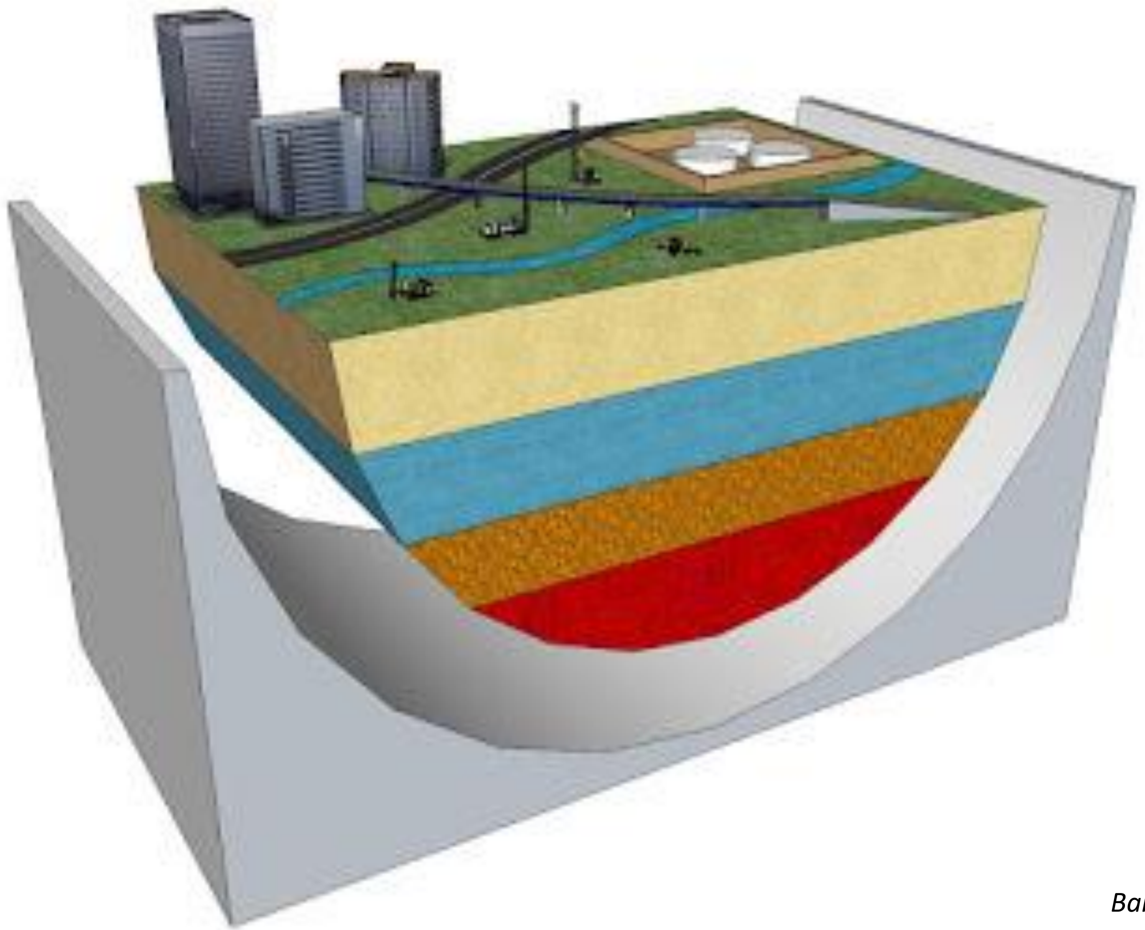
GEOLOGY & CIVIL ENGINEERING

Understanding The Relationship



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GENERAL DEFINITION

Geology : The science of rocks & earth processes

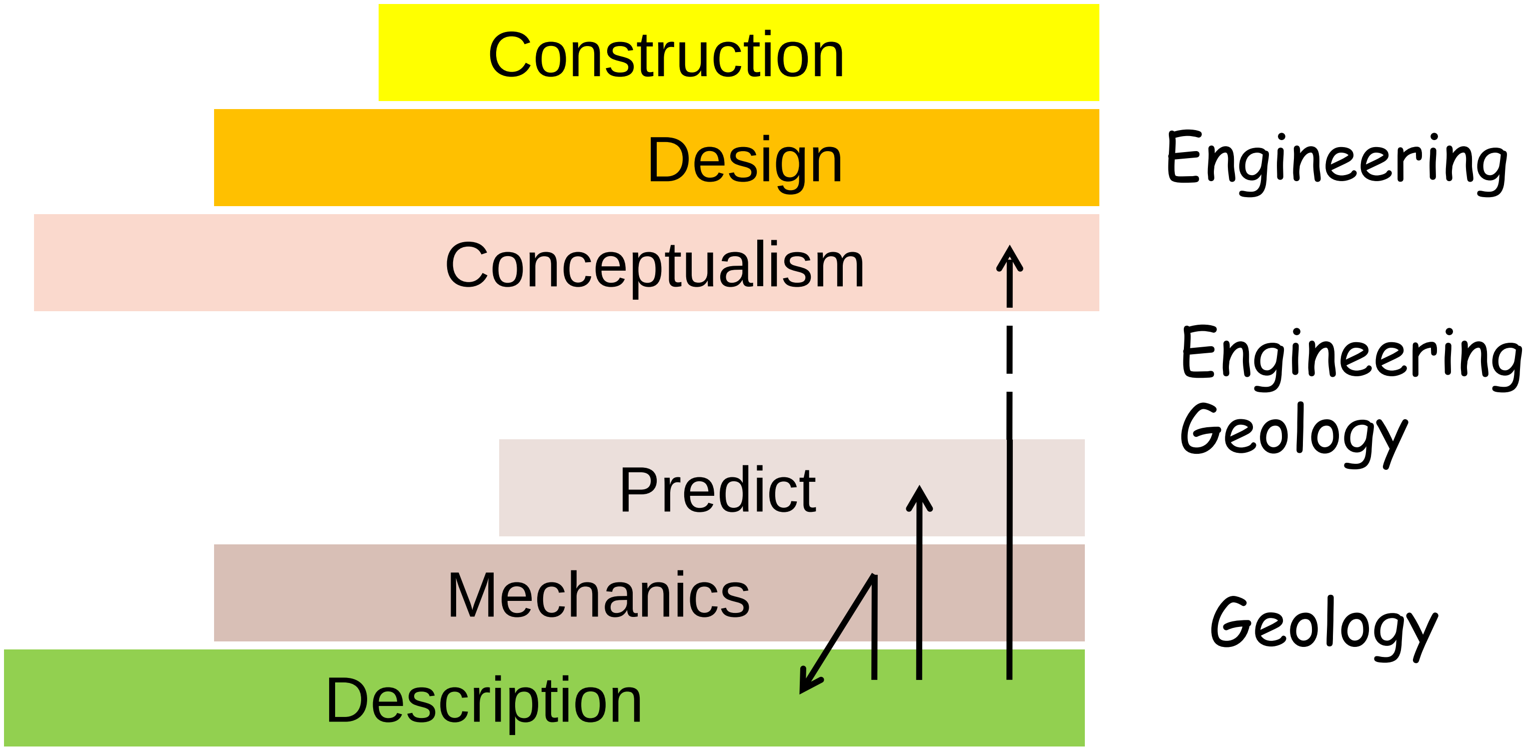
(Dictionary of Geological Terms)

Engineering : The science concerned with putting scientific knowledge to practical uses *(Webster)*

Engineering Geology : The geological sciences (geologic knowledge) that applied to engineering practice

(Dictionary of Geological Terms)

Relationships Between Geology, Engineering Geology & Engineering



(Source: Christopher C.Mathewson)

In View Of Engineering Geologist

Looking back at geologic processes and forward to engineering products

Geologic Process

Engineering Products

Engineering Geologist's interpretation often has a direct impact on human life & property

SIGNIFICANT OF ENGINEERING GEOLOGY

- **Civil Engineering Works** are all carried out on or in the ground. Its properties & processes are significant.
  Example: strength of rocks and soils

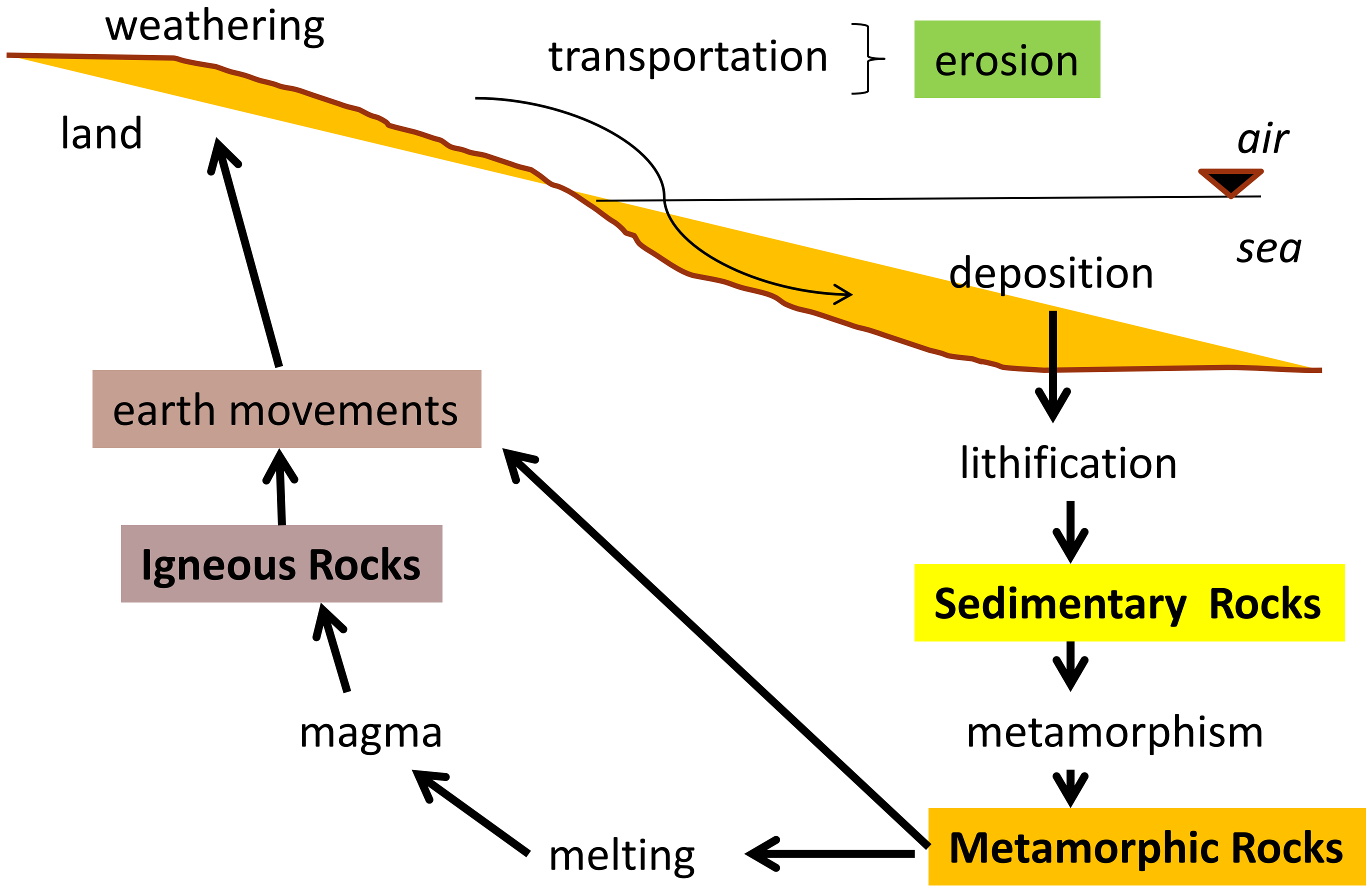
- **Site Investigation** is where most geological aspects encountered. This involves the interpretation of ground conditions & recognition of areas of difficult ground or potential geohazards.

- **Civil Engineering Design** can accommodate almost any ground conditions that are correctly assessed and understood prior to & during construction.

ENGINEERING RESPONSES TO GEOLOGICAL CONDITIONS

GEOLOGY	RESPONSE
1. Soft ground & settlement	1. Foundation design to reduce or redistribute loading
2. Weak ground & potential failure	2. Ground improvement or cavity filling; avoid hazard zone
3. Unstable slope & potential sliding	3. Stabilize or support slopes; avoid hazard zone
4. Severe river or coastal erosion	4. Slow down process with rock or concrete defences
5. Potential earthquake hazard	5. Structural design to withstand vibration
6. Potential volcanic hazard	6. Avoid hazard zone
7. Rock required as a material	7.Resource assessment & rock testing

THE GEOLOGICAL CYCLE



Land: mainly erosion & rock destruction
Sea : mainly deposition, forming new sediments
Underground: new rocks created & deformed

ROCKS AND MINERALS

- **ROCKS** : mixtures of minerals ; variables properties

- **MINERALS** : compounds of elements; fixed properties

Rocks Properties depend on:

- Strength & stability of constituent minerals
- Interlocking or weaknesses of mineral structure
- Fractures, bedding & larger rock structures

It must be accepted that rocks are not engineered materials and their properties do vary from site to site

STRONG & WEAK ROCKS

Strong Rocks	Weak Rocks
1. UCS > 100 MPa	1. UCS < 10 MPa
2. Little fracturing	2. Fractured & bedded
3. Minimal weathering	3. Deep weathering
4. Stable foundations	4. Settlement problems
5. Stand in steep faces	5. Fail on low slopes
6. Aggregate resource	6. Require engineering care

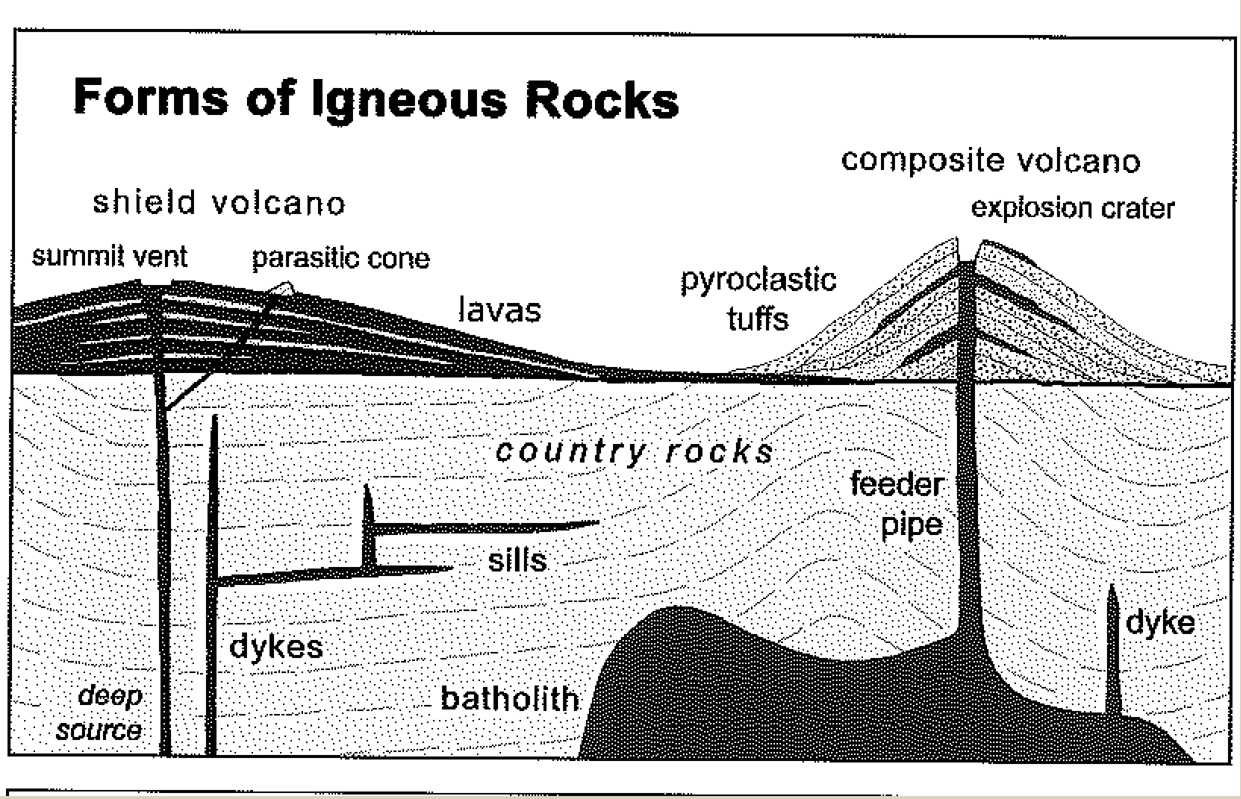
Assessment of ground conditions must distinguish:

- ✓ **Intact rock-** strength of an unfractured, small block
- ✓ **Rock mass-** properties of a large mass of fractured rock in the ground

ROCK FAMILY

Rock Family	***Igneous***	***Sedimentary***	***Metamorphic***
Material origin	Crystallized molten magma	Erosional debris on earth's surface	Altered by heat/pressure
Environment	Underground & as lava flows	Deposition basins; mainly sea	Mostly deep inside mountain chains
Rocks texture	Mosaic of interlocking crystals	Mostly granular & cemented	Mosaic of interlocking crystals
Rock structure	Massive (structureless)	Layered, bedded, bedding planes	Crystal orientation due to pressure
Rock strength	Uniform high strength	Variable low	Variable high
Major types	Granite , basalt	Sandstone, limestone, clay	Schist, slate

IGNEOUS ROCKS



- **Magma** is generated by local heating & melting of rocks within Earth's crust, mostly at depths between 10 and 100 km.
- Most composition of rock melt at 800-1200^{0} C
- When magma cools, it solidifies by crystallizing into a mosaic of minerals, to form an **IGNEOUS ROCK**.

TYPES OF IGNEOUS ROCKS

EXTRUSIVE IGNEOUS ROCKS (Volcanic)	INTRUSIVE IGNEOUS ROCKS (Hypabyssal/Plutonic)
1. Magma is extruded onto the Earth's surface to create a volcano	1. Magma solidifies below the surface of the Earth
2. **Lava** is the name for both molten rock on the surface, and also the solid rock formed when it cools	2. **Batholiths** are large intrusion; **Dykes** are smaller sheet intrusion; **Sills** are sheet intrusion which parallel to the bedding of the country rocks
3. Low viscousity	3. High viscousity

- **Minor Intrusive (Hypabyssal)**
- **Major Intrusive (Plutonic)**

CLASSIFICATION OF IGNEOUS ROCKS

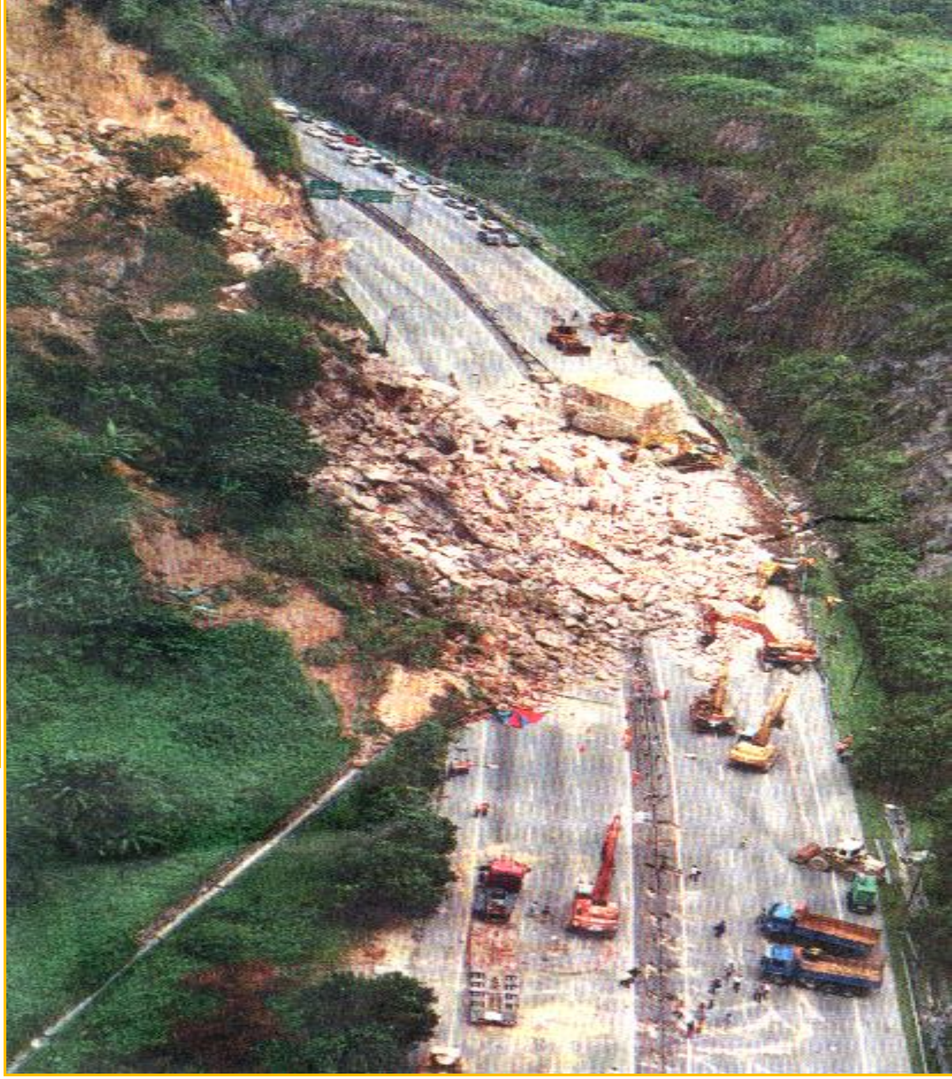
Rock Name	Occurrence	Form	Cooling	Grain	Size
Rhyolite Andesite Basalt	Extrusions	Lavas	Fast	Fine	<0.1 mm
Dolerite Porphyry	Minor intrusion	Dykes	Medium	Medium	0.1 - 2.0 mm
Granite Diorite Gabbro	Major intrusion	Batholiths	Slow	Coarse	> 2.0 mm

MAIN MINERALS OF IGNEOUS ROCKS

Minerals	Composition	Colour	H	D	Morphology & Features
Quartz	SiO_2	Clear	7	2.7	Mosaic; no cleavage; glassy lustre
Feldspar	$(K,Na,Ca)(Al,Si)_4\ O_8$	White	6	2.6	Mosaic- orthoclase & plagioclase
Muscovite	$Kal_2AlSi_3O_{10}\ (OH)_2$	Clear	2 .5	2.8	Thin sheets
Biotite	$K(Mg,Fe)_3AlSi_3O_{10}\ (OH)_2$	Black	2.5	2.9	Mica group of minerals
Mafics	Mg-Fe Silicates	Black	5-6	>3.0	Long or short prism

*** *H- Hardness (on a scale 1-10)*
D-Density, measured in grams/cm^3 or tonnes/m^3

Granite Formation In Kuala Lumpur



Granite Rock Slope Failure

SEDIMENTARY ROCKS

Sedimentary Rocks are formed by the consolidation, cementation & lithification of deposits of granular material after their deposition in large bodies of water.

Consolidation refers to the increase in strength in clays, due to their restructuring, improved packing, loss of water and reduced porosity caused by compaction under load

Cementation refers to the filling of the intergranular pore spaces by deposition of a mineral cement brought in by circulating groundwater. Examples: Silica (strongest); Clay (weakest)

Lithification are processes by which a weak, loose sediment is turned into a stronger sedimentary rock. Induced by burial pressure and slightly increased temperature beneath a kilometre or more of overlying sediment.

- **The most abundant rocks on earth, cover up to 60%**

CLASSIFICATION OF SEDIMENTARY ROCKS

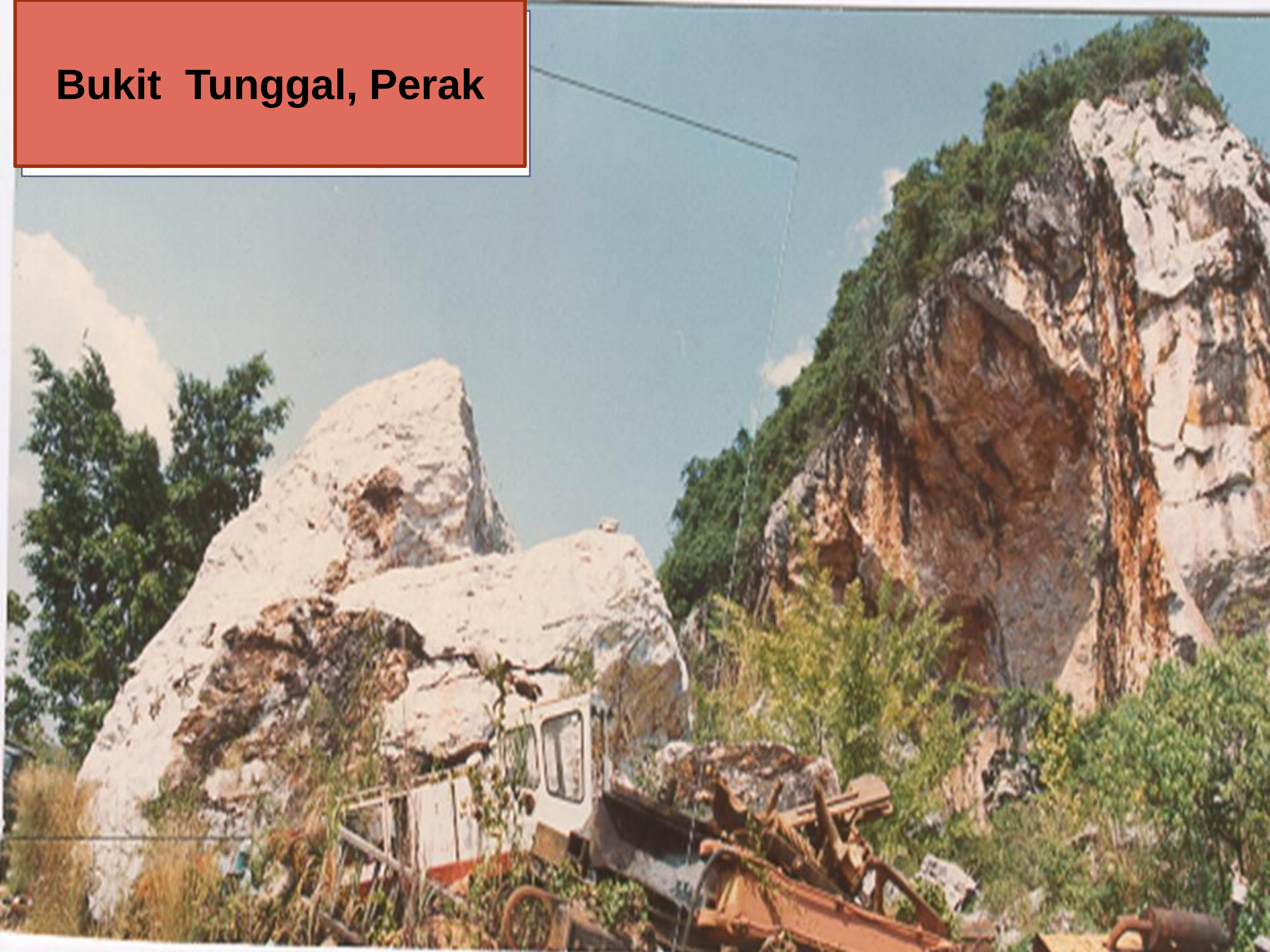
CLASTIC ROCKS (DETRITAL)	NON-CLASTIC ROCKS (CHEMICAL & BIO-CHEMICAL)
1. Made up of fragments derived from the breakdown of older rocks	1. Formed from various sources, from skeletal remains of sea plants and animals, from organic remains of sea plants and animals, from precipitation of salts dissolved in water & combination of all these
2. Rudaceous:coarse grained < 2mm Conglomerate- rounded fragment Breccia- angular fragment	2. Carbonates, consisting mainly of calcite such as Limestone
3. Arenaceous: medium grained 0.06-2 mm Sandstone	3. Non-carbonates Chert,coal,lignite,salt & gypsum
4. Argillaceous:fine grained < 0.06mm Siltstone, Clay, Shale, Mudstone	

Interbedded Sandstone & Shale

Limestone Hill

Sinkhole occurrence in limestone area

Bukit Tunggal, Perak



METAMORPHIC ROCKS

Metamorphic Rocks are formed when existing rocks (sedimentary, igneous or metamorphic) are altered by the effects of new temperature and pressure/stress conditions

- Metamorphism can cause recrystallisation, the growth of new minerals and development of new textures

- The type of rock formed depends on the original rock type and the temperature / pressure conditions to which it is subjected.

METAMORPHISM OF DIFFERENT ROCKS

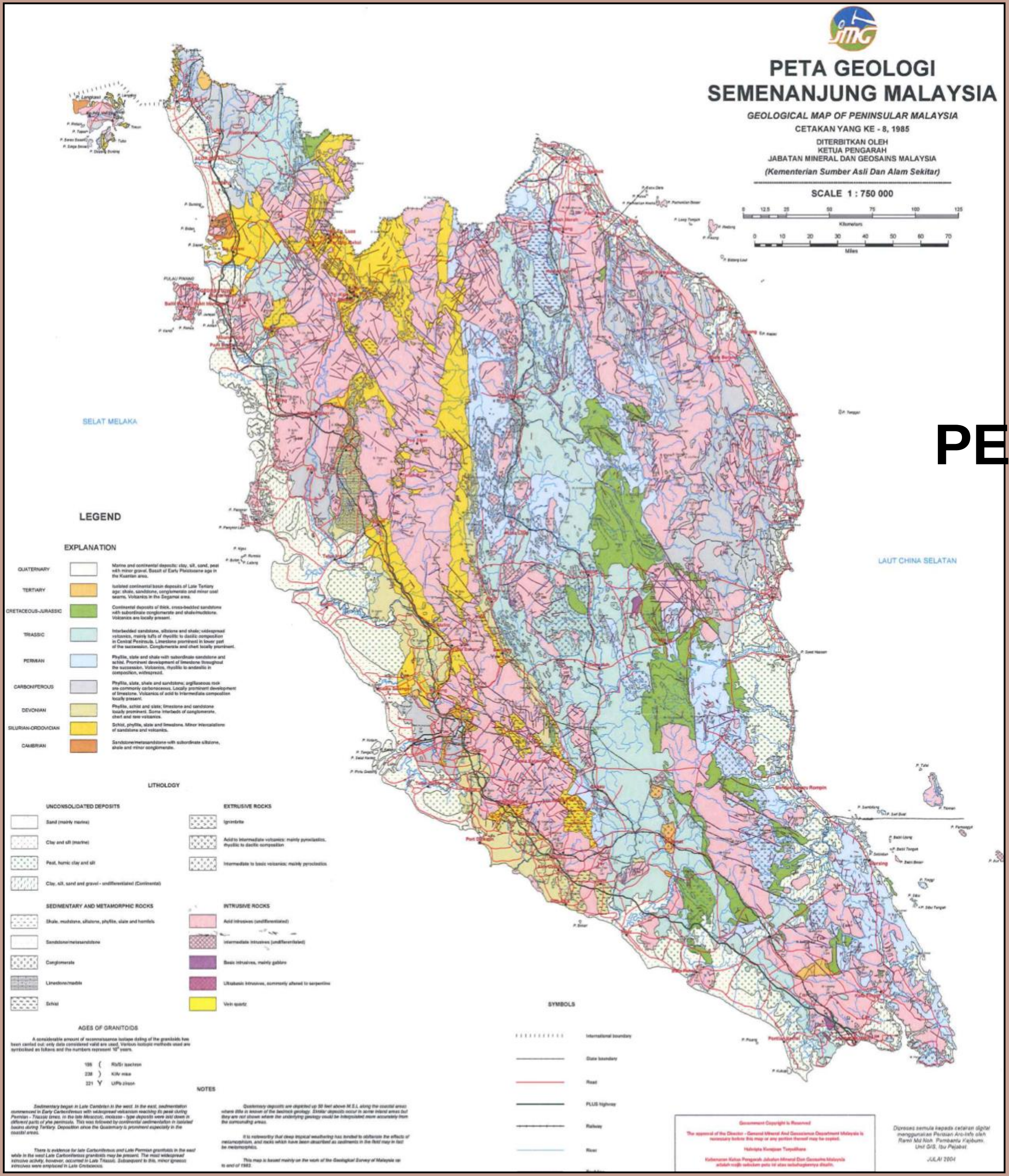
ORIGINAL ROCK	METAMORPHIC ROCK
Limestone	Marble
Sandstone	Quartzite
Basalt	Greenstone
Granite	Little change, largely stable in metamorphic conditions
Clay	Hornfels, slate, schist or gneiss depending on type and grade of metamorphism

MAIN METAMORPHIC ROCKS

Name	Grain Size	Main Minerals	Structure	Strength	UCS (MPa)
Hornfels	Fine	Mica, quartz,clay minerals	Uniform	Very strong	200
Slate	Fine	Mica, quartz,clay minerals	Cleavage	Low shear,high flexural	20-120
Schist	Coarse	Mica, quartz	Schistosity	Very low shear	20-70
Gneiss	Coarse	Quartz,feldspar, mafics,mica	Foliation	Strong	100

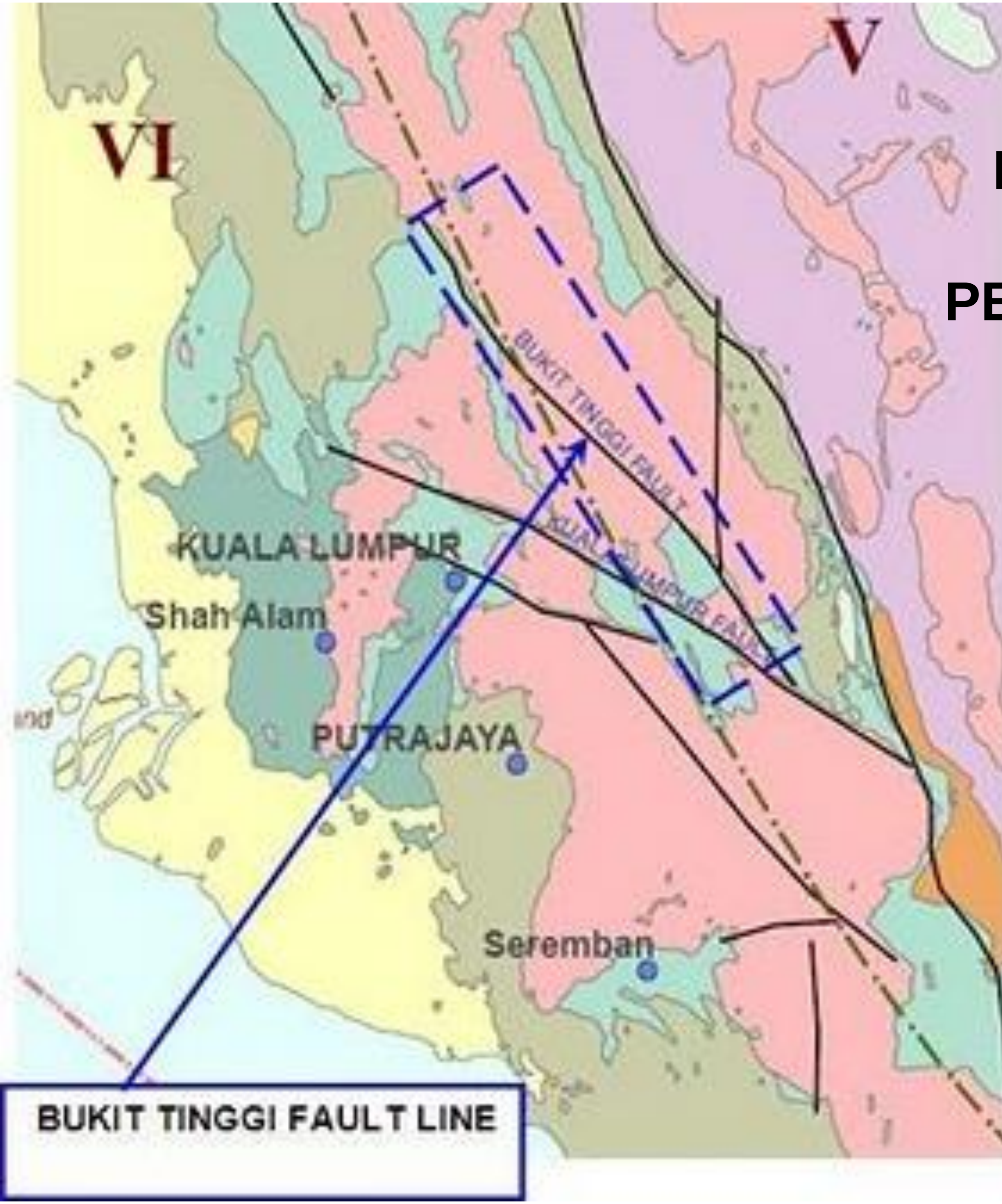
Schist Outcrop In Gunung Pass

Engineering problem in Schist slope



GEOLOGY MAP
OF
PENINSULAR MALAYSIA

MAJOR FAULT LINE
IN
PENINSULAR MALAYSIA

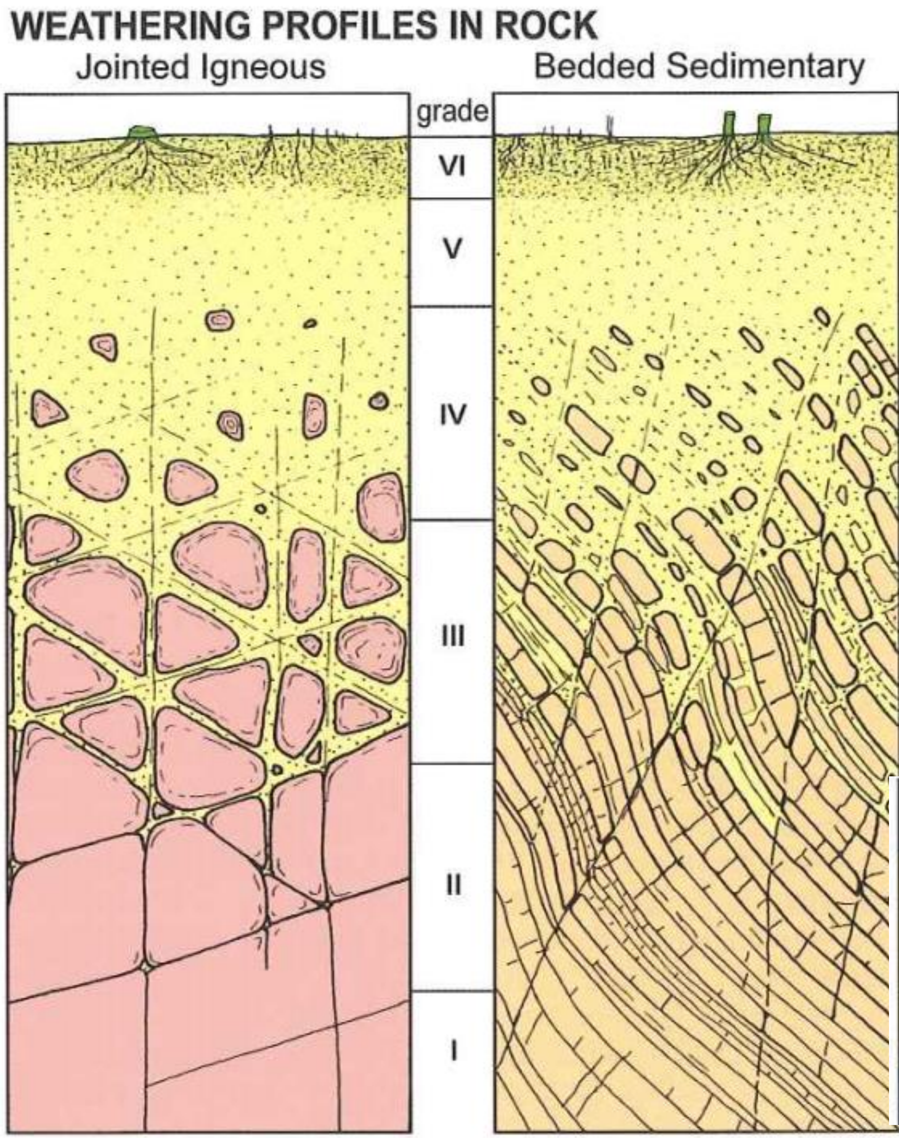


GEOLOGICAL STRUCTURES

- **Faults** are fractures that have had displacement of the rock along them
- **Joints** are rock fractures with no movement along them
- **Beddings** are horizontal layering resulting from accumulation of sediments under the influence of gravity
- **Fold** are upward anticlines or downward synclines
- **Foliation** is planar structure, similar to bedding, formed by parallel orientation of platy minerals in a rock

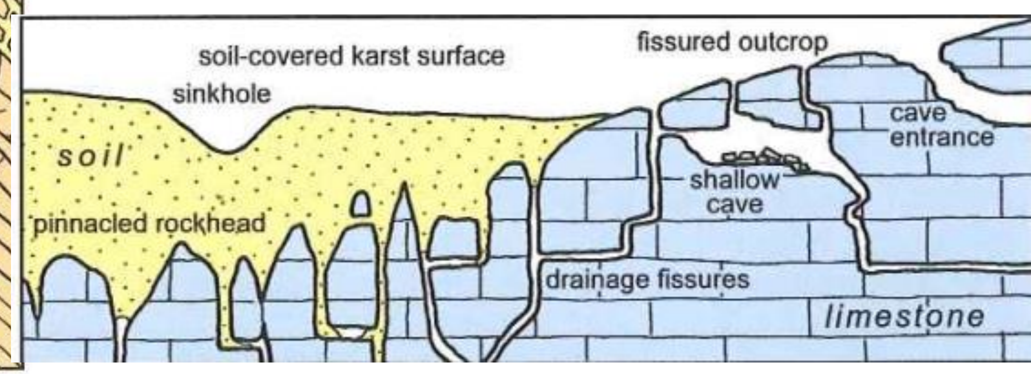
All the above structures known as **DISCONTINUITIES**

ROCK WEATHERING

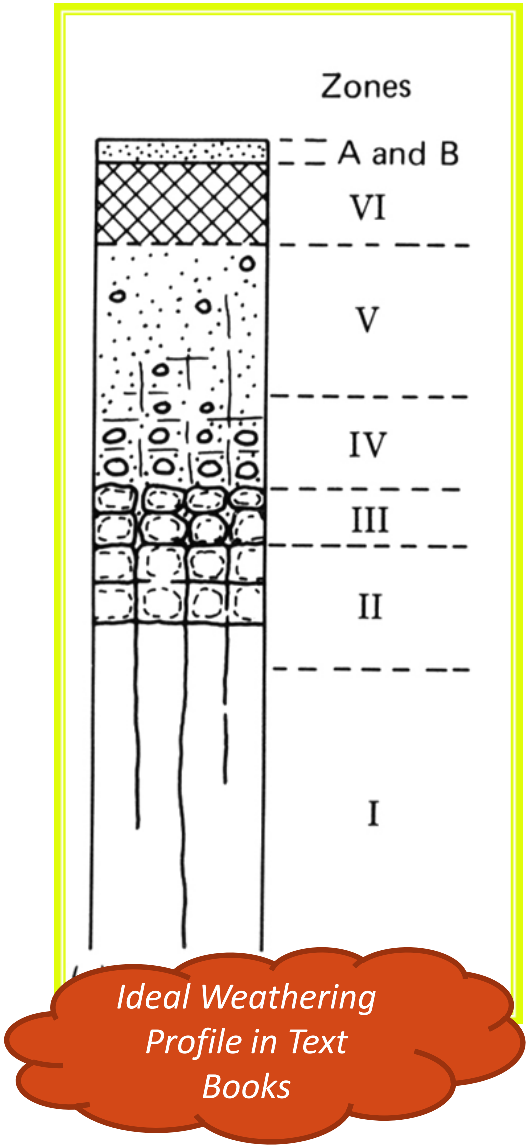


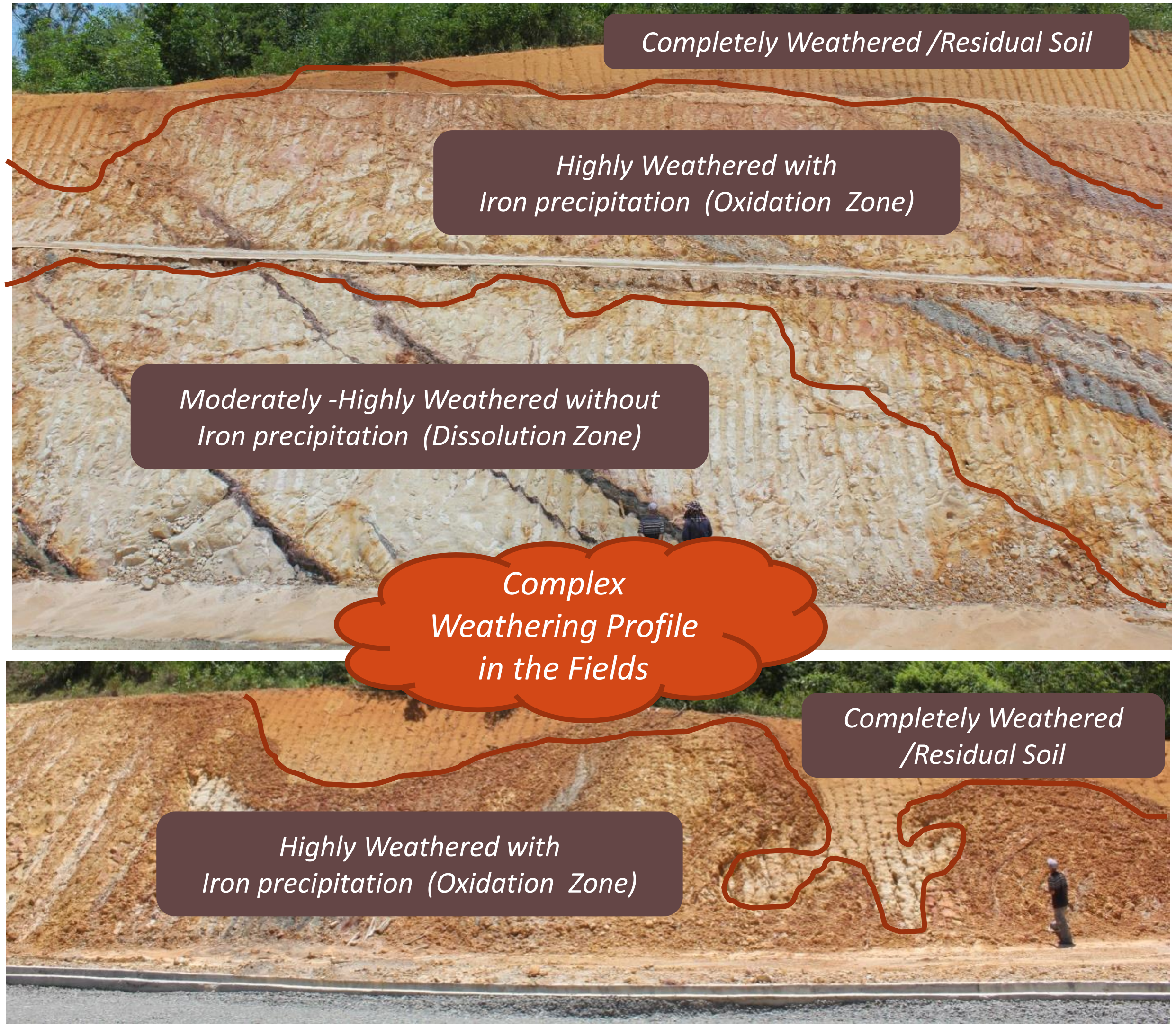
The natural decay & breakdown of rock that is in contact with air and water which generally occurred to depth of less than 10m

Weathering + Transport = Erosion



Weathering Processes and Profile





ENGINEERING CLASSIFICATION OF WEATHERED 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 changed 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

(More complex schemes, for description of non-uniform and mixed rock masses, are given in BS 5930.)

WEATHERING GRADE AND ROCK PROPERTIES

Some representative values for selected materials to demonstrate physical changes in weathered rock

Grade of weathering		I	II	III	IV	V
Granite: unconfined compressive strength	MPa	250	150	5–100	2–15	<1
Triassic sandstone: unconfined compressive strength	MPa	30	15	5	2	0
Carboniferous sandstone: rock quality designation	%	80	70	50	20	<15
Chalk: standard penetration test	N value	>35	30	22	17	75
Chalk: safe bearing pressure	kPa	1000	750	400	200	
Triassic mudstone: safe bearing pressure	kPa	400	250	150	50	
Triassic mudstone: clay particle fraction	%	10–35		10–35	30–50	
Typical depth in Britain	metres	5–30	1–5	1–2		

GROUNDWATER

Groundwater is all water flowing through or stored within the ground, in both rocks and soils; it is derived from infiltration

- ✓ The groundwater provides the pore water pressure (p.w.p) in saturated rocks and soils
- ✓ Increased p.w.p. may cause slope failure
- ✓ Decreased p.w.p. may cause subsidence in clays

Permeability is the ability of a rock to transmit water through its interconnected voids

Porosity is % volume of voids or pore spaces in a rock

Spesific Yield is % volume of water that can drain freely from a rock

Typical Hydrological Values For Rocks

Rock Type	Permeability m/day	Porosity %	Spesific Yield %
Granite	0.0001	1	0.5
Shale	0.0001	3	1
Clay	0.0002	50	3
Sandstone (Fractured)	5	15	8
Sand	20	30	28
Gravel	300	25	22
Limestone	erratic	5	4
Fracture Zone	50	10	

- K < 0.01 m/day = impermeable rock
- K > 1m/day = exploitable aquifer rock

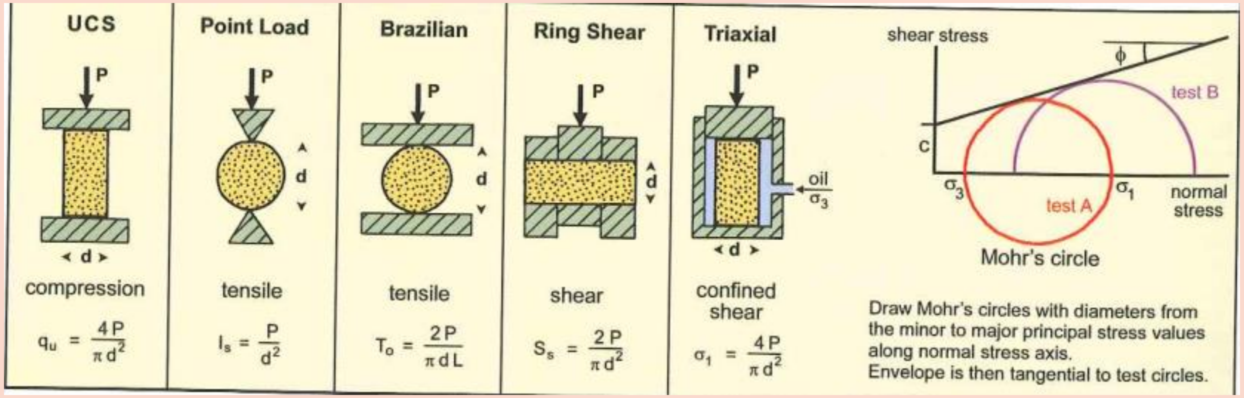
ROCK STRENGTH

- **INTACT ROCK** Strength depends on component mineral strength and the way they are bound together – by interlocking or cementation

- **ROCK MASS** Strength largely depends on the density, nature and extent of the fractures within it

INTACT ROCK STRENGTH

Rock Strength Testing



Strength Properties of Rocks

rock type	*density dry t/m³*	*porosity %*	*dry UCS range MPa*	*dry UCS mean MPa*	*UCS saturated MPa*	*modulus of elasticity GPa*	*tensile strength MPa*	*shear strength MPa*	*friction angle φ°*
Granite	2·7	1	50–350	200		75	15	35	55
Basalt	2·9	2	100–350	250		90	15	40	50
Greywacke	2·6	3	100–200	180	160	60	15	30	45
Sandstone – Carboniferous	2·2	12	30–100	70	50	30	5	15	45
Sandstone – Triassic	1·9	25	5–40	20	10	4	1	4	40
Limestone – Carboniferous	2·6	3	50–150	100	90	60	10	30	35
Limestone – Jurassic	2·3	15	15–70	25	15	15	2	5	35
Chalk	1·8	30	5–30	15	5	6	0·3	3	25
Mudstone – Carboniferous	2·3	10	10–50	40	20	10	1		30
Shale – Carboniferous	2·3	15	5–30	20	5	2	0·5		25
Clay – Cretaceous	1·8	30	1–4	2		0·2	0·2	0.7	20
Coal	1·4	10	2–100	30		10	2		
Gypsum	2·2	5	20–30	25		20	1		30
Salt	2·1	5	5–20	12		5			
Hornfels	2·7	1	200–350	250		80			40
Marble	2·6	1	60–200	100		60	10	32	35
Gneiss	2·7	1	50–200	150		45	10	30	30
Schist	2·7	3	20–100	60		20	2		25
Slate	2·7	1	20–250	90		30	10		25

Strength Recognition & Description

Rock/Soil Description	UCS (MPa)	Field Properties
Very strong rock	> 100	Firm hammering to break
Strong rock	50 - 100	Break by hammer in hand
Moderately strong rock	12.5 - 50	Dent with hammer pick
Moderately weak rock	5.0 – 12.5	Cannot cut by hand
Weak rock	1.5 – 5.0	Crumbles under pick blows
Very weak rock	0.6 – 1.5	Break by hand
Very stiff soil	0.3 – 0.6	Indent by fingernail
Stiff soil	0.15 – 0.3	Cannot mould in fingers
Firm soil	0.08 – 0.15	Mould by fingers
Soft soil	0.04 – 0.08	Mould easily in fingers
Very soft soil	< 0.04	Exudes between fingers

ROCK MASS STRENGTH

- Rock Mass Strength is generally lower than the strength of a rock sample- mainly because rock masses are not usually intact or homogeneous

    - Primarily depends on the fractures within it (number, spacing, extent, nature), the condition of the rock (state of weathering etc) and the groundwater condition

- Assessment of rock mass strength can be conducted by recognizing cumulative effect of different geological features

Rock Mass Classification Schemes

The most widely used systems are:

- ***The Geomechanics Rock Mass Rating (RMR)***
- ***The Norwegian Q System***

Both systems are dominated by **fractures properties**

Geomechanics System of Rock Mass Rating

Parameter	*Assessment of values and rating*				
Intact rock UCS, MPa	>250	100–250	50–100	25–50	1–25
Rating	15	12	7	4	1
RQD %	>90	75–90	50–75	25–50	<25
Rating	20	17	13	8	3
Mean fracture spacing	>2 m	0·6–2 m	200–600 mm	60–200 mm	<60 mm
Rating	20	15	10	8	5
Fracture conditions	rough tight	open <1 mm	weathered	gouge <5 mm	gouge >5 mm
Rating	30	25	20	10	0
Groundwater state	dry	damp	wet	dripping	flowing
Rating	15	10	7	4	0
Fracture orientation	v. favourable	favourable	fair	unfavourable	v. unfavourable
Rating	0	−2	−7	−15	−25
Rock mass rating (RMR) is sum of the six ratings			Note that orientation ratings are negative		

RMR = Intact Rock UCS rating + RQD rating + Mean fracture spacing rating + Fracture condition rating + Groundwater state rating + Fracture orientation rating

Norwegian Q System

The Q factor also looks at 6 factors:

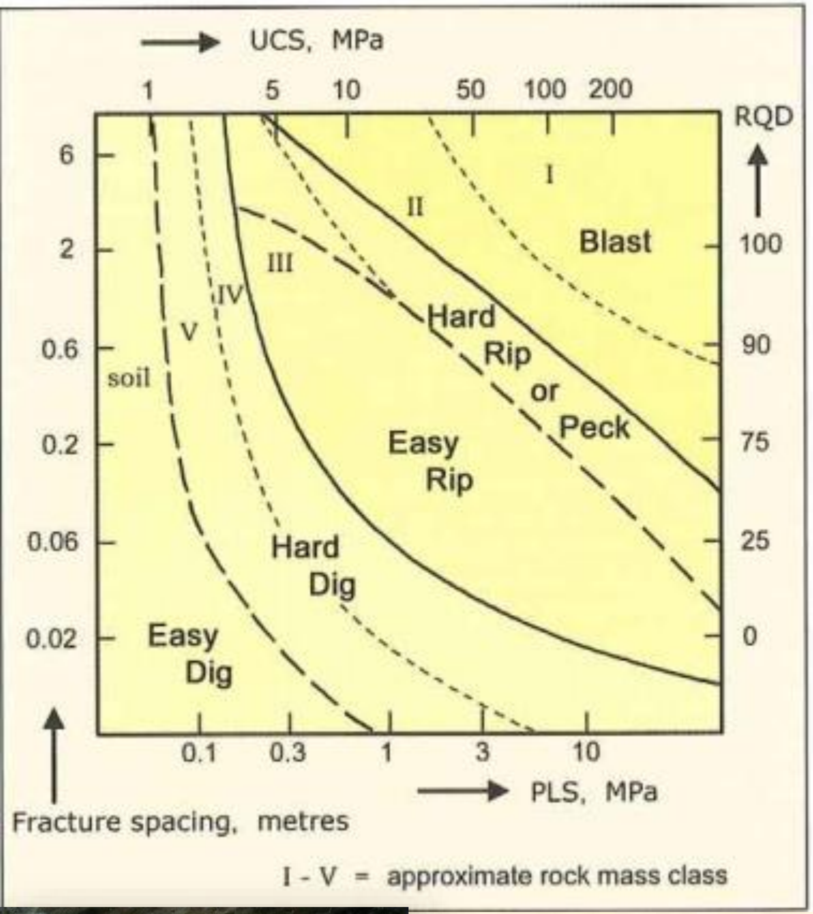
- RQD
- J_n - the joint set number
- J_r - the joint roughness factor
- J_a - the joint alteration and clay filling
- J_w-the joint water inflow or pressure
- SRF- the stress reduction factor due to excavation

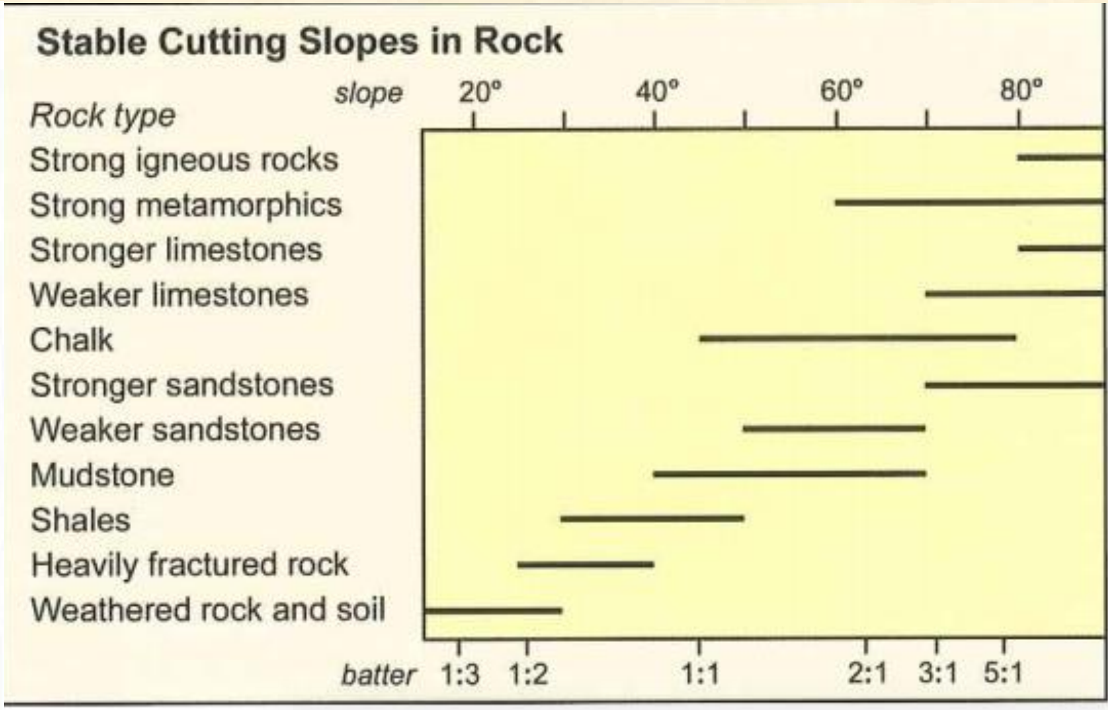
$$Q = RQD/J_n \times J_r/J_a \times J_w/SRF$$

Guideline Properties Of Rock Mass Classes

Class	I	II	III	IV	V
Description	very good rock	good rock	fair rock	poor rock	very poor rock
RMR	80–100	60–80	40–60	20–40	<20
Q Value	>40	10–40	4–10	1–4	<1
Friction angle φ (°)	>45	35–45	25–35	15–25	<15
Cohesion (kPa)	>400	300–400	200–300	100–200	<100
SBP (MPa)	10	4–6	1–2	0.5	<0.2
Safe cut slope (°)	>70	65	55	45	<40
Tunnel support	none	spot bolts	pattern bolts	bolts + shotcrete	steel ribs
Stand up time for span	20 yr for 15 m	1 yr for 10 m	1 wk for 5 m	12 h for 2 m	30 min for 1 m

Usage Of Rock Strength Information



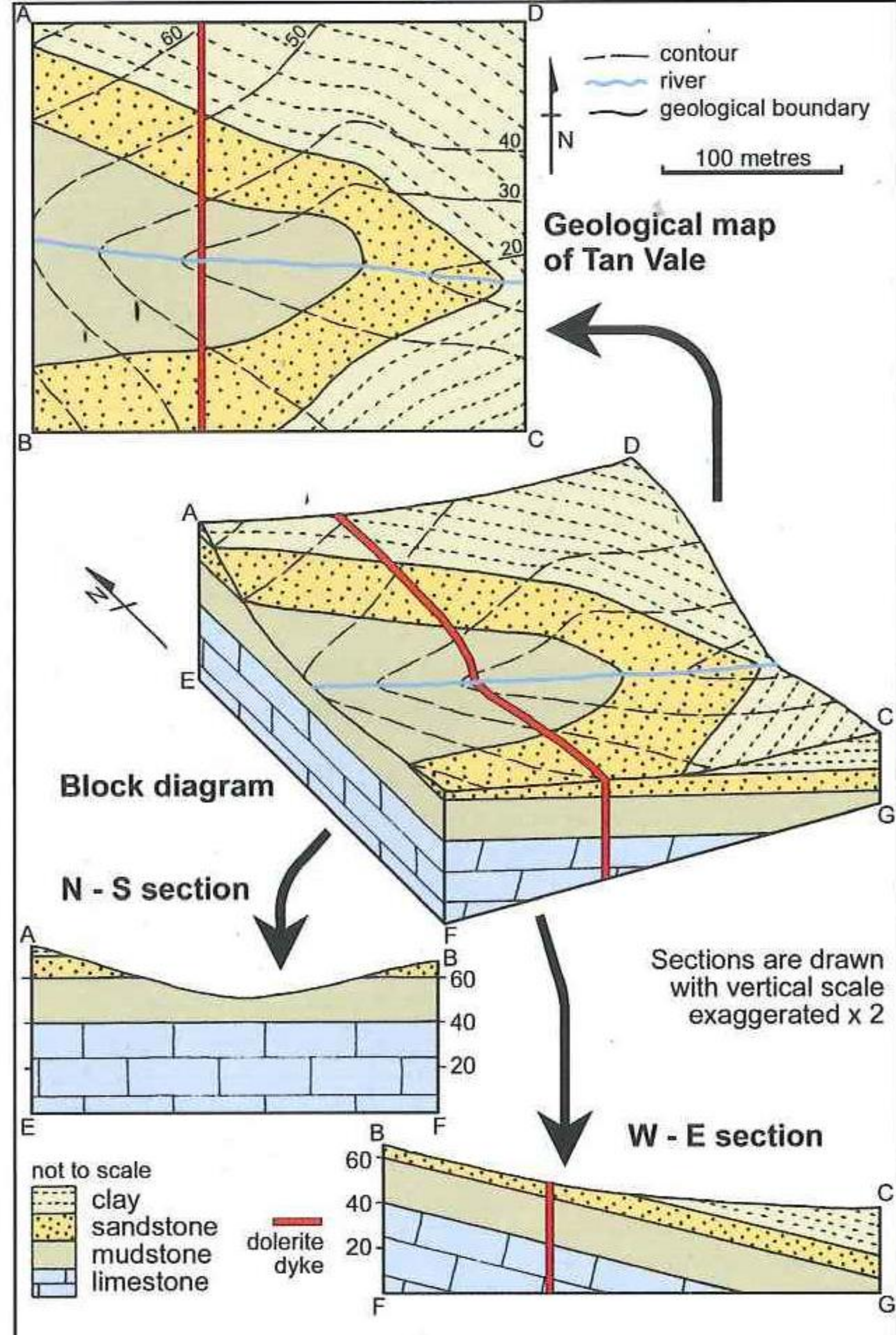


Geological Model

- The role of the geologist in engineering projects is to build the geological model for the site.
- A geological model should be available during the design stage.
- The geological model will be imperfect and will be improved during the project as greater understanding of the site is revealed

GEOLOGICAL MODEL

- Geological Map
- Geological Cross-Section
- 3-D Structure



Geological Model

- The geological model is based on
  - Desk study
    - Geological, topographic and historical maps
  - Site investigation
    - Site walkover, trial pits, boreholes, chemical analysis

Geological Model

The general rules are:

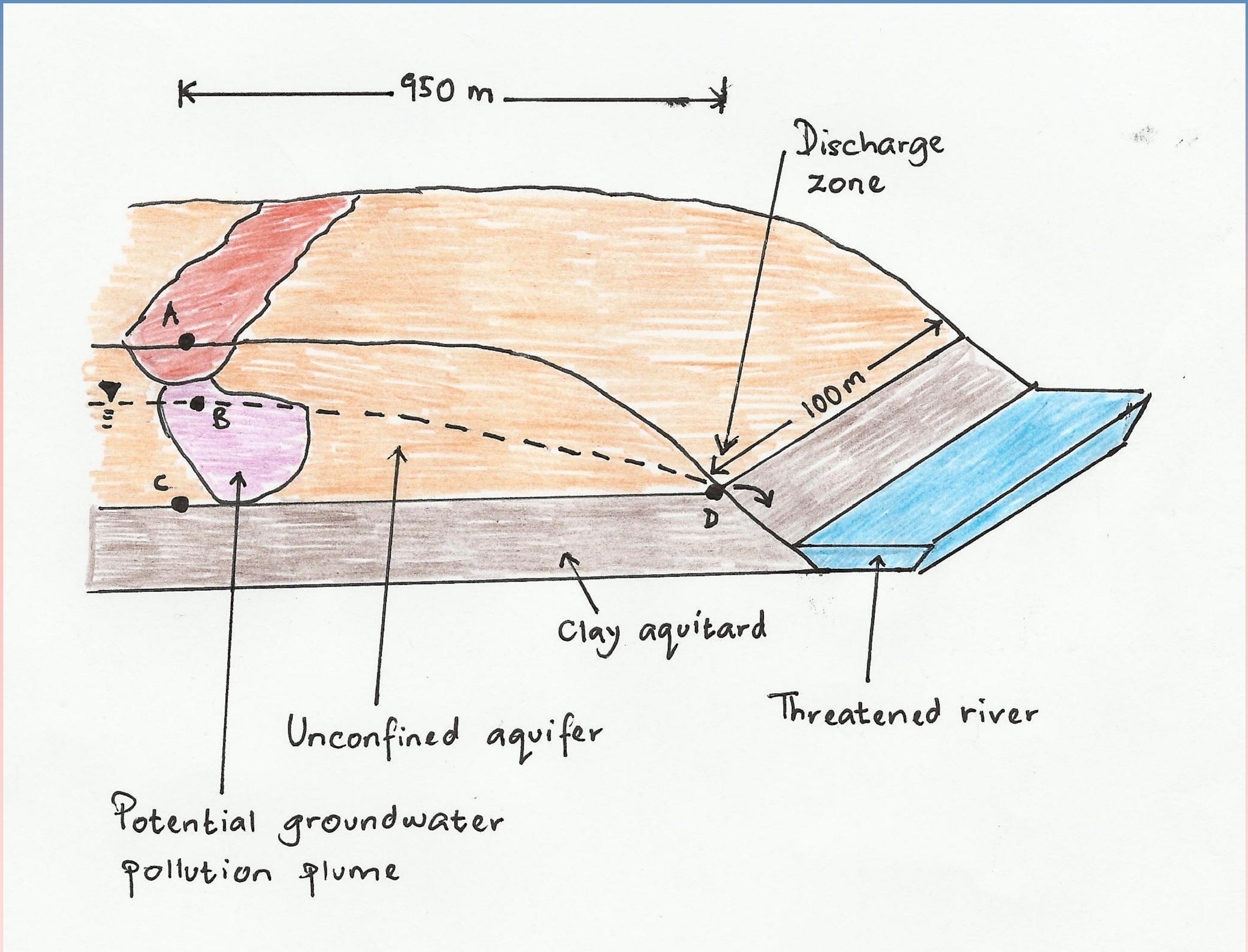
- Most engineering projects only exist in the top few metres of the geology
- Soils and rocks are not made to a British Standard
- Geological knowledge is always imperfect
- “Pay for the geological survey at the start because you will pay for it later”

“Trial Pit” Projek Naiktaraf Jeti Dan Bangunan Terminal Jeti Baru Di Jeti Kuah , Langkawi

Failure of the Geological Model

- Geological models fail for the following reasons
  - Lack of engineering knowledge by geologist
  - Incorrect or insufficient geological advice
  - Inadequate subsurface exploration
  - Poor data collection
  - Not all geological questions asked or answered
  - Inappropriate mapping scales
  - Over reliance on technology
  - Poor communication
  - Excessive workload

Usage Of Groundwater Knowledge



Based on Figure 1 above, elevations as metres above ordnance datum (m AOD)for the spots A – D are given as follows:

A- 100.7 m AOD

B -98.6 m AOD

C-90.7 m AOD

D-90.7 m AOD

Another informations provided are:

Hydraulic conductivity (K) = 90 m/d

Effective porosity (n) = 17% = 0.17

The estimated time that it will take for polluted plume to emerge at the discharge zone can be defined by the distance from spot A to D (950 m) divided by the actual velocity (v_i) of groundwater.

Actual velocity , v_i = K i/n

Where i = hydraulic gradient

Hydraulic gradient, i = Δh/L = (98.6 m – 90.7 m)/950 m

= 8.316×10^{-3}

Actual velocity, v_i = K i/n = (90 m/d x 8.316×10^{-3})/0.17

= 4.403 m/d

The estimated time for polluted plume to emerge at the discharge zone, t = 950 m/4.403 m/d

= **215.76 days**

Total flow-rate at the discharge zone, Q = T i w

Where T – Transmissivity

w- Width of the aquifer

i – Hydraulic gradient

Transmissivity T = Kb

Where K-Hydraulic conductivity (90 m/d)

b-Mean saturated thickness in an aquifer

Mean saturated thickness in an aquifer, b = (98.6 m – 90.7 m)/2

= 3.95 m

Transmissivity, T = Kb = 90 m/d x 3.95 m

= 355.5 m^2/d

Total flow-rate at the discharge zone, Q = T i w

= 355.5 m^2/d x 8.316 x 10^{-3} x 100 m

= 295.63 m^3/d

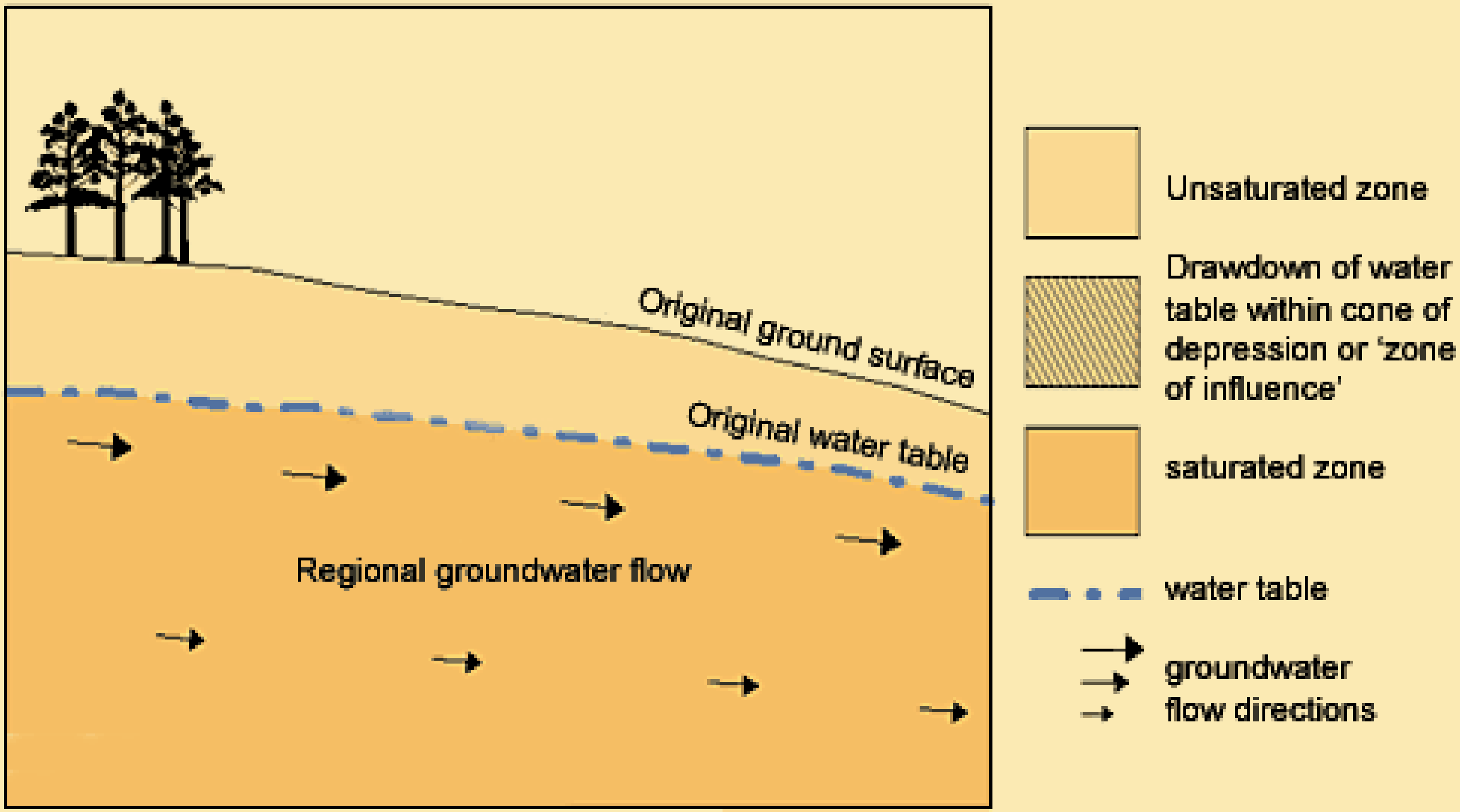
= **3.42 L/s**

Civil Engineering Projects

- Groundwater is a problem when the civil engineering project goes below the water table
- Tunnels
- Inner city developments where space is at a premium

POTENTIAL EFFECTS Figure 06

A) Original, natural conditions

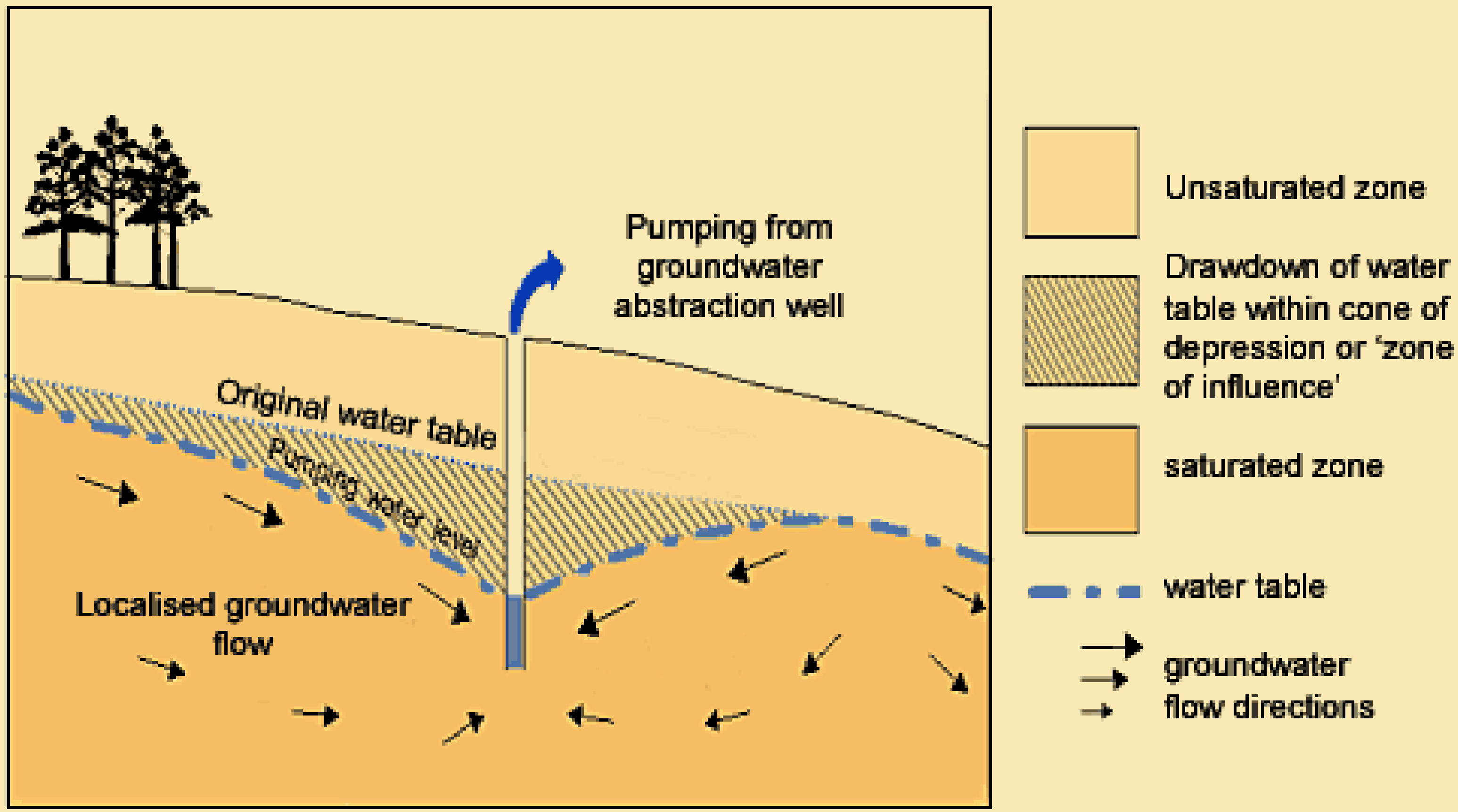


http://www.goodquarry.com

POTENTIAL EFFECTS

Figure 07

B) Dewatering associated with abstraction wells



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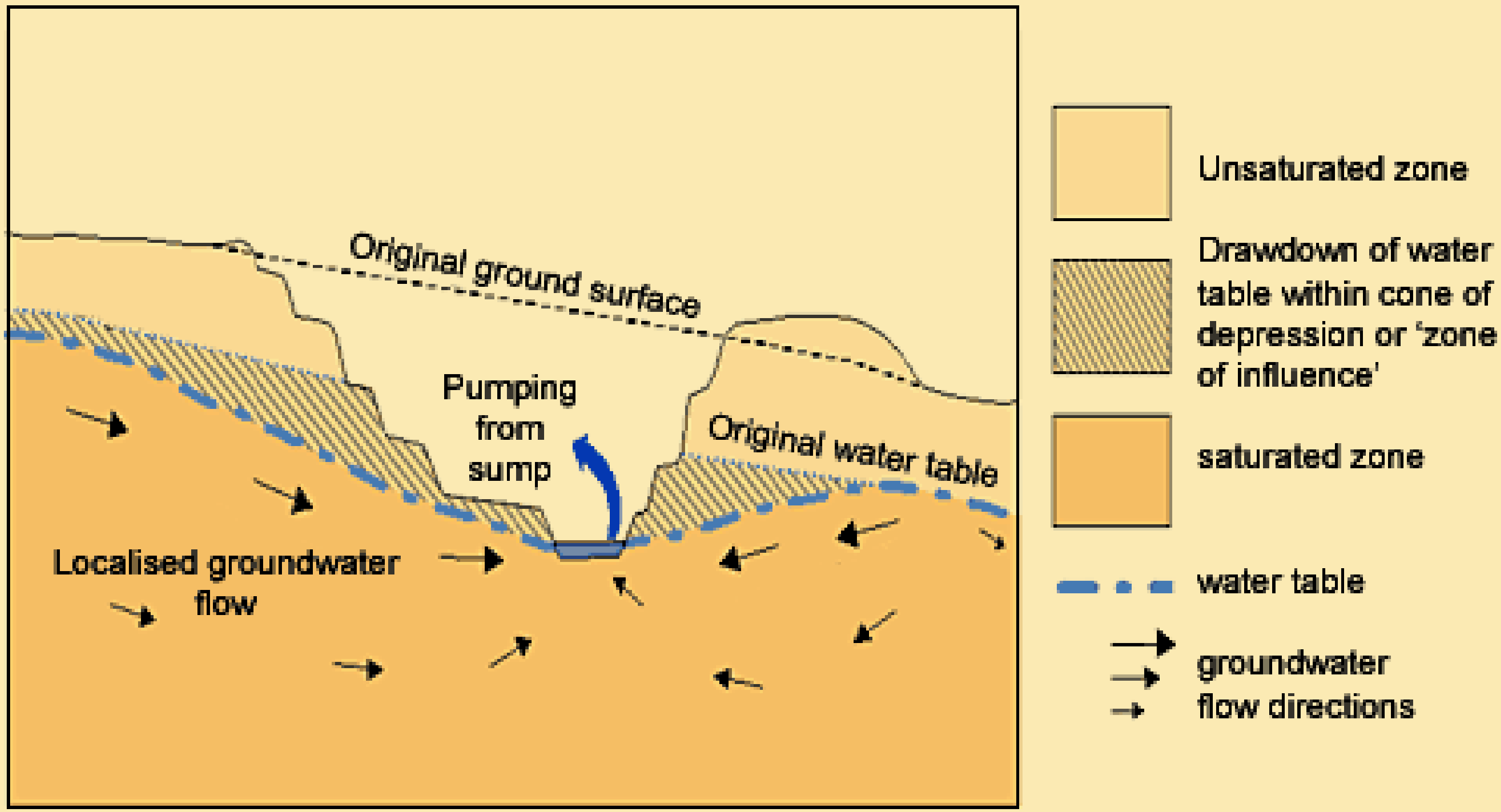
POTENTIAL EFFECTS

Figure 08

C) Dewatering associated with pumping from the base of an excavation



http://www.goodquarry.com

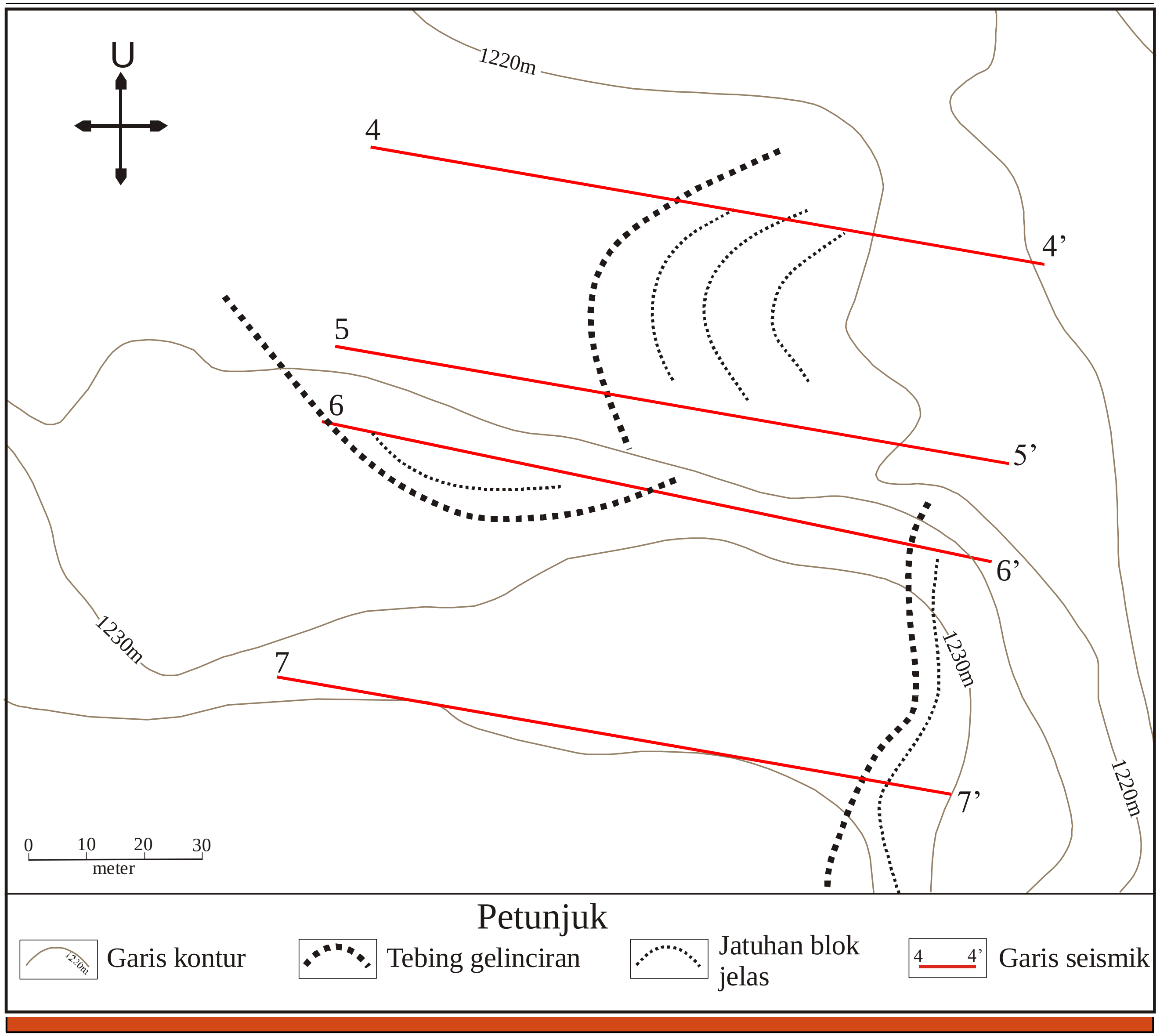
Kajian Seismos Di SMK Kundasang

OBJEKTIF

- Menentukan kedalaman batuan dasar;
- Mengenalpasti zon-zon lemah
- Menentukan kehadiran zon-zon retakan, sesar sekiranya mungkin

KAEDAH SEISMOS BIASAN

- Seismograf – Geometrics Smartseis 24 Ch
- Penukul – 10 pound
- Sela jarak antara geofon – 5 m
- Panjang satu bentangan (spread) – 115 m
- Bilangan titik tembak – 5 lokasi
- Perisian pemprosesan data – *REFRACT* oleh RTA Ver 1.0



Lokasi garis seismik dan kontur SMK Kundasang

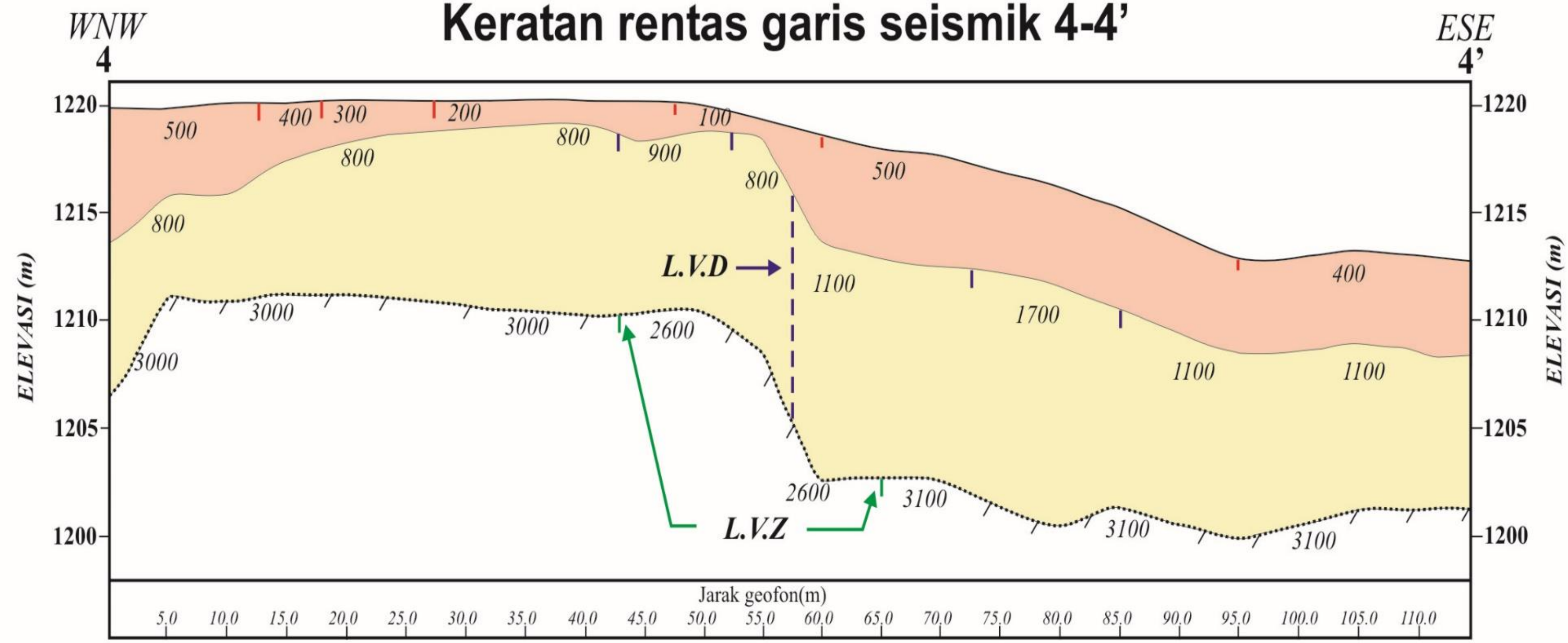
“Bukaan” yang terbentuk akibat gelinciran tanah kawasan flat guru SMK Kundasang.

Gelinciran tanah kawasan padang SMK Kundasang.

PROJEK SIASATAN GEOFIZIK UNTUK PEMETAAN TERAIN KAWASAN KUNDASANG, RANAU

(SMK 1)

Keratan rentas garis seismik 4-4'



Tanah atas (*Top soil)*

Bahan tak konsolidat / tanah isian / tanah padat. *(Unconsolidated material / landfill / compacted materials)*

Permulaan antaramuka batuan terluluhawa sederhana ke rendah.(*The beginning of moderately to slightly weathered rock interface. Unbottomed)*

Tarikh siasatan	:	Jun, 2003
Alat yang digunakan	:	Seismograf-*Geometrics Smartseis 24-Channels*
Sumber tenaga	:	Tukul 10 paun
Jarak Geofon	:	5 meter
Pelanggan	:	(Projek Pembangunan- Pemetaan Terain)
Dikendalikan oleh	:	Aktiviti Geofizik, JMG Sabah

N 100° 4 4'

1700 - Halaju seismik dalam m/s

L.V.D - *Lateral Velocity Discontinuity*

L.V.Z - Zon berhalaju rendah.[*Low velocity zone.(infered fault/fracture zone)*]

0 10.0 *meter*

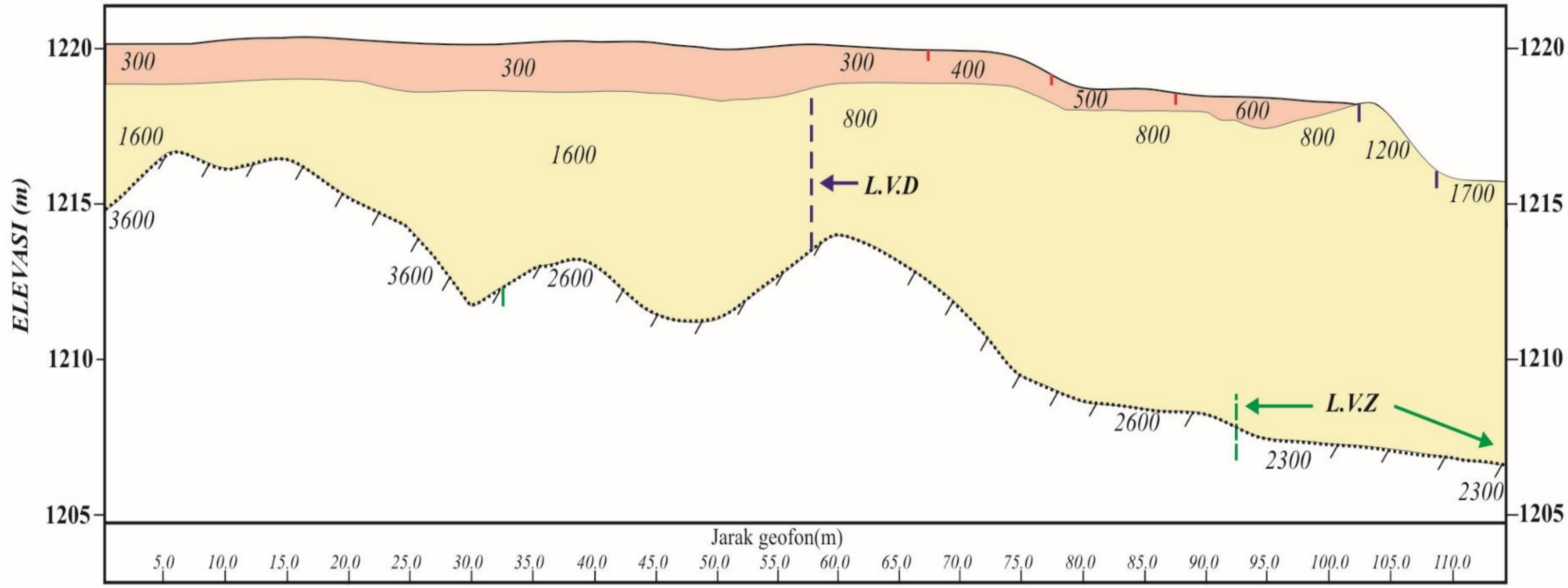
Rajah 14 . Keratan rentas garis seismik 4-4' di SMK Kundasang.

PROJEK SIASATAN GEOFIZIK UNTUK PEMETAAN TERAIN KAWASAN KUNDASANG, RANAU

(SMK 2)

Keratan rentas garis seismik 5-5’

WNW **5** — *ESE* **5’**



Tanah atas (*Top soil*)

Bahan tak konsolidat/tanah isian dan batuan terluluhawa penuh.(*Unconsolidated material/landfill and completely weathered rock*)

Permulaan antaramuka batuan terluluhawa tinggi ke rendah.(*The beginning of highly to slightly weathered rock interface. Unbottomed*)

Tarikh siasatan	:	Jun, 2003
Alat yang digunakan	:	Seismograf-*Geometrics Smartseis 24-Channels*
Sumber tenaga	:	Tukul 10 paun
Jarak Geofon	:	5 meter
Pelanggan	:	(Projek Pembangunan- Pemetaan Terain)
Dikendalikan oleh	:	Aktiviti Geofizik, JMG Sabah

N — 5 — 100° — 5’

100 - Halaju seismik dalam m/s

L.V.D - *Lateral Velocity Discontinuity*

L.V.Z - Zon berhalaju rendah.[*Low velocity zone.(infered fault/fracture zone)*]

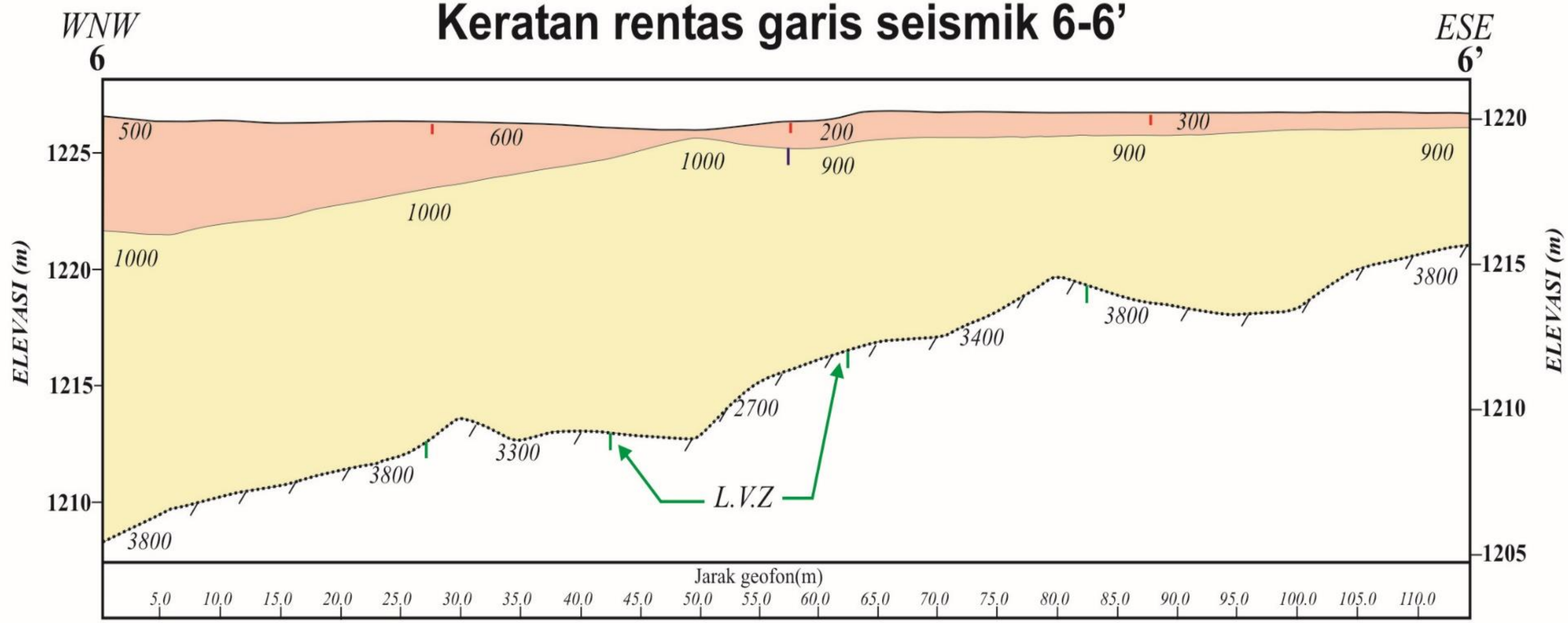
0 — 10.0 *meter*

Rajah 15 . Keratan rentas garis seismik 5-5’ di SMK Kundasang.

PROJEK SIASATAN GEOFIZIK UNTUK PEMETAAN TERAIN KAWASAN KUNDASANG, RANAU

(SMK 3)

Keratan rentas garis seismik 6-6’

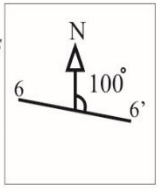


Tanah atas. (*Top soil)*

Bahan tak konsolidat/tanah isian.*(Unconsolidated material/landfill)*

Permulaan antaramuka batuan terluluhawa sederhana ke batuan segar.(*The beginning of moderately weathered rock to fresh bedrock interface. Unbottomed)*

Tarikh siasatan	:	Jun, 2003
Alat yang digunakan	:	Seismograf-*Geometrics Smartseis 24-Channels*
Sumber tenaga	:	Tukul 10 paun
Jarak Geofon	:	5 meter
Pelanggan	:	(Projek Pembangunan- Pemetaan Terain)
Dikendalikan oleh	:	Aktiviti Geofizik, JMG Sabah



2700 - Halaju seismik dalam m/s

0 *10.0* *meter*

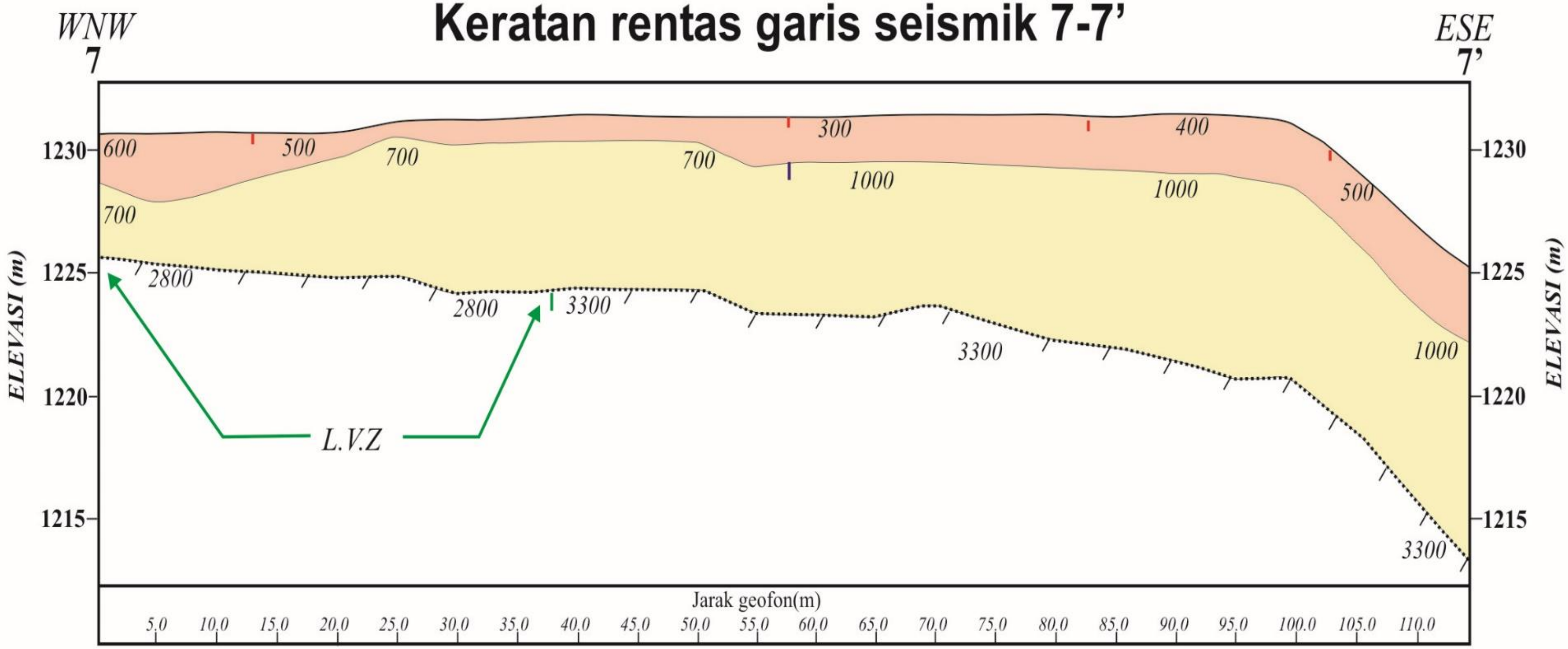
L.V.Z - Zon berhalaju rendah.[*Low velocity zone.(infered fault/fracture zone)*]

Rajah 16 . Keratan rentas garis seismik 6-6’ di SMK Kundasang.

PROJEK SIASATAN GEOFIZIK UNTUK PEMETAAN TERAIN KAWASAN KUNDASANG, RANAU

(SMK 4)

Keratan rentas garis seismik 7-7’

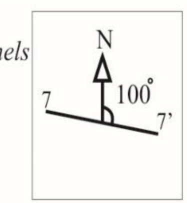


Tanah atas. (*Top soil*)

Bahan tak konsolidat/tanah isian.(*Unconsolidated material/landfill)*

Permulaan antaramuka batuan terluluhawa sederhana ke rendah.(*The beginning of moderately to slightly weathered rock interface. Unbottomed)*

Tarikh siasatan	:	Jun, 2003
Alat yang digunakan	:	Seismograf-*Geometrics Smartseis 24-Channels*
Sumber tenaga	:	Tukul 10 paun
Jarak Geofon	:	5 meter
Pelanggan	:	(Projek Pembangunan- Pemetaan Terain)
Dikendalikan oleh	:	Aktiviti Geofizik, JMG Sabah



3300 - Halaju seismik dalam m/s

0 10.0 meter

L.V.Z - Zon berhalaju rendah.[*Low velocity zone.(infered fault/fracture zone)*]

Rajah 17. Keratan rentas garis seismik 7-7’ di SMK Kundasang.

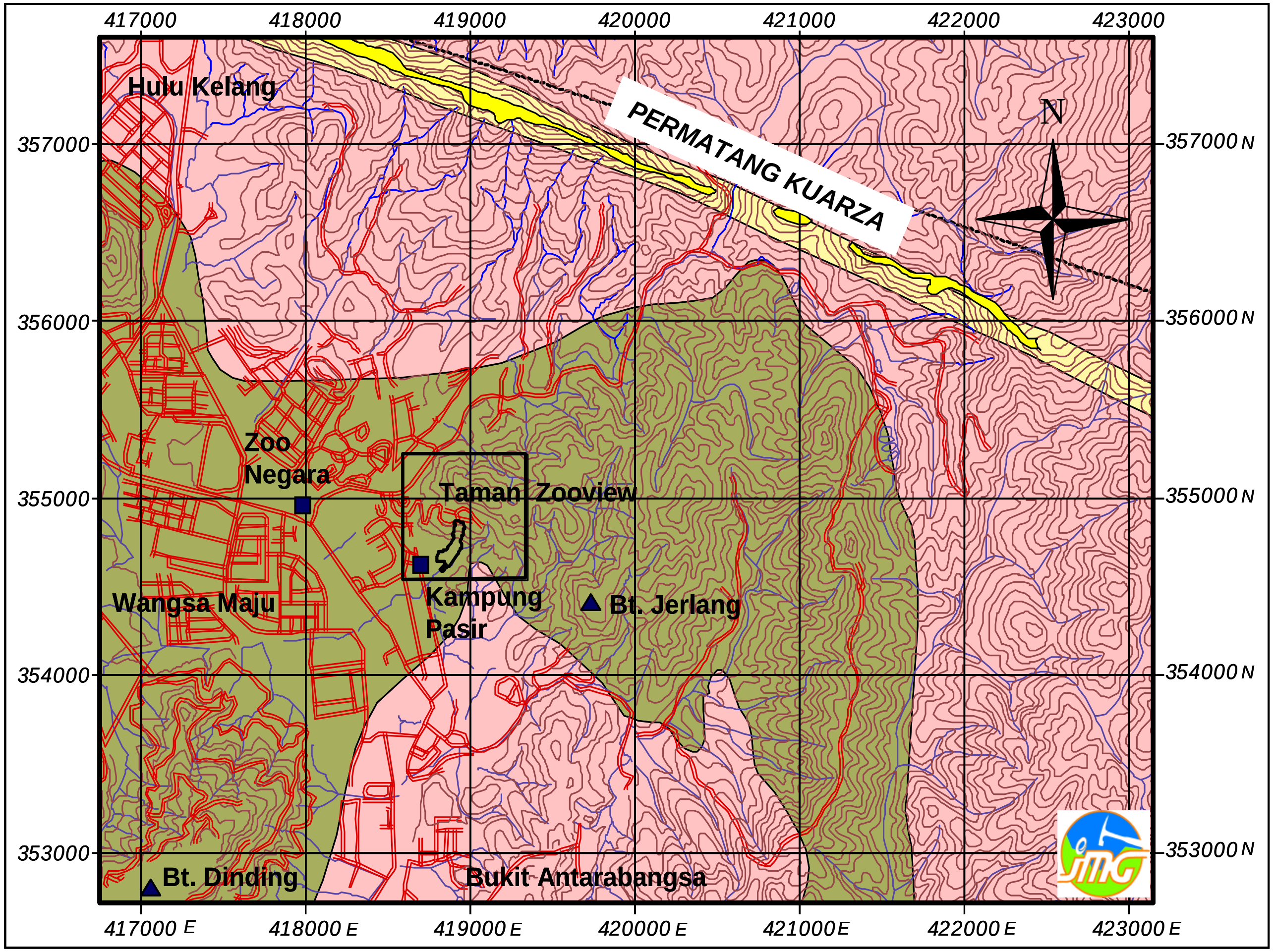
NILAI HALAJU DAN KETEBALAN LAPISAN

Lapisan	Halaju (m/s)	Ketebalan (m)	Korelasi geologi
1	300 – 600	2 - 5	Bahan tak konsolidat (batu kelikir?)
2	800 – 1,700	4 - 15	Batuan terluluhawa penuh
3	2,300 – 3,800	10 - 25	Batuan dasar terluluhawa tinggi ke segar

Kajian Resistivity Di Taman Zoo View

- **31 MEI 2006**
- **4.45 p.m.**
- **Kg. Pasir, Hulu Kelang**
- **Filled-slope**
- **Reinforced Earth Wall on the filled-slope**

GEOLOGY



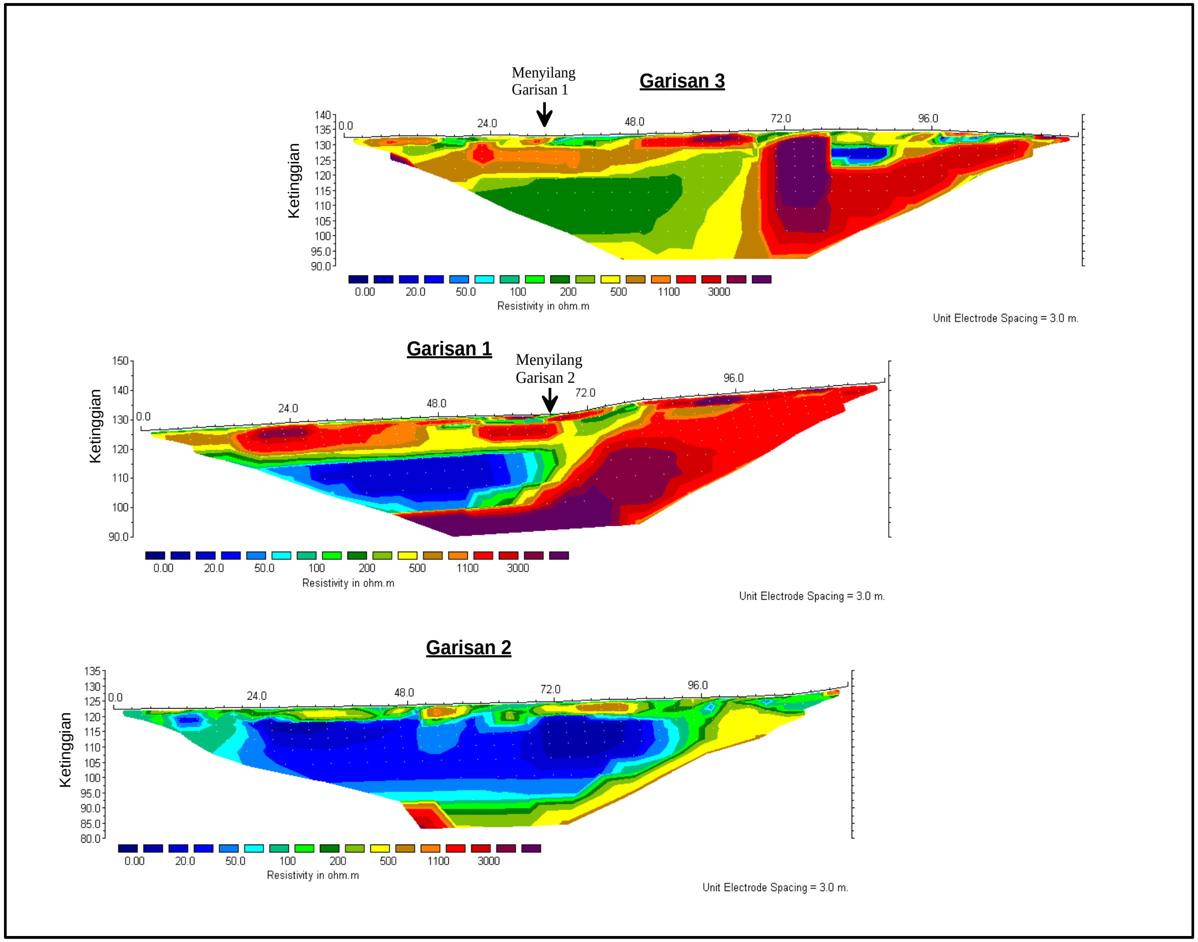
PETUNJUK

(yellow)	Kuarza
(pink)	Kuala Lumpur Granit
(green)	Syis dan filit (Formasi Hawthornden)

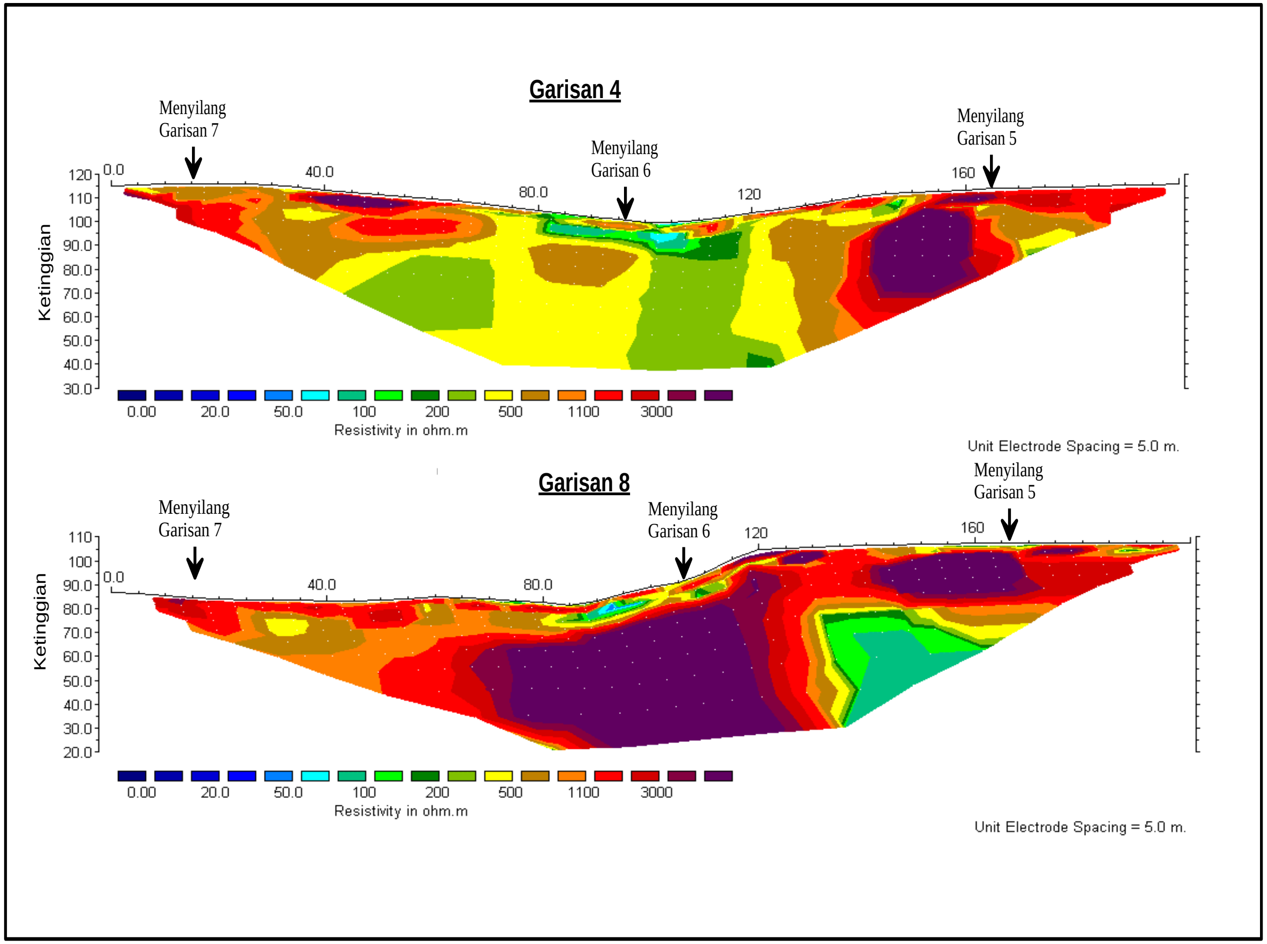

31.05.2006 18:09

2 DIMENSIONAL RESISTIVITY SURVEY

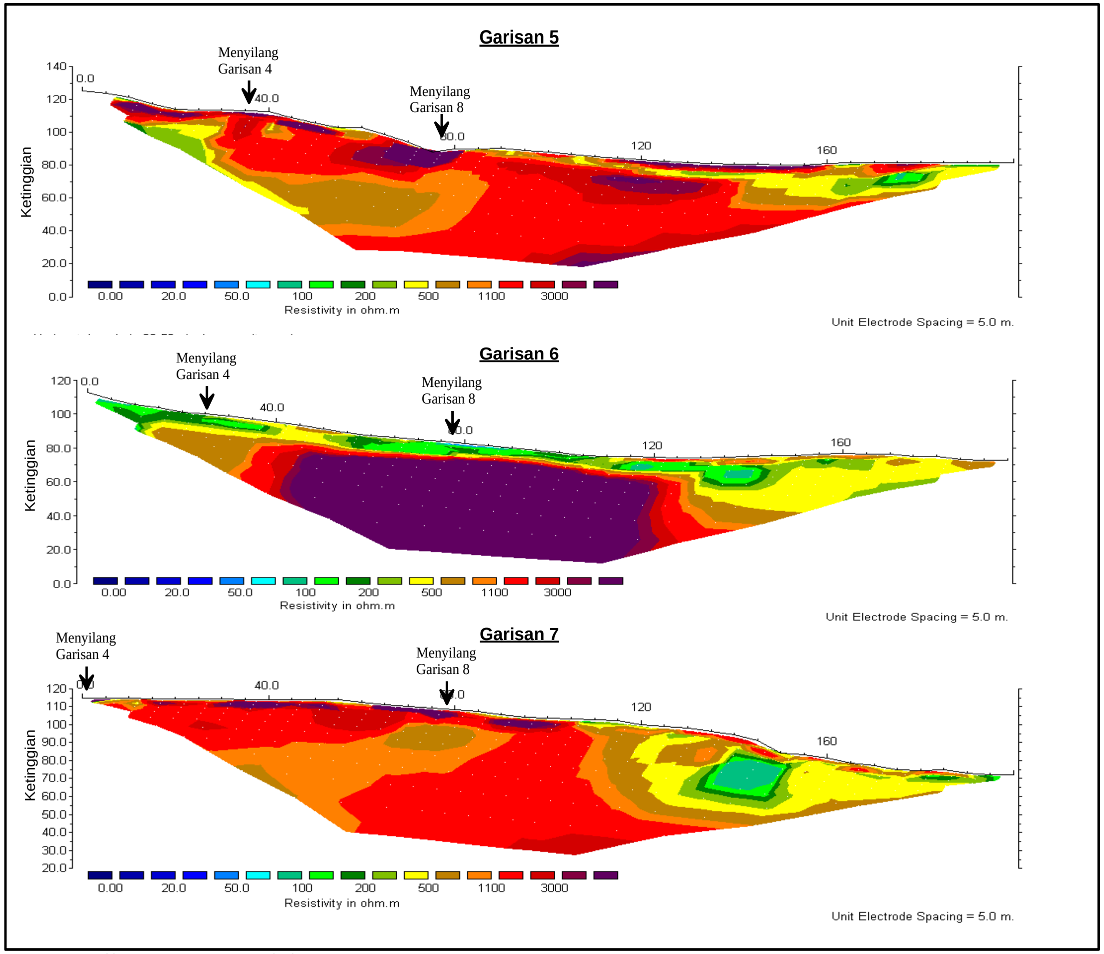
RESULTS AND DISCUSSION

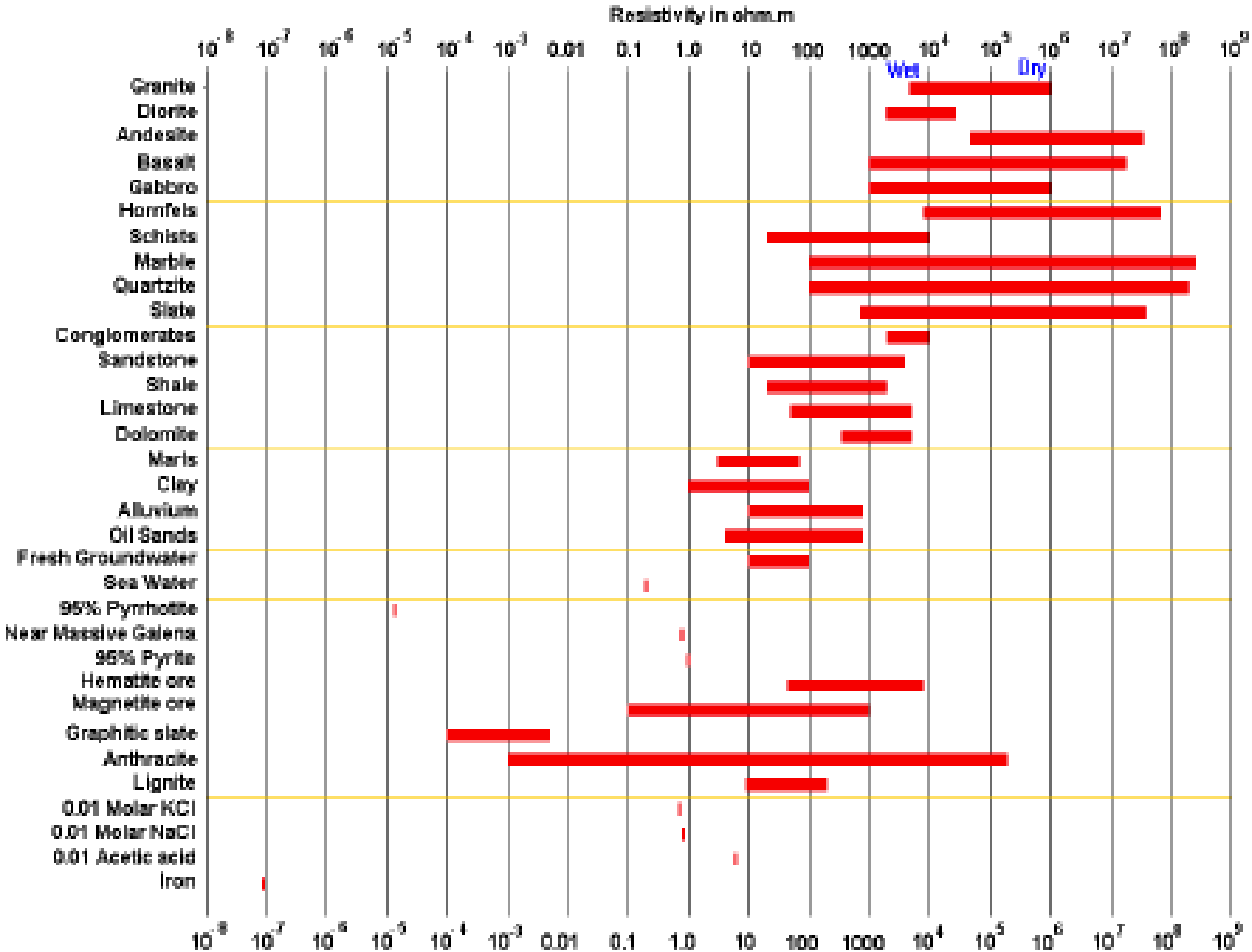


RESULTS AND DISCUSSION



RESULTS AND DISCUSSION





Resistivity in ohm.m
10^-8
10^-7
10^-6
10^-5
10^-4
10^-3
0.01
0.1
1.0
10
100
1000
10^4
10^5
10^6
10^7
10^8
10^9
Wet
Dry
Granite
Diorite
Andesite
Basalt
Gabbro
Hornfels
Schists
Marble
Quartzite
Slate
Conglomerates
Sandstone
Shale
Limestone
Dolomite
Marls
Clay
Alluvium
Oil Sands
Fresh Groundwater
Sea Water
95% Pyrrhotite
Near Massive Galena
95% Pyrite
Hematite ore
Magnetite ore
Graphitic slate
Anthracite
Lignite
0.01 Molar KCl
0.01 Molar NaCl
0.01 Acetic acid
Iron

TYPES OF ROCK SLOPE FAILURE

- **Failure of rock slopes in rock mass could be either one or combination of the following modes;**
  - **Circular failure** – generally occurs within a very heavily jointed rock mass where no identifiable patterns of discontinuities present

    .
  - **Planar Failure** – failure take place along a dominant discontinuity plane or highly ordered structure (e.g. bedding), which is parallel or nearly parallel to the slope face
  - **Wedge Failure** – commonly occurs at two or more intersecting discontinuity planes
  - **Toppling or rock fall** – failure in hard rock which can form columnar or block structures separated by steeply dipping discontinuities

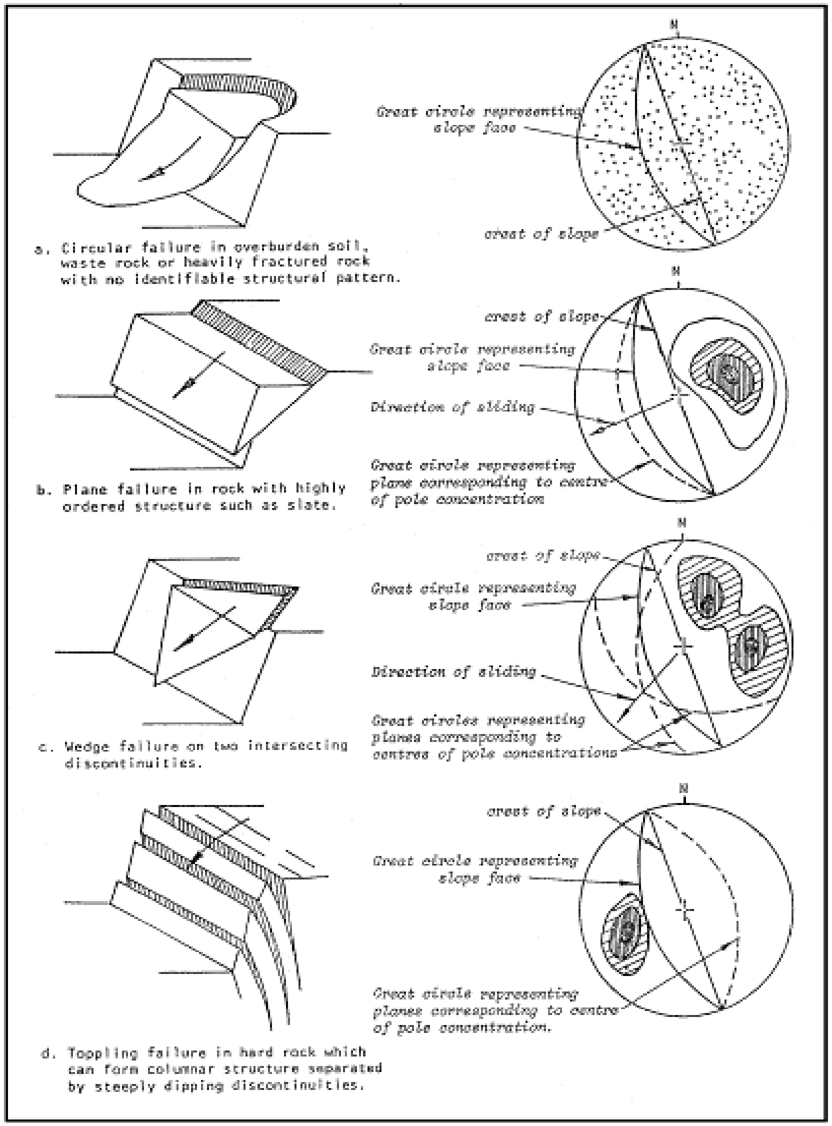


Figure 13: Main type of slope failures and stereoplots of structural conditions likely to give rise to these failures (Hoek & Bray, 1981)

Rock Slide – (Planar Failure)

…. *Due to daylighting sheet joints in granitic rock slope.*

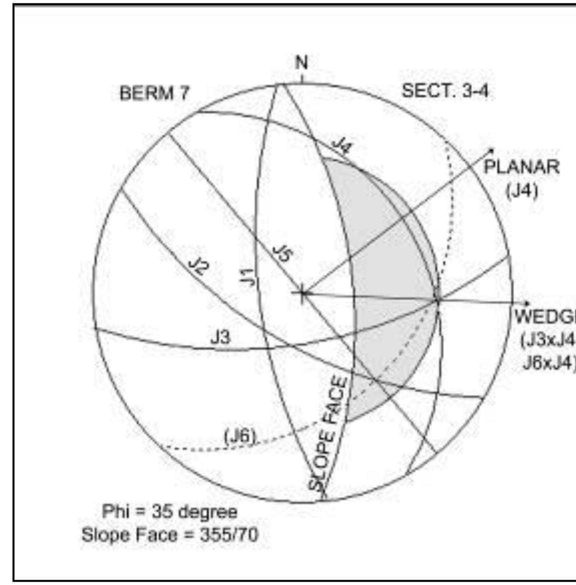
SLIDE – Rock Wedge

A typical example of wedge failure at Cameron Highland Gua Musang Road

"Rock Falls"

…. primarily due to very steep joints in overhanging rock face. (Limestone cliff near Simpang Pulai, Ipoh)

- **Mode of failures: planar + toppling.**



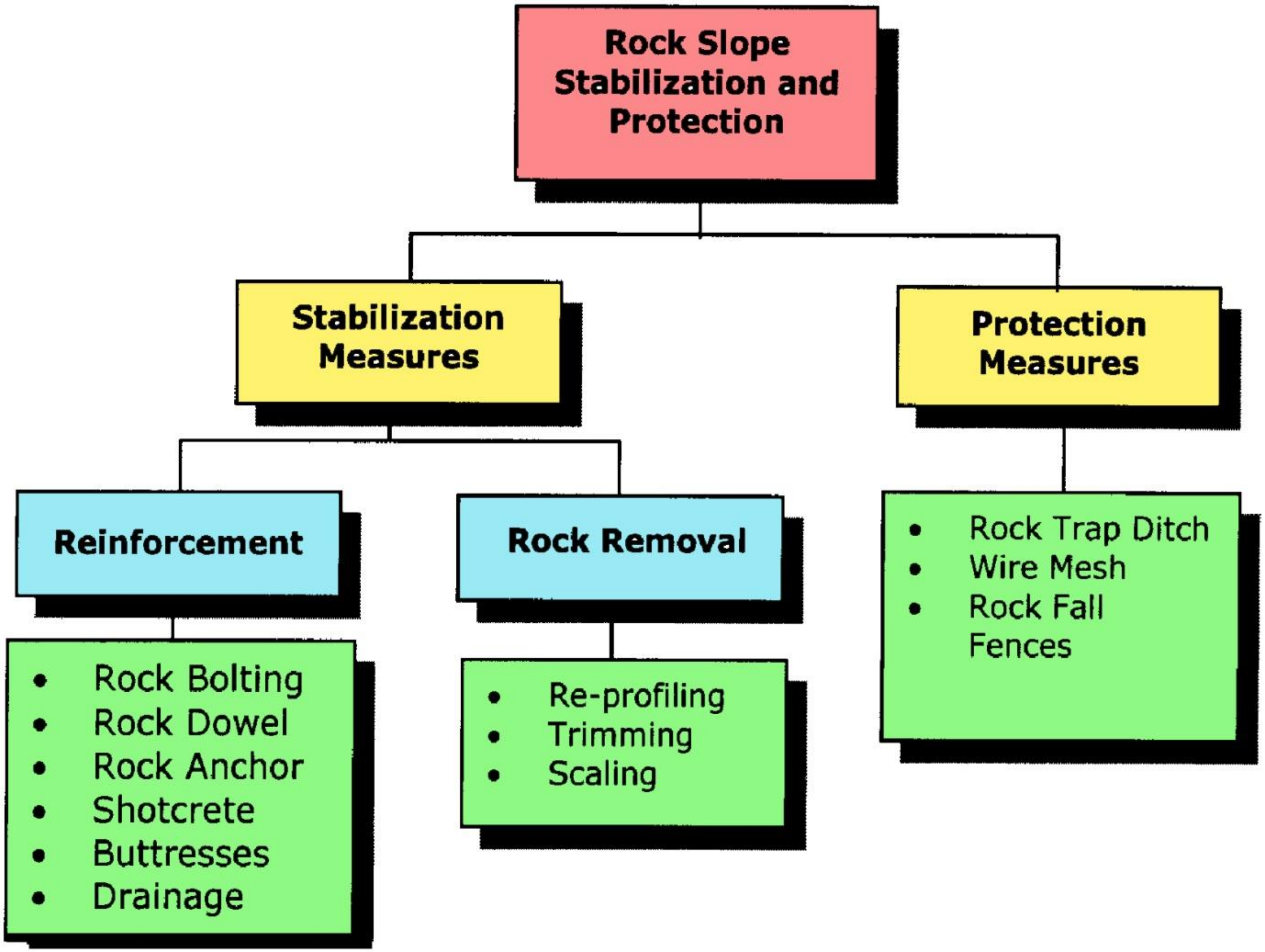
Stereographic plots of the discontinuities

Bukit Lanjan Rock Slope – a combination of multiple modes of failure (wedge & planar)

How To Select Suitable Slope Stabilisation Measures?

- To answer this we must first answer the following questions:
  1) What are the factors affecting slope instability?
     - Geology – structural discontinuities, rock types, geomorphology, weathering, etc.?
     - Shear strength of the slope forming materials/discontinuities?
     - Surface & Ground water conditions?
     - External loading?
     - Slope Geometry & Design?
  2) Mode of failures?
     - Planar, wedge, toppling, combined modes?

Rock Slope Stabilization & Protection Measures



Retaining Walls

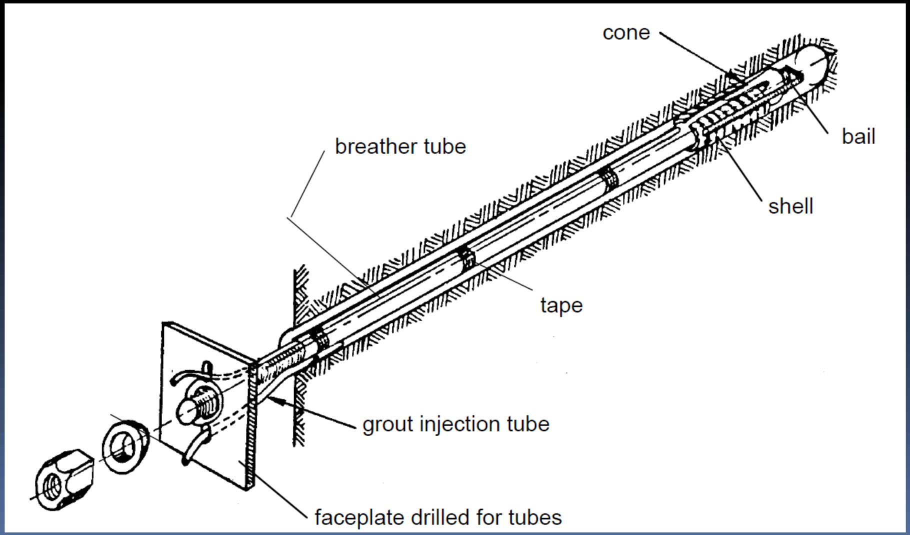
- Retaining wall are structures usually provided at the toe of a slope to stabilize it from slide, overturn or collapse
  - **To arrest deep-seated and large-scale failure**

Contiguous Bored-Pile Wall

Rock Butress

Rockbolts

- Rockbolts generally consist of plain steel rods with a mechanical anchor at one end and a face plate and nut at the other.
- They are always tensioned after installation.
- the space between the bolt and the rock can be filled with cement or resin grout.



Wire Netting at site Y

The “daylighting blocks” should be anchored with rock bolts/nails before wrapping with the wire mesh.

CONCLUSION

- The role of a geologist is to develop a geological model such that the ground to be used is **FIT FOR PURPOSE**

Thank You for your kind attention!!

“it is better to be approximately right than precisely wrong” (Hammah and Curran 2009).

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