
  - **Petroleum**
  - **Geothermal**
  - **Nuclear (Power plants, Waste Disposal)**
  - **Energy storage caverns**

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Rock as a Construction Material

- For laying structural foundations to support structures
- For constructing Underground openings
- For protecting slopes
- For supporting railway tracks – Ballasts
- As base and sub-base for roads and runways
- As aggregate in concrete
- Making facia for buildings.

Geologic Time Scale

Era	Period	Epoch	Time Boundaries (Years Ago)
Cenozoic	Quaternary	Holocene - Recent	10,000
		Pleistocene	2 million
	Tertiary	Pliocene	5 million
		Miocene	26 million
		Oligocene	38 million
		Eocene	54 million
		Paleocene	65 million
Mesozoic	Cretaceous		130 million
	Jurassic		185 million
	Triassic		230 million
Paleozoic	Permian		265 million
	Carboniferous	Pennsylvanian	310 million
		Mississippian	355 million
	Devonian		413 million
	Silurian		425 million
	Ordovician		475 million
	Cambrian		570 million
Precambrian			3.9 billion
Earth Beginning			4.7 billion

Greenland

What are we calling a rock?

Grade	Description	Lithology	Excavation	Foundations
VI	Soil	Some organic content, no original structure	May need to save and re-use	Unsuitable
V	Completely weathered	Decomposed soil, some remnant structure	Scrape	Assess by soil testing
IV	Highly weathered	Partly changed to soil, soil > rock	Scrape NB corestones	Variable and unreliable
III	Moderately weathered	Partly changes to soil, rock > soil	Rip	Good for most small structures
II	Slightly weathered	Increased fractures and mineral staining	Blast	Good for anything except large dams
I	Fresh rock	Clean rock	Blast	Sound

Engineering

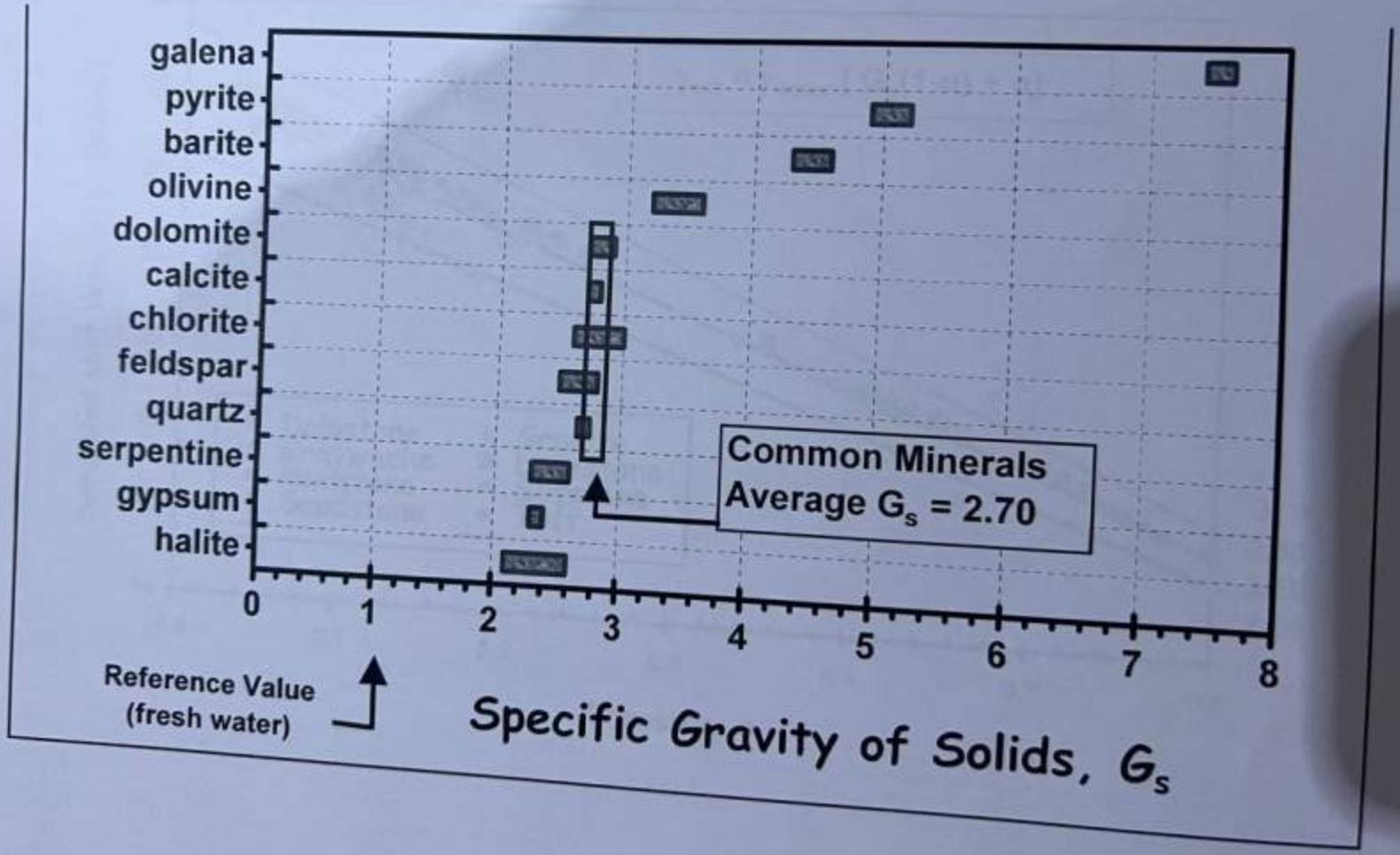
Primary Rock Types by Geologic Origin

	Sedimentary Types		Metaphorphic		Igneous Types	
Grain Aspects	Clastic	Carbonate	Foliated	Massive	Intrusive	Extrusive
Coarse	Conglomerate Breccia	Limestone Conglomerate	Gneiss	Marble	Pegmatite Granite	Volcanic Breccia
Medium	Sandstone Siltsone	Limestone Chalk	Schist Phyllite	Quartzite	Diorite Diabase	Tuff
Fine	Shale Mudstone	Calcareous Mudstone	Slate	Amphibolite	Rhyotite	Basalt Obsidian

Index Properties of Intact Rock

- Specific Gravity of Solids, G_s
- Unit Weight, γ
- Porosity, n
- Ultrasonic Velocities (V_p and V_s)
- Compressive Strength, q_u
- Tensile Strength, T_0
- Elastic Modulus, E_R (at 50% of q_u)

Specific Gravity of Rock Minerals



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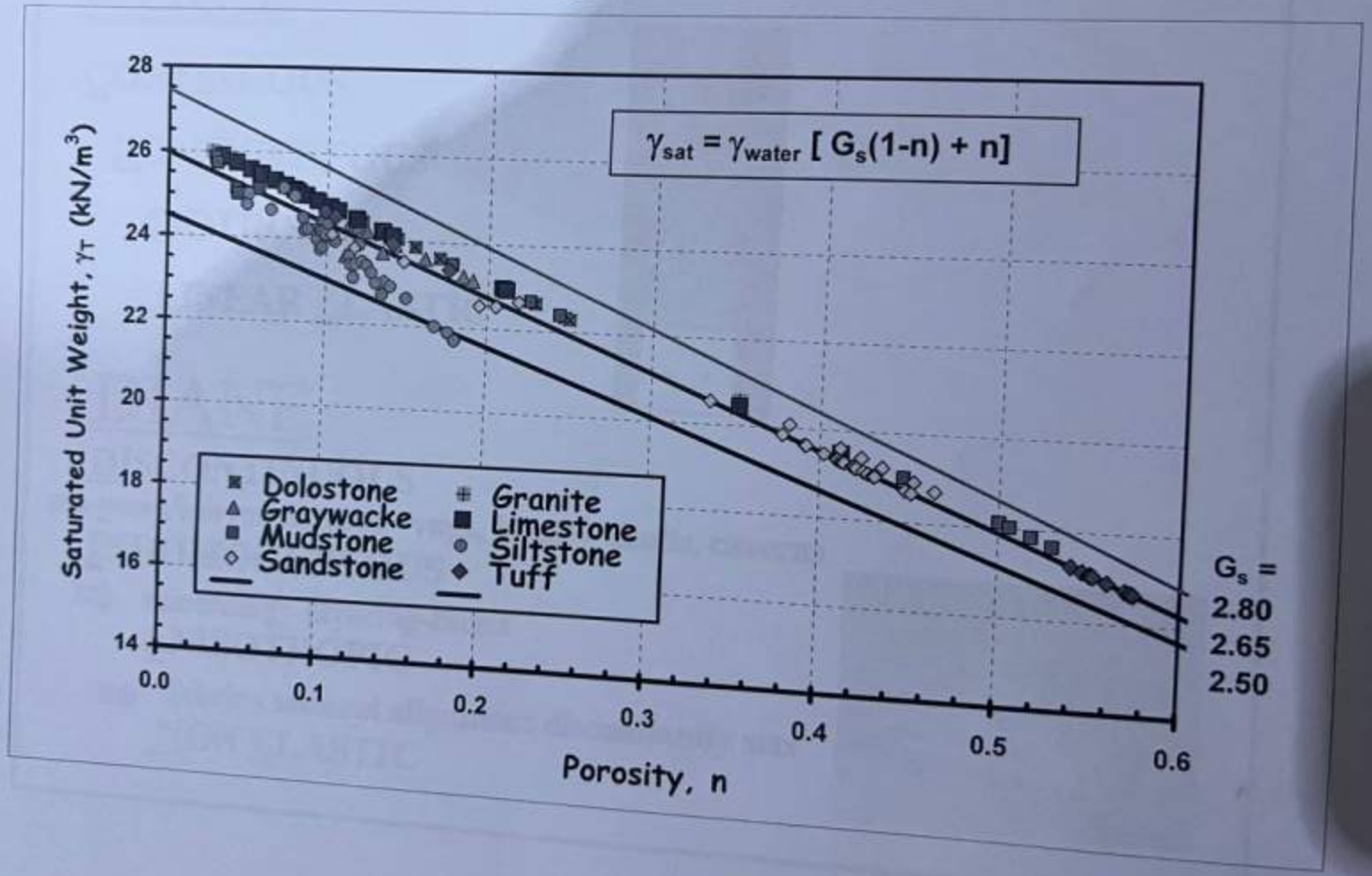
Unit Weights of Rocks



CHILE

CONTINUOUS

HOMOGENEOUS

ISOTROPIC

LINEAR ELASTIC

DIANE

DISCONTINUOUS

➡ **pores/microfractures - vugs, joints - faults, caverns**

INHOMOGENEOUS

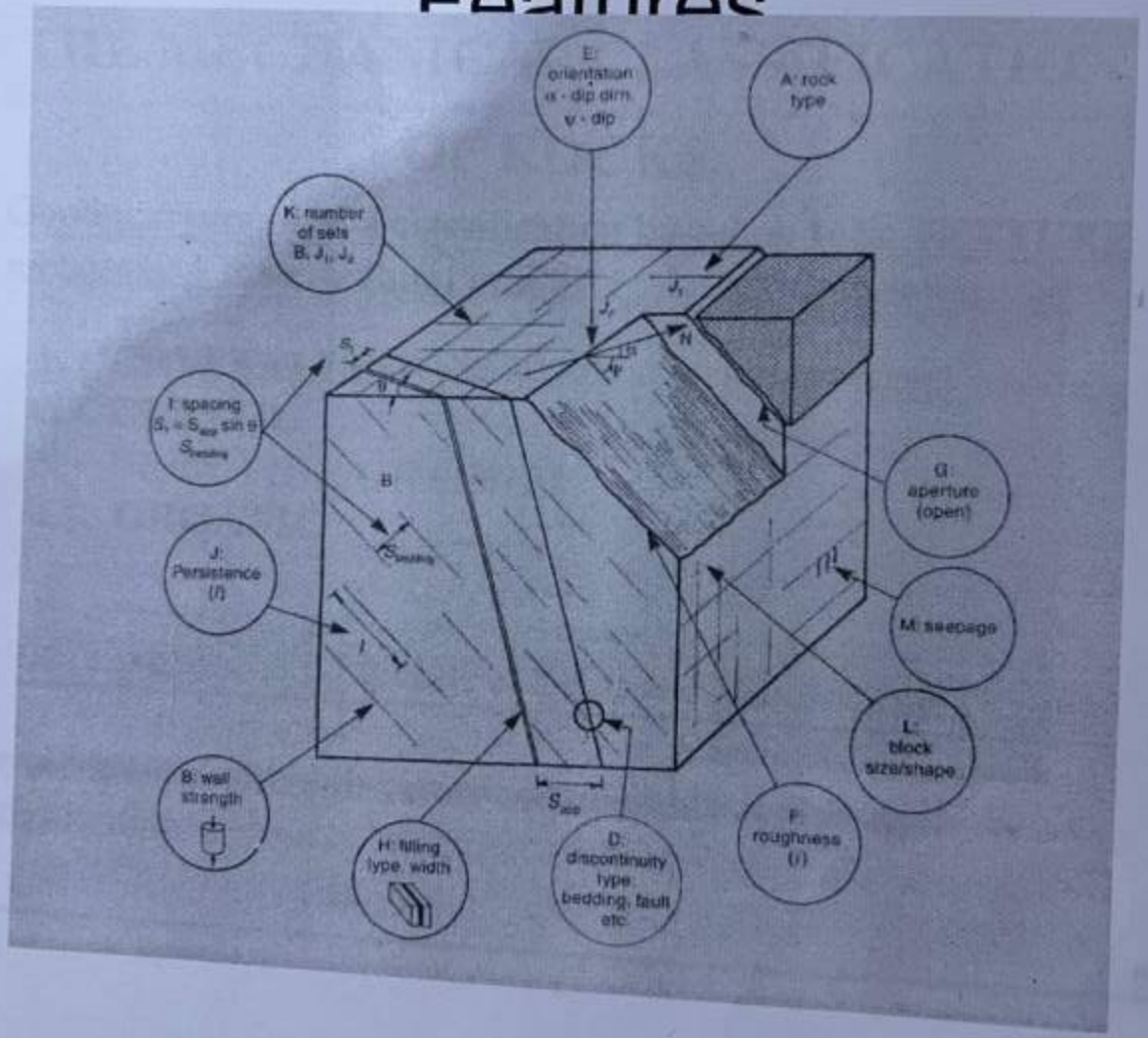
➡ **mineralogy-layering-facies**

ANISOTROPIC

➡ **fabric - mineral alignment-discontinuity sets**

NON ELASTIC

Geologic Mapping of Rock Mass Features



THE MECHANICAL CLASSIFICATION OF ROCKS

Goodman proposed a classification based on rock TEXTURE recognizing four textural groups

1. CRYSTALLINE
2. CLASTIC
3. VERY FINE GRAINED
4. ORGANIC

The mechanical strength varies considerably within each textural group.

APPLICATION OF ROCK MECHANICS

- SURFACE STRUCTURES
- Low rise (Housing)
- High rise (Tower blocks)
- High load (Dams, power plants, bridges)

- TRANSPORTATION ROUTES
- Highways, railways
- Canals
- Pipelines

- SHALLOW EXCAVATIONS
- Quarries
- Open pits, strip mines
- Trenches, cuttings

CRYSTALLINE TEXTURE

• *characterized by tightly interlocked texture*

A. **Evaporites** .. carbonates, sulphates, halides etc
B. **Banded Phyllosilicates** .. mica schists etc.
C. **Banded Silicates** .. some schists, gneiss etc.
D. Plutonic igneous .. granite, gabbro etc
E. **Porphyritic igneous** .. lavas etc.
F. **Highly sheared** .. serpentinite, mylonite

i. Unweathered banded silicates, plutonic and porphyritic igneous rocks tend to behave in a **BRITTLE-ELASTIC** manner under **normal** rock engineering conditions.
ii. Evaporites and weathered crystalline silicates behave in a **PLASTIC** or **VISCO- ELASTO-PLASTIC** manner.
iii. Banded phyllo- (sheet) silicates, banded silicates and highly sheared rocks often are very strongly **ANISOTROPIC** and **ELASTO-PLASTIC.**

CLASTIC TEXTURE

... Characterized by the presence of strong mineral grains in a cement or binder matrix

A. **Stably cemented** .. silica and limonite cements
B. **Slightly soluble cement**.. calcareous cement
C. **Highly soluble cement** .. gypsum cement
D. **Weakly cemented**.. friable sandstones, some tuffs
E. **Uncemented** .. clay-bound sandstones etc.

i. **Stably cemented** rocks often behave in a **BRITTLE-ELASTIC** manner
ii. Rocks with slightly-**highly soluble** cements tend to show **ELASTO-PLASTIC** behavior characteristic of the cement
iii. Weakly cemented or **uncemented** rocks (and **B** and **C** in the presence of water) exhibit behavior resembling **UNCONSOLIDATED SOILS**.