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เอกสารประกอบการสอน

วิชาธรณีวิทยา (Physical Geology) 538201

อาจารย์ ดร.อานิสงส์ จิตนารินทร์

มหาวิทยาลัยเทคโนโลยีสุรนารี

สาขาวิชาเทคโนโลยีธรณี

สำนักวิชาวิศวกรรมศาสตร์

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เมษายน 2557

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เมษายน 2557

Physical Geology (538201)

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Chapter 3 Rocks
Chapter 4 Geological processes
Chapter 5 Geological time and history
Chapter 6 Geological structure
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Chapter 10 Map and images for Geology
Chapter 11 Geological investigation

มหาวิทยาลัยเทคโนโลยีสุรนารี

Chapter1 Introduction to Physical Geology

ธรณีวิทยากายภาพ

มหาวิทยาลัยเทคโนโลยีสุรนารี

Contents

1. Introduction to Physical Geology
2. Earth and Universe
3. Plate tectonics

1. Introduction to Physical Geology

Why do we have to study Geology?
How important is Geology?
Who needs Geology?



Photo from internet

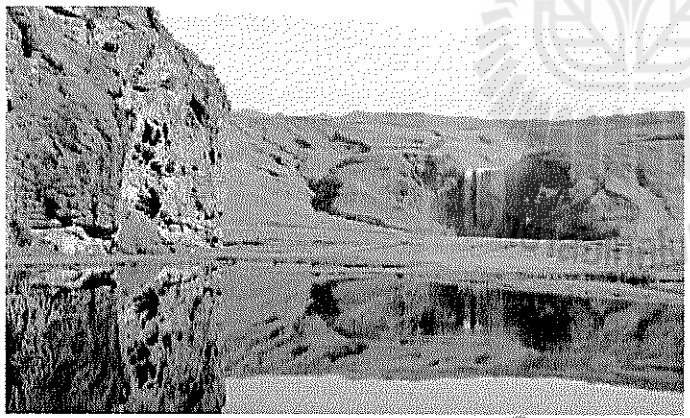
มหาวิทยาลัยเทคโนโลยีสุรนารี

Geology: the scientific study of the Earth

Geos + Logi or Logus
(Earth) (Science)

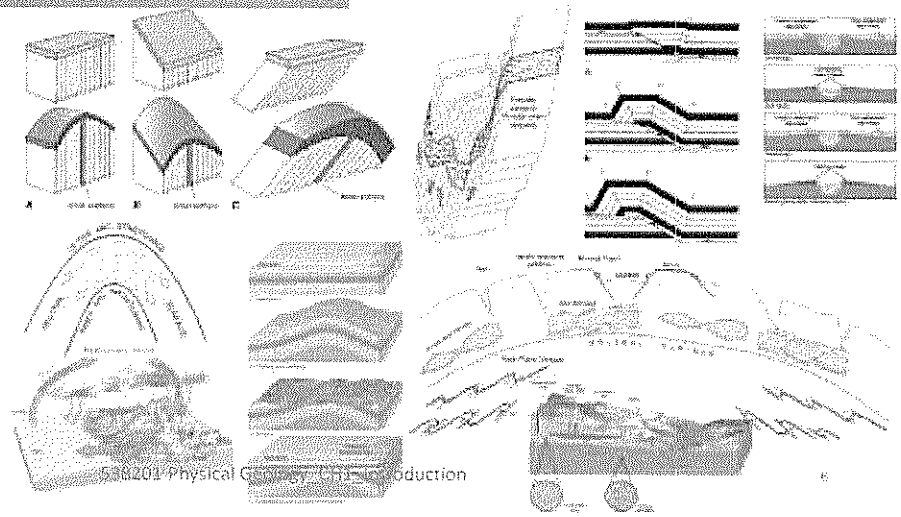
ธรณีวิทยาคือแขนงของวิทยาศาสตร์ ที่ศึกษาเกี่ยวกับส่วนประกอบของโลก โครงสร้างของโลก กระบวนการทางธรรมชาติที่เกิดขึ้นภายในและบนโลก และวิวัฒนาการของโลก (วัสดุ-กระบวนการ-วิวัฒนาการ ของโลก)

วิทยาศาสตร์เกี่ยวกับโลกพิภพหรือโลกมนุษย์ ซึ่งครอบคลุมถึงกำเนิดของโลกและดวงดาวต่าง ๆ ระบบสุริยะจักรวาล วัสดุรูปร่างของโลก ความเป็นมาและกระบวนการที่กระทำต่อโลกทั้งในอดีตและปัจจุบัน รวมถึงแรงที่มากระทำ ที่มีผลต่อการเปลี่ยนแปลงหรือยังคงมีผลต่อการเปลี่ยนแปลงสภาวะเคมี มวลสารและส่วนประกอบ ตลอดจนอายุและร่องรอยการบันทึกในอดีตของโลก มนุษย์ ซึ่งแสดง ออกด้วยส่วนที่เหลืออยู่ของสิ่งมีชีวิตซึ่งคงอยู่ในหินบนเปลือกโลก และโดยการตีความจากรูปแบบและสภาวะแวดล้อมที่ยังคงเหลืออยู่ให้เห็นในปัจจุบัน (ปัญญา จารุศิริ และคณะ 2551)



นักธรณีวิทยามองเห็นภูเขา หน้าผา ทางน้ำ แหล่งน้ำ แตกต่างจากคนทั่วไป ทั้งคอยมองหาหลักฐานที่ถูกเก็บไว้ในชั้นหิน เพื่อตอบคำถามสมมุติฐานที่ได้ตั้งไว้

Photo from internet



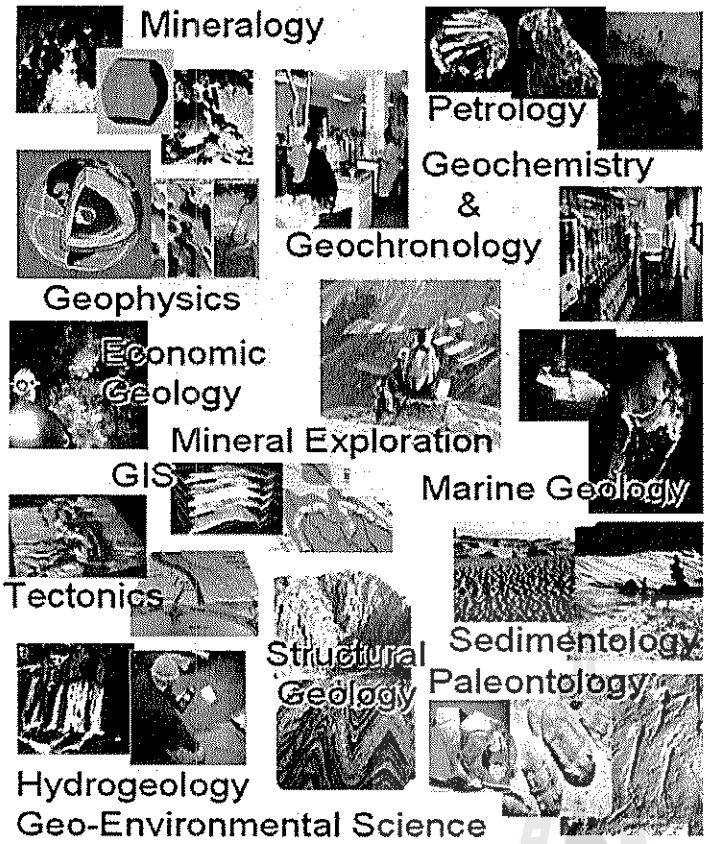


Photo from internet

ศาสตร์ต่าง ๆ ในธรณีวิทยา

Mineralogy
Petrology
Geochemistry
Geochronology
Geophysics
Economic geology
Mineral exploration
GIS
Marine geology
Petroleum geology
Tectonics
Structural geology
Engineering geology
Sedimentology
Paleontology
Stratigraphy
Hydrogeology
Geo-Environmental science
Geohazard
Geotourism

ธรณีวิทยาประวัติ (Historical Geology) กับ ธรณีวิทยากายภาพ (Physical Geology)

ธรณีวิทยาประวัติ: กล่าวถึงหลักฐานของสิ่งมีชีวิตบนโลกตั้งแต่เริ่มมีสิ่งมีชีวิต จนถึงปัจจุบัน และหลักฐานต่าง ๆ ที่เกี่ยวข้องกับการเปลี่ยนแปลงและพัฒนาการของโลก

ธรณีวิทยากายภาพ (Physical Geology): กล่างถึงธรรมชาติและคุณสมบัติของวัสดุที่ประกอบเป็นโลก และการกระจายตัวของวัสดุทางธรณีวิทยาเหล่านั้นตามแหล่งต่าง ๆ ของโลก กระบวนการในการเกิดวัสดุเหล่านั้น การเปลี่ยนแปรรูปร่าง และการพัฒนาของสภาพภูมิประเทศในธรรมชาติ

Origin of the Universe and the Earth

Wave, beach, coast

Plate tectonic

Glaciers and glaciation

Mountain and continental crust

Desert and wind

Sea Floor and oceanic crust

Groundwater

Physical Geology

Earthquakes

Minerals

Stream and flood

Igneous rocks

Geologic time

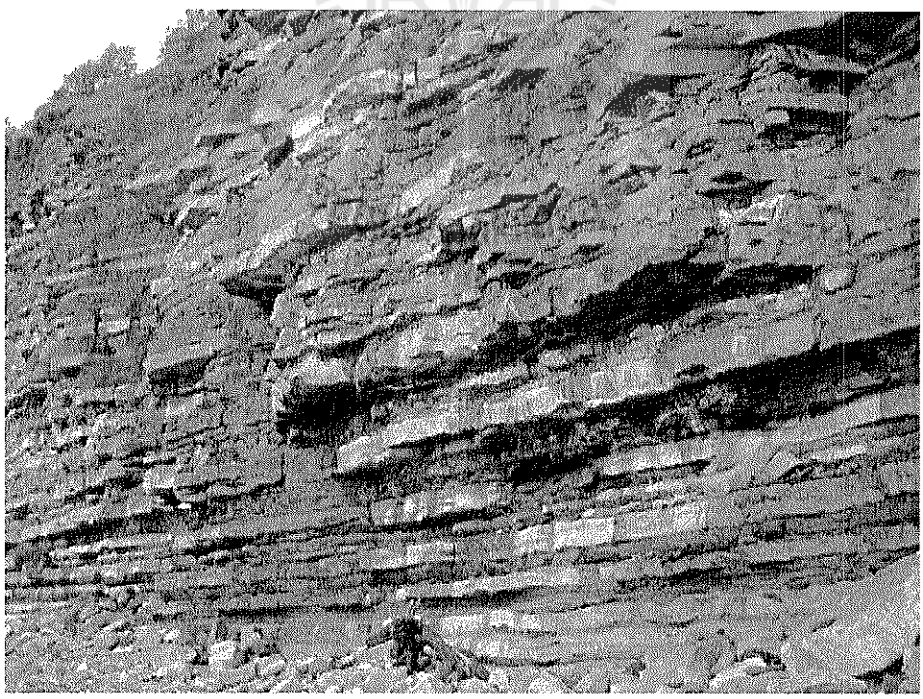
Sedimentary rocks

Stratigraphy

Metamorphic rocks

Geological processes

Geological structure



Lyme Regis Jurassic interbedded fossiliferous shale and limestone. The shale used to be a reservoir rock and can be lit on fire due to its hydrocarbon content.
***(The Jurassic Coast*, Lyme Regis, UK)**

Photo from internet

ธรณีวิทยาไม่ใช่เรื่องเล่าแต่เป็นวิทยาศาสตร์ที่ต้องอาศัยกระบวนการทางวิทยาศาสตร์ในการศึกษา

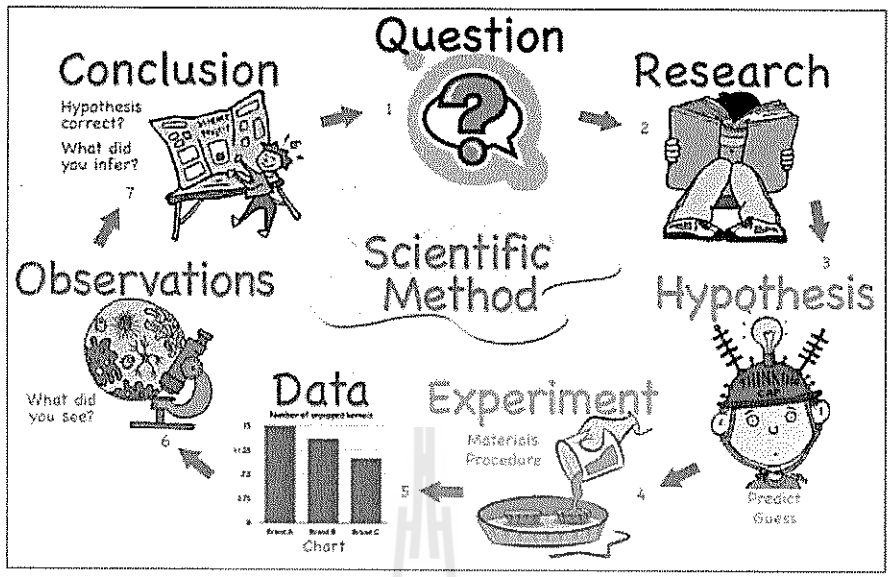
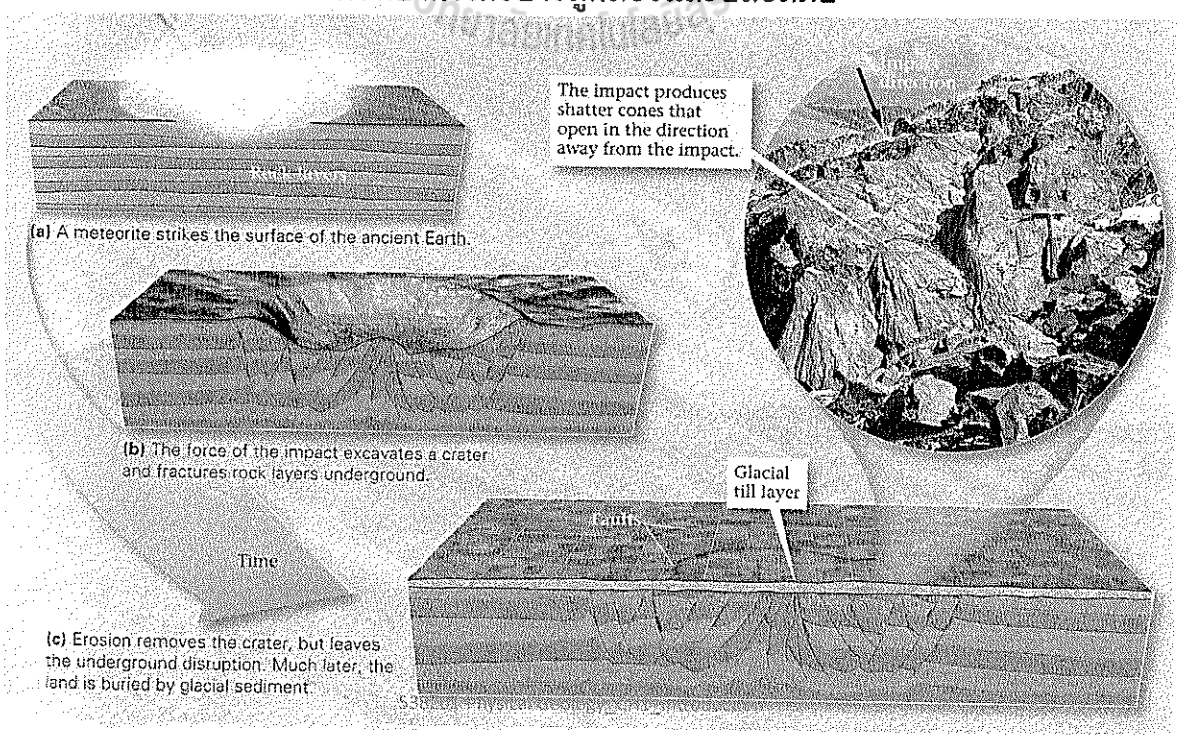


Photo from internet

ตัวอย่างการหาคำตอบโครงสร้างทางธรณีวิทยา: โครงสร้างธรณีวิทยาบางชนิดอาจเกิดได้เนื่องจากหลายเหตุ การเข้าใจถึงเหตุที่แท้จริงทำให้สามารถวางแผนการใช้ประโยชน์แหล่งทรัพยากรได้อย่างถูกต้องและปลอดภัย



ความรู้ด้านธรณีวิทยาสำคัญสำหรับโลกปัจจุบัน เพราะทำให้เข้าใจถึงการเกิดธรณีภัย สามารถนำข้อมูลไปพยากรณ์ ออกแบบ หรือวางแผนป้องกับวิบัติภัย ต่างๆได้

Geohazards: Earthquake, landslide, tsunami, volcano, flood

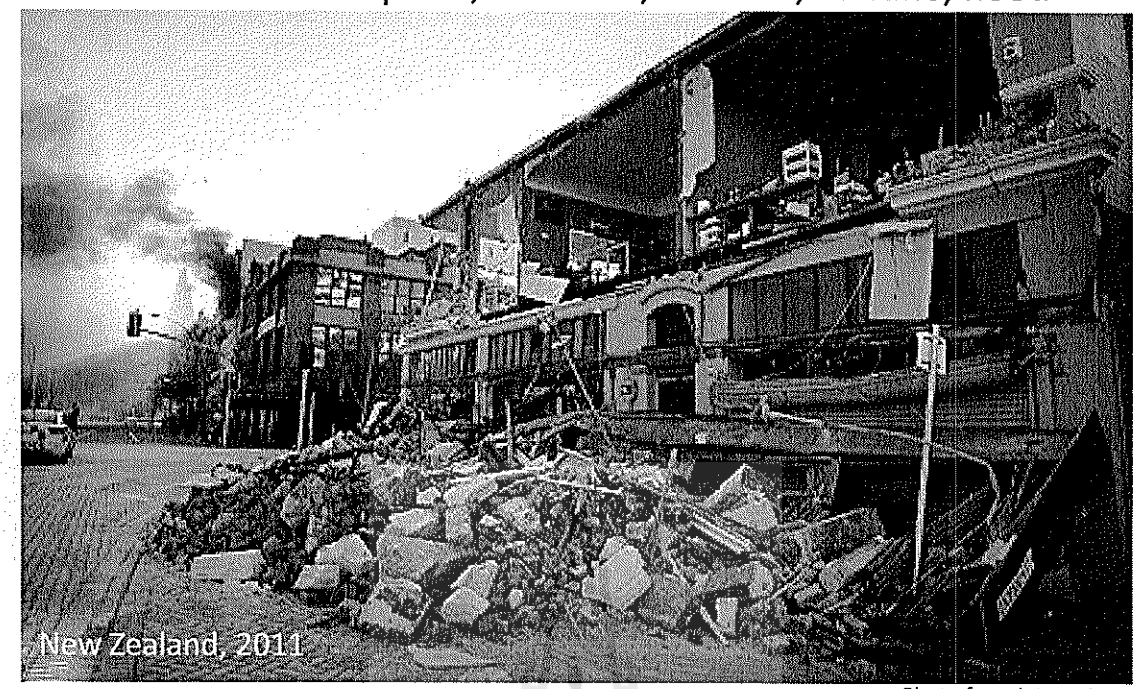


Photo from internet



Photo from internet



Photo from internet

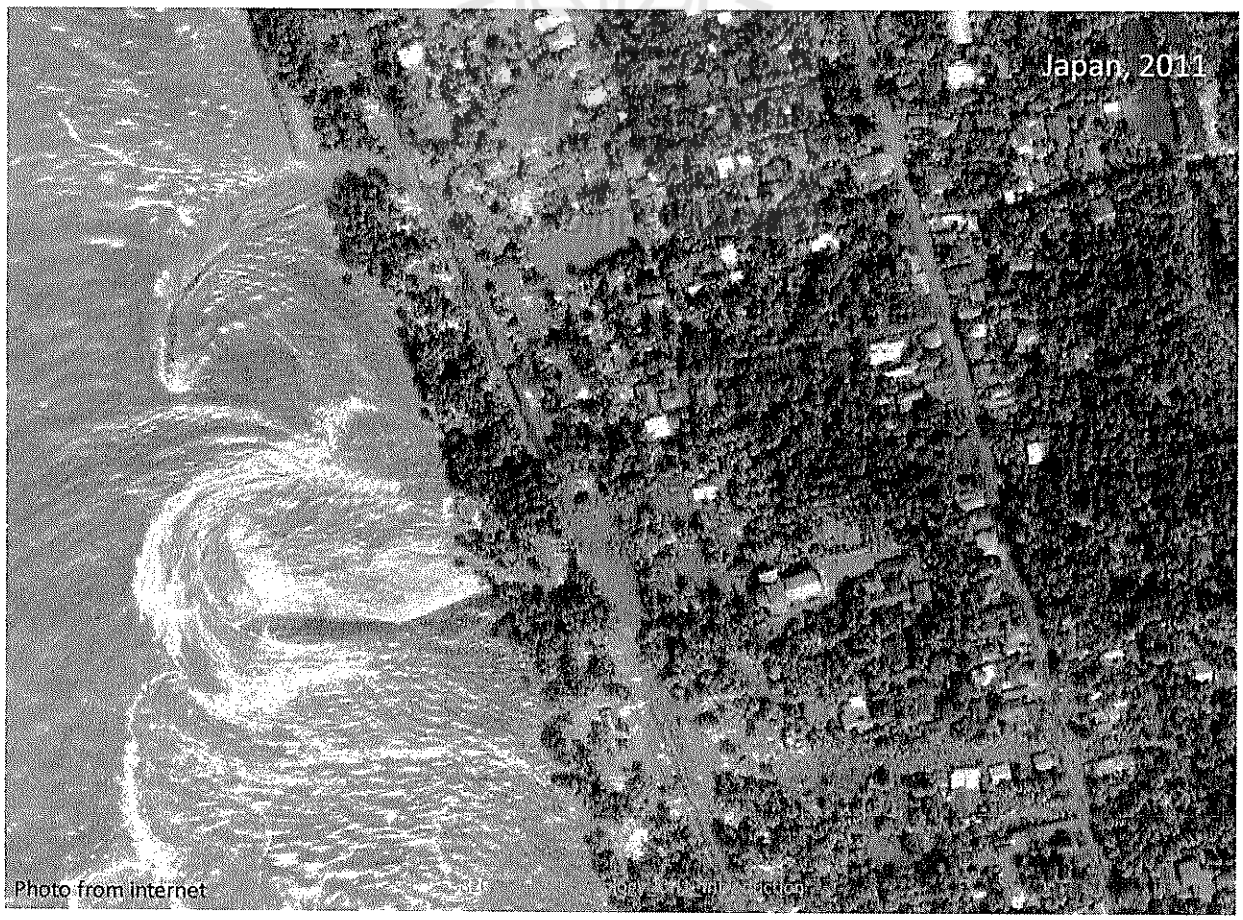
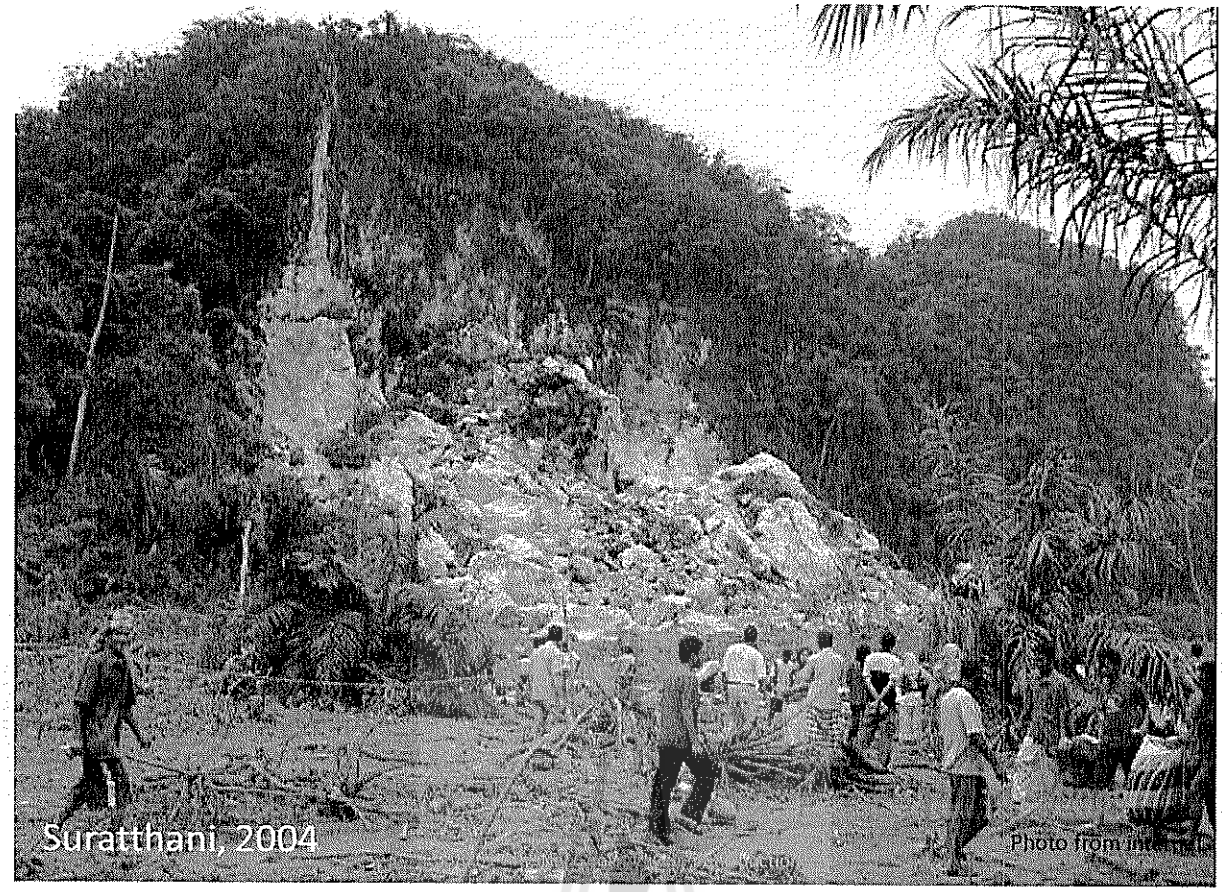
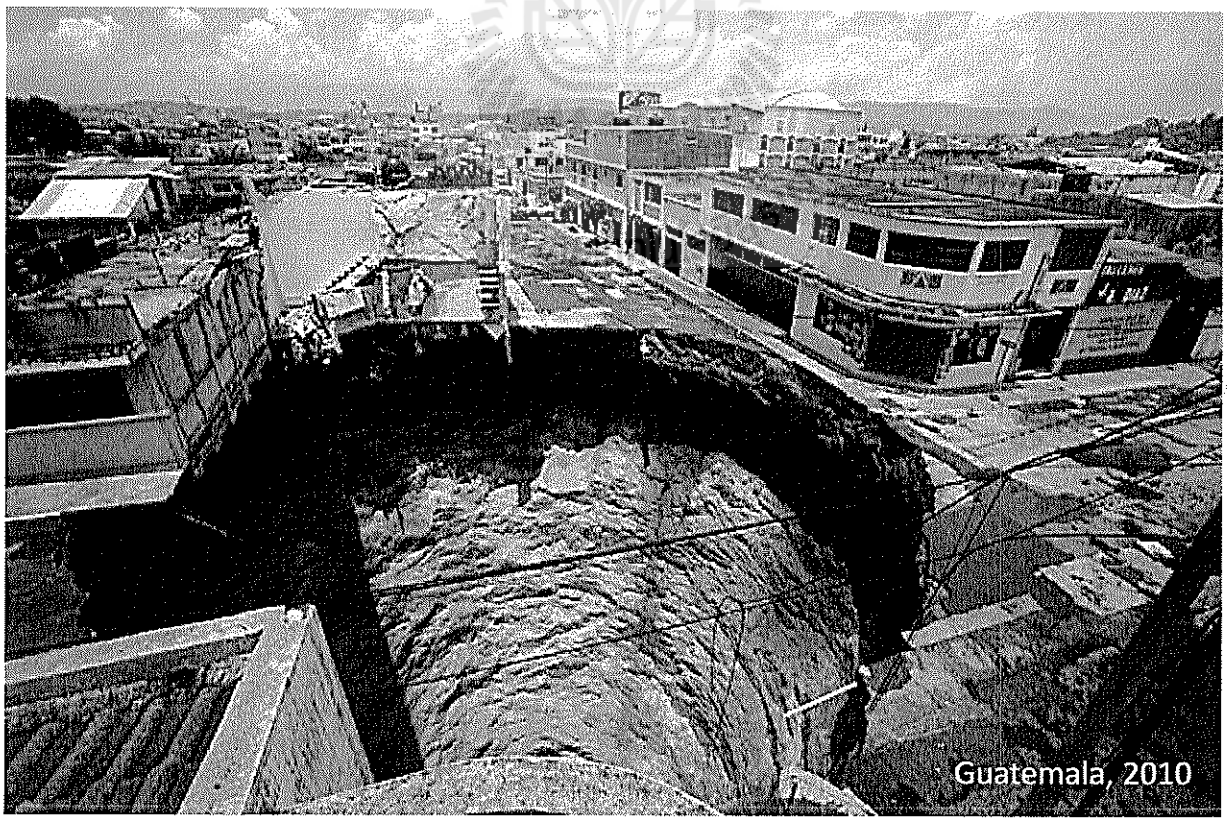


Photo from internet



Suratthani, 2004

Photo from internet



Guatemala, 2010

Photo from internet

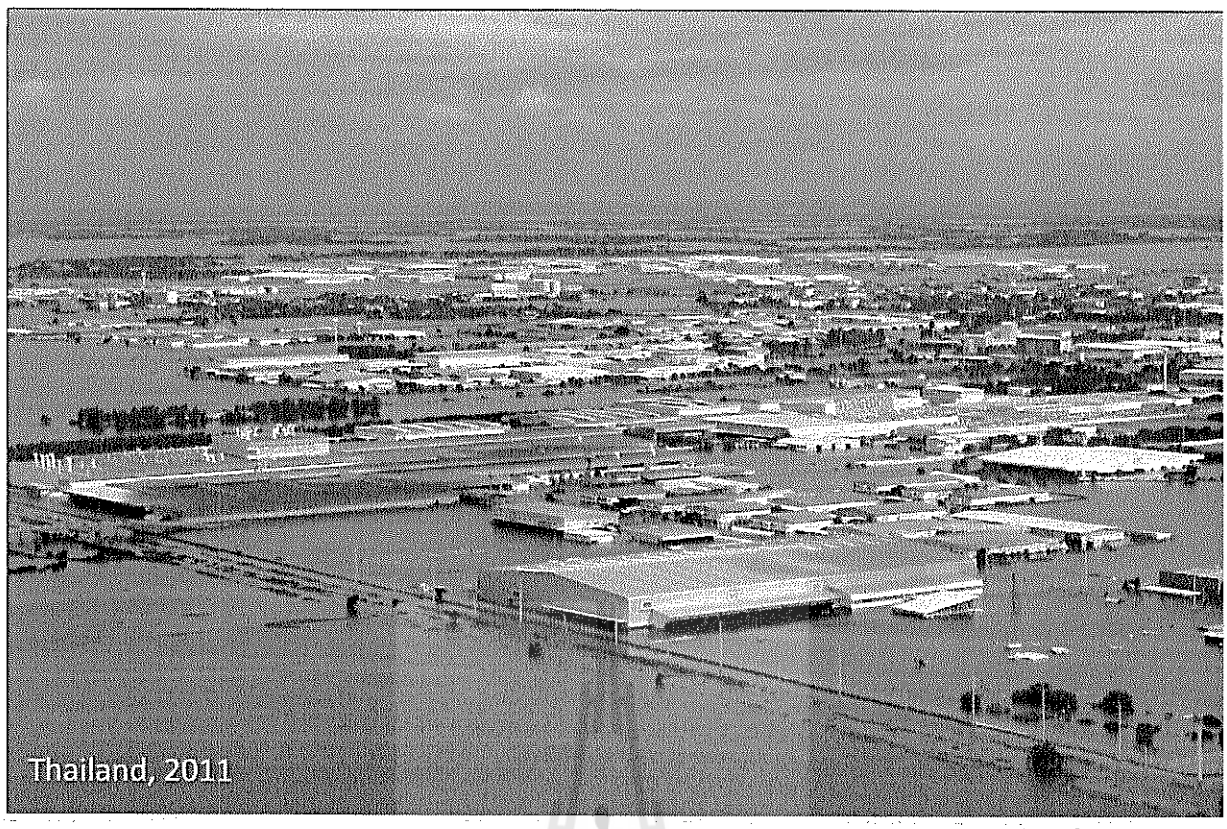
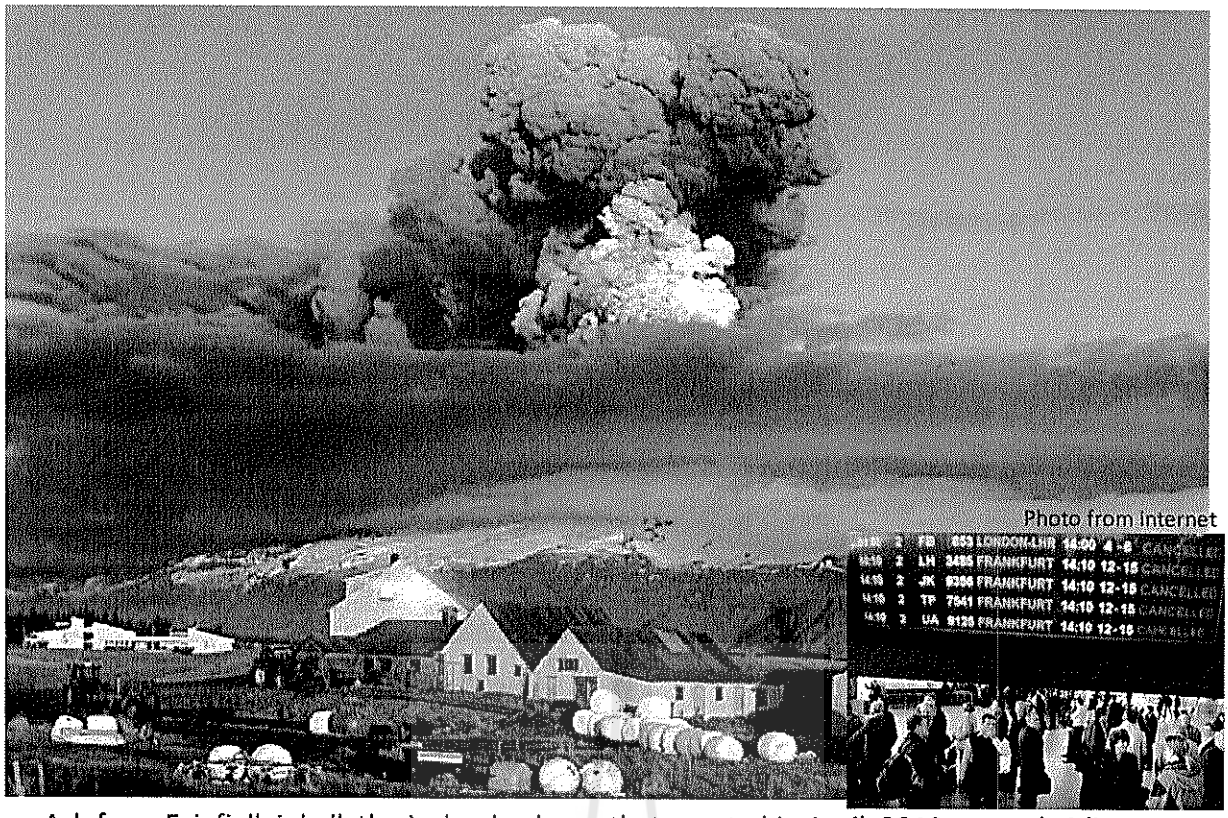


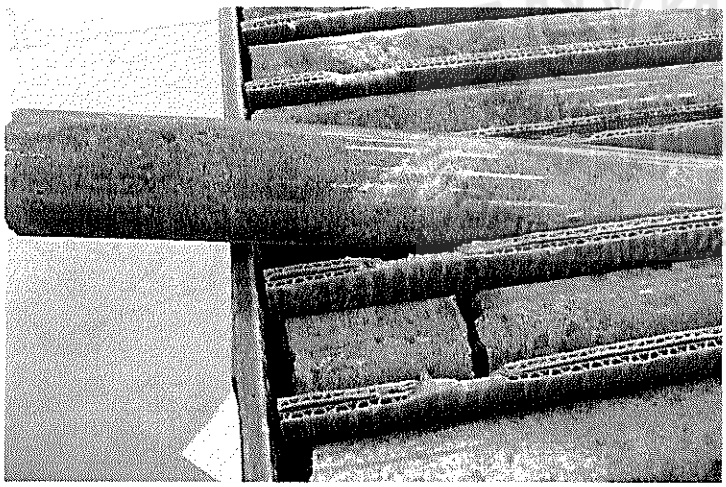
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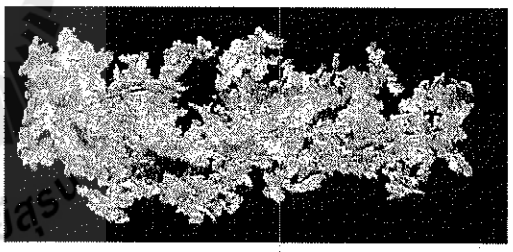


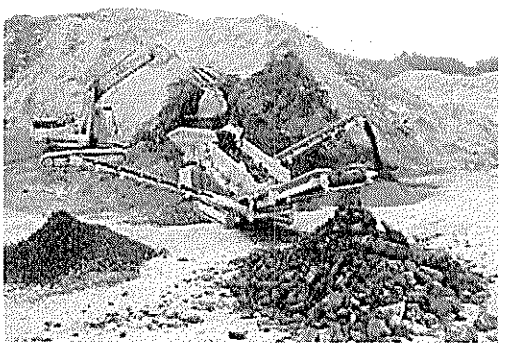
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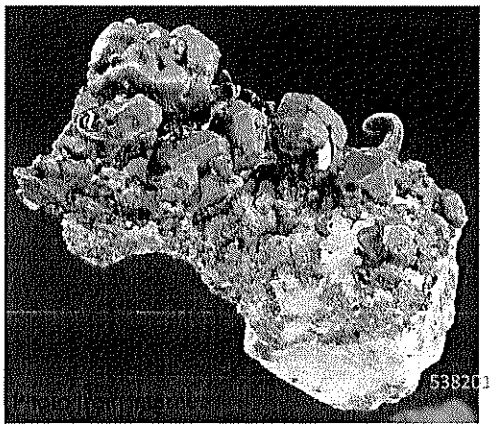


Ash from Eyjafjallajokull, the Iceland volcano that erupted in April, 2010, caused airlines to cancel thousands of flights. (Christian Science Monitor , 2010)



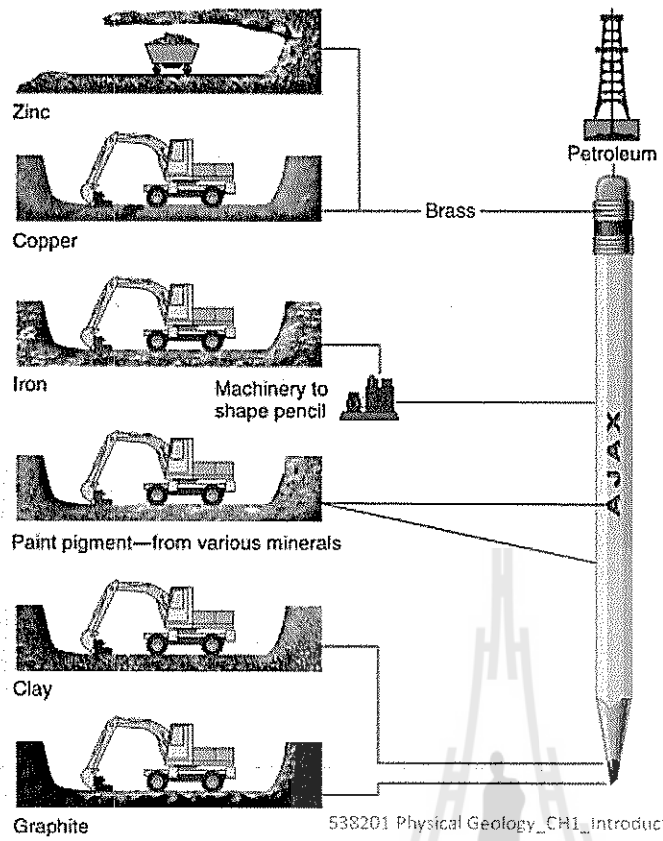






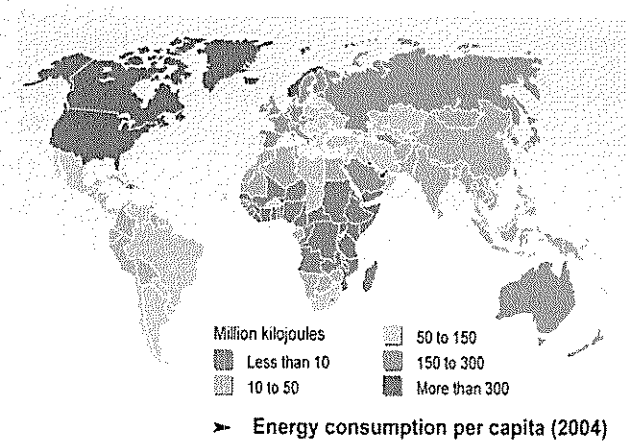
Economic mineral demands

ทุกอย่างบนโลกล้วนผลิตจากทรัพยากรธรณี ซึ่งส่วนใหญ่เป็นทรัพยากรที่หมดไป (non-renewable resources)

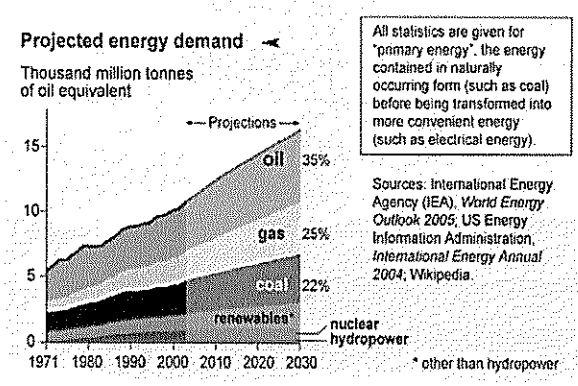


Energy demands

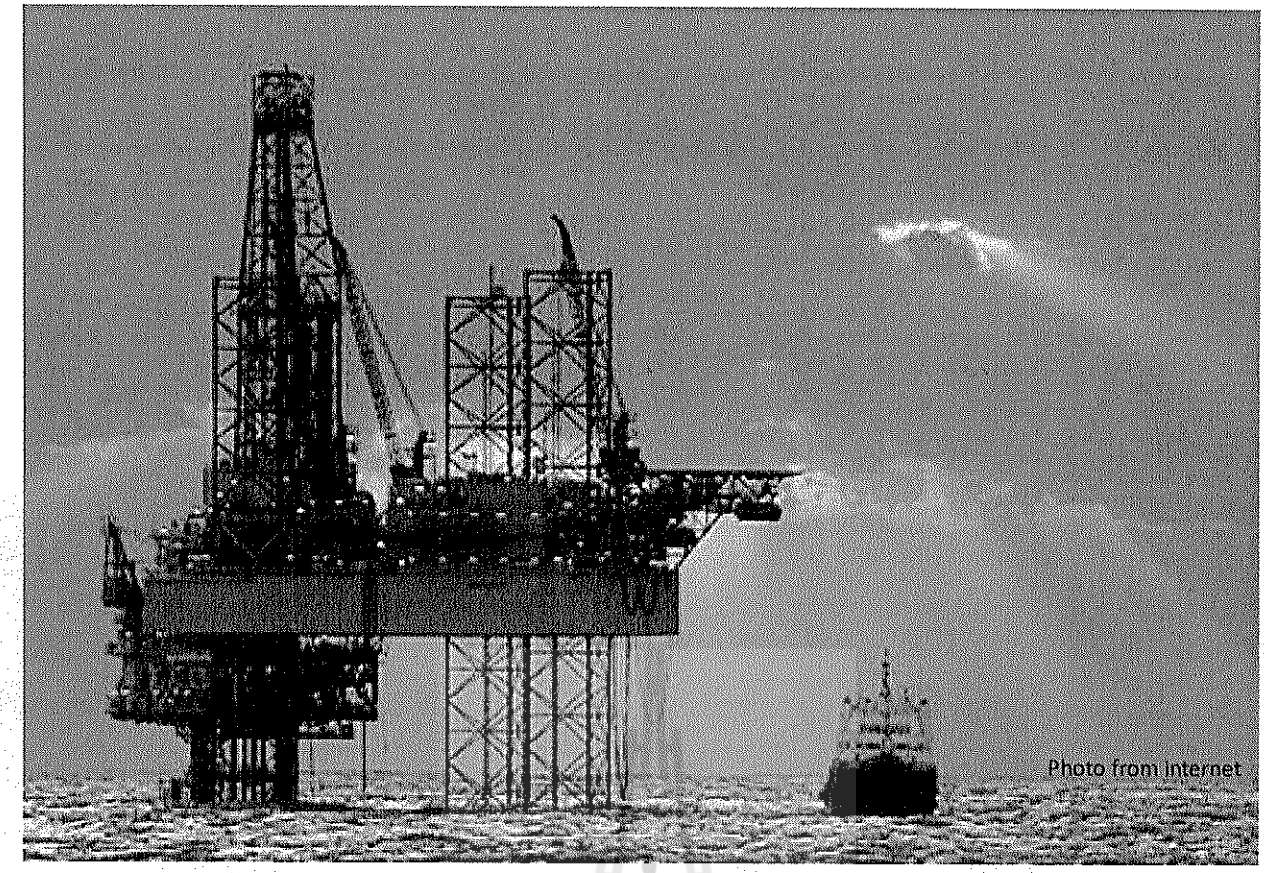
ความต้องการใช้พลังงานที่เพิ่มมากขึ้นเรื่อย ๆ และส่วนใหญ่ยังเป็นพลังงานจากซากดึกดำบรรพ์



Energy consumption per capita (2004)



BP Oil, 2004



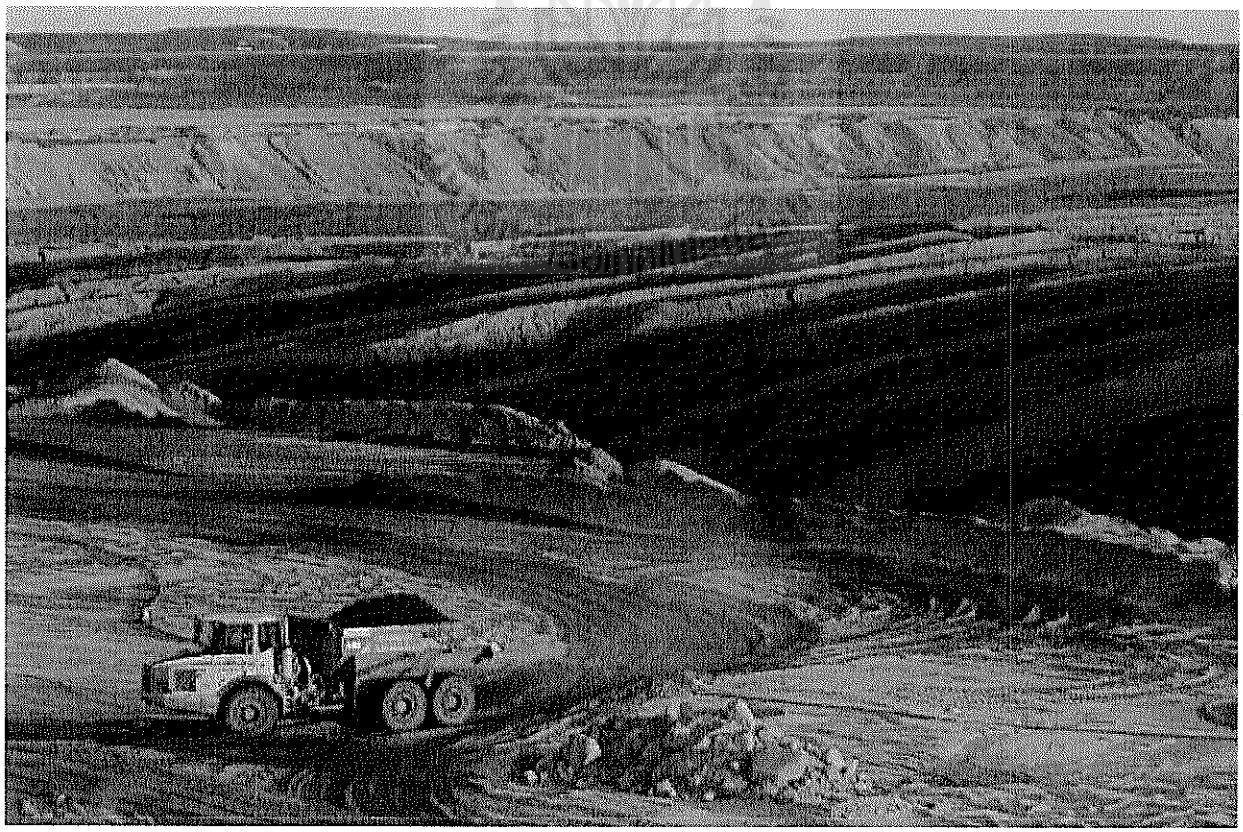
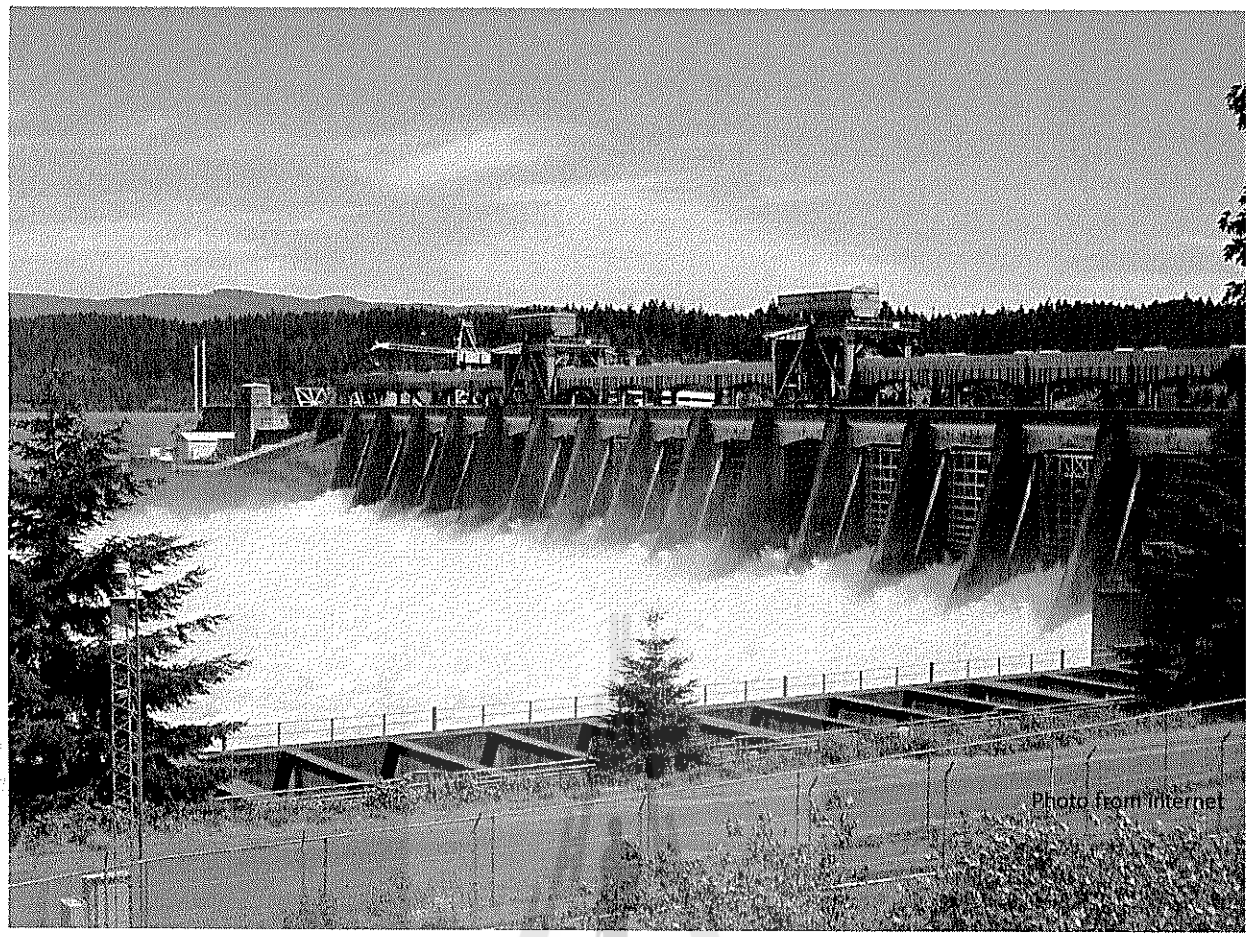
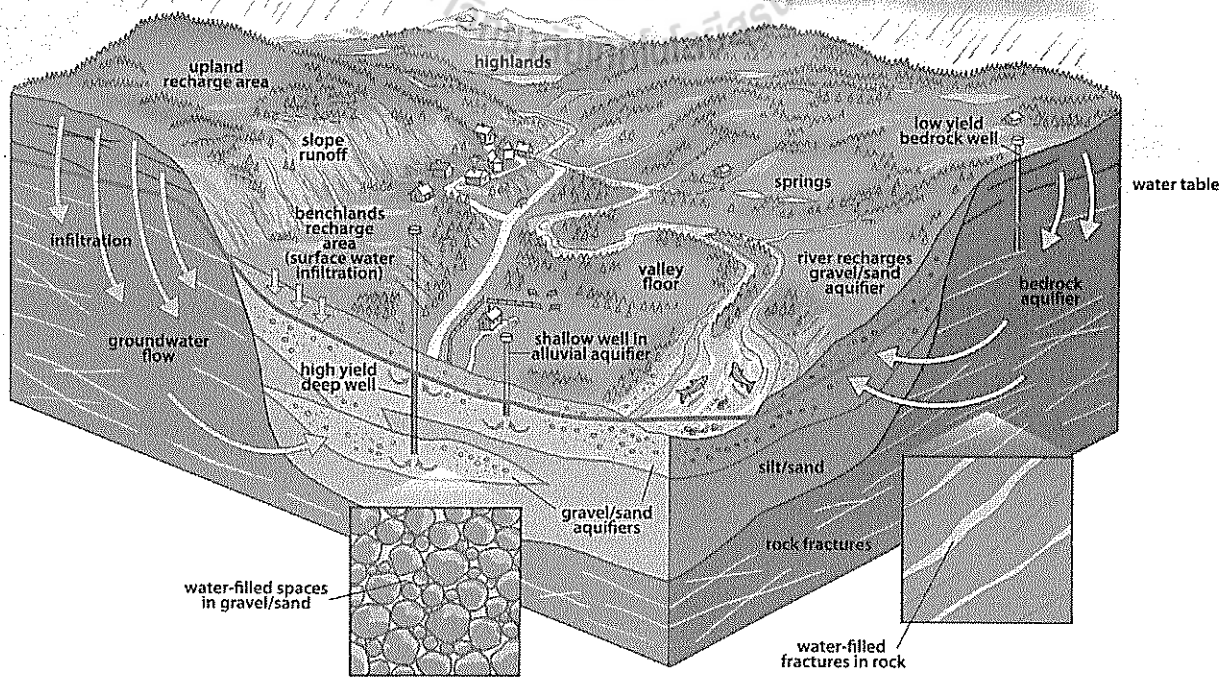


Photo from internet



Groundwater demands น้ำบาดาลสำหรับการอุปโภคบริโภค กักเก็บอยู่ในช่องว่างของเม็ดตะกอน และรอยแตกของชั้นหิน



Environmental safety

ความปลอดภัยด้านสิ่งแวดล้อมของแหล่งที่อยู่อาศัยและแหล่งน้ำ ซึ่งตั้งอยู่บนพื้นที่ที่มีลักษณะธรณีวิทยาเฉพาะ เช่น แหล่งแร่ แหล่งน้ำพุร้อน พื้นที่เสี่ยงต่อการเกิดธรณีภัย การปนเปื้อนของน้ำใต้ดิน ต้องอาศัยข้อมูลด้านธรณีวิทยาของพื้นที่นั้นๆ ในการป้องกันและแก้ไข



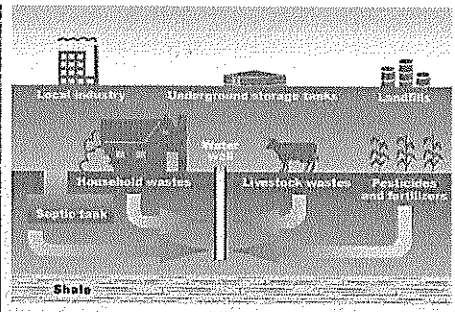
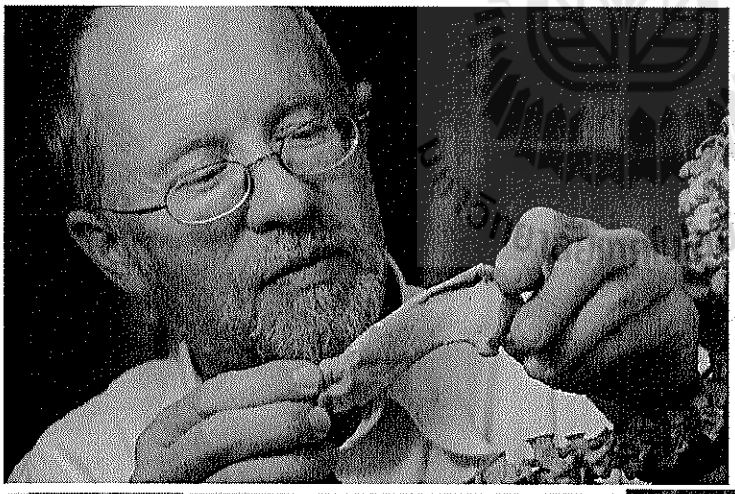


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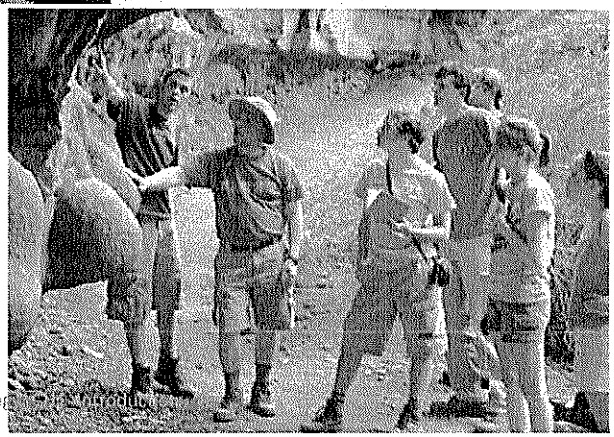


Academic desires

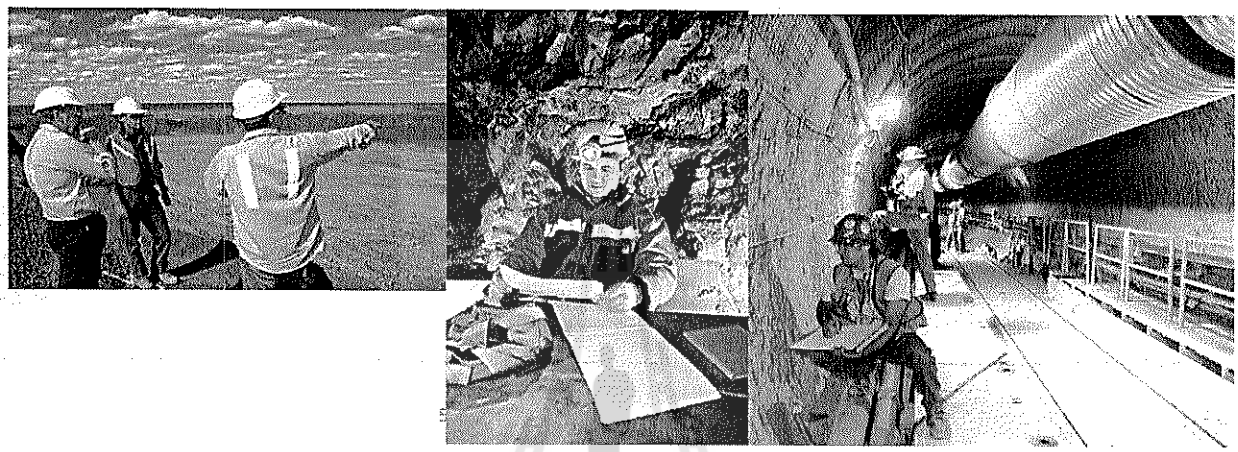
การค้นคว้าวิจัย และการศึกษา เป็นแรงผลักดันให้มีการสำรวจและเรียนรู้ด้านธรณีวิทยาอยู่เสมอ

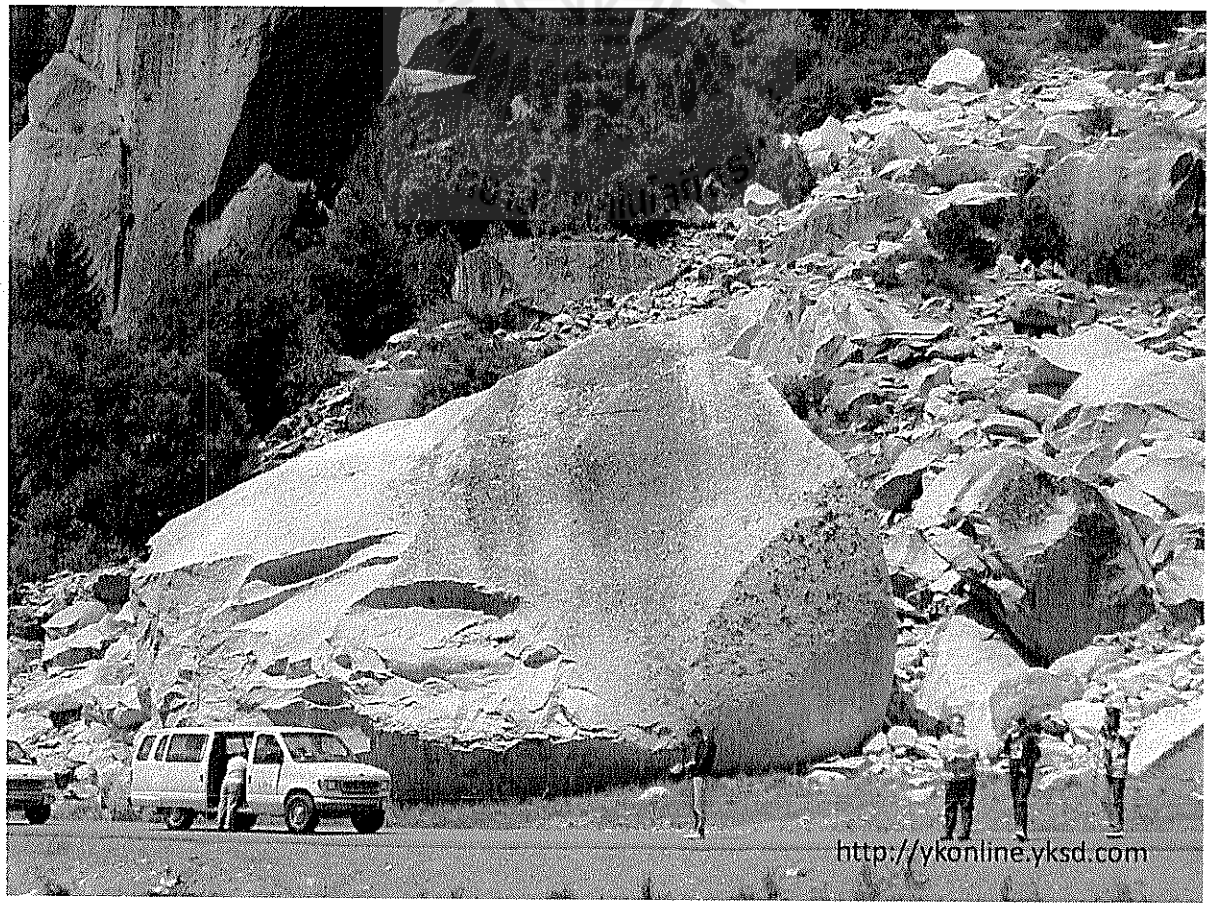


Photo from internet



นักธรณีวิทยา	วิศวกรธรณี
นักวิทยาศาสตร์	วิศวกร
ศึกษาวัสดุทางธรณีวิทยา	เข้าใจสมบัติของวัสดุทางธรณี
กระบวนการ	ทดสอบคุณสมบัติของวัสดุ
ประวัติของโลก	ออกแบบงานวิศวกรรมบนมวลหิน
ค้นพบหลักฐานใหม่ๆ	ออกแบบป้องกันเสถียรภาพ







http://www.balkanforum.info



http://www.psmconsult.com.au

2. Earth and Universe

Contents

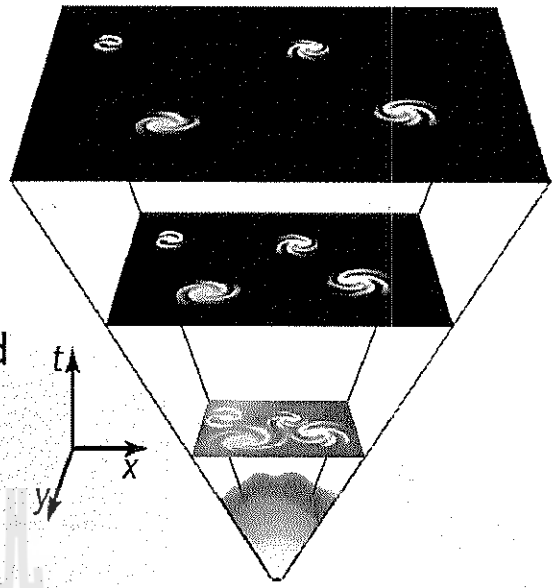
- Forming The Universe and the Earth
- The solar system
- The earth system
  (Earth's magnetic field, atmosphere, surface)
- The earth's interior

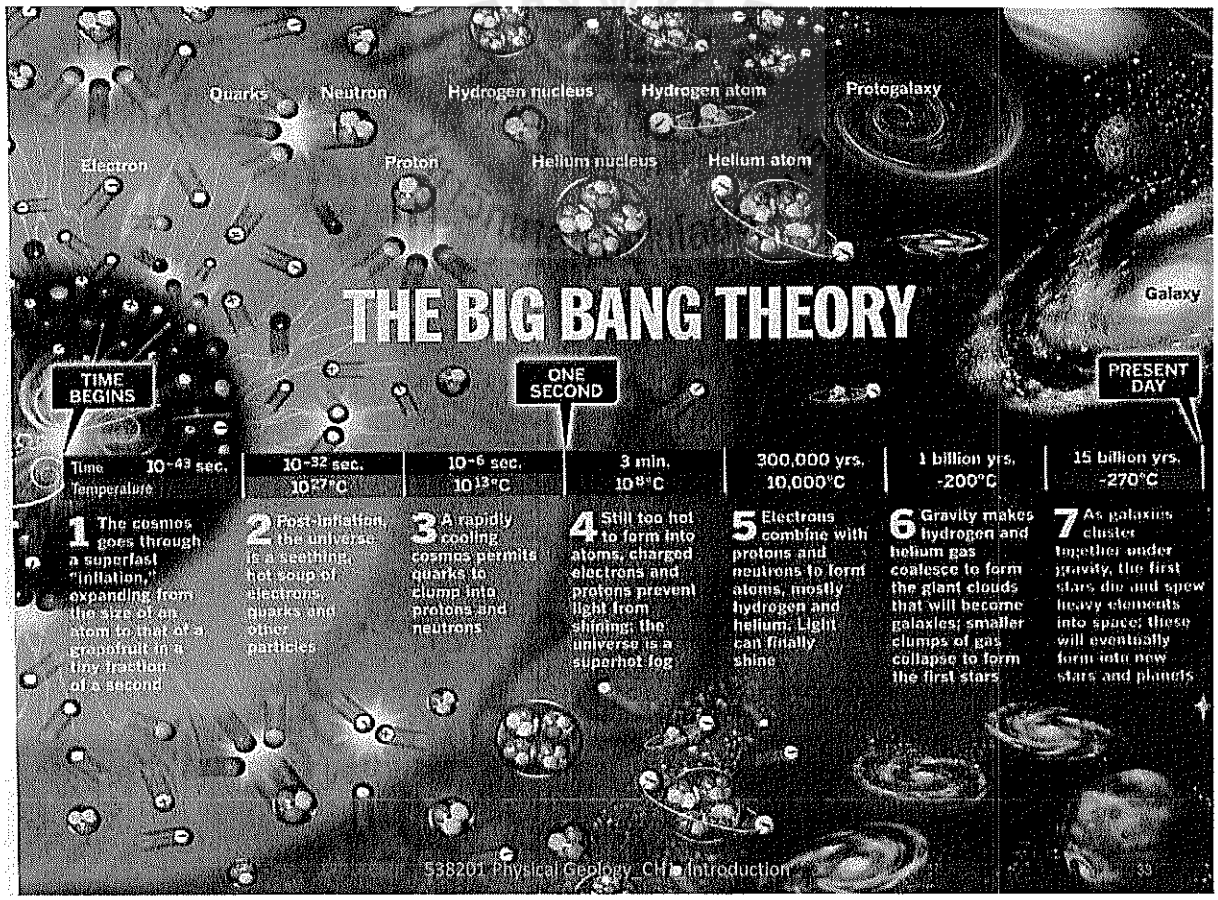
Theory:
scientific idea supported by an abundance of evidence, has passed many tests and has failed none

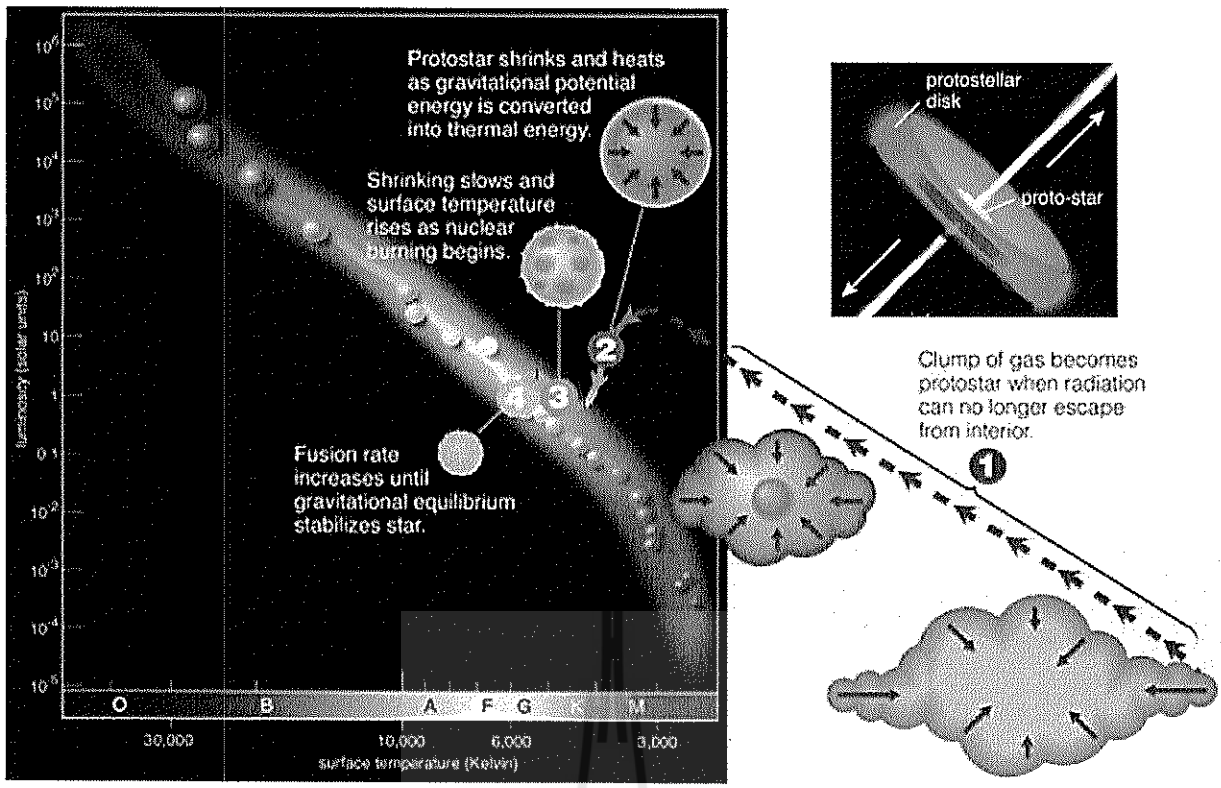
Scientific Law:
scientific idea that must be considered absolutely correct, for if it were violated, the natural Universe as we know it would not be exit. (for example; Law of gravity)

Forming the Universe and the Earth

Big Bang:
- 13.7 Ba
- T fell and diameter expanded
- H and He formed
- Nebulae formed



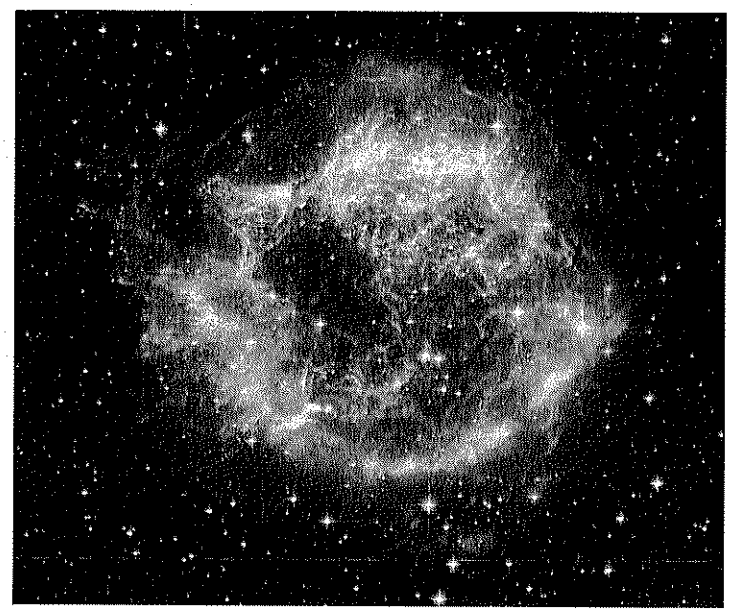




First stars formed when gravity caused nebulae to collapse inward, packing tightly together that nuclear fusion reaction could begin.

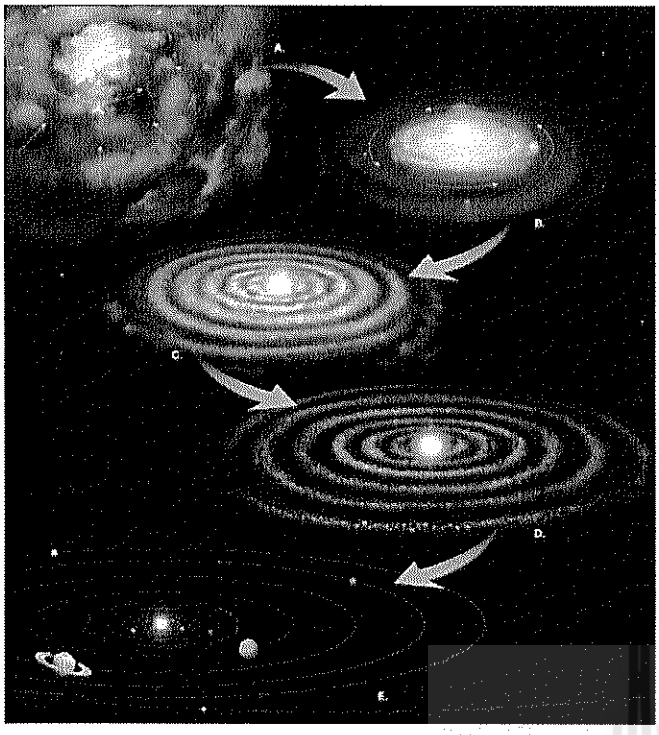
A supernova:

- A star explosion that is very energetic, extremely luminous and causes a burst of radiation.
- The explosion expels much or all of a star's material.

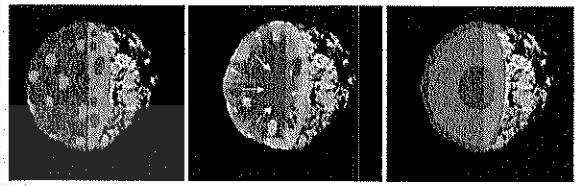


The Cassiopeia, a supernova remnant, which exploded more than 11,300 years ago.

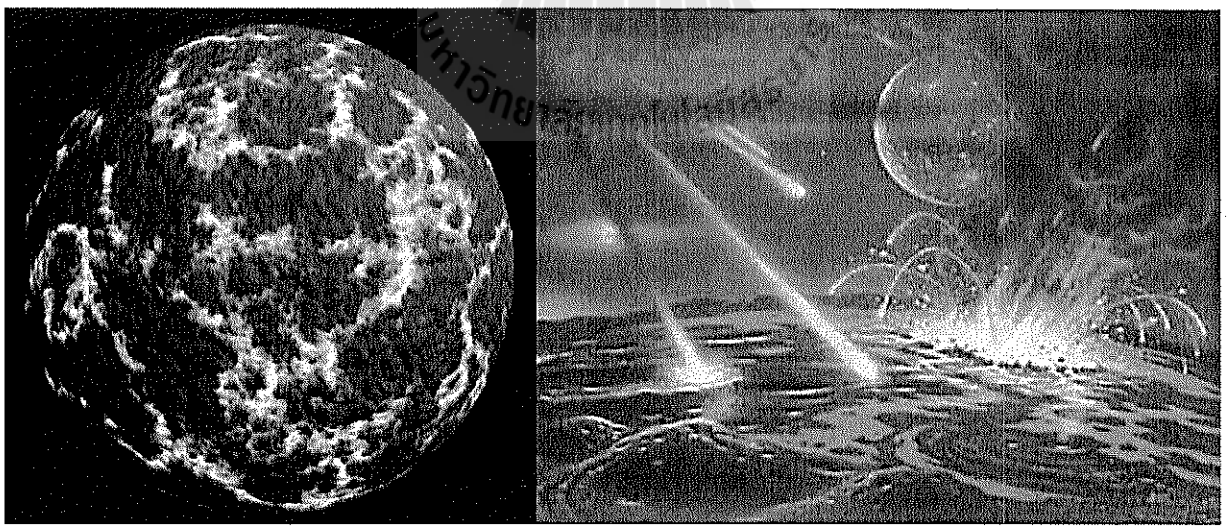
Image credits: NASA/JPL-Caltech/Univ. of Minn



Solar nebula :
the rotating cloud of gas and dust that began to collapse about 5 billion years ago to form the Solar System.

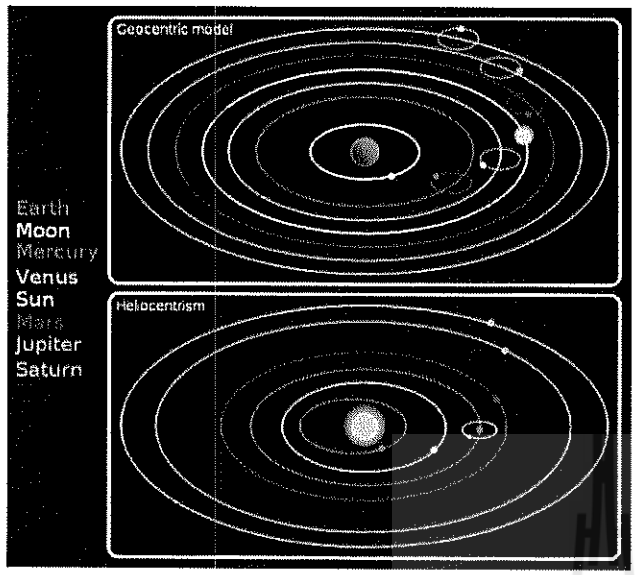


Primordial Earth



Earth's primordial surface

The solar system



Before 15th century

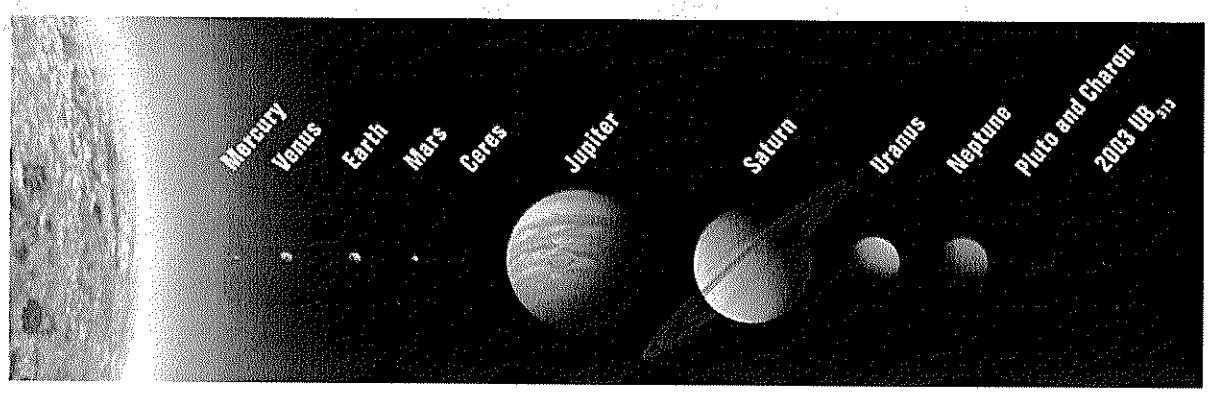
Geocentric vs Heliocentric models

- Geocentric: Earth at the center
- Heliocentric: Sun at the center

15th Century, new age of exploration and discovery

- Nicolus Copernicus (1473-1543)
- Galileo Galilei (1564-1642)
- Issac Newton (1643-1727)

Solar System consists of the Sun and the astronomical objects gravitationally bound in orbit around it, formed about 4.6 billion years ago.



The Sun; 98% of mass.

The 4 inner planets(terrestrial planets);

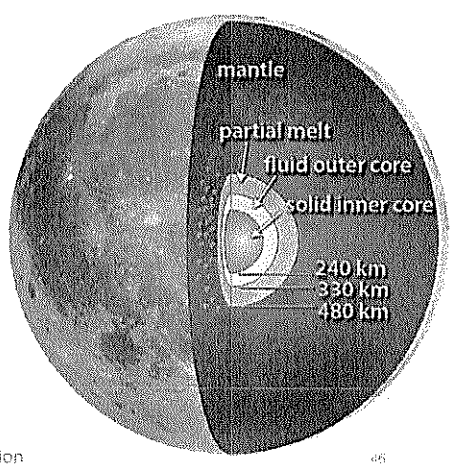
- Mercury, Venus, Earth and Mars (rock and metal)

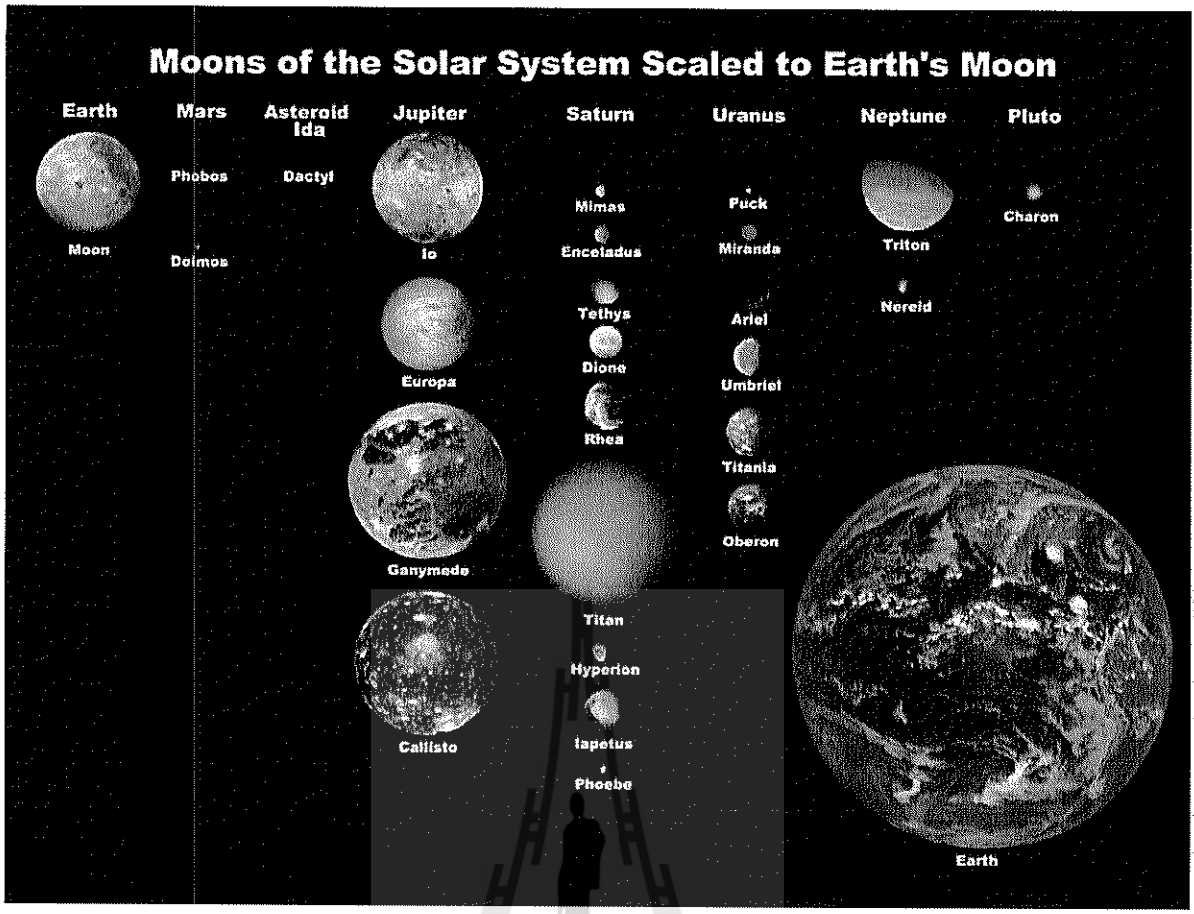
The 4 outer planets (the gas giants);

- Jupiter and Saturn (hydrogen and helium)
- Uranus and Neptune (ices-water, ammonia and methane)

Moon

- formed 0–50 million years after the origin of the Solar System
- Earth's moon - a result of a giant impact: a Mars-sized body hitting the newly formed proto-Earth, blasting material into orbit around it.
- evidenced by oxygen and tungsten isotopic compositions

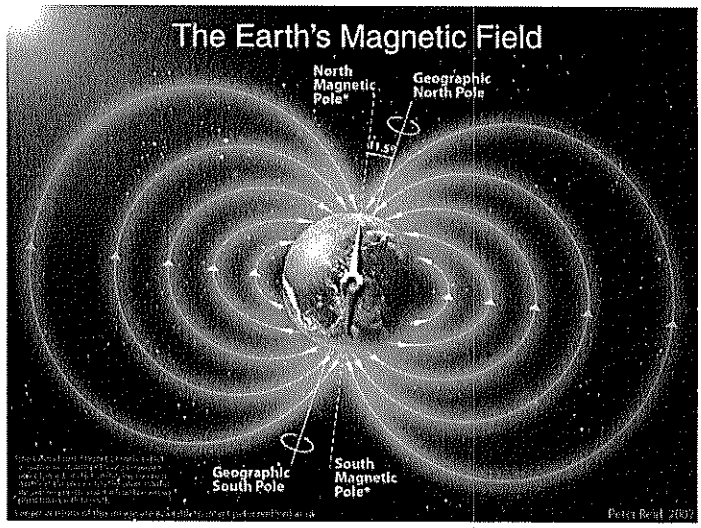




The earth system



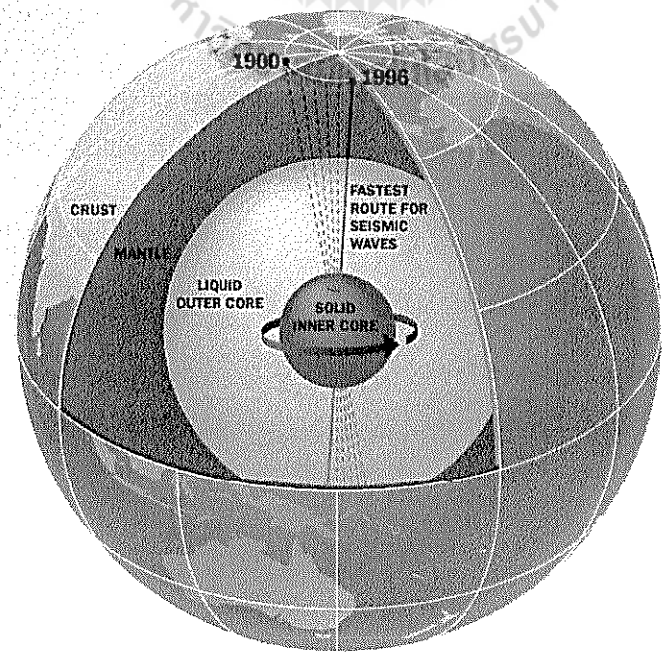
- magnetic field
- atmosphere
- surface

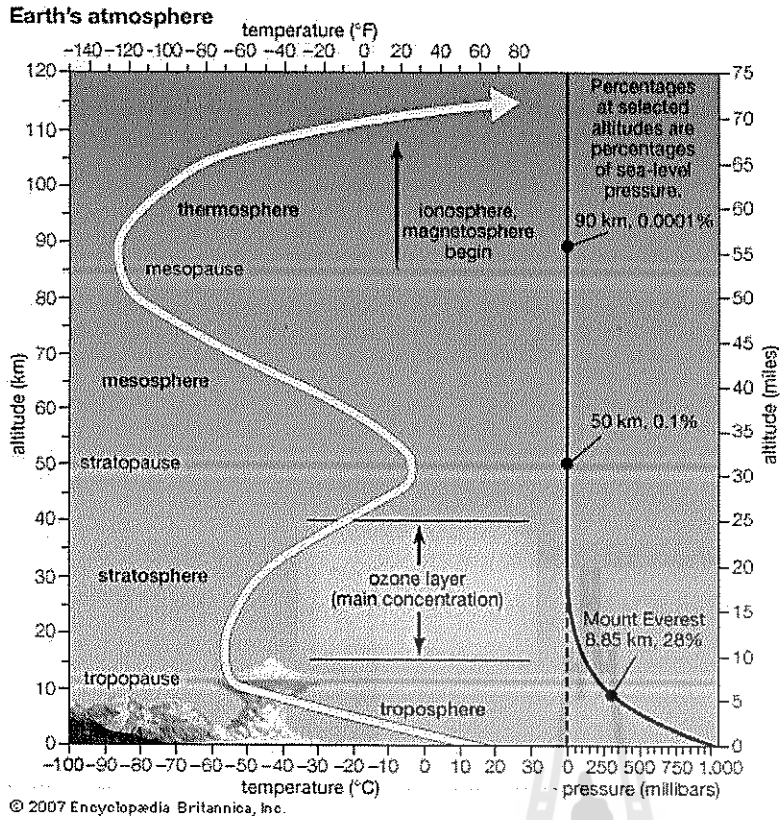


Earth's magnetic field

- the magnetic field that extends from the inner core.
- generated by the motion of molten iron alloys in the Earth's outer core.
- approximately tilted at an angle of 11 degrees with respect to the rotational axis.

Earth's magnetic field changes over time.
(The Magnetic North Pole wanders)



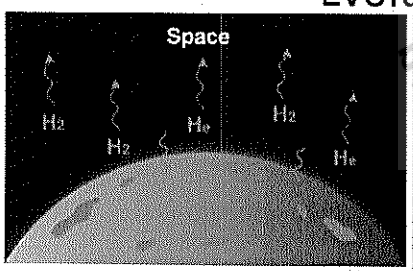


Atmosphere

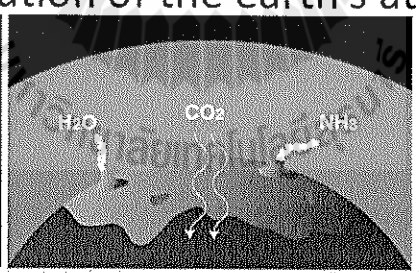
Gases in the Earth's atmosphere

- 78% N_2
- 21% O_2
- 1% Ar, Co_2, Ne, O_3, CO, So_2, methane

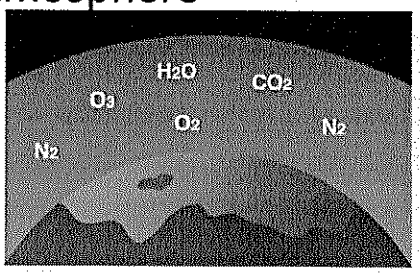
Evolution of the earth's atmosphere



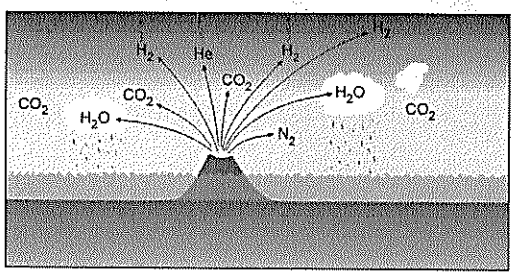
Atmosphere #1

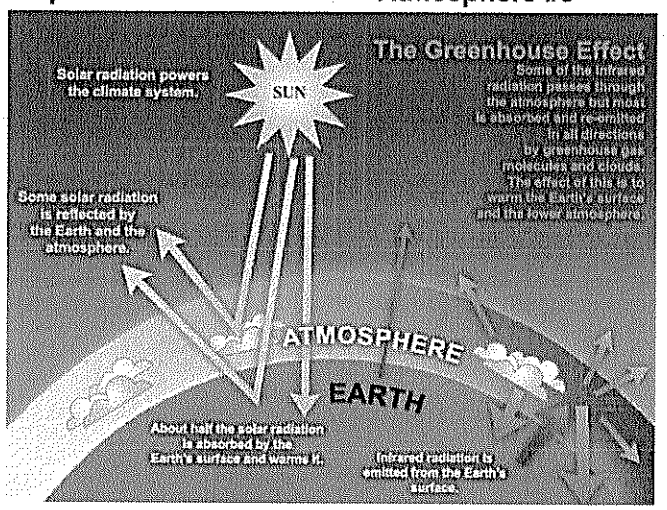


Atmosphere #2

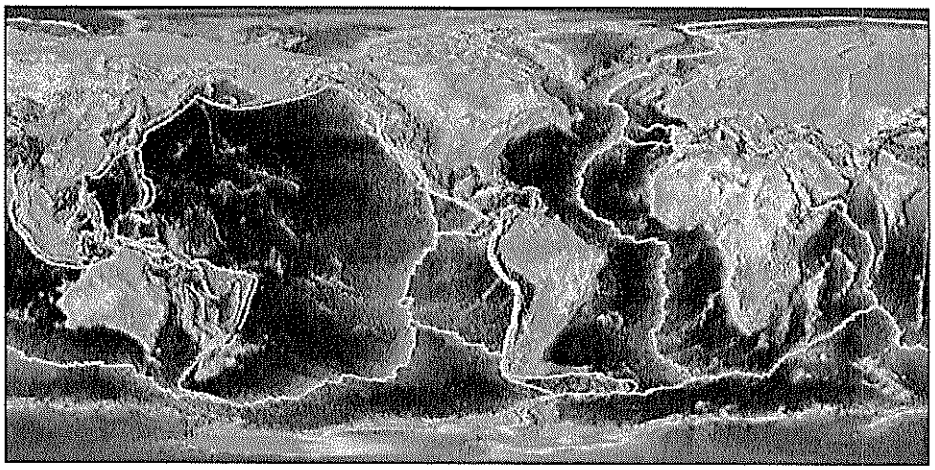


Atmosphere #3





Earth's surface

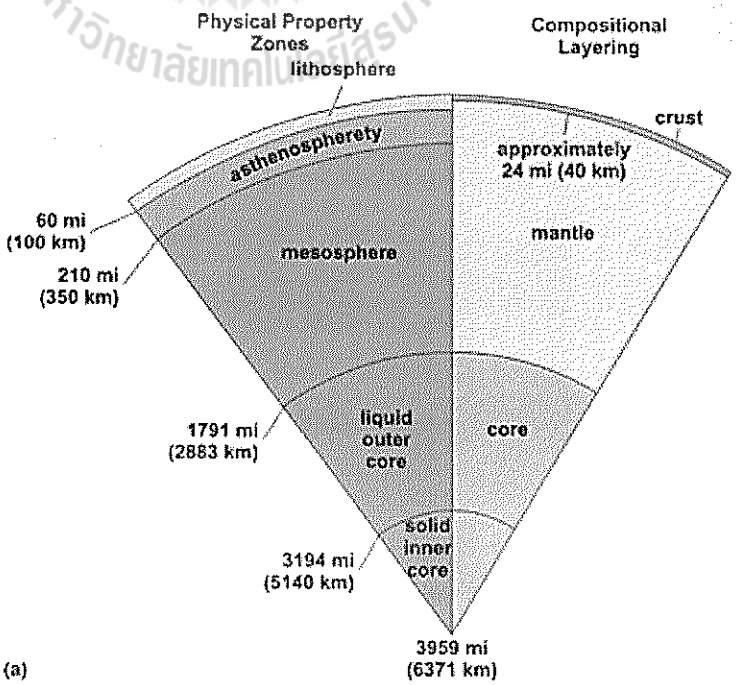


Land and oceans

rocks, minerals, sediments, surface water, groundwater, melts (magma and lava), organic chemicals

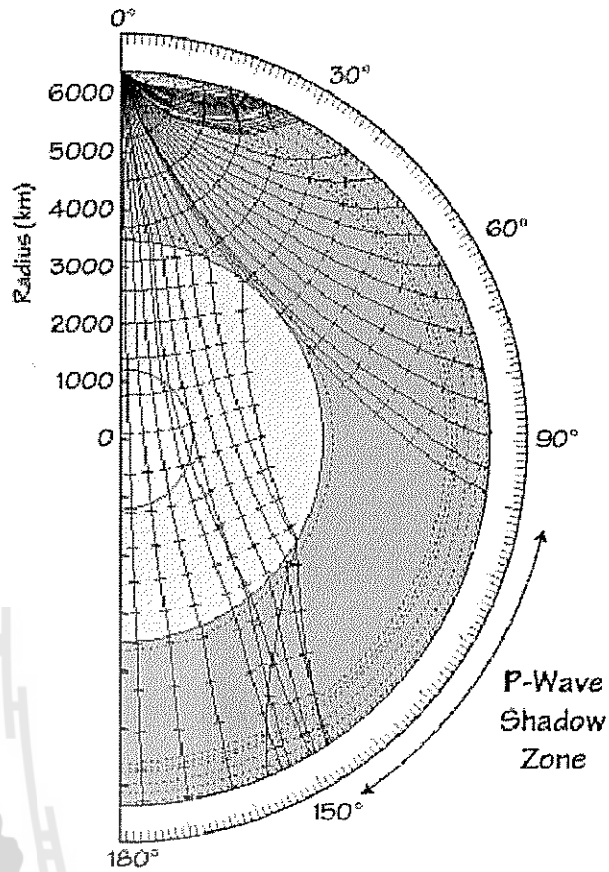
The Earth's interior

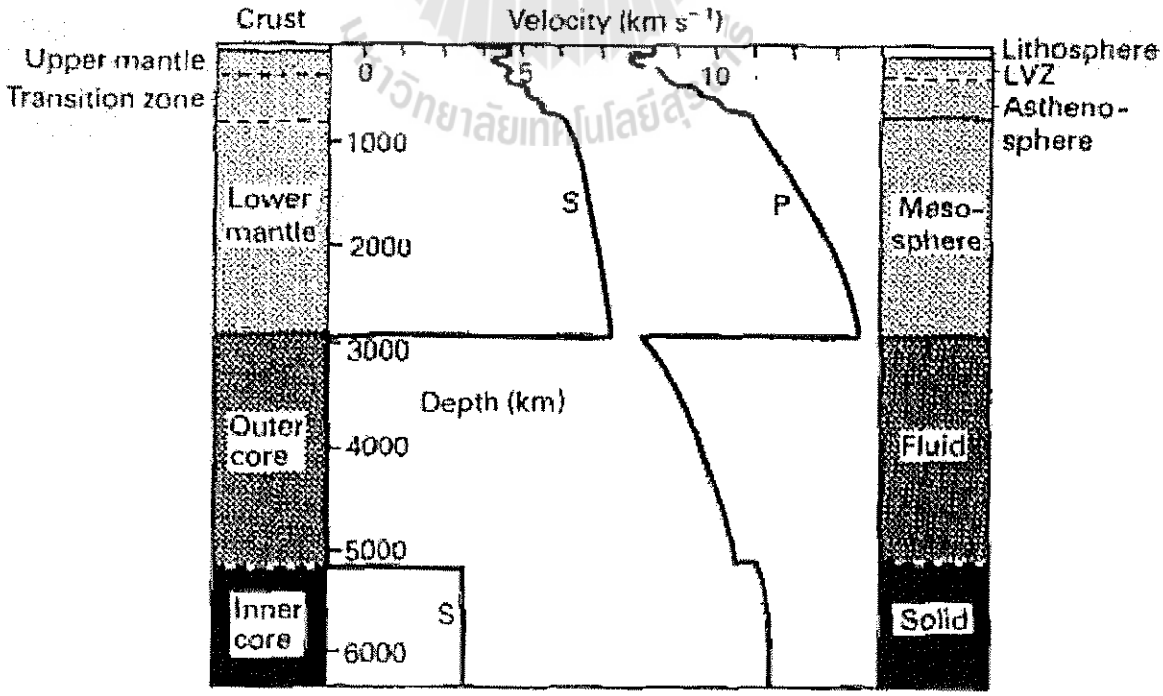
Two different classification of the Earth's interior, physically and chemically



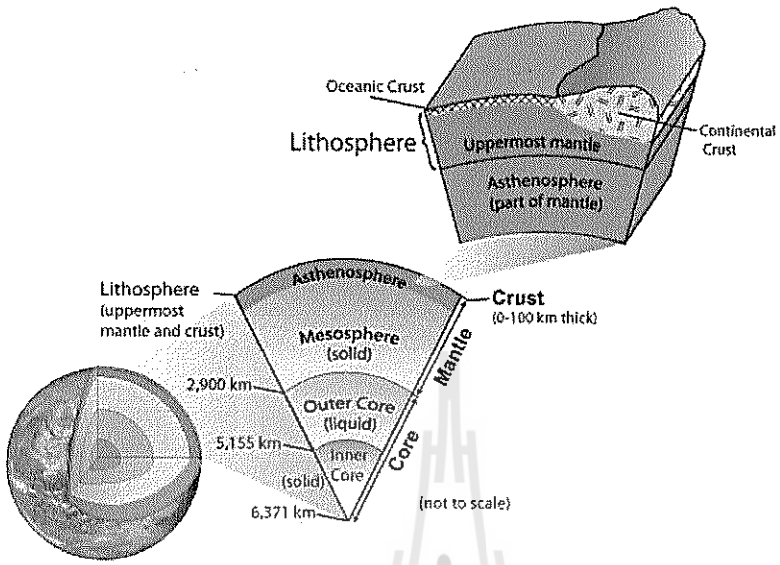
Physical property

- Using seismic wave
- P wave, S wave





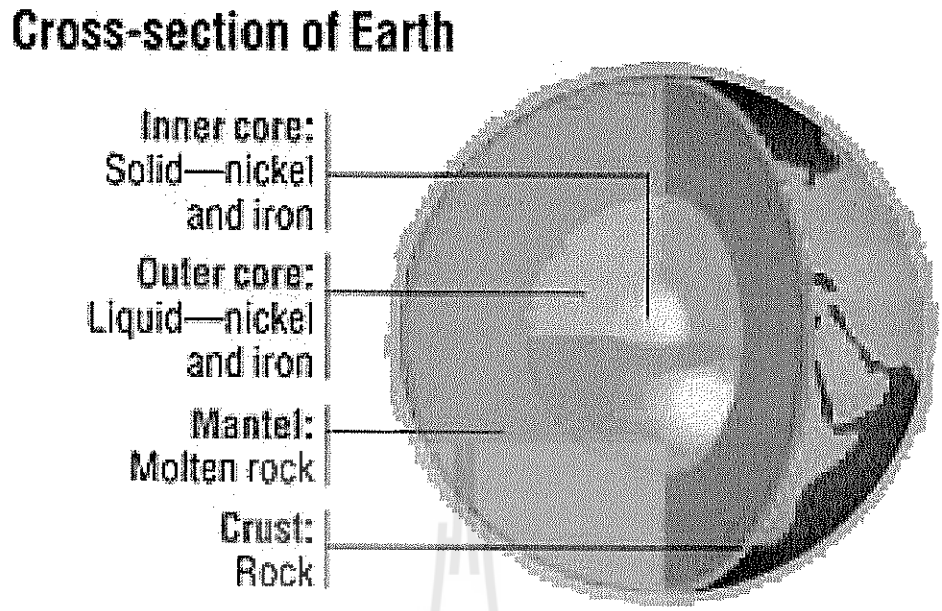
Lithosphere
- Rigid, brittle rock, broken into lithospheric plates
- about 60 to 150 km thick
- Comprises the crust and upper mantle



Asthenosphere
- Viscous and is a ductile-deforming region of the upper mantle
- Upper boundary between 100 and 200 km depth
- Lower boundary about 350 km depth
- Temp reaches 1400°C
- the lithosphere moves on the asthenosphere

Mesosphere
- The upper boundary defined by the sharp increase in seismic wave velocities and density (350 km depth)
- The deeper, the denser, the greater velocity

Chemical property



The outer core

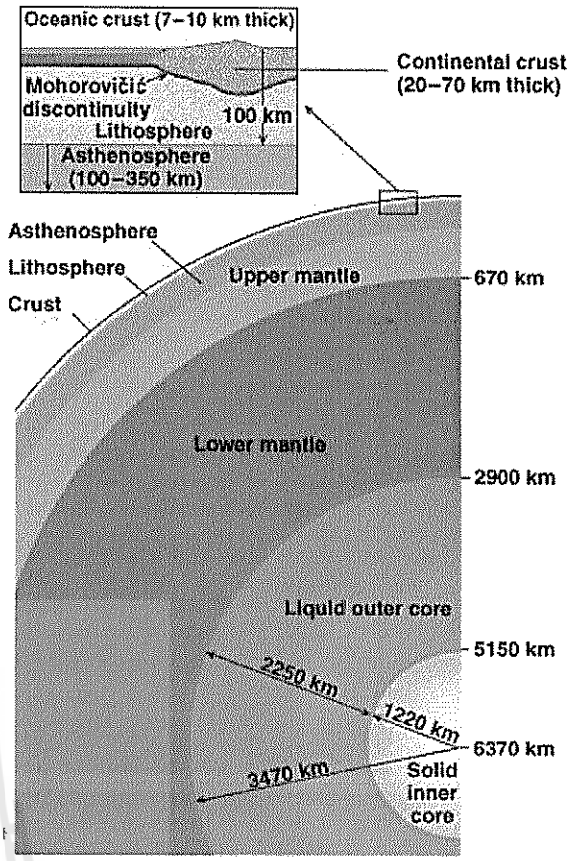
-low viscosity fluid that convects turbulently
- less dense, less velocity of seismic wave
- iron and nickel
- boundary lies 2,890 km depth
- the transition between the inner core and outer core is located about 5,150 km depth

The inner core

- innermost part, solid ball causing the higher velocity of seismic wave
- a radius of about 1,220 km
- consist primarily of an iron–nickel alloy
- Temperature approximately 5430 °C

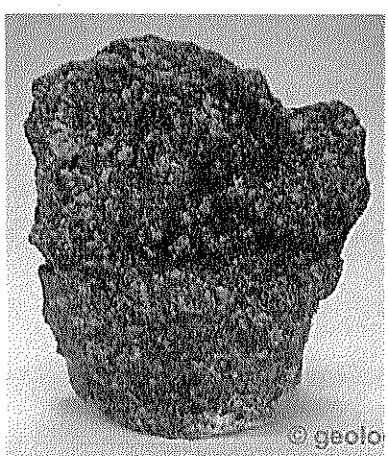
Core

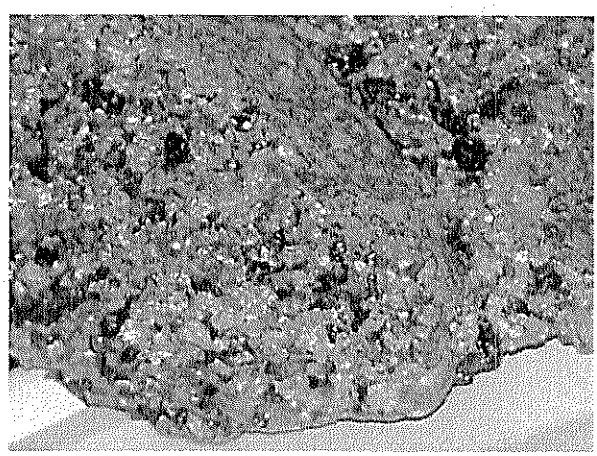
- 3,500 Km radius
- divided into inner and outer
- iron and nickel
- 3000 – 5000 °C
- SG > 5.5



Mantle

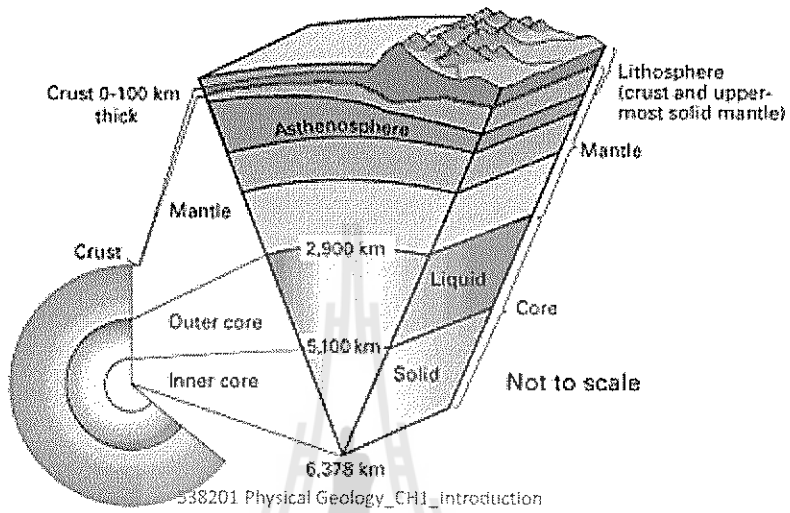
- ultramafic minerals,
- peridotite
- 1800 – 2800 °C
- Upper mantle down to the depth of 660 km
- Lower mantle from 660-2,900 km

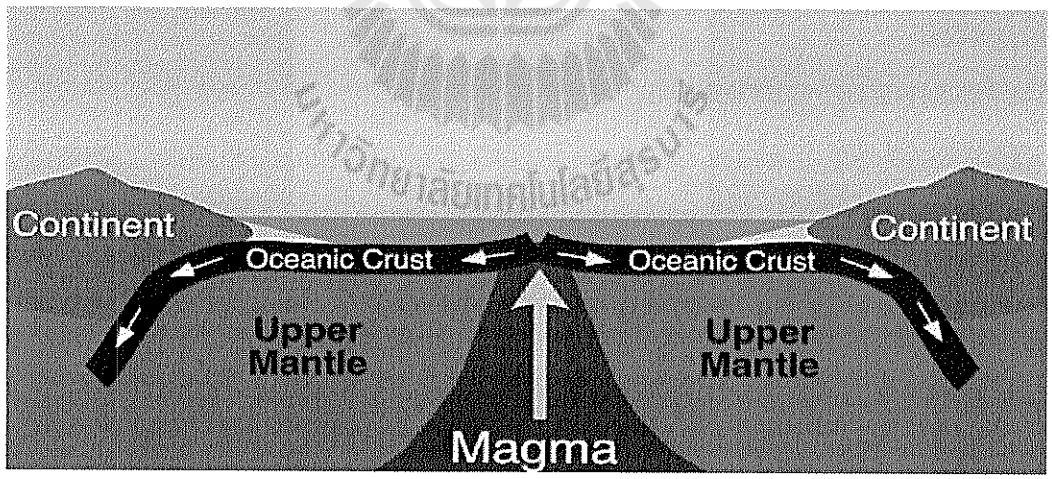




Crust

- 8 – 40 Km thick
- mostly igneous rocks, with some metamorphic rocks and a thin layer of sedimentary rocks
- Boundary between mantle and crust defined at the Mohorovicic discontinuity (*Moho)*





Continental crust:

- called *sial* (Silicate and Aluminium minerals)
- mostly of granitic rock (felsic rocks)
- density of about 2.7 g/cm^3
- 25 to 70 km of thickness

Oceanic crust:

- called *sima* (Magnesium silicates minerals) rich in Iron (Fe) and Magnesium (Mg)
- mafic rocks such as basalt and gabbro, and the upper mantle consists of peridotite.
- less than 10 km thick
- density of about 2.9 g/cm^3

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3. Plate Tectonic

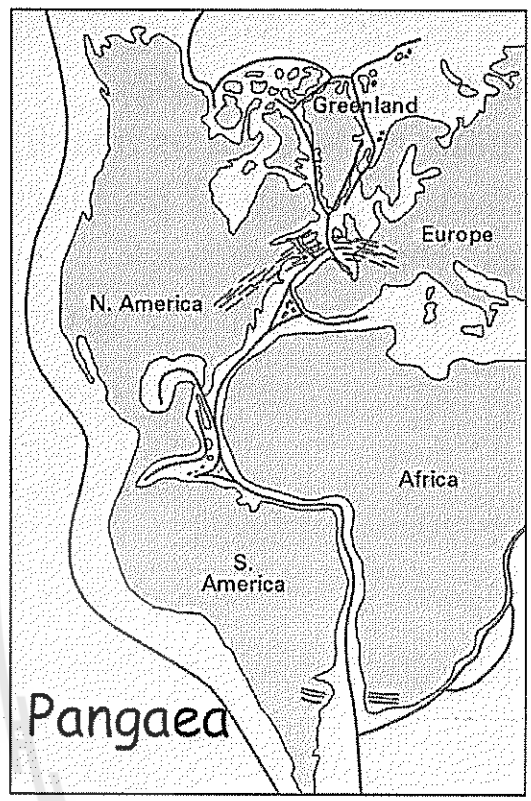
Contents

- Continental drift
- Sea-floor spreading
- Plate Tectonics
- Plate boundaries

Continental drift

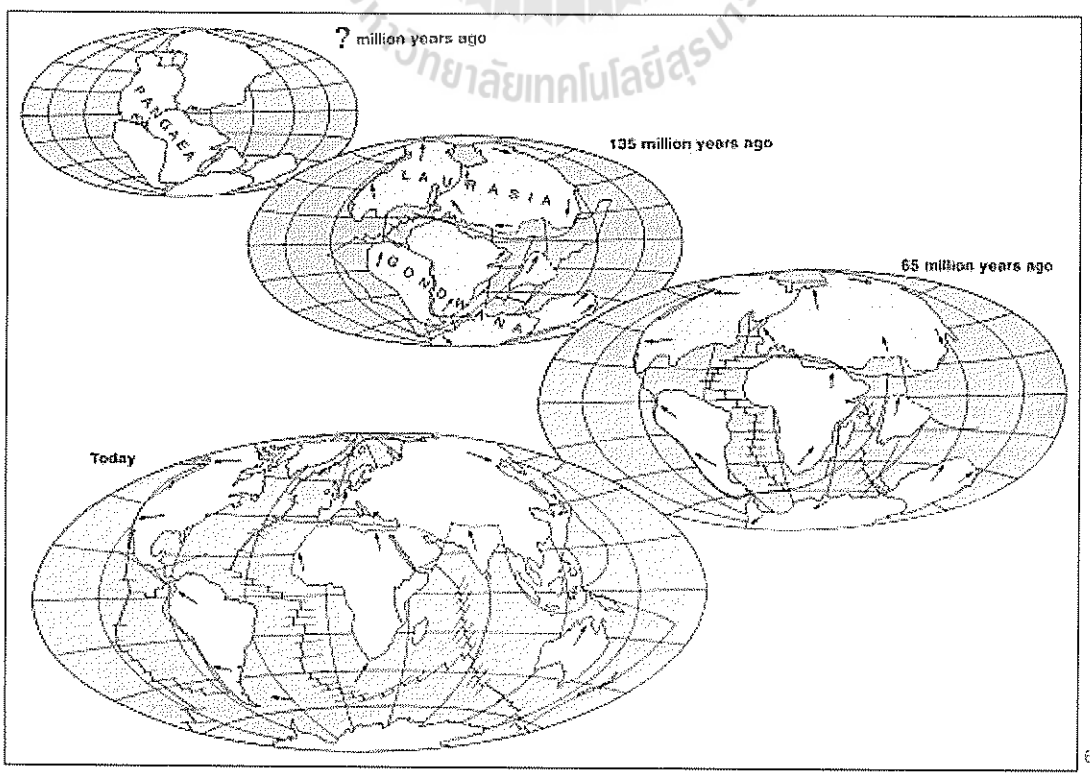
Alfred Wegener, early 1900's





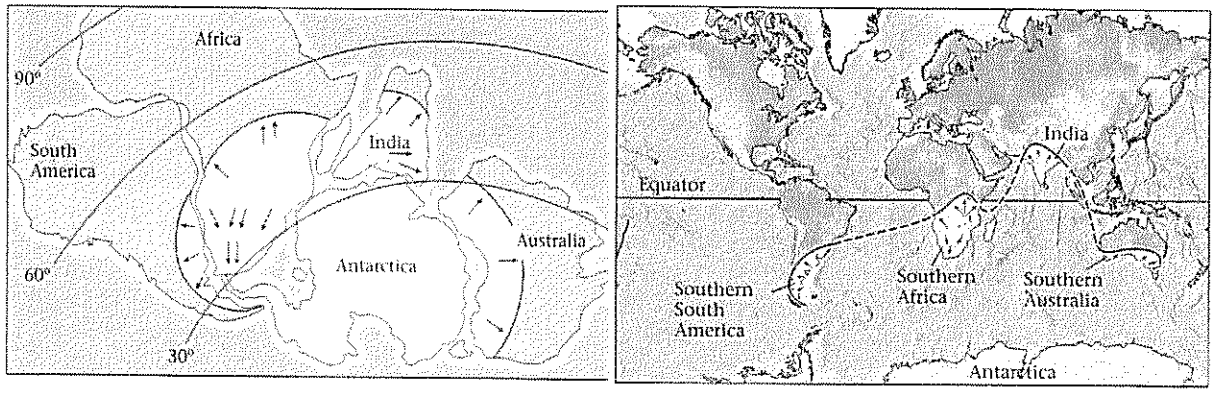
Wegner's evidences for continental drift:

- The fit of the continents



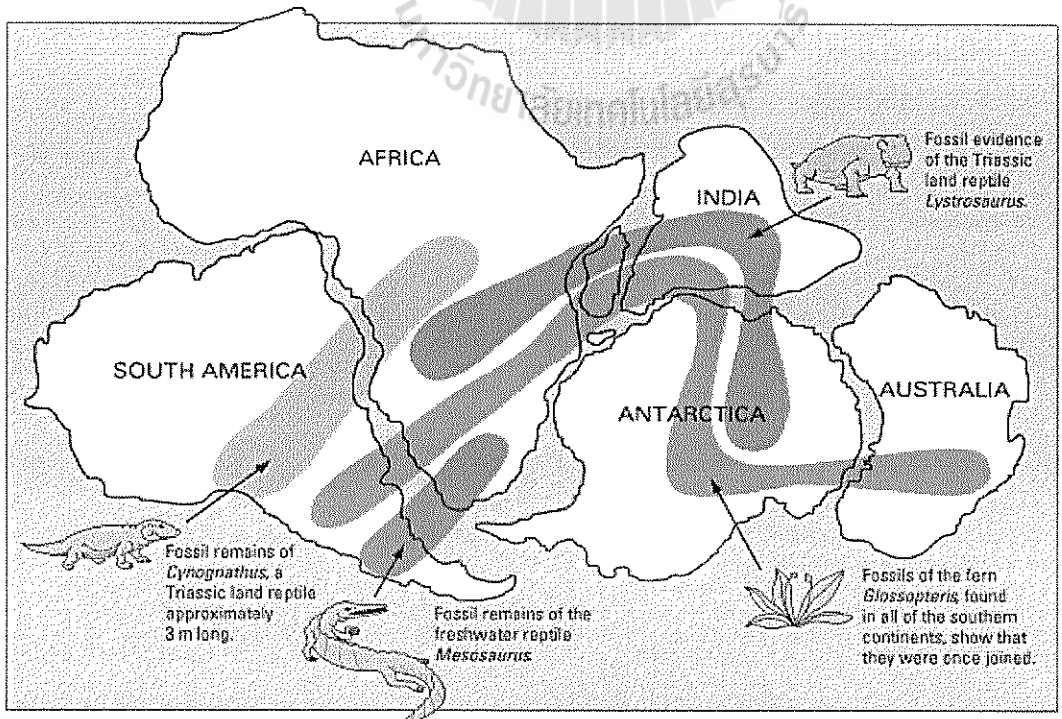
Wegner's evidences for continental drift:

- The fit of the continents
- Location of past glaciations



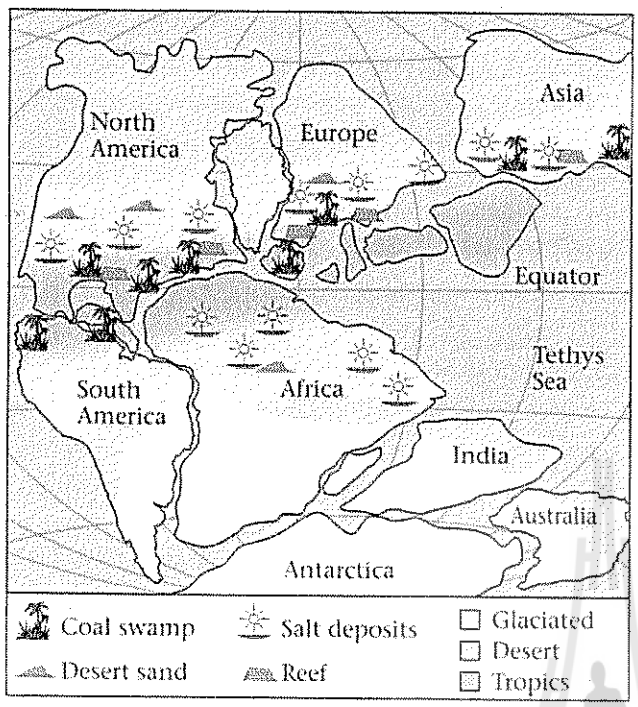
Wegner's evidences for continental drift:

- Distribution of fossils and plant species



Wegner's evidences for continental drift:

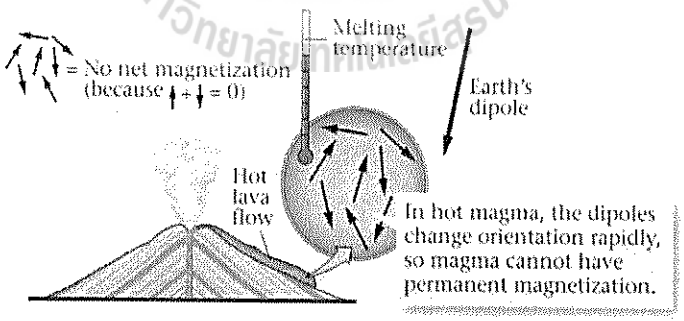
- Geologic Structures and Deposits

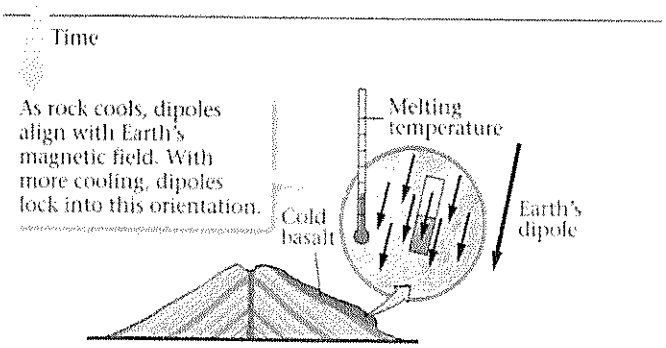




Wegner's evidences for continental drift:

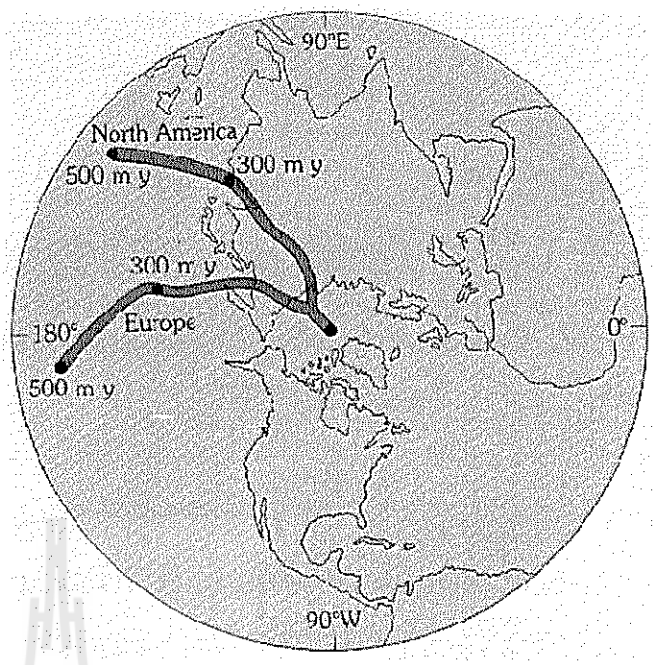
- Paleomagnetisms





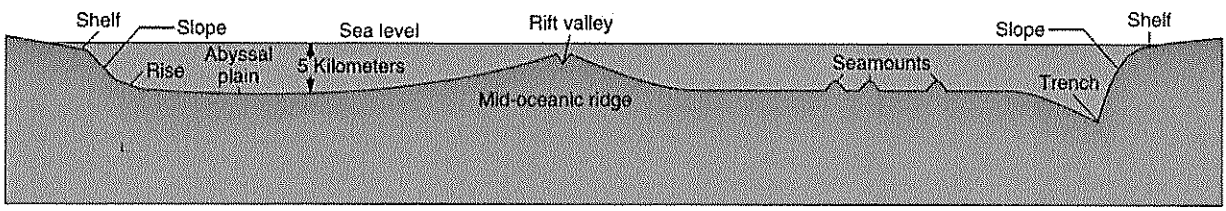
Continental drift and paleomagnetism

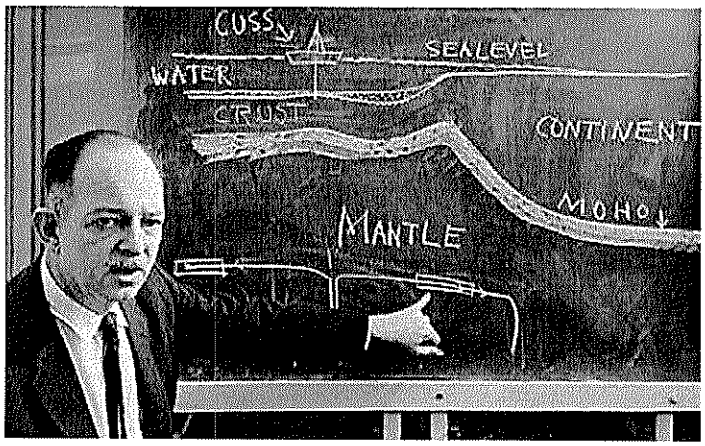
Polar wandering
- the apparent movement of the magnetic poles shown in magnetized rocks
- indicates that continents have moved

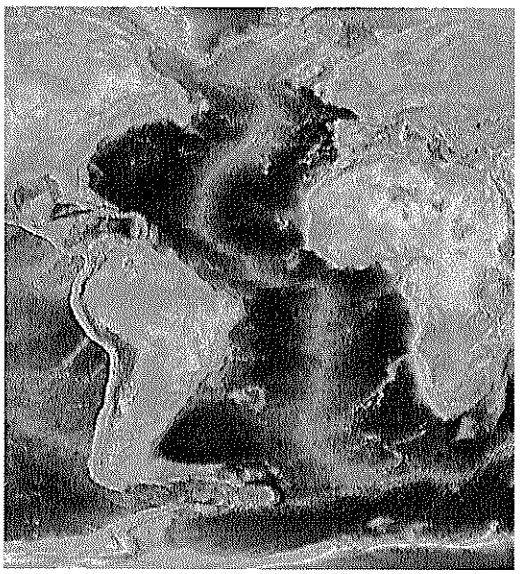


Sea-floor spreading





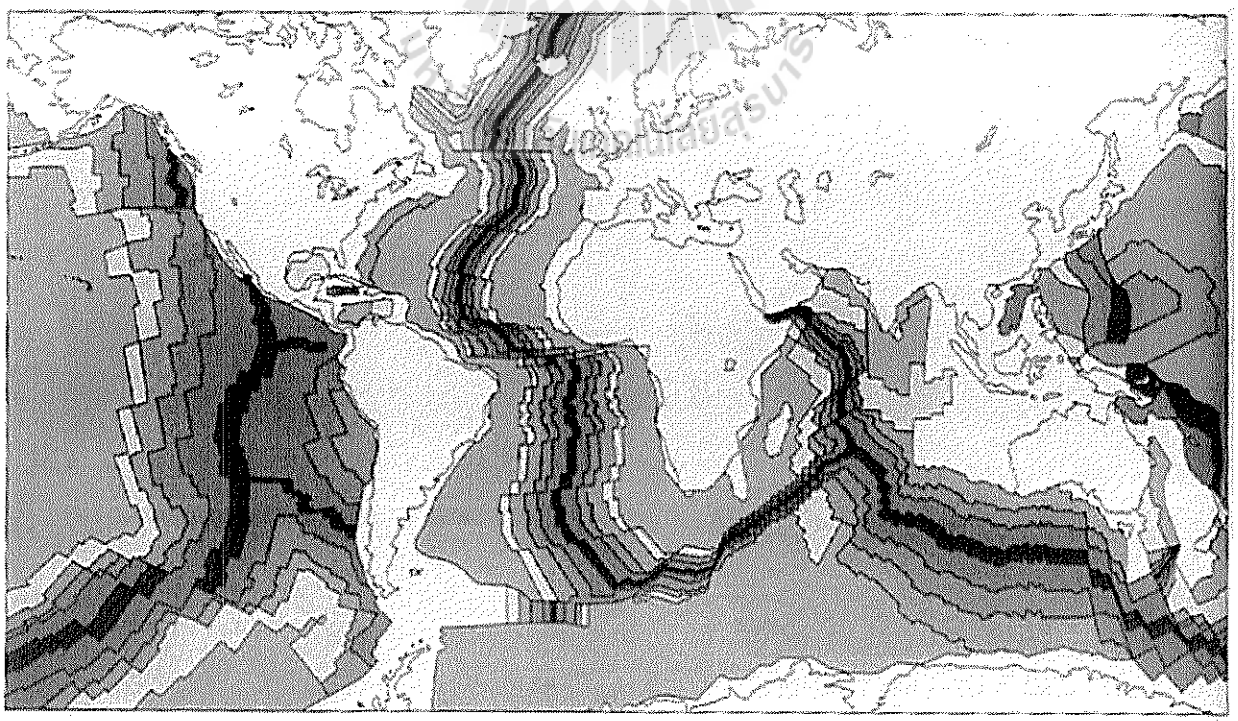




Harry Hess, early 1960s

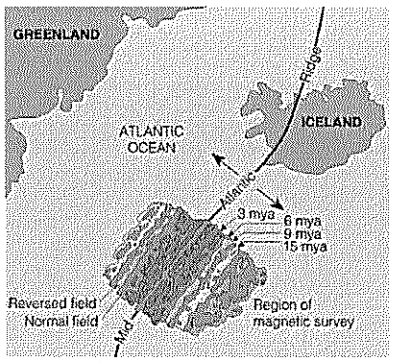
New ocean floor must be forming at the ridges due to the thickness of sediments thickened away from the ridges.

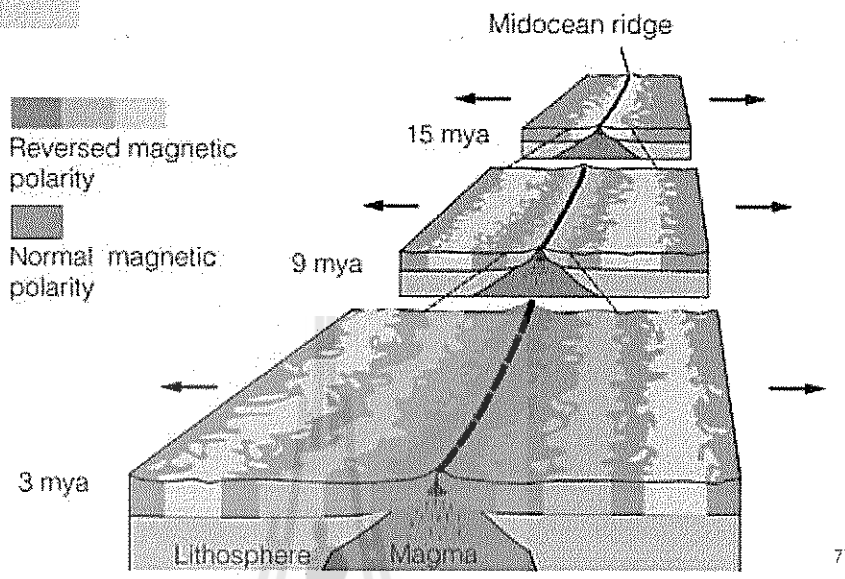
Evidences for the Sea-floor spreading



Deep-sea drilling
(Glomar Challenger, late 1960s)

Geomagnetic reversals

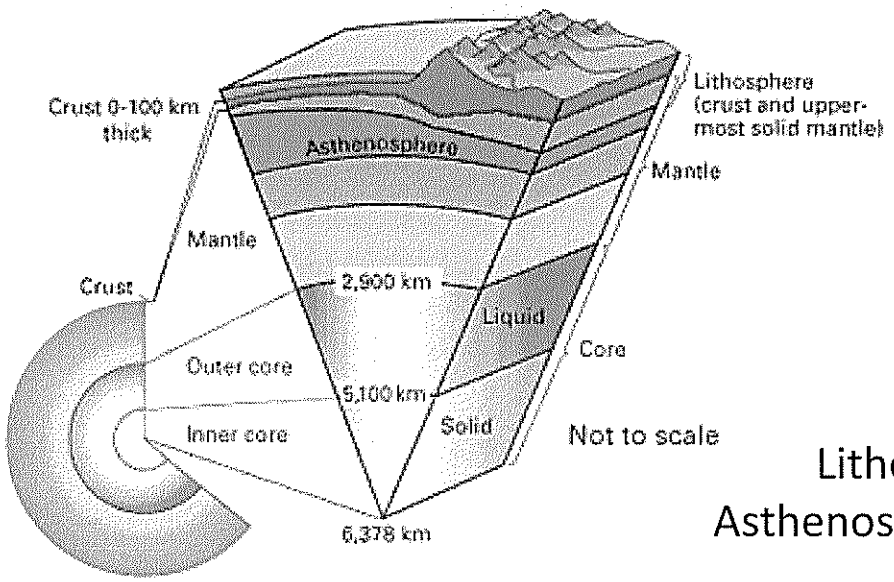




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Plate Tectonics

A composite of a variety of ideas that explain the observed motion of Earth's lithosphere through the mechanisms of subduction and sea-floor spreading.

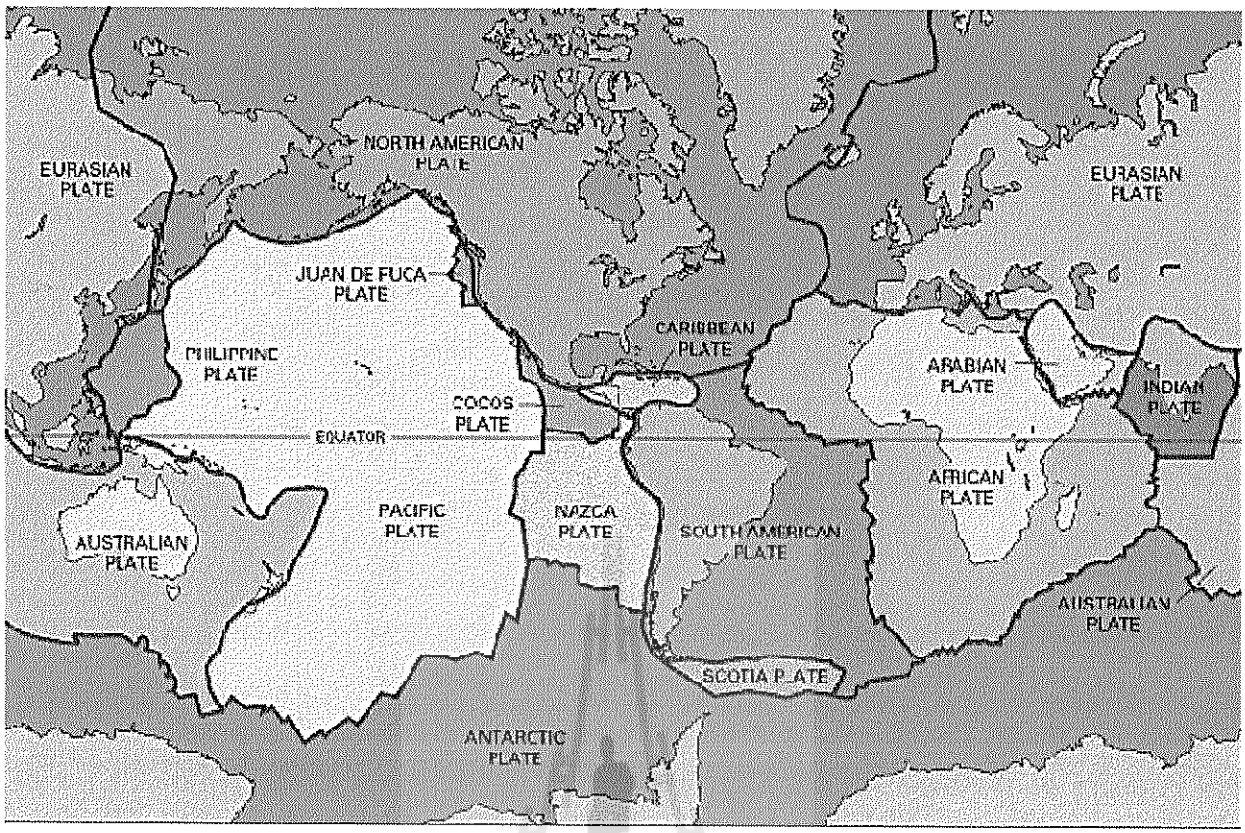


Lithosphere: rigid

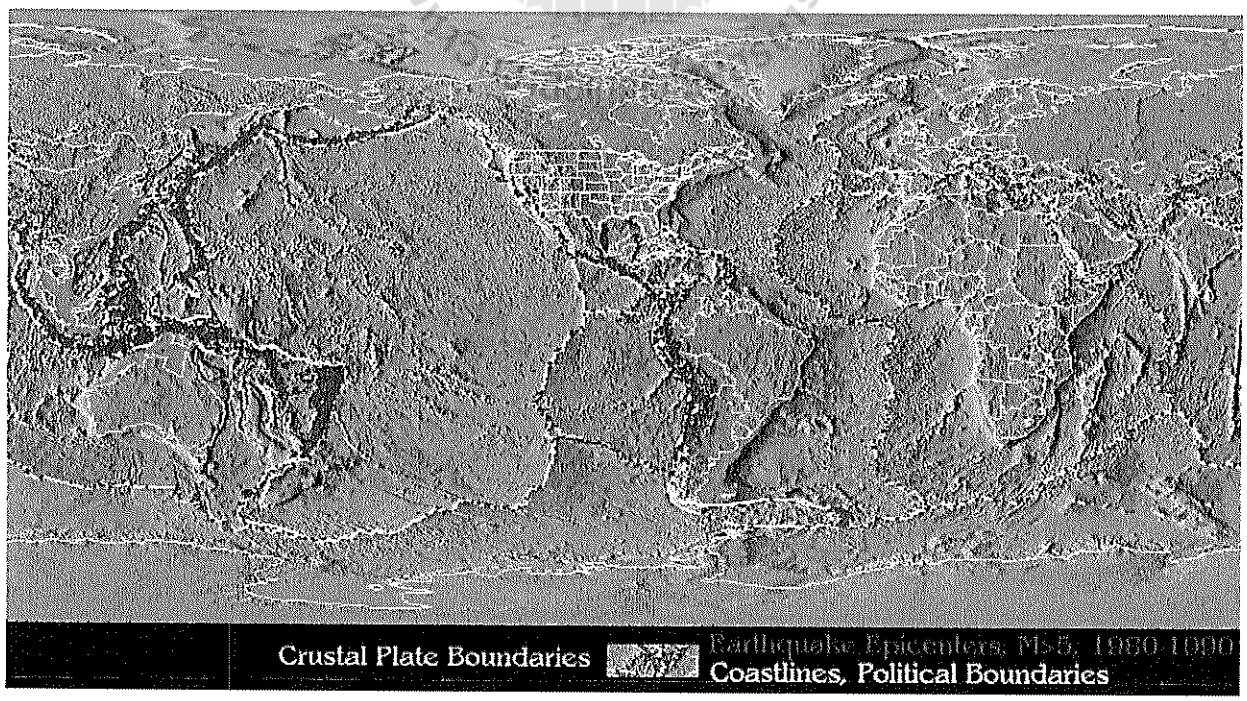
Asthenosphere: plastic

78

Lithosphere plates



Locations of earthquakes that correspond to plate boundaries



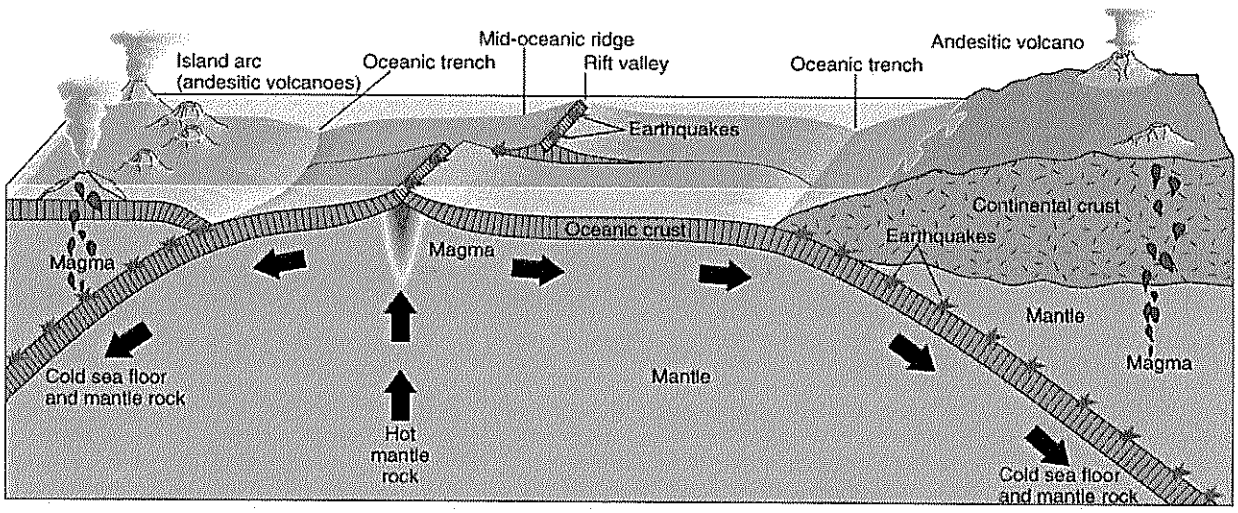
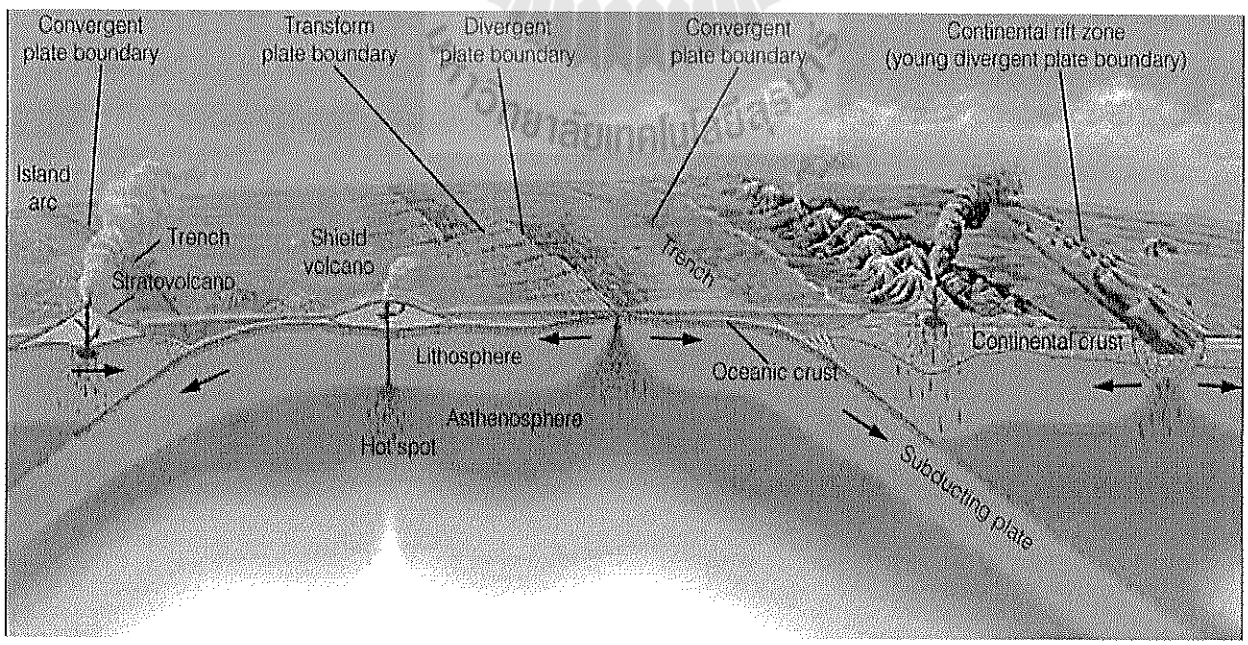
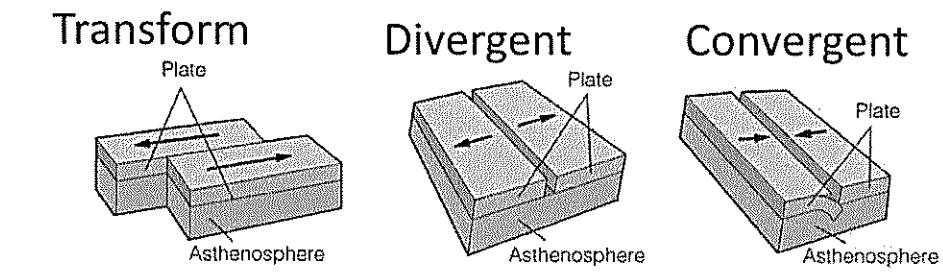
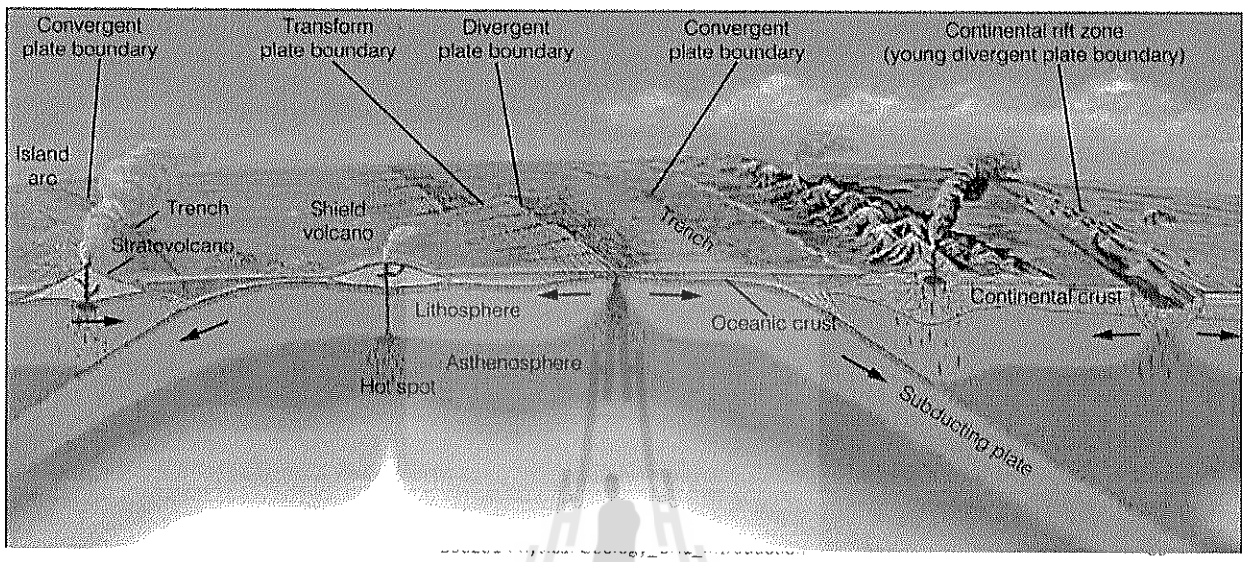


Plate boundary

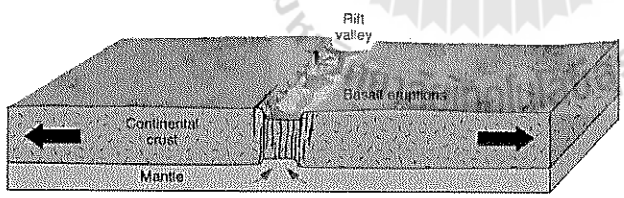


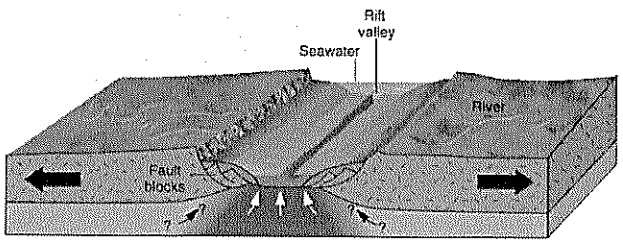


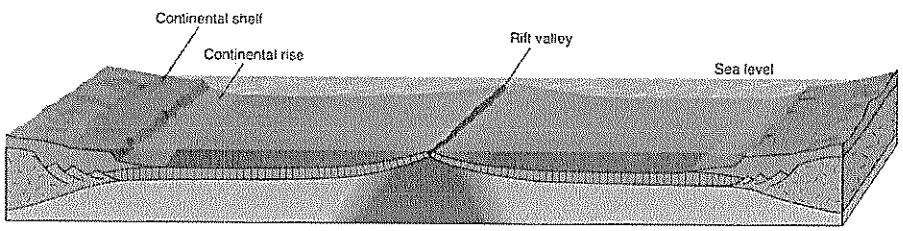


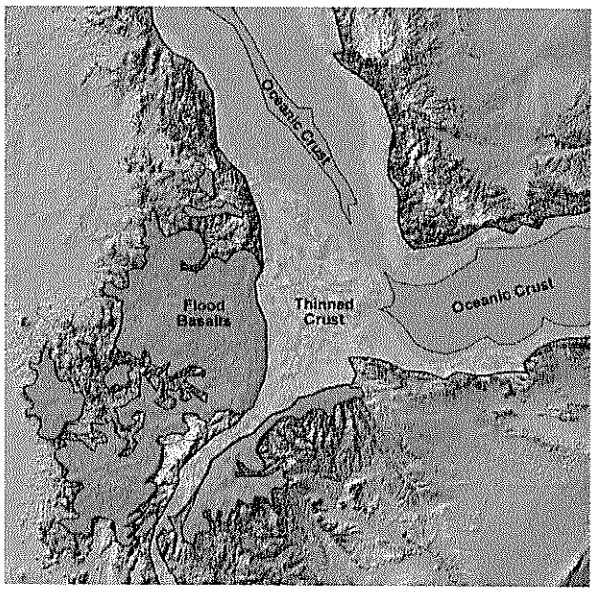
Divergent plate boundaries (constructive plate margins)

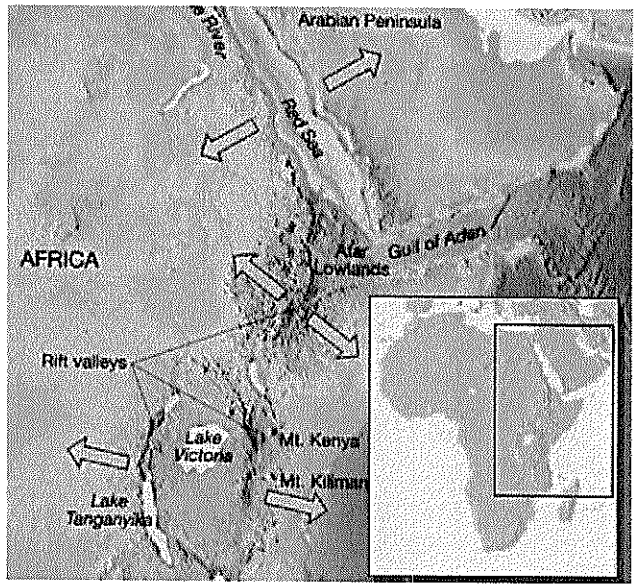
- Volcanism
- Normal fault basins
- Sedimentary deposits of arkosic sandstone

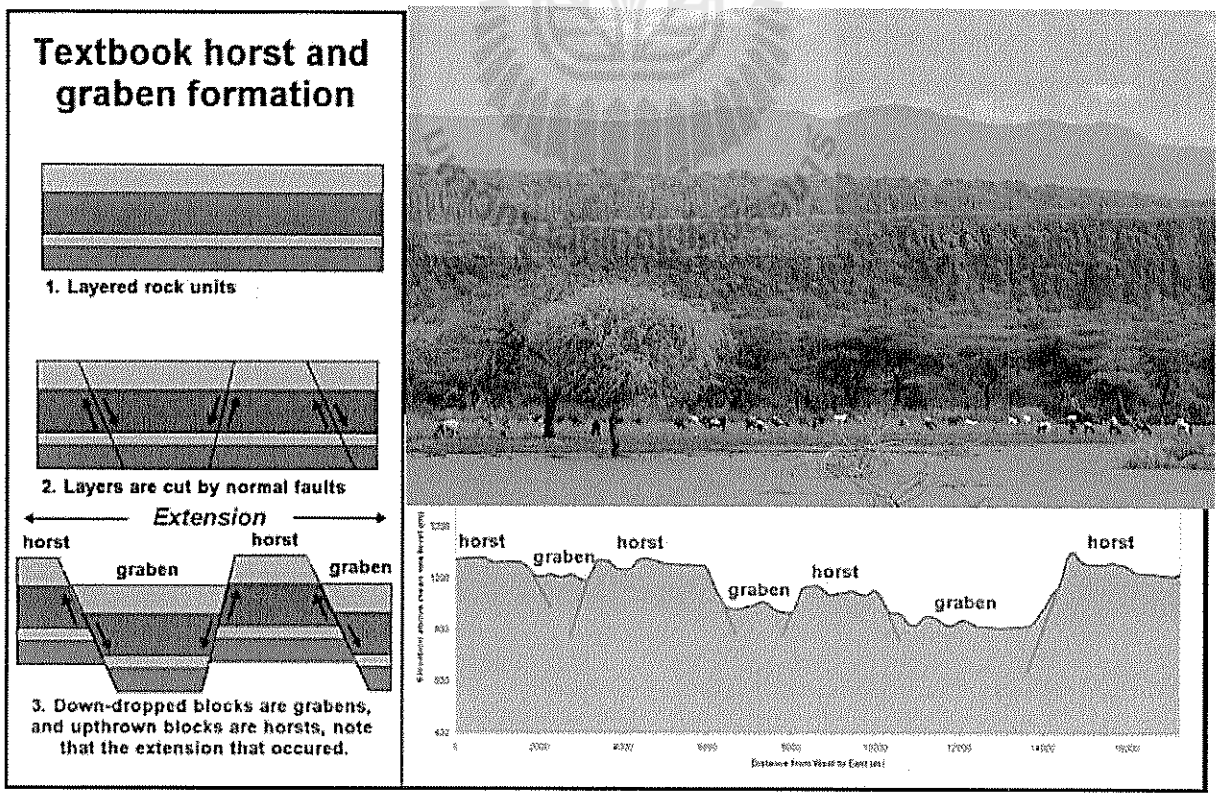






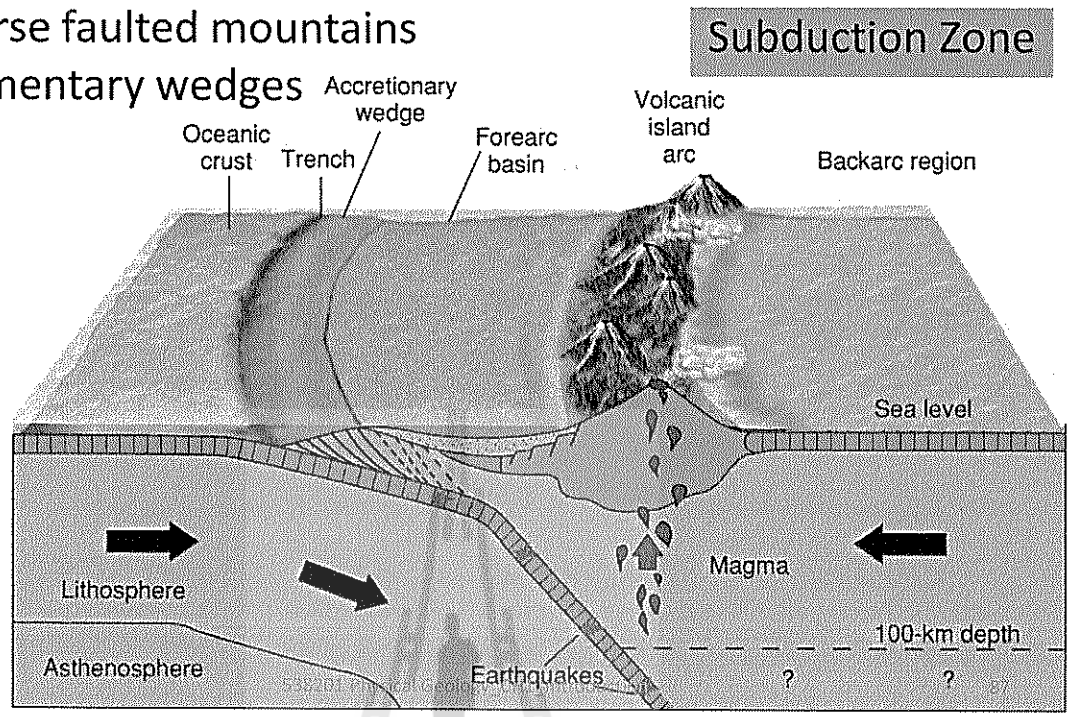

Oceanic Crust
Flood Basalts
Thinned Crust
Oceanic Crust


Arabian Peninsula
Red Sea
AFRICA
Afar Lowlands
Gulf of Aden
Rift valleys
Lake Victoria
Mt. Kenya
Mt. Kilimanjaro
Lake Tanganyika


Textbook horst and graben formation
1. Layered rock units
2. Layers are cut by normal faults
Extension
horst
graben
horst
graben
3. Down-dropped blocks are grabens, and upthrown blocks are horsts, note that the extension that occured.
horst
graben
horst
graben
horst
graben
horst

Convergent plate boundaries (Destructive margins)

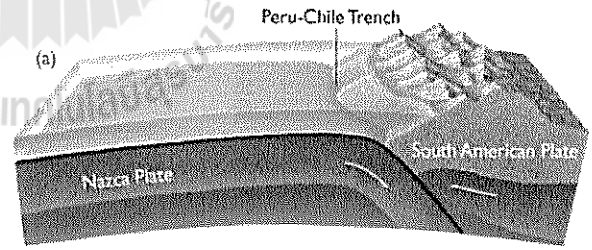
- Metamorphism
- Volcanism
- Reverse faulted mountains
- Sedimentary wedges



Types of convergent boundaries

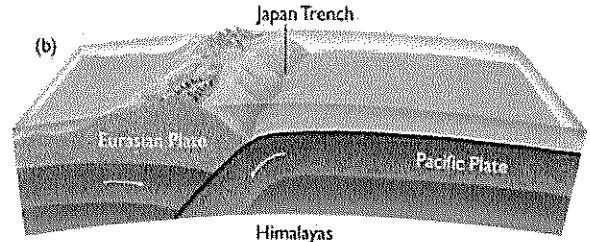
Oceanic – continent

Volcanic arcs



Oceanic – oceanic

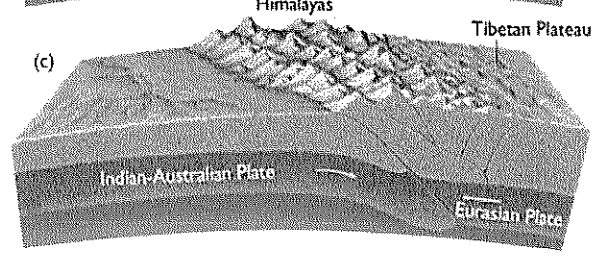
Island arcs

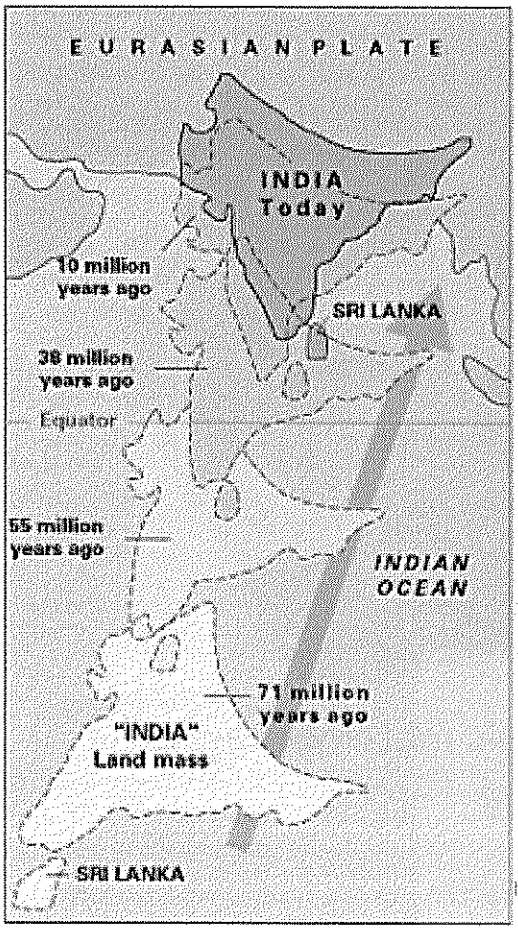


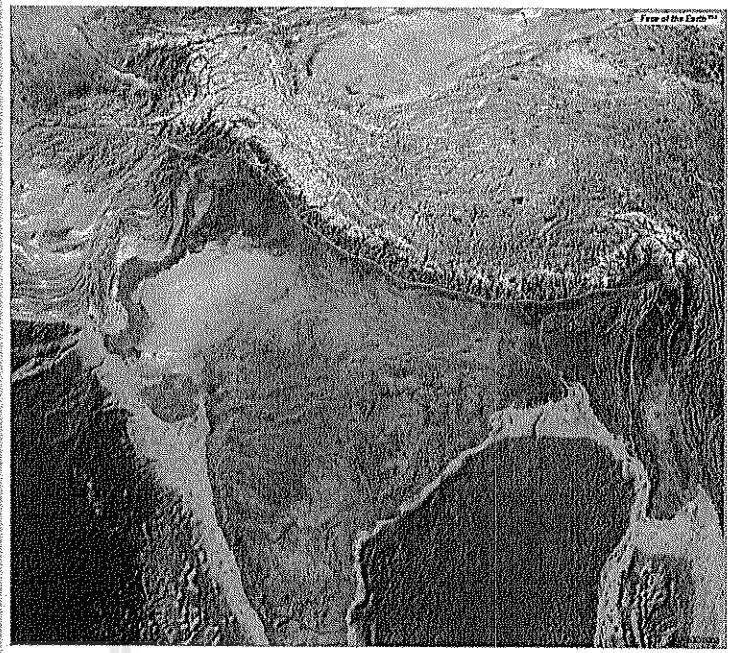
Continental – continental

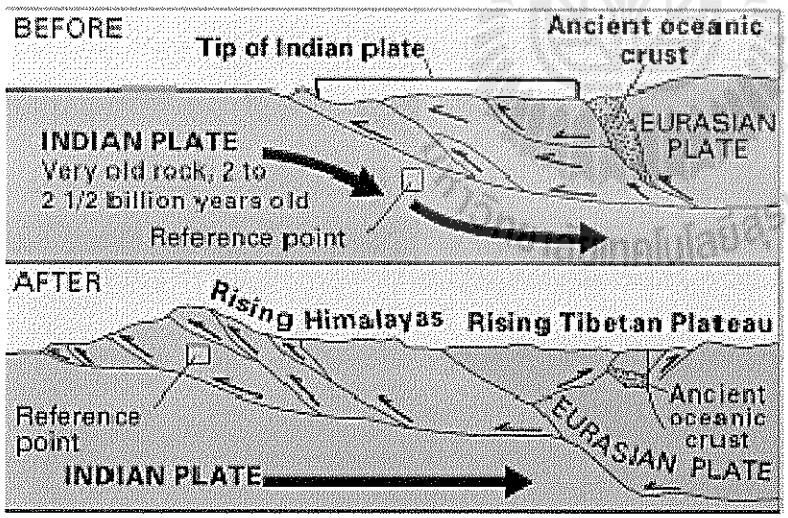
Mountains

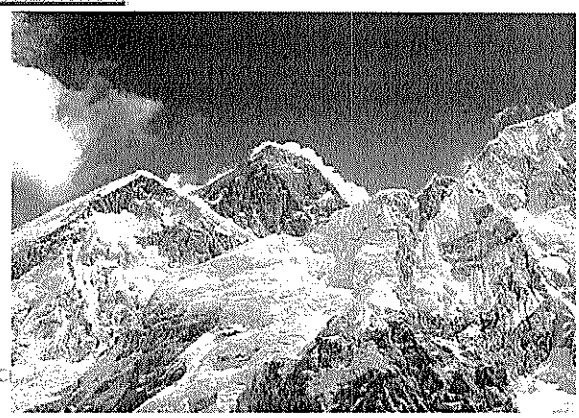
Continental collision




EURASIAN PLATE
INDIA
Today
10 million
years ago
SRI LANKA
38 million
years ago
Equator
55 million
years ago
INDIAN
OCEAN
71 million
years ago
"INDIA"
Land mass
SRI LANKA

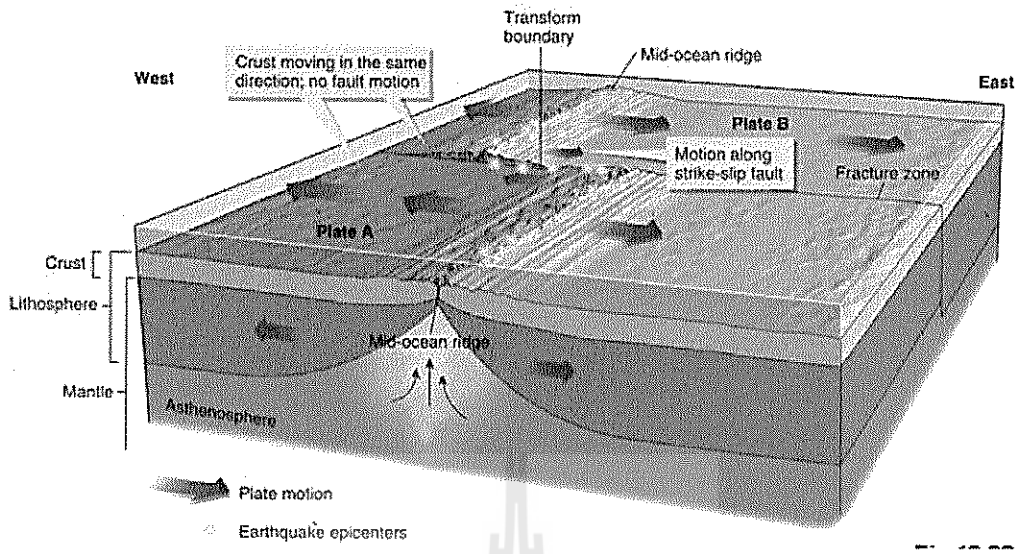



BEFORE
Tip of Indian plate
Ancient oceanic
crust
EURASIAN
PLATE
INDIAN PLATE
Very old rock, 2 to
2 1/2 billion years old
Reference point
AFTER
Rising Himalayas
Rising Tibetan Plateau
Reference
point
Ancient
oceanic
crust
EURASIAN PLATE
INDIAN PLATE



Transform plate boundaries

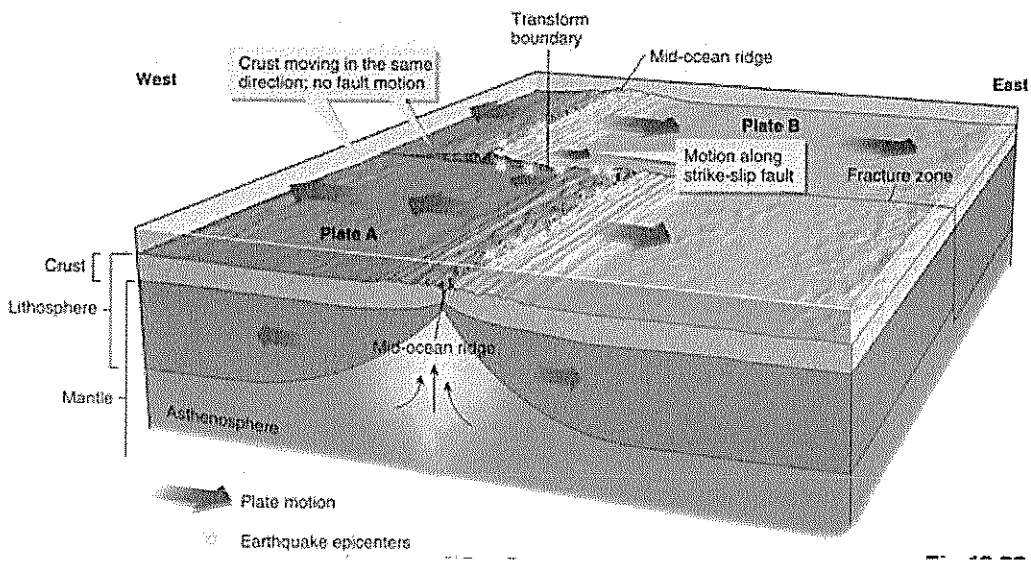
no new lithosphere is created or destroyed

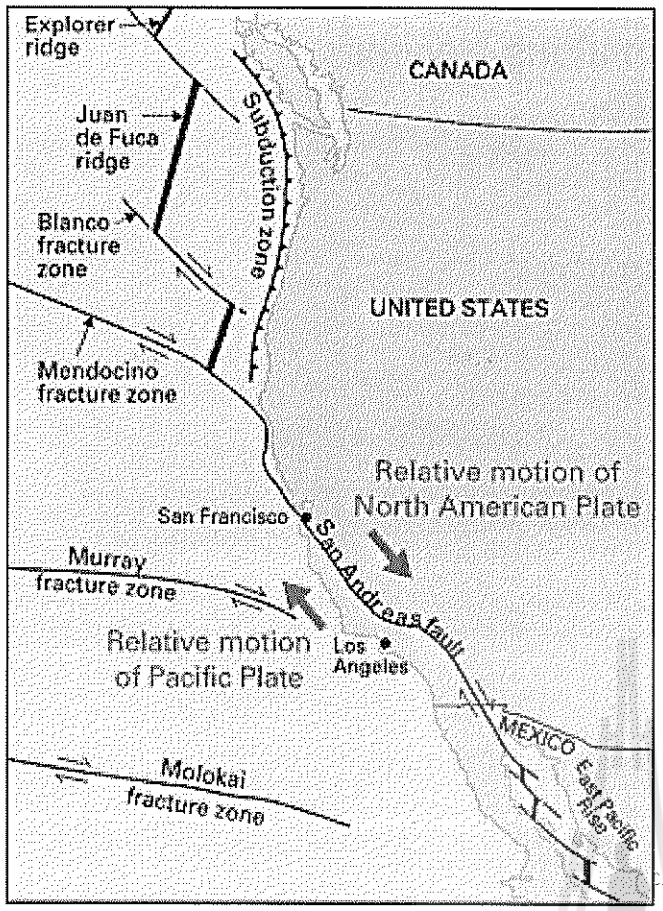


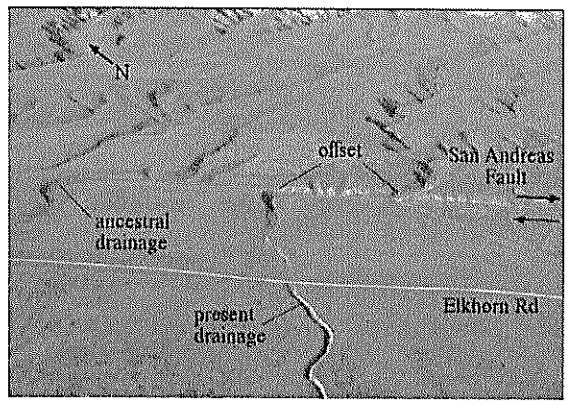
Dynamic metamorphism

Faulting

- usually associated with mid-oceanic ridges (fracture zones)
- a few cut through continental crust (the San Andreas fault and Alpine fault of New Zealand)







Wallace creek

Testing the plate tectonic model

Earthquakes

Deep focus associated with subduction zones

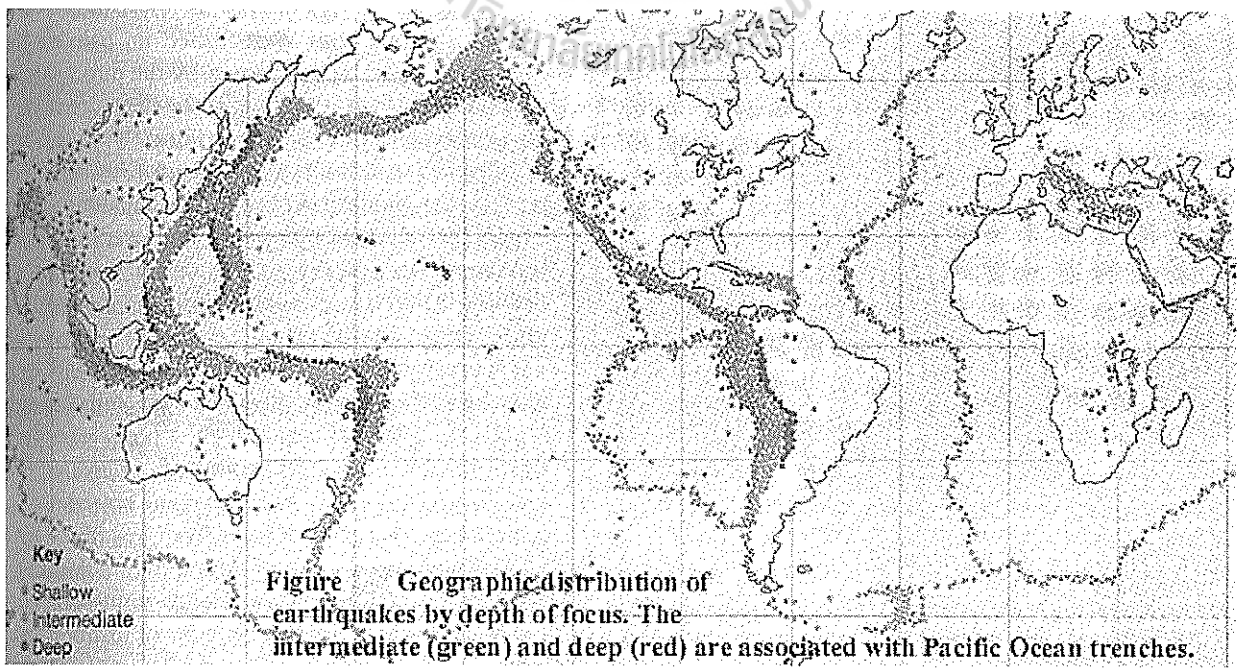
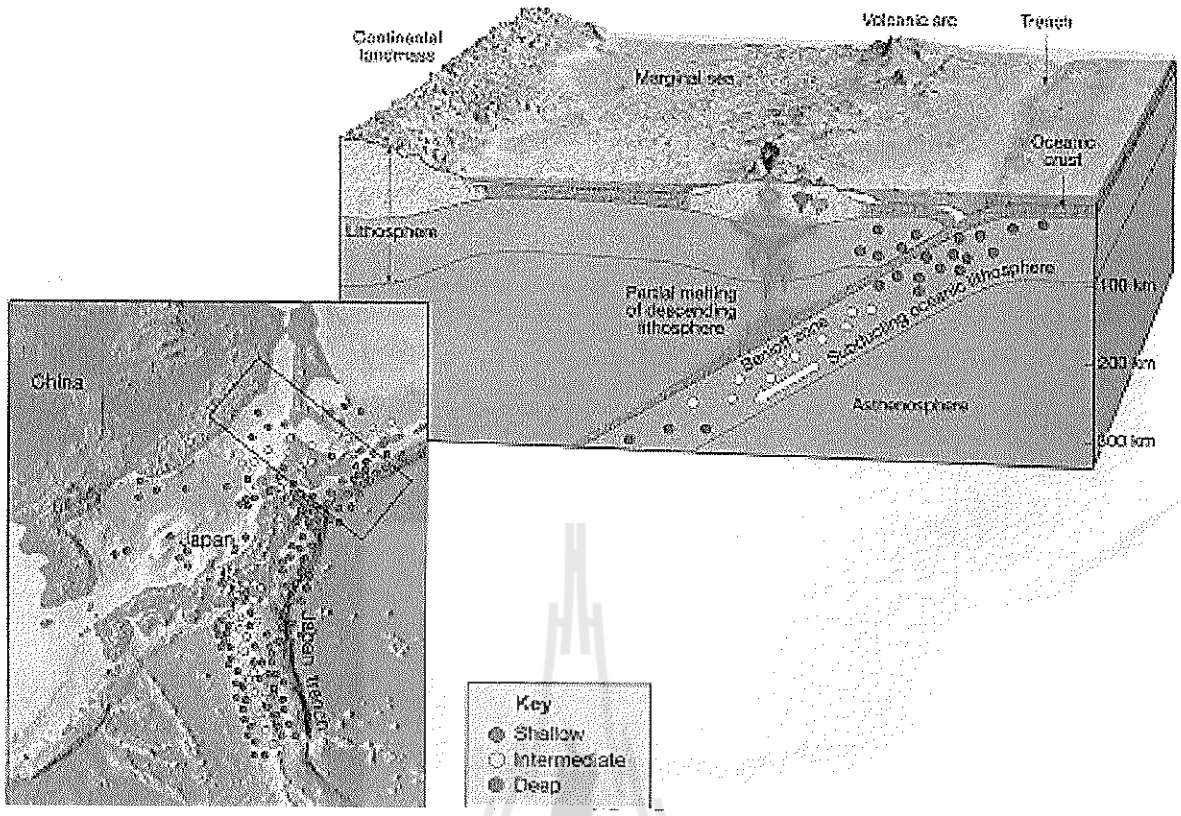


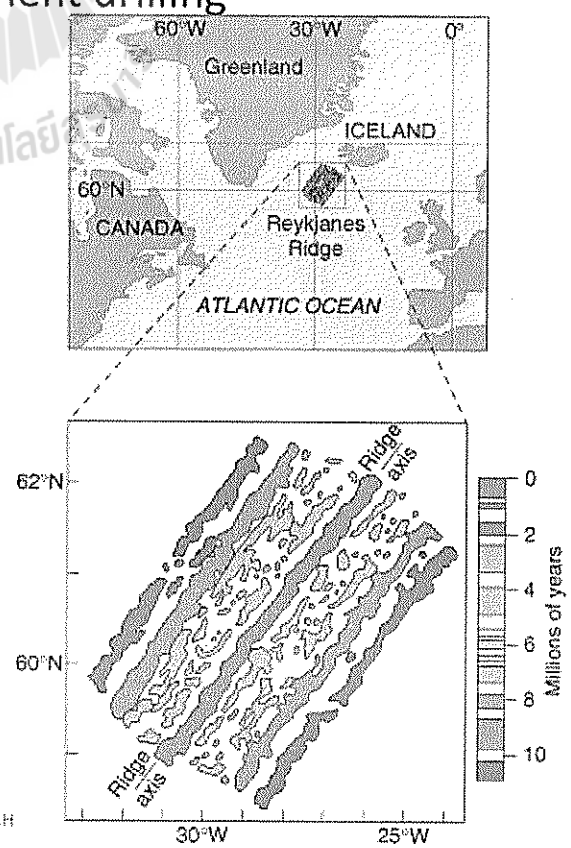
Figure Geographic distribution of earthquakes by depth of focus. The intermediate (green) and deep (red) are associated with Pacific Ocean trenches.

Earthquakes pattern happen along trenches



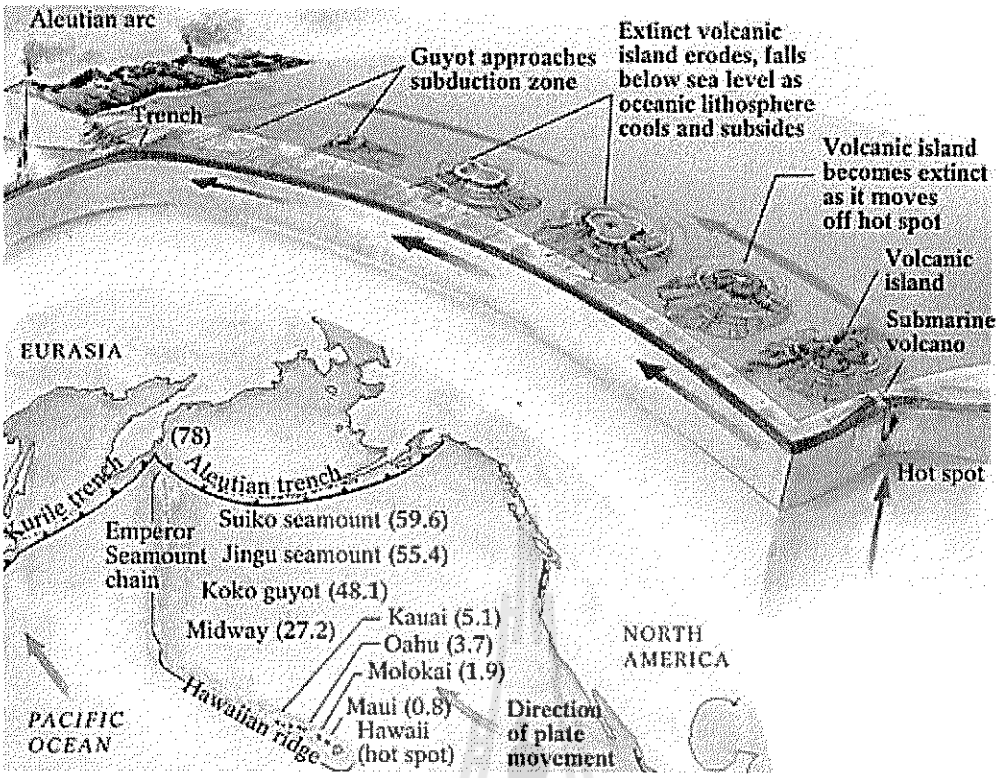
Evidence from ocean-floor sediment drilling

- Age of deepest sediments
- Thickness of ocean-floor sediments

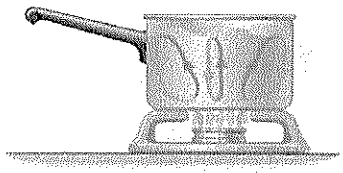


Hot spot

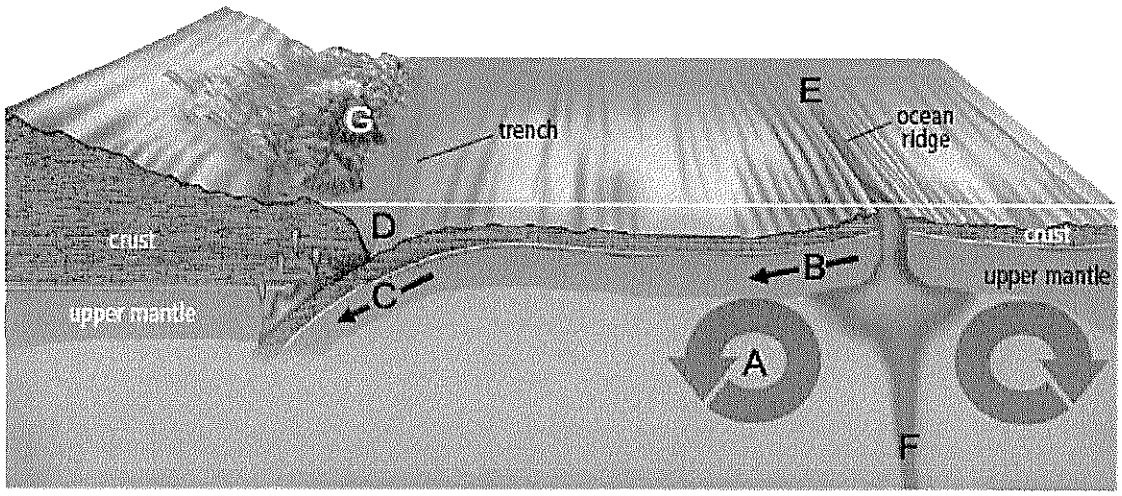
- Caused by rising plumes of mantle material
- Volcanoes can form



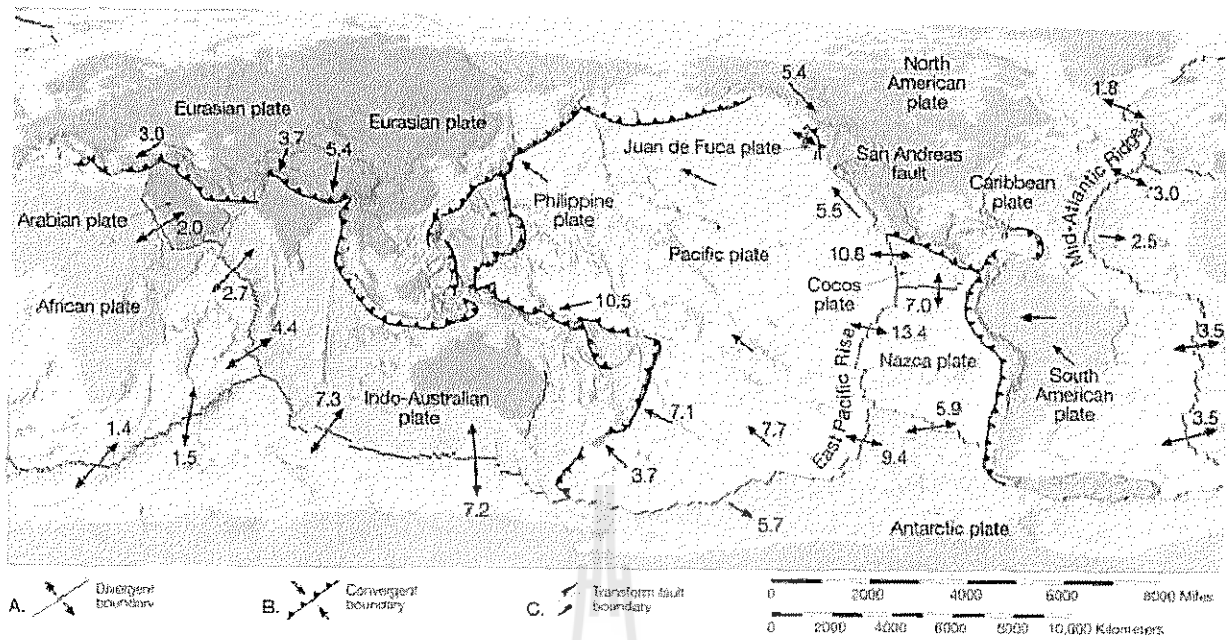
Driving mechanism

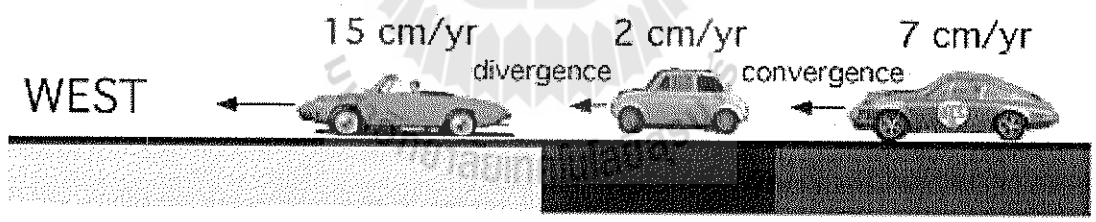


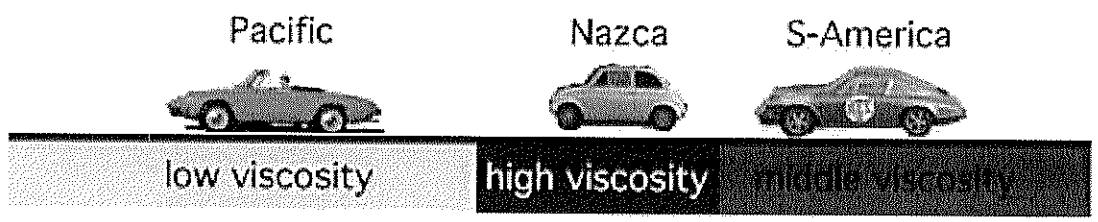
Convective flow (A) + Ridge-push (B) + Slab-pull (C)

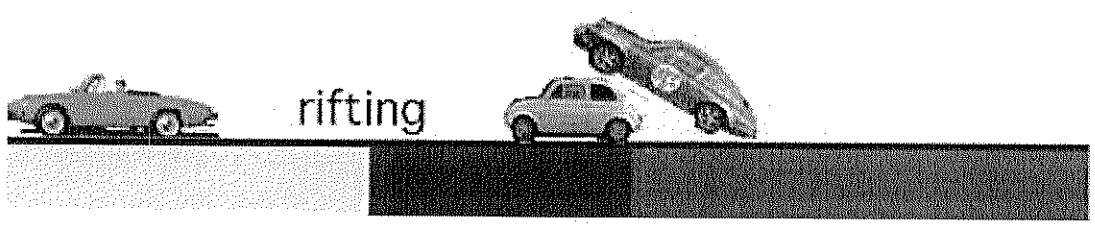


Velocity of plate motion







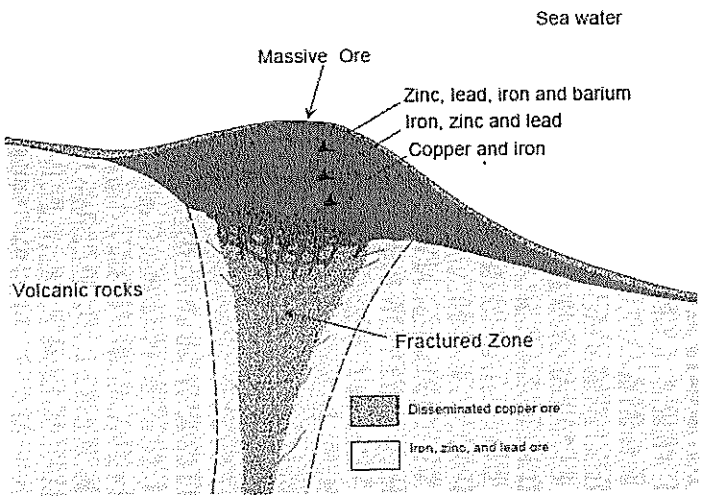


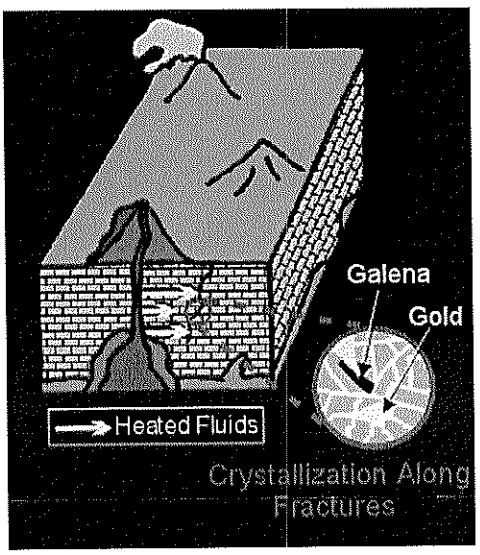
subduction

Importance of Plate Tectonics

- a unified explanation of Earth's major surface processes
- explanations for the geologic distribution of earthquakes, volcanoes, and mountains
- Plate tectonics also can explain past distributions of plants and animals

- helps understanding mechanism of the earth and predicting geoharzards
- ideas of rock distributions and mineral deposits.
- ideas of geological structures and correlations.





Chapter 2 Minerals

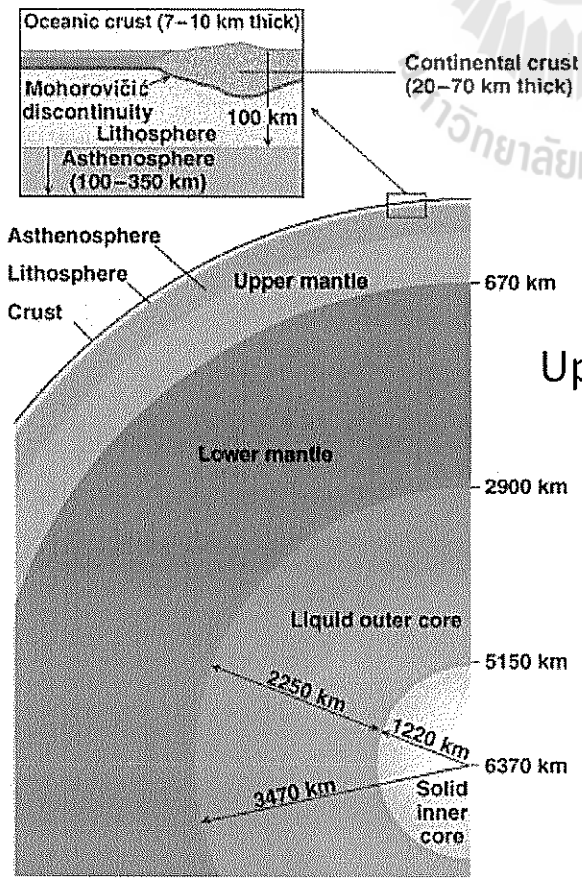
แร่



Giant Crystal Cave: a cave connected to the Naica Mine 300 m below the surface in Naica, Chihuahua, Mexico. The main chamber contains giant selenite crystals (gypsum, $CaSO_4 \cdot 2\,H_2O$), some of the largest natural crystals ever found.

Contents

1. Definition
2. Mineral physical properties
3. Mineral classification
4. Mineral Formation



Internal structure of the Earth

Crust — Sial, Sima

Upper mantle (molten rock)
Lower mantle (solid) — Ultra mafic rock

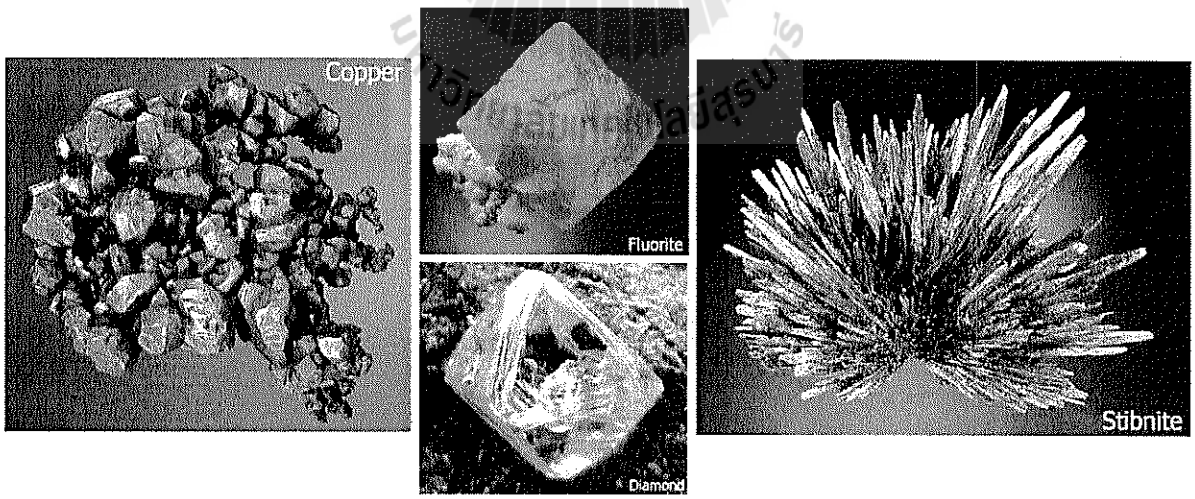
Outer core (liq)
Inner core (solid) — Fe, Ni

P and T increase with depth

Chemical composition of the Earth

An average estimate for Bulk Earth composition (weight%)		Main elements in continental crust (weight%)	
Fe	34.63	O	94.05
O	29.53	Si	0.88
Si	15.20	Al	0.48
Mg	12.70	Fe	0.48
Ni	2.39	Ca	1.19
S	1.93	Na	1.11
Ca	1.13	Mg	0.32
Al	1.09	K	1.49

1. Definition



A mineral is a naturally occurring solid, formed by geological processes, that has a crystal structure and definable chemical composition. Almost all minerals are inorganic. (Marshak, 2009)

Minerals >> Formation of elements by chemical bonds

Minerals >> Crystallization, with changing **T, P, Conc,** atoms may join in an ordered solid arrangement

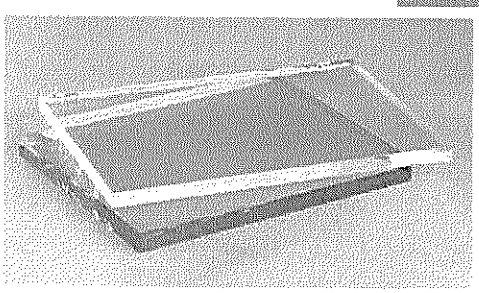
Minerals >> Specific but variable chemical composition

e.g., Dolomite $CaMg(CO_3)_2$,
but $Mg \Leftrightarrow Fe, Mn$;
$Ca(Mg_{0.6}Fe_{0.3}Mn_{0.1})(CO_3)_2$.

Minerals >> Crystalline solid indicates an internal structural framework of atoms (or ions) arranged in a regular geometric pattern

Minerals >> not formed by organic activity

glass, ice, halite

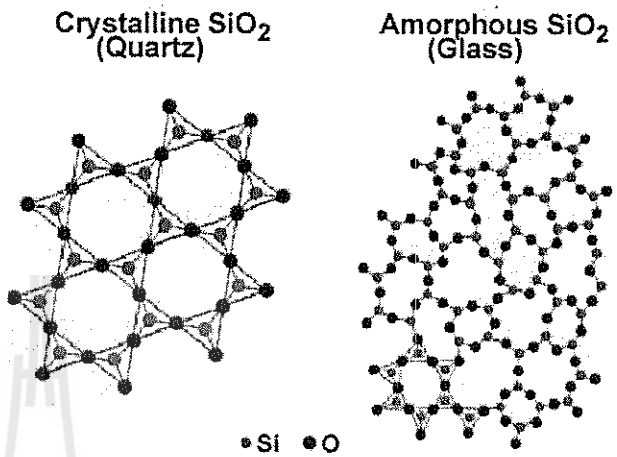




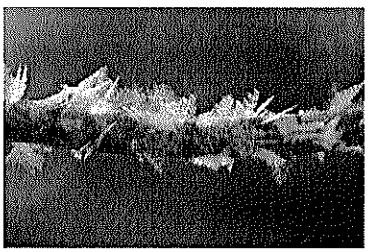
Glass- can be naturally formed (volcanic glass: obsidian).

solid, chemical composition ✓
crystalline structure **(amorphous)** ✗

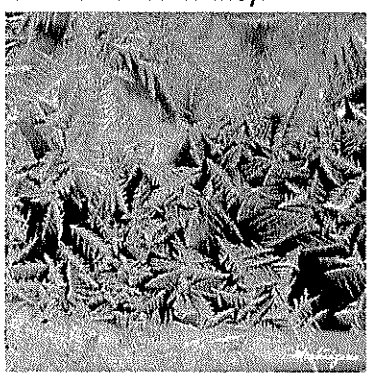


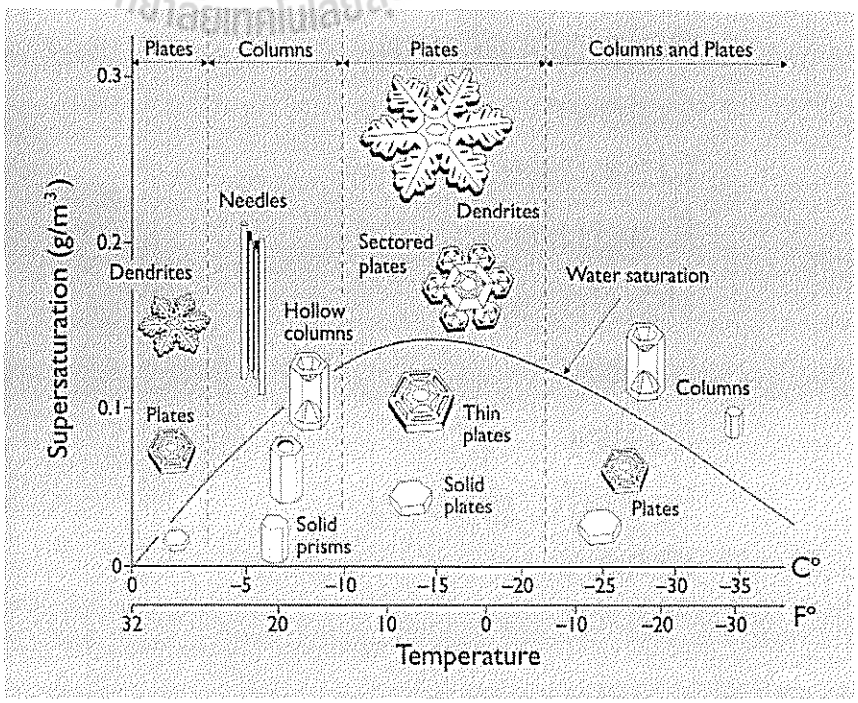


Ice - naturally formed, solid, chemical composition (H_2O), definite crystalline structure <u>when solid</u>. ✓
Ice is a mineral, but liquid water is not .

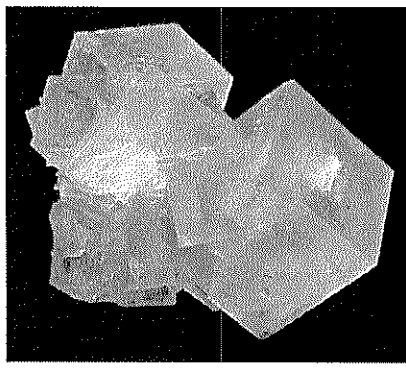


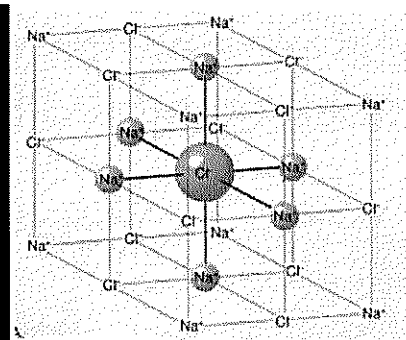
Crystal shape depends on T and humidity.

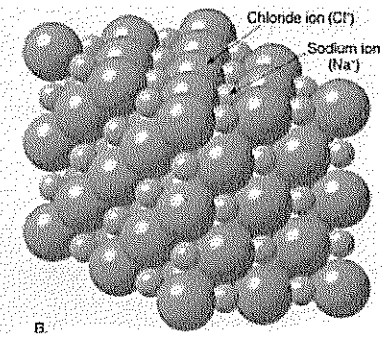




Halite (salt) - naturally formed, solid, chemical composition (NaCl), crystalline structure



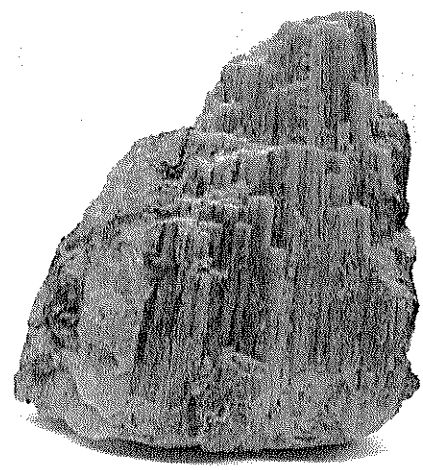






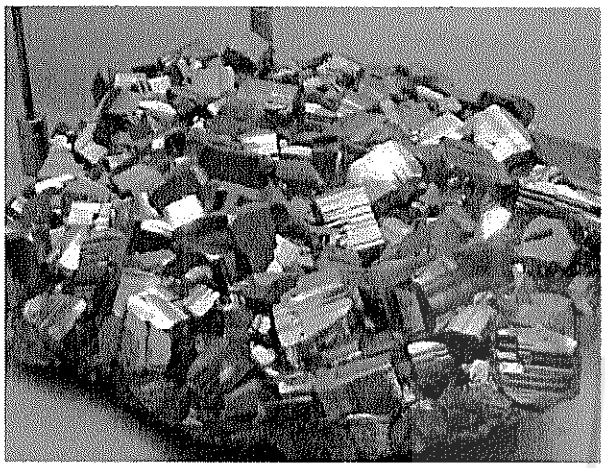
2. Physical properties of minerals

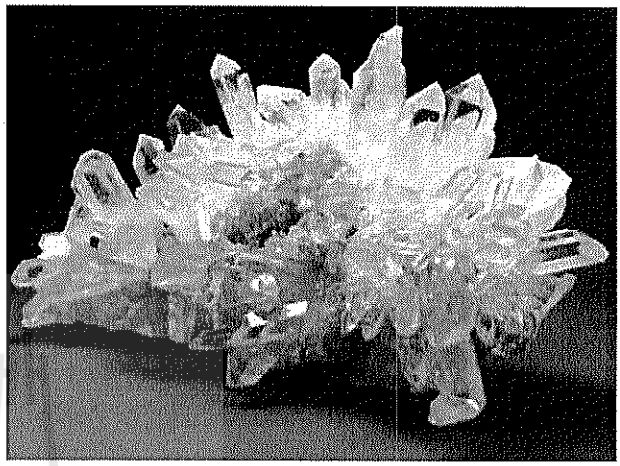
Crystal habit
Polymorphism
Colour
Cleavage
Fracture
Hardness
Streak
Luster
Specific gravity
others



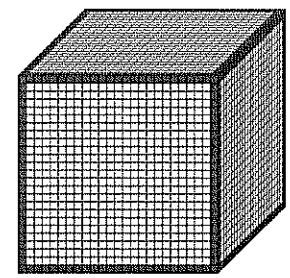
Crystal habit

A crystal: a solid material whose atoms, molecules, or ions are arranged in an orderly, repeating pattern extending in all three spatial dimensions.

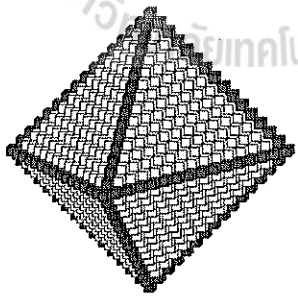




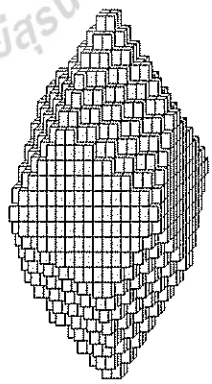
Crystal structure:
a unique arrangement of atoms or molecules (unit cell) in a crystal.

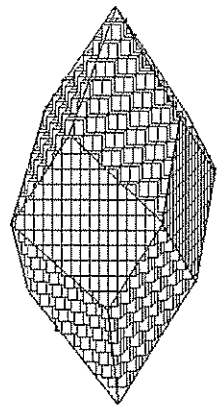


Cube

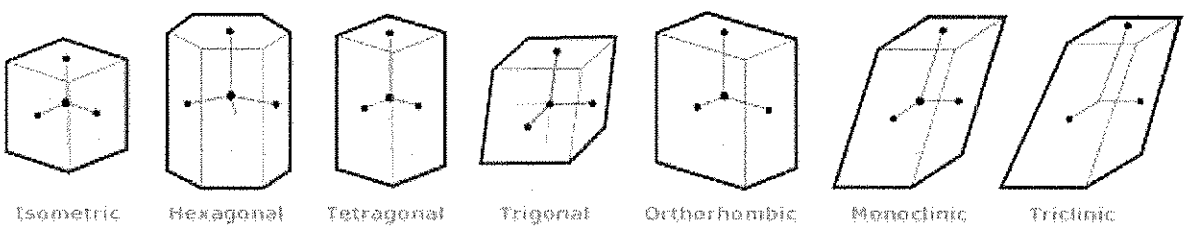


Octahedron

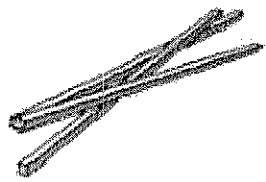




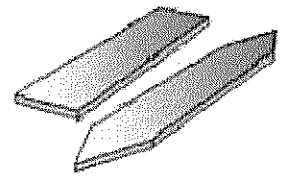
Tetragonal Prism and Trapezohedron



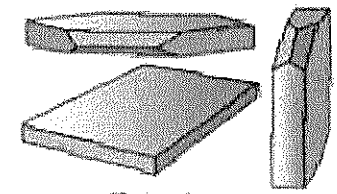
Crystal habit



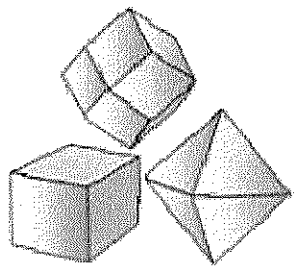
Acicular
(needle-like)



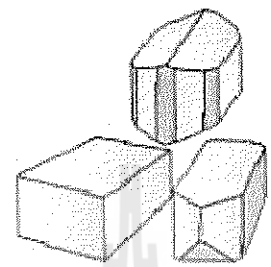
Bladed
(like a knife blade)



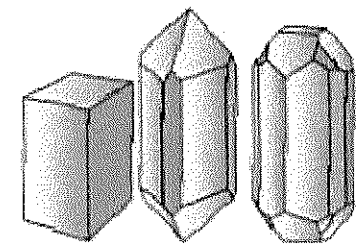
Tabular
(like a tablet of paper)



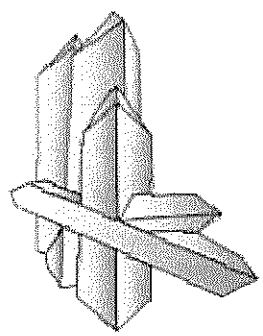
Equant or stubby
(nearly equal width, depth, height)



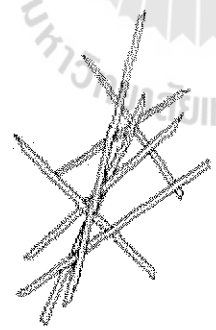
Blocky
(block-shaped)



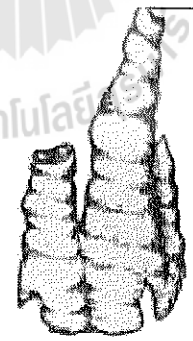
Columnar or prismatic
(column-shaped)



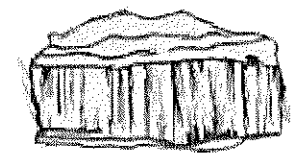
Bladed



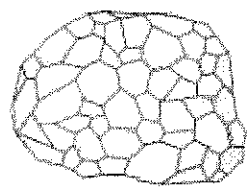
Reticulate



Stalagtitic



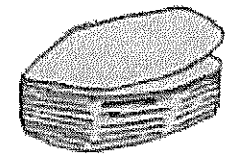
Fibrous massive



Granular massive



Botryoidal



Micaceous foliate

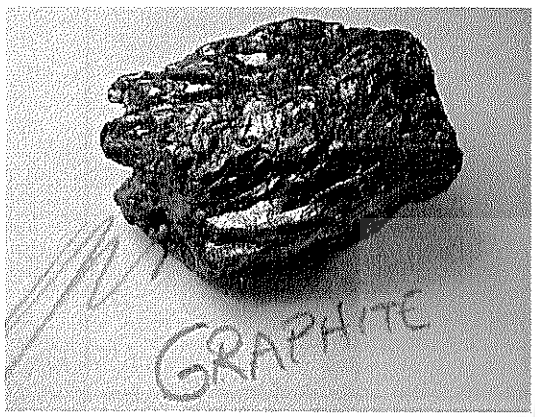


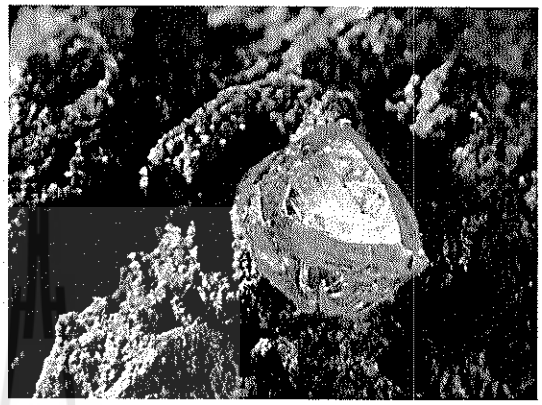
Dendritic

Polymorphism

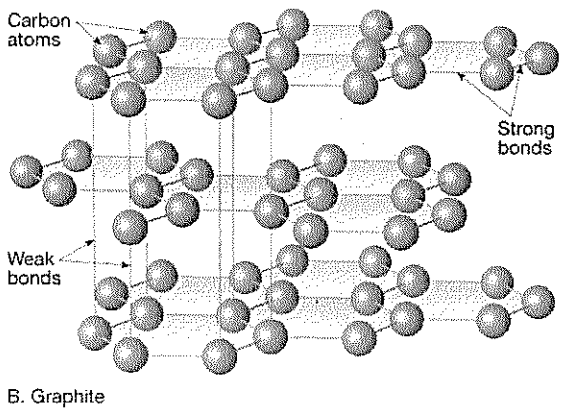
Minerals having same chemical composition may show different crystal structure (as a function of changes in **P&T** or both).

Being crystallized in different Symmetry Systems they exhibit different physical properties, called polymorphism.

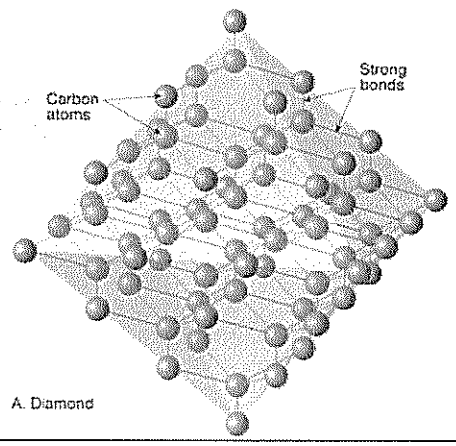




Dimorphic	Comp.	SG.	System	Hardness
Diamond	C	3.51	Cubic	10
Graphite	C	2.23	Hex.	1-2

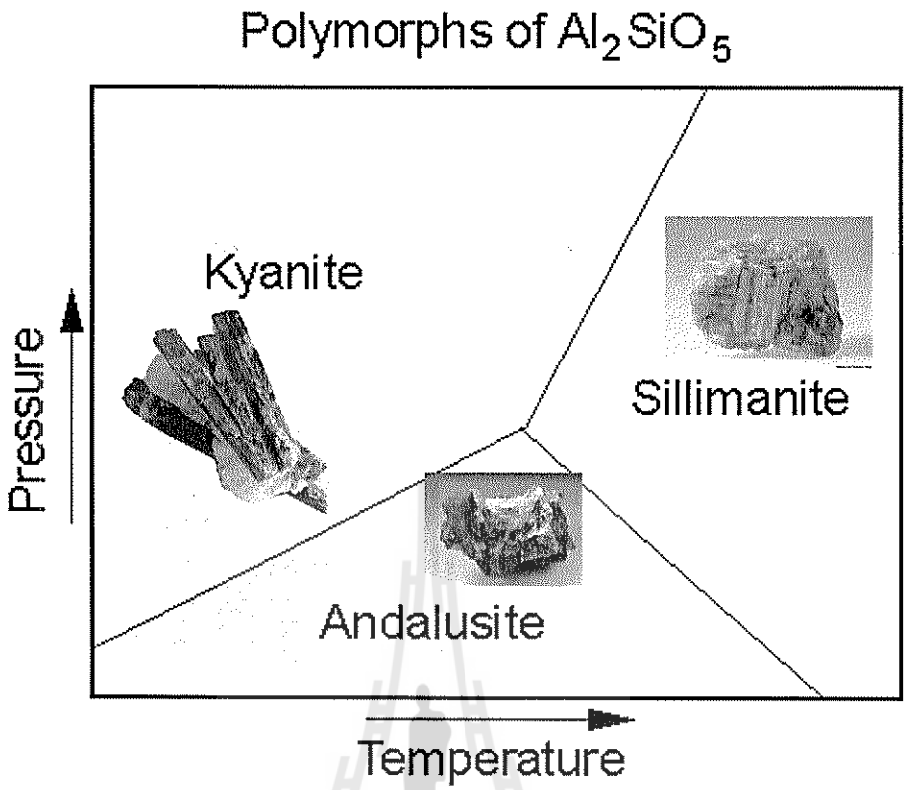


B. Graphite



A. Diamond

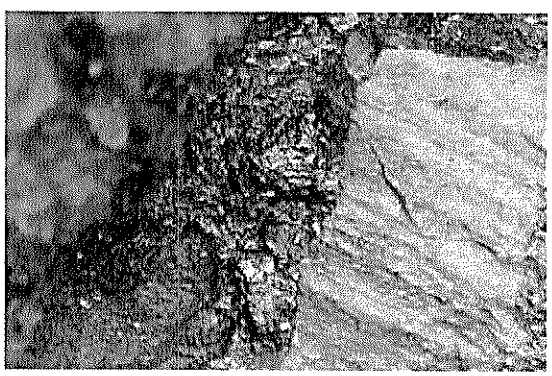
The compound Al_2SiO_5 has three **polymorphs**



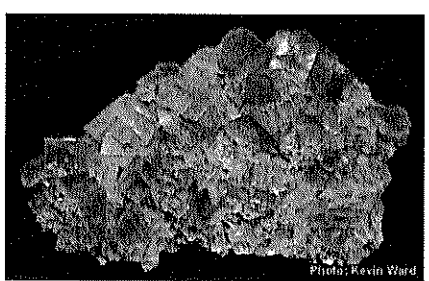
Colour

Certain wave lengths of light which are reflected and perceived by the viewer to possess the property of **color**.

Idiochromatic minerals: "self colored" due to composition



Gold

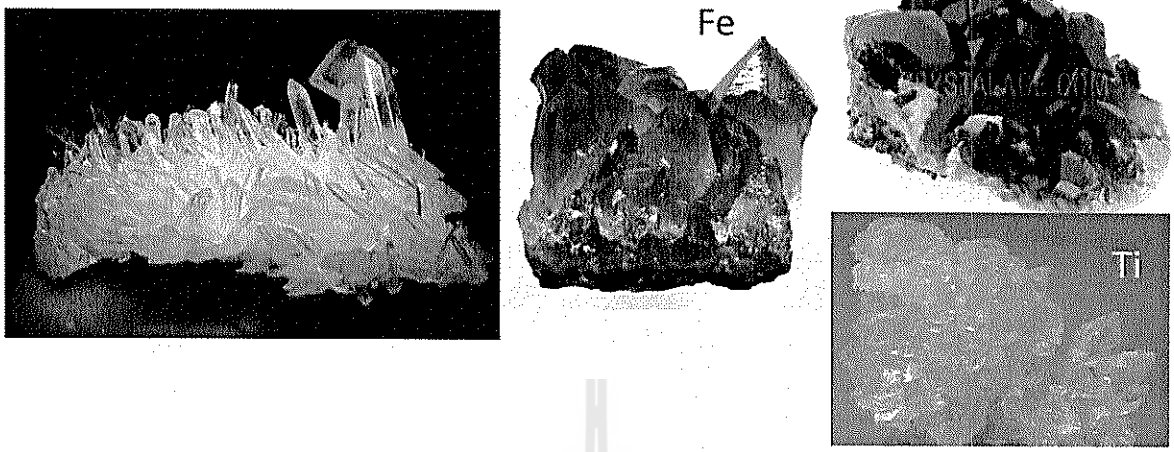


Rhodochrosite



Malachite and Azurite

Coloration caused by the presence of an element foreign to the crystal lattice, whether in mixture or in trace amounts, is termed **allochromatism**.

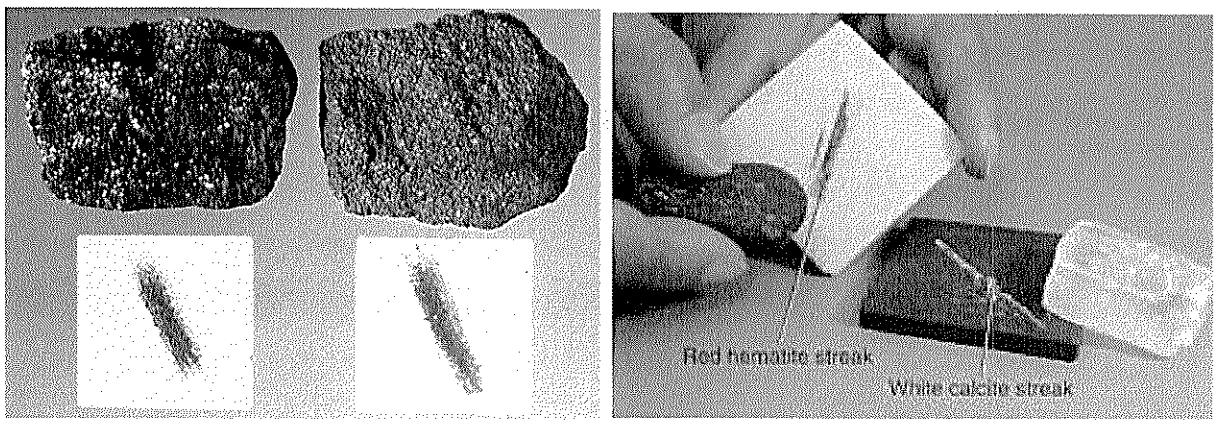


chromophores; they possess strong pigmenting capabilities

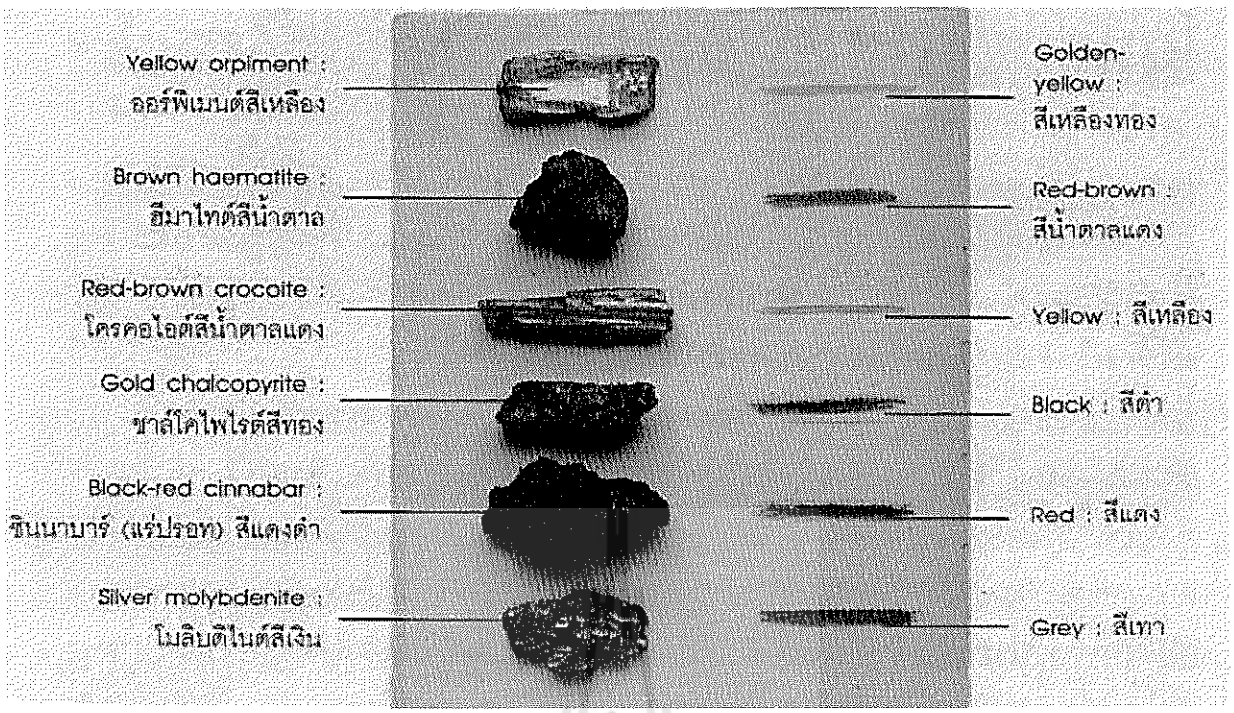
vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), Titanium (Ti), and copper (Cu)

Streak

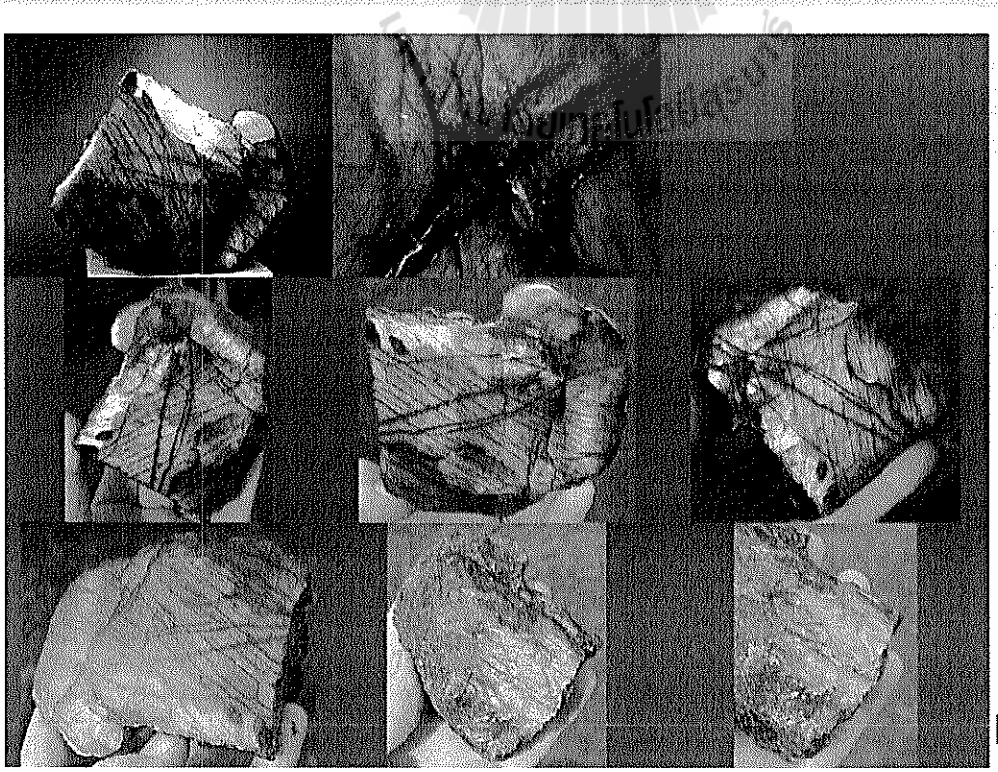
Streak: color of a mineral in its powdered form; obtained by rubbing the mineral against an unglazed porcelain plate.



magnetite & hematite

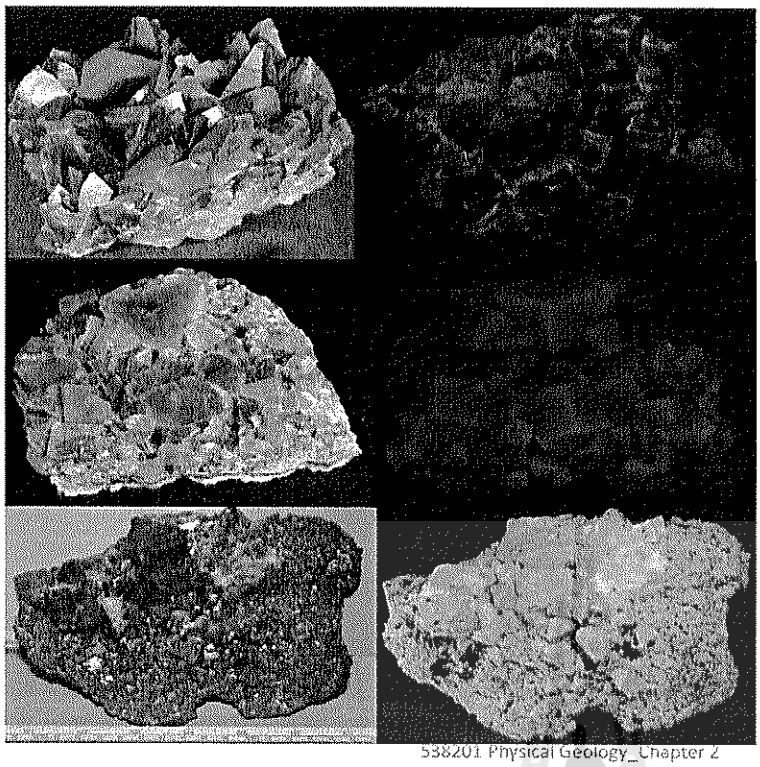


Play of color



Labradorite

Luminescence (Fluorescence)



response to UV light

calcite

fluorite

scheelite

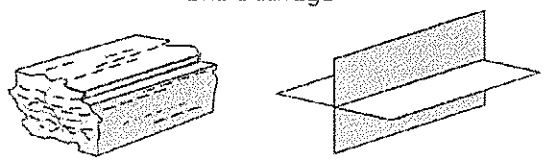
Cleavage

Cleavage: orientation and number of planes of weakness within a mineral, directly reflects the orientation of weak bonds within the crystal structure.

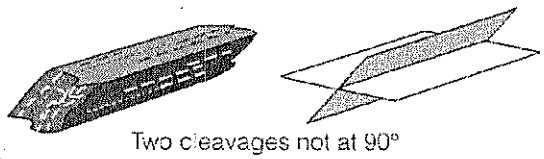




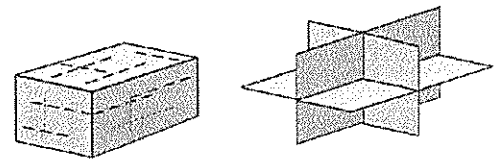
One cleavage



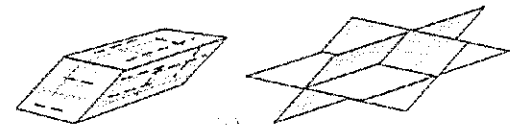
Two cleavages at 90°



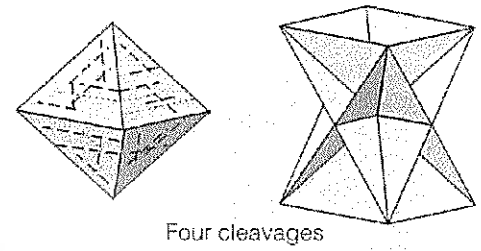
Two cleavages not at 90°



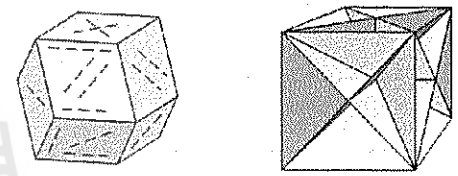
Three cleavages at 90°



Three cleavages not at 90°

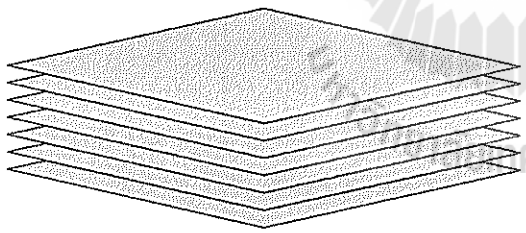


Four cleavages

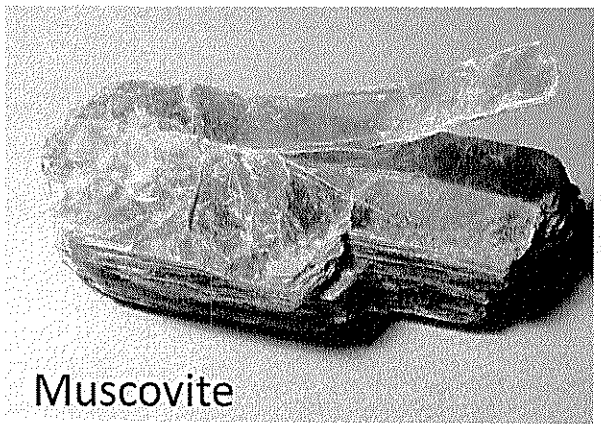


Six cleavages

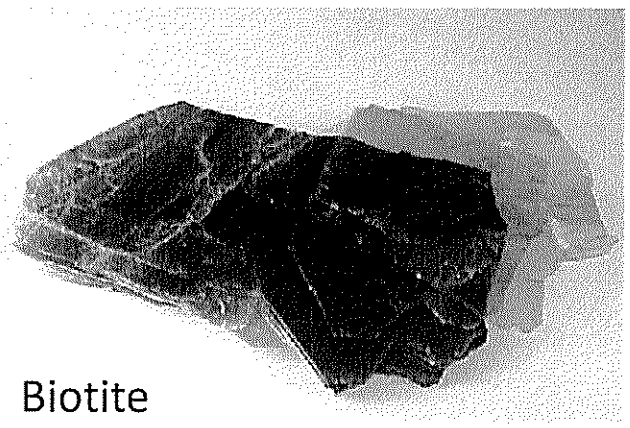
Quality of cleavage
- perfect
- good
- distinct or indistinct
- poor



One cleavage direction

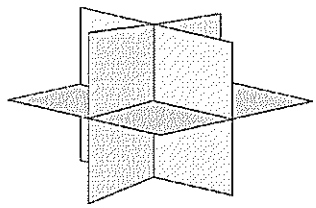


Muscovite

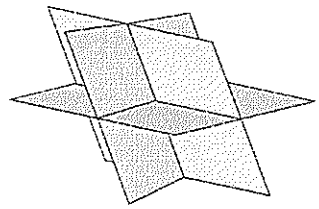


Biotite

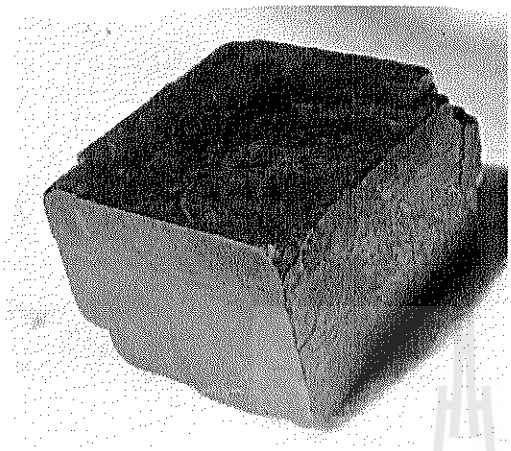
Three cleavage directions



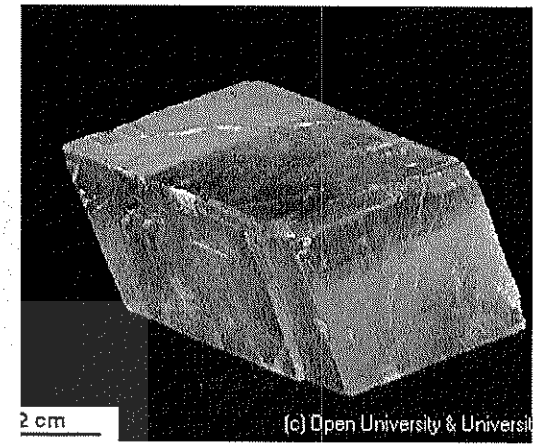
Three cleavage directions at 90 degrees



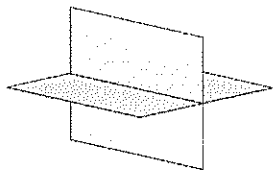
Three cleavage directions not at 90 degrees



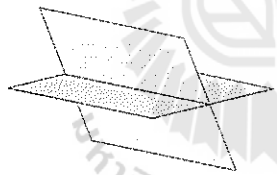
Galena



Calcite

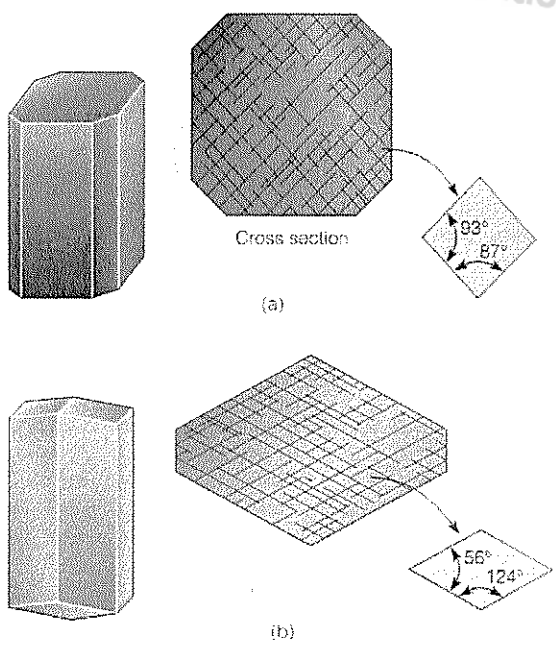


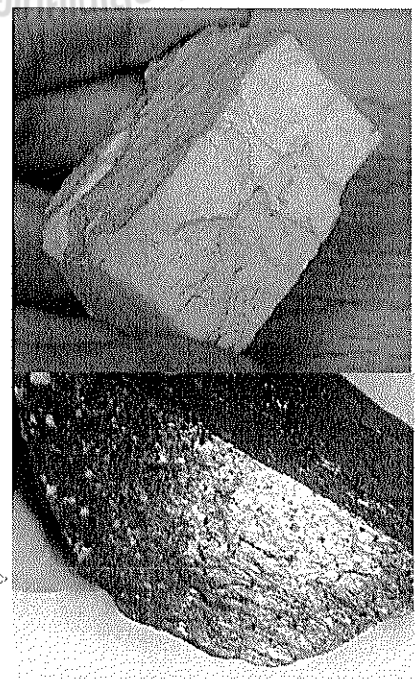
Two cleavage directions at 90 degrees



Two cleavage directions not at 90 degrees

Two cleavage directions

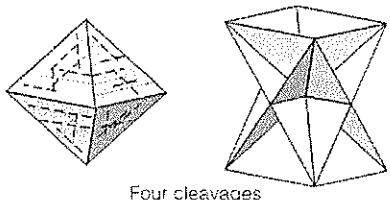




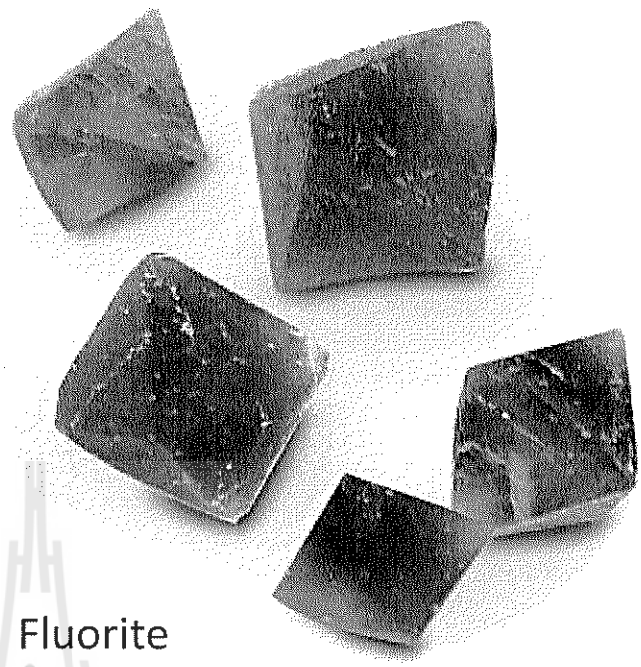
Orthoclase

Amphibole

Four cleavage directions

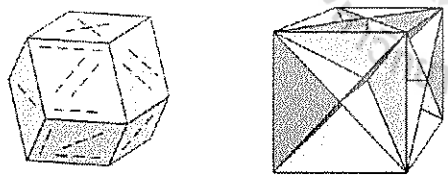


Four cleavages

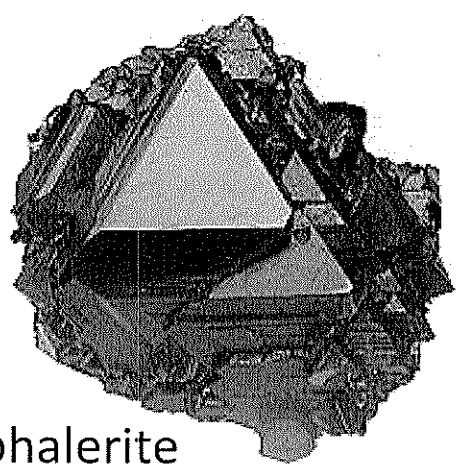


Fluorite

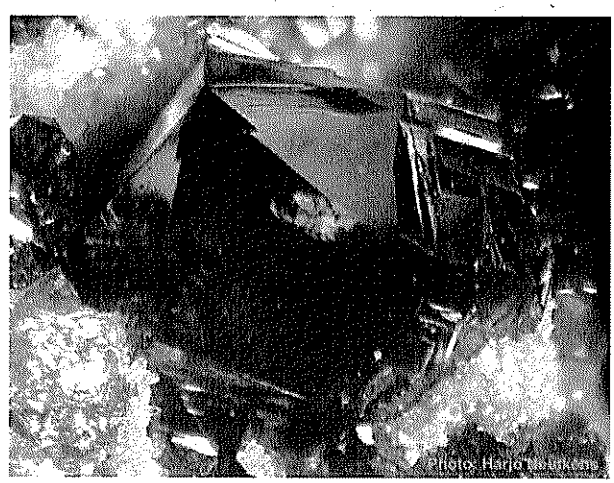
Six cleavage directions



Six cleavages



Sphalerite

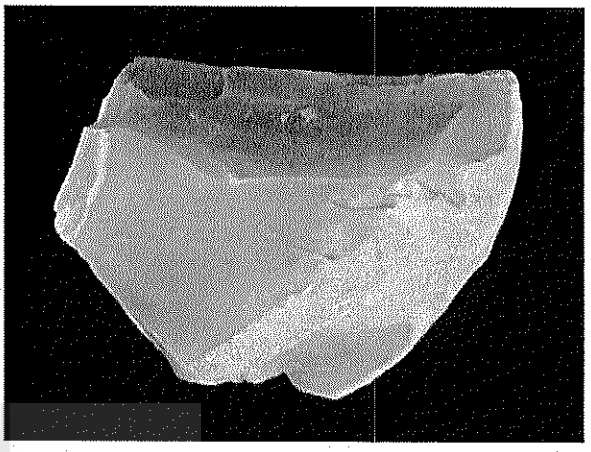


Fracture

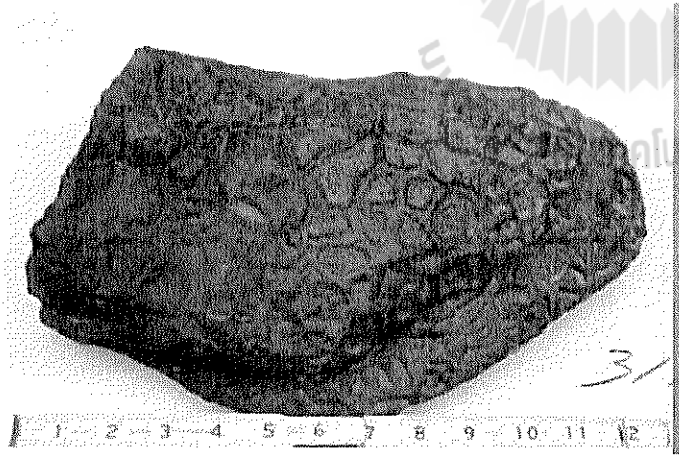
Fracture: describes how a mineral breaks, not along well defined planes.



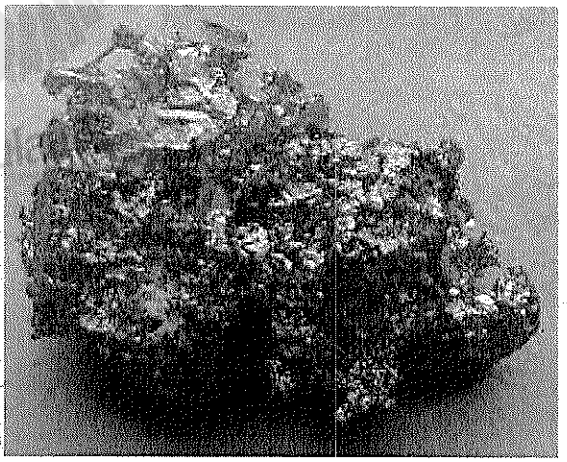
Concoidal fracture (Quartz)



Uneven fracture (Quartz)



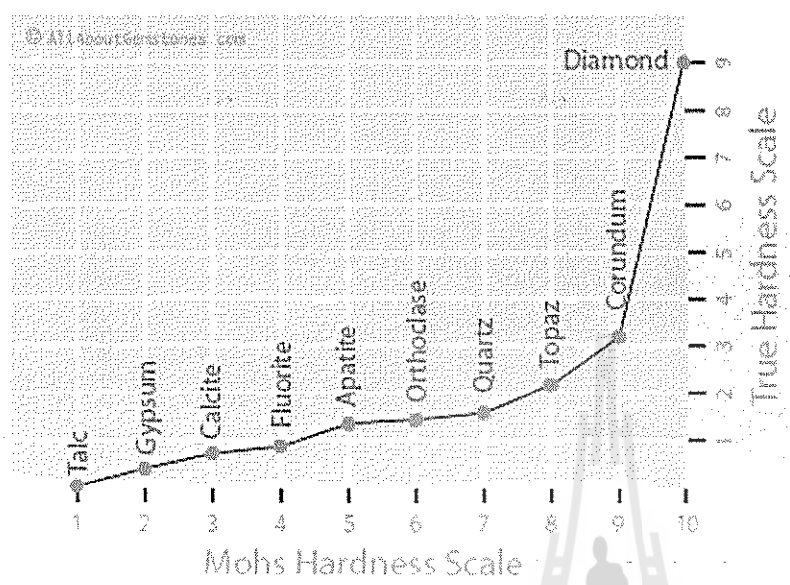
Uneven fracture in hematite

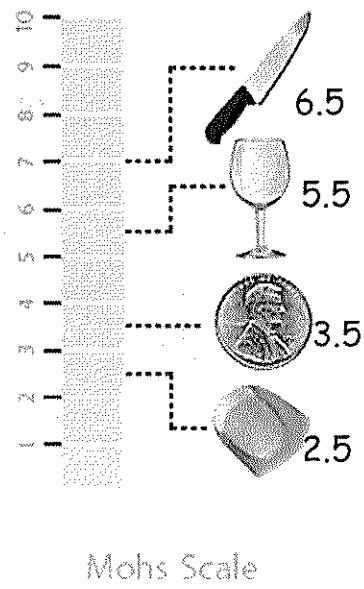


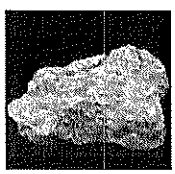
Hackly fracture in copper

Hardness

Hardness: resistance to scratching, directly related to relative strength of atomic bonds.





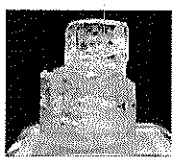


Talc=1



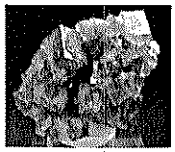
Gypsum=2

Finger nail 2.5



Calcite=3

Penny 3.5



Fluorite=4



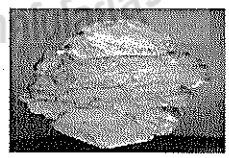
Apatite=5

Knife >5

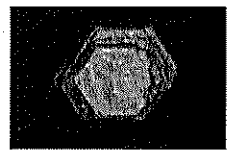
Window glass 5.5



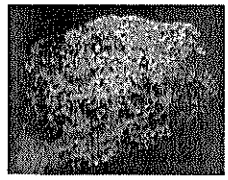
Feldspar=6



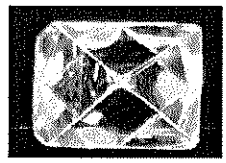
Quartz=7



Topaz=8



Corundum=9



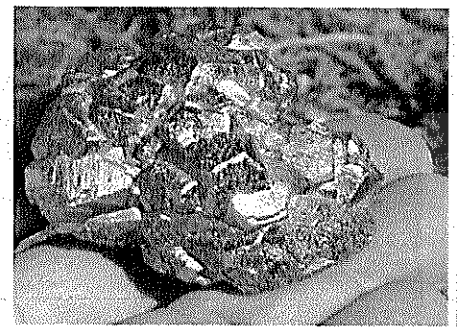
Diamond=10

Luster

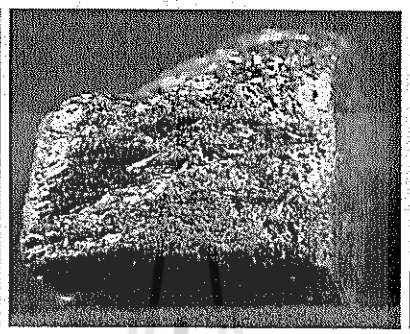
Luster: indicates the way a mineral's surface interacts with light.

Metallic: luster of metal – shines like a hard metal
Sub-metallic: slightly less than metallic reflectivity
Non-metallic: vitreous or glassy; silky; pearly; greasy; waxy; rasinous; earthy

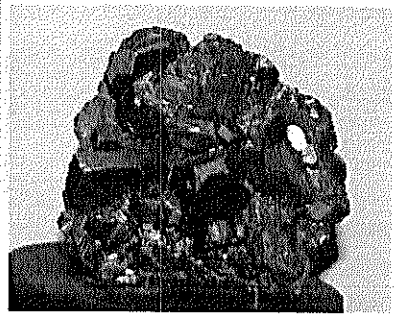
Metallic luster



Pyrite

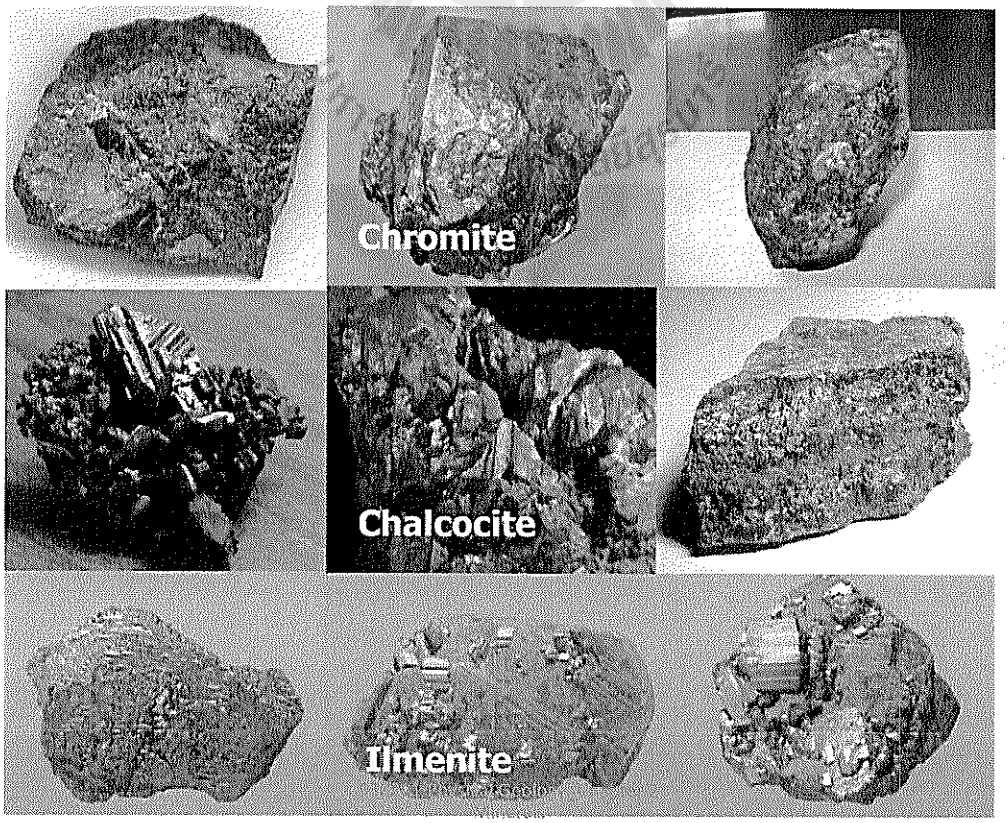


Graphite



Galena

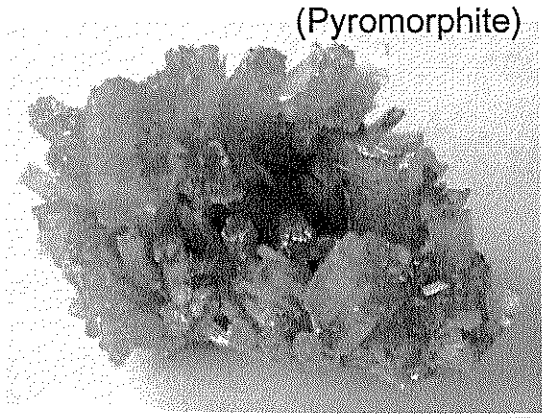
Sub-metallic luster

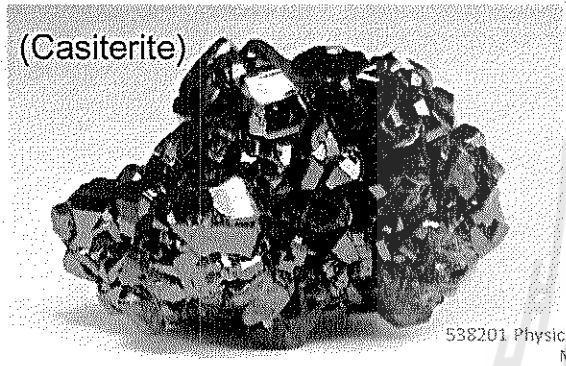


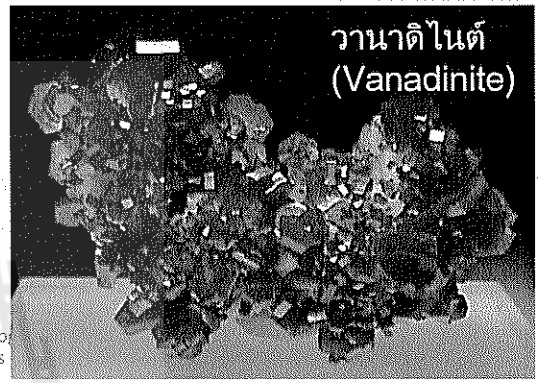
Adamantine

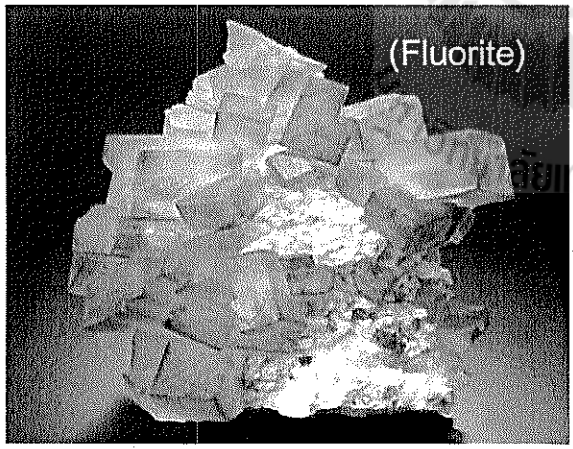


ไพโรมอร์ไฟต์
(Pyromorphite)

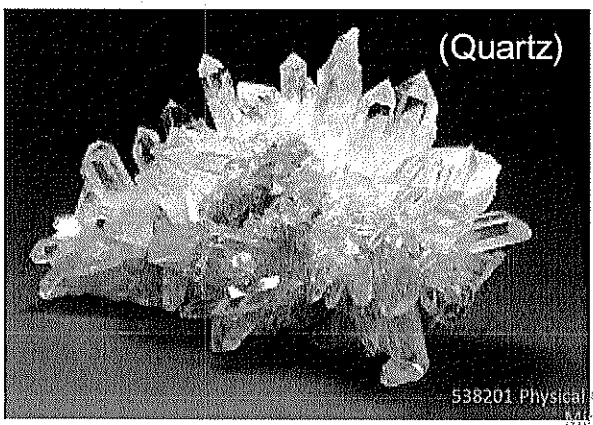


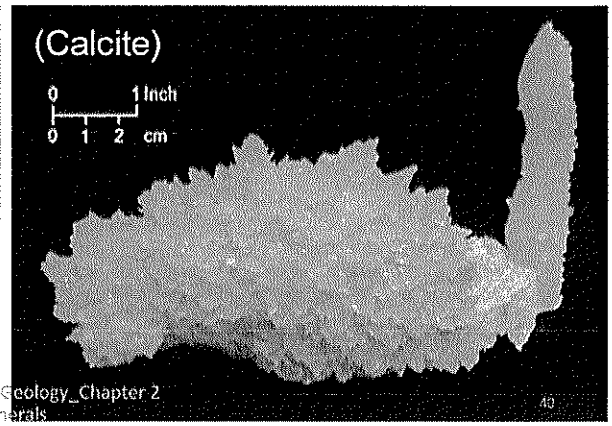




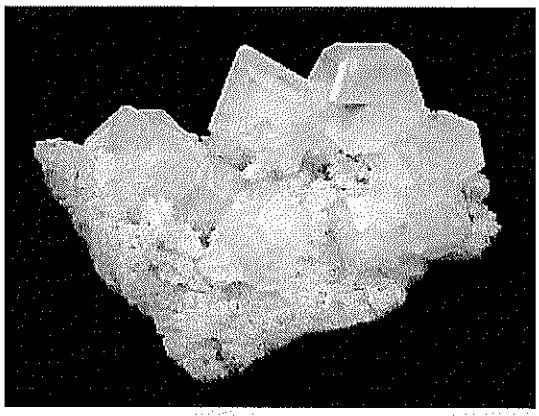


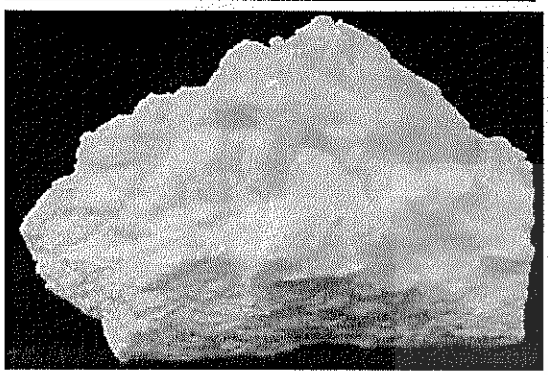
Vitreous or glassy



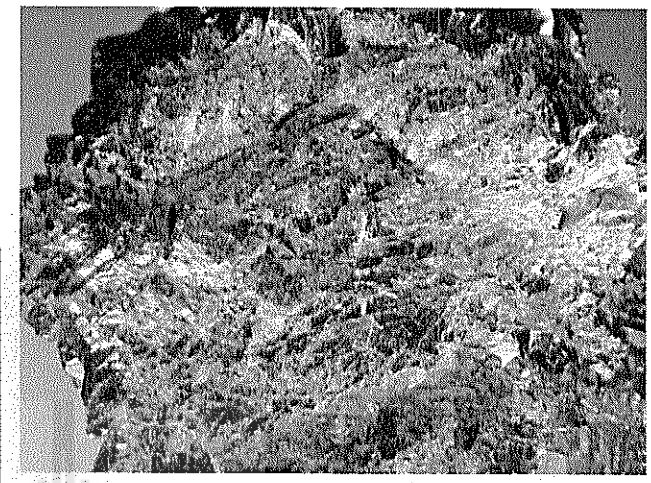


Resinous



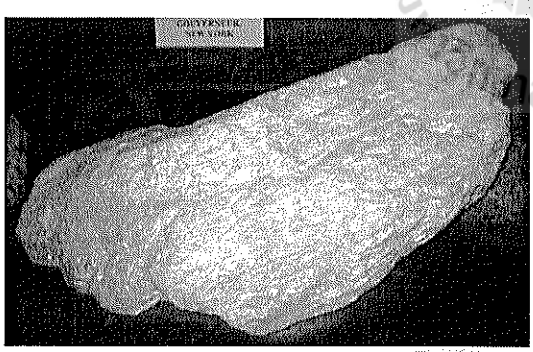


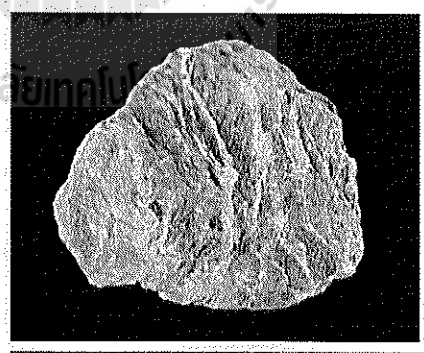
ซัลเฟอร์ (Sulfur)



สฟาเรอไลต์ (Sphalerite)

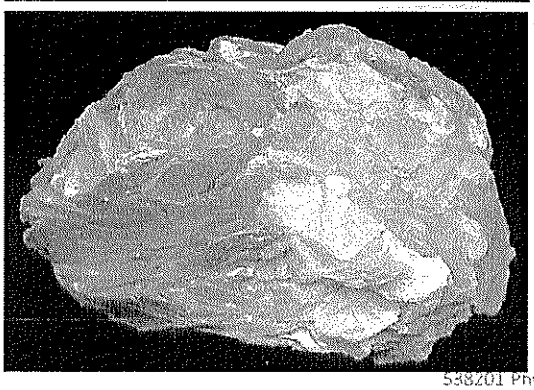
Pearly



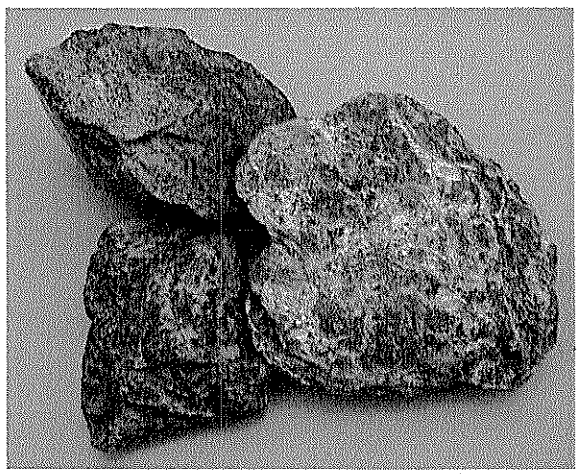


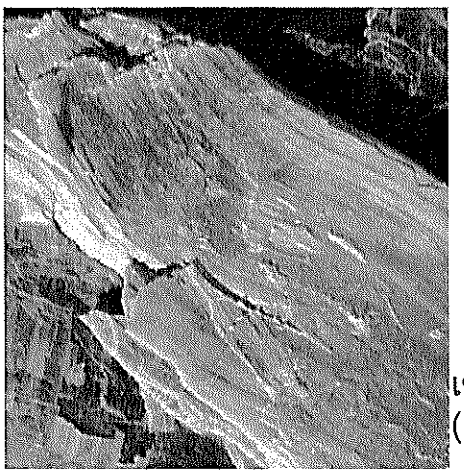
ทัลค์ (Talc)

มัสโคไวท์
(Muscovite)



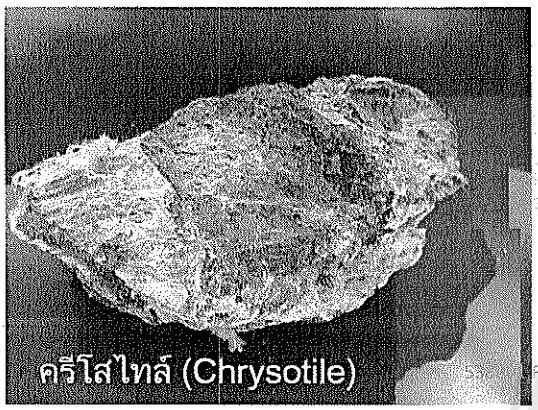


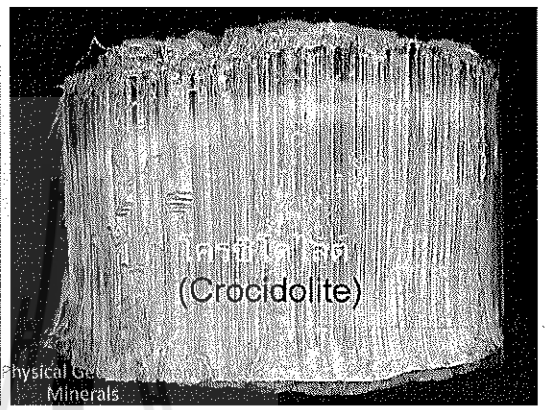




Greasy

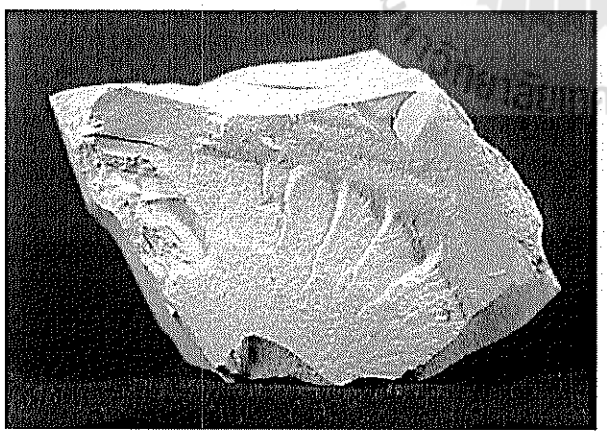
เซอร์เพนทีน
(Serpentine)





Silky

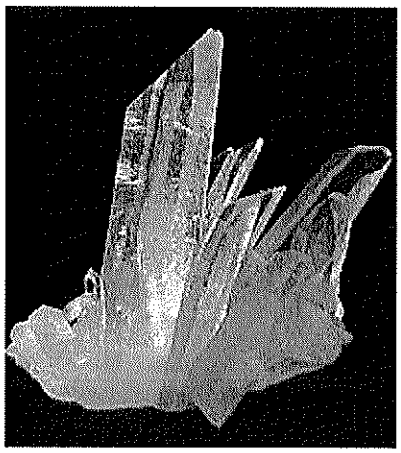
Earthy / Dull

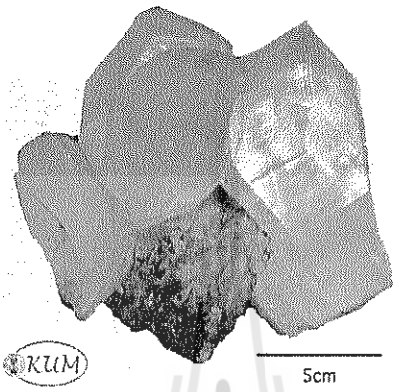


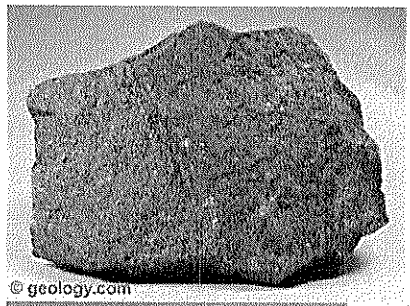


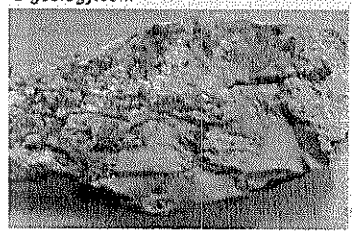
Diaphaneity

How well light passes through a mineral; Transparent: objects can be seen through, Translucent: light passes through but no objects can be seen, Opaque: no light passes through the mineral









Specific gravity

Specific gravity: a unitless number that expresses the ratio between the weight of a substance and the weight of an equal volume of water at 4°.

$$SG = \rho \text{ mineral} / \rho H_2O$$

1. Minerals with non-metallic luster have average SG between 2.6-3.0, (**Quartz** = 2.65, **Calcite** = 2.72, **Feldspars** = 2.60-2.75)

2. Hydrated and soft minerals have **SG** < 2.6

3. Hard minerals with heavy elements (Sr, Ba, Fe, W, Cu, Ag, Pb, Hg) have **SG** > 3.5

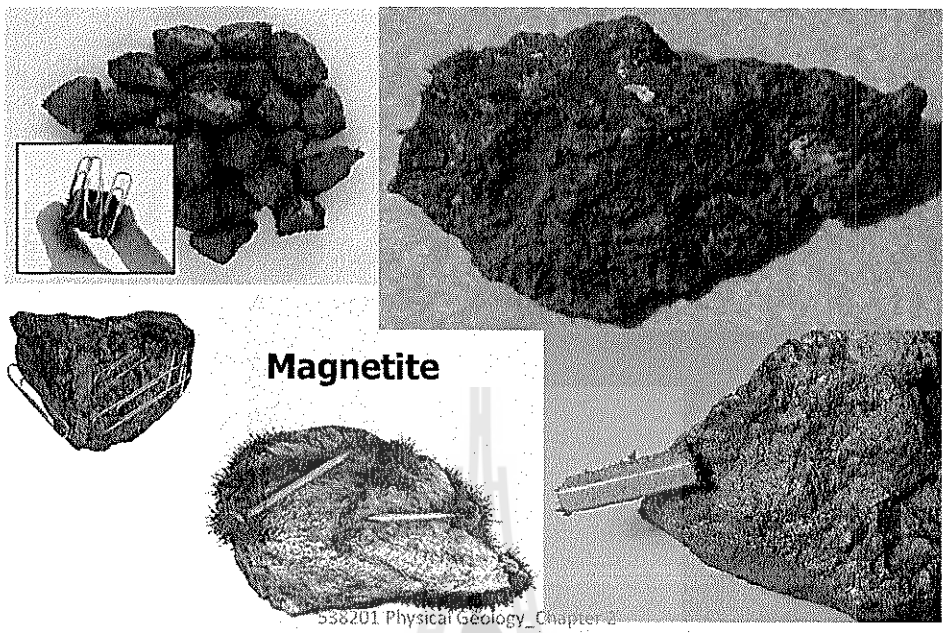
4. Minerals with metallic luster have **SG** >/=5
   (**Pyrite** = 5, **Galena** =7.5)

5. In solid solution series, there is a continuous change in **SG** with change in chemical composition
   (**Fosterite** = 3.3 → **Fayalite** = 4.4)

6. In polymorphous compounds those with closest atomic packing have higher **SG**
   (**Graphite** =2.23 → **Diamond** =3.5)

Magnetism

Magnetism: a property of materials responding to the magnetic field.



Tenacity

Tenacity: response to mechanical induced changes of shape or form.

Brittle เปราะหรือร่อน: Fluorite, Apatite

Sectile ตัดออกเป็นแผ่นบางๆ ได้ แต่มีความเปราะ: Graphite

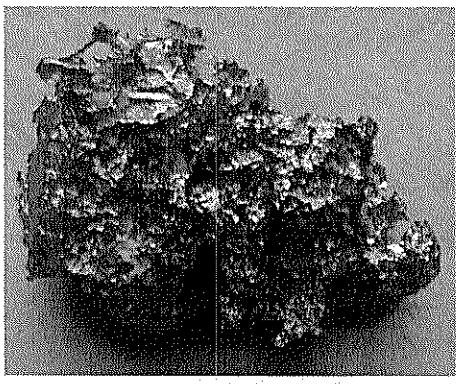
Malleable ทุบให้เป็นแผ่นบาง ๆ ได้: Gold, Silver, Copper

Ductile ดึงยืดให้เป็นเส้นลวดได้: Gold, Silver

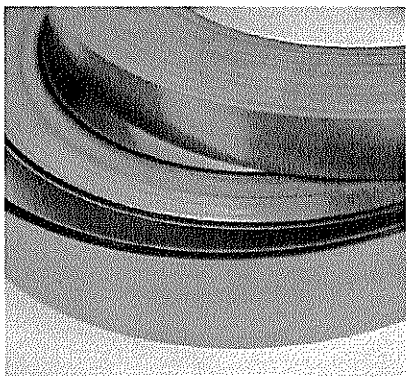
Flexible but inelastic: Gypsum, Copper

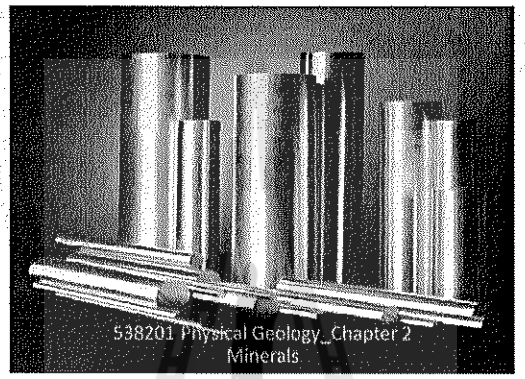
Flexible and elastic : Muscovite, Biotite

Electrical properties

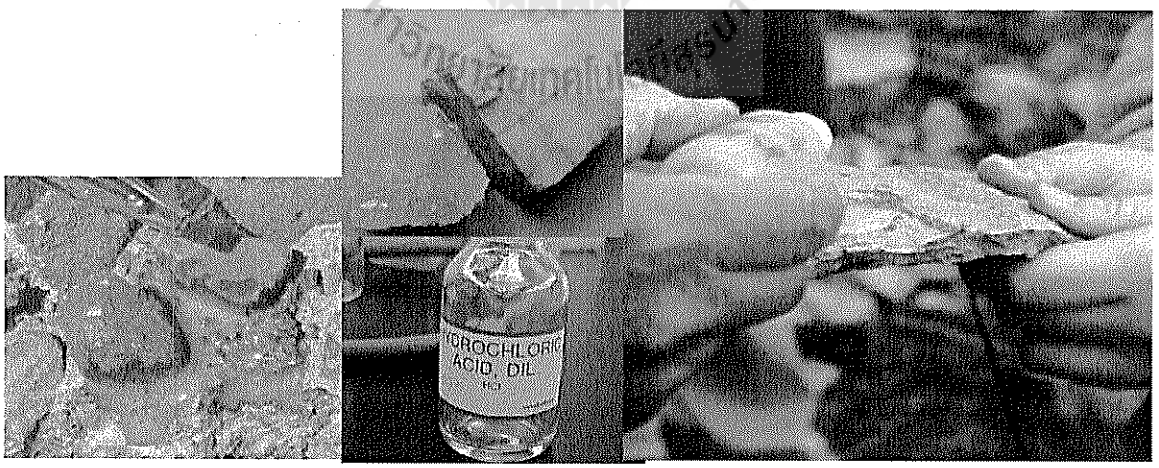


ทองแดง (Copper)





Effervescence (reactivity to dilute acids)



Other physical properties: Odor /Feel / Taste

3. Mineral Classification

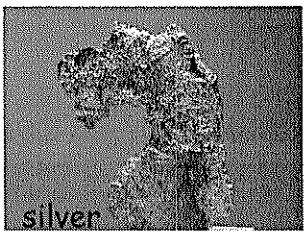
- Based on chemical composition
- Minerals are divided into classes depending on the dominate anion or anionic groups
  - native elements
  - sulfides
  - sulfarsenides
  - arsenides
  - oxides
  - hydroxides
  - halides
  - carbonates
  - nitrate
  - borates
  - sulphates (sulfates)
  - chromate
  - tungstates
  - phosphates
  - vanadates
  - arsenates
  - silicates

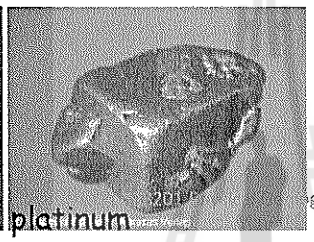
Minerals

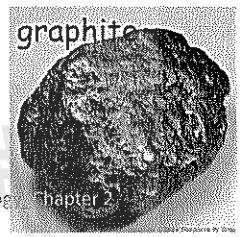
Non-Silicates	Silicates
- Native Elements - Other types of anions such as Halides, Sulfides, Oxides, Hydroxides, Carbonates, Sulphates, Phosphates	Inosilicates, Sorosilicates, Cyclosilicates, Nesosilicates, Phyllosilicates, Tectosilicates

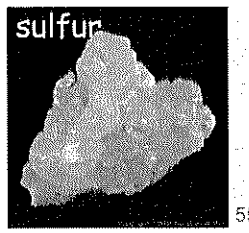
Native elements

Metal	**Semi-metal**	**Non-metal**
Gold group	Arsenic group	Sulfur
Gold	Arsenic	Diamond
Silver	Bismuth	Graphite
Copper		
Platinum group		
Platinum		
Iron group		
Iron		







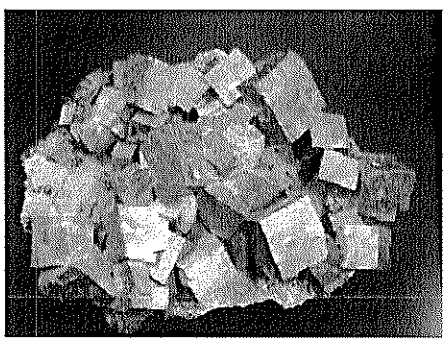
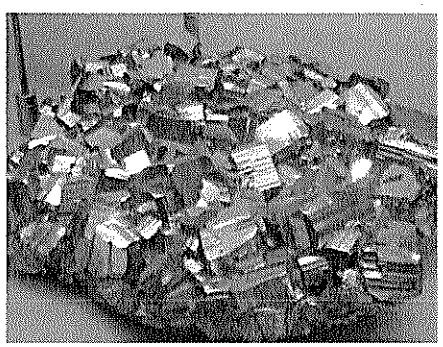


Sulfides, sulfarsenides, arsenides

Sulfide minerals: containing sulfide (S^{2-})

Arsenide mineral: contains arsenide (As)

Sulfarsenide mineral: the sulfide minerals which include arsenic replacing sulfur as an anion in the formula

Acanthite (Argentite)	Ag_2S	Cinnabar	HgS
Chalcocite	Cu_2S	Realgar	AsS
Bornite	Cu_5FeS_4	Orpiment	As_2S_3
Galena	PbS	Stibnite	Sb_2S_3
Sphalerite	ZnS	Pyrite	FeS_2
Chalcopyrite	$CuFeS_2$	Marcasite	FeS_2
Pyrrhotite	$Fe_{1-x}S$	Molybdenite	MoS_2
Nickeline	NiAs	Cobaltite	(Co, Fe)AsS
Millerite	NiS	Arsenopyrite	FeAsS
Pentlandite	$(Fe, Ni)_9S_8$	Skutterudite	$(Co, Ni)As_3$
Covellite	CuS		

Oxides

X_2O and *XO* types

Cuprite	Cu_2O
Zincite	ZnO

X_2O_3 type

Hematite Group

Corundum	Al_2O_3
Hematite	Fe_2O_3
Ilmenite	$FeTiO_3$

XO_2 type (excluding SiO_2)

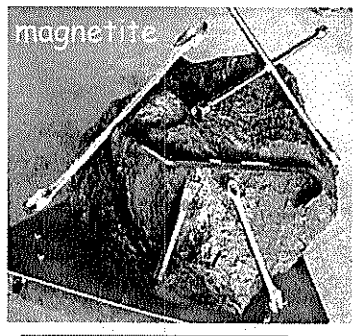
Rutile Group

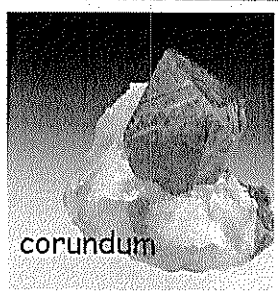
Rutile	TiO_2
Pyrolusite	MnO_2
Cassiterite	SnO_2
Uraninite	UO_2

XY_2O_4 type

Spinel Group

Spinel	$MgAl_2O_4$
Gahnite	$ZnAl_2O_4$
Magnetite	Fe_3O_4
Franklinite	(Zn,Fe,Mn)-$(Fe,Mn)_2O_4$
Chromite	$FeCr_2O_4$
Chrysoberyl	$BeAl_2O_4$
Columbite	(Fe,Mn)-$(Nb,Ta)_2O_6$





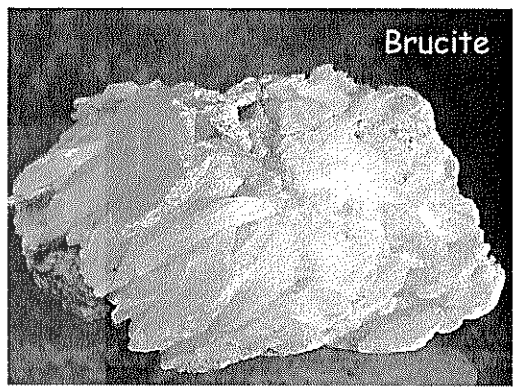
Hydroxides

Brucite	$Mg(OH)_2$
Manganite	$MnO(OH)$
Romanechite	$BaMn^{2+}Mn_8^{4+}O_{16}(OH)_4$

Goethite Group

Diaspore	α $AlO(OH)$
Goethite	α $FeO(OH)$

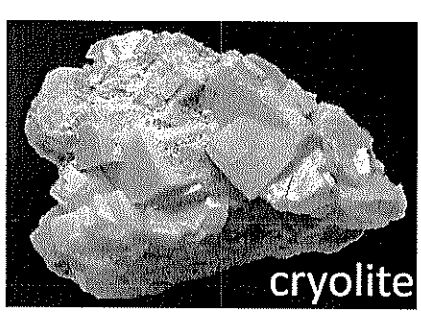
Bauxite—mixture of diaspore, gibbsite, and boehmite

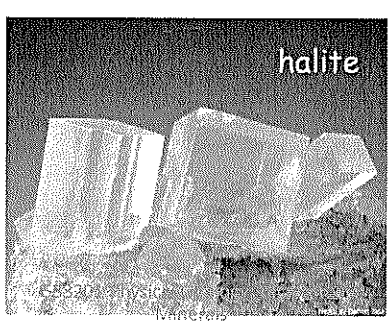


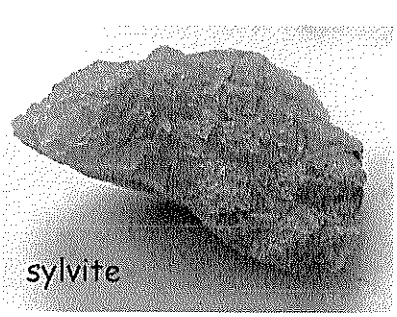
Halides

Halite	NaCl	Cryolite	Na_3AlF_6
Sylvite	KCl	Fluorite	CaF_2
Chlorargyrite	AgCl	Atacamite	$Cu_2Cl(OH)_3$

The **halide mineral** class include minerals with a dominant halide anion (F^-, Cl^-, Br^- and I^-).







Carbonates

Calcite Group
(Hexagonal; $R\bar{3}c$)

Calcite	$CaCO_3$
Magnesite	$MgCO_3$
Siderite	$FeCO_3$
Rhodochrosite	$MnCO_3$
Smithsonite	$ZnCO_3$

Aragonite Group
(Orthorhombic; *Pmcn*)

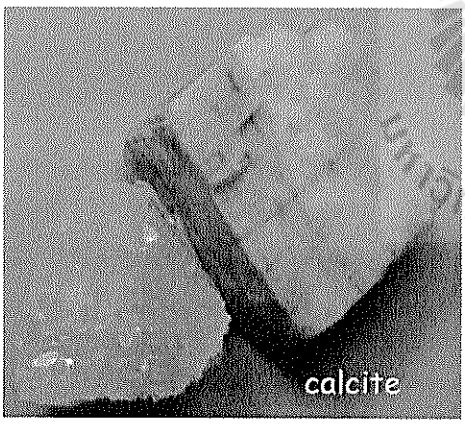
Aragonite	$CaCO_3$
Witherite	$BaCO_3$
Strontianite	$SrCO_3$
Cerussite	$PbCO_3$

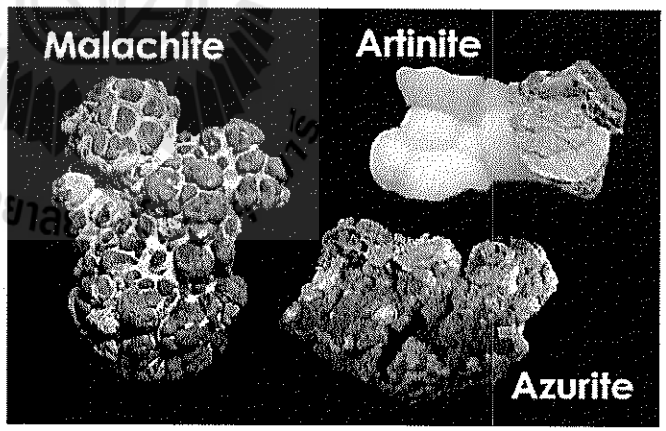
Dolomite Group
(Hexagonal; $R\bar{3}$)

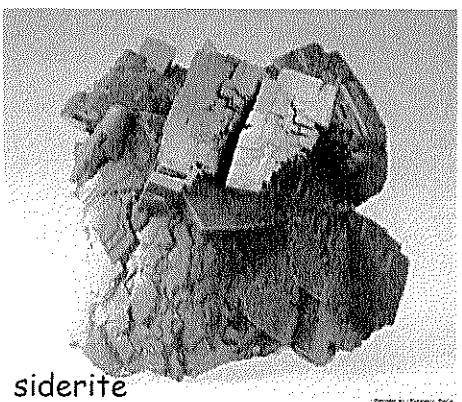
Dolomite	$CaMg(CO_3)_2$
Ankerite	$CaFe(CO_3)_2$

Monoclinic Carbonates with (OH)

Malachite	$Cu_2CO_3(OH)_2$
Azurite	$Cu_3(CO_3)_2(OH)_2$

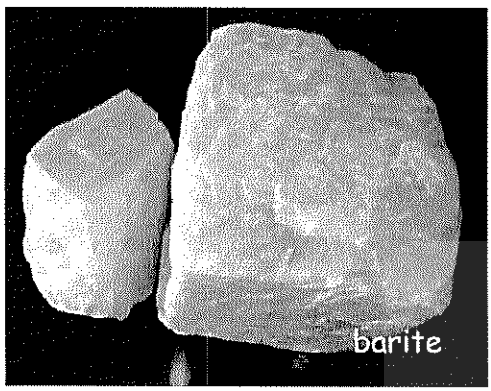


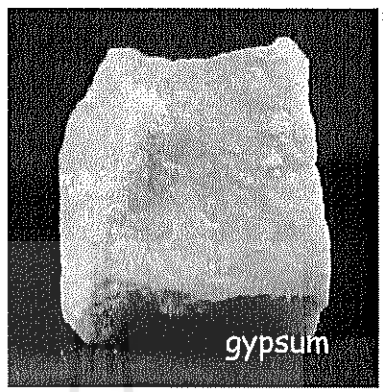


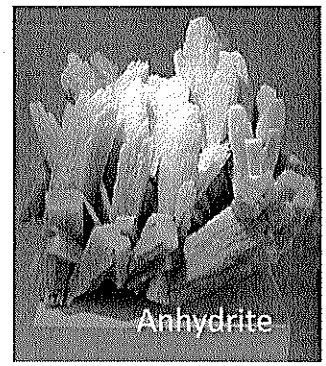


Sulphates and chromate

The sulfate and chromate minerals include the sulfate ion (SO_4^{2-}) and chromate ion (CrO_4^{2-} or $Cr_2O_7^{2-}$) within their structure.







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Anhydrous Sulfates and Chromate

Barite group

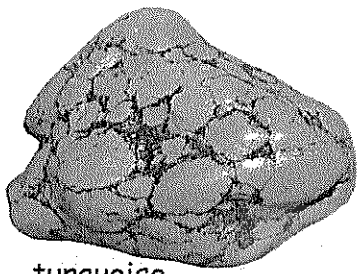
Barite	$BaSO_4$
Celestite	$SrSO_4$
Anglesite	$PbSO_4$
Anhydrite	$CaSO_4$
Crocoite	$PbCrO_4$

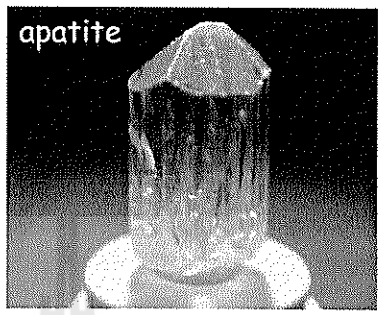
Hydrous and Basic Sulfates

Gypsum	$CaSO_4 \cdot 2H_2O$
Antlerite	$Cu_3SO_4(OH)_4$
Alunite	$KAl_3(SO_4)_2(OH)_6$

Phosphates, arsenates, vanadates

Phosphate minerals: containing the tetrahedrally coordinated phosphate (PO_4^{3-}) anion along with the freely substituting arsenate (AsO_4^{3-}) and vanadate (VO_4^{3-}).


turquoise

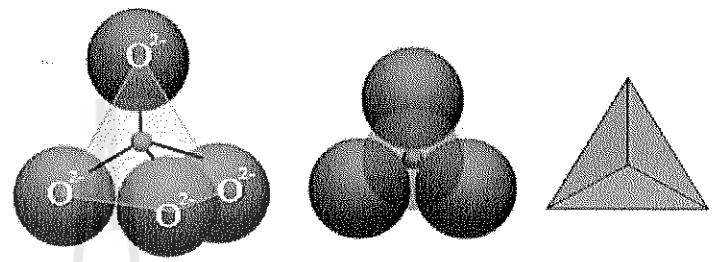


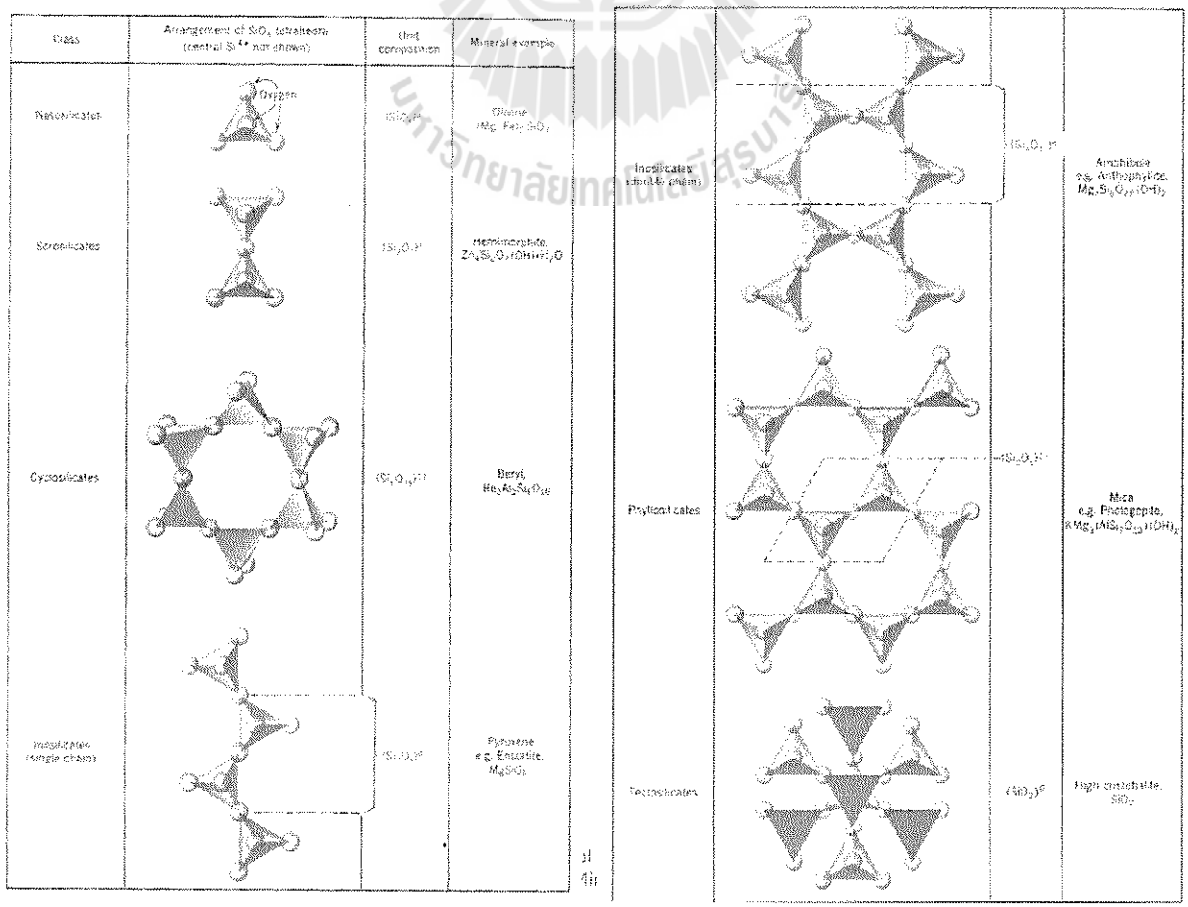
Triphylite—	$Li(Fe,Mn)PO_4$
Lithiophilite	$Li(Mn,Fe)PO_4$
Monazite	$(Ce,La,Y,Th)PO_4$
Apatite Group	
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$
Pyromorphite	$Pb_5(PO_4)_3Cl$
Vanadinite	$Pb_5(VO_4)_3Cl$
Erythrite	$Co_3(AsO_4)_2{\cdot}8H_2O$
Amblygonite	$LiAlPO_4F$
Lazulite—	$(Mg,Fe)Al_2(PO_4)_2(OH)_2$
Scorzalite	$(Fe,Mg)Al_2(PO_4)_2(OH)_2$
Wavellite	$Al_3(PO_4)_2(OH)_3{\cdot}5H_2O$
Turquoise	$CuAl_6(PO_4)_4(OH)_8{\cdot}4H_2O$
Autunite	$Ca(UO_2)_2(PO_4)_2{\cdot}10-12H_2O$
Carnotite	$K_2(UO_2)_2(VO_4)_2{\cdot}3H_2O$

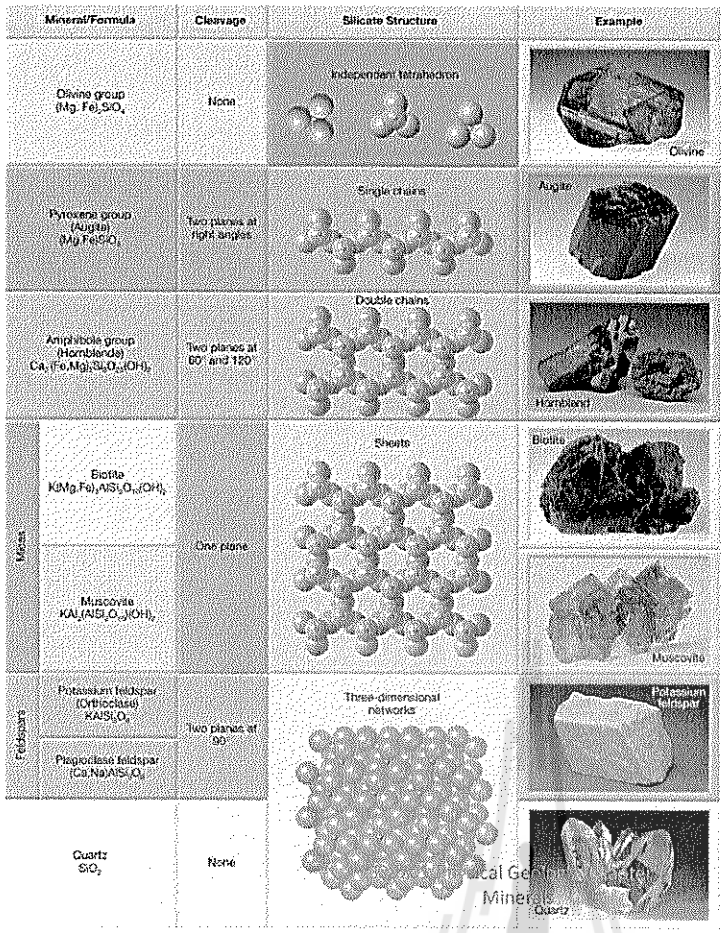
Silicate minerals

Silicate minerals: the largest and most important class of rock-forming minerals, approximately 90% of the crust of the Earth, classified based on the structure of their silicate group: containing silicon (Si) and oxygen (O)

Silicate anion $(SiO_4)^{-4}$ silicon-oxygen tetrahedron molecule







Nesosilicates

Inosilicates

Phyllosilicates

Tectosilicates

Physical Geology Minerals

Nesosilicates

Phenacite Group

Phenacite	Be_2SiO_4
Willemite	Zn_2SiO_4

Olivine Group

Forsterite	Mg_2SiO_4
Fayalite	Fe_2SiO_4

Garnet Group $A_3B_2(SiO_4)_3$

Pyrope	Mg_3Al_2	Uvarovite	Ca_3Cr_2
Almandine	Fe_3Al_2	Grossular	Ca_3Al_2
Spessartine	Mn_3Al_2	Andradite	$Ca_3Fe_2^{3+}$

Zircon Group

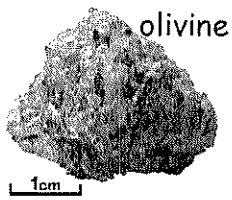
Zircon	$ZrSiO_4$

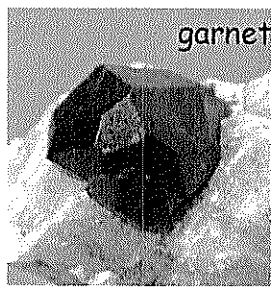
Al_2SiO_5 Group

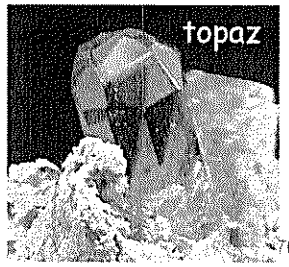
Andalusite, Sillimanite, Kyanite	Al_2SiO_5
Topaz	$Al_2SiO_4(F,OH)_2$
Staurolite	$Fe_2Al_9O_6(SiO_4)_4(O,OH)_2$

Humite Group

Chondrodite	$Mg_5(SiO_4)_2(OH,F)_2$
Datolite	$CaB(SiO_4)(OH)$
Titanite	$CaTiO(SiO_4)$
Chloritoid	$(Fe,Mg)_2Al_4O_2(SiO_4)_2(OH)_4$

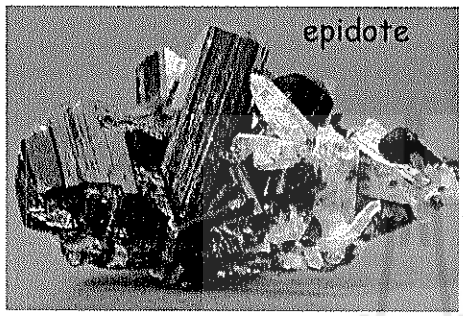


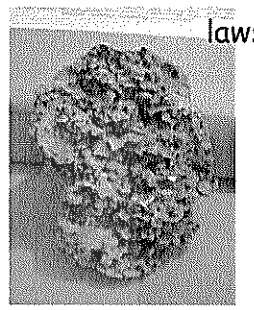




Sorosilicates and neso-sorosilicates

Hemimorphite	$Zn_4(Si_2O_7)(OH)_2 \cdot H_2O$
Lawsonite	$CaAl_2(Si_2O_7)(OH)_2 \cdot H_2O$
Epidote group	
Clinozoisite	$Ca_2Al_3O(SiO_4)(Si_2O_7)(OH)$
Epidote	$Ca_2(Fe^{3+},Al)Al_2O(SiO_4)(Si_2O_7)(OH)$
Allanite	$X_2Y_3O(SiO_4)(Si_2O_7)(OH)$
Vesuvianite	$Ca_{10}(Mg,Fe)_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$

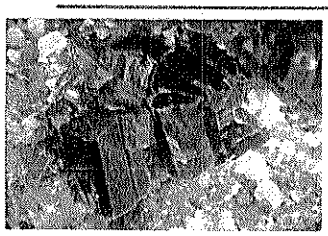




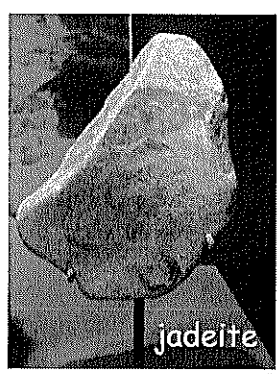
Inosilicate-single chain

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PYROXENES	
Enstatite-Ferrosilite Series	
Enstatite	$MgSiO_3$
Ferrosilite	$FeSiO_3$
Pigeonite	$Ca_{0.25}(Mg,Fe)_{1.75}Si_2O_6$
Diopside-Hedenbergite Series	
Diopside	$CaMgSi_2O_6$
Hedenbergite	$CaFeSi_2O_6$
Augite	$XY(Z_2O_6)$
Sodium Pyroxene Group	
Jadeite	$NaAlSi_2O_6$
Aegirine	$NaFe^{3+}Si_2O_6$
Spodumene	$LiAlSi_2O_6$



hedenbergite



Inosilicate-double chain

AMPHIBOLES

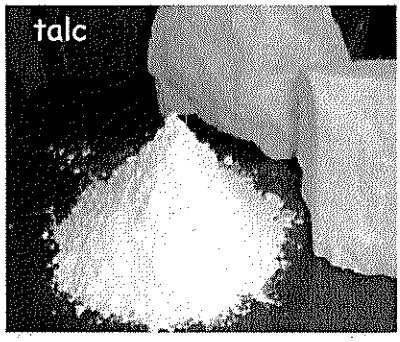
Anthophyllite	$(Mg,Fe)_7Si_8O_{22}(OH)_2$
Cummingtonite Series	
Cummingtonite	$Fe_2Mg_5Si_8O_{22}(OH)_2$
Grunerite	$Fe_7Si_8O_{22}(OH)_2$
Tremolite Series	
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
Hornblende	$X_{2-3}Y_5Z_8O_{22}(OH)_2$
Sodium Amphibole Group	
Glaucophane	$Na_2Mg_3Al_2Si_8O_{22}(OH)_2$
Riebeckite	$Na_2Fe_3^{2+}Fe_2^{3+}Si_8O_{22}(OH)_2$

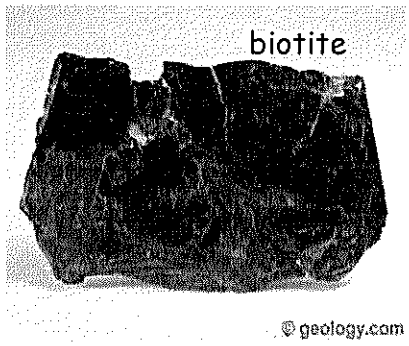


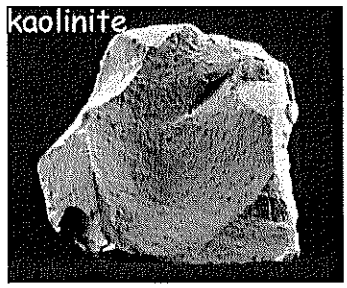
actinolite

Phyllosilicates

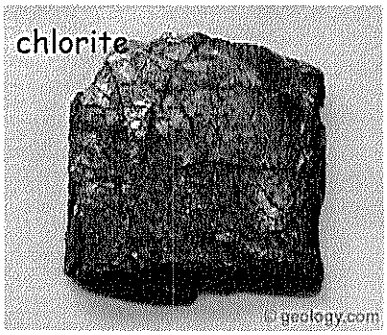
Serpentine Group	
Antigorite, Chrysotile, Lizardite	$Mg_3Si_2O_5(OH)_4$
Clay Mineral Group	
Kaolinite	$Al_2Si_2O_5(OH)_4$
Talc	$Mg_3Si_4O_{10}(OH)_2$
Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$
Mica Group	
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$
Phlogopite	$KMg_3(AlSi_3O_{10})(OH)_2$
Biotite	$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$
Lepidolite	$K(Li,Al)_{2-3}(AlSi_3O_{10})(OH)_2$
Margarite	$CaAl_2(Al_2Si_2O_{10})(OH)_2$
Chlorite Group	
Chlorite	$(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2(Mg,Fe)_3(OH)_6$

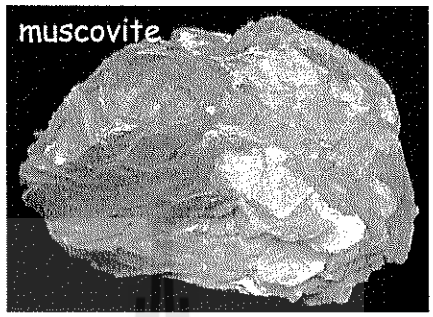






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Tectosilicates

SiO_2 Group

- Quartz, Tridymite, Cristobalite — SiO_2
- Opal — $SiO_2 \cdot nH_2O$

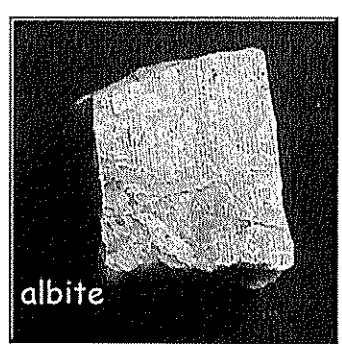
Feldspar Group

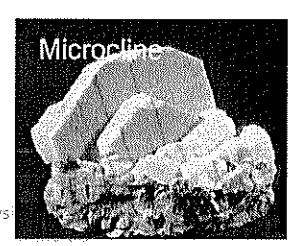
K-Feldspars

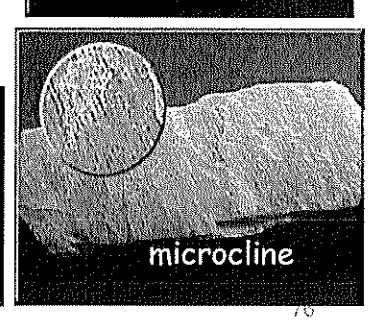
- Microcline, Orthoclase, Sanidine — $KAlSi_3O_8$

Plagioclase Feldspars

- Albite — $NaAlSi_3O_8$
- Anorthite — $CaAl_2Si_2O_8$







Feldspathoid Group

Leucite	$KAlSi_2O_6$
Nepheline	$(Na,K)AlSiO_4$
Sodalite	$Na_8(AlSiO_4)_6Cl_2$
Lazurite	$(Na,Ca)_8(AlSiO_4)_6(SO_4,S,Cl)_2$
Petalite	$LiAlSi_4O_{10}$

Scapolite Series micropores

Marialite	$Na_4(AlSi_3O_8)_3(Cl_2,CO_3,SO_4)$
Meionite	$Ca_4(Al_2Si_2O_8)_3(Cl_2,CO_3,SO_4)$
Analcime	$NaAlSi_2O_6 \cdot H_2O$

Zeolite Group

Natrolite	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$
Chabazite	$CaAl_2Si_4O_{12} \cdot 6H_2O$
Heulandite	$CaAl_2Si_7O_{18} \cdot 6H_2O$
Stilbite	$NaCa_2Al_5Si_{13}O_{36} \cdot 14H_2O$



Over 100 elements are known on crust and more than 2,000 minerals have been identified, although; eight of them are major elements of crustal rocks i.e., O, Si, Al, Fe, Ca, Na, Mg, and K.

Rock Forming Minerals

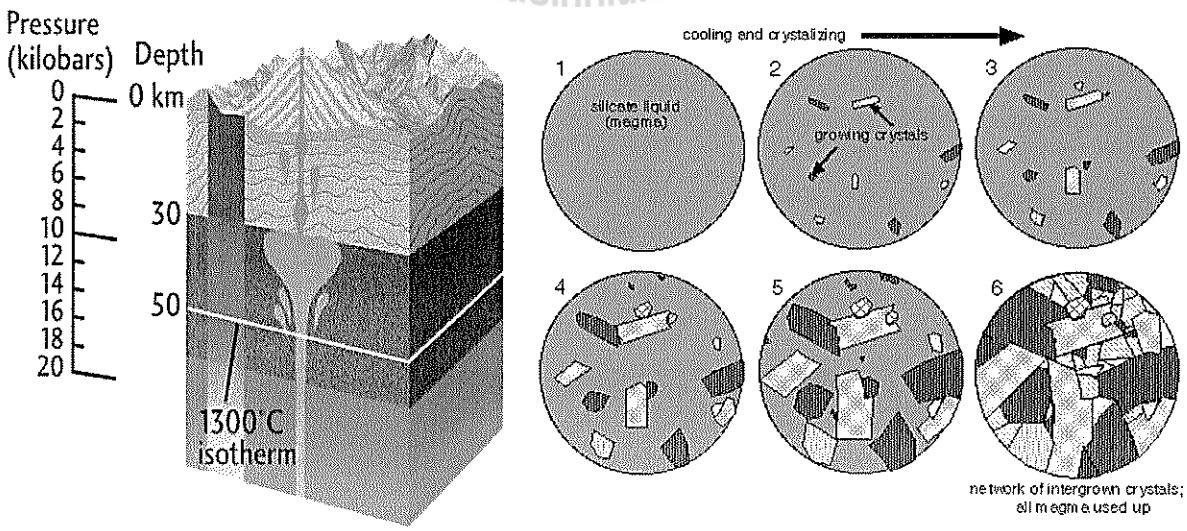
Silicates		*Oxides*	*Sulfides*	*Carbonates*	*Sulphates*	*Prosphates*
Garnet, Olivine, Pyroxene, Amphibole	Iron and Magnesium Rich	Magnetite, Hematite, Limonite, Corundum, Quartz	Galena, Sphalerite, Pyrite	Dolomite, Calcite	Gypsum, Anhydrite, Barite	Apatite
Feldspar, Clay, Mica	No Iron and Magnesium					

4. Mineral formation

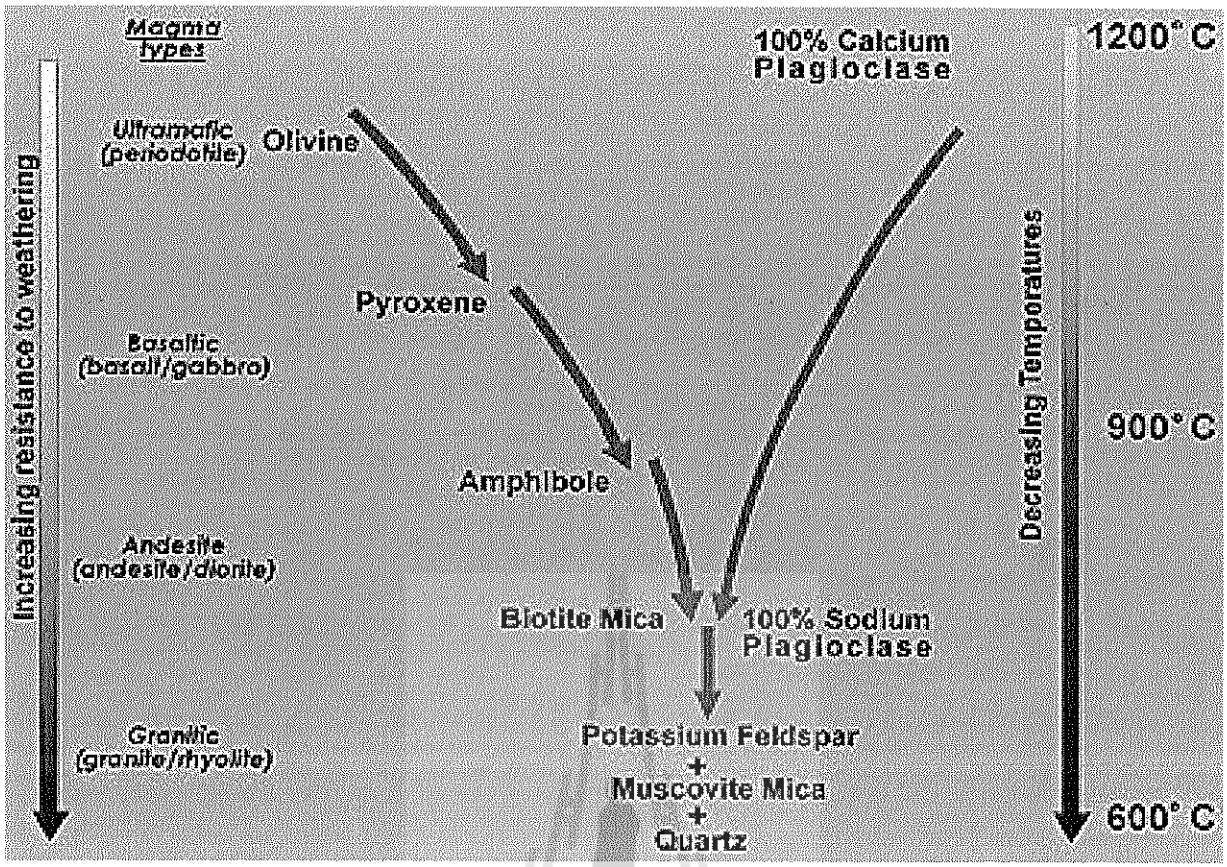
Contents

- Crystallization from magma
- Associated with hydrothermal processes
- Associated with sedimentary processes

Crystallization from magma

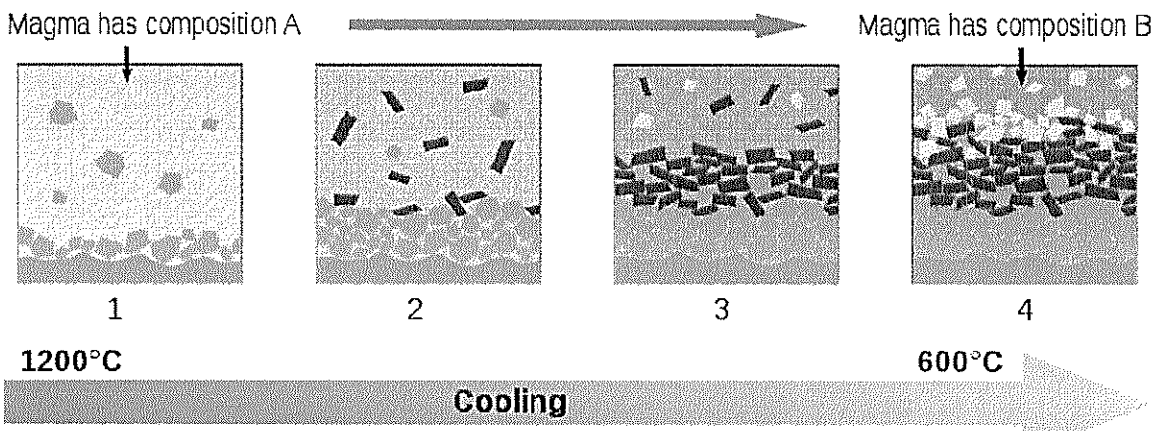


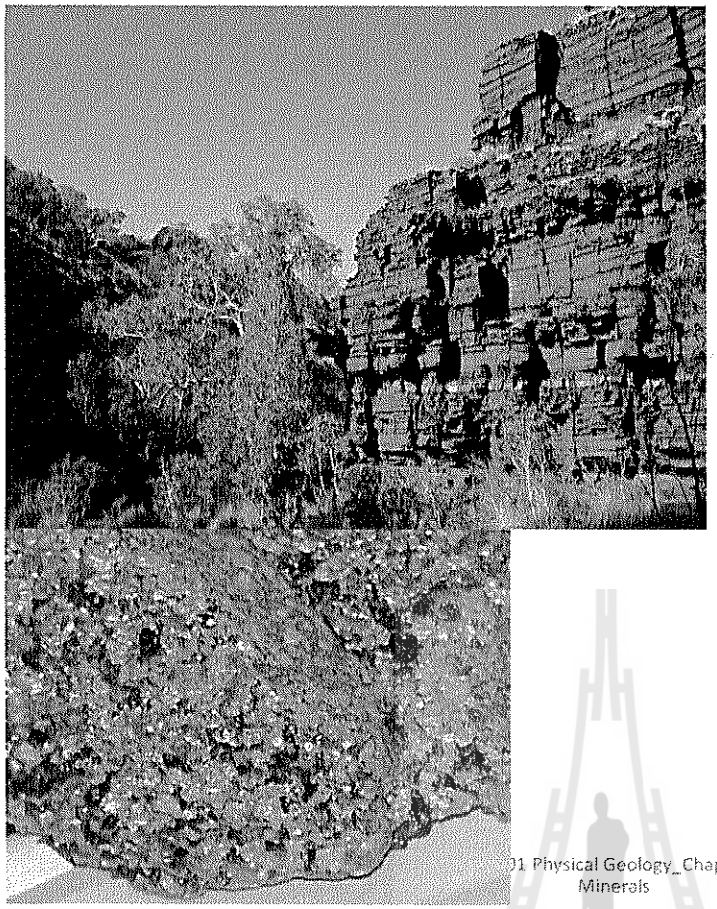
Bowen's Reaction Series

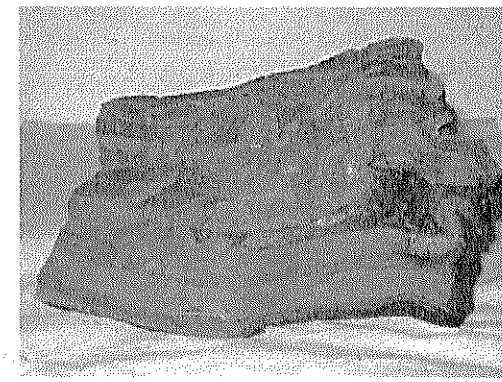


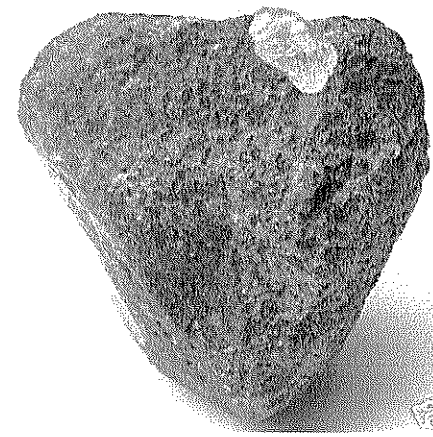
Mineral formations associated with mafic and ultramafic igneous rocks

- Dipersal; Cr, Ni, Co in peridotite and diamond in kimberlite
- Banded; Ce, Fe, Ti, Pt, Ni, Co

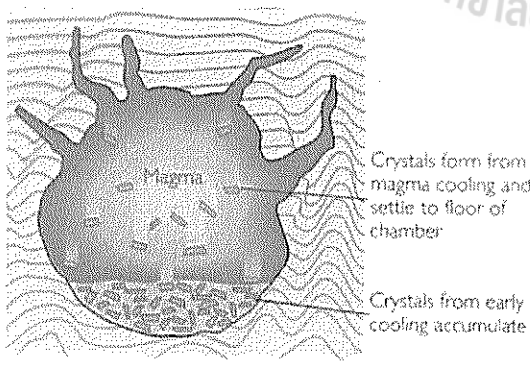


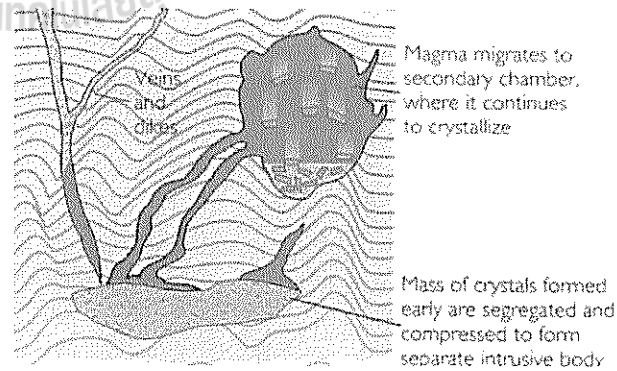






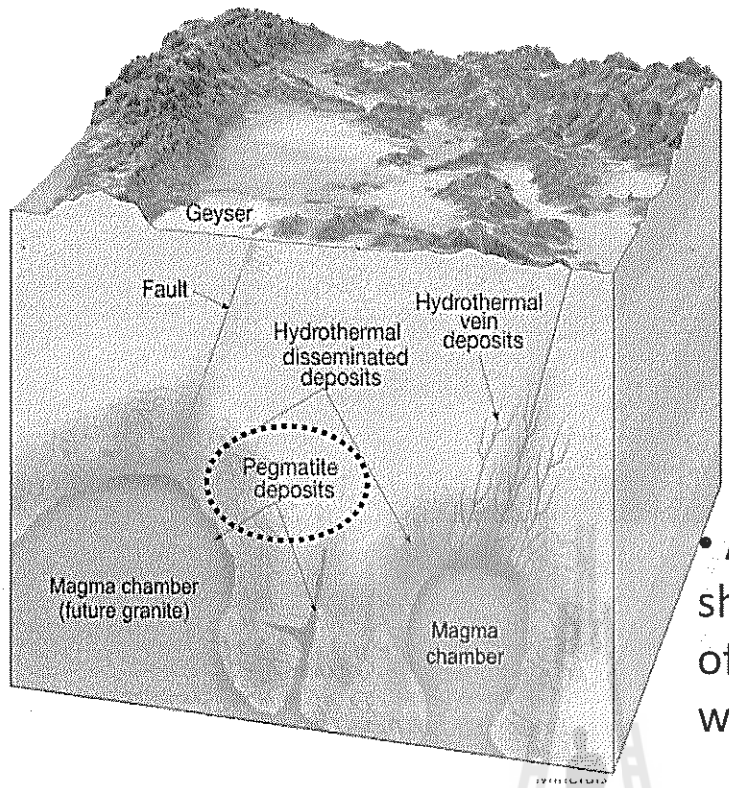
Mineral formations associated with felsic igneous rocks





Crystallized from magma (felsic composition), occur with granitic rocks and pegmatite (high P, rich of vapor, F, Br).

Associated with hydrothermal processes



- **A vein** is a distinct sheetlike body of crystallized minerals within a rock.

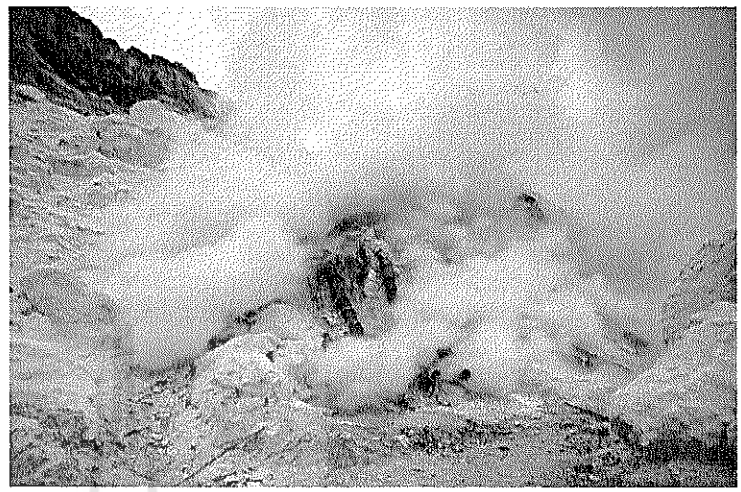
- Veins form when mineral constituents carried by an aqueous solution within the rock mass are deposited through precipitation.





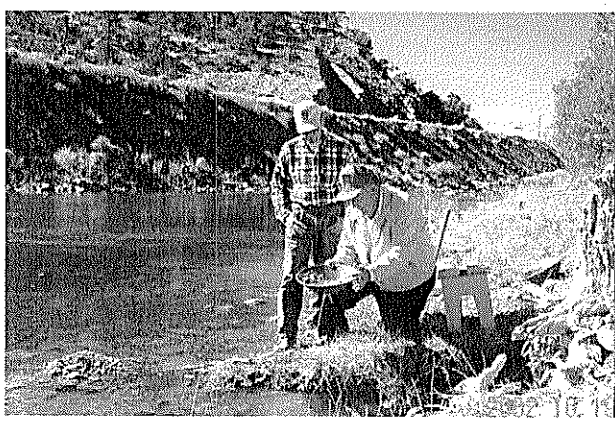
Hydrothermal mineral deposits may contain a vast range of different mineral's, including native elements, sulphides, oxides, halides, carbonates, sulphates, phosphates and silicates.





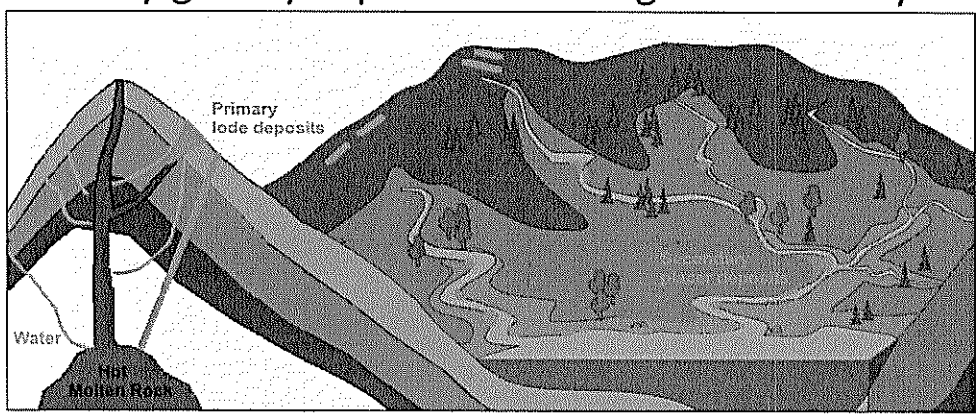
Associated with sedimentary processes

- Placer deposits
- Residual deposits
- Evaporites

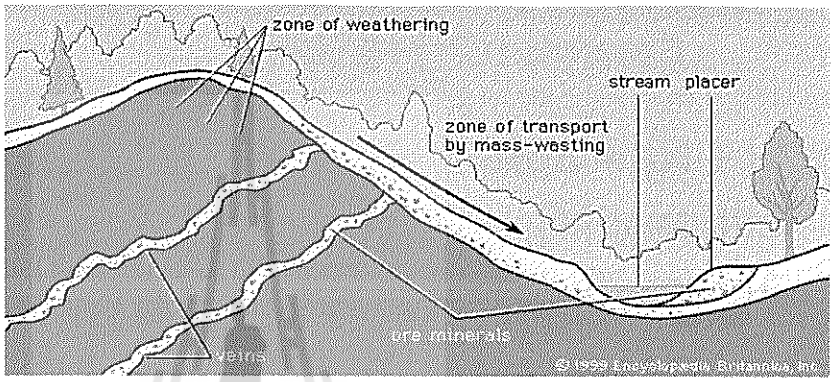




Placer deposit (Placer) : an accumulation of valuable minerals formed by gravity separation during sedimentary processes.





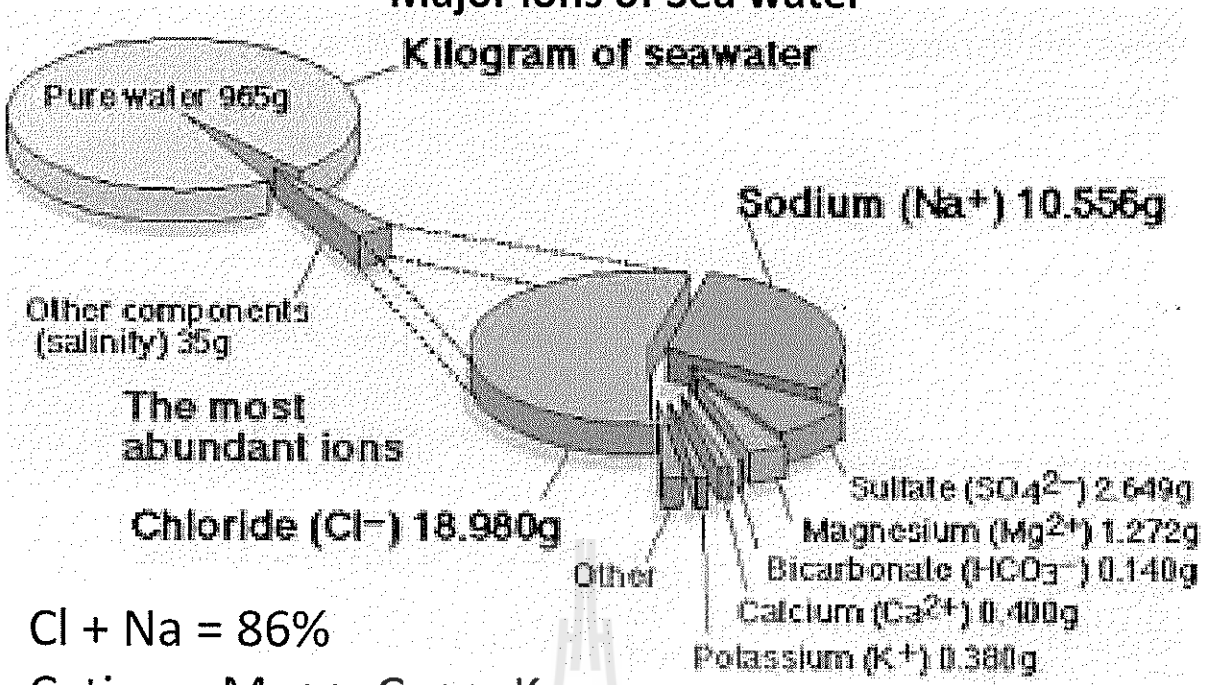




Residual deposits: in situ



Major ions of Sea water



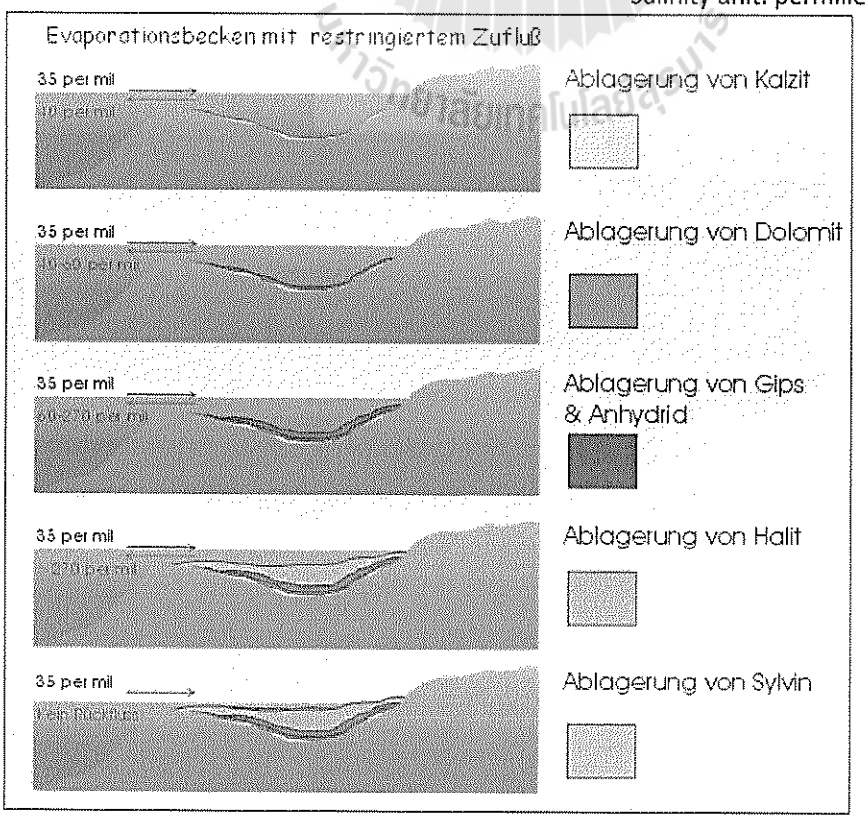
Cl + Na = 86%

Cations: Mg++, Ca++, K+

Anions: SO_4, HCO_3

Evaporites: precipitation from solution

Salinity unit: permille (parts per thousand) (‰)



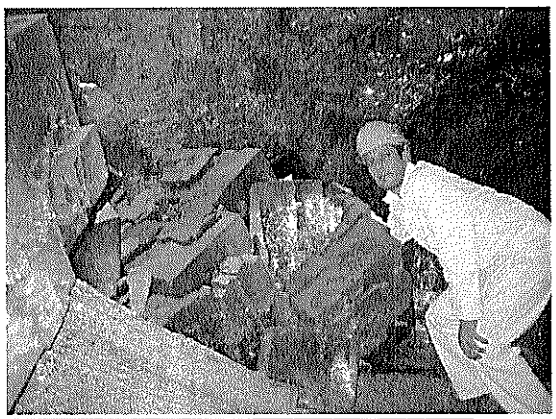
Precipitation of calcite

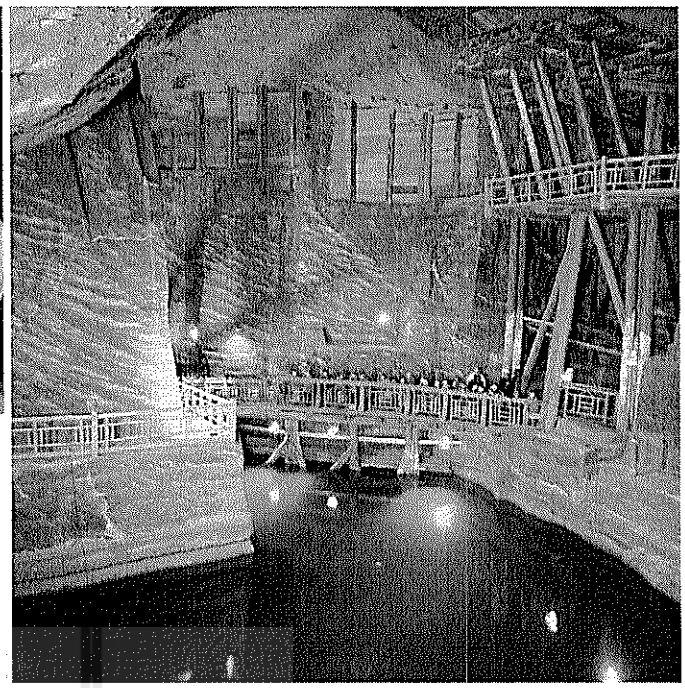
Precipitation of dolomite

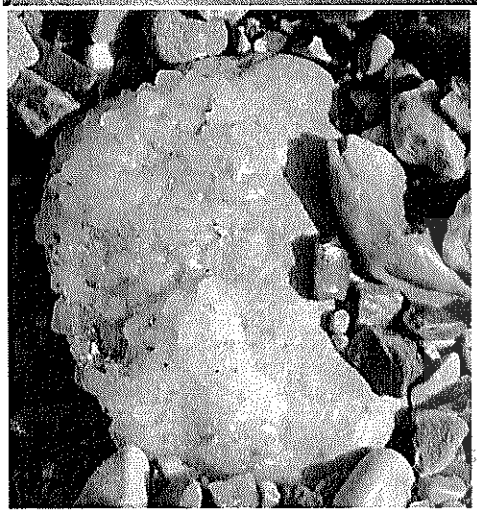
Precipitation of anhydrite

Precipitation of halite

Precipitation of sylvite







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Chapter 3 Rocks

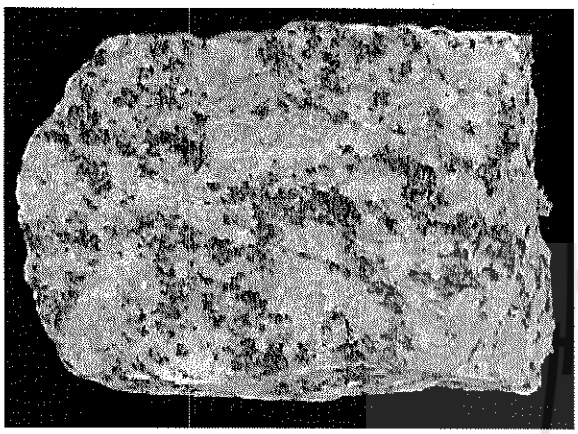
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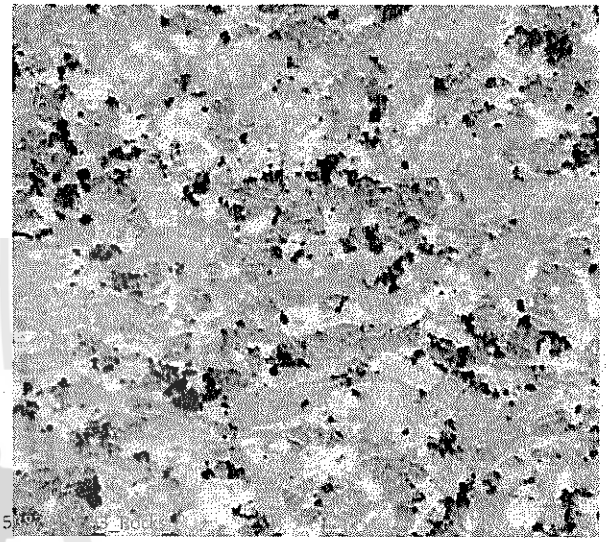
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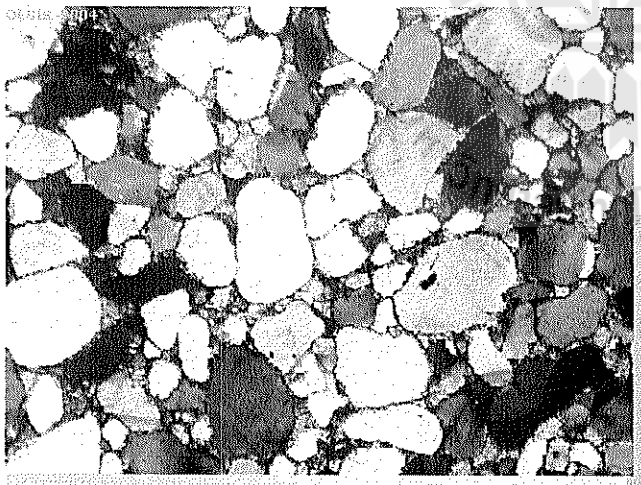
1. Definition
2. Rock cycle
3. Igneous rocks
4. Sedimentary rocks
5. Metamorphic rocks

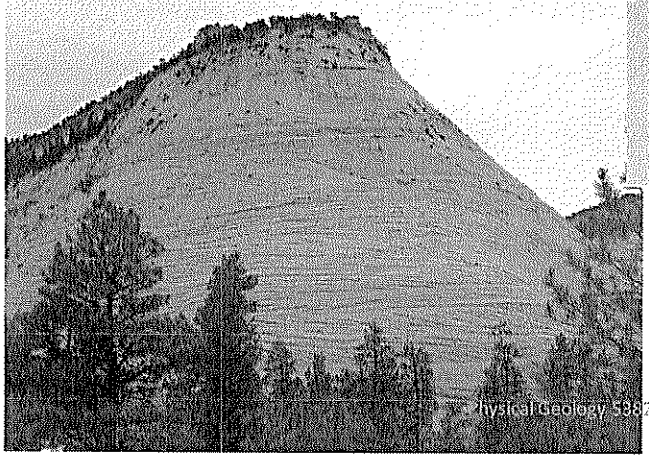
1. Definition

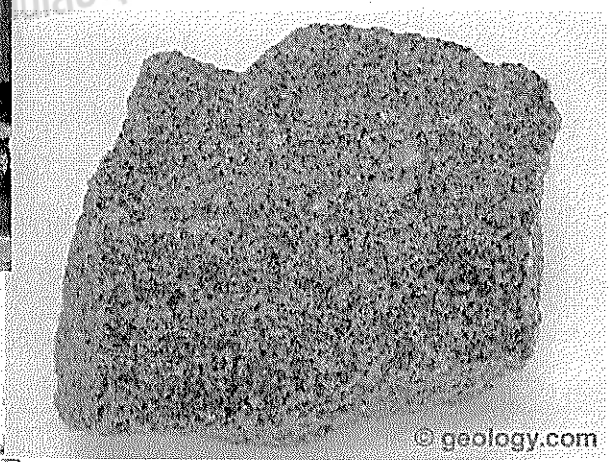
Rock: a naturally formed, consolidated material usually composed of grains of one or more minerals, or a mass of glass.

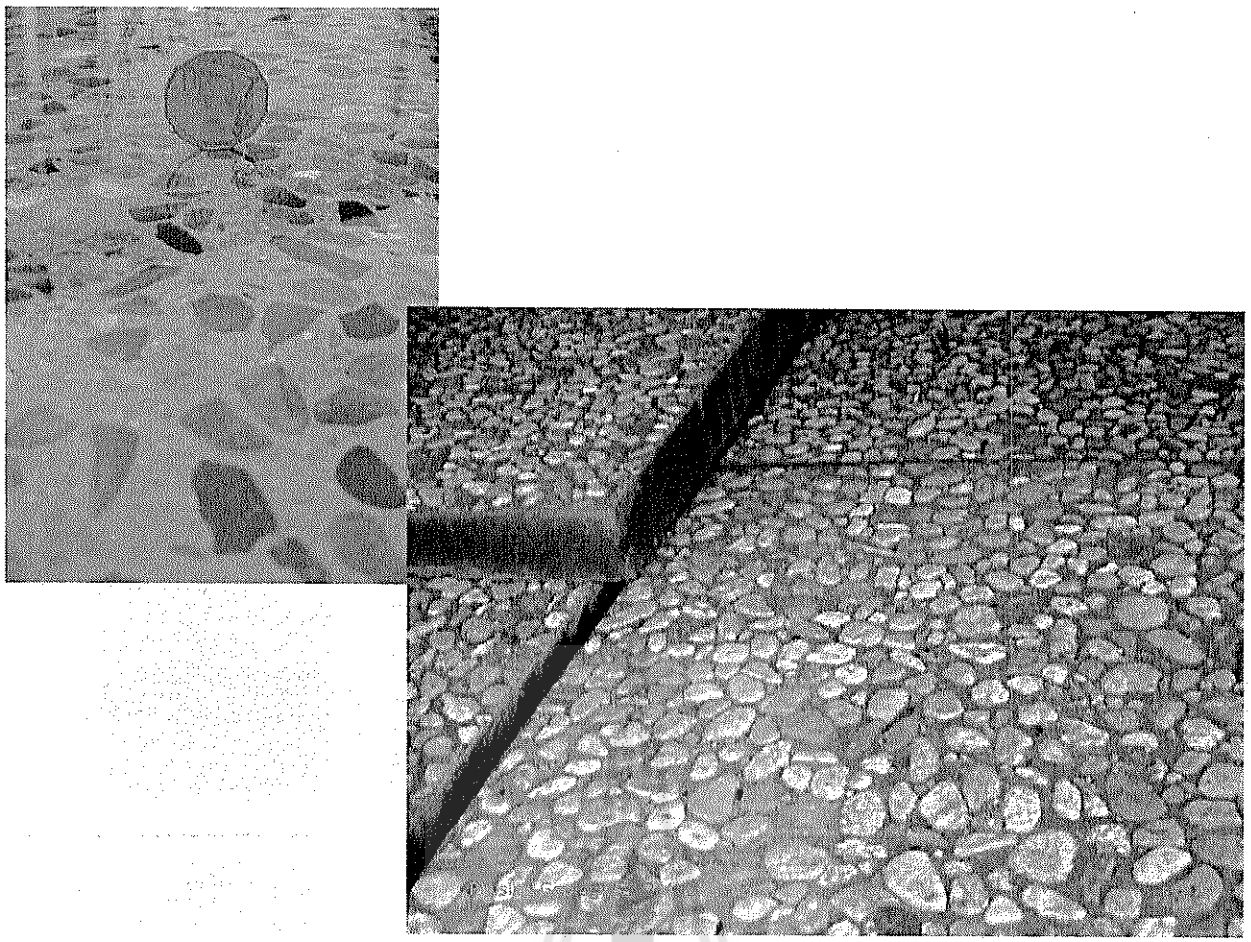












The basis of rock classification

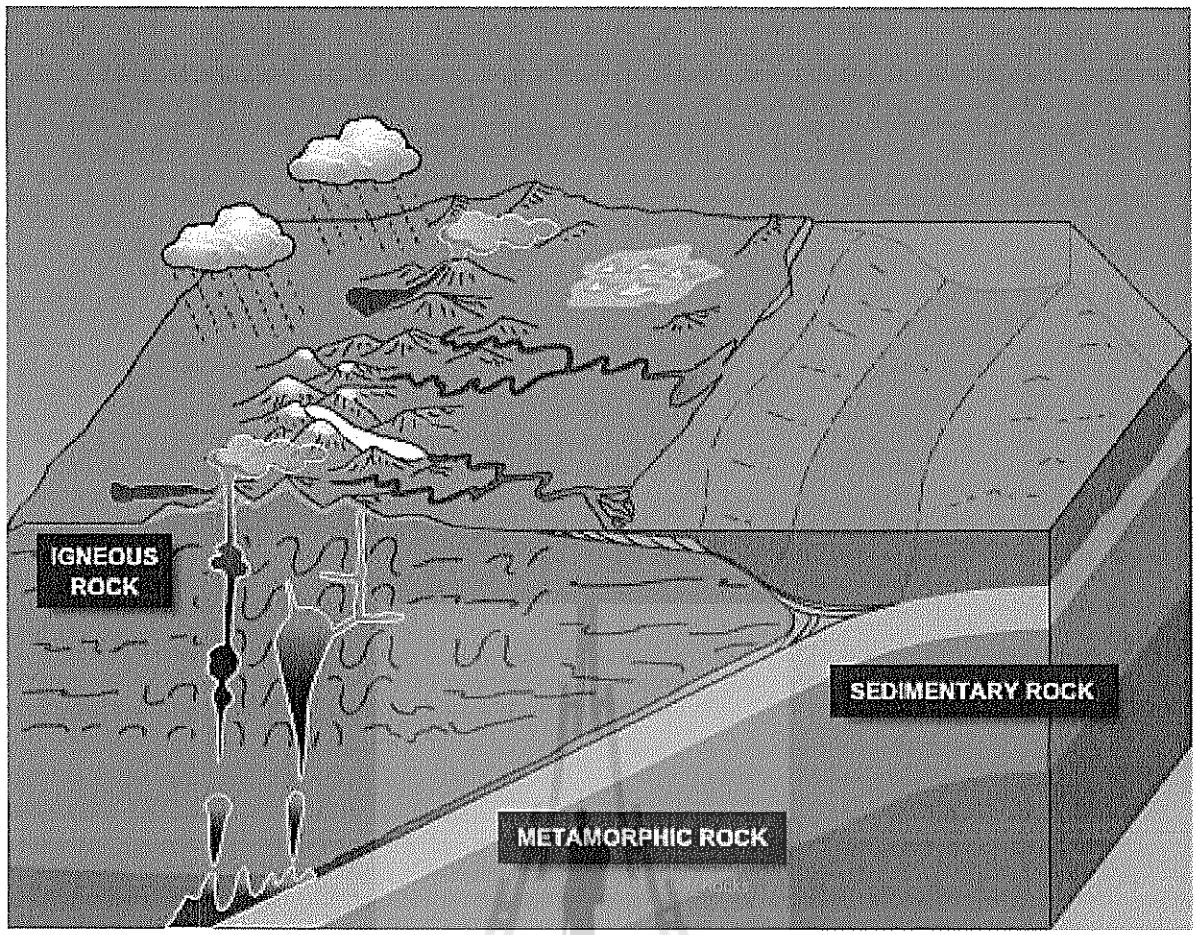
3 types of rocks

Igneous rocks: form by solidification of melt.

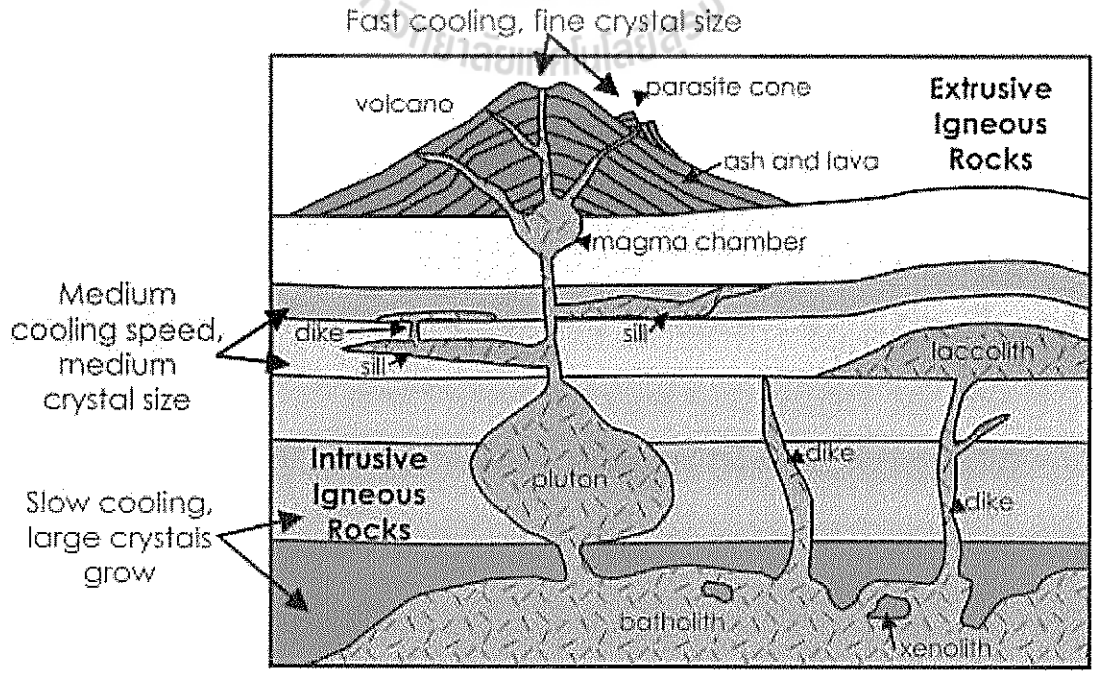
Sedimentary rocks: form by the cementing of fragments broken off preexisting rocks or by precipitation of mineral crystals out of water solutions at near the earth's surface.

Metamorphic rocks: form when preexisting rocks change character in response to a change in P and T conditions.

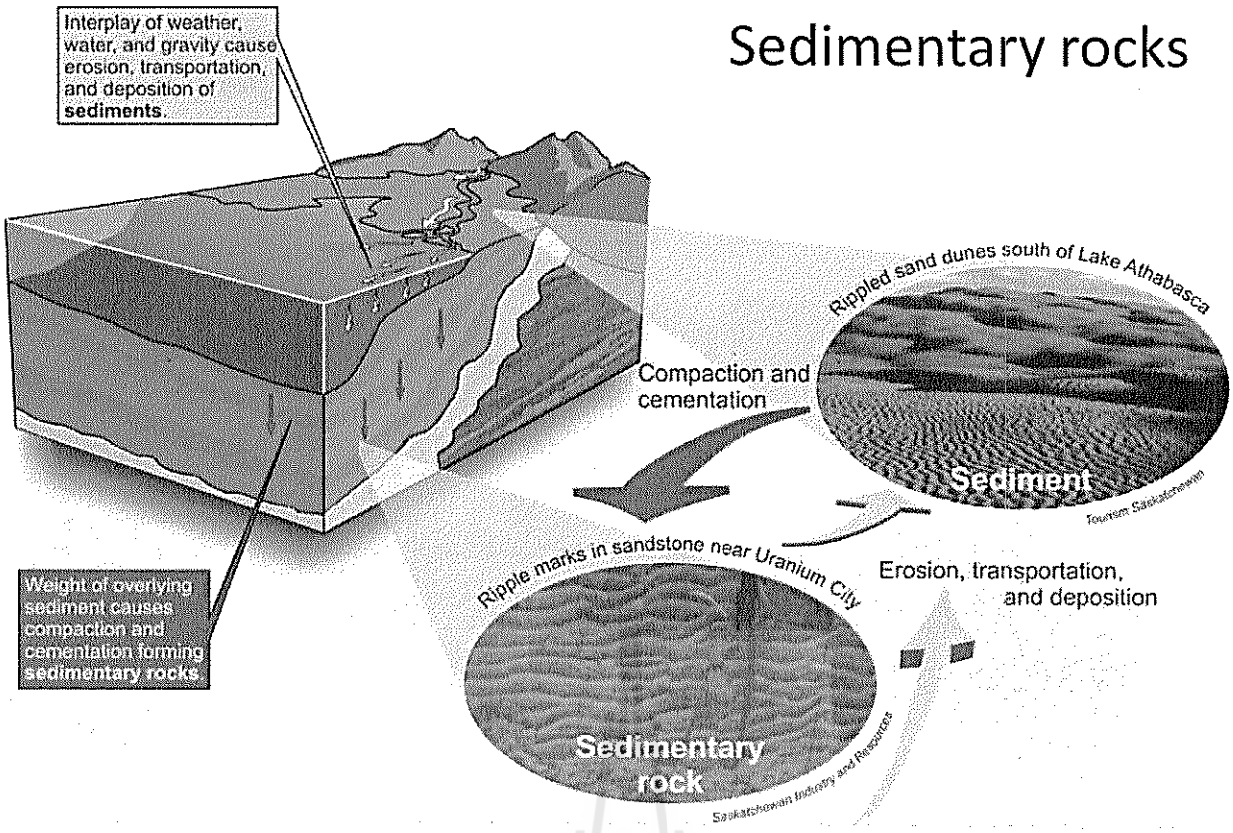
มหาวิทยาลัยเทคโนโลยีสุรนารี



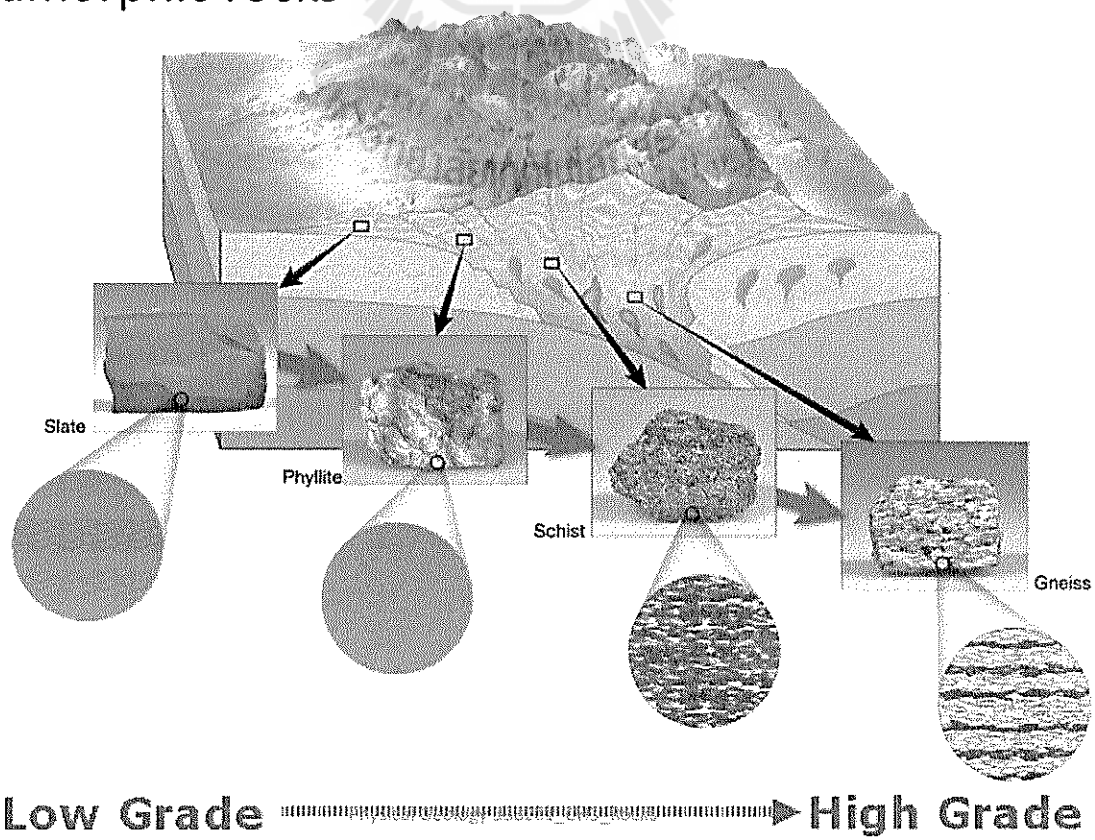
Igneous rocks: form by solidification of melt



Sedimentary rocks

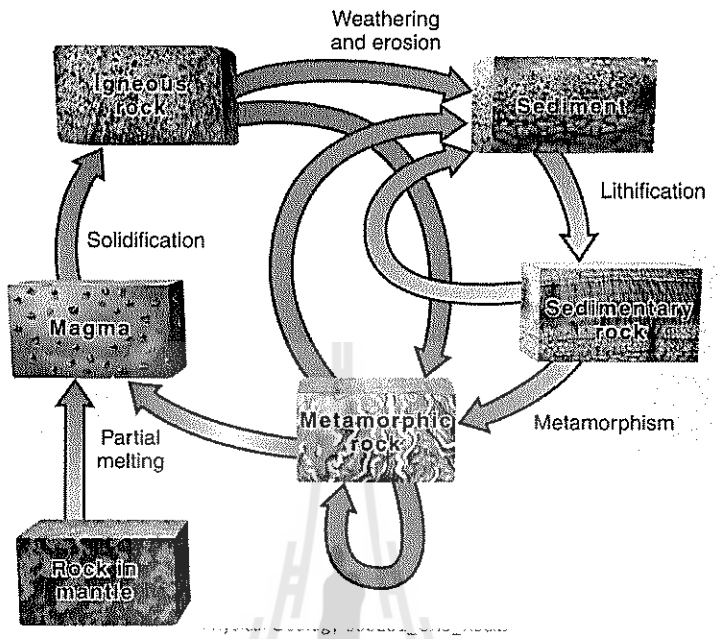


Metamorphic rocks

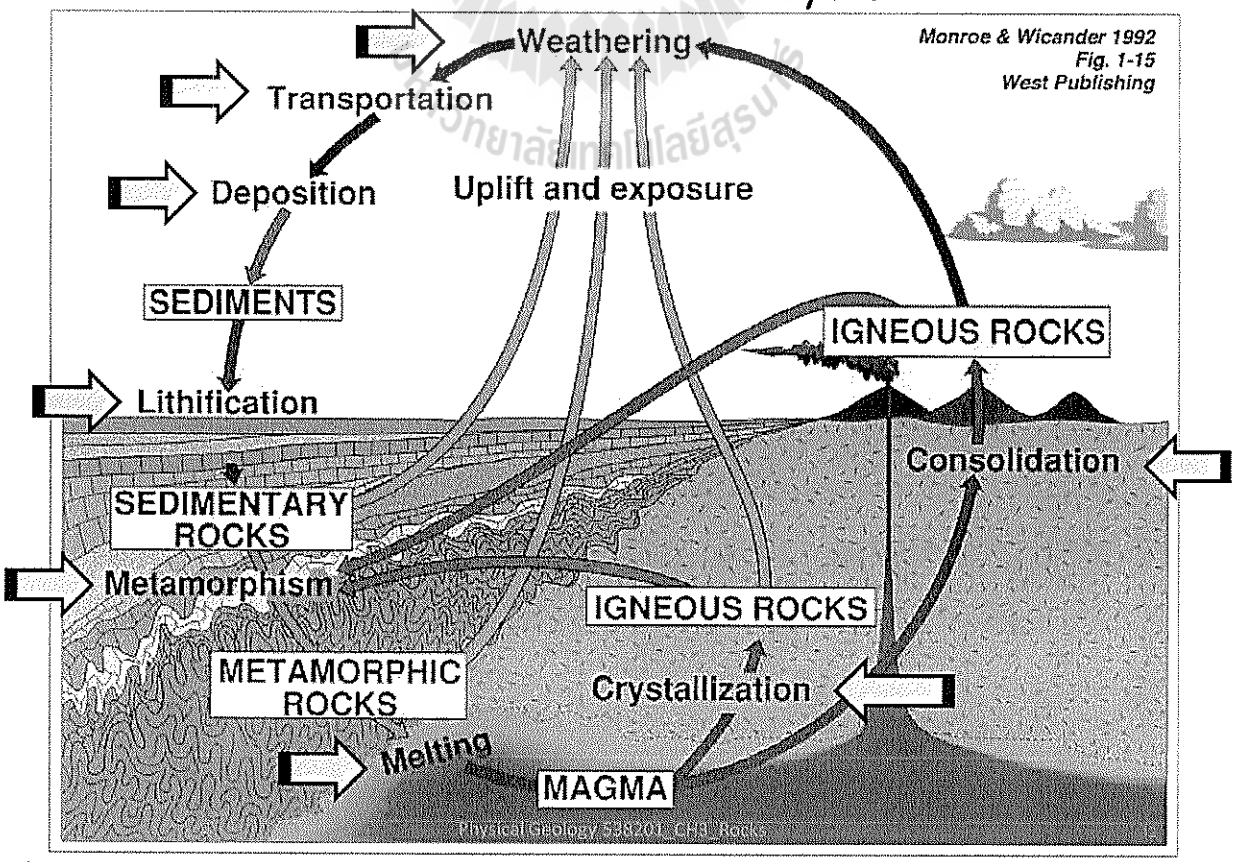


2. Rock cycle

The rock cycle shows how one type of rocky material gets transformed into another.

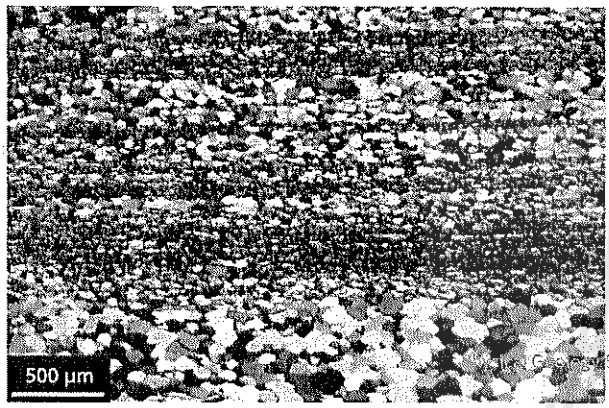


Processes in the rock cycle



Physical characteristics used to classify rocks

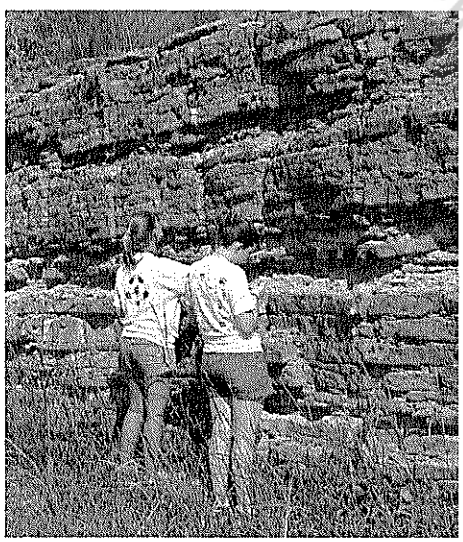
1) Grain size
2) Chemical composition
3) Texture
4) Layering



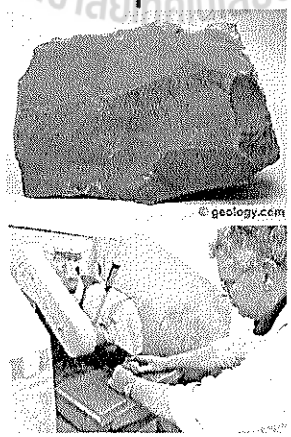


Studying rocks

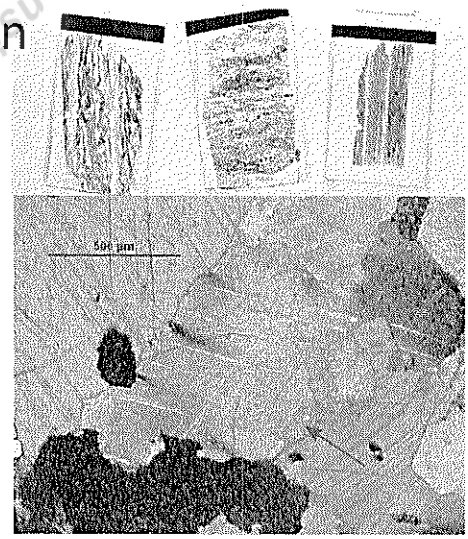
Outcrop observations



Hand specimen



Thin-section study

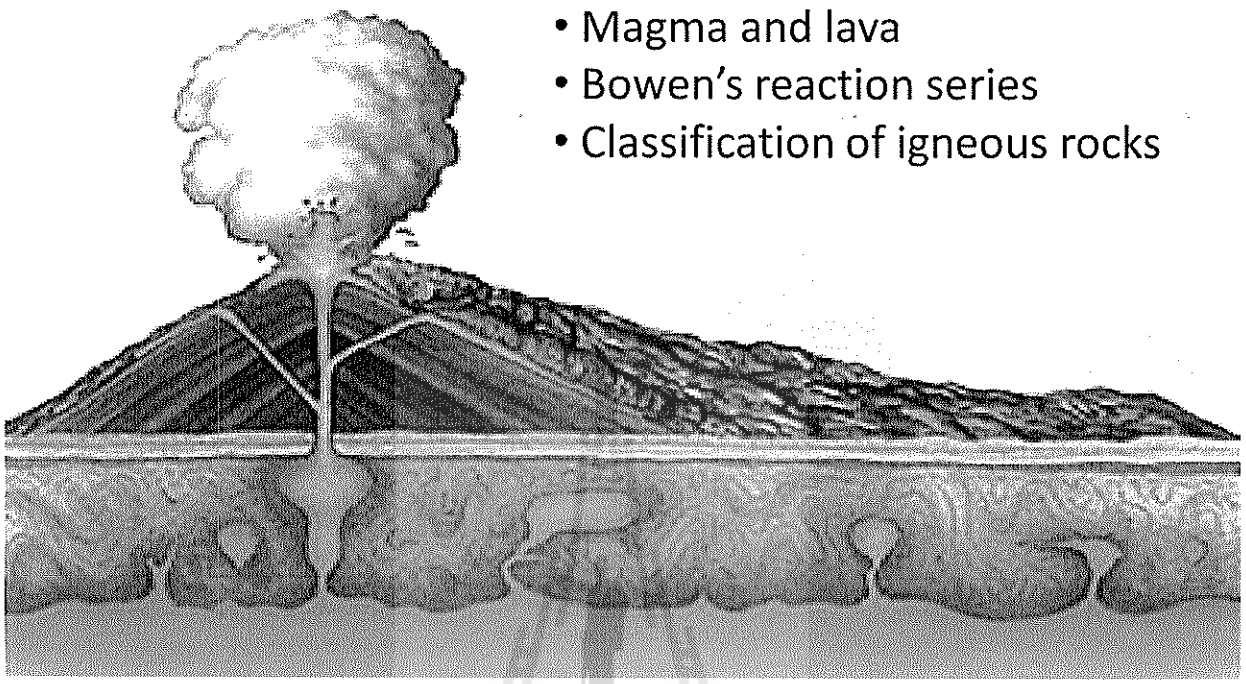


High-Tech Analytical Equipment

Electron microprobes, mass spectrometers, X-ray diffractometers

3. Igneous Rocks

Contents



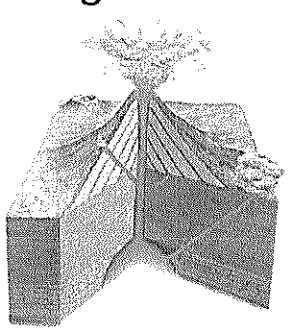
- Magma and lava
- Bowen's reaction series
- Classification of igneous rocks

Magma and lava

Magma: a mixture of molten or semi molten rock, volatiles and solids that is found beneath the surface of the Earth

Magma often collects in magma chambers that may feed a volcano or turn into a pluton.

Magma extrudes onto the surface as **lava**,



Temperatures of most magmas are in the range 700 °C to 1300 °C

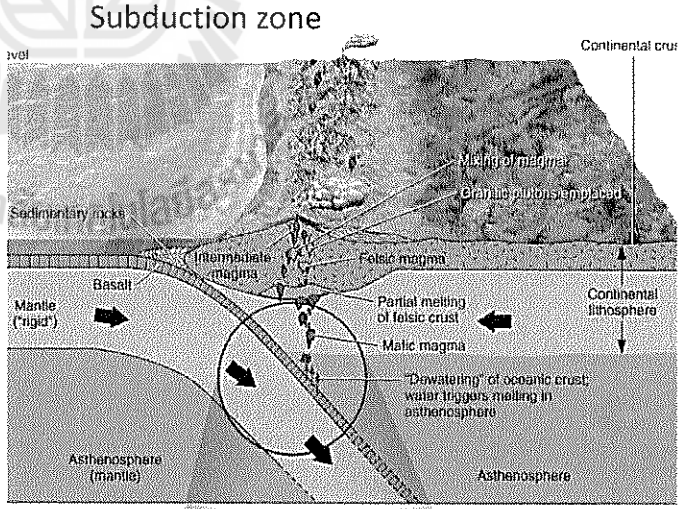
Partial melting occurs when only a portion of a solid is melted.

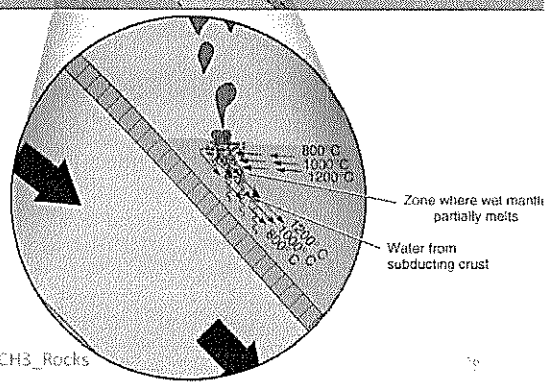


How are rocks melted?

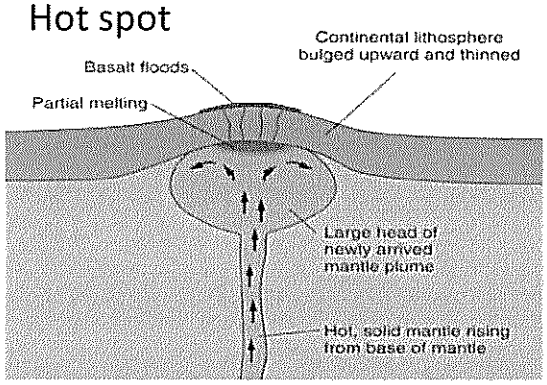
1. Heating
2. Increase water content
3. Increased silica content
4. Depressurization

Subduction zone



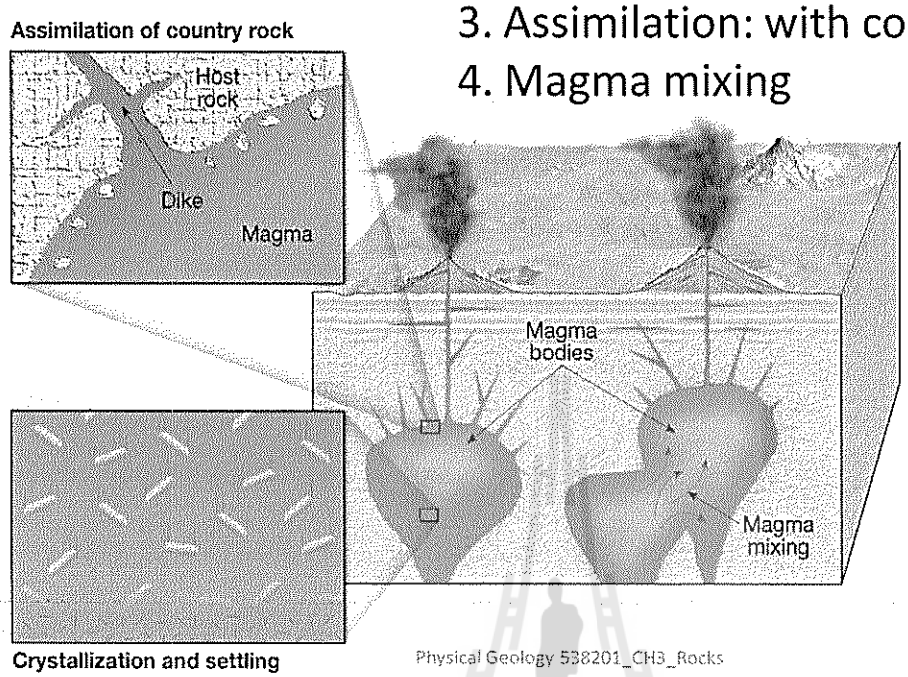


Hot spot



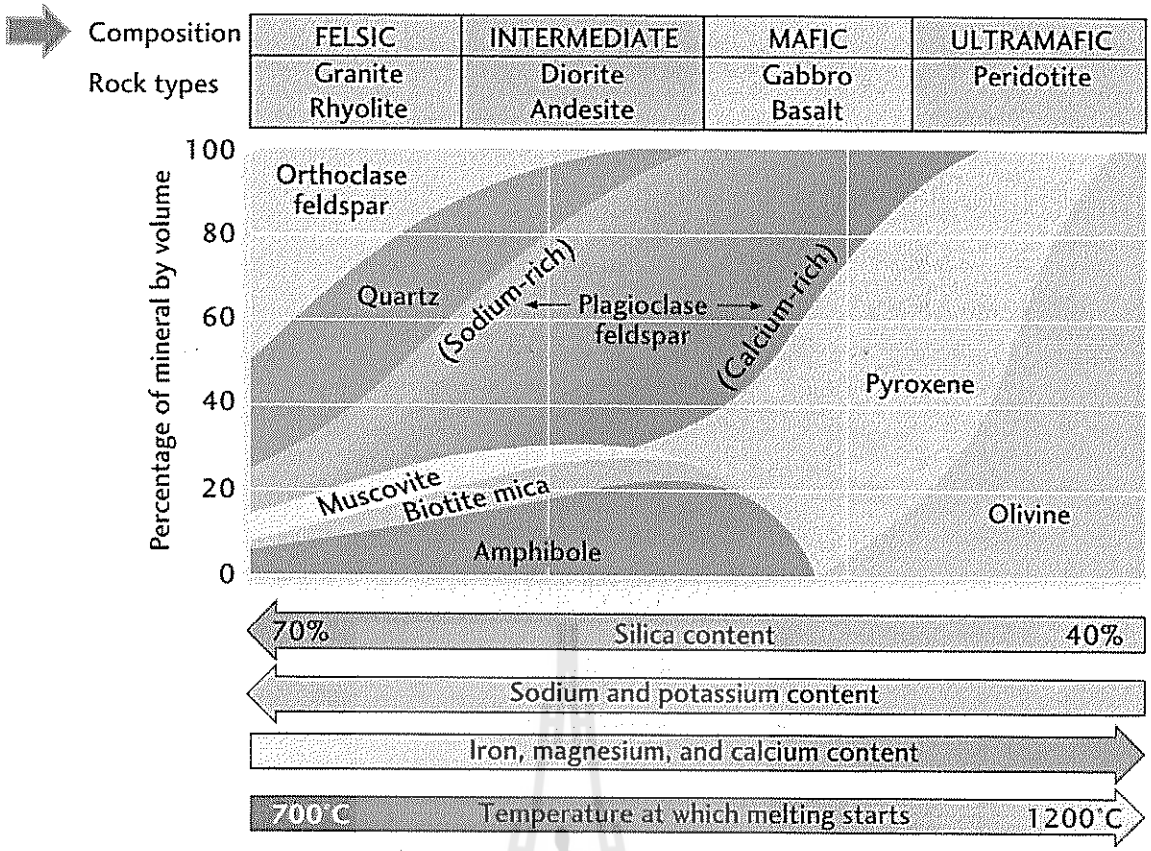
Several factors controlling magma composition

1. Source rock composition
2. Partial melting
3. Assimilation: with country rocks
4. Magma mixing

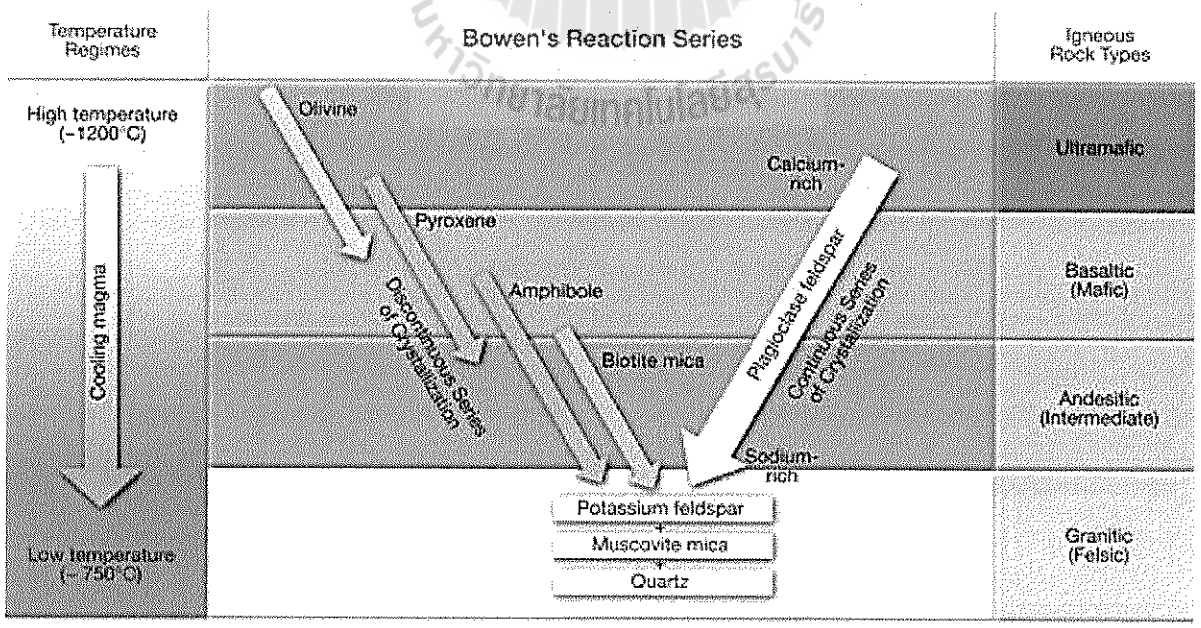


Four types of magma

Type	Silica (SiO_2) contents
Felsic (silicic or granitic)	66-76 %
Intermediate (andesitic)	52-66 %
Mafic (basic or basaltic)	45-52 %
Ultramafic	38-45 %



Bowen's Reaction Series



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Classification of igneous rocks

Intrusive & Extrusive

Where they were formed

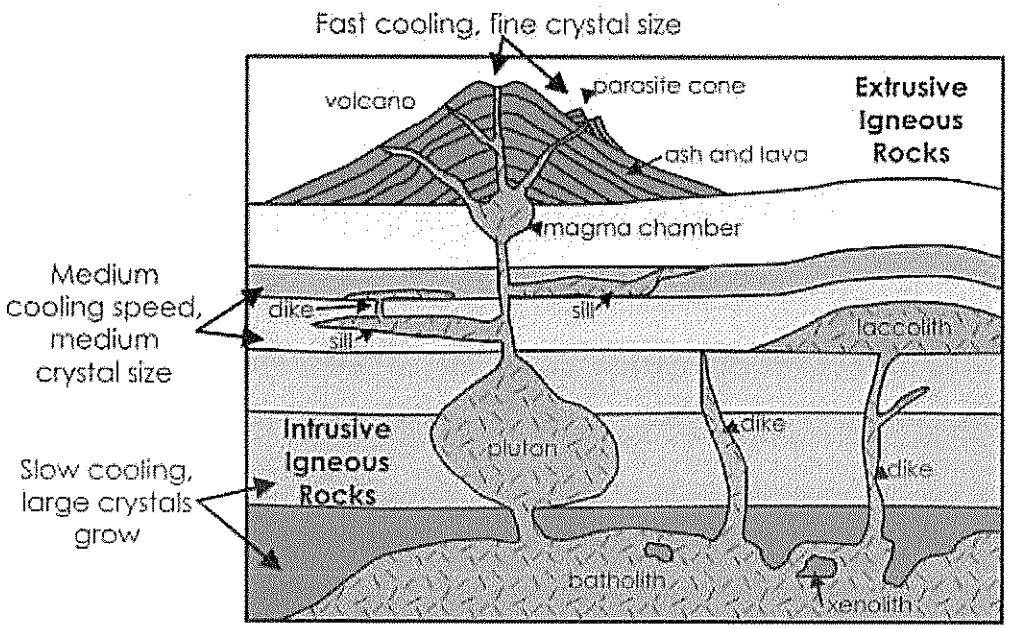
Igneous rocks

What they were made of

Granitic & Andesitic & Basaltic

Intrusive igneous rocks

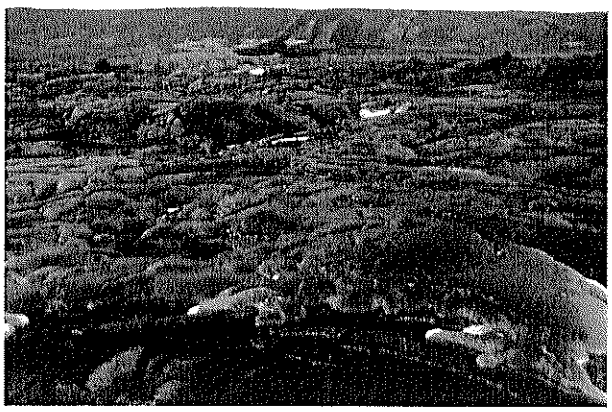
Igneous rocks that form below the Earth's surface are called intrusive igneous rocks (or plutonic).

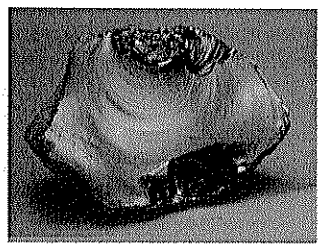


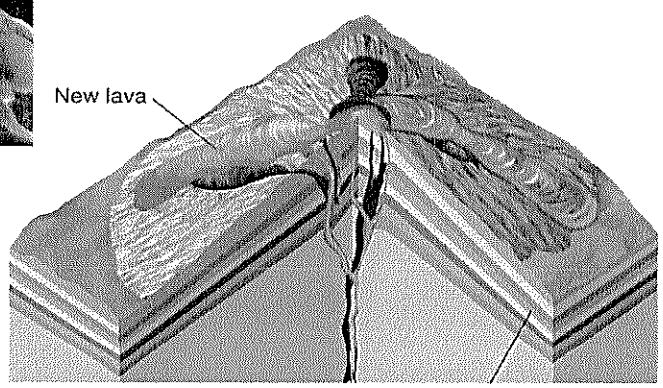
Extrusive igneous rocks

Extrusive igneous rocks (volcanics) form when magma makes its way to Earth's surface. The molten rock erupts or flows above the surface as lava, and then cools forming rock.

Glassy Igneous Rocks cool so rapidly, that atoms do not have enough time to get together, bond and form crystals. To cool this quickly the rocks MUST be extrusive.







Granitic igneous rocks

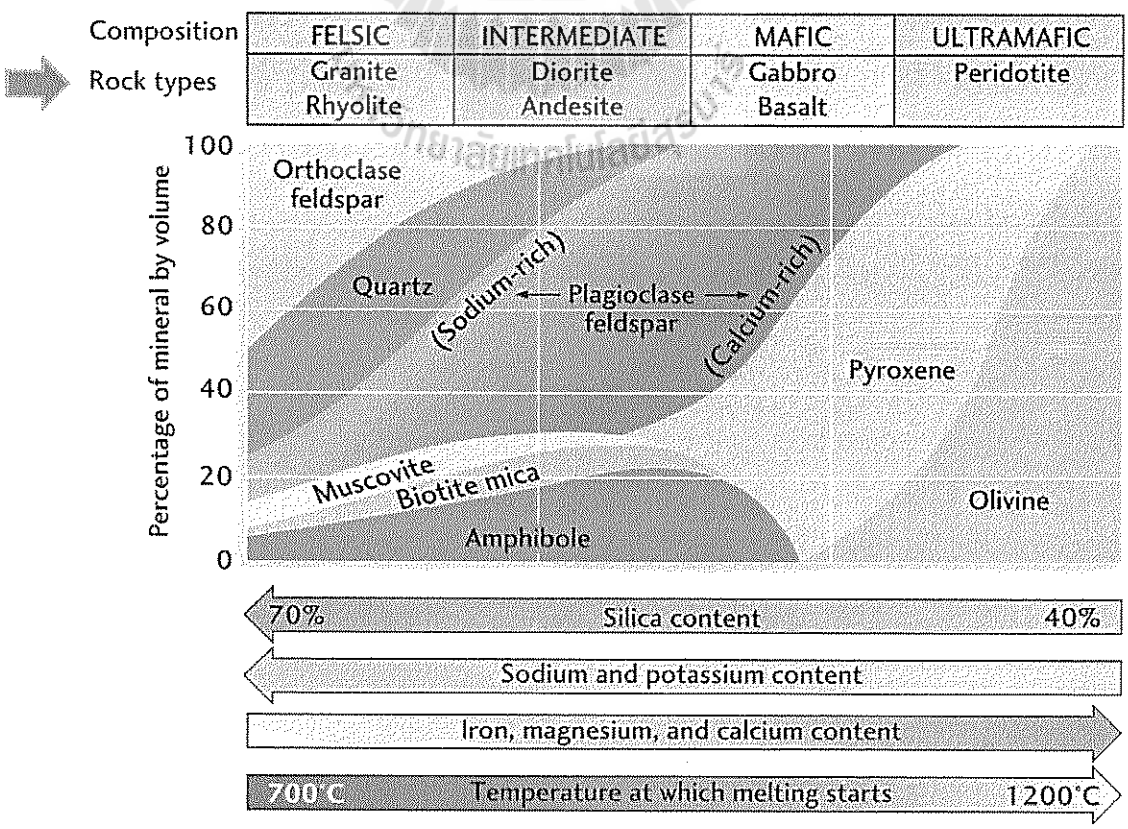
Light-colored, contains lots of silica but lesser amounts of iron and magnesium, found on continental land masses

Andesitic igneous rocks

Having mineral compositions between those of basaltic and granitic rocks, many volcanoes around the rim of the Pacific Ocean formed from andesitic magmas.

Basaltic igneous rocks

Dense, dark-colored, rich in iron and magnesium and poor in silica, most of the ocean floor is made of basalt



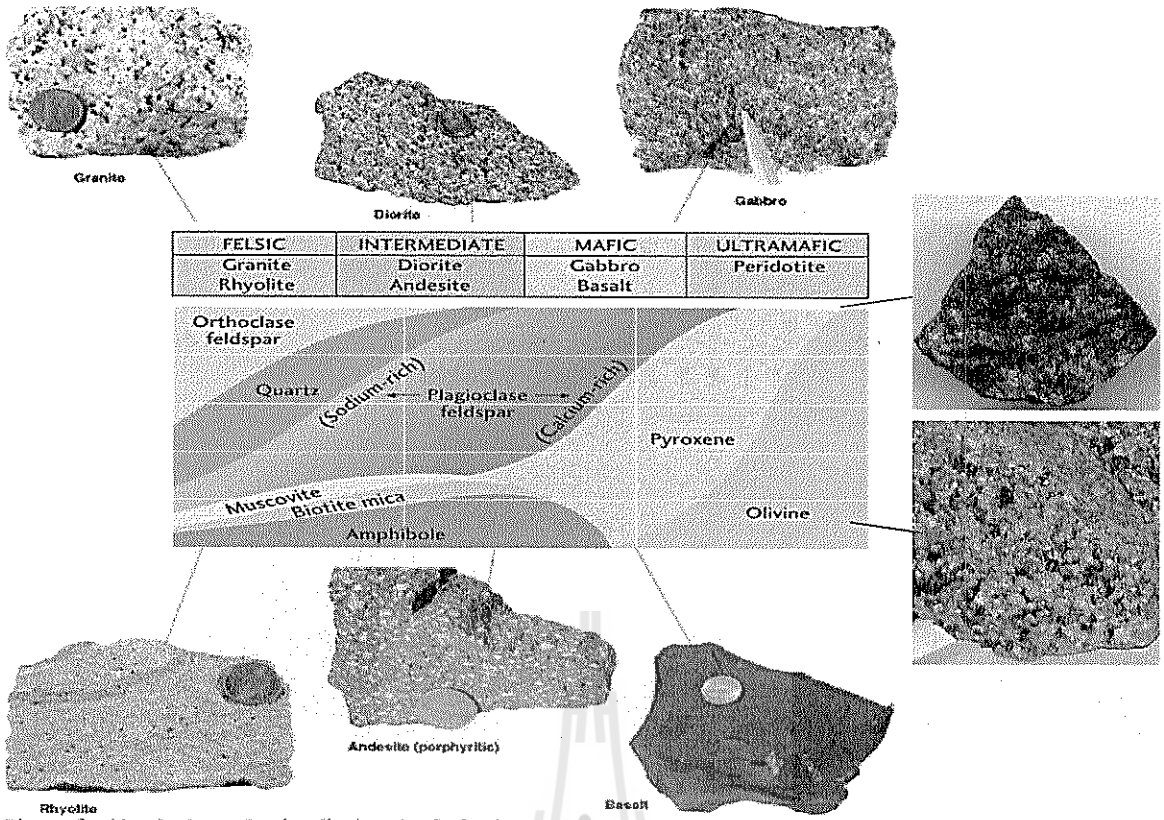


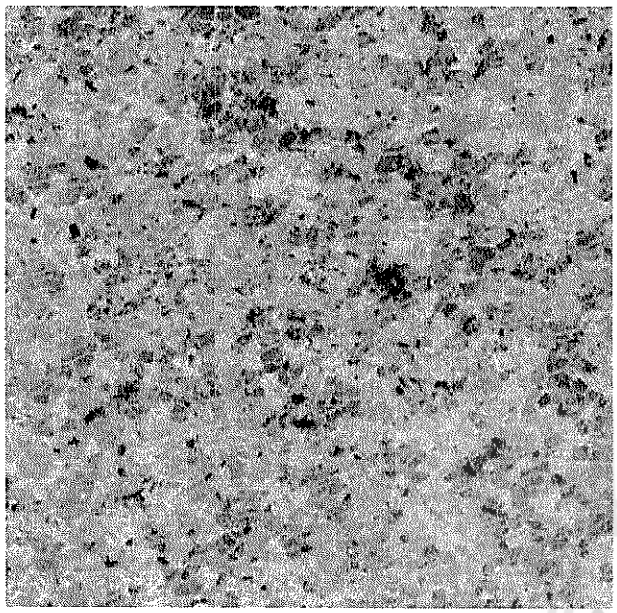
Photo of gabbro by Larry Davis; all others by C. C. Plummer

Igneous rock texture

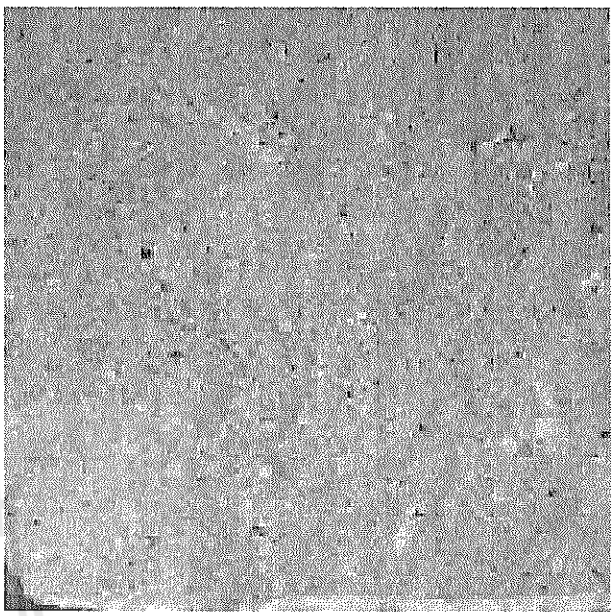
- Crystalline
- Porphyritic
- Pegmatitic
- Glassy
- Vesicular
- Clastic

Crystalline texture

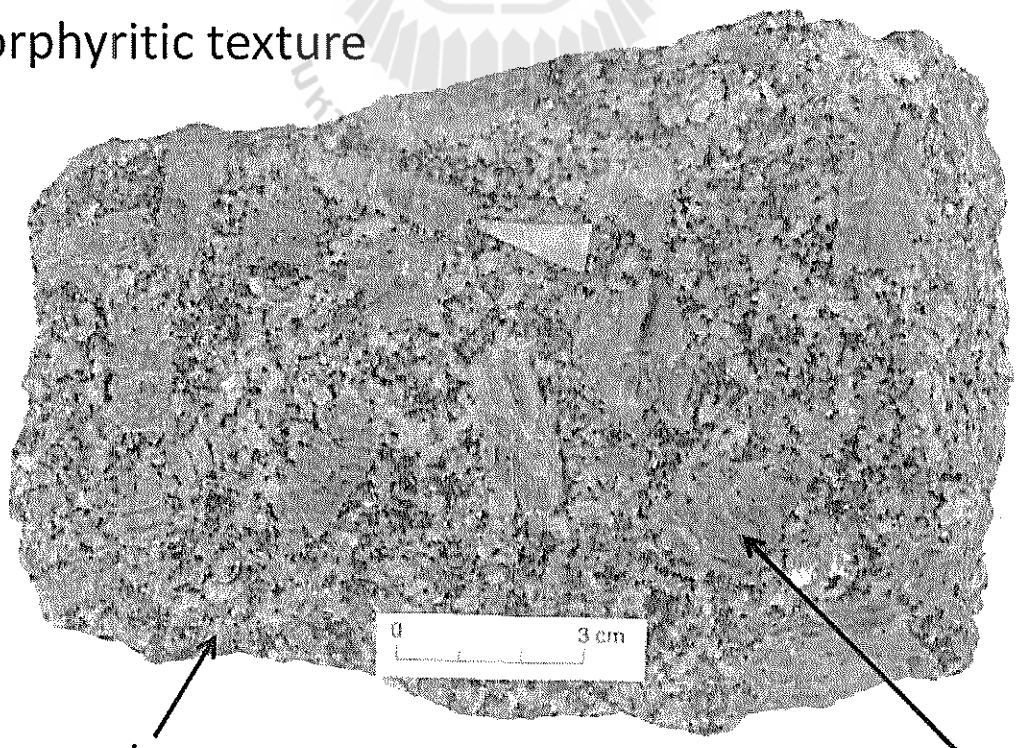
Phaneritic (coarse)



Aphanitic (fine)



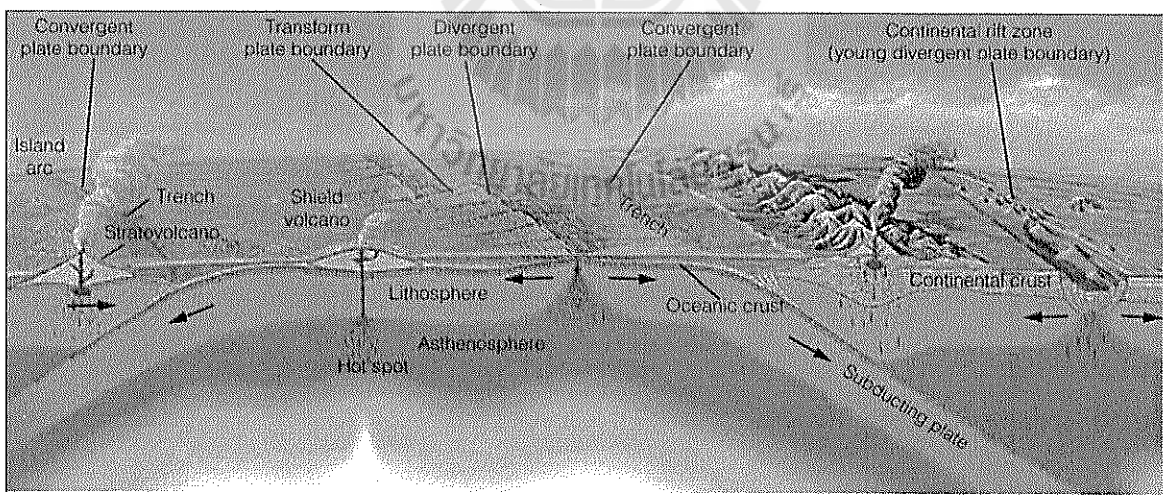
Porphyritic texture

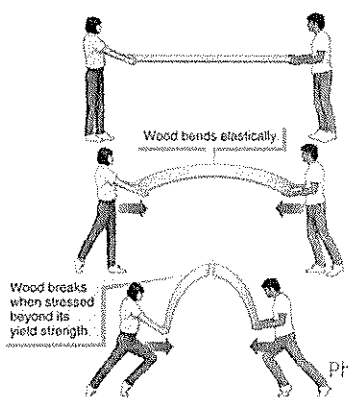


Secondary geological structures develop after formation of the rock body



2. Rock deformation





Contents

- Stress
- Strain
- Factors controlling rock behavior

Stress

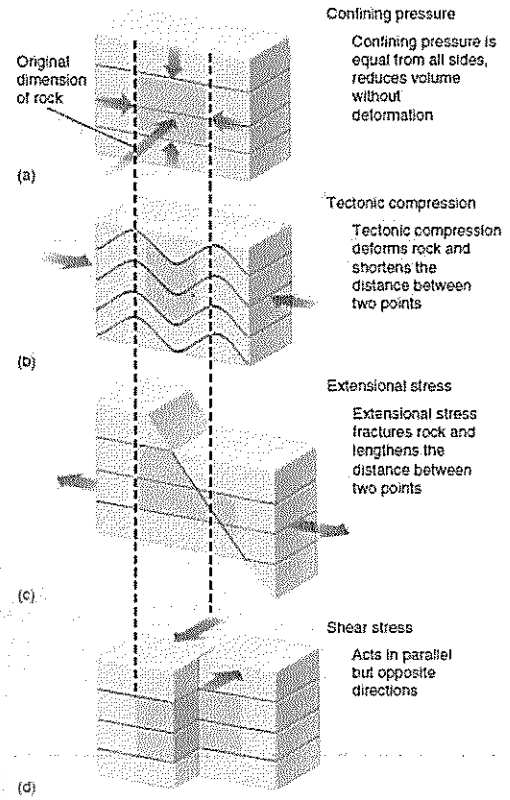
Confining stress
(confining pressure)

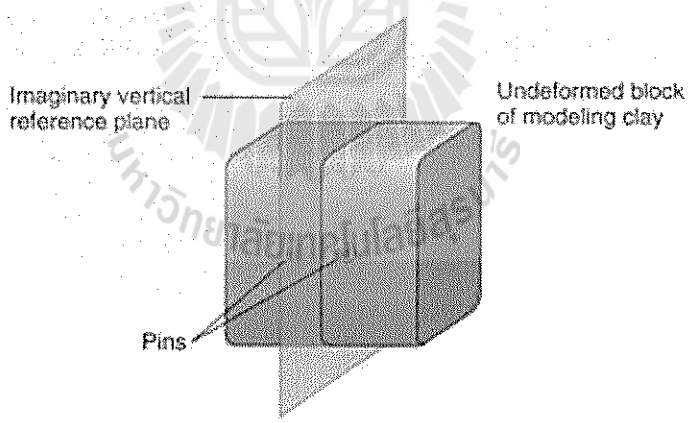
Directed stress

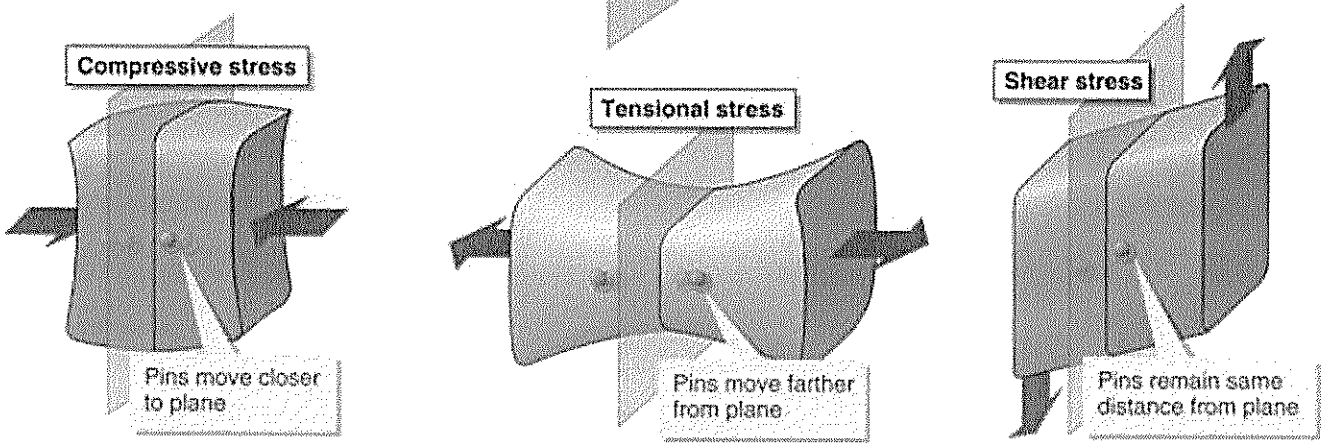
Compressive stress

Tension stress

Shear stress







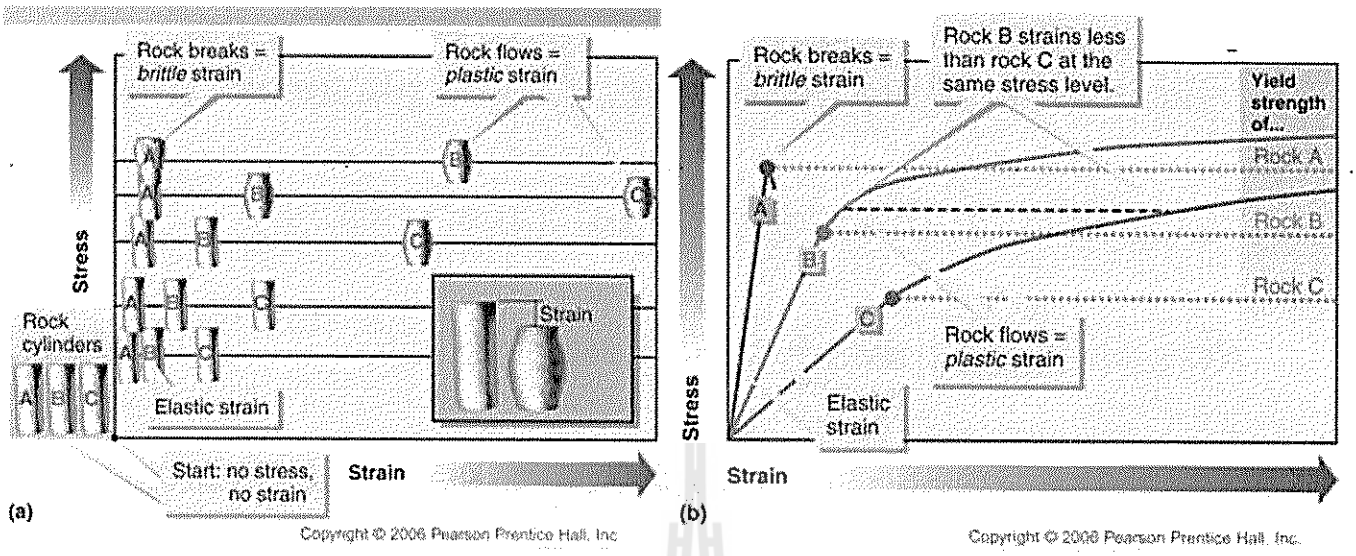
Shortening strain:
Block becomes shorter parallel to stress and thicker perpendicular to stress.

Elongation strain:
Block becomes longer parallel to stress and thinner perpendicular to stress.

Shear strain:
Block neither shortens nor elongates parallel to stress.

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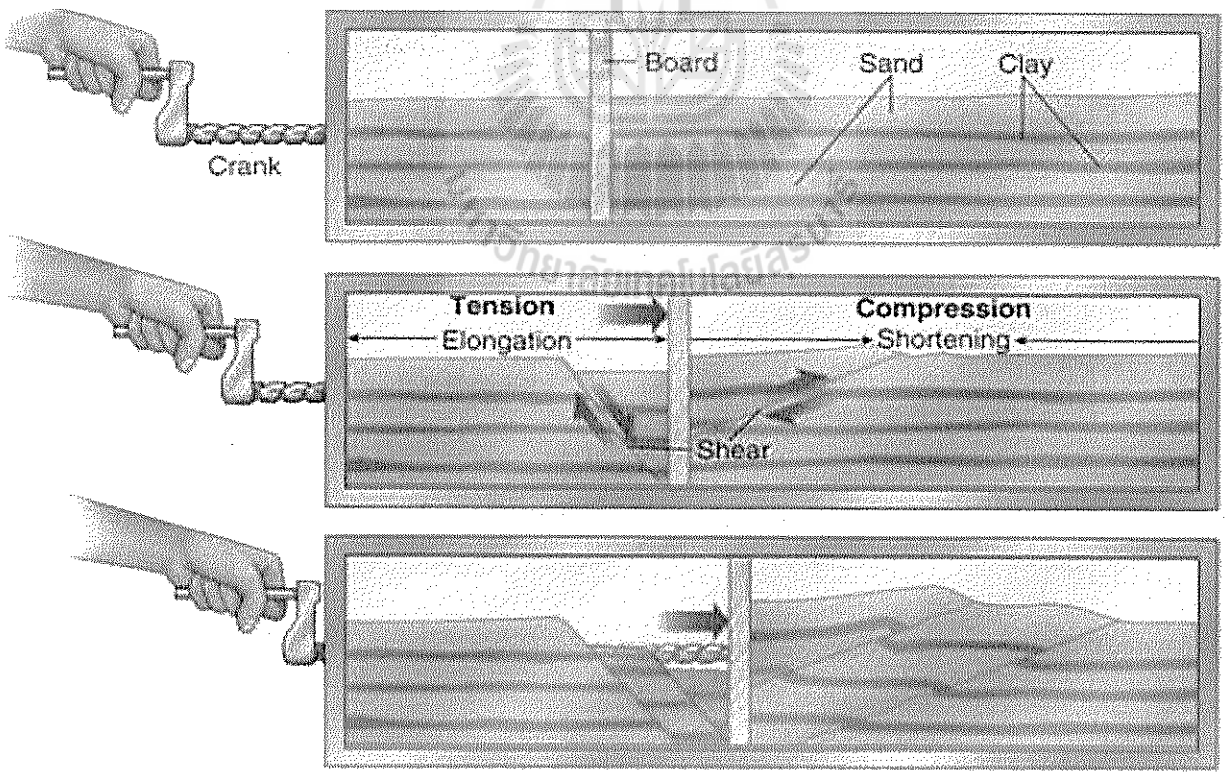
Strain: deformation produced by stress



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Elastic deformation, Plastic deformation, Brittle deformation



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Folding, faulting, fracturing are strains

Factors controlling rock behavior

- Materials: nature of material
  e.g., granite and quartzite tend to be brittle def.
  limestone, shale, marble tend to be plastically def.

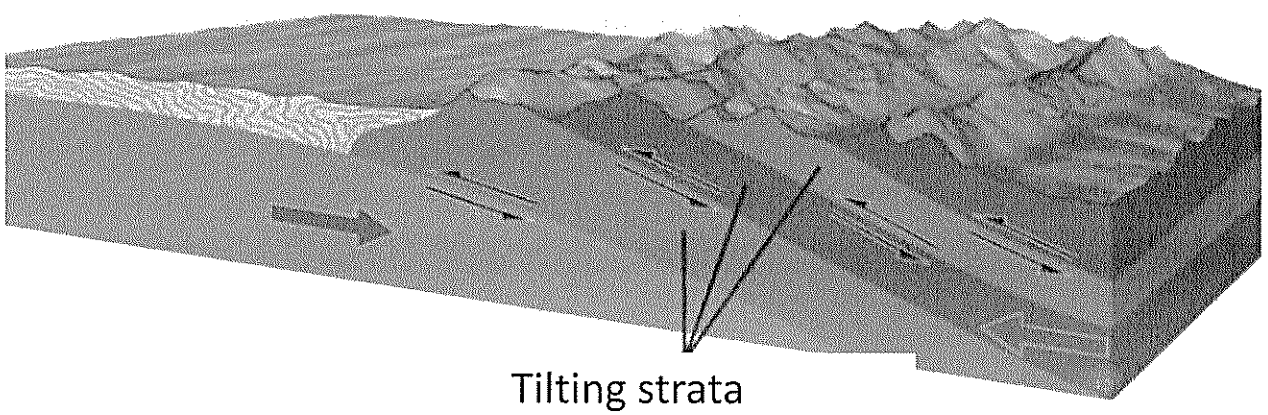
- Temperature: the higher T, the more plasticity

- Pressure: the more P, the more plasticity

- Time: stressed for a long time, not suddenly favors plastic behavior.

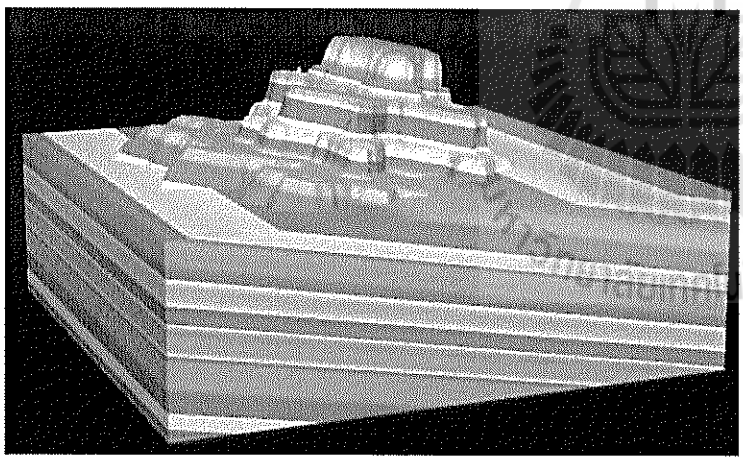
3. Strike / Dip

Tilting is how bedding is orientated away from horizontal origin and is a result of external stress such as a collision of tectonic plates.

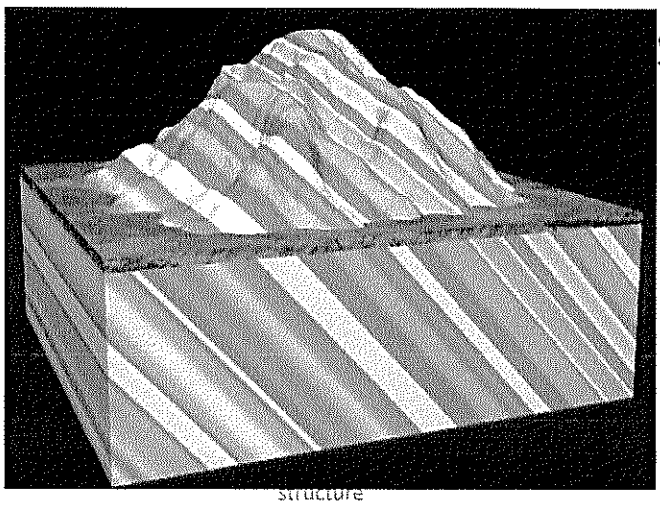


Tilting strata

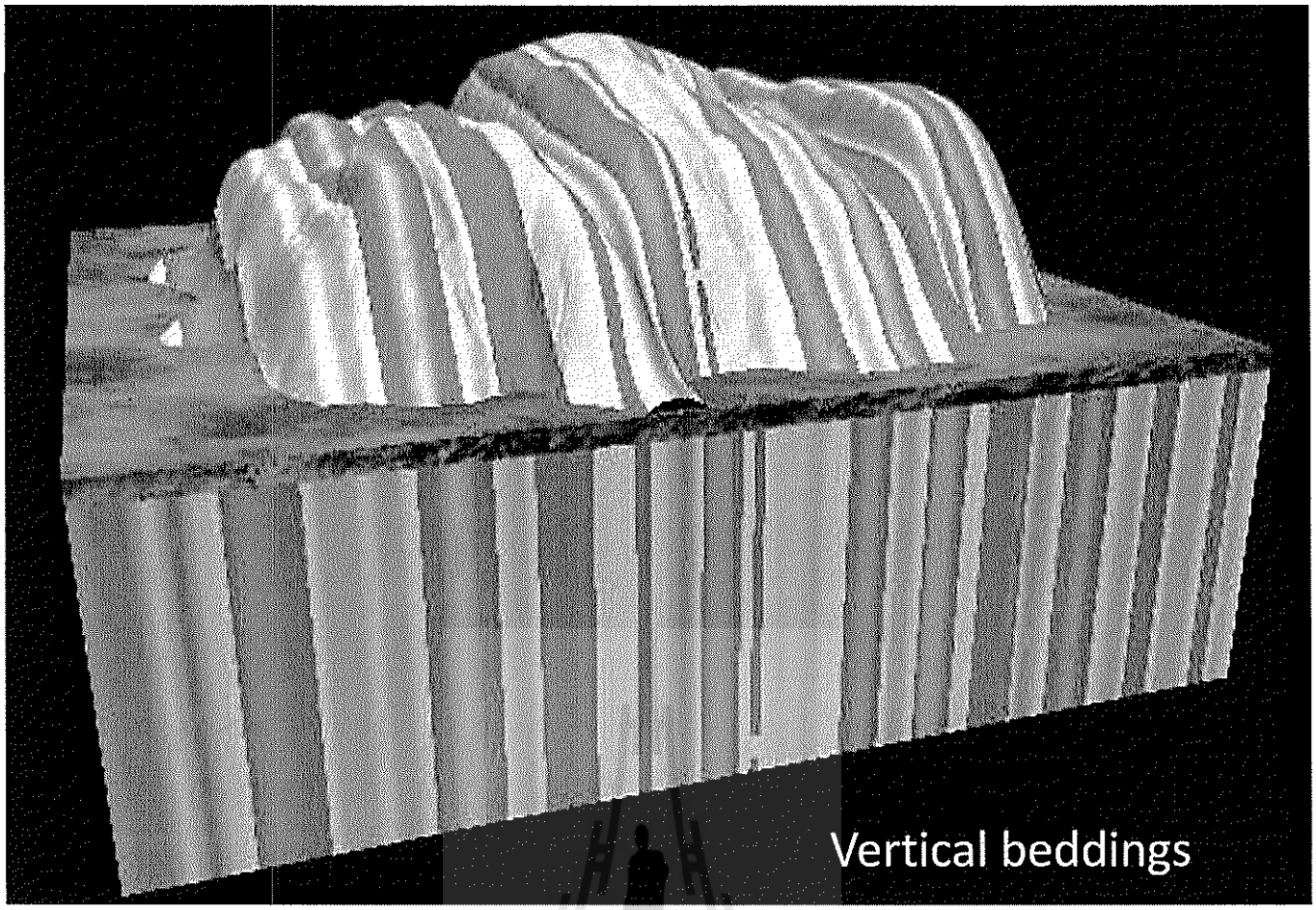




Gentle angle

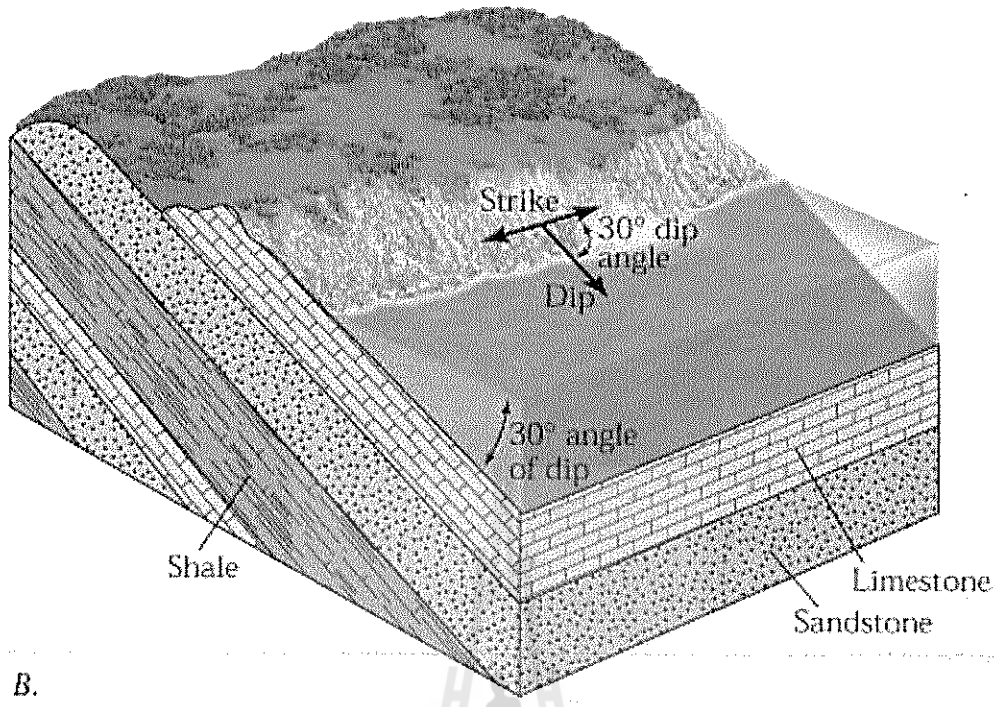


Steep angle


Vertical beddings



Bedding orientation (attitude): term of orientation of a plane, related to geographical coordinates and the horizontal. (trend and inclination)



B.

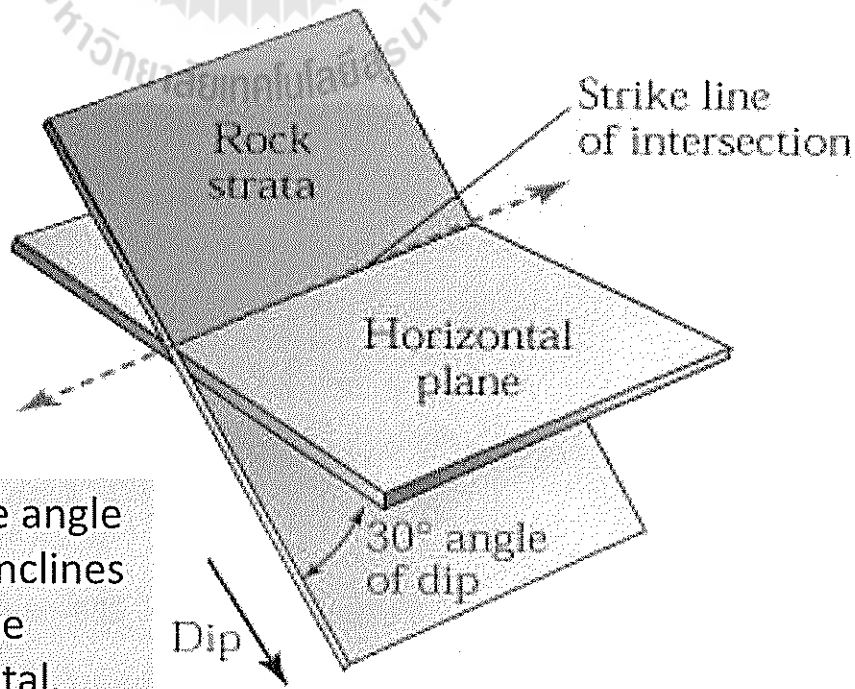
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Attitude: consists of strike and dip.

Strike: a trend of a horizontal line on an incline plane.

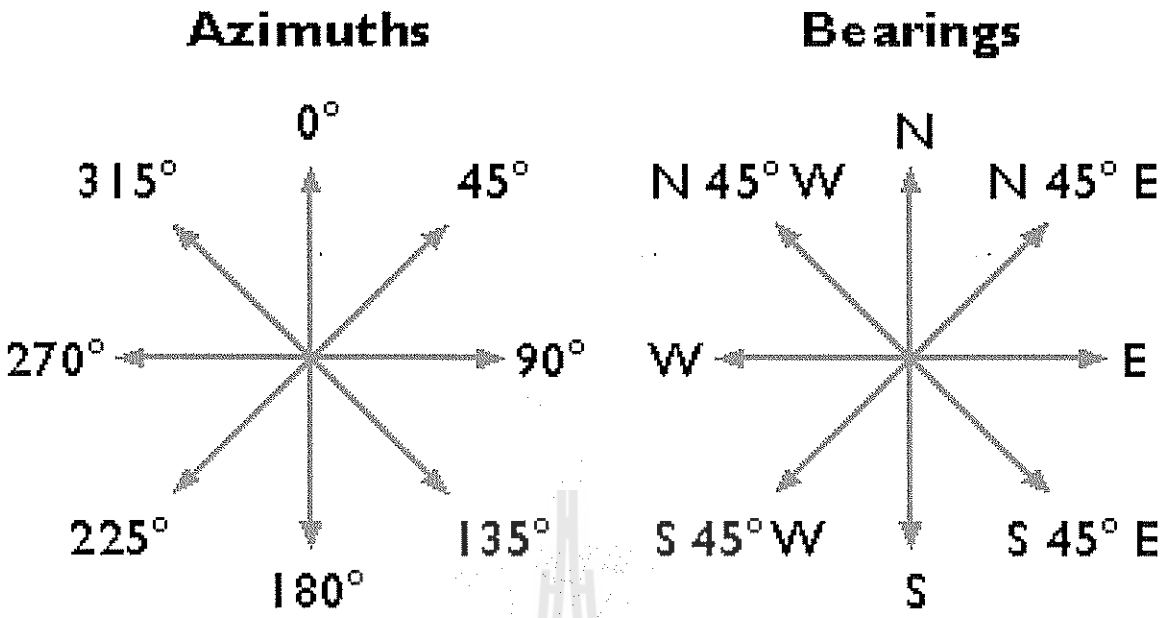
Dip: the inclination of the line on a plane.

Strike: the direction of horizontal line specified by its bearing or azimuth.

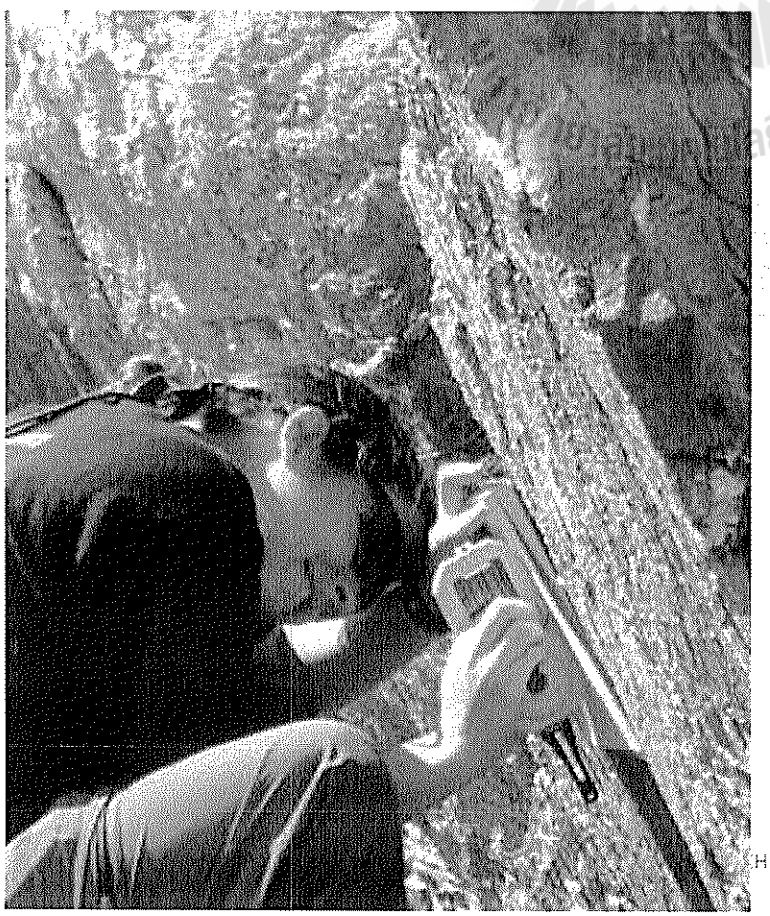


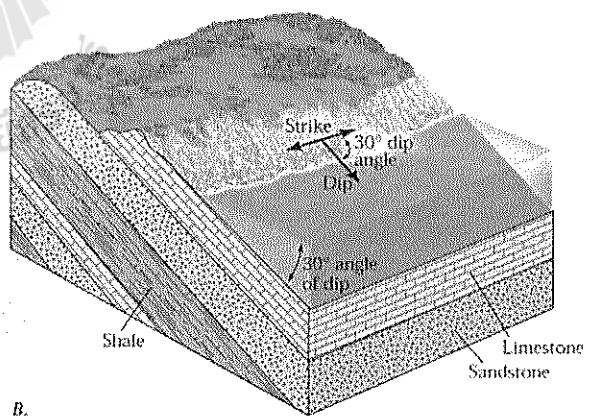
Dip: the angle which inclines from the horizontal.

Telling the strike



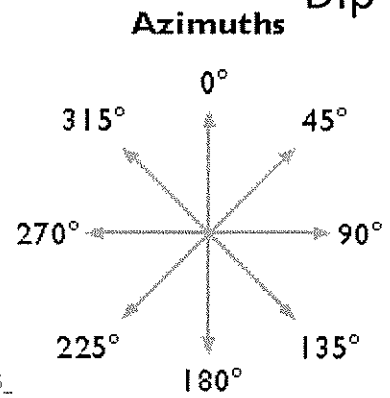
Telling the dip



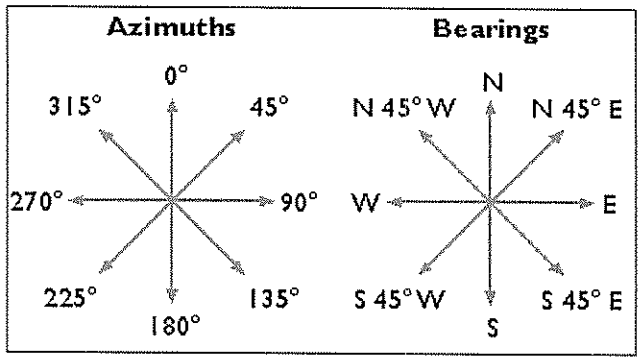


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Dip direction



Telling the attitude



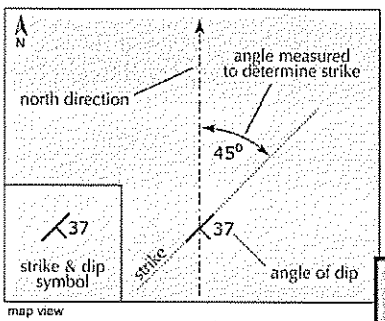
Strike notation: strike, dip

a) Bearing; N 65 W, 25 S
Azimuth; 295, 25 S

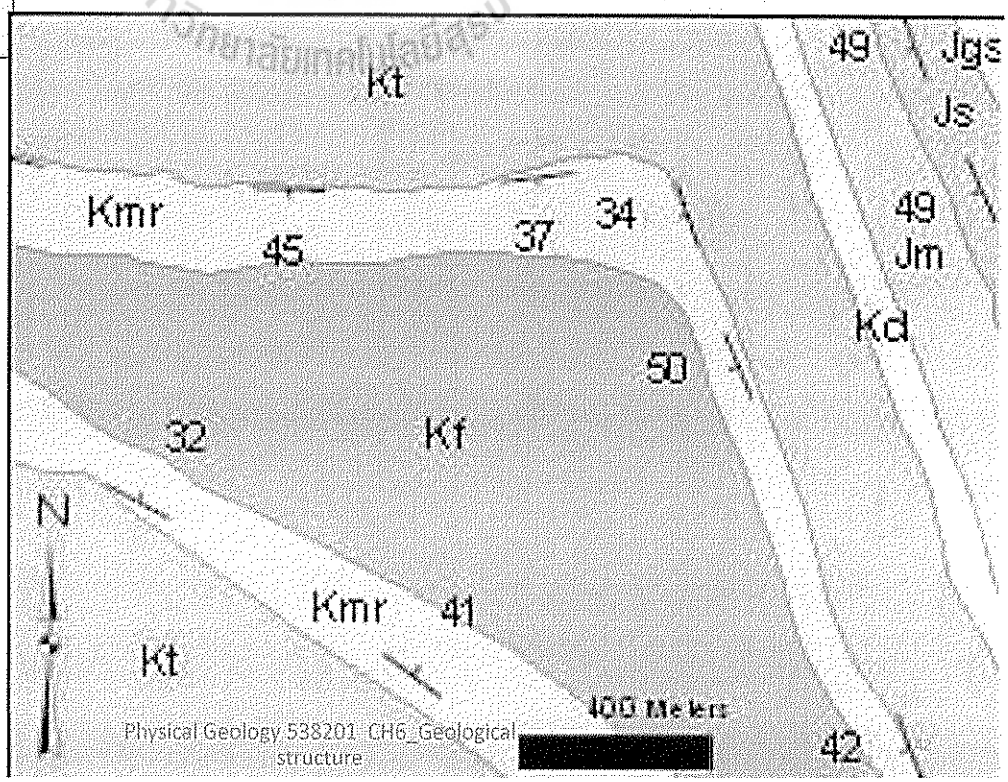
b) Bearing; N 50 E, 40 N
Azimuth;

c) Bearing;
Azimuth; 355, 70 N

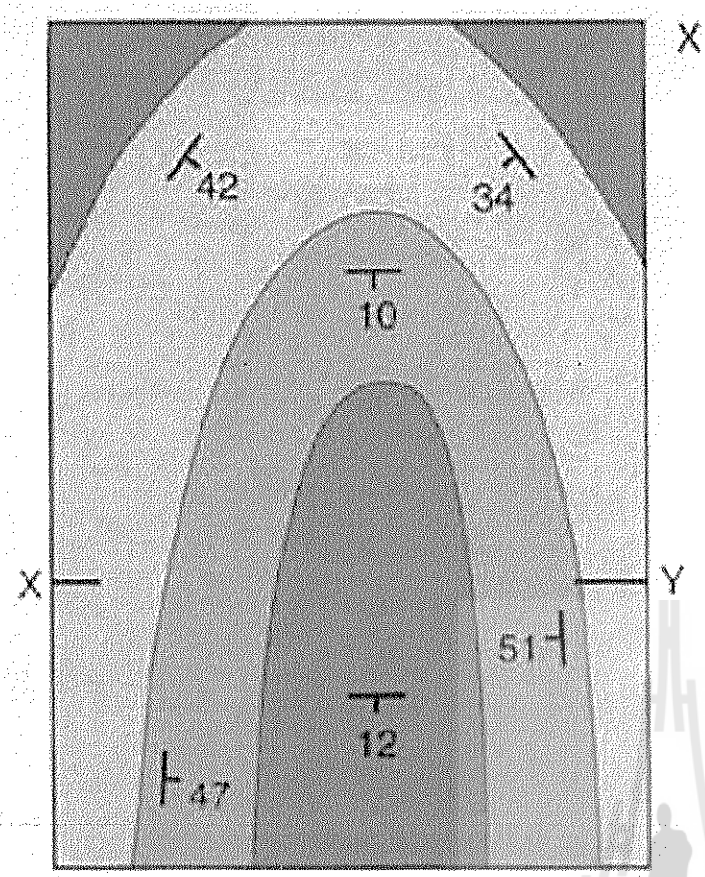
Physical Geology 538201 CH6_Geological structure



Strike/Dip symbol

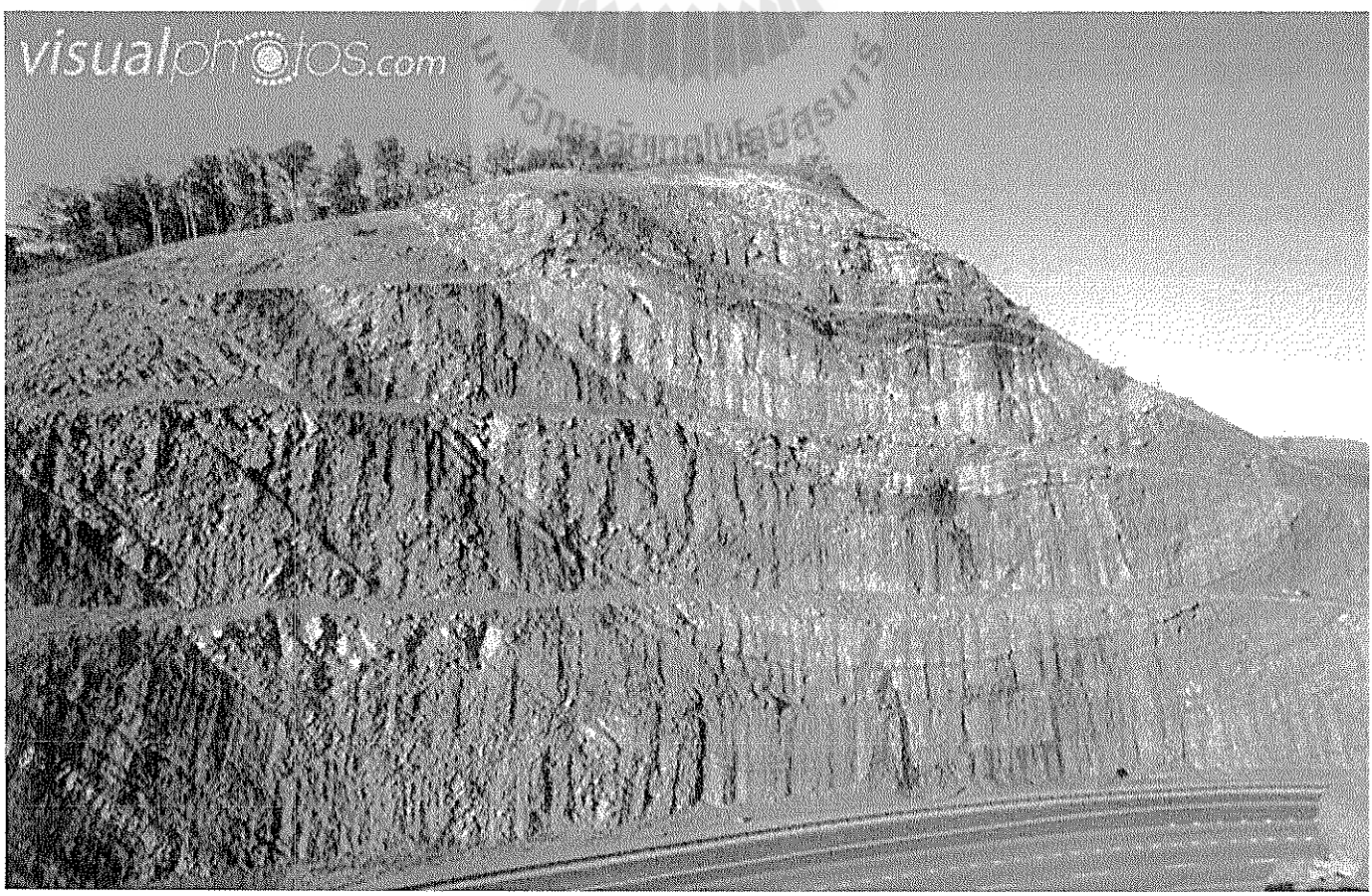


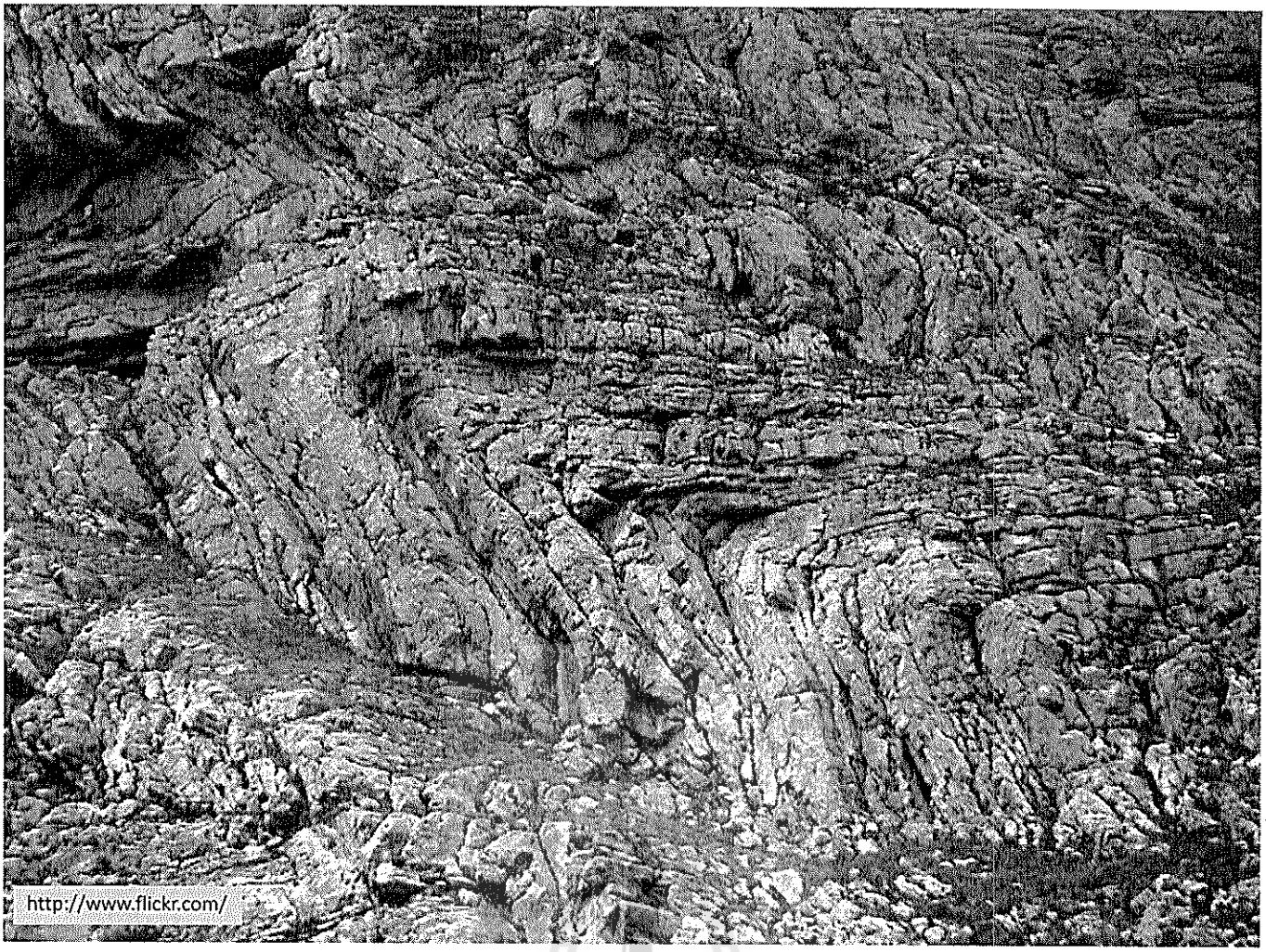
Physical Geology 538201 CH6_Geological structure



A. Map

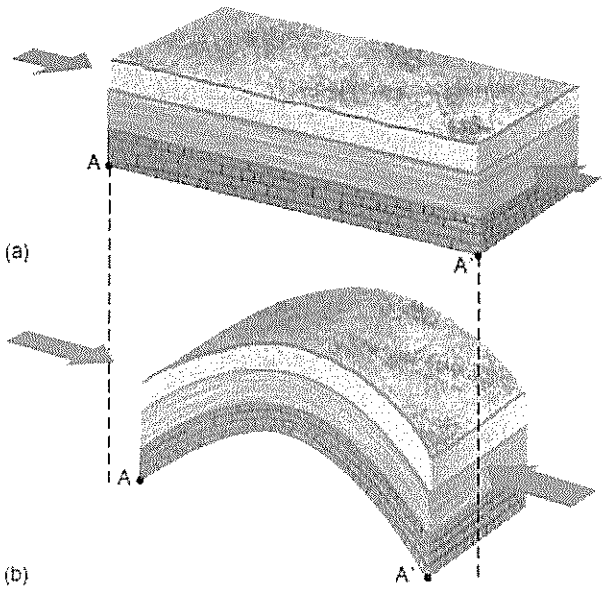
4. Folds

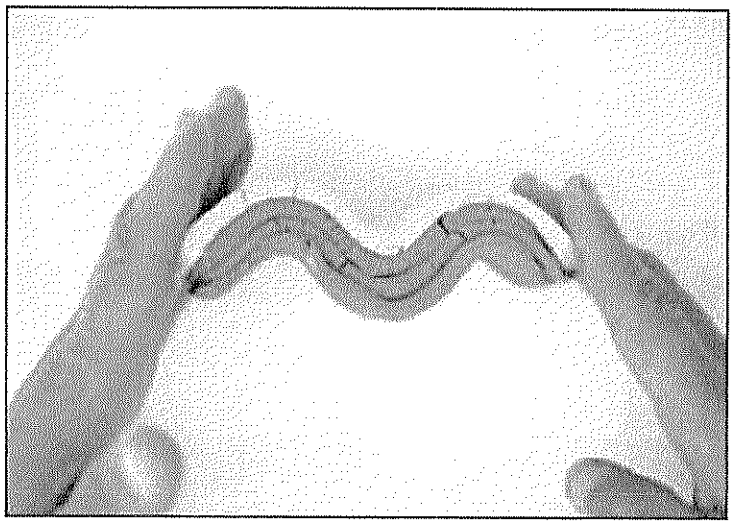


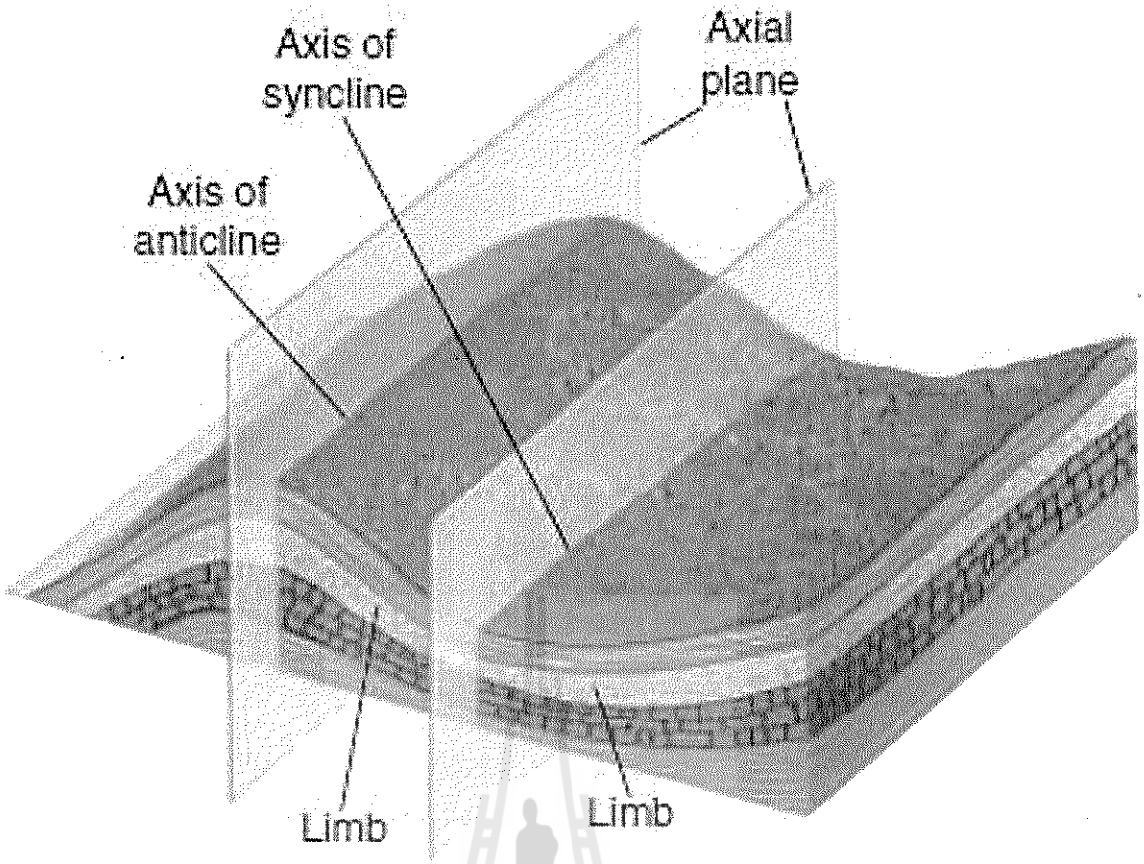


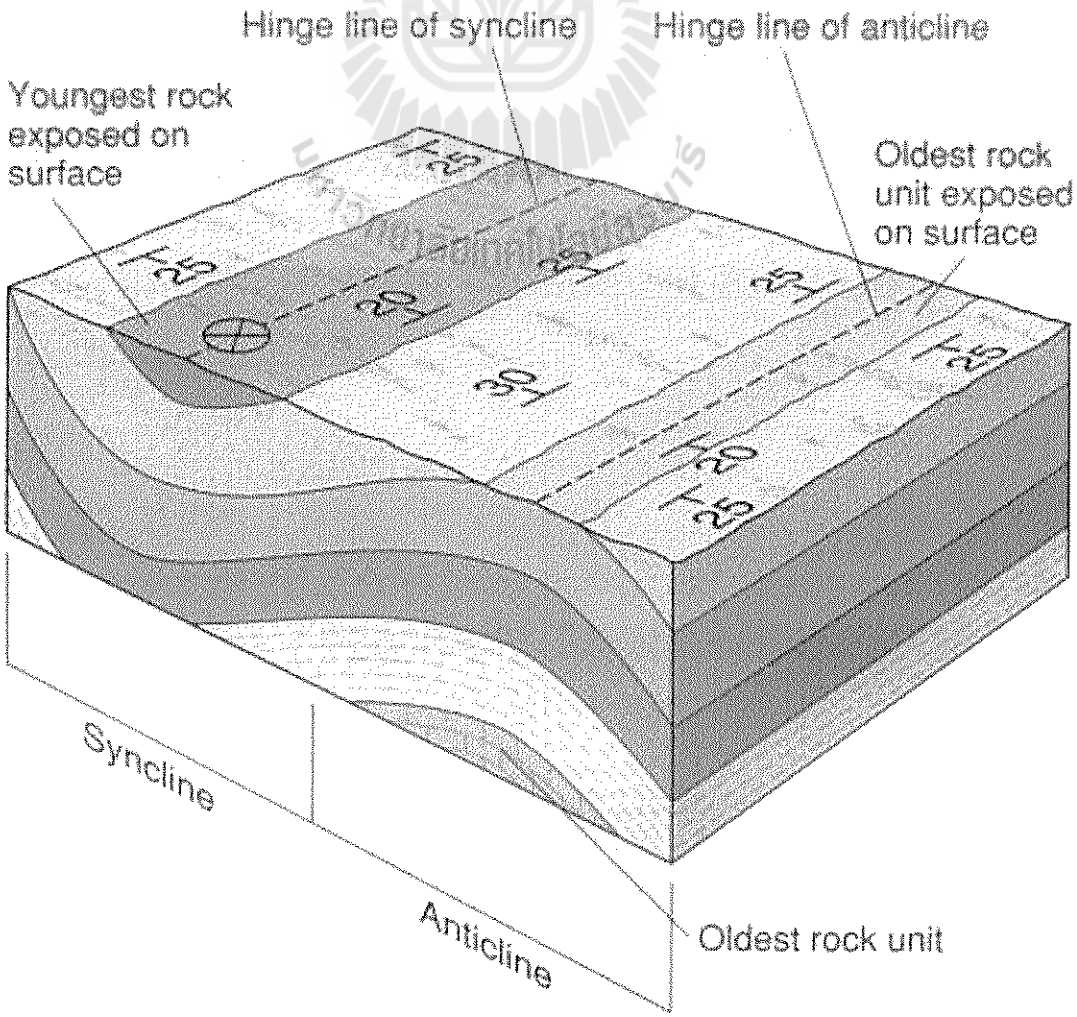
Fold: a bend in rock

- usually results from compressive stress.
- always shortens the horizontal distances in rock.
- usually occur as a repeating pattern of many folds.

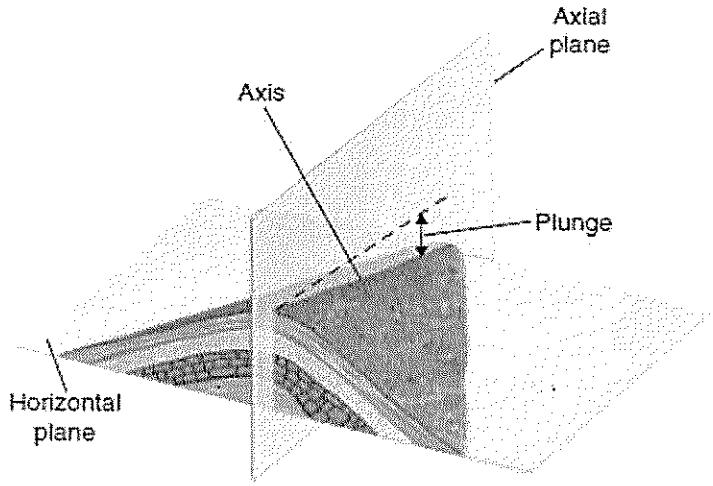




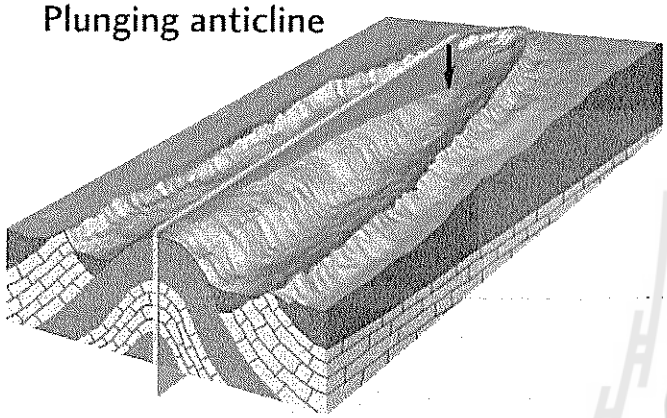

Axis of syncline
Axial plane
Axis of anticline
Limb
Limb


Hinge line of syncline
Hinge line of anticline
Youngest rock exposed on surface
Oldest rock unit exposed on surface
Syncline
Anticline
Oldest rock unit

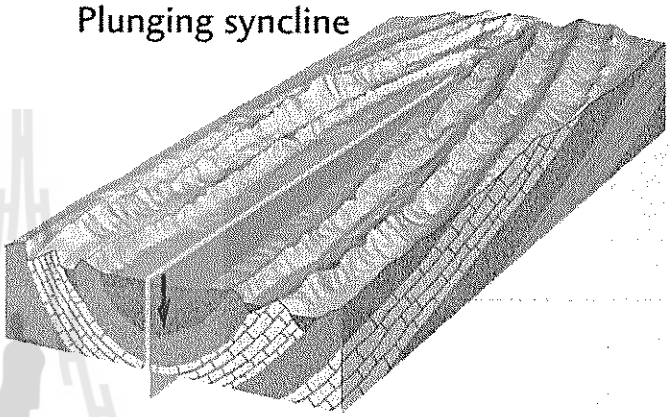
Plunging fold



Plunging anticline

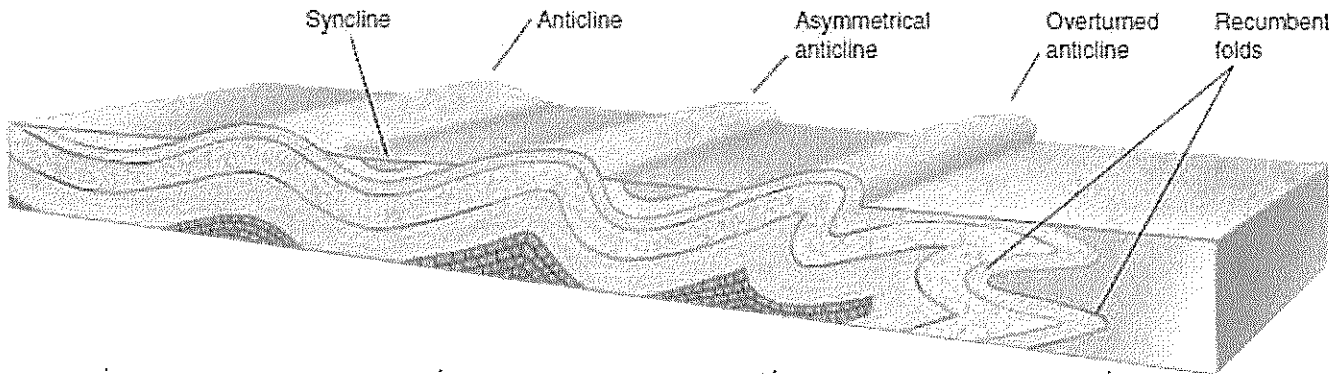


Plunging syncline

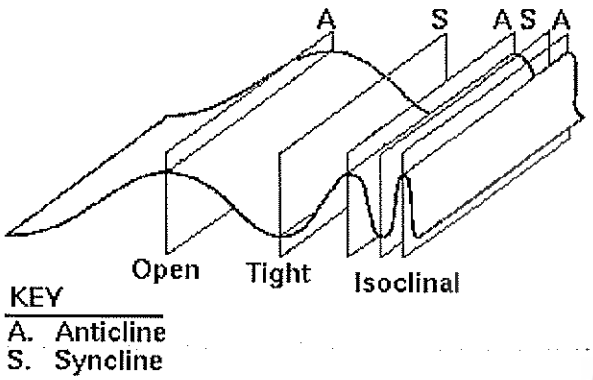


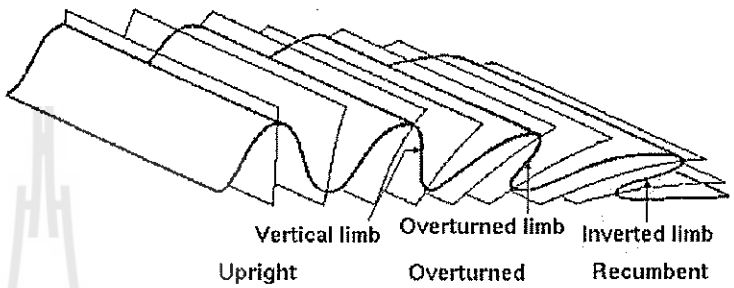


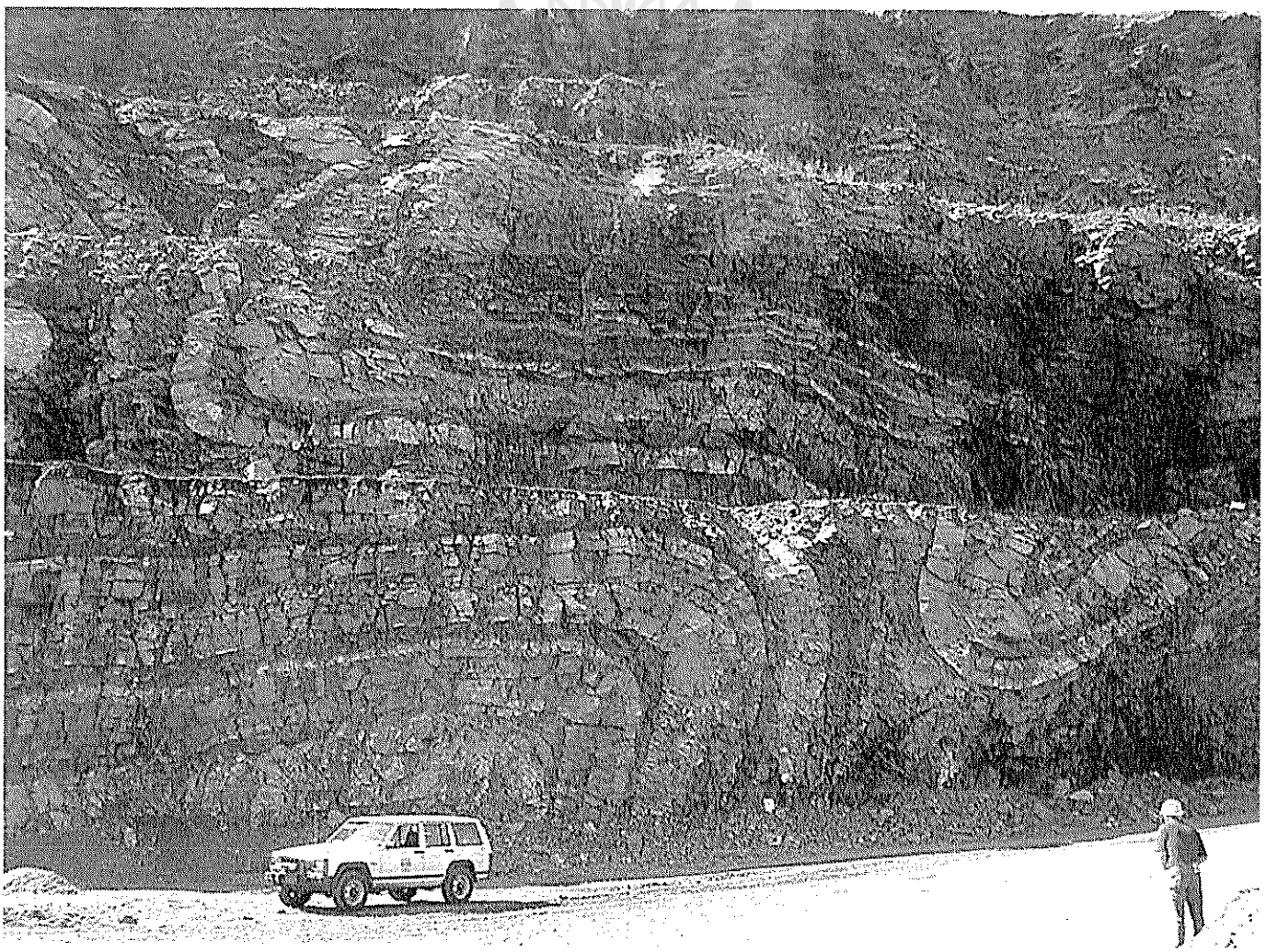
Sheep Mountain anticline between Greybull and Lovell, WY, USA. View to southeast. Anticline plunges to northwest. At left is northwest-plunging syncline.

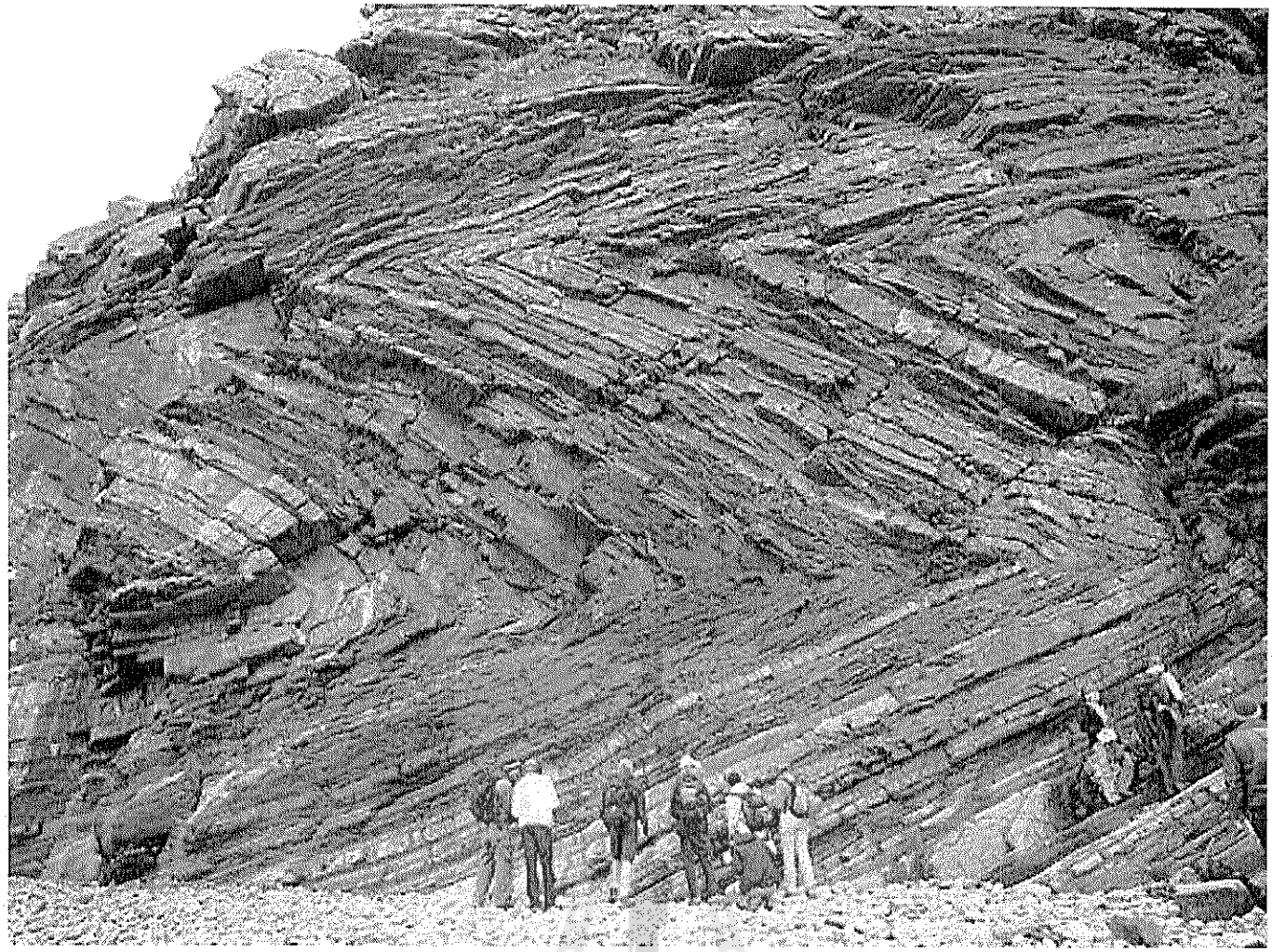


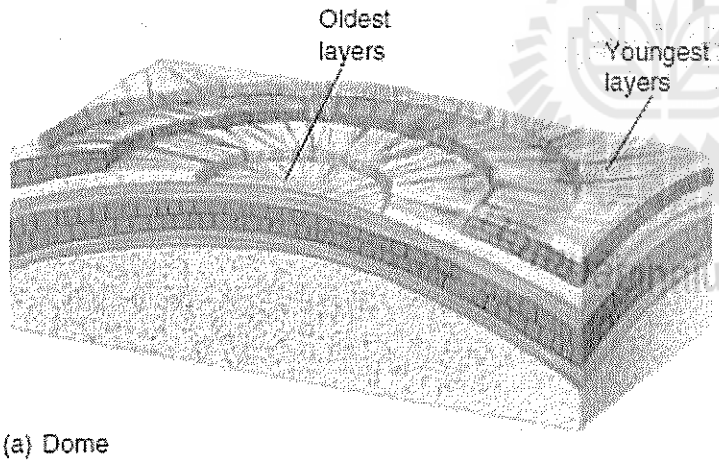
Fold classification





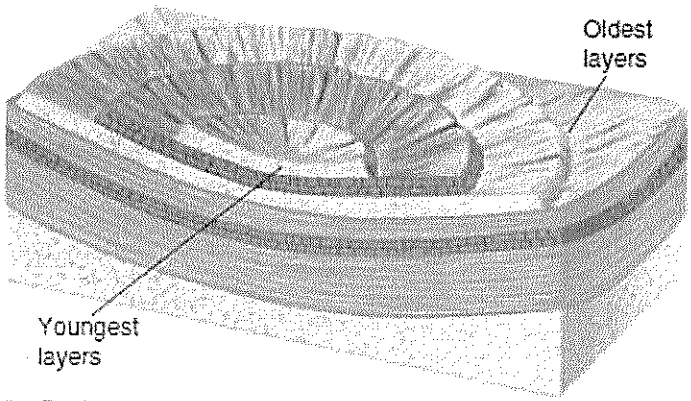






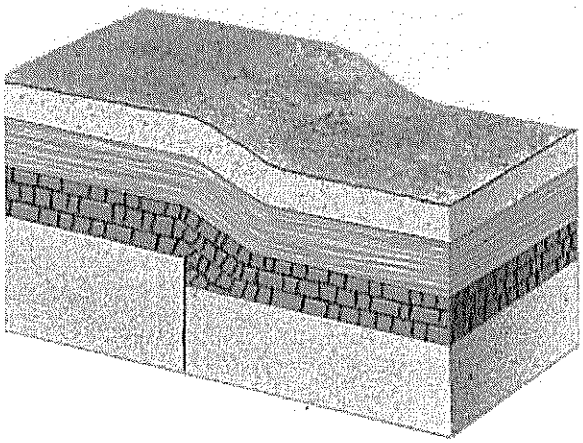
Dome: as a result of fold

(a) Dome

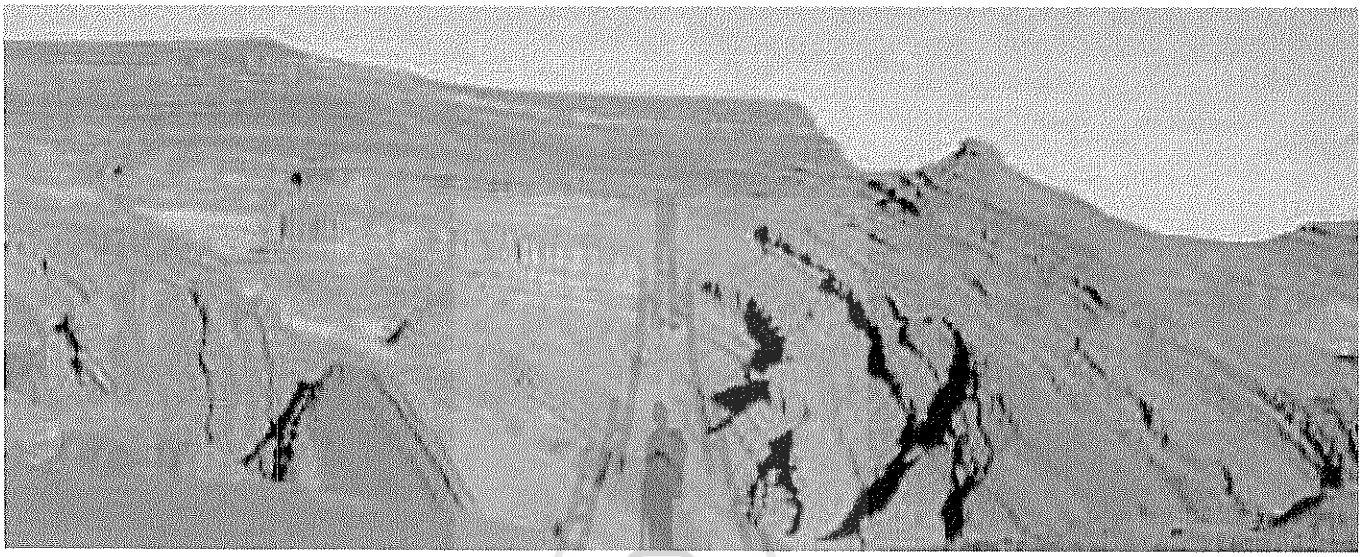


Basin: as a result of fold

(b) Basin

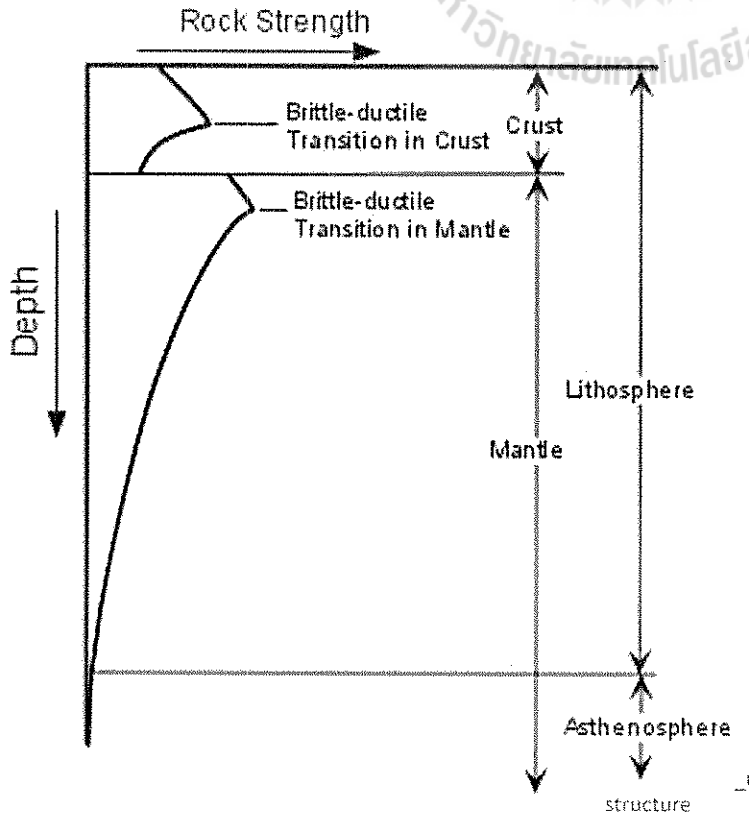


Monocline



5. Fractures in Rock

If a rock is brittle, it will fracture.



- Most rock at or near the surface is brittle, so nearly all exposed rock is jointed in some extent.

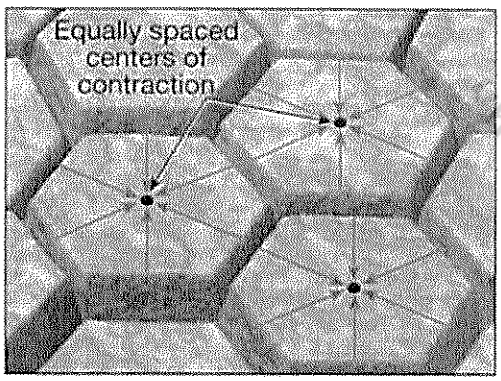
structure

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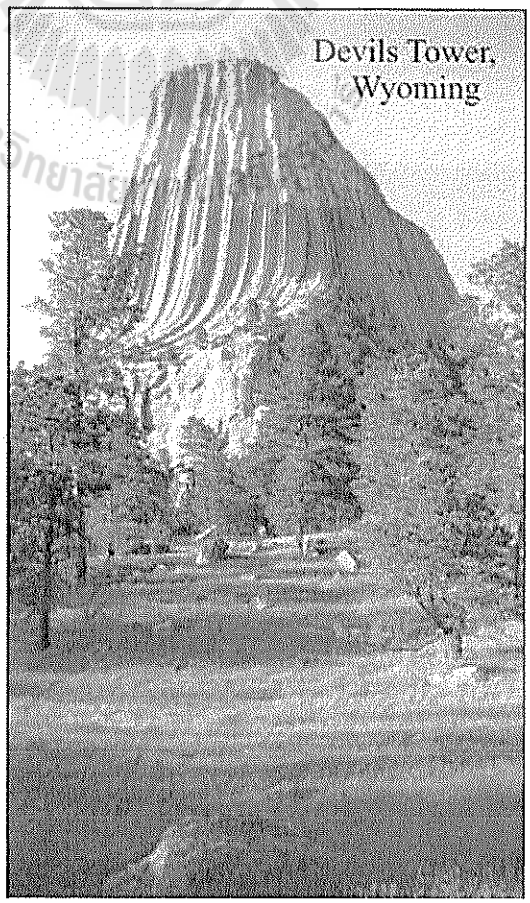
If there is no shear displacement, it is called a “joint”.



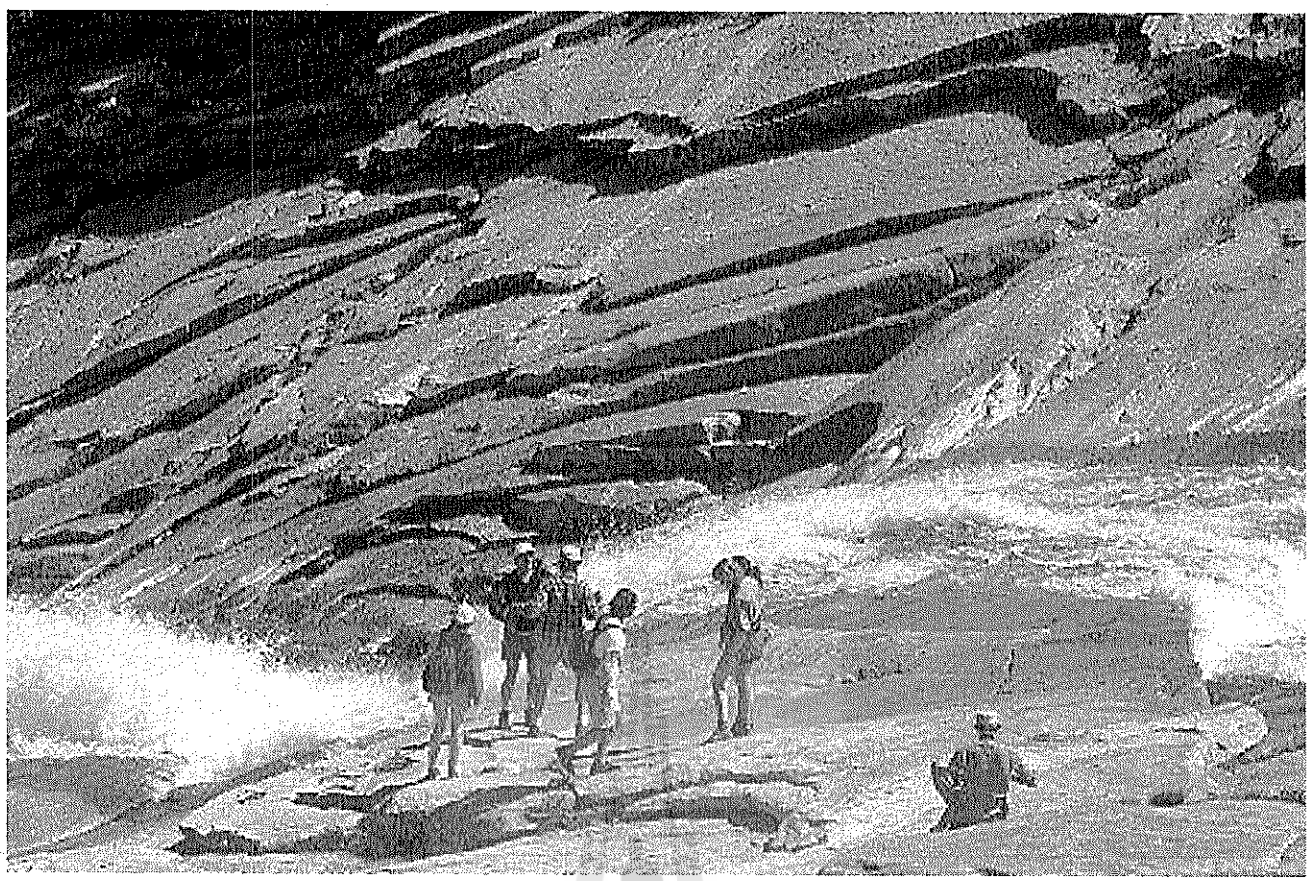
Primary joint: columnar jointing, sheet jointing





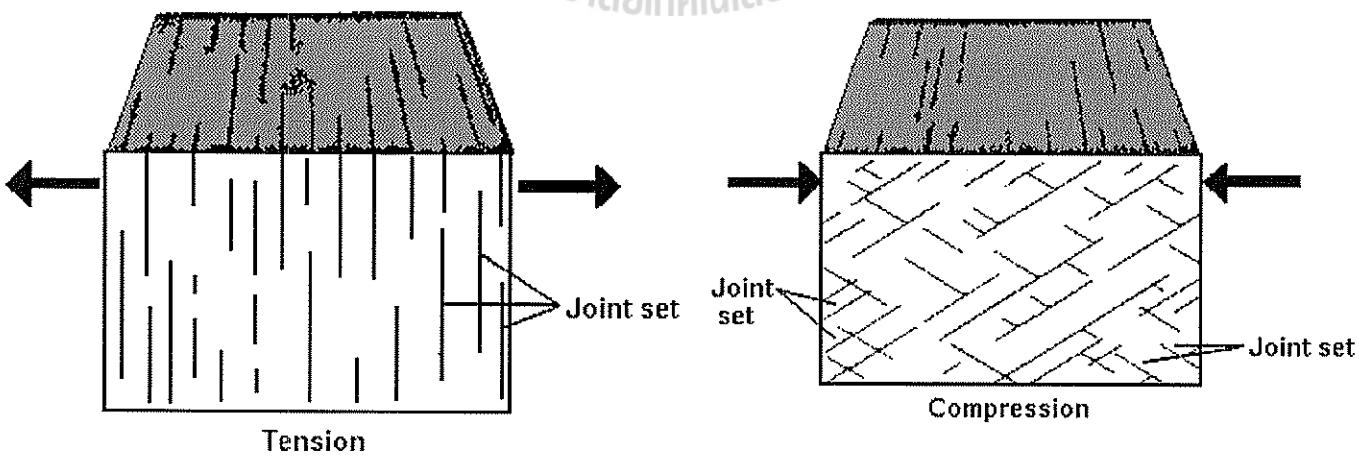


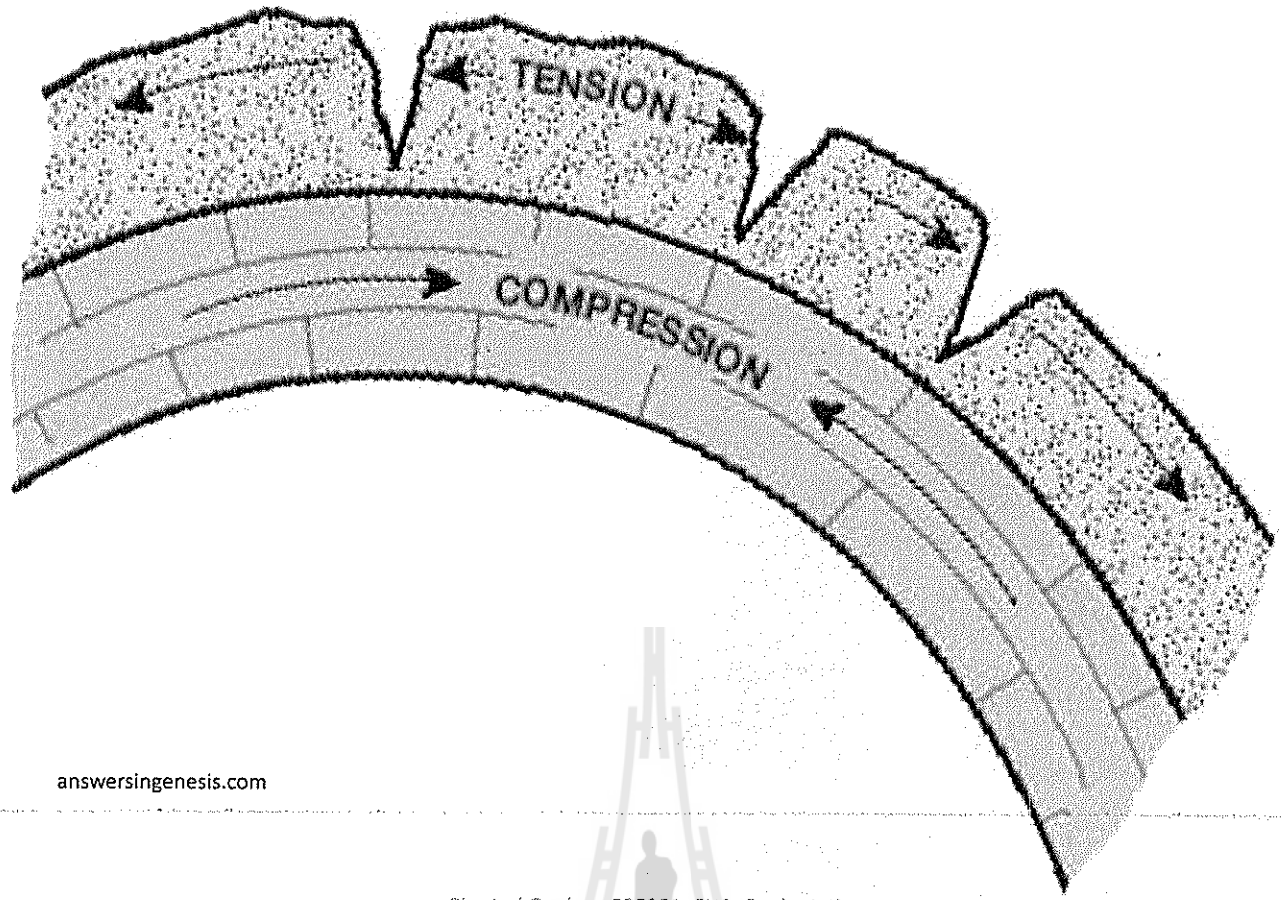
Columnar jointing in basalt



Sheet jointing in granite

Secondary joint: joints caused by tectonic stresses.



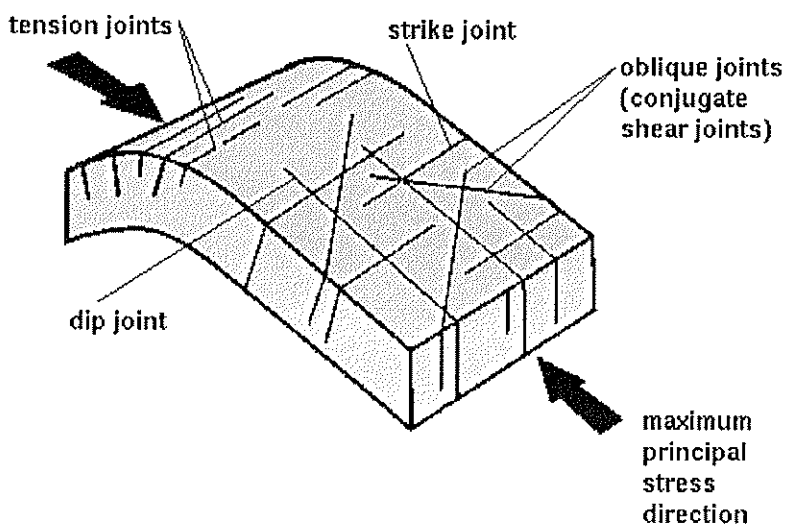


answersingenesis.com





Joints form at shallow depths in the crust where rock breaks in a brittle way and is pull apart slightly by tensional stresses caused by bending or regional uplift.

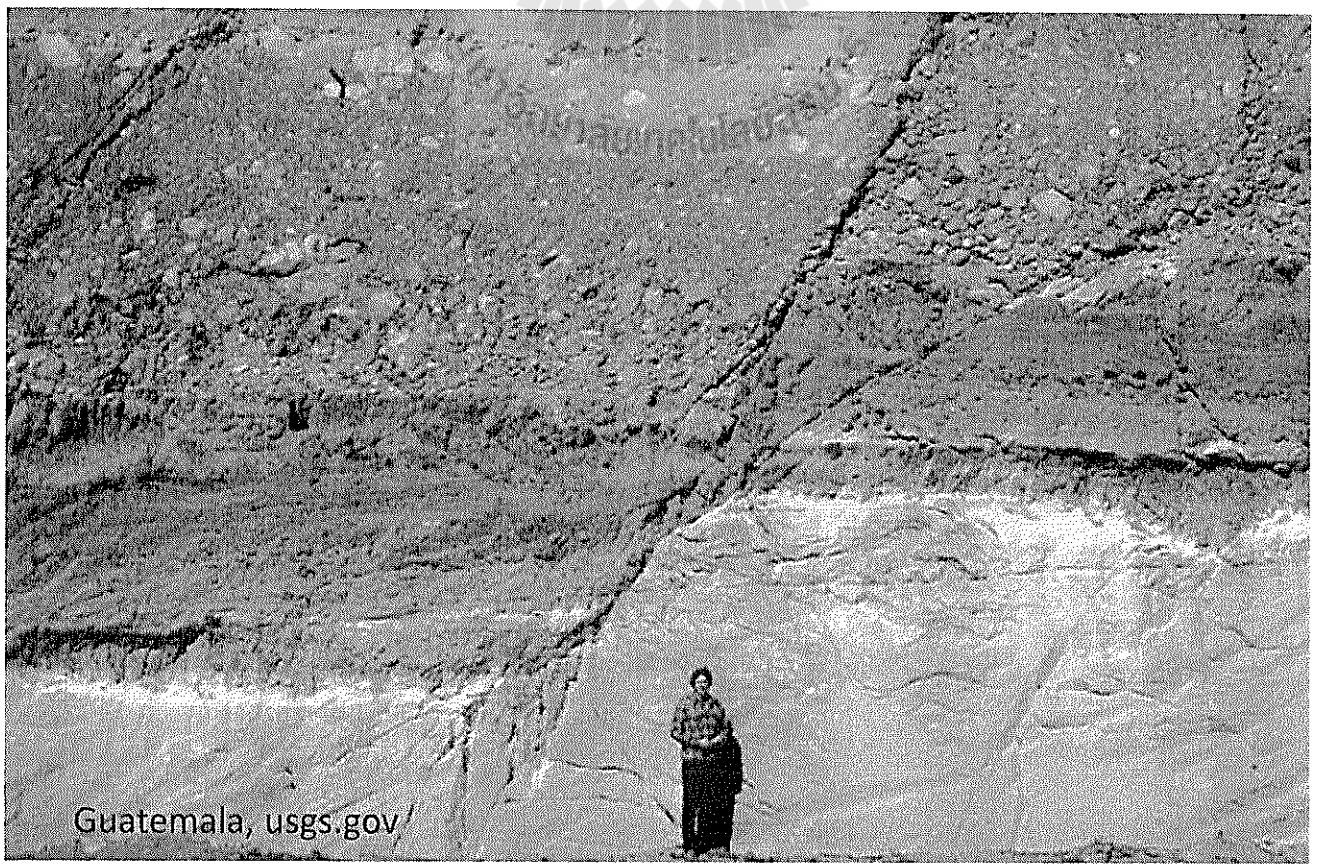


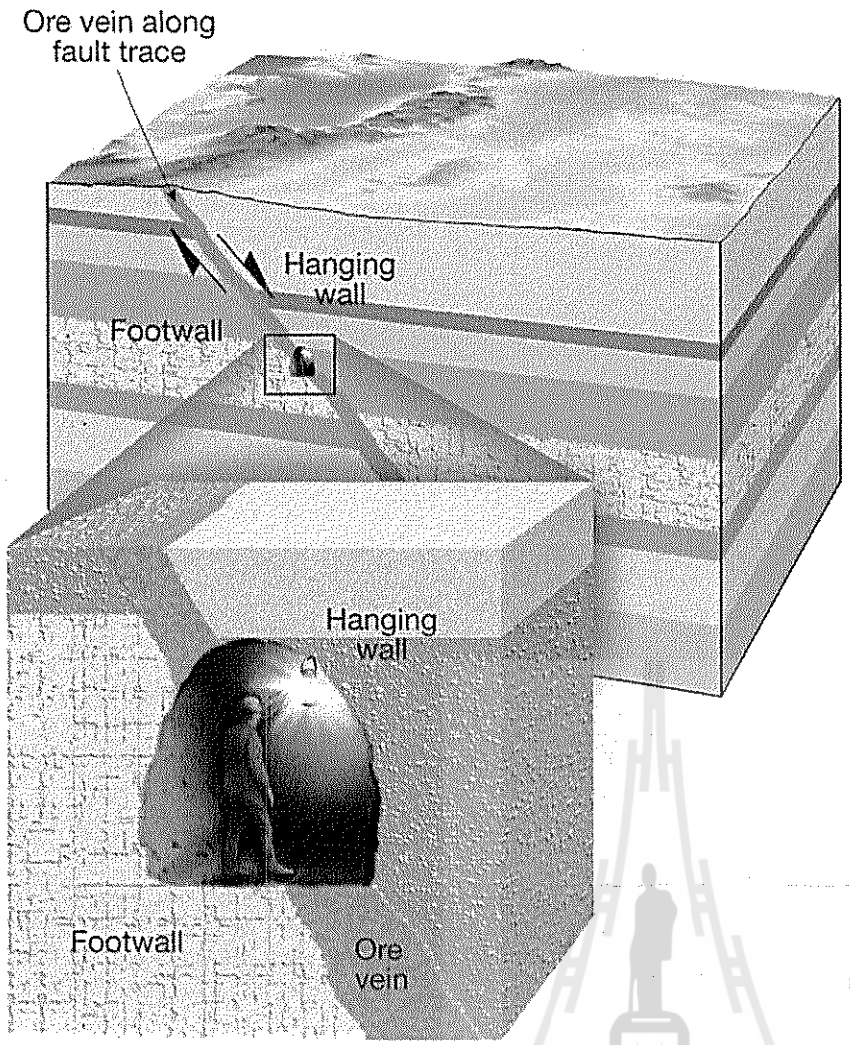
Where joints are oriented approximately parallel to one another ,a joint set can be defined.

Joint set



If the rock on either side of a fracture moves parallel to the fracture plane, it is called a “fault”.

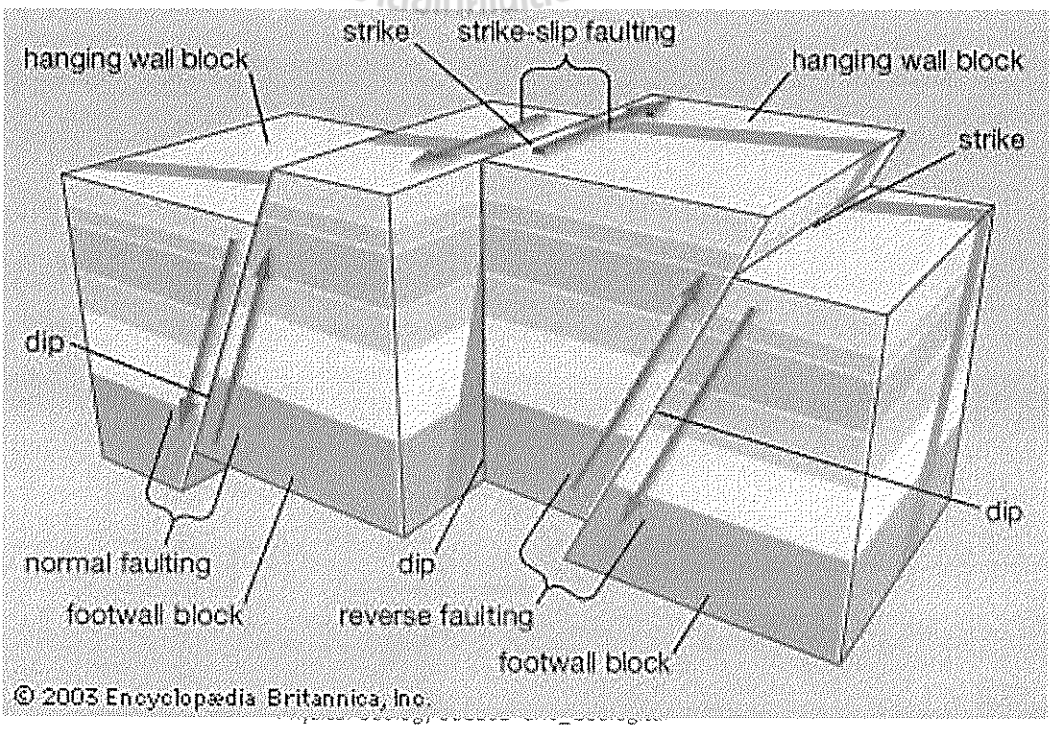




Define a fault:
Fault plane
Footwall block
Hanging wall block

Types of fault

1. Dip-slip fault: Normal fault, Reverse fault
2. Strike-slip fault: Right-lateral fault, Left-lateral fault
3. Oblique-slip fault

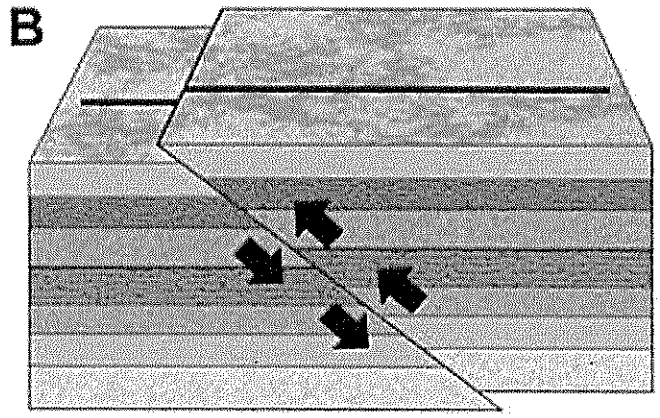


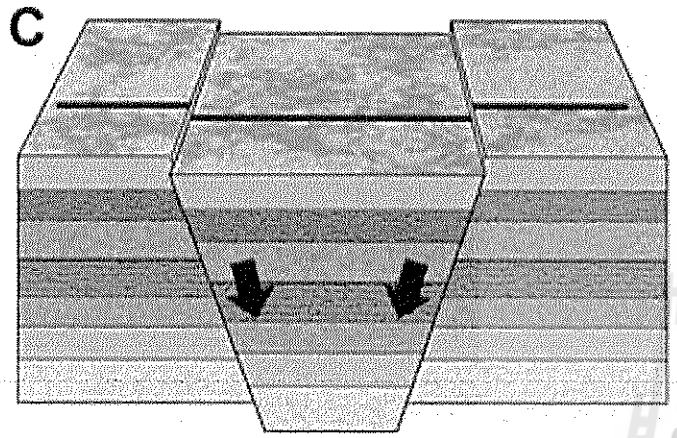
structure

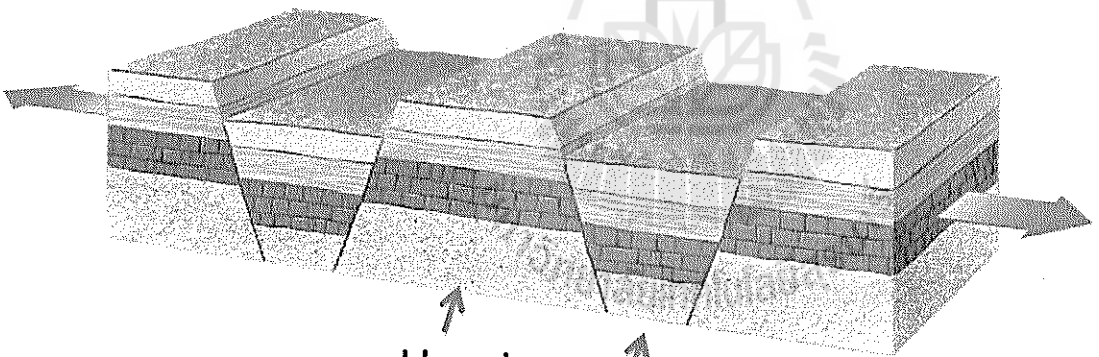
Dip-slip fault

Normal fault,

Reverse fault

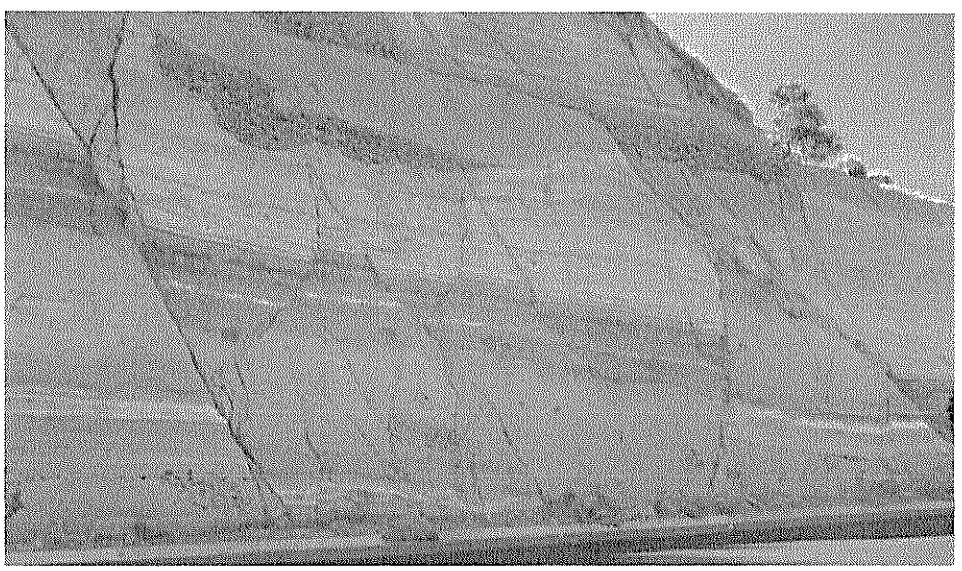






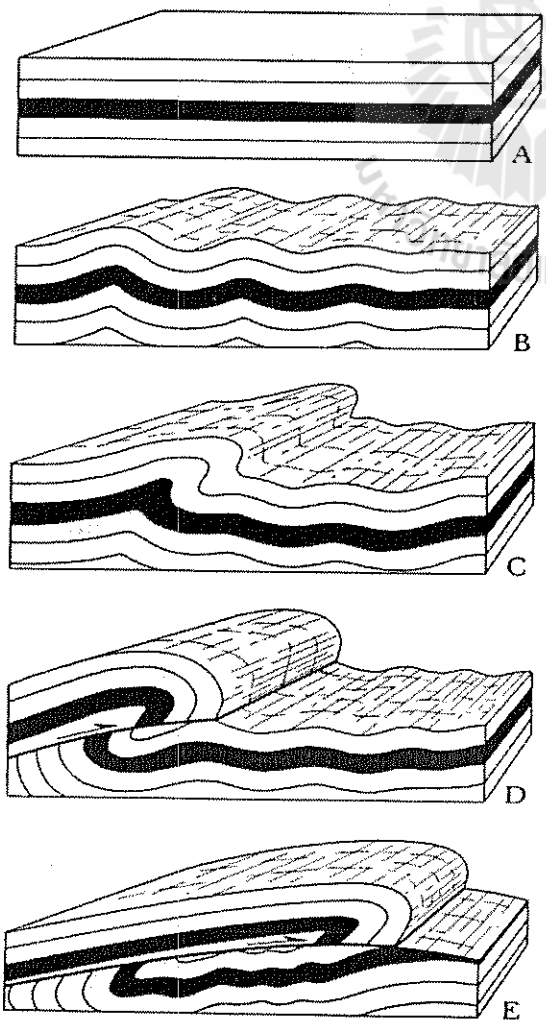
Horst

Graben



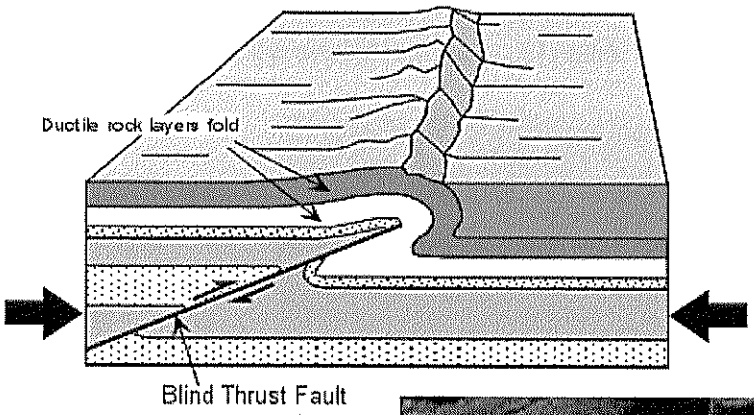


http://www.flickr.com/photos/httpwwwfacebookcomalbumphpid100001688331802aid22549/

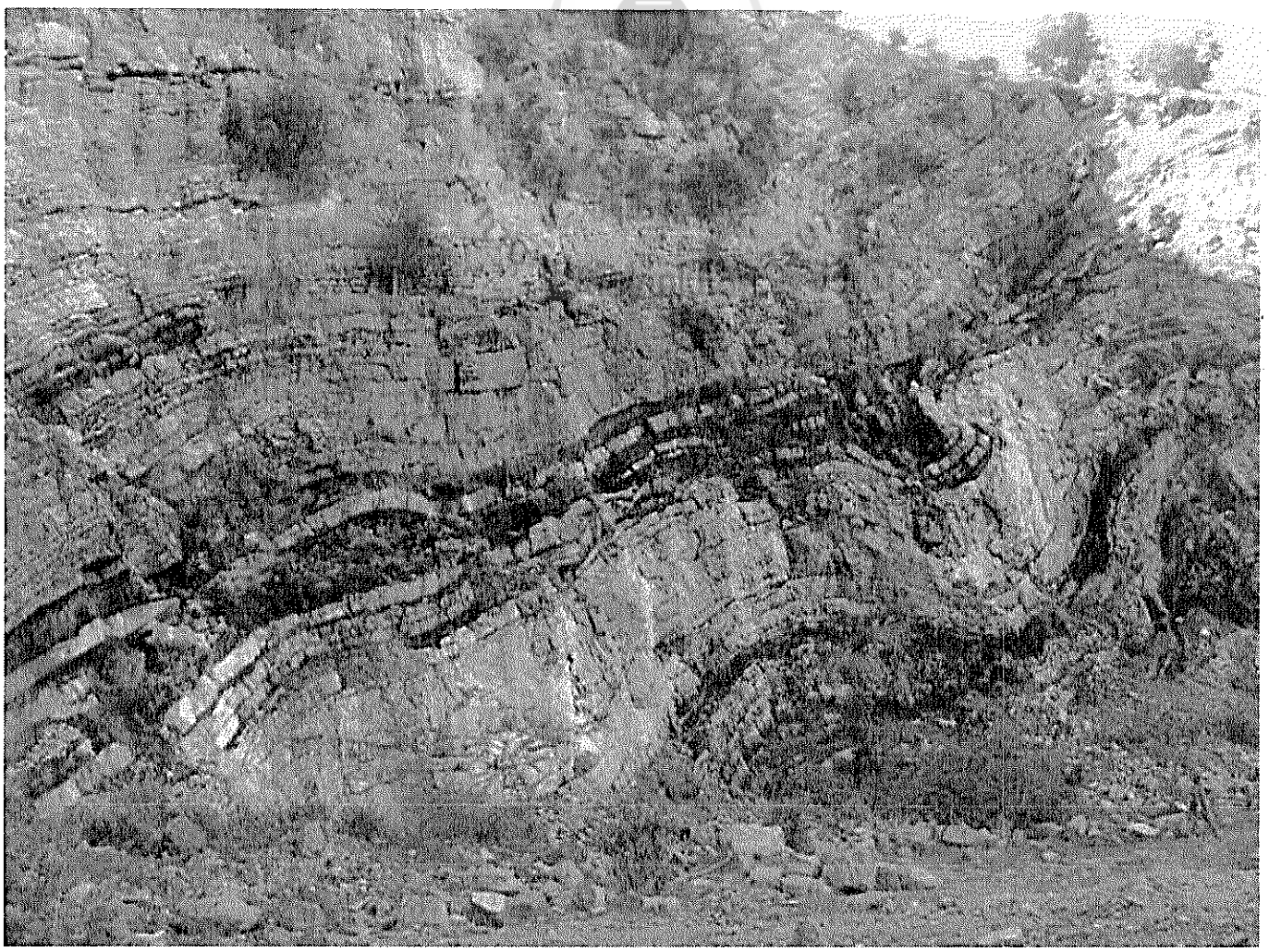


Thrust fault: low angle reverse fault with an angle of <20°

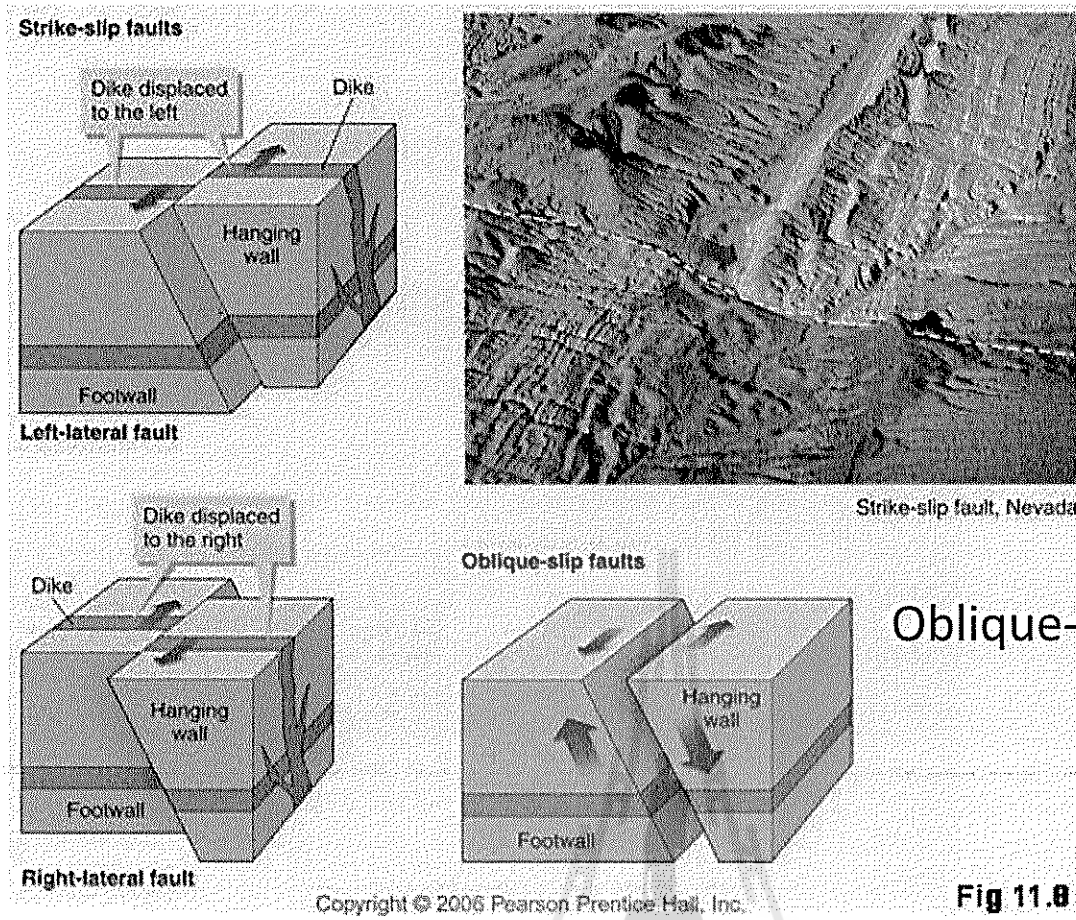
http://www.nps.gov


Ductile rock layers fold
Blind Thrust Fault





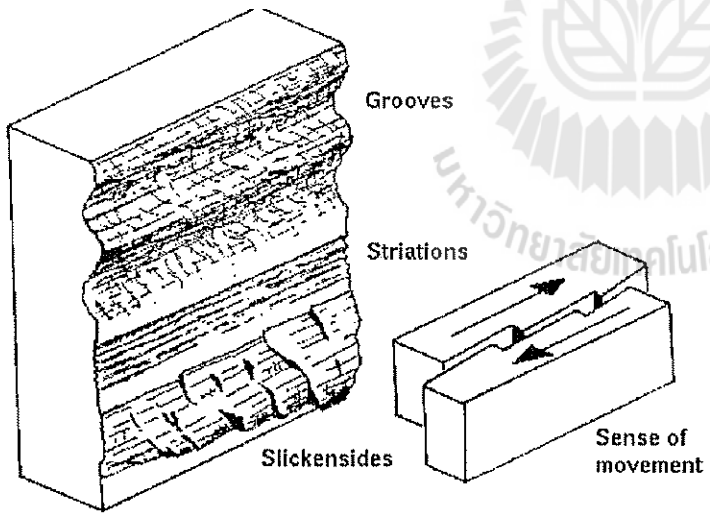
Strike-slip fault: Right-lateral fault, Left-lateral fault



Oblique-slip fault

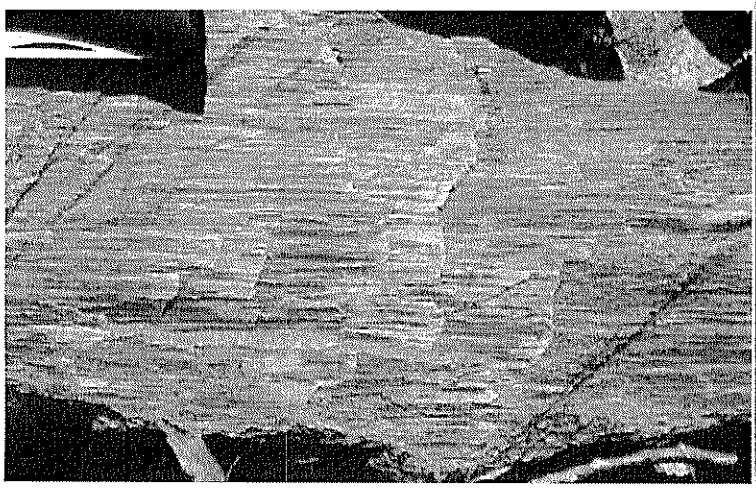
Copyright © 2006 Pearson Prentice Hall, Inc.

Fig 11.8



Features on a fault plane

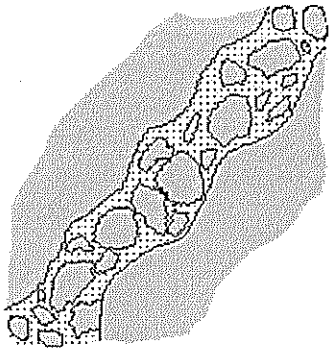
Grooves
Striations
Slickensides



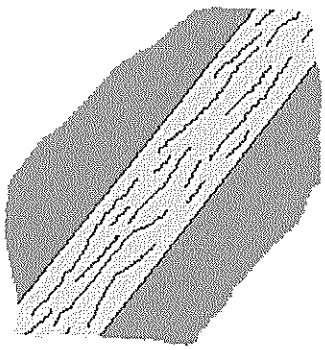


Features in a fault zone

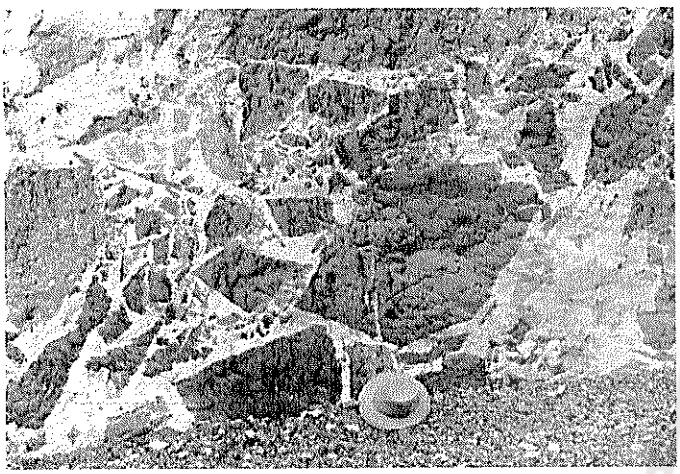
Fault breccias
Fault gouge

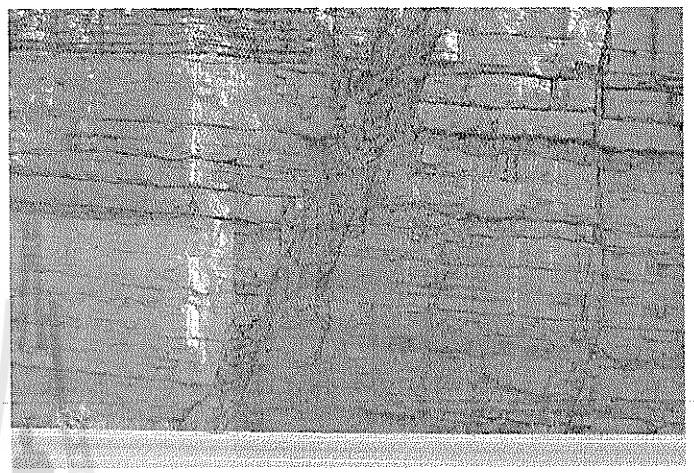


Breccia



Gouge





มหาวิทยาลัยเทคโนโลยีสุรนารี

Chapter 4
Geological Processes

กระบวนการเปลี่ยนแปลงของโลก

Contents

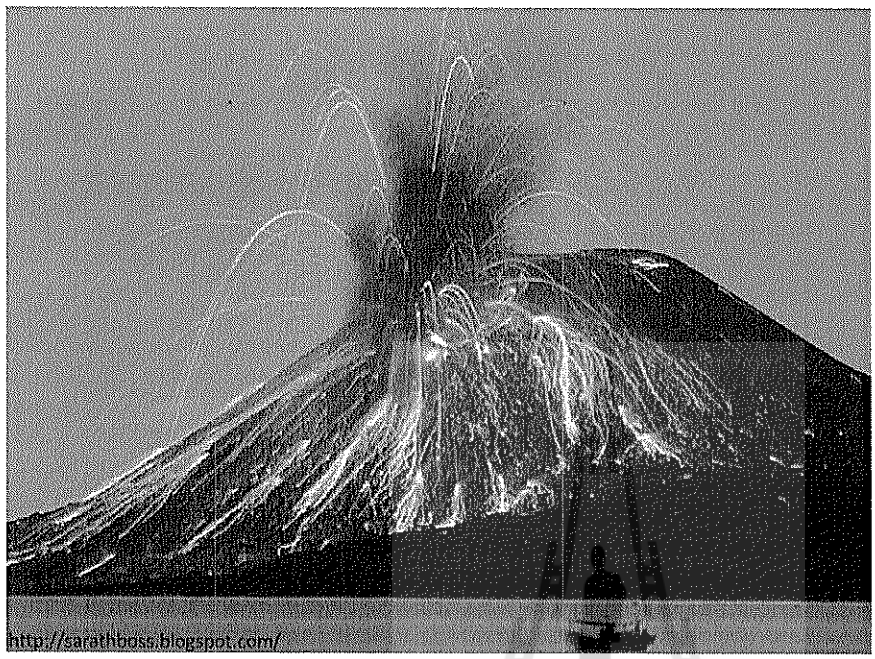
1. Internal processes
   - Earthquake
   - Volcano

2. External processes
   - Weathering
   - Erosion
   - Soil formation

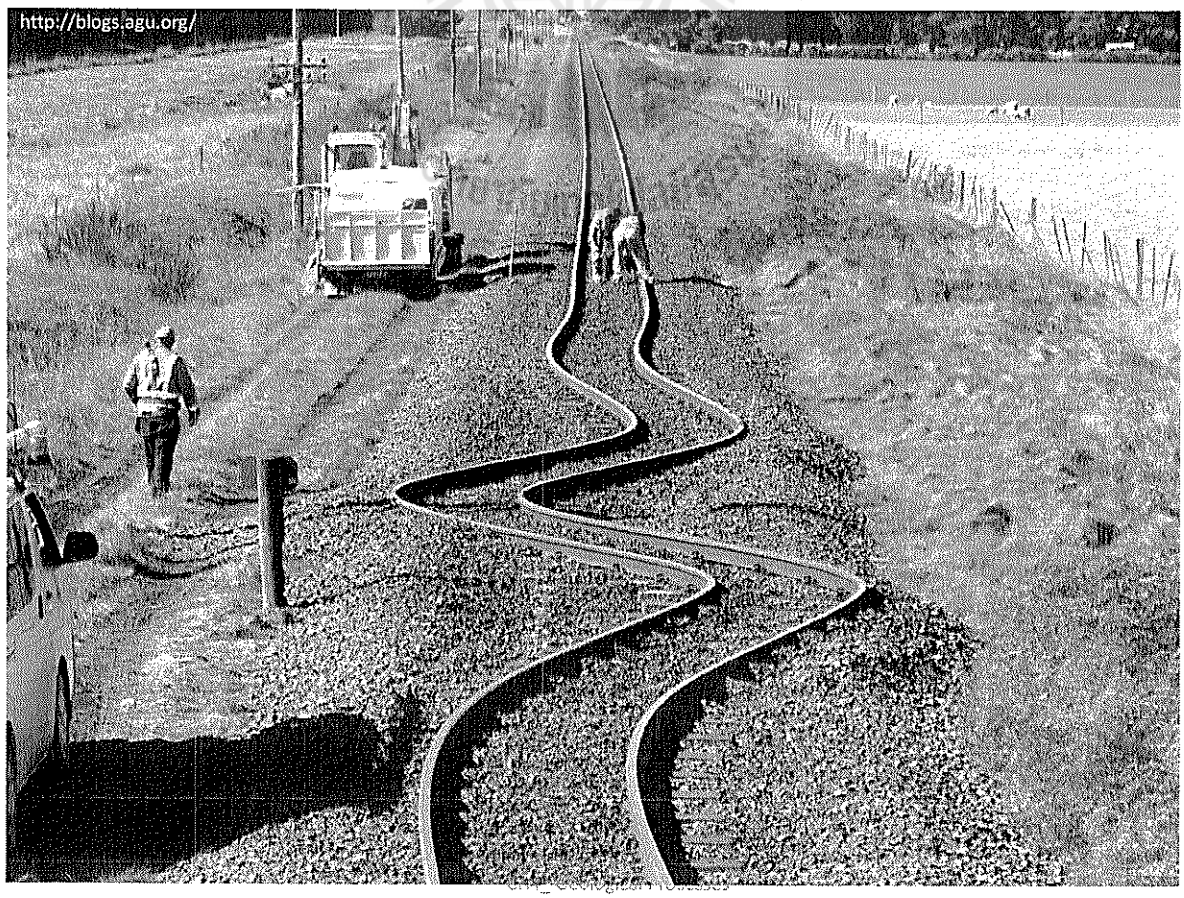
Internal processes: geological changes originating from the earth's interior

Contents

- Earthquake
- Volcano

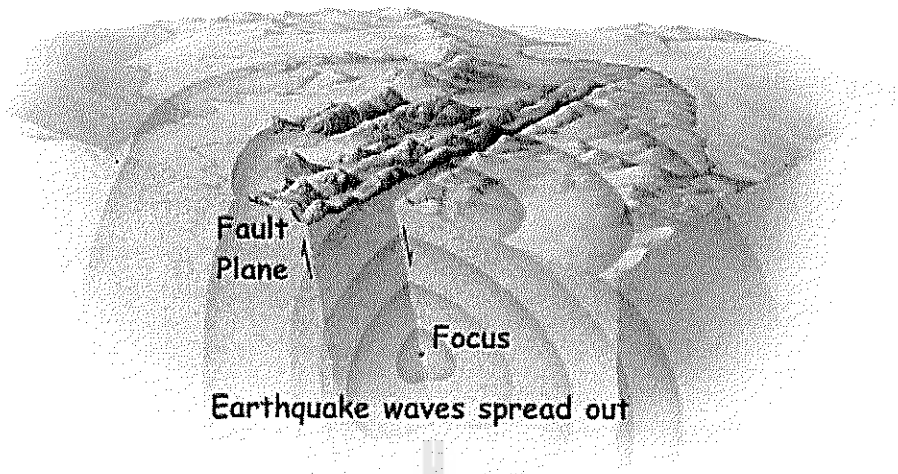


Mt. Krakatoa, Indonesia, 1883: Death 36,000 – The devastation wrought by the volcanic explosion left 75% of the island in total ruin. The sound blast was the loudest that was ever recorded and was even heard as far as Australia



Earthquake

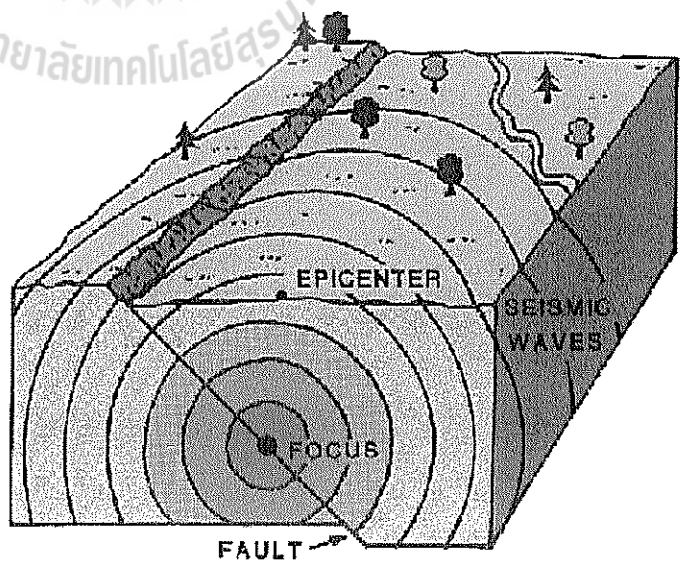
Earthquake: an episode of ground shaking



Fault: fracture in the earth's crust

Earthquakes: caused by faulting or the abrupt movement on a fault.

Energy is released as shock waves, which move outward form the earthquake's focus (the point of initial movement)



Epicenter: the point on the surface directly above the focus

((((((Seismic wave))))))

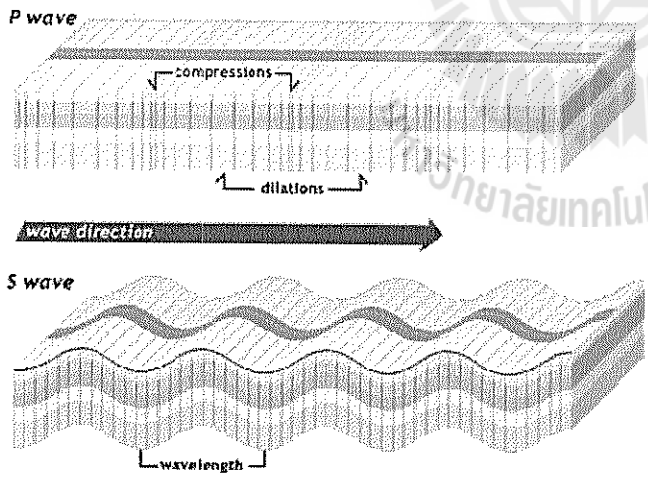
Body waves and Surface waves

Body waves: travel inside the Earth's interior

P-waves (primary wave, pressure wave): the particles vibrate along or parallel to the direction of wave propagation. **fastest waves

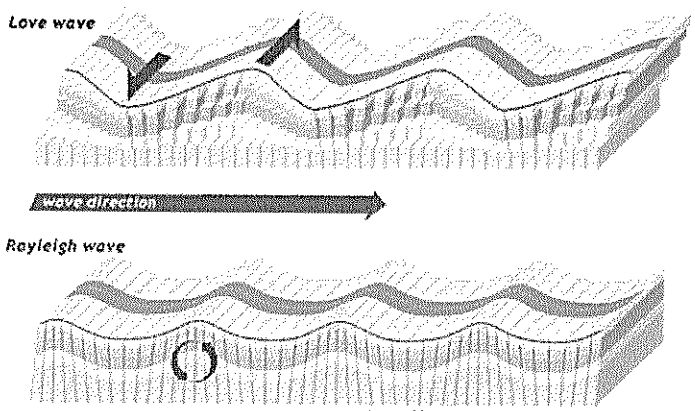
S-waves (shear wave, secondary wave, or transverse wave): the particles vibrate perpendicular to the direction of the wave propagation.

538201 Physical Geology_
CH4_ Geological Processes



Body waves

Surface waves

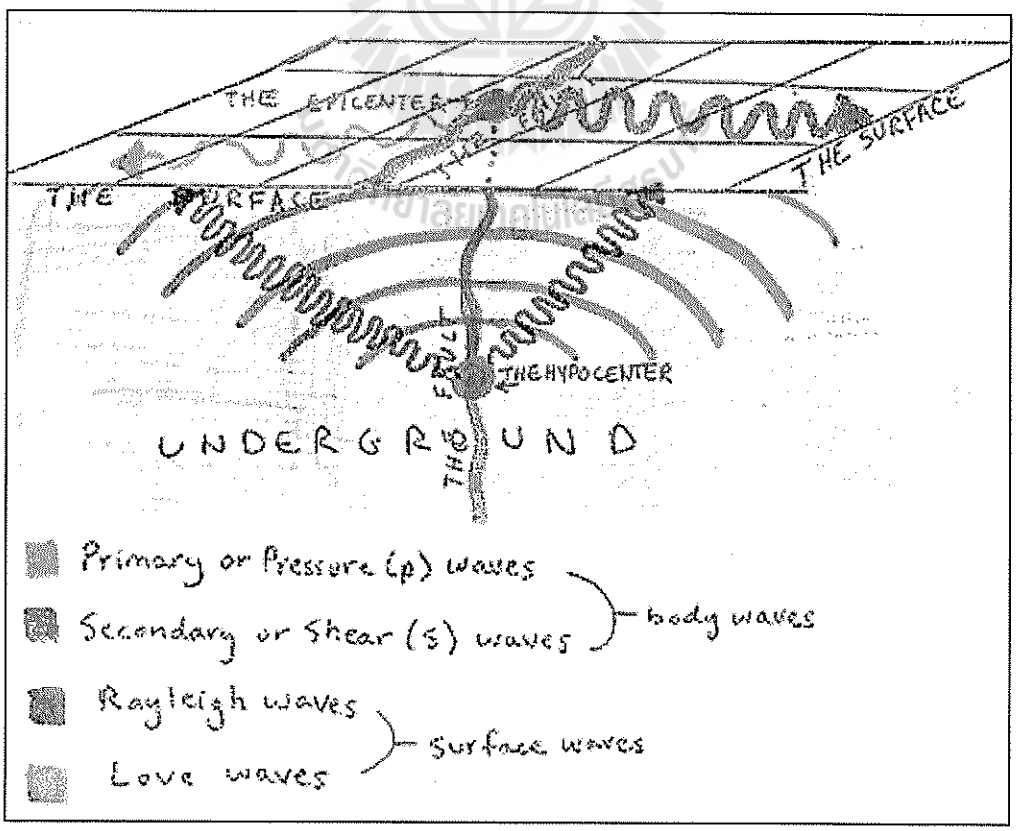


http://www.sms-tsunami-warning.com

Surface waves: waves that travel along the Earth's surface and the layers near the surface.

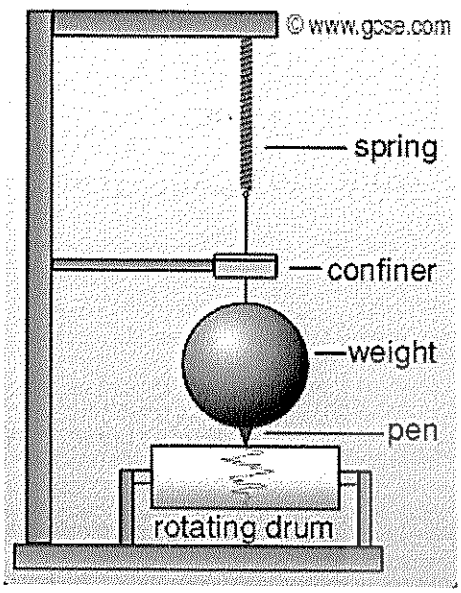
Love waves: the particles vibrate on a horizontal plane and perpendicular to the direction of wave propagation.

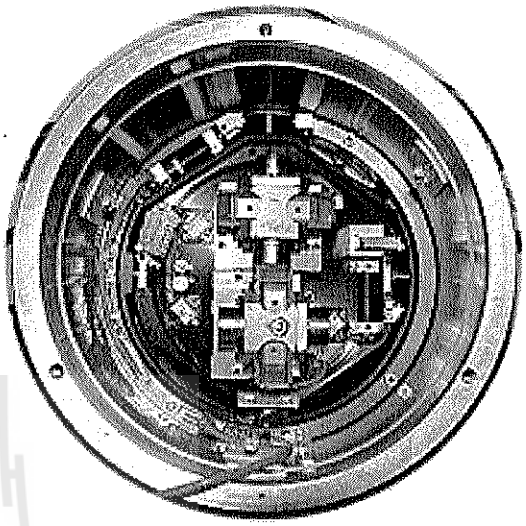
Rayleigh waves: the particles vibrate on a vertical plane and follow a retrograde ellipse.



Seismometer

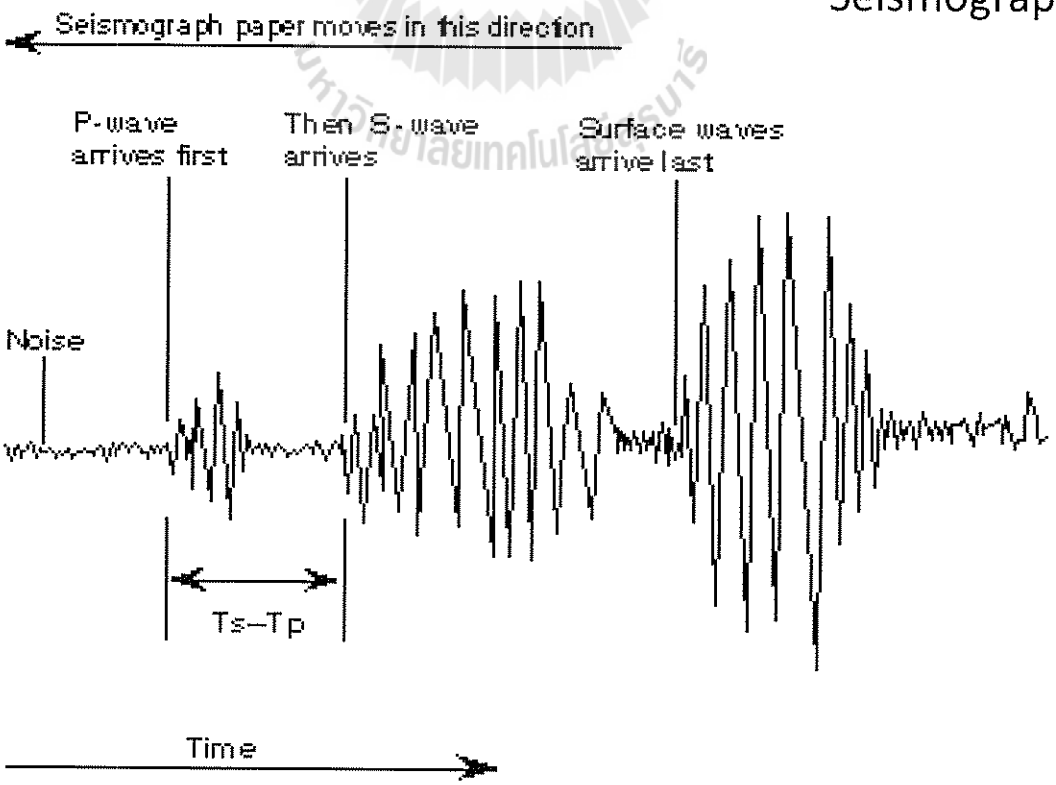
Seismometers: instruments that measure motions of the ground, including seismic waves.





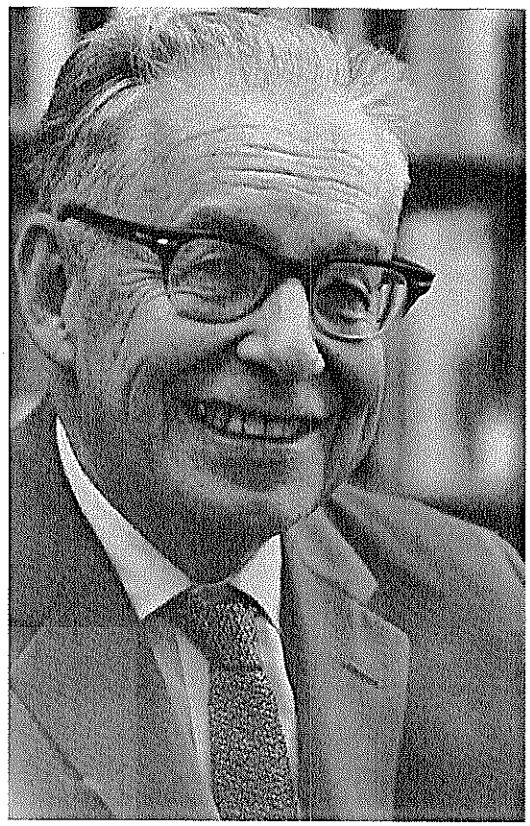
A low-frequency 3-direction ocean-bottom seismometer (cover removed).

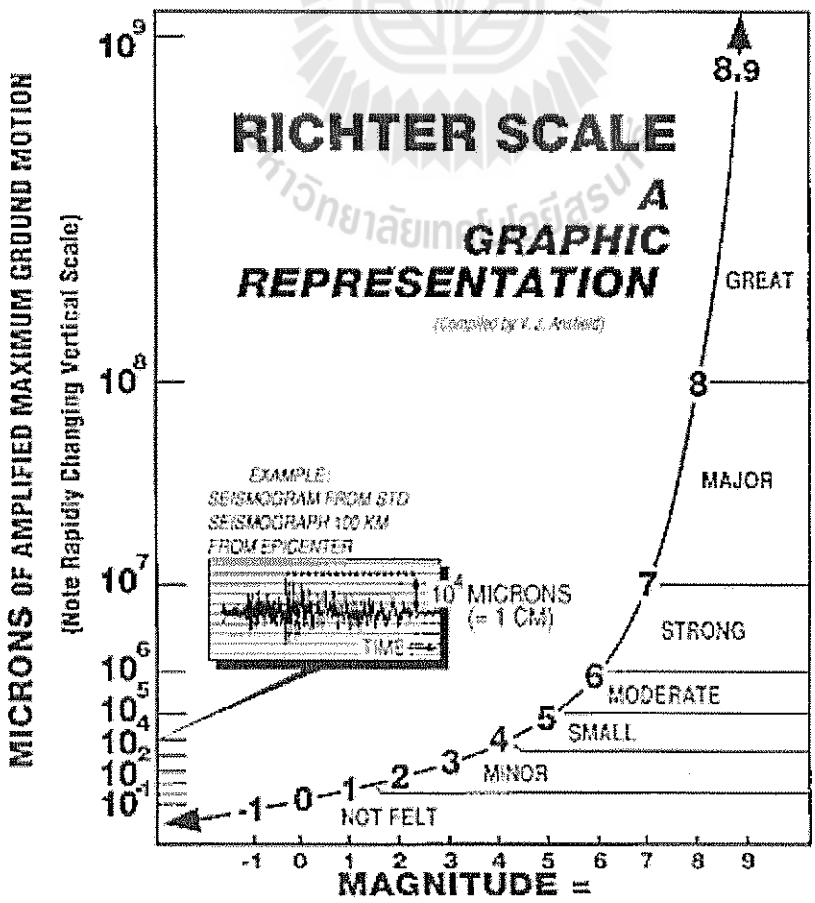
Seismograph



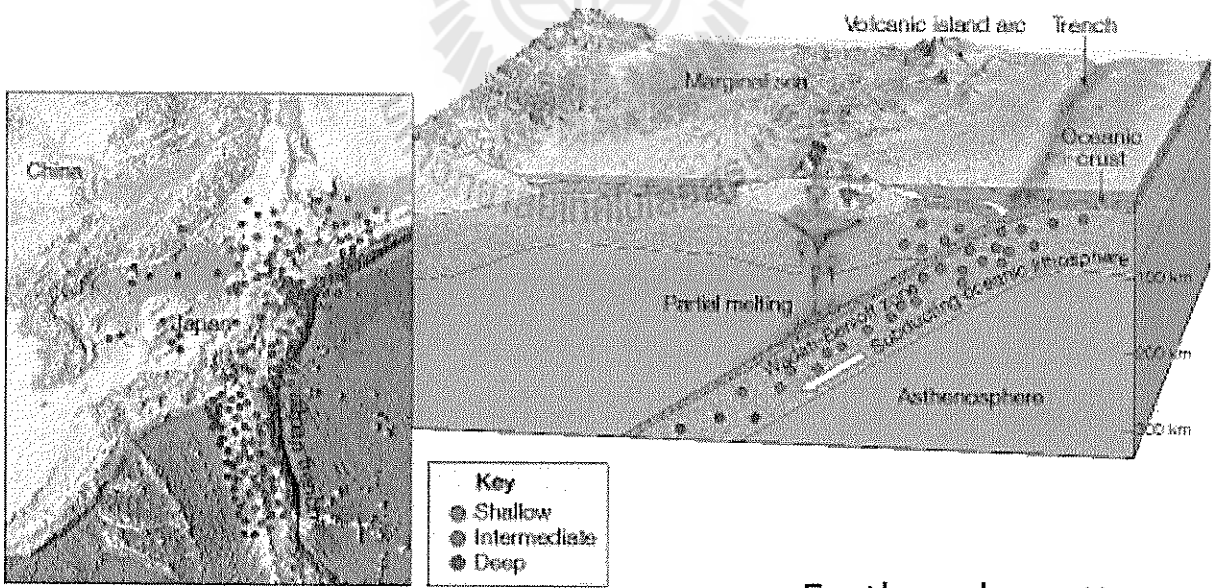
The Richter Scale: the best known scale for measuring the magnitude of earthquakes (since 1935).

The magnitude value is proportional to the logarithm of the amplitude of the strongest wave during an earthquake.





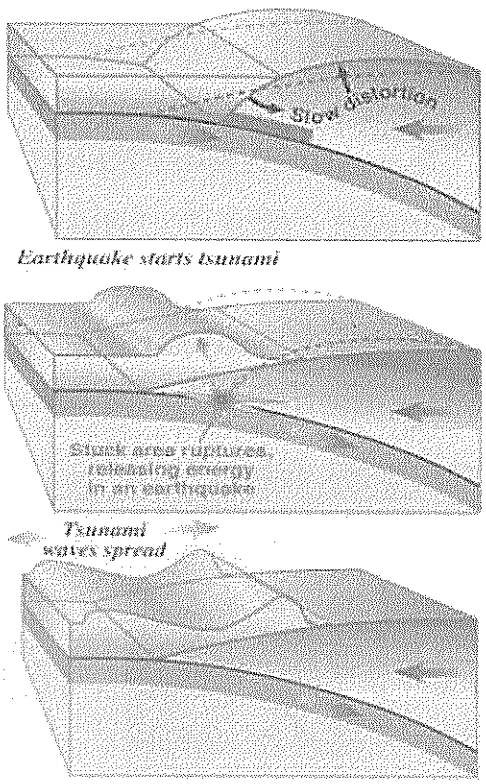
Magnitude	type	Earthquake effects	Frequency of occurrence
< 2.0	Micro	Micro earthquakes, not felt.	Continual
2.0–2.9	Minor	Generally not felt, but recorded.	1,300,000 per year (est.)
3.0–3.9		Often felt, but rarely causes damage.	130,000 per year (est.)
4.0–4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	13,000 per year (est.)
5.0–5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	1,319 per year
6.0–6.9	Strong	Can be destructive in areas up to about 160 kilometres (99 mi) across in populated areas.	134 per year
7.0–7.9	Major	Can cause serious damage over larger areas.	15 per year
8.0–8.9	Great	Can cause serious damage in areas several hundred kilometres across.	1 per year
9.0–9.9		Devastating in areas several thousand kilometres across.	1 per 10 years (est.)
10.0+	Massive	Never recorded, widespread devastation across very large areas; see below for equivalent seismic energy yield.	Extremely rare (Unknown/May not be possible)

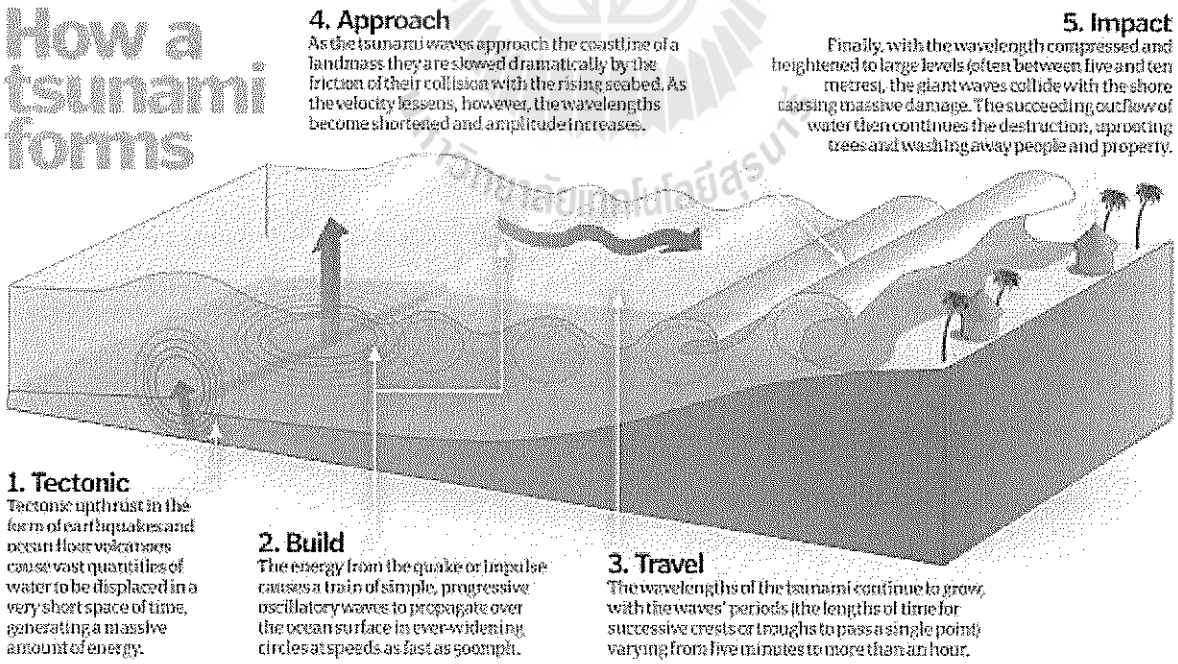


http://cosscience1.pbworks.com

Earthquake pattern

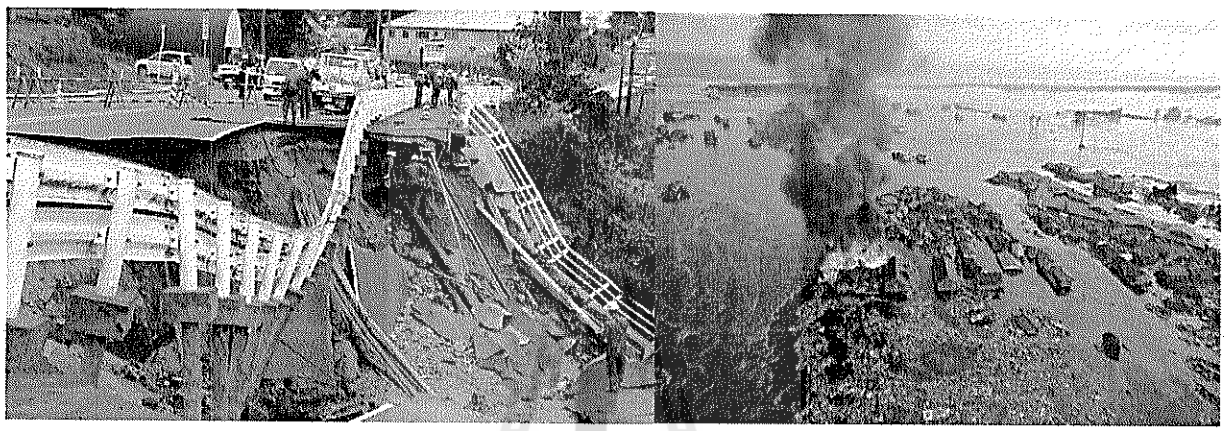
Tsunami: a series of water waves caused by the displacement of a large volume of a body of water, generally an ocean or a large lake. Earthquakes, volcanic eruptions and other underwater explosions, landslides, glacier calvings, meteorite impacts and other disturbances above or below water all have the potential to generate a tsunami.





Reducing Earthquake Hazards

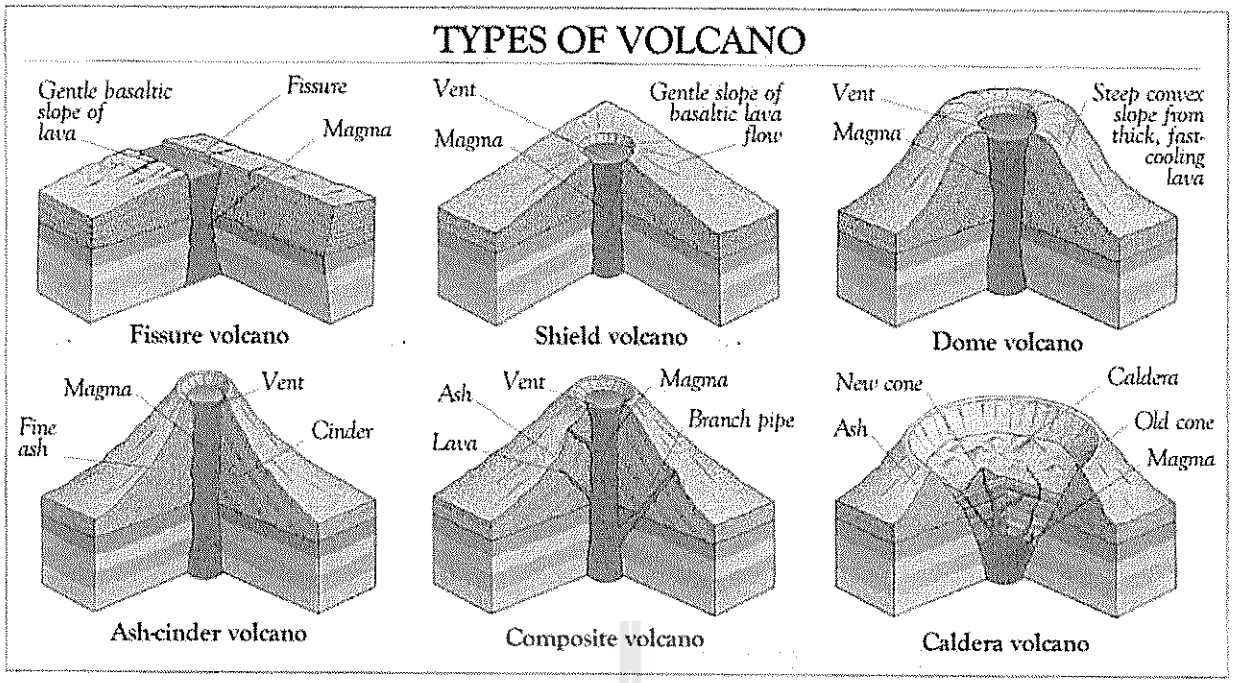
- Examine historical records and make geological measurements to locate active fault zones
- Make maps showing high-risk areas.
- Establish building codes that regulate the placement and design of buildings
- Predicting when and where earthquakes will occur



Volcano

Volcano: an opening, or rupture, in a planet's crust, which allows hot magma, volcanic ash and gases to escape from below the surface.





Volcanic fissure (fissure): s a linear volcanic vent through which lava erupts, usually without any explosive activity.

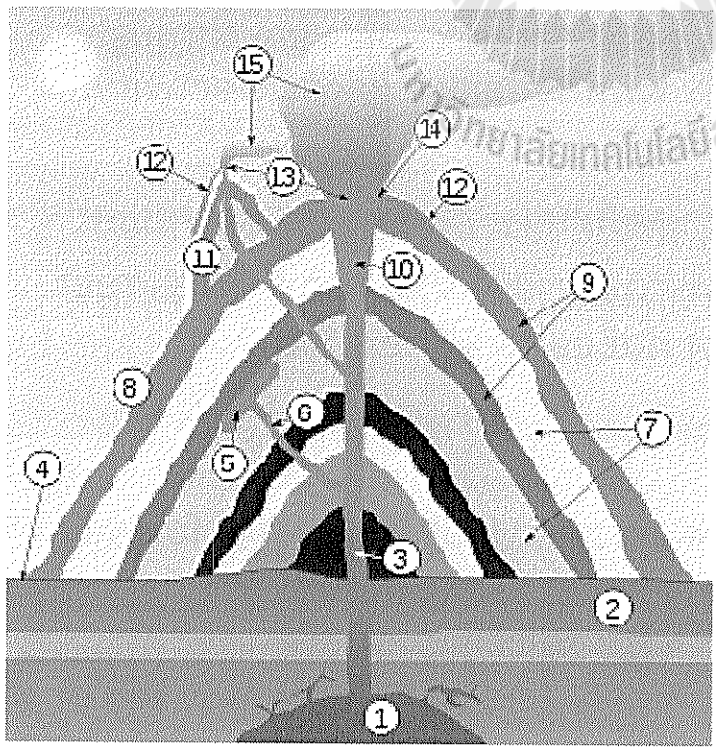
Shield volcanoes: broad, shield-like profiles, are formed by the eruption of low-viscosity lava that can flow a great distance from a vent, but not generally explode catastrophically.

A caldera: a cauldron-like volcanic feature usually formed by the collapse of land following a volcanic eruption. They are sometimes confused with volcanic craters.

Stratovolcanoes or composite volcanoes: tall conical mountains composed of lava flows and other ejecta in alternate layers and created from several structures during different kinds of eruptions.

Dome volcanoes: built by slow eruptions of highly viscous lavas. They can produce violent, explosive eruptions, but their lavas generally do not flow far from the originating vent.

Ash-cinder volcanoes: the result from eruptions that erupt mostly small pieces of scoria and pyroclastics (both resemble cinders) that build up around the vent.



Cross-section through a stratovolcano (vertical scale is exaggerated):

1. Large magma chamber
2. Bedrock
3. Conduit (pipe)
4. Base
5. Sill
6. Dike
7. Layers of ash emitted by the volcano
8. Flank
9. Layers of lava emitted by the volcano
10. Throat
11. Parasitic cone
12. Lava flow
13. Vent
14. Crater
15. Ash cloud

Types of Lava

Aa: basaltic lava characterized by a rough or rubbly surface composed of broken lava blocks called clinker.

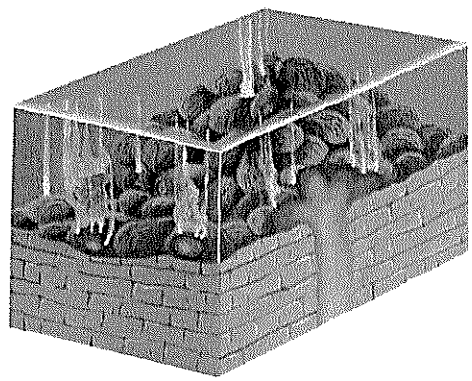


Pahoehoe*:* basaltic lava that has a smooth, billowy, undulating, or ropy surface.

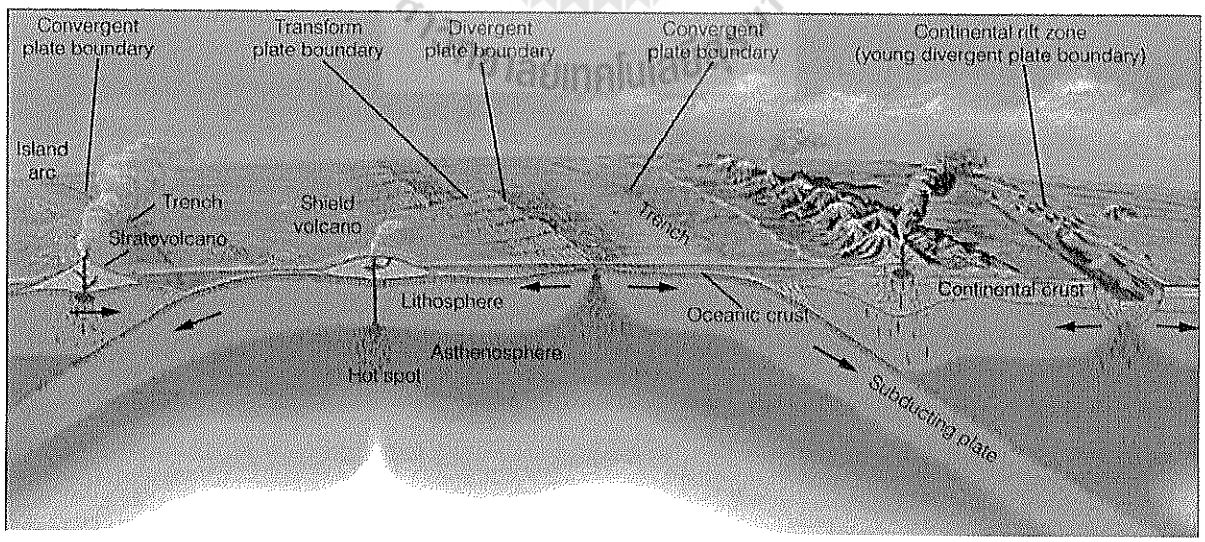


Pillow lava: the lava structure typically formed when lava emerges from an underwater volcanic vent or subglacial volcano or a lava flow enters the ocean.

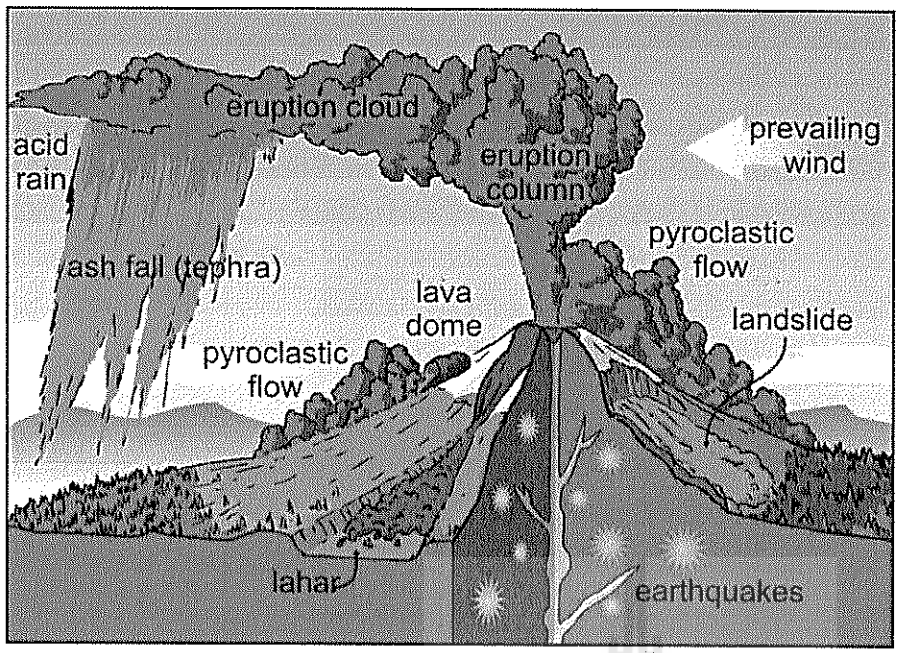




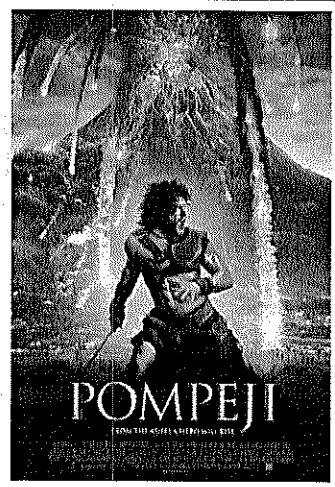
Where can the volcanoes erupt?



Volcano Hazards





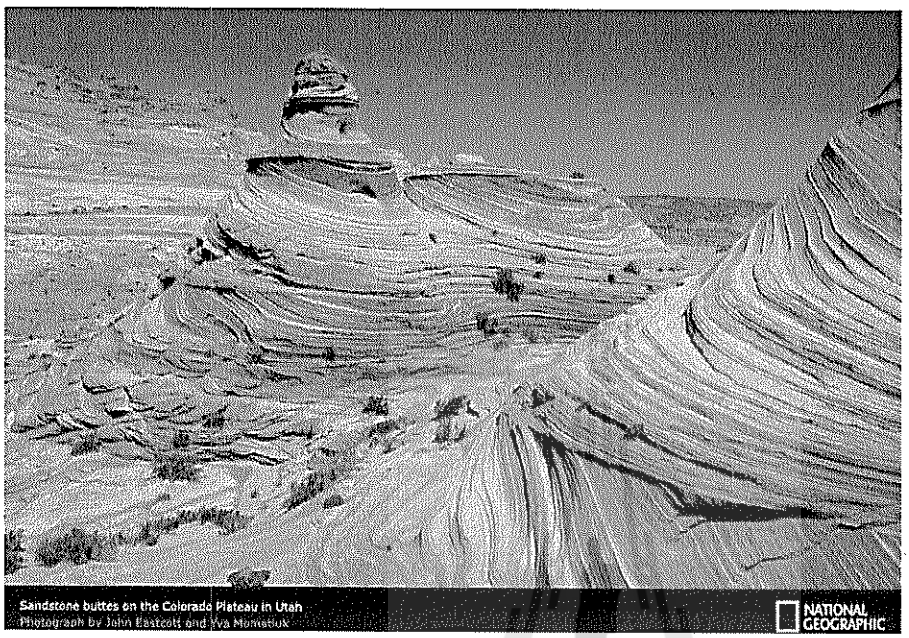


Reducing Volcano Hazards

- Land use planning
- Better predictions of volcanic eruptions
- Effective evacuation plans
- Studying phenomena that precede an eruption for examples; tilting or swelling of the cone, changes in magnetic and thermal properties of the volcano,changes in gas composition, increased seismic activity

2. External processes

External Processes: geological changes based directly or indirectly on energy from the sun and on gravity.



Contents

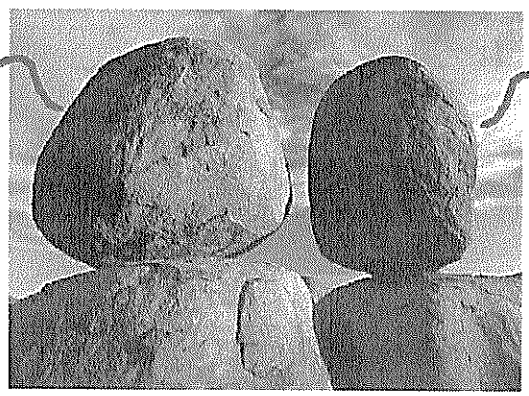
- Weathering
- Erosion
- Soil formation

Weathering

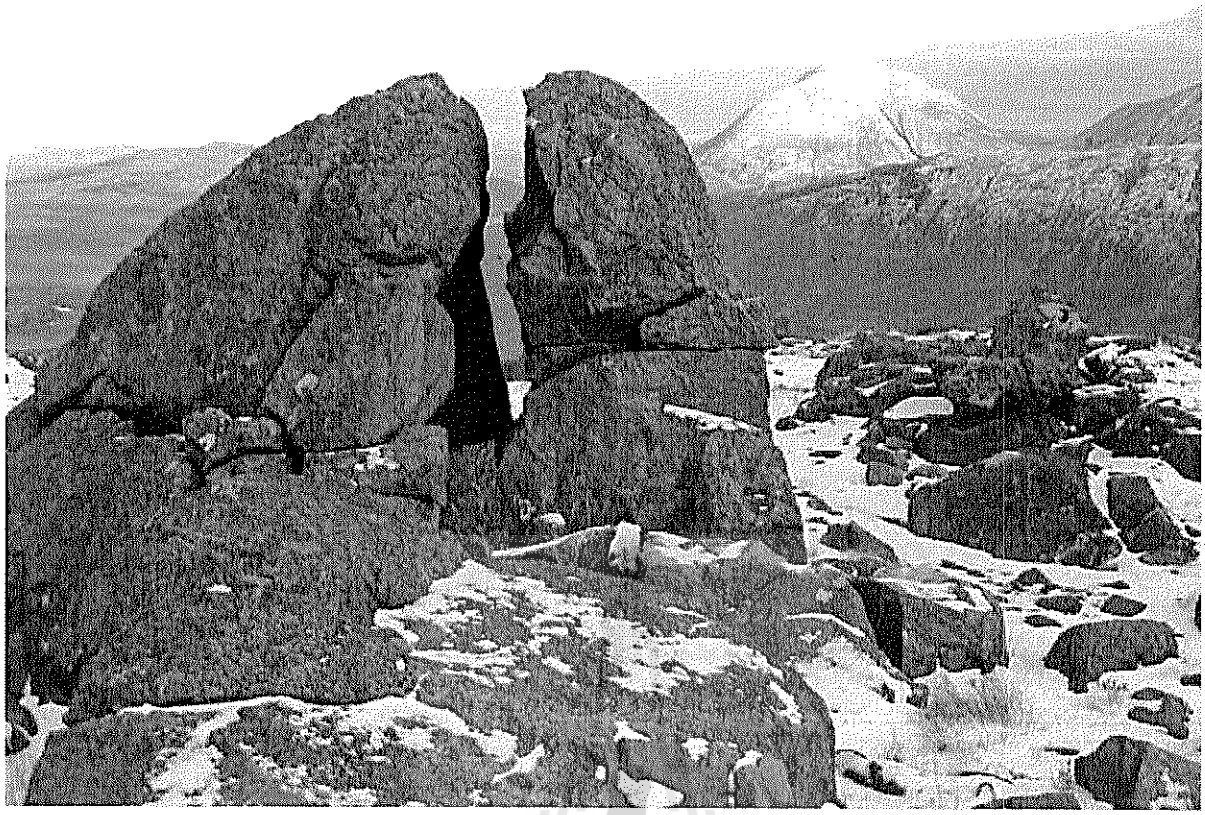
Weathering: caused by mechanical or chemical processes usually produces loosened material that can be eroded.

Mechanical weathering

Chemical weathering

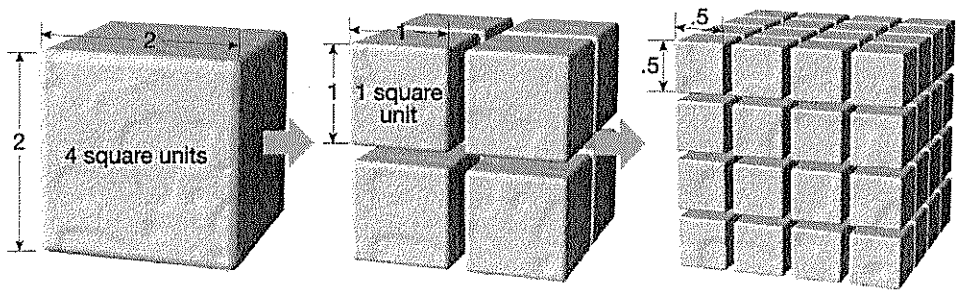


http://www.geograph.org.uk/



Mechanical weathering

A large rock mass is broken into smaller fragments providing more spaces of rock to expose with air and water



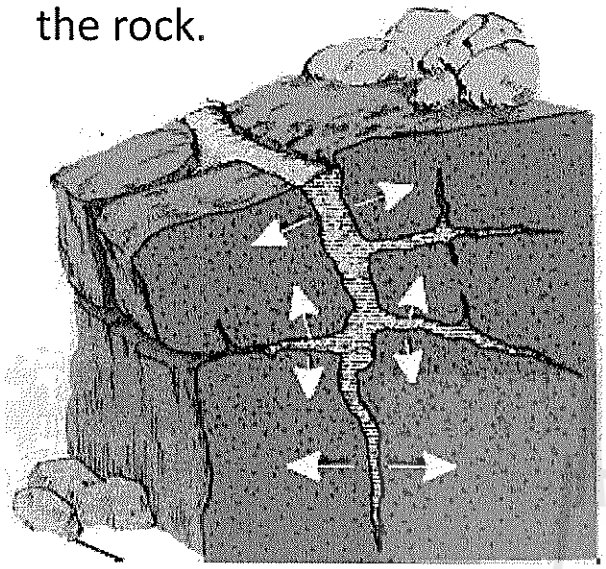
4 square units ×
6 sides ×
1 cube =
24 square units

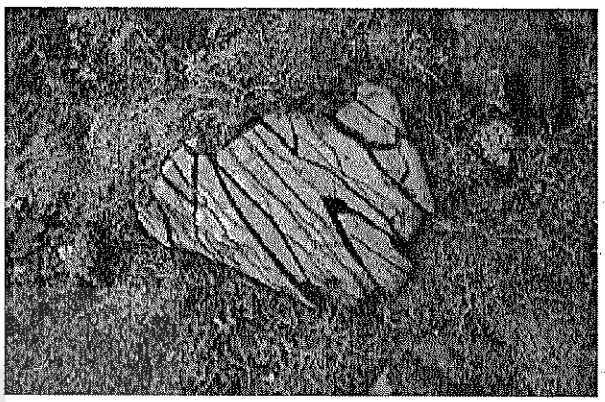
1 square unit ×
6 sides ×
8 cubes =
48 square units

.25 square unit ×
6 sides ×
64 cubes =
96 square units

Types of mechanical weathering

Frost wedging is when water collects in pores and cracks of rock, expands upon freezing, and splits off pieces of the rock.



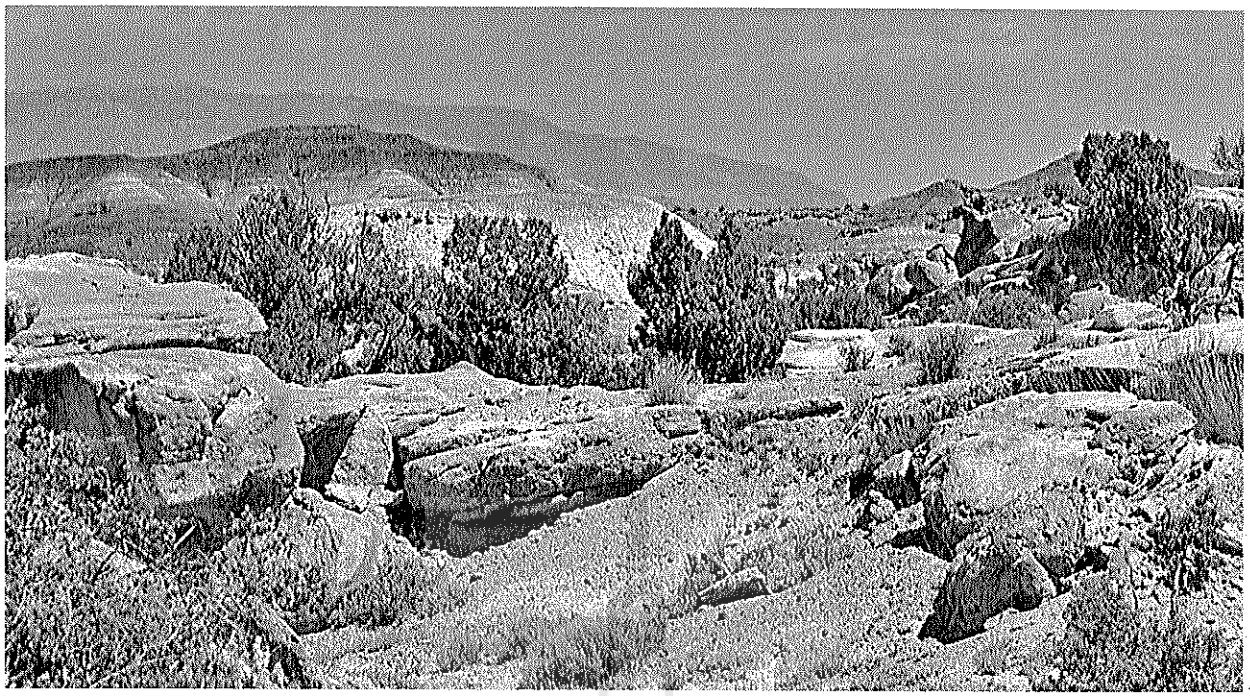


Water expands 9% on freezing



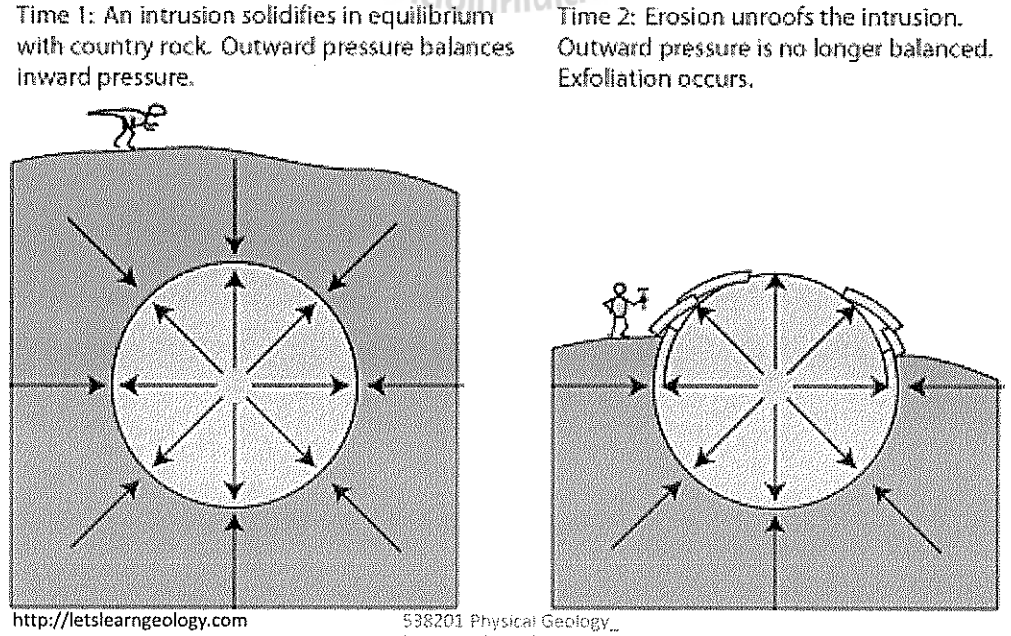
http://www.summitpost.org/

Thermal expansion: change in temperature during day and night induces the expansion of rock mass.



http://www.marietta.edu

Unloading: removal of overburden by erosion, decrease in pressure due to removal of overburden, decrease in temperature, increase in radius of Earth as isostasy causes uplift

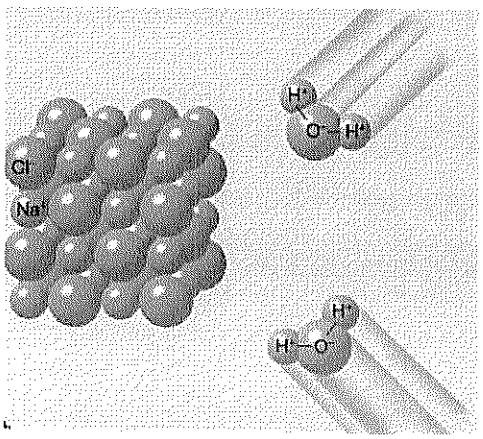


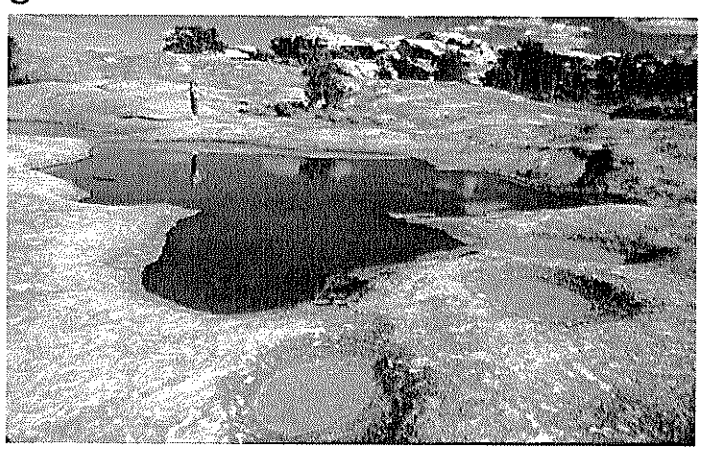
http://letslearngeology.com

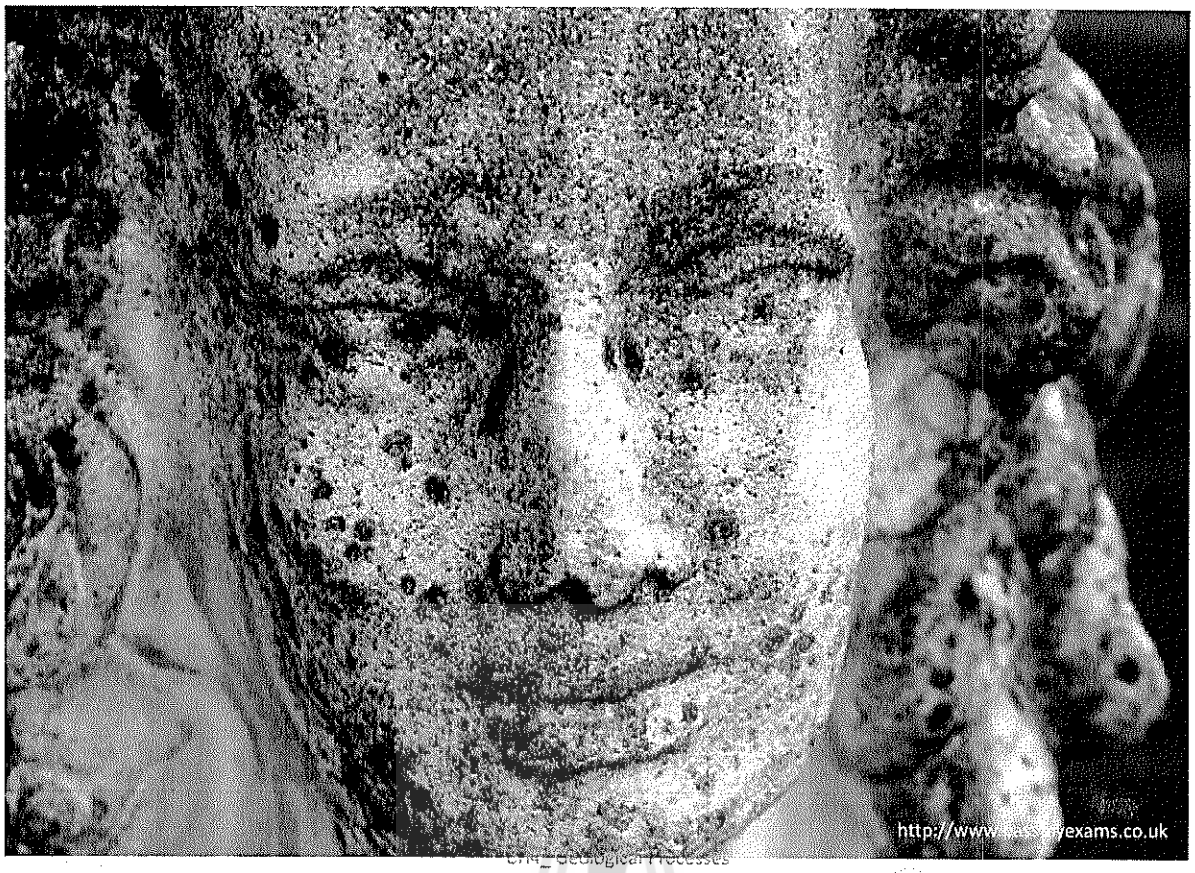


Chemical weathering

Processes of weathering in which one or more chemical reactions decompose a mass or rock ; usually a reaction of rock material with oxygen, carbon dioxide, and moisture in the atmosphere and the ground.



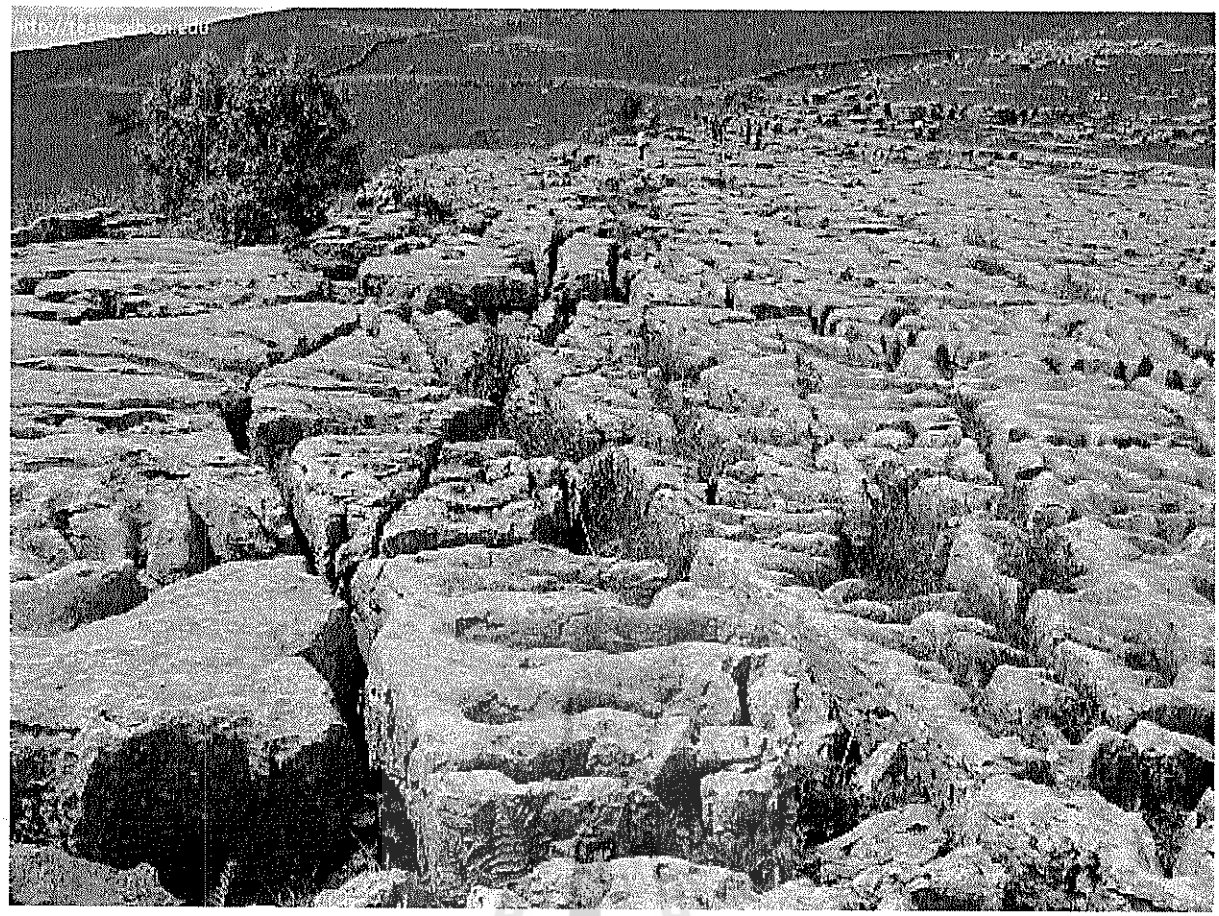




Types of chemical weathering

Dissolution: most minerals insoluble in pure H_2O and much more soluble in acid solution

- carbonic acid: $CO_2 + H_2O = H_2CO_3$
  e.g., calcite easily dissolved by weak acids, caves, karst
- sulfuric acid: S in most coal => H_2S in air
- organic acids: organic decay



Oxidation: loss of electrons

- Fe-Mg minerals (olivine, pyroxene) => hematite, limonite
- sulfide minerals => limonite, sulfuric acid

Oxidation can be characterized by red, orange, and yellow stains that look like rust.





Hydrolysis: reaction of substance with water, important with silicates

quartz ==> qtz + silica in solution

feldspars ==> clay mineral+ silica + K^{+}, Na^{+}, Ca^{2+}

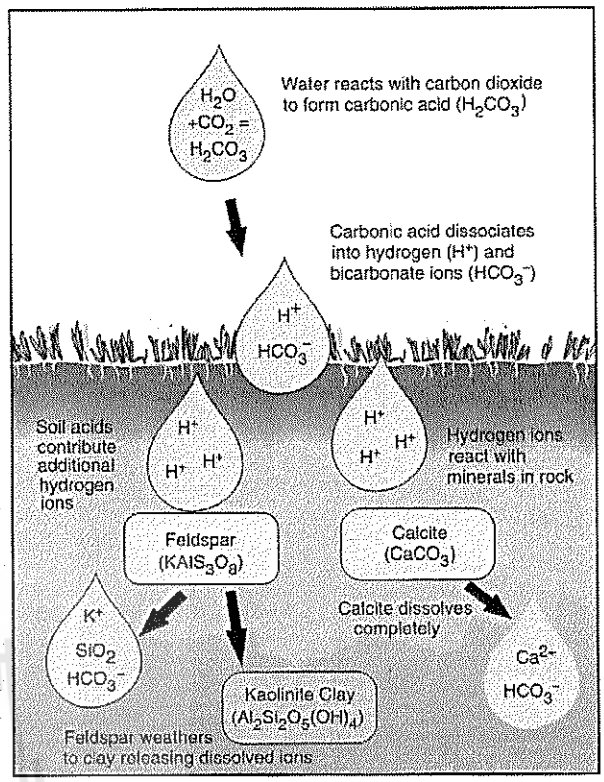
amphiboles ==> clay min, limonite, hematite + Ca^{2+}, Mg^{2+}

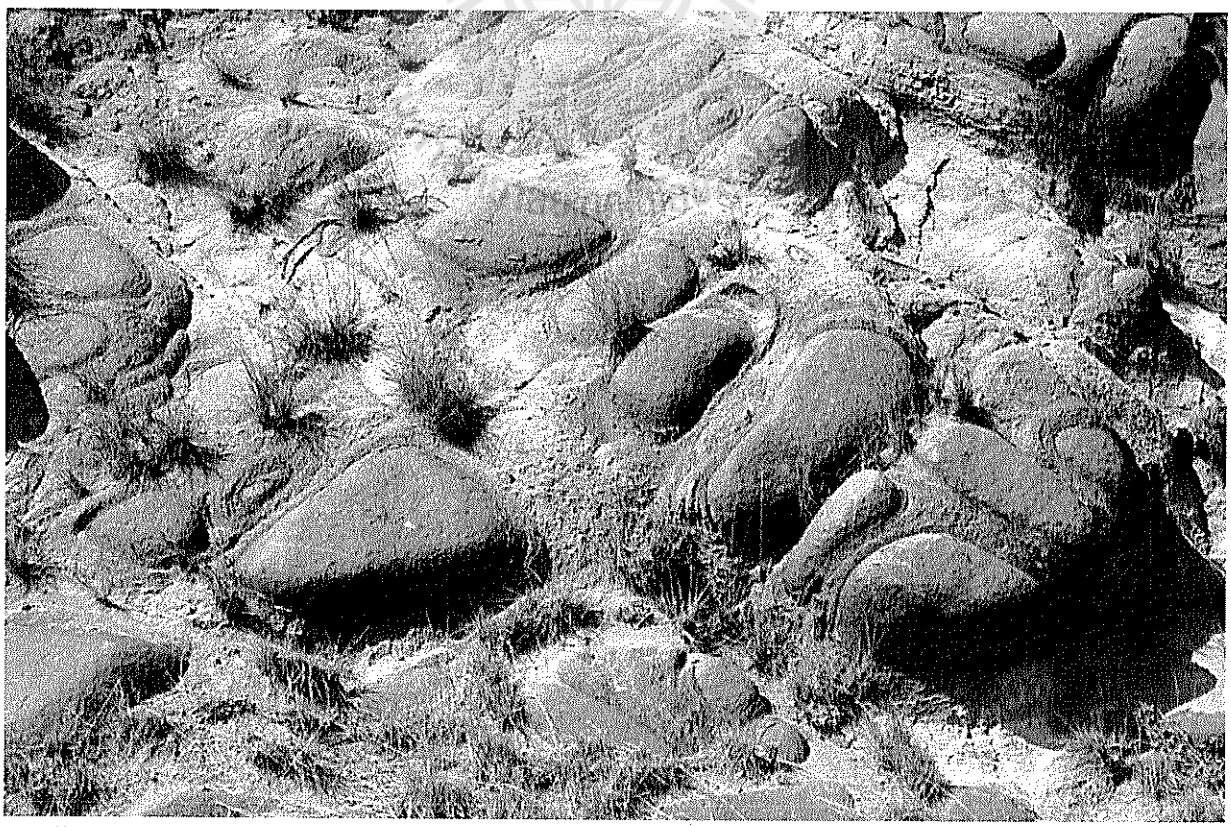
olivine ==> limonite, hematite + Mg^{2+}



Spheroidal weathering of basalt
(geology.about.com)

Chemical weathering causes the alteration of feldspars and produces clay minerals whereas the soluble calcite is dissolved by water.

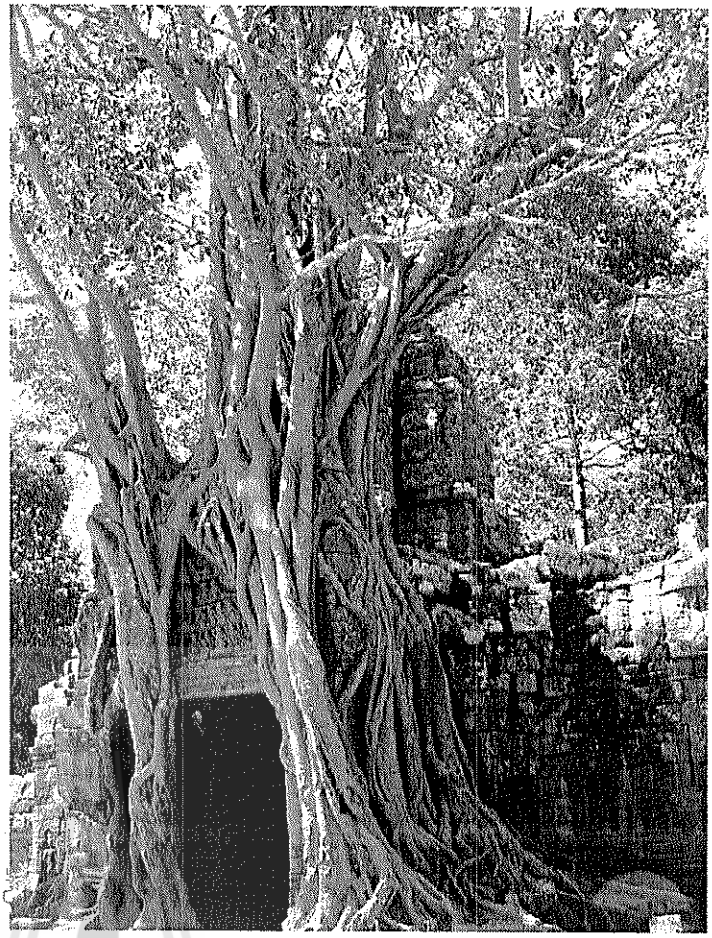




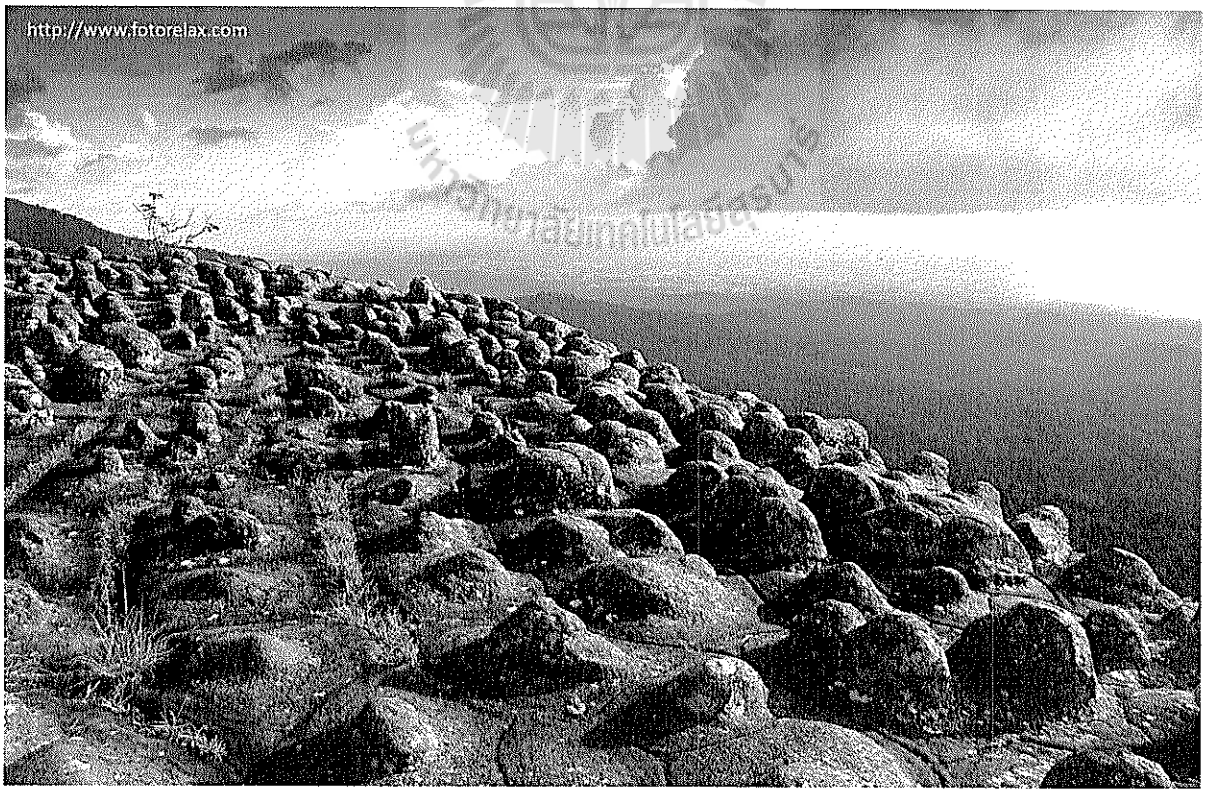
http://www.treknature.com

Weathered basalt in South Africa

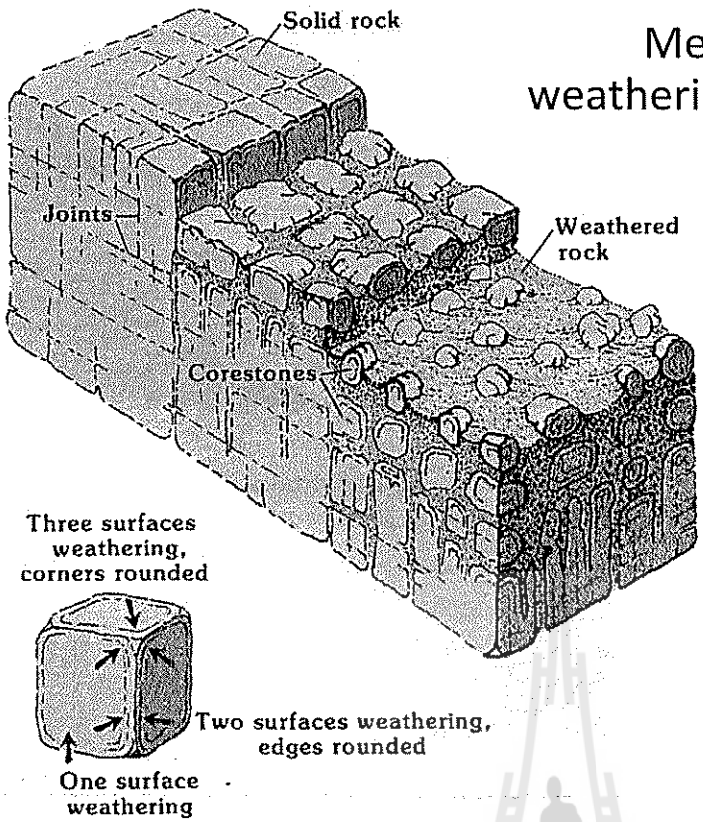
Aided by plants



http://tripwow.tripadvisor.com

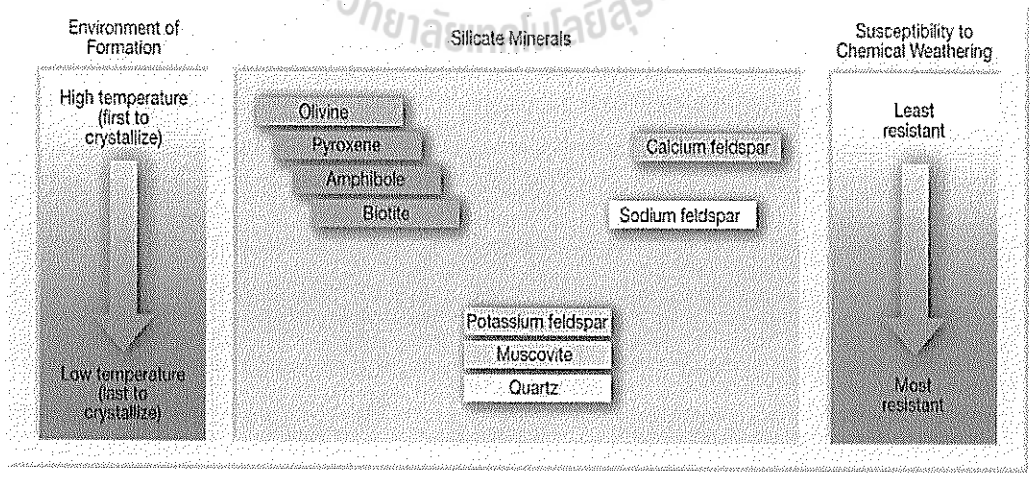


Mechanical and chemical weathering work well together.



Factors affecting weathering rate

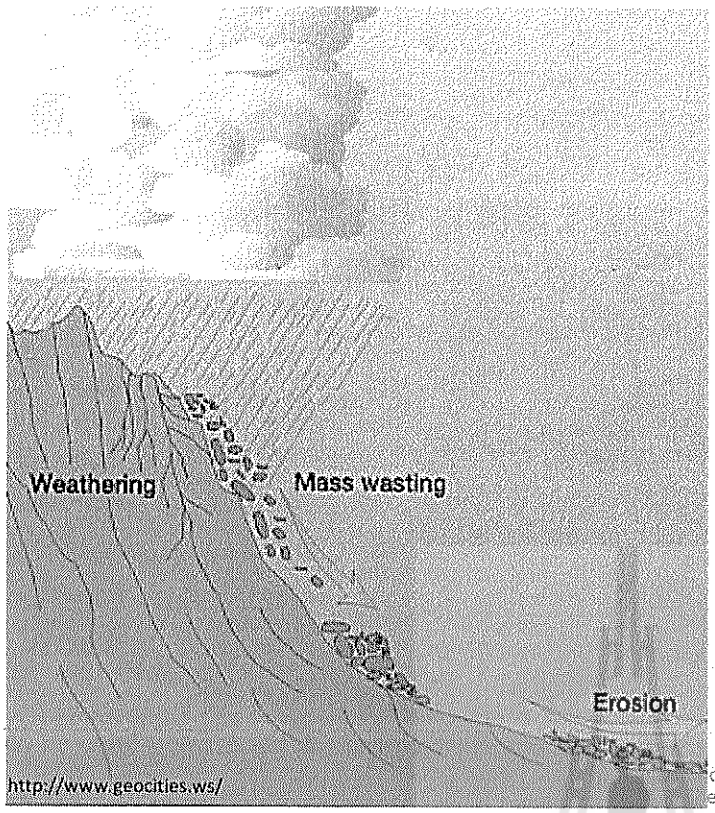
1) Resistance of minerals



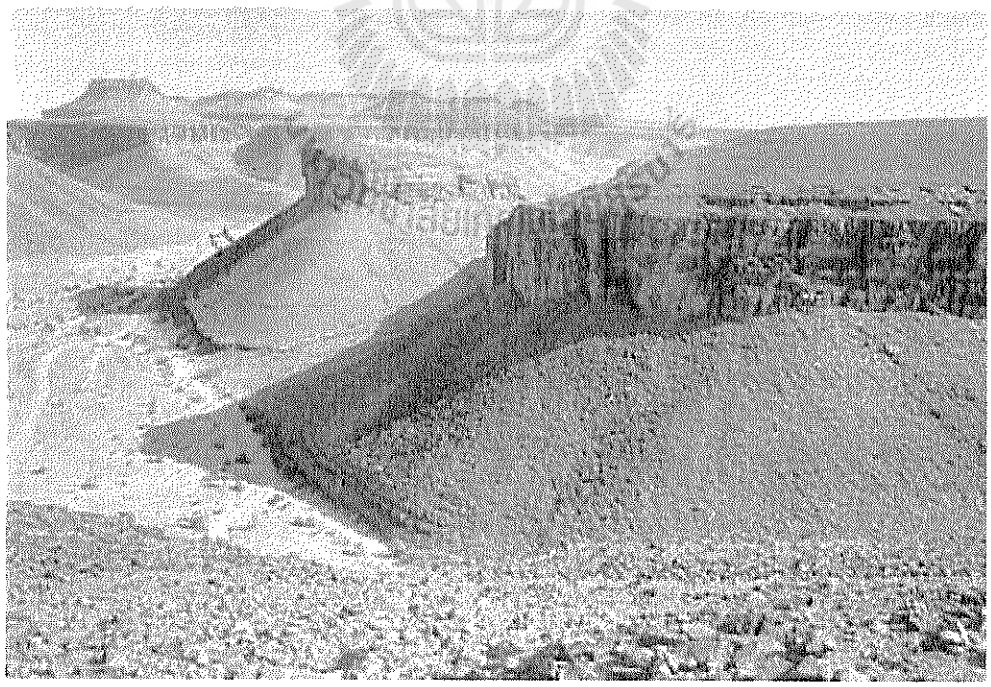
2) Climate

3) Topography

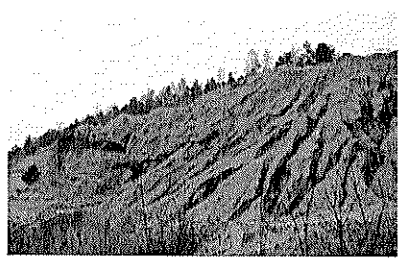
Erosion



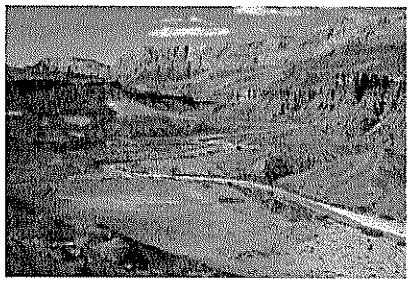
Erosion: the process by which soil and rock are removed from the Earth's surface by natural processes such as wind or water flow, and then transported and deposited in other locations.



Streams are the most important agent of erosion which produce valley, canyons, and deltas.



Surface runoff



Rivers and streams



Glaciers

Rainfall

Erosion by water

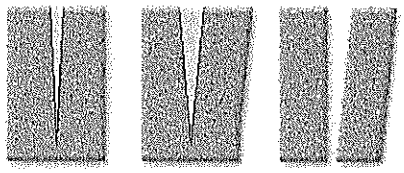
Coastal erosion



Floods

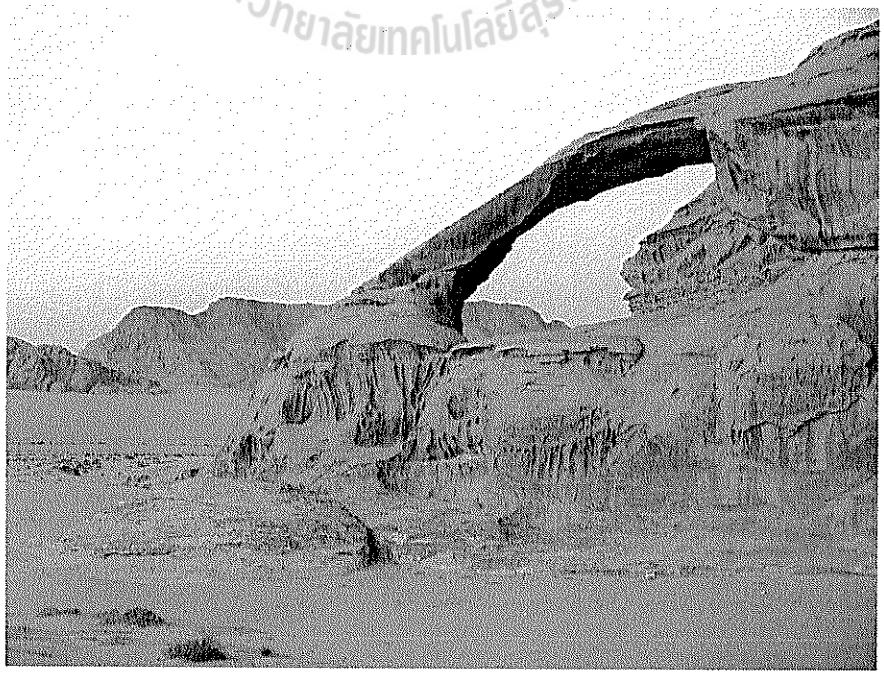


Freezing and thawing

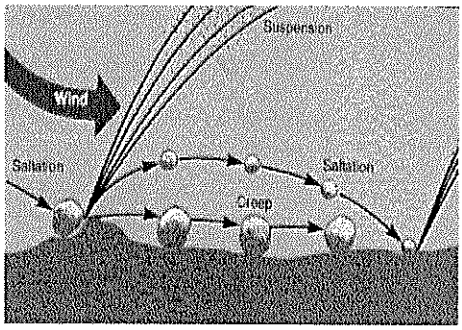


Wind erosion

Arid and semi-arid regions

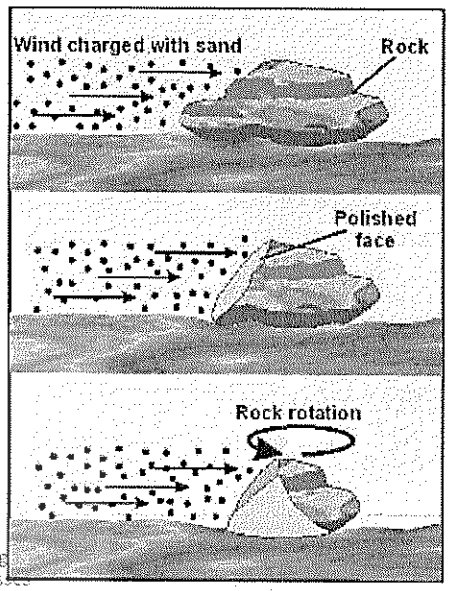


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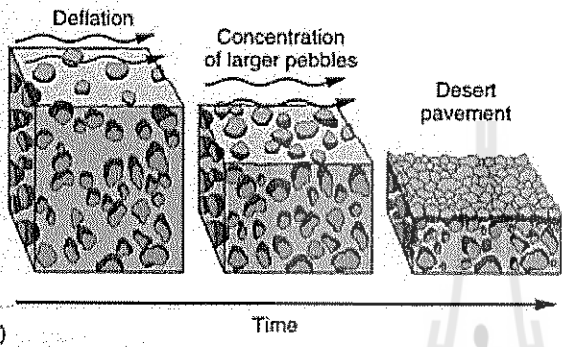


Wind transportation and processes

Abrasion



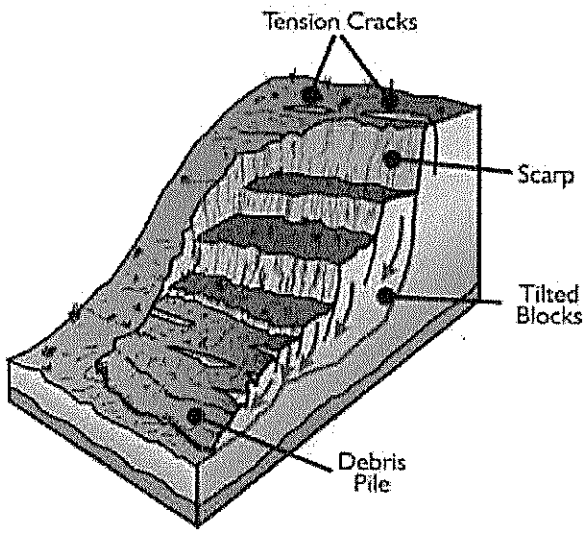
Deflation

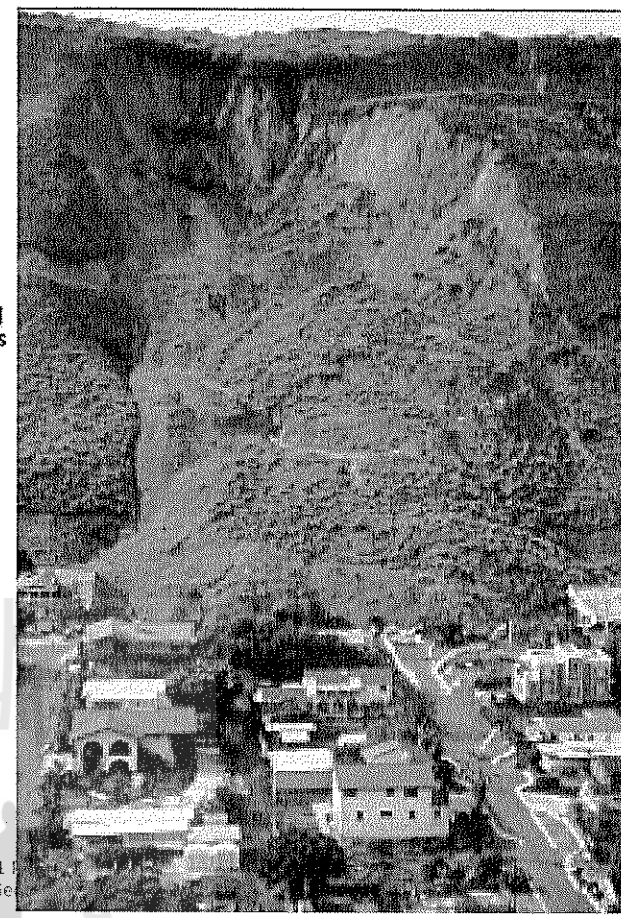


Gravitational erosion

Mass movement: the downward and outward movement of rock and sediments on a sloped surface, mainly due to the force of gravity. For example, landslide, slumping, surface creep.







http://web.mst.edu

Soil formation

Soil: natural surficial material that consists of layers (soil horizon), composed mainly of minerals.

In engineering, soil is called regolith: loose rock material which is influenced by plant roots.

Soil is composed of typically:

25% air
25% water
45% mineral matter
5% organic matter

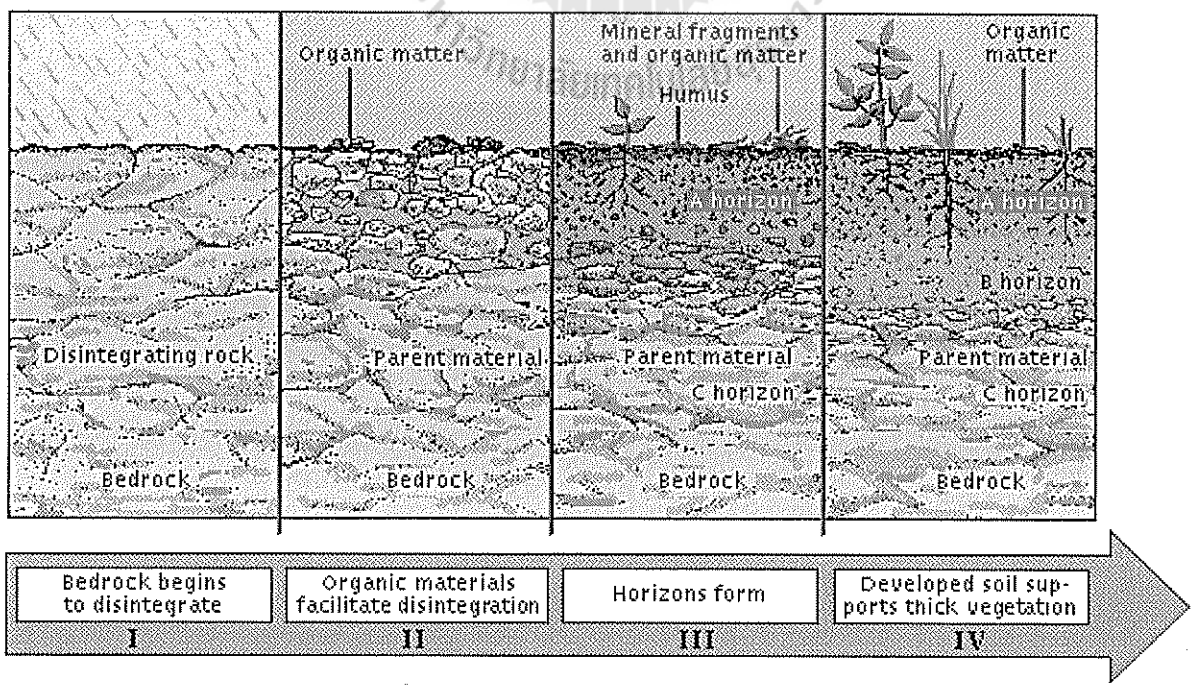
Parent materials are causes of difference in soil texture, structure, consistency, color, chemical, biological and other physical characteristics.

Residual soil: developed on bedrock

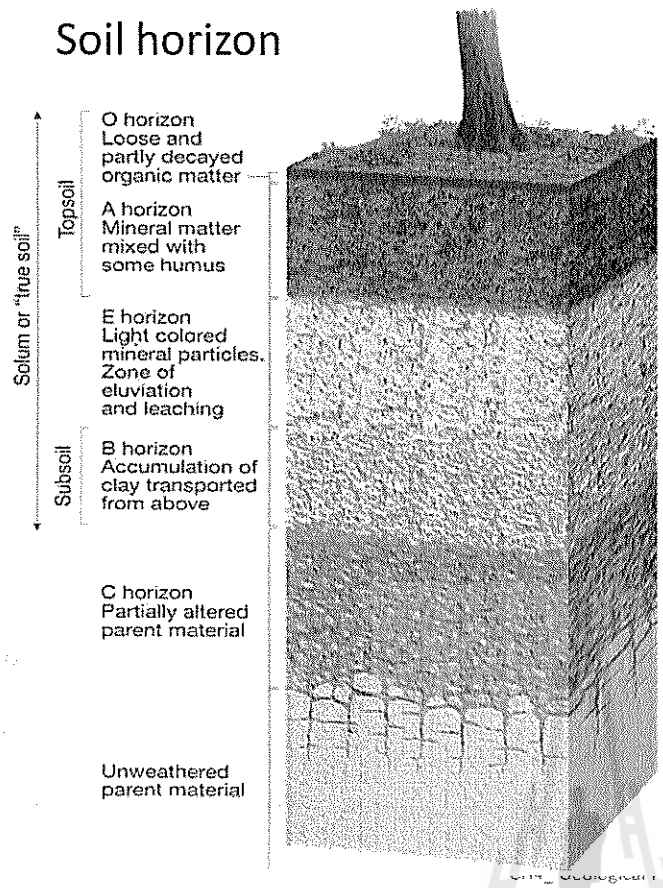
Transported soil: developed on transported material such as stream deposits, glacial till

Residual soil

Developed from weathered bedrock at the site



Soil horizon

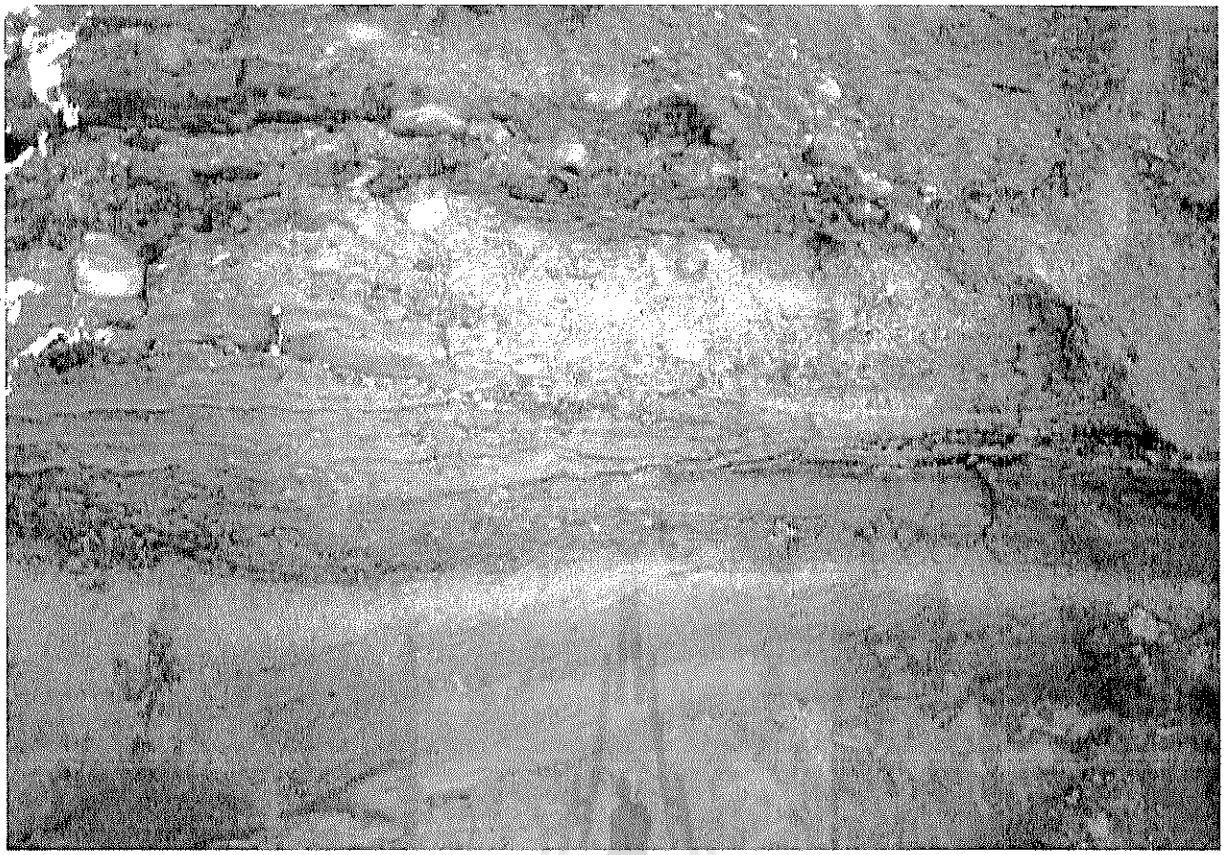


Transported soil

Colluvial soil



Alluvial soil



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Chapter 5 Geological time and history

เวลาทางธรณีกาลและธรณีประวัติ

Contents

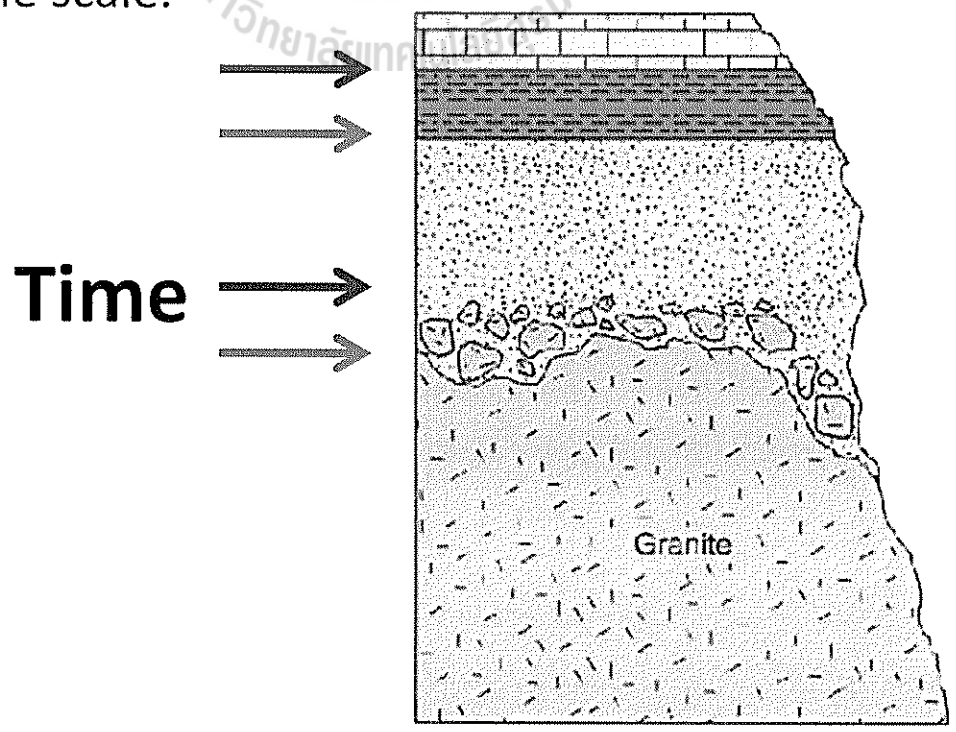
1. Principles in stratigraphy
2. Unconformity
3. Geologic time

1. Principles in stratigraphy

Contents

- Uniformitarianism
- Original horizontality
- Original lateral continuity
- Law of superposition
- Principle of faunal succession
- Cross-cutting relations

Stratigraphy: scientific discipline concerned with description of rock successions and their interpretation in terms of a general time scale.



Lithostratigraphy

Each layer is a different rock type

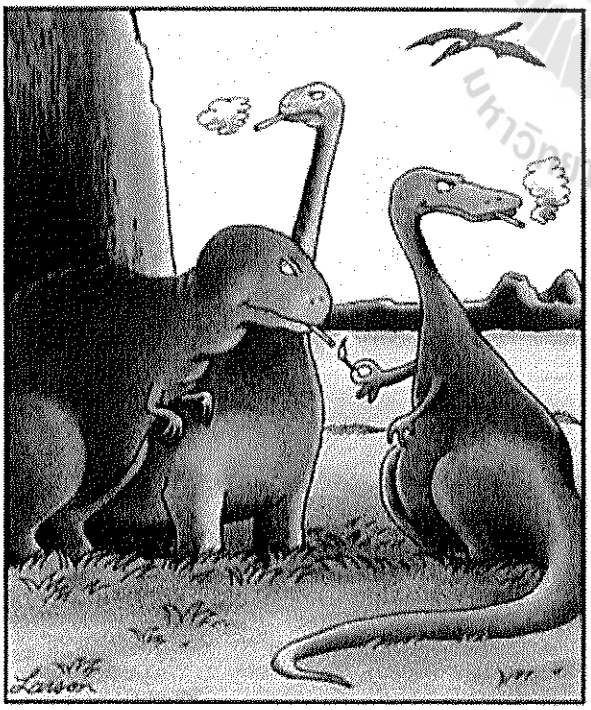
Chronostratigraphy

Each layer is a different age

Biostratigraphy

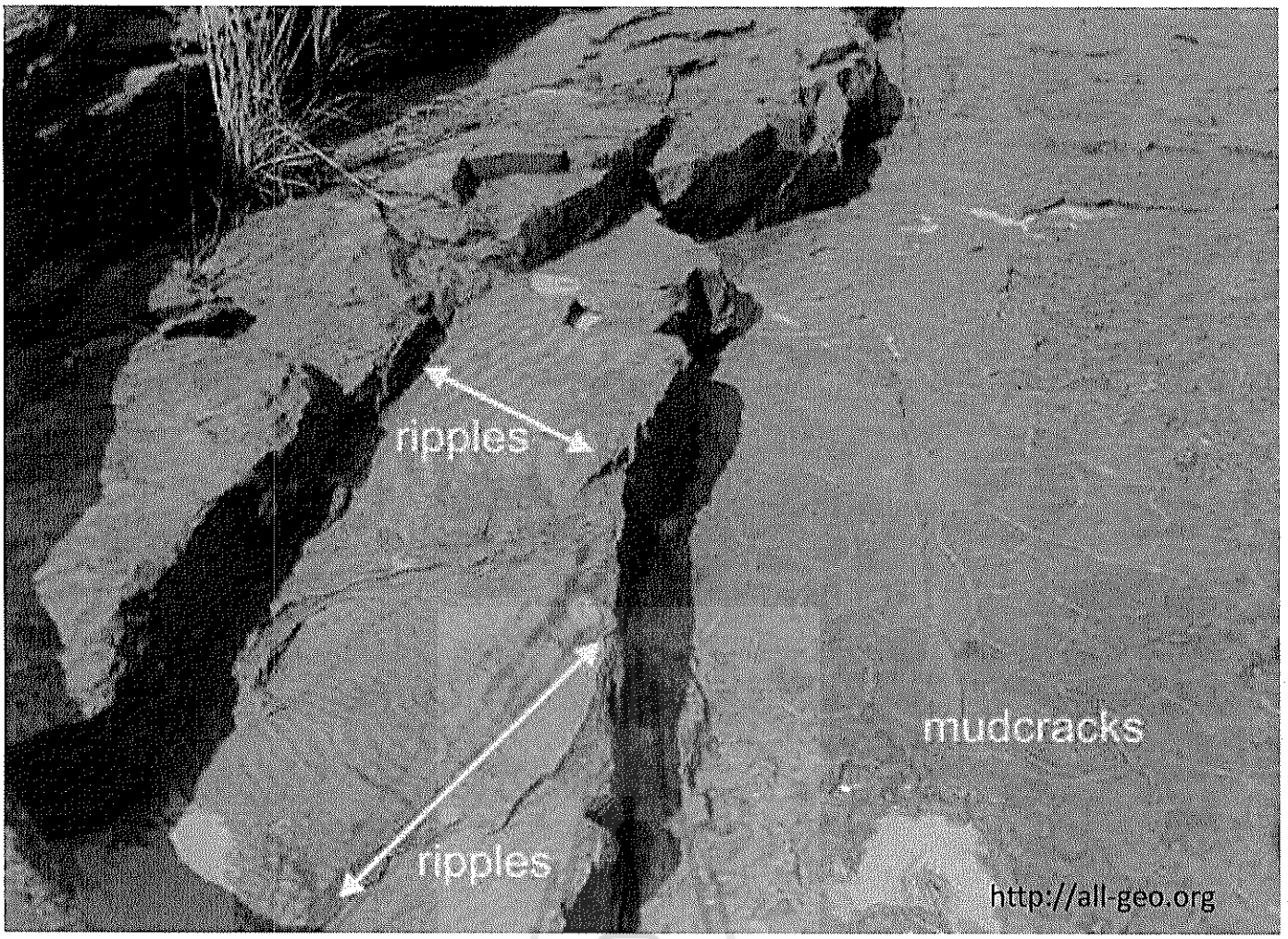
Each layer contains a different fossil assemblage

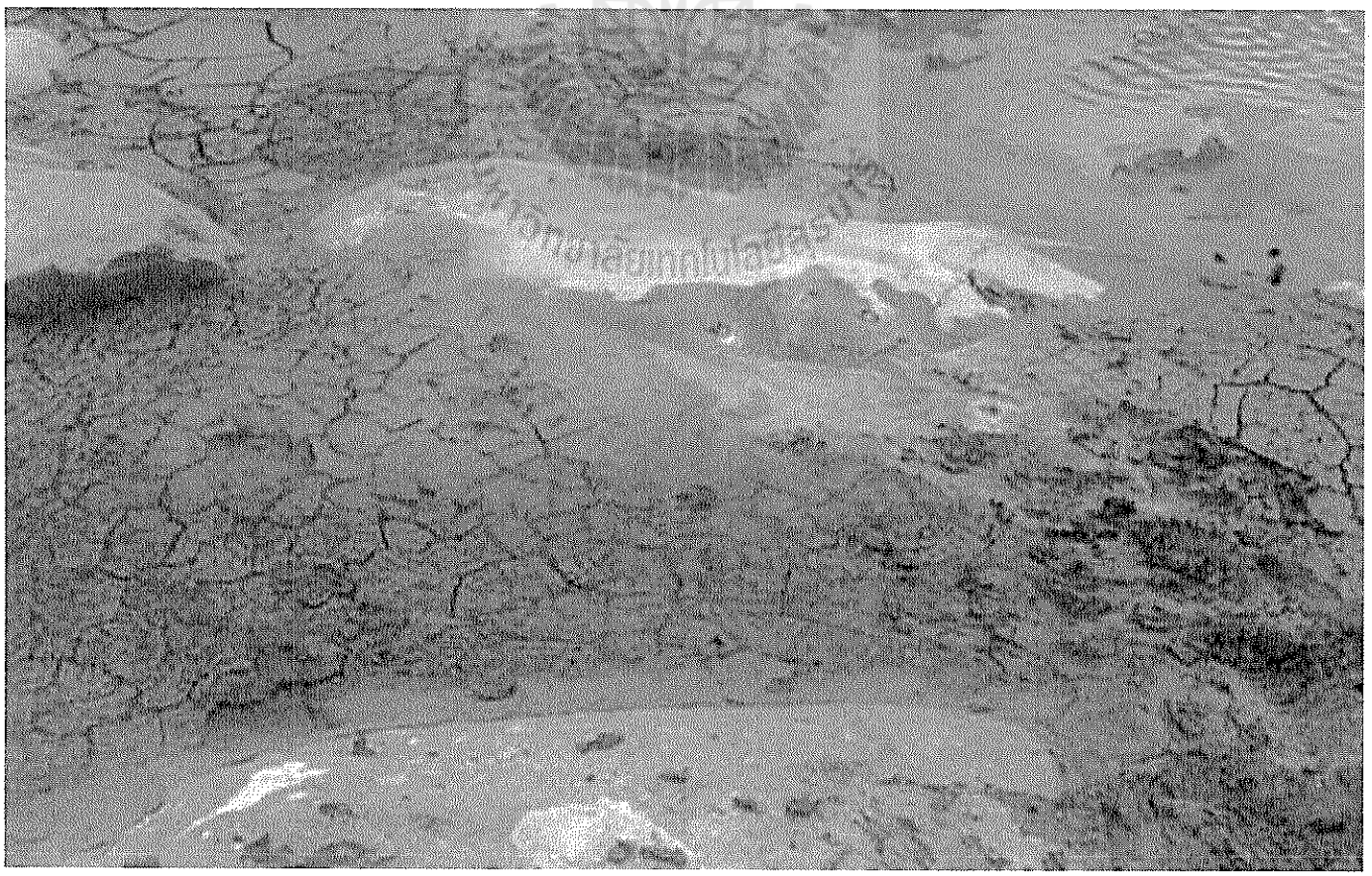
Uniformitarianism



The assumption that the same natural laws and processes that operate in the universe now, have always operated in the universe in the past and apply everywhere in the universe. (James Hutton)

"the present is the key to the past"





http://all-geo.org

http://commons.wikimedia.org

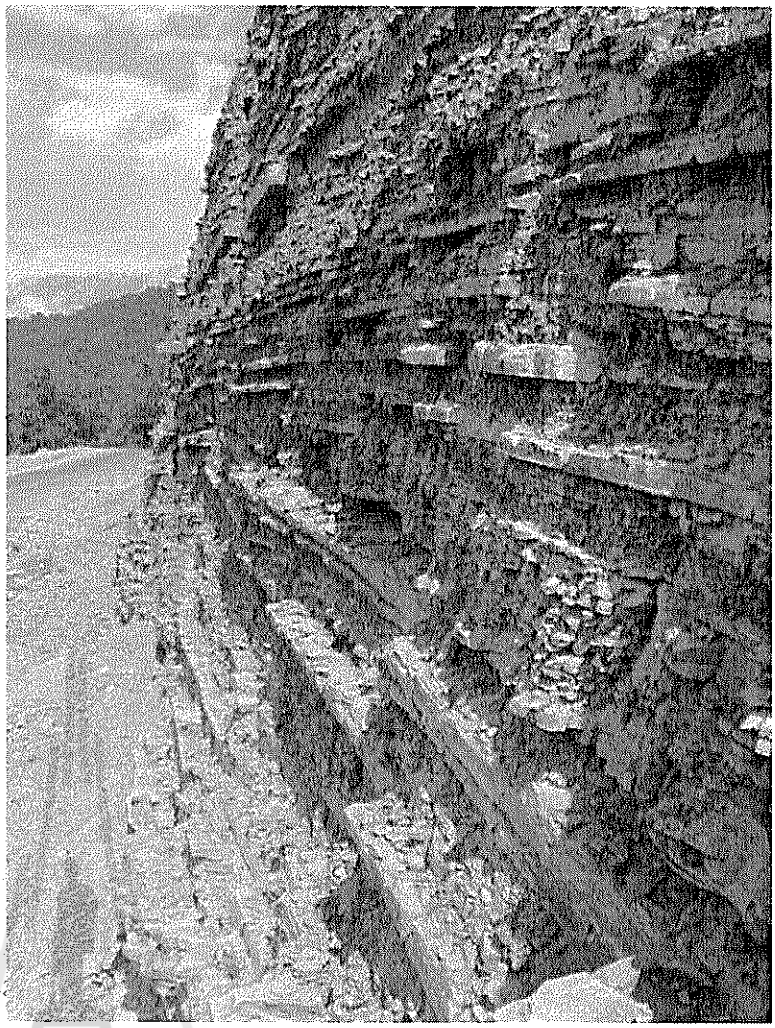


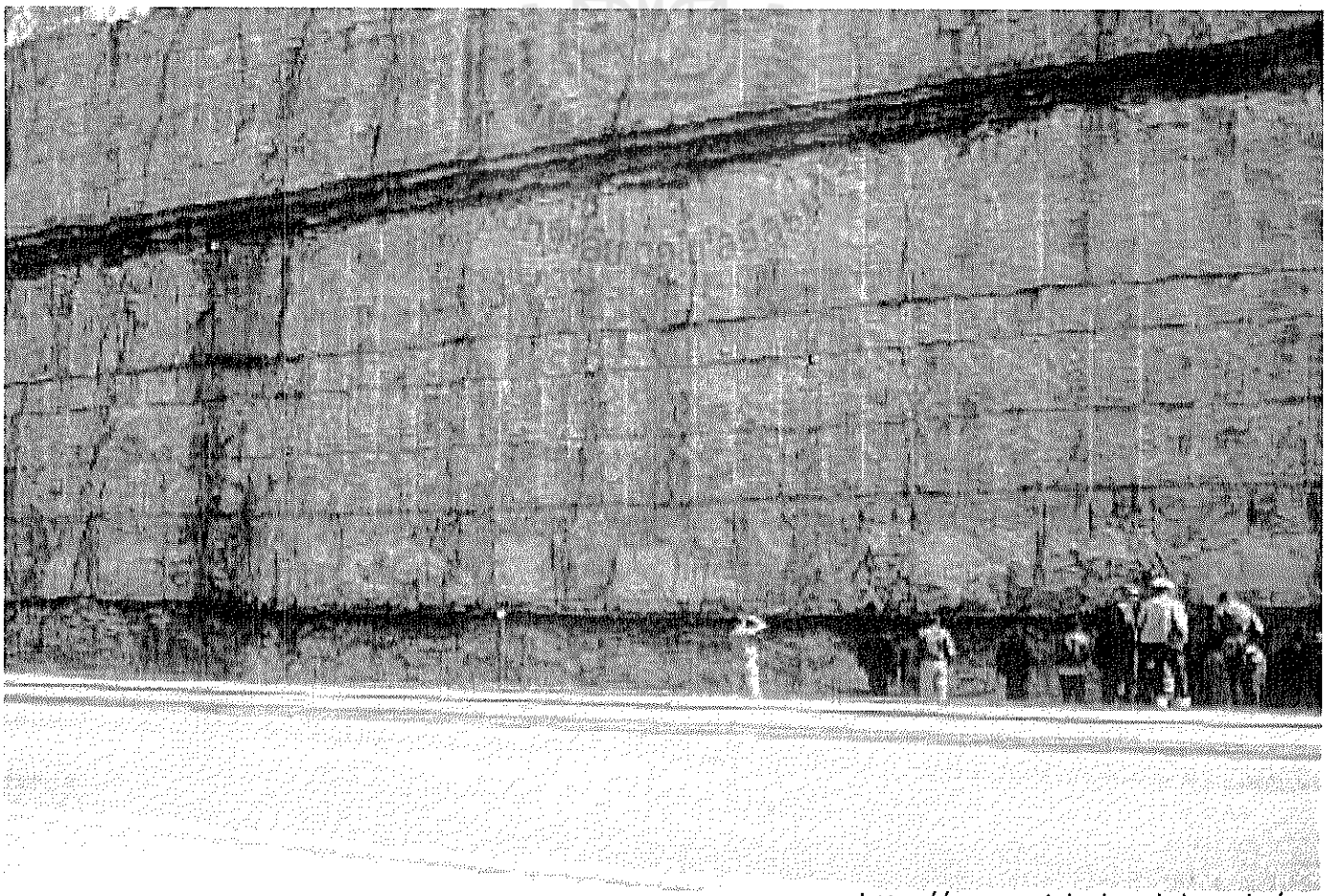
Original horizontality

Sediments usually form flat-layering deposits on the earth's surface.



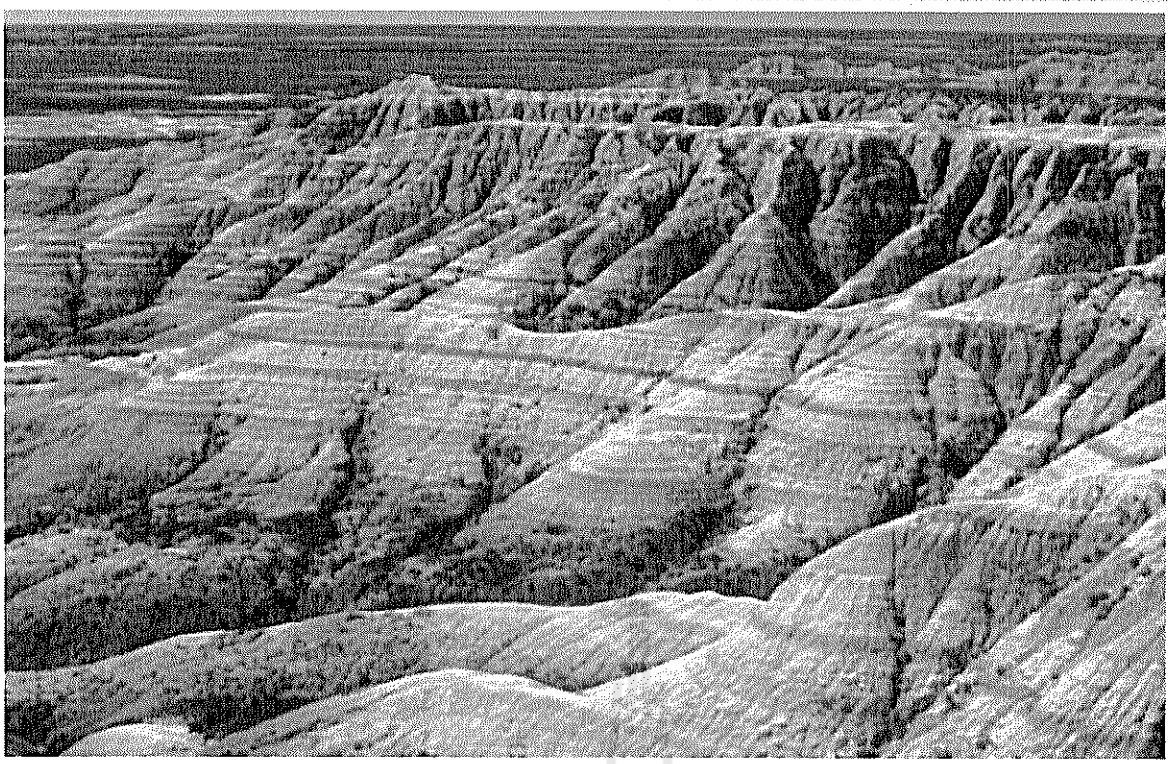
Sedimentary rocks are horizontal due to the original sediments. (Nicolas Steno)





http://www.nicholas.duke.edu/

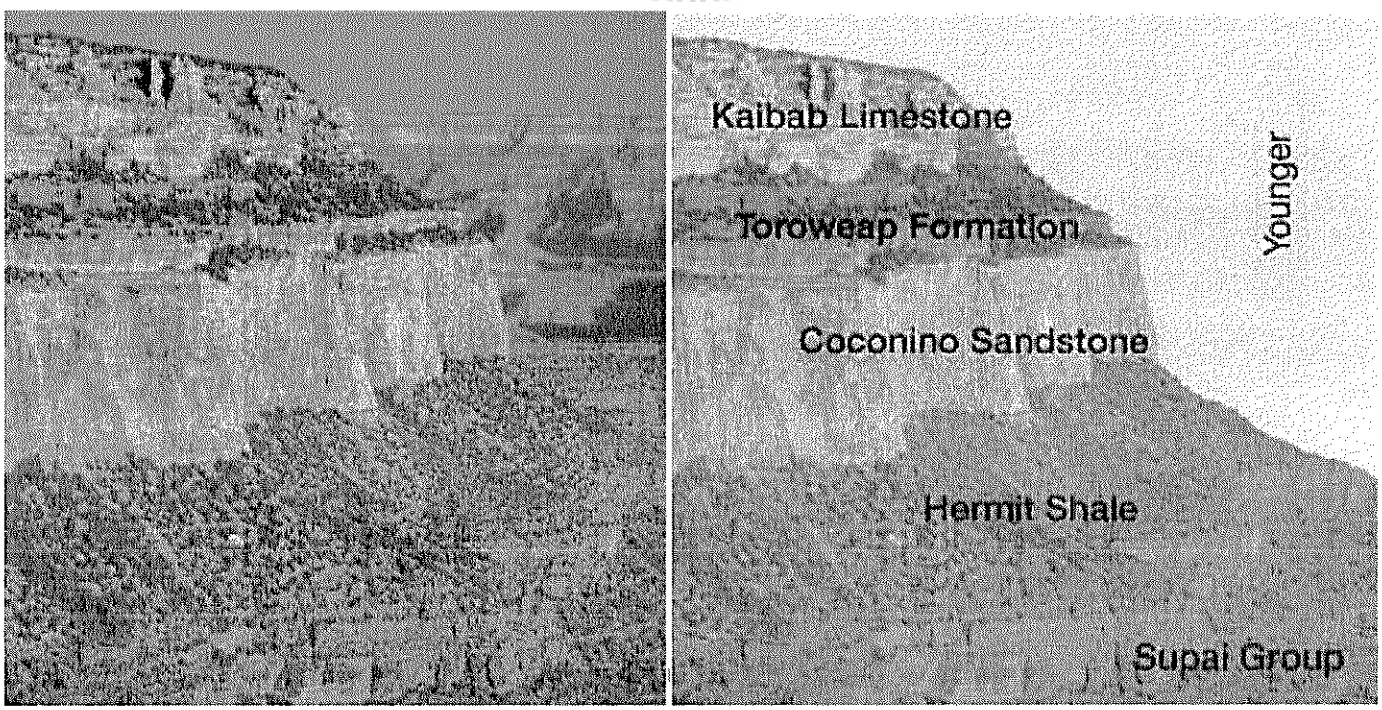
Original lateral continuity



Logically, from extension of original horizontality, individual beds are the same age along an outcrop.

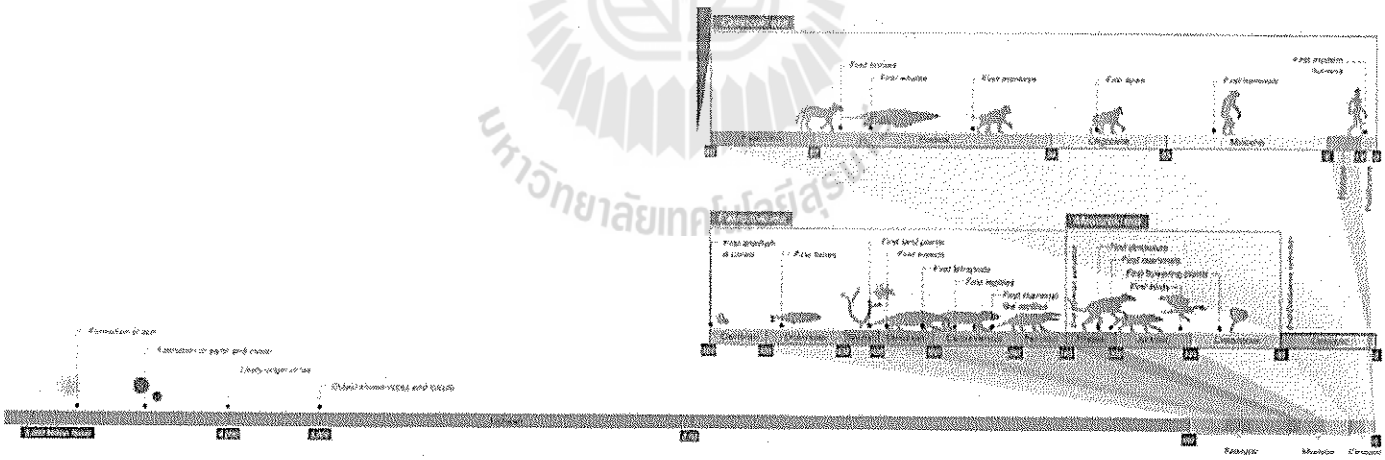
Law of Superposition

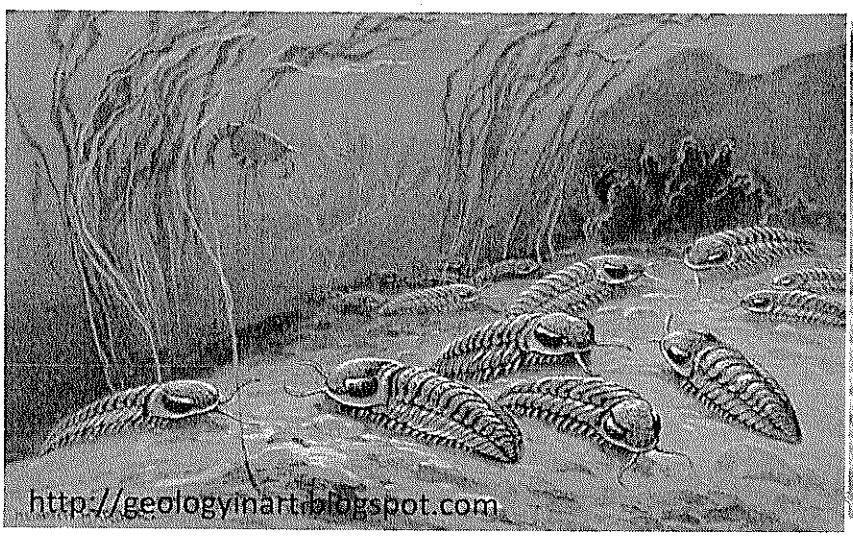
Sedimentary layers are deposited in a time sequence, with the oldest on the bottom and the youngest on the top. (Nicolas Steno)

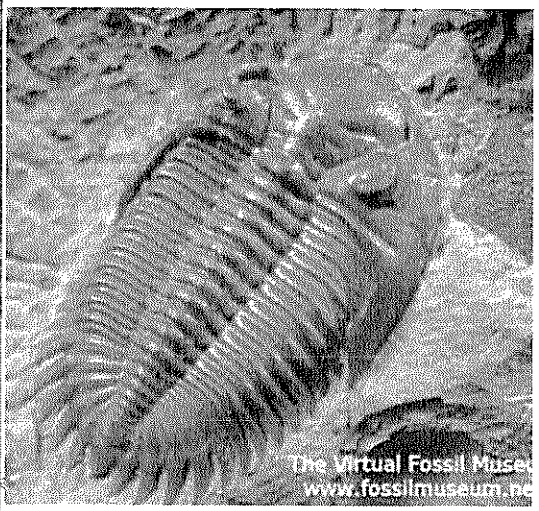


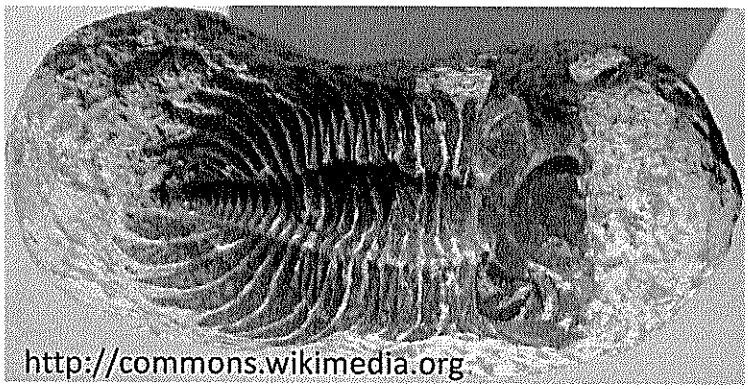
Principle of faunal succession

Principle is based on the observation that sedimentary rock strata contain fossilized flora and fauna, and that these fossils succeed each other vertically in a specific, reliable order that can be identified over wide horizontal distances. (William Smith)









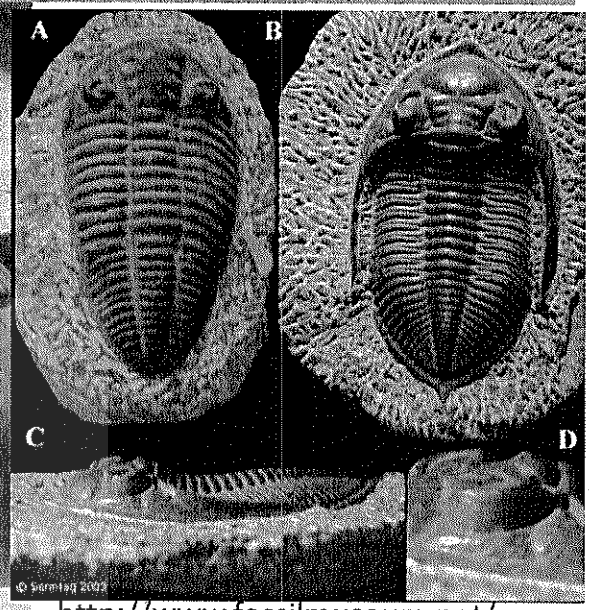
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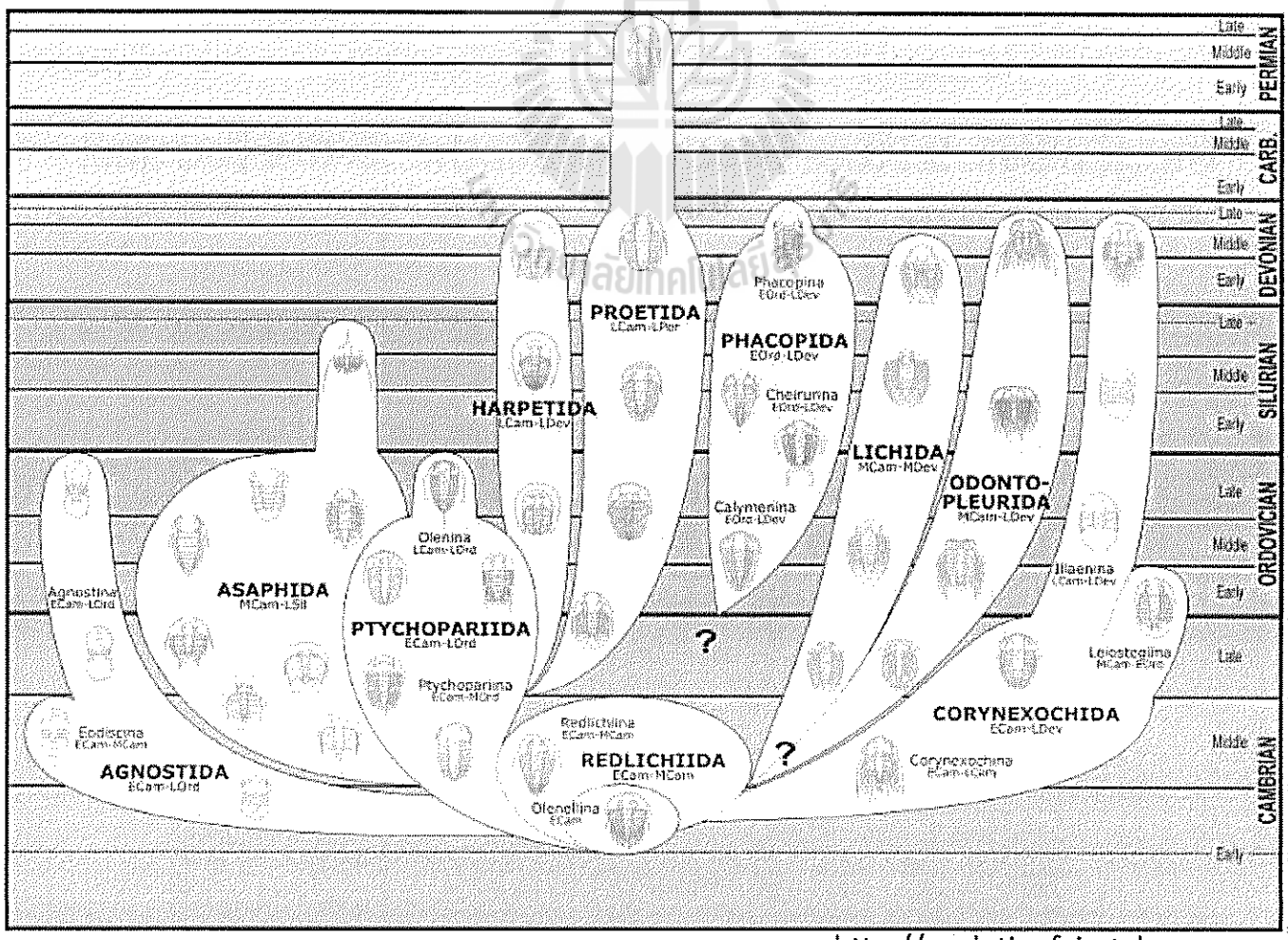
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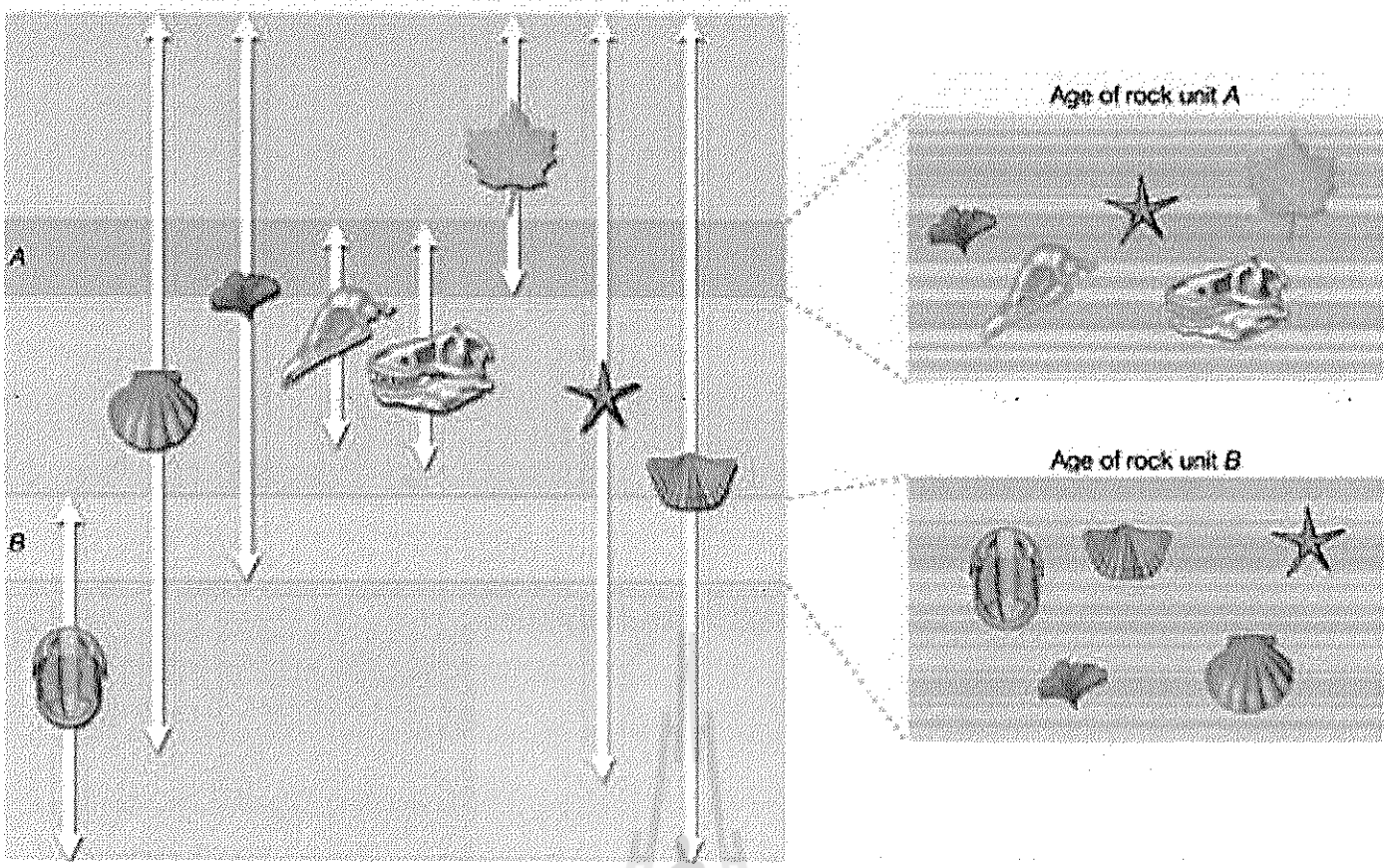
http://www.photos-morocco.com



http://www.fossilmuseum.net/

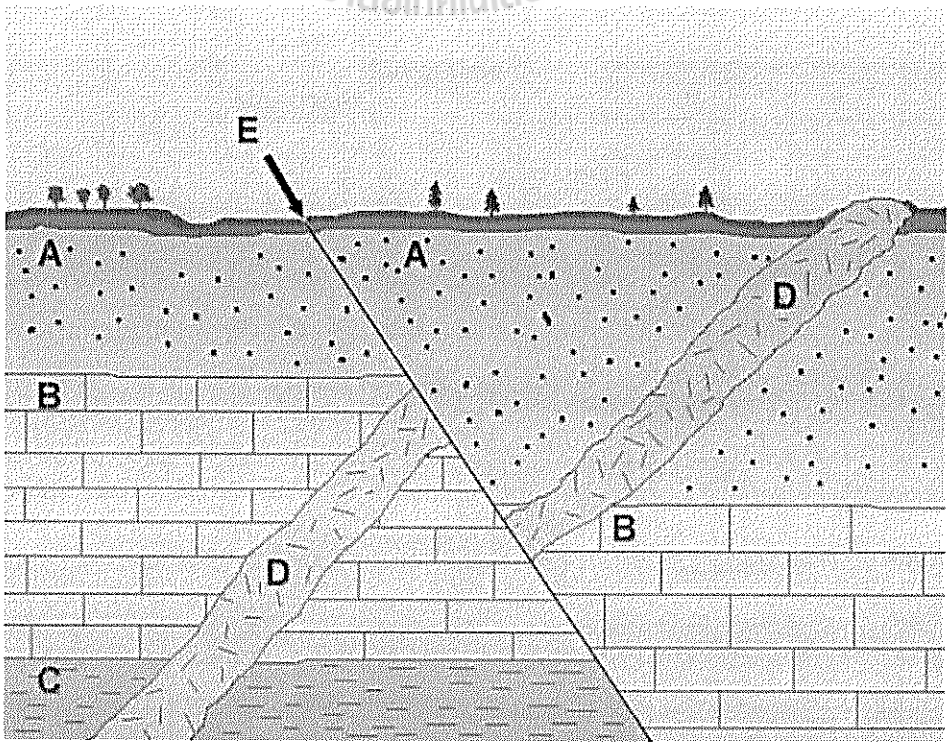


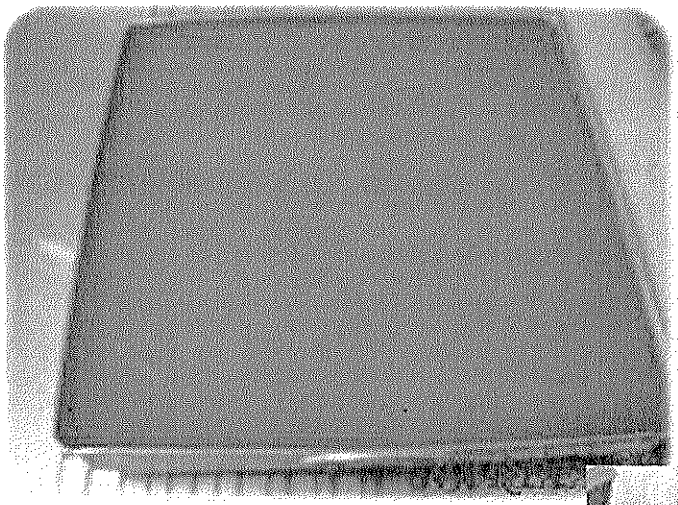
http://evolutionfairytale.com



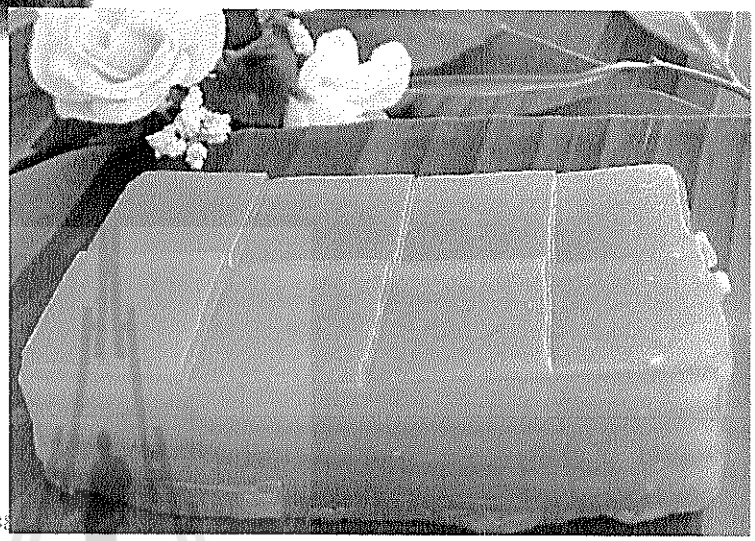
Law of cross-cutting relationships

The geologic feature which cuts another is the younger of the two features. (James Hutton)

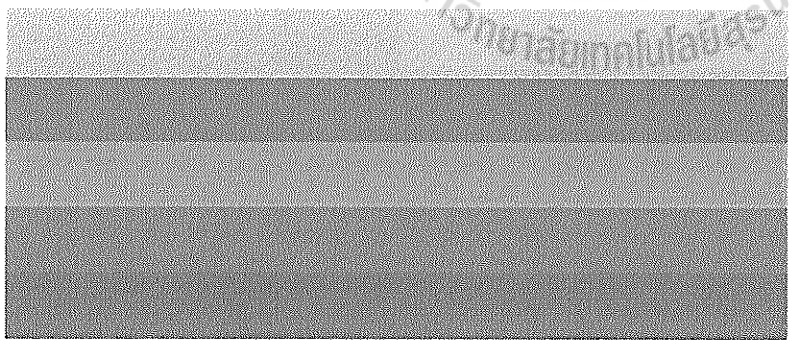


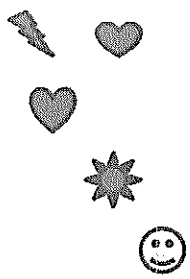






Sedimentary rocks
=
Layering ขนมชั้น





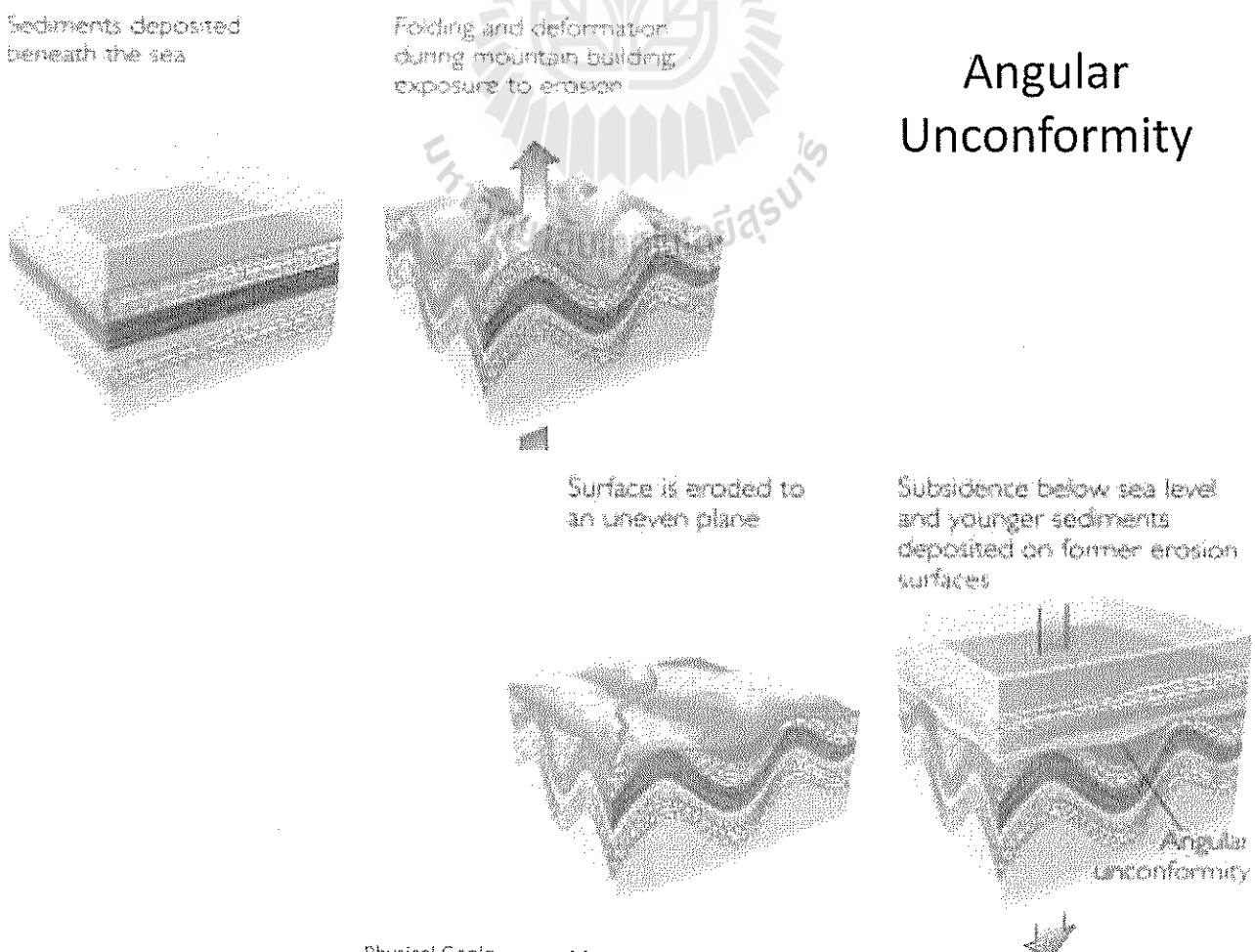
2. Unconformity

A buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. (James Hutton)

- Angular Unconformity
- Nonconformity
- Disconformity

They indicate the missing times in rock records.

Angular Unconformity



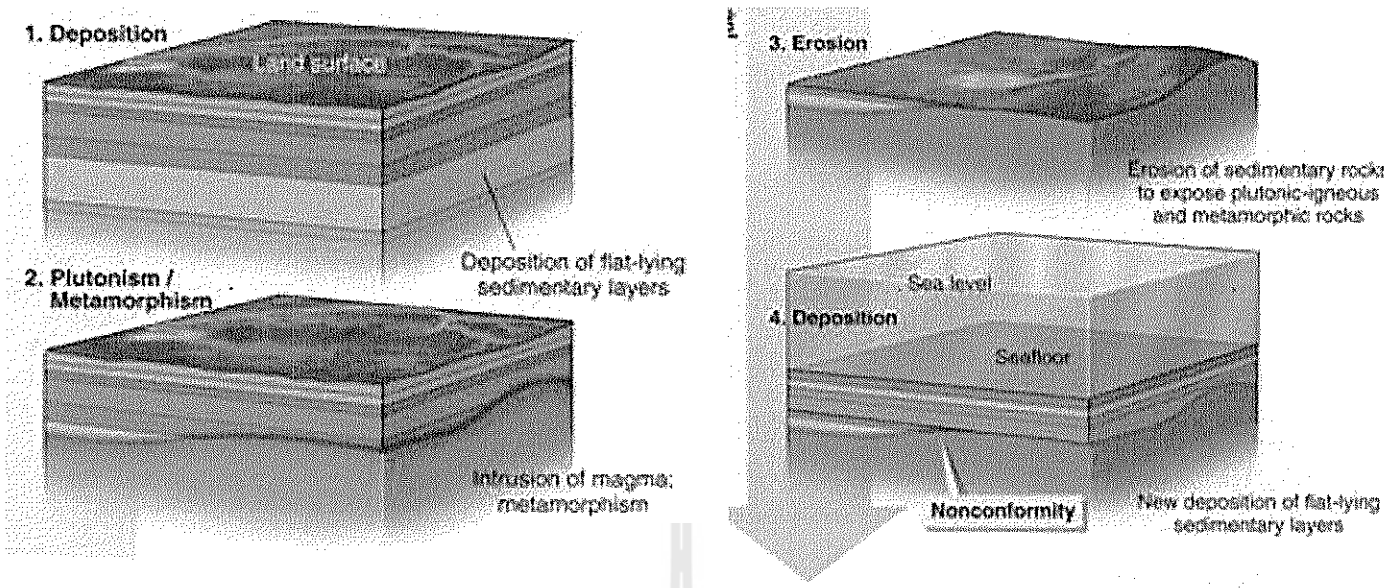
http://web.arc.losrios.edu



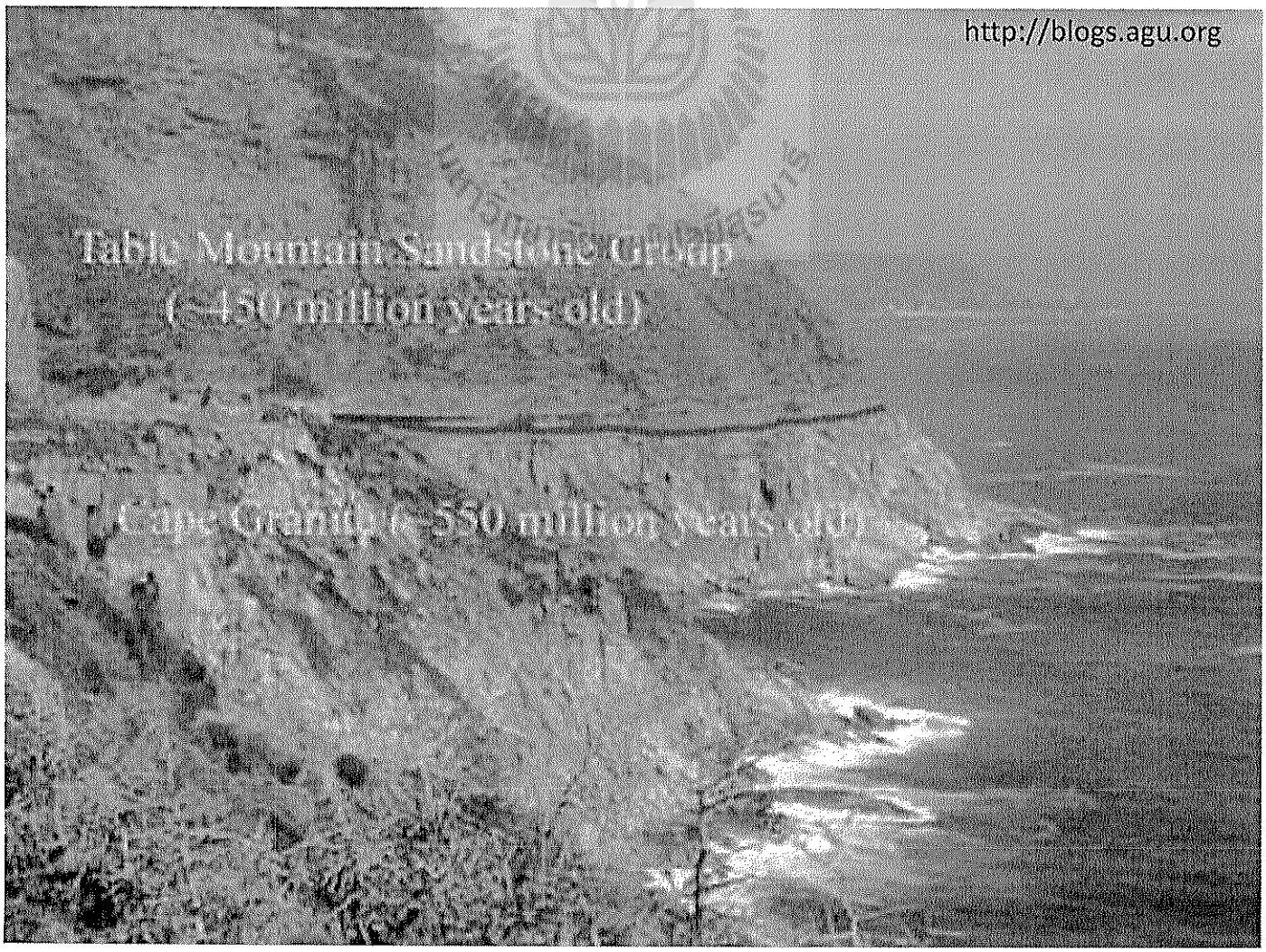


http://www.geograph.org.uk

Nonconformity

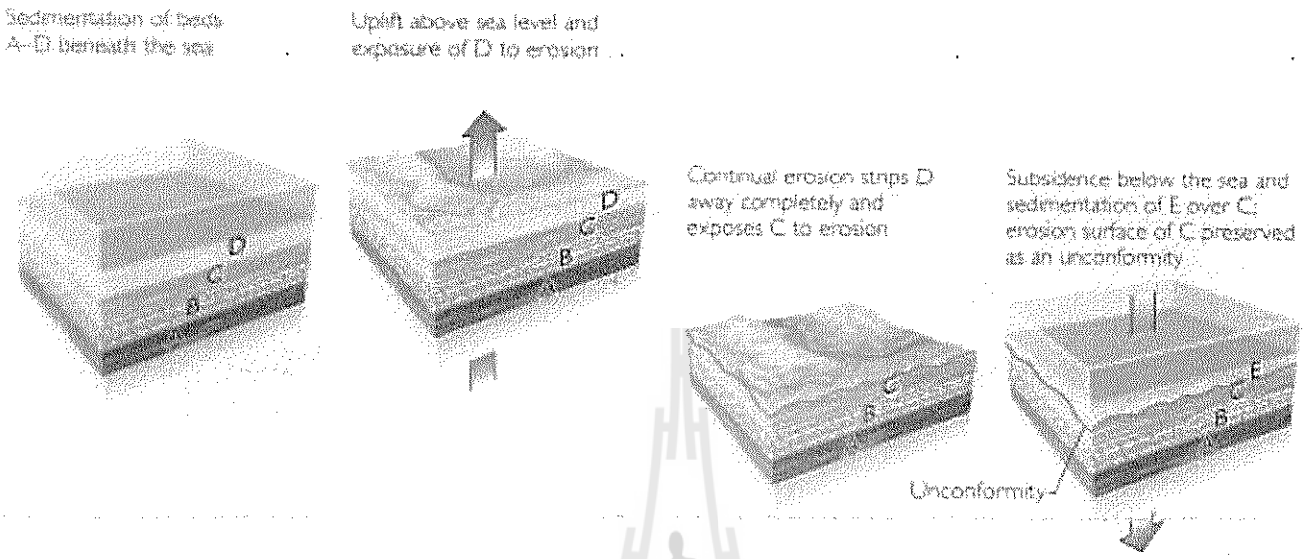


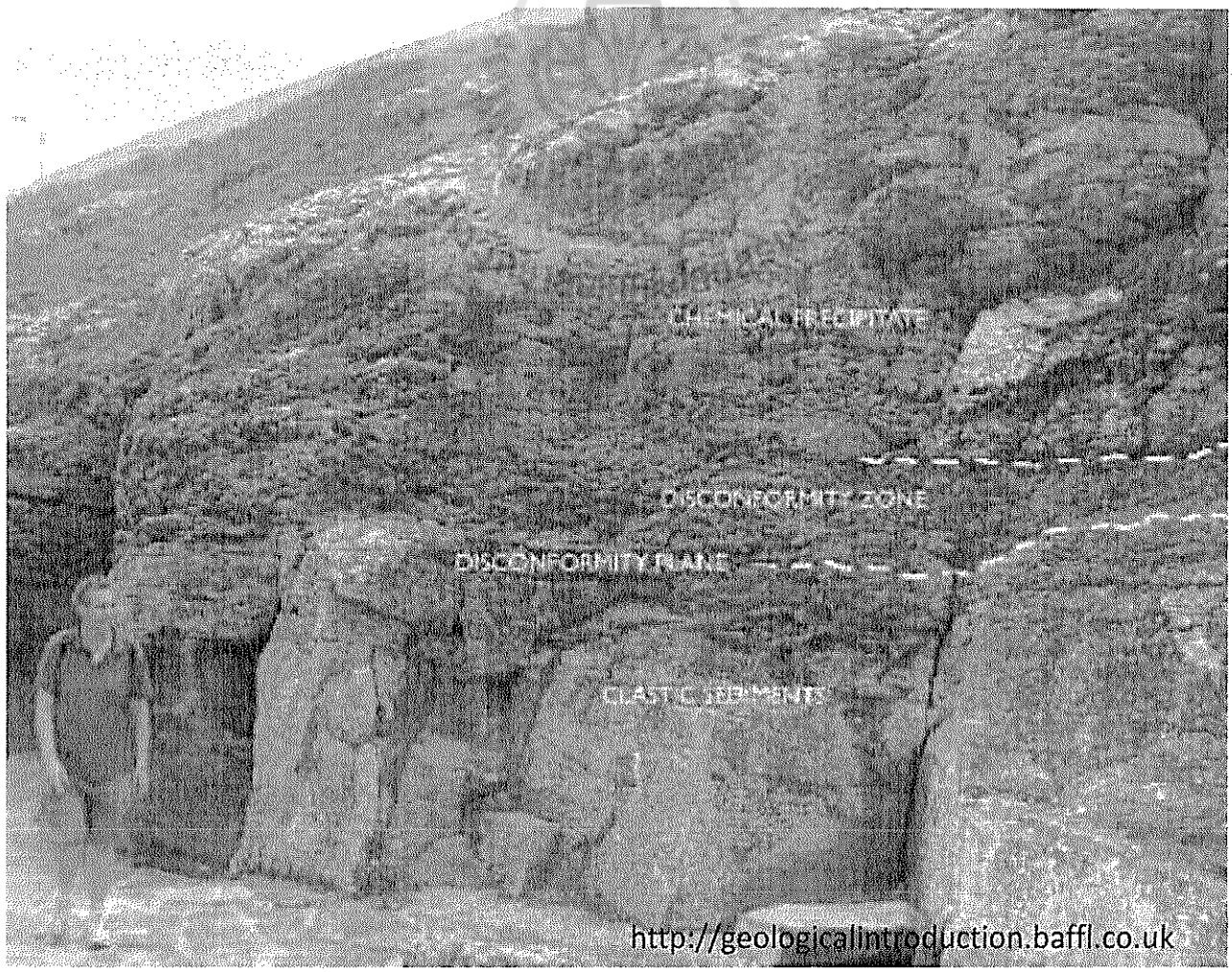
Nonconformity is related with intrusion



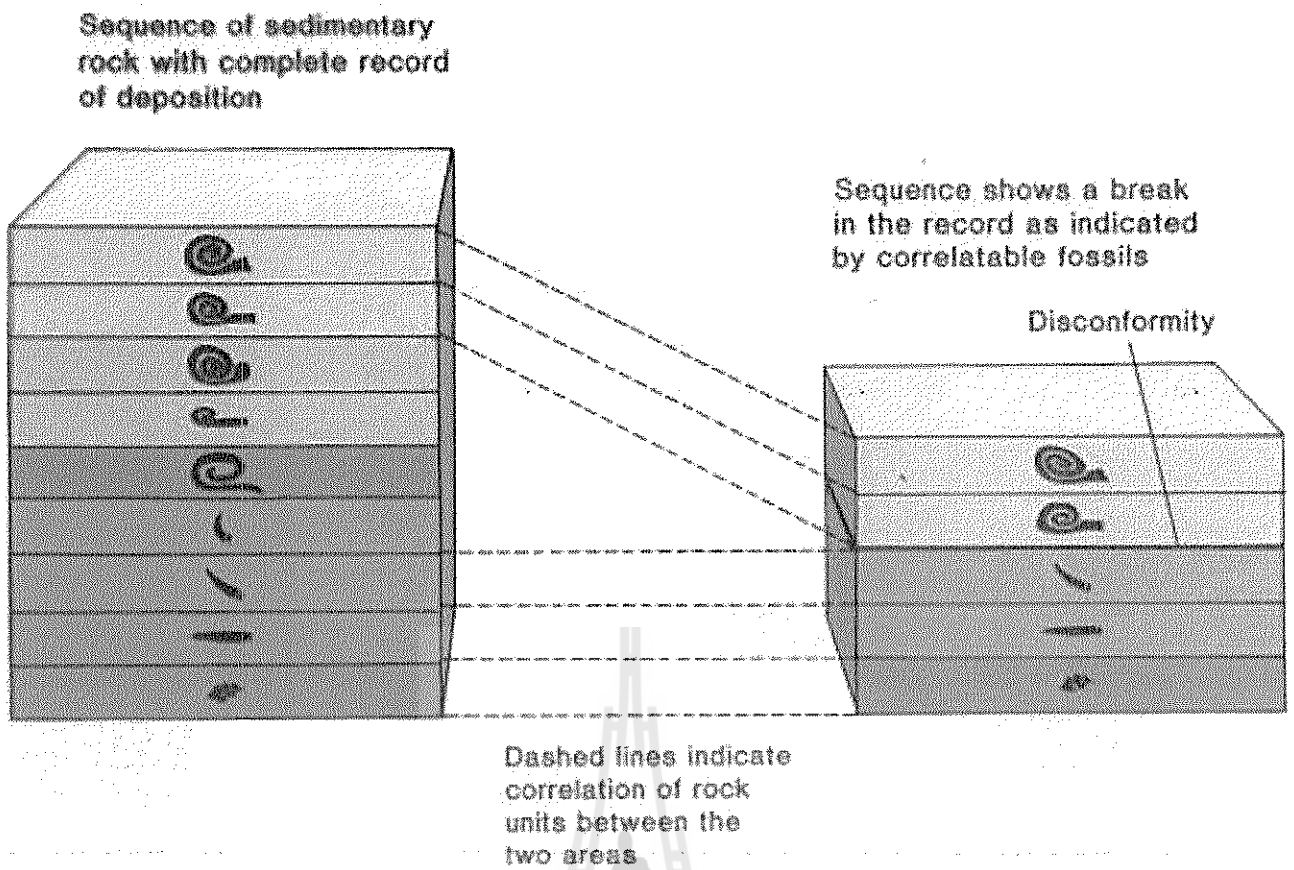
Disconformity

Disconformity is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition.





http://geologicalintroduction.baffl.co.uk



3. Geologic time

มหาวิทยาลัยเทคโนโลยีสุรนารี

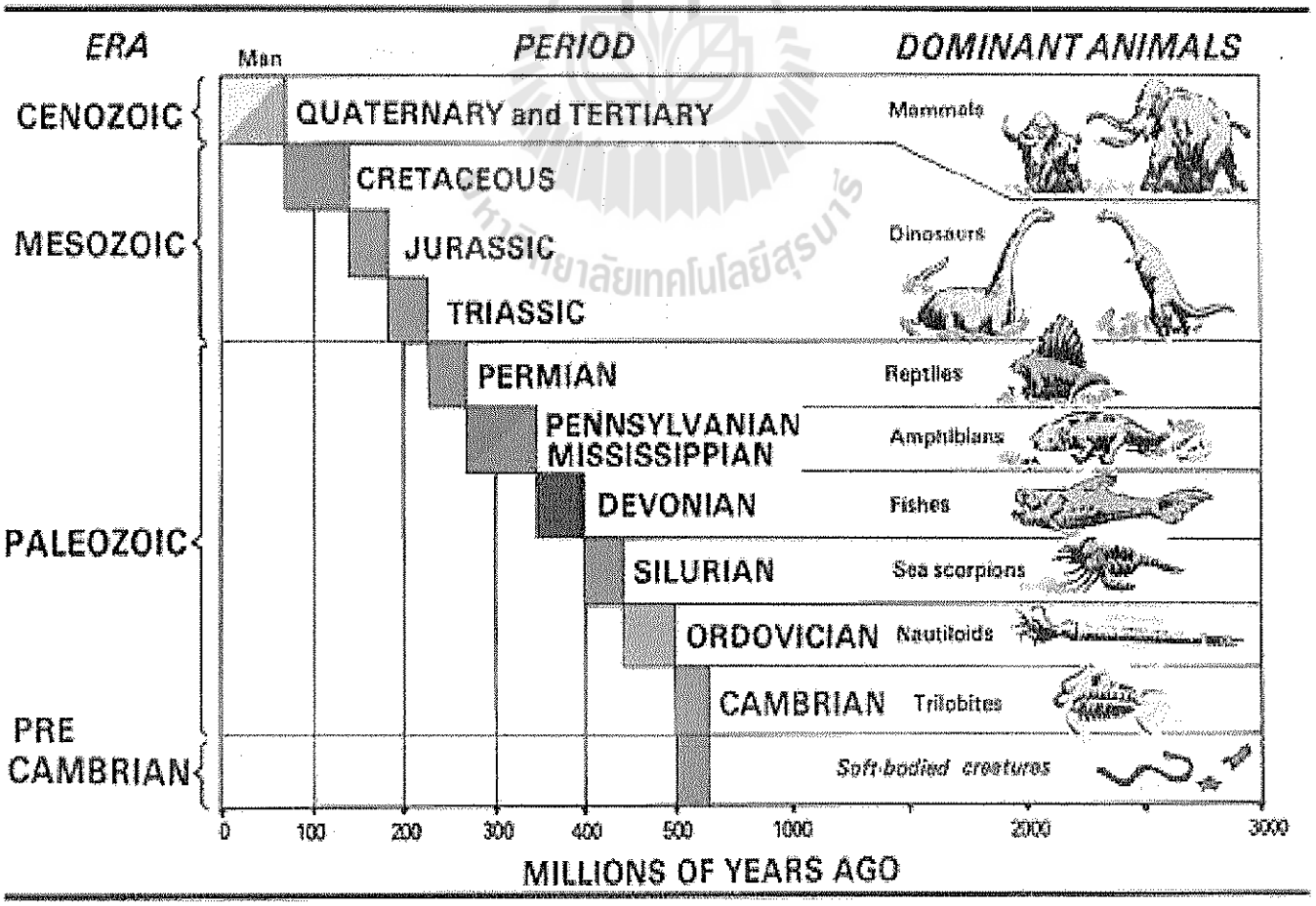
Contents

- Relative time & Absolute time
- Radiometric dating techniques
- Geologic time scale

Relative time and Absolute time

Relative time: subdivisions of the Earth's geology in a specific order based upon relative age relationships (most commonly, vertical/ stratigraphic position).

These subdivisions are given names, most of which can be recognized globally, usually on the basis of fossils.

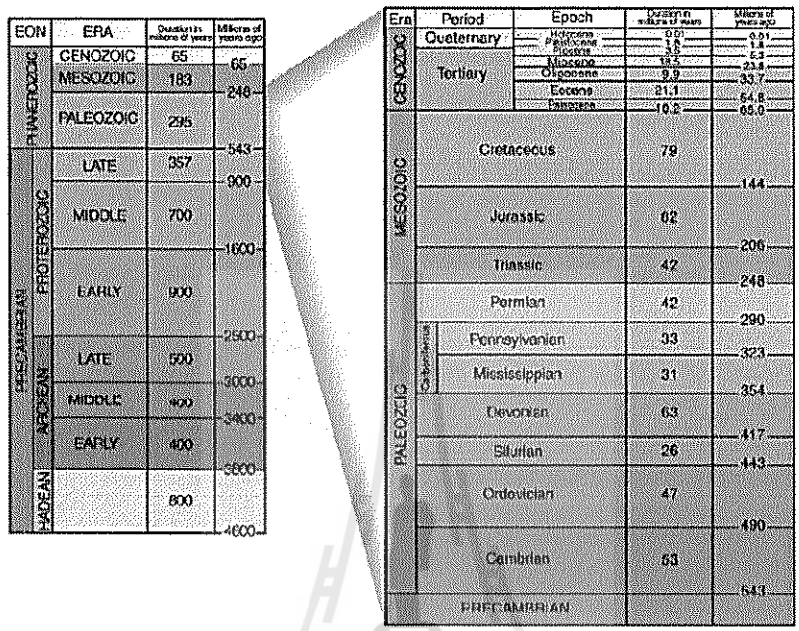


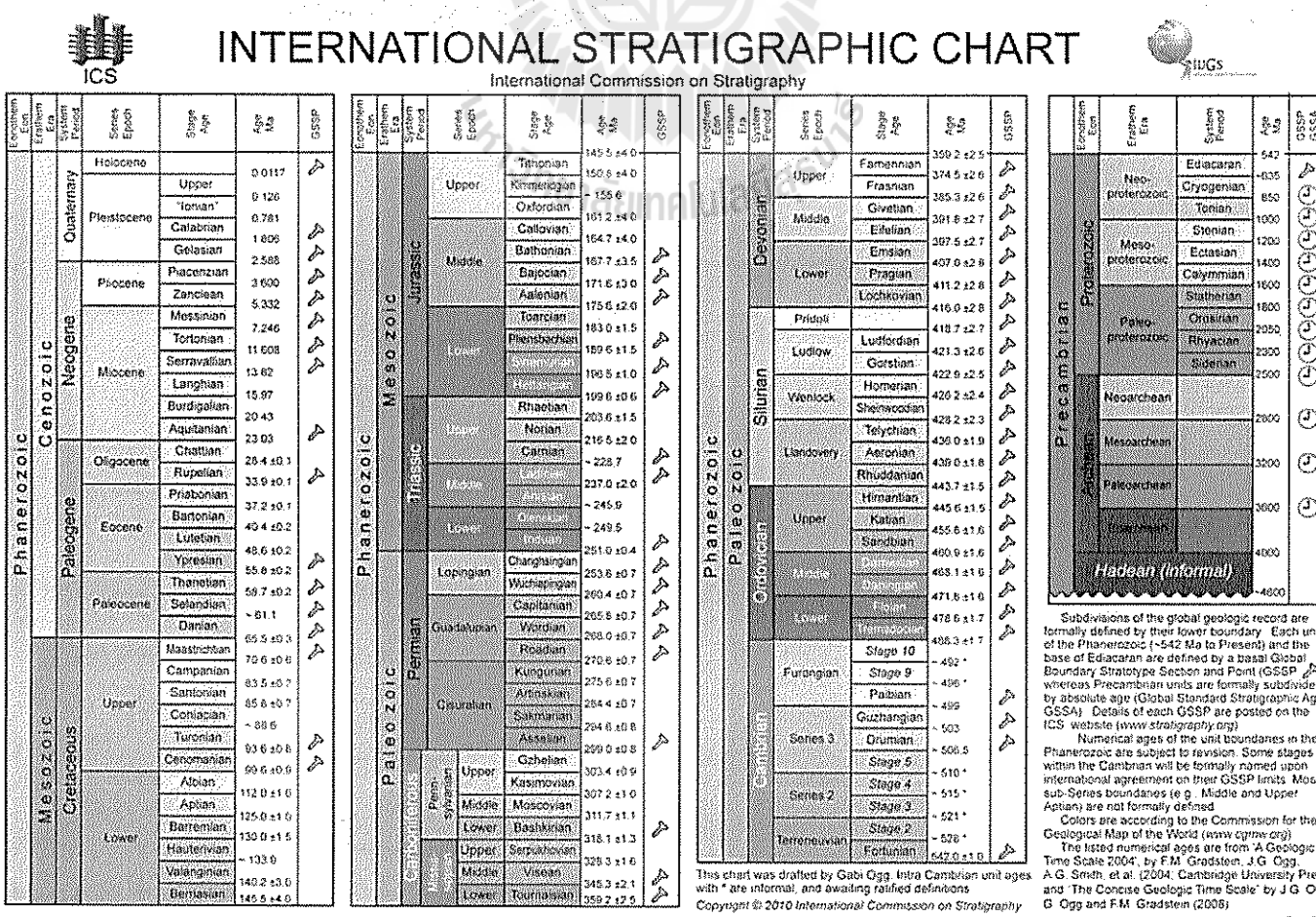
http://www.mbmg.mtech.edu/

Major divisions of geologic time.

Absolute time: numerical ages in "millions of years" or some other measurement.

These are most commonly obtained via radiometric dating methods performed on appropriate rock types.





Subdivisions of the global geologic record are formally defined by their lower boundary. Each unit of the Phanerozoic (~542 Ma to Present) and the base of Ediacaran are defined by a basal Global Boundary Stratotype Section and Point (GSSP) whereas Precambrian units are formally subdivided by absolute age (Global Standard Stratigraphic Age, GSSA). Details of each GSSP are posted on the ICS website (www.stratigraphy.org).

Numerical ages of the unit boundaries in the Phanerozoic are subject to revision. Some stages within the Cambrian will be formally named upon international agreement on their GSSP limits. Most sub-Series boundaries (e.g., Middle and Upper Aptian) are not formally defined.

Colors are according to the Commission for the Geological Map of the World (www.cgmw.org).

The listed numerical ages are from 'A Geologic Time Scale 2004', by F.M. Gradstein, J.G. Ogg, A.G. Smith, et al. (2004, Cambridge University Press) and 'The Concise Geologic Time Scale' by J.G. Ogg, G. Ogg and F.M. Gradstein (2008).

This chart was drafted by Gabi Ogg. Intra Cambrian unit ages with * are informal, and awaiting ratified definitions.

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Sept. 2010

Time units of Stratigraphy

Geologic time: interval of time necessary for deposition of time-stratigraphic units.

Geochronologic unit

- Era
  - Period
    - Epoch
      - Age

Time-stratigraphic unit: all rock deposited in a given time and may include other rock types.

Time-stratigraphic unit

- Erathem
  - System
    - Series
      - Stage

Rock-stratigraphic unit: distinctive from rock above and below

Group

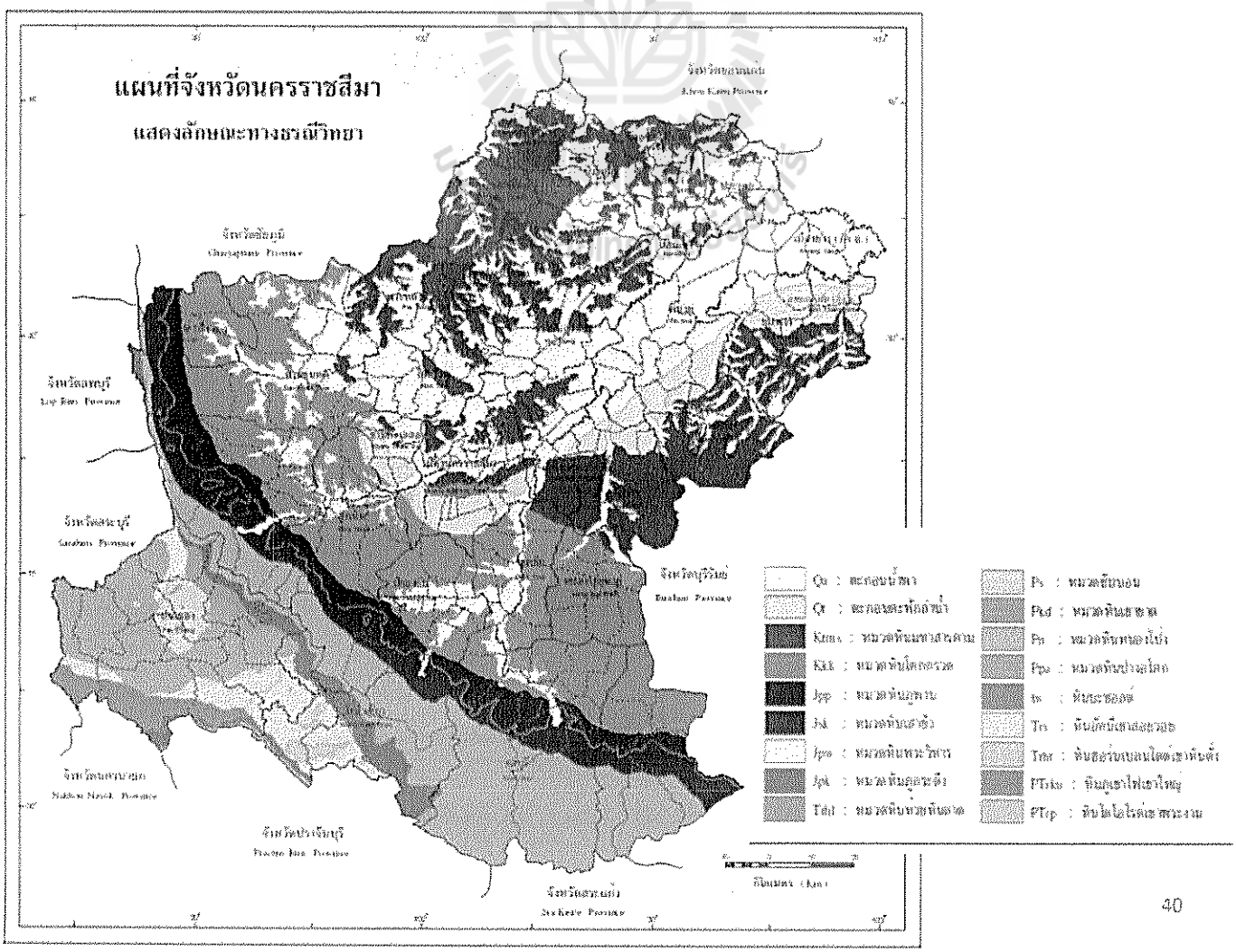
Formation

Member

Formation name consist of two parts:

Geographic name + Lithology or simply Formation

For example: Khorat Group (Mesozoic Era; Triassic-Jurassic-Cretaceous) is composed of five Formations namely, Phu Kradung, Phra Wihan, Sao Kao, Phu Phan, Khok Krued.

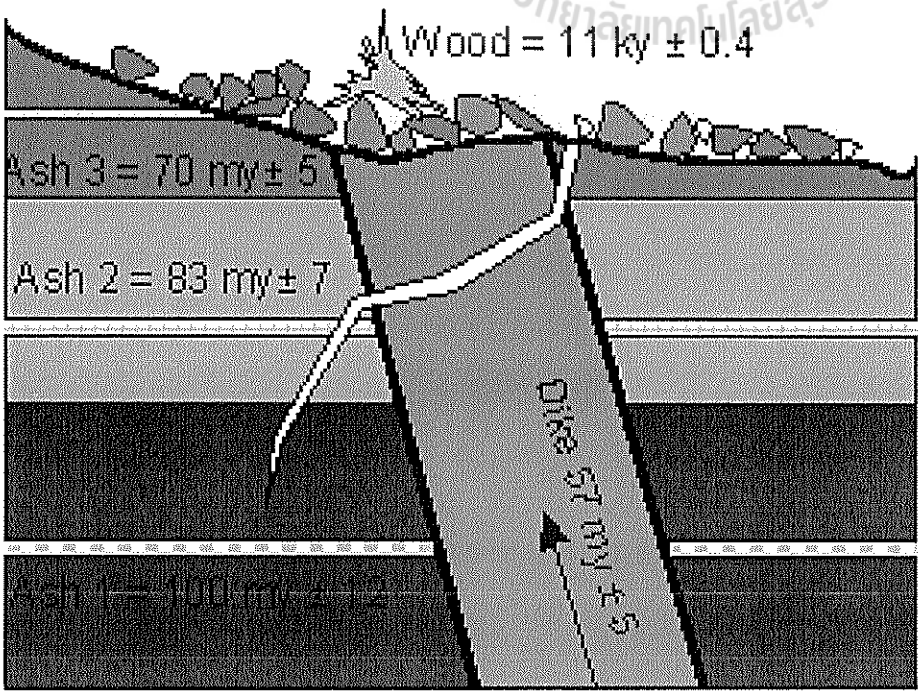


For examples:

Mahasarakham Formation	Cretaceous
Khorat Group:	
Khok Krued Formation	
Phu Phan Formation	Jurassic
Sao Khao Formation,	
Phra Wihan Formaion	
Phu Kra Dueng Formation	
Huai Hin Lat Formation	**Triassic**
Saraburi Group:	Permian
Dan Sai Shale	
Saraburi Limestone	
Khao Luak Formation	

Absolute time: Geochronology

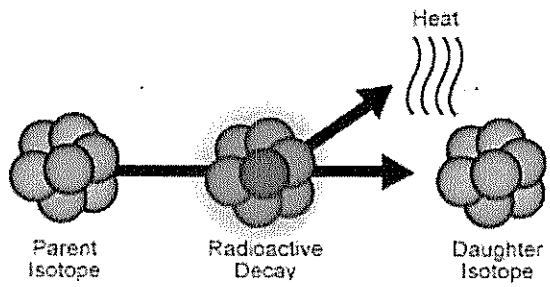
Radiometric dating (Isotopic dating): the source of the dates on the Geologic time scale.



http://www.youtube.com/watch?v=1920gi3swe4

Radioactive elements can decay. Decay occurs as an element changes to another element.

The parent element is radioactive, the daughter element is stable.



Decay rate is constant.

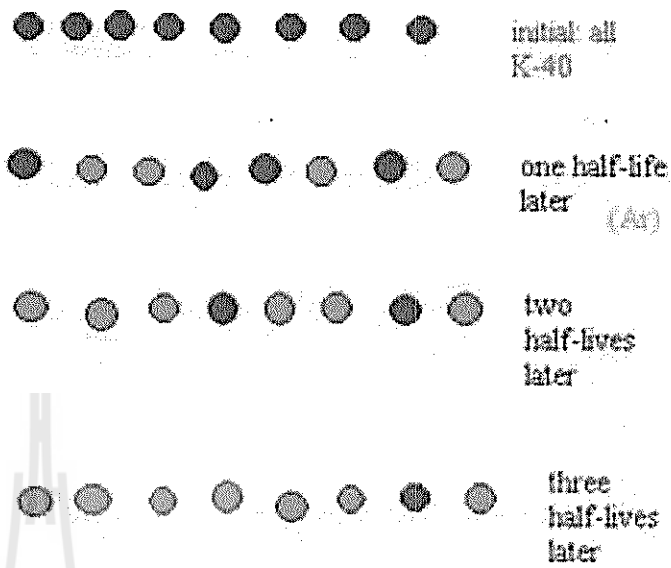
Decay Constant, λ

C-14	1.21×10^{-4} atoms/y
U-235	9.72×10^{-10} atoms/y
K-40	5.34×10^{-10} atoms /y

Common radioactive elements, parents and daughters

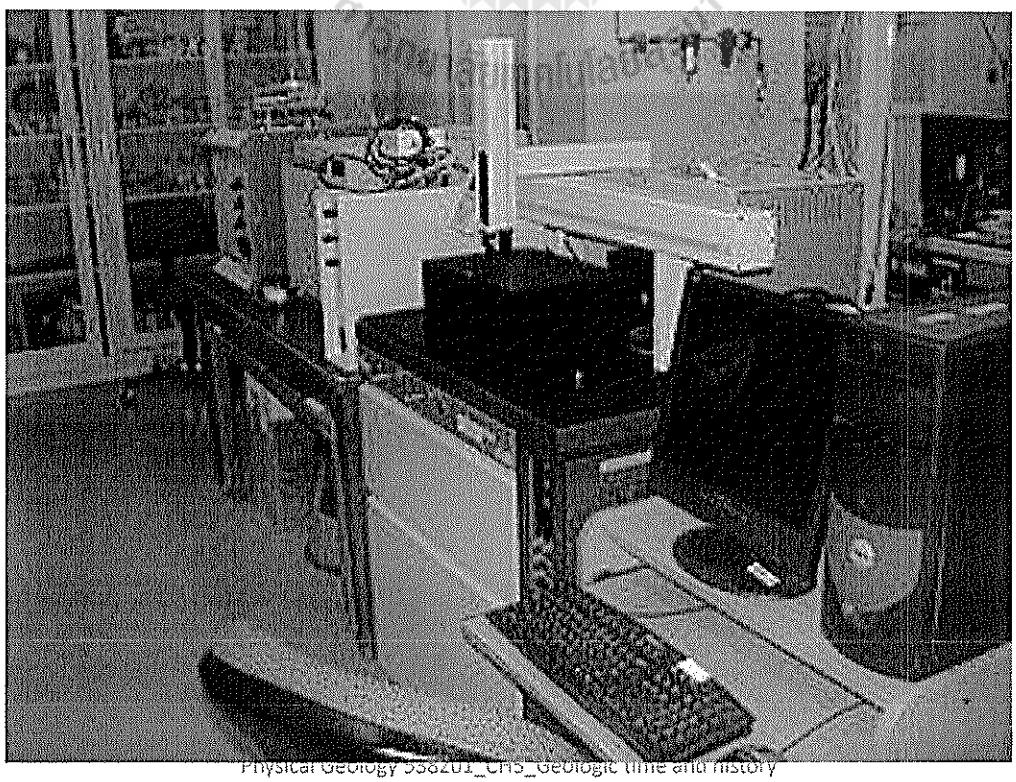
Carbon -14	⇨	Nitrogen-14
Uranium-235	⇨	Lead-207
Potassium-40	⇨	Argon-40
Uranium-238	⇨	Lead-206
Rubidium-87	⇨	Strontrium-87

Half life	
C-14	5,728 years
U-235	713 MY
K-40	1.3 BY
U-238	4.5 BY
R-87	48.8 BY



The parent: daughter ratio measured with a mass spectrometer.

The decay constant measured by a scintillometer.

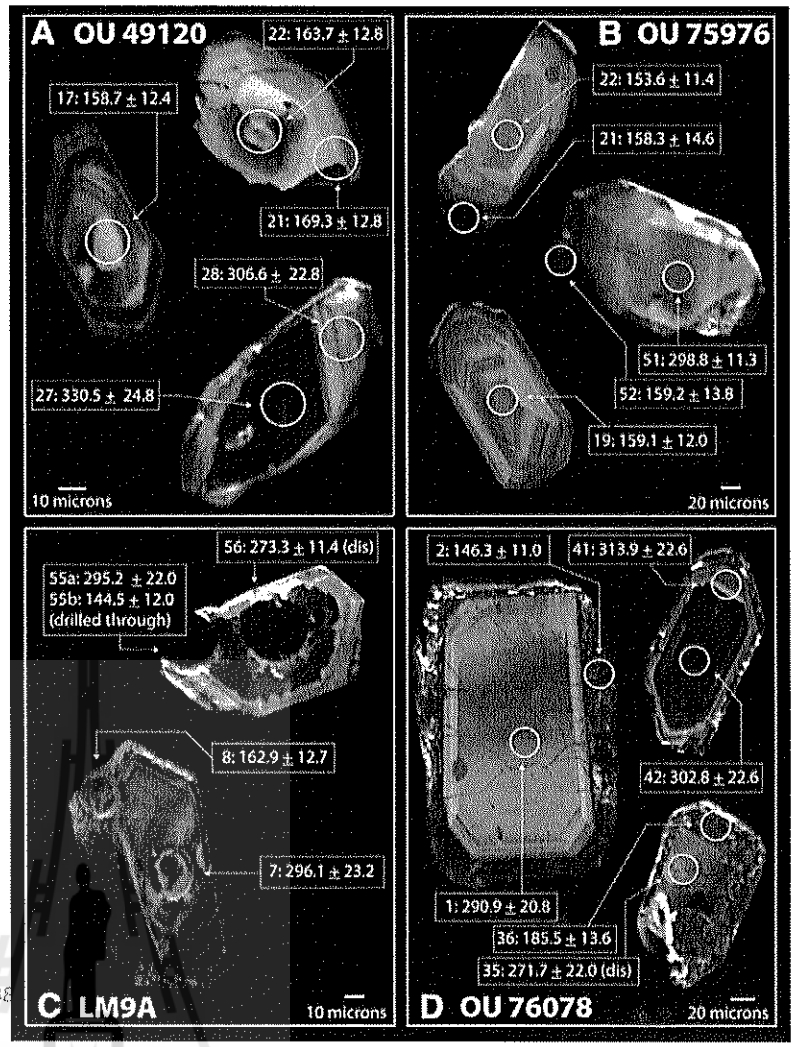


Setting the radiometric clock

When an igneous melt crystallizes, parent and daughter elements are chemically separated into different crystals.

Further radioactive decay keeps the parent and daughter elements in the same crystal.

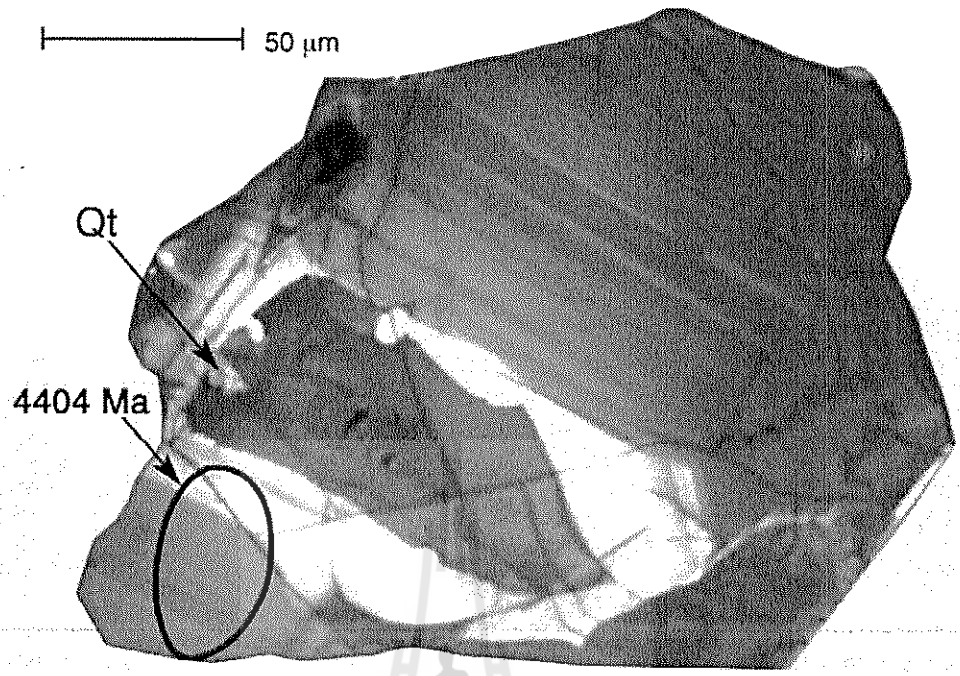
Individual crystals of the same mineral are dated to give the age crystallization, e.g., zircon, muscovite, biotite.



Age of the Earth: 4.6 BY

- The oldest rocks found on earth are 4.0 BY from NW Canada.
- 4.3 BY detrital zircons have been found in younger sandstones in Australia.
- Meteorites and moon rocks are 4.6 BY.
- Rocks older than 4.0 BY on earth have apparently been destroyed by weathering and plate tectonics.

4.4 BY zircon grain from Australia found in 3 BY sandstone

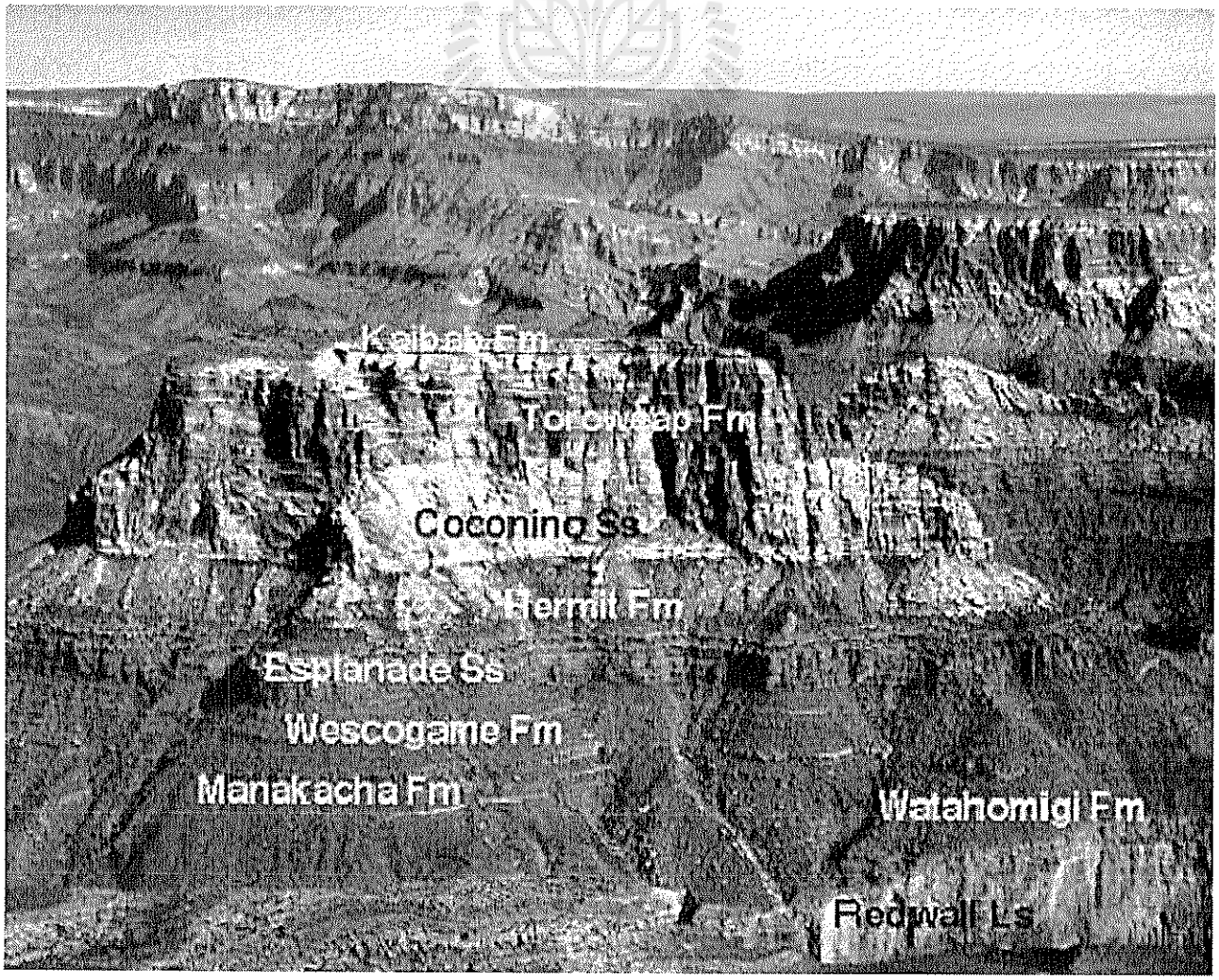


Stratigraphic correlation

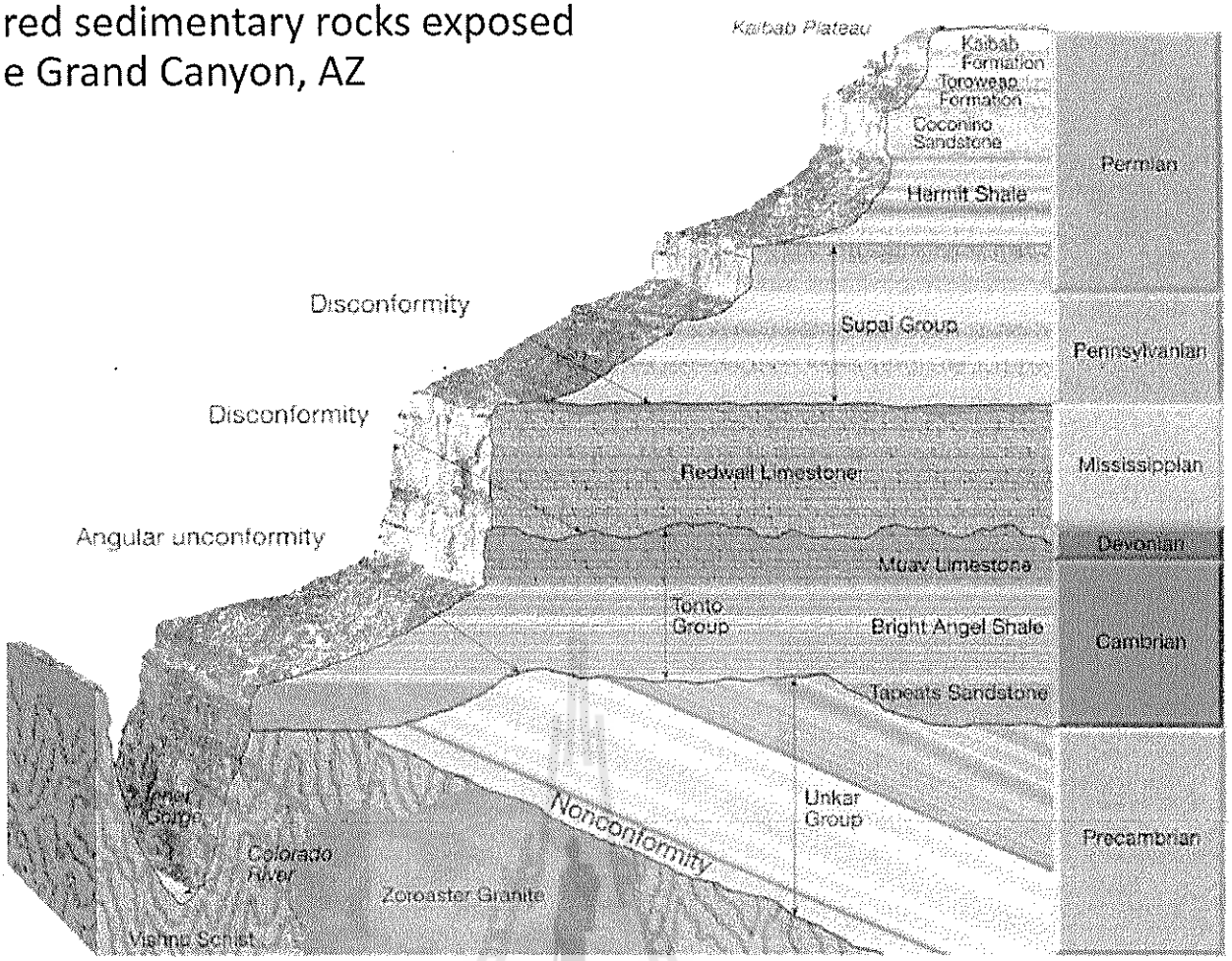
Determination of the equivalence of bodies of rock at different locations.
There are two kinds of correlation:

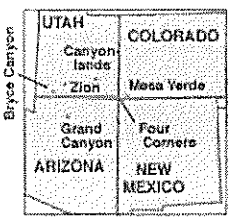
- Lithostratigraphic: matching up continuous formations.
- Chronostratigraphic: matching up rocks of the same age, usually done with fossils using biostratigraphy.

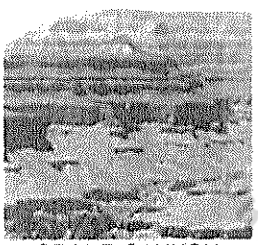

http://www.nature.nps.gov


Kaibab Fm
Toroweap Fm
Coconino Ss
Hermit Fm
Esplanade Ss
Wescogame Fm
Manakacha Fm
Watahomigi Fm
Redwall Ls

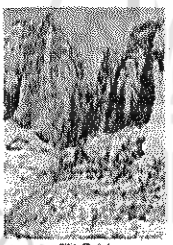
Layered sedimentary rocks exposed in the Grand Canyon, AZ



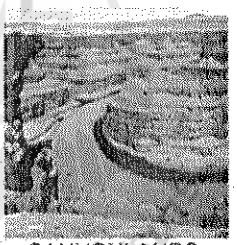




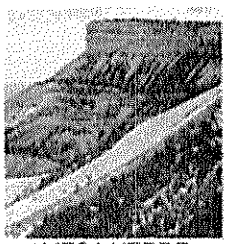
GRAND CANYON NATIONAL PARK ARIZONA



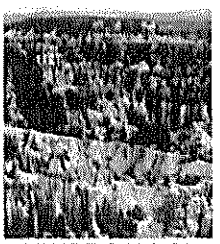
ZION NATIONAL PARK UTAH



CANYONLANDS NATIONAL PARK UTAH



MESA VERDE NATIONAL PARK COLORADO



BRYCE CANYON NATIONAL PARK UTAH

	GRAND CANYON NATIONAL PARK ARIZONA	ZION NATIONAL PARK UTAH	CANYONLANDS NATIONAL PARK UTAH	MESA VERDE NATIONAL PARK COLORADO	BRYCE CANYON NATIONAL PARK UTAH
TERTIARY PERIOD					Wasatch Fm
CRETACEOUS PERIOD				Mesaverde Fm Mancos Shale Dakota Ss	Kaiparowits Fm Wahweap Ss Straight Cliffs Ss Tropic Shale Dakota Ss
JURASSIC PERIOD		Carmel Fm Navajo Ss	Morrison Fm Summerville Fm Curtis Fm Entrada Ss Carmel Fm Navajo Ss	Morrison Fm Summerville Fm Curtis Fm Entrada Ss	Winsor Fm Curtis Fm Entrada Ss Carmel Fm Navajo Ss
TRIASSIC PERIOD	Moenkopi Fm	Kayenta Fm Wingate Ss Chinle Fm Moenkopi Fm	Kayenta Fm Wingate Ss Chinle Fm Moenkopi Fm	Older rocks not exposed	Older rocks not exposed
PERMIAN PERIOD	Kaibab Ls Toroweap Fm Coconino Ss Hermit Shale	Kaibab Ls Older rocks not exposed	Cutler Fm Rico Fm Hermosa Fm		
PENNSYLVANIAN PERIOD	Supai Fm				
MISSISSIPPIAN PERIOD	Redwall Ls				
DEVONIAN PERIOD*	Temple Butte Ls		Older rocks not exposed		
CAMBRIAN PERIOD	Muav Fm Bright Angel Shale Tapeats Ss				
PRECAMBRIAN PERIOD	Vishnu Schist				

*Rocks of Ordovician and Silurian age not present in Grand Canyon
Ss-Sandstone, Fm-Formation, Ls-Limestone

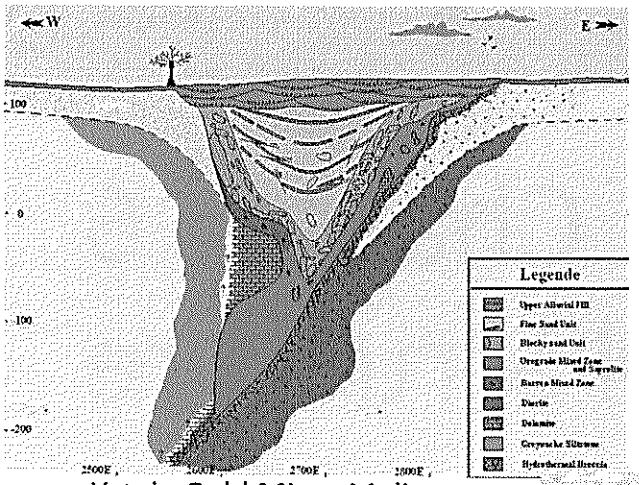
http://creationwiki.org

Chapter 6
Geological Structure

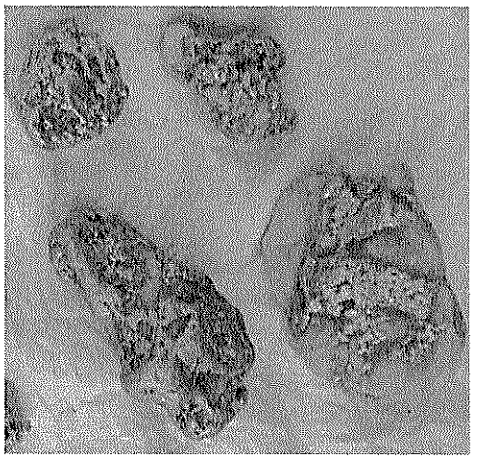
โครงสร้างธรณีวิทยา

Contents

1. Primary structure
2. Rock deformation
3. Strike / Dip
4. Folds
5. Fractures in rock

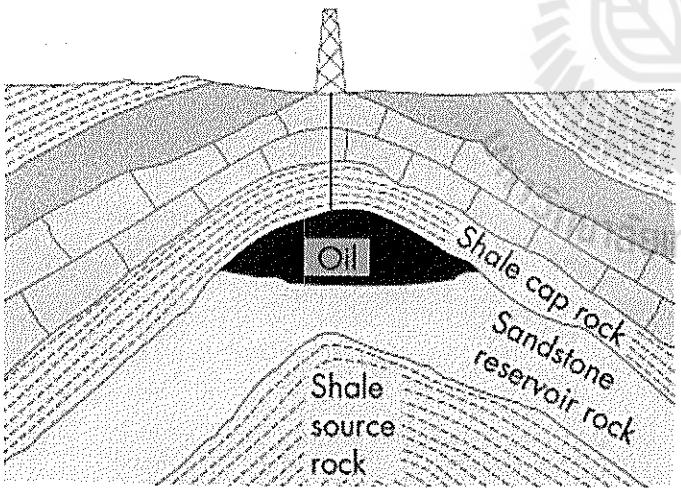


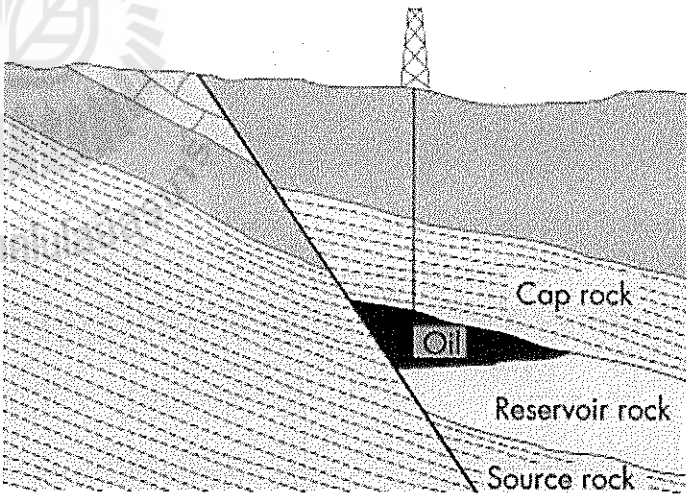
Yatela Gold Mine, Mali



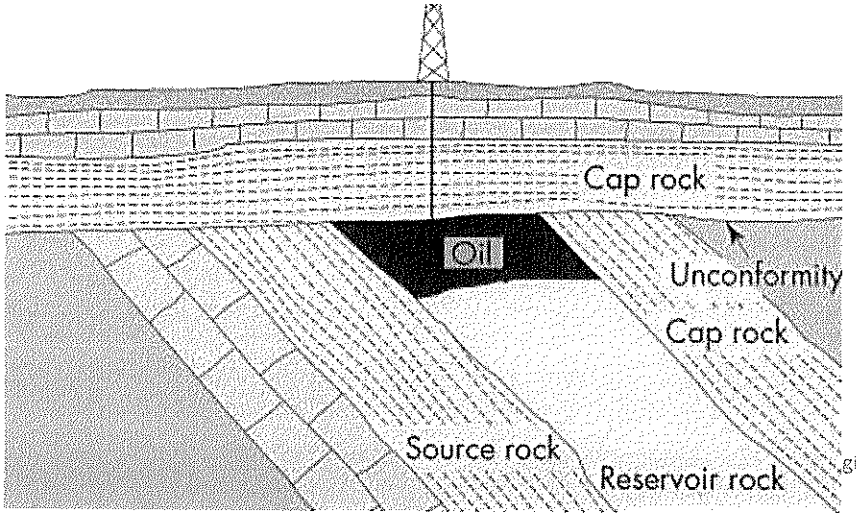


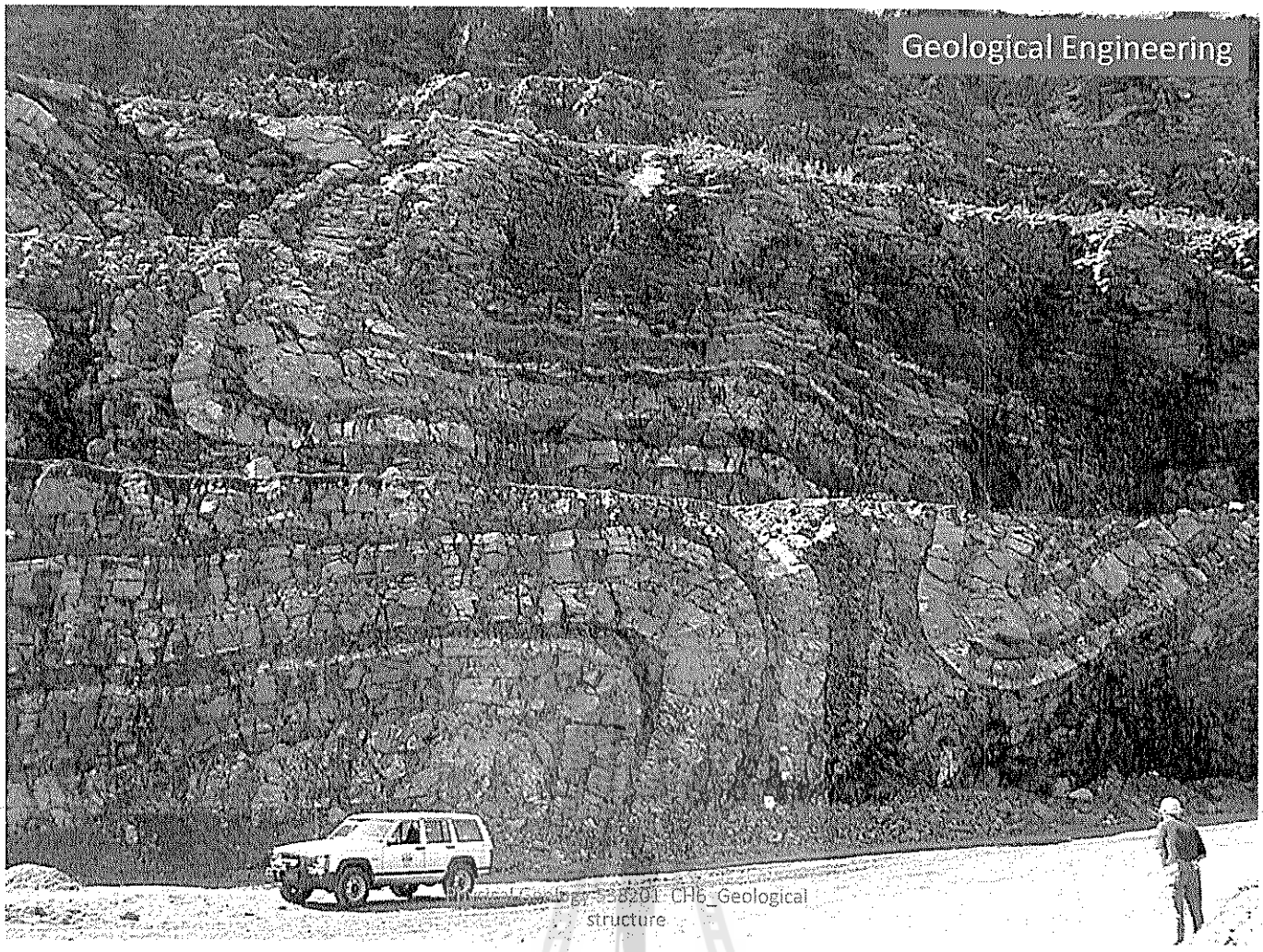
Akara Mining, Thailand



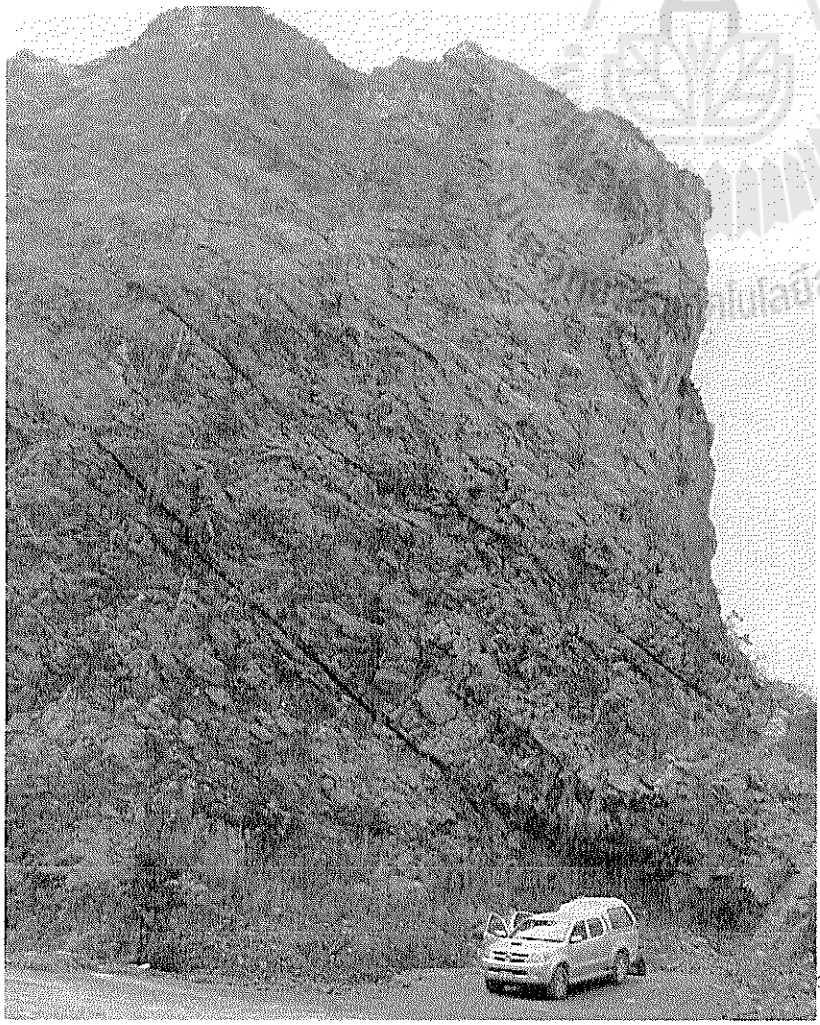


Petroleum reservoirs





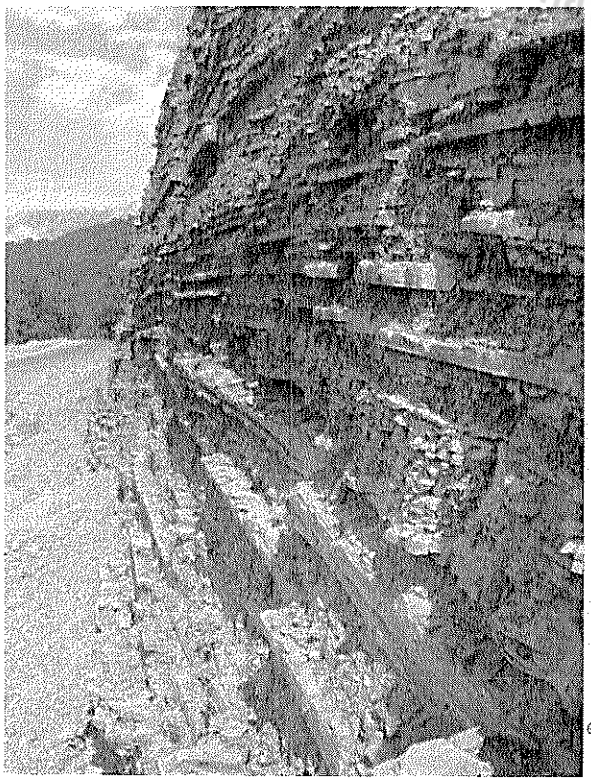
Safety??



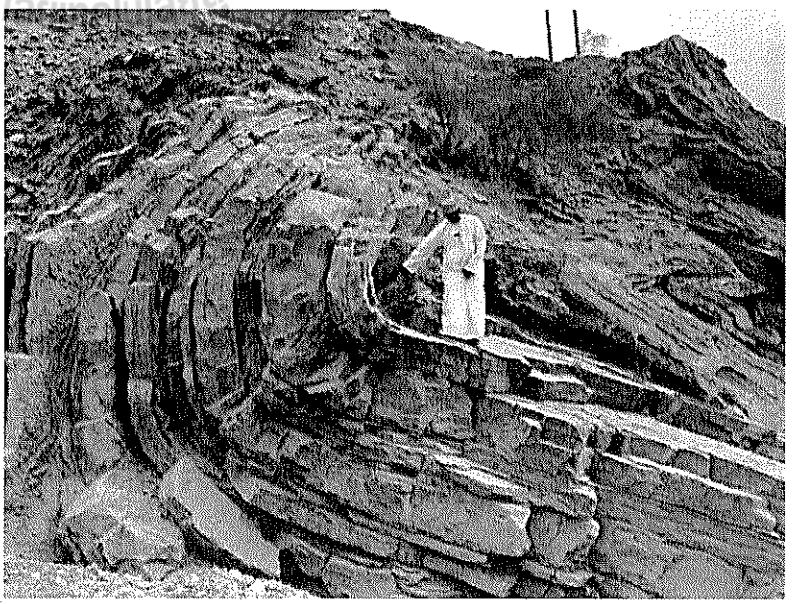


Geological structures

Primary structure



Secondary structure



1. Primary structure

Contents

- Sedimentary structure
- Igneous structure

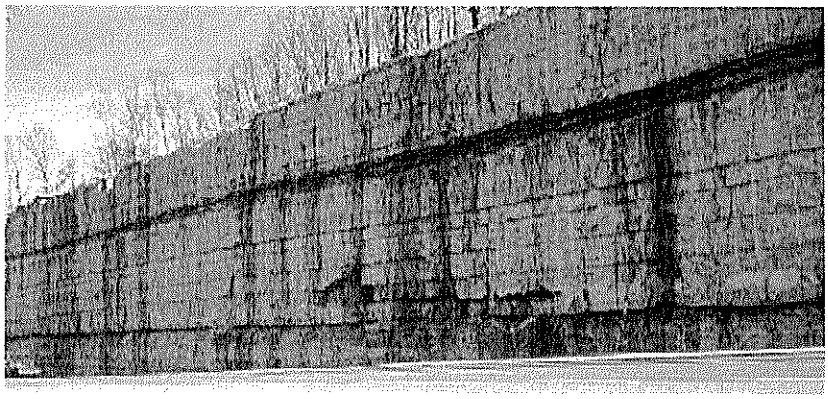
Primary structures are geometric features developed during formation of a rock body in bothsedimentary or igneous environments, can be small (microscopic) to large (mountain) scale and which provide clues about environment of rock formation.

Sedimentary structures

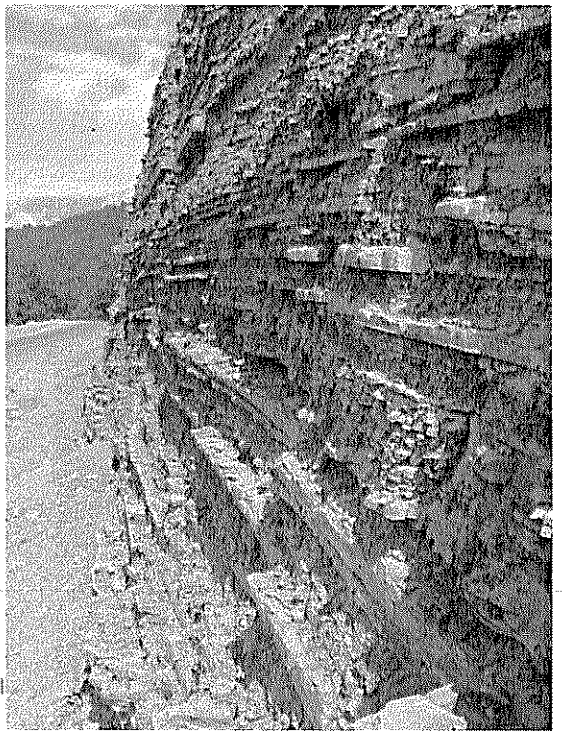
Features within sedimentary rocks produced during or just after sediment deposition.

Sedimentary structures provide clues to how and where deposition of sediments occurred

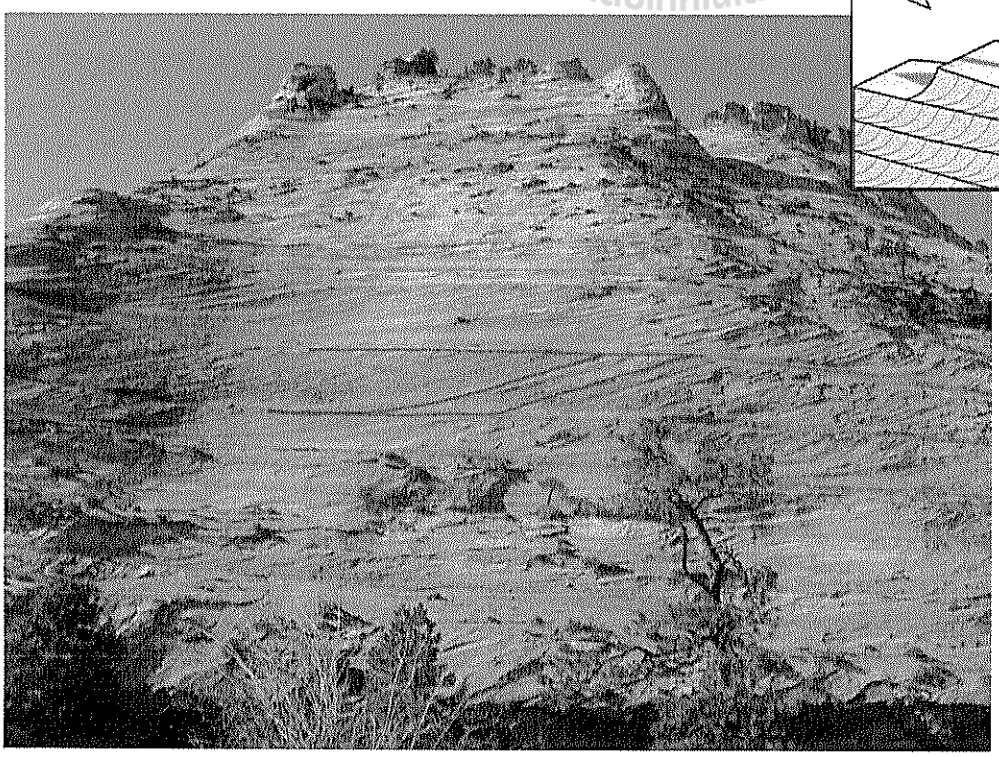
- Bedding
- Unconformity
- Cross bedding
- Graded bedding
- Ripple marks
- Mud cracks
- Trace fossils

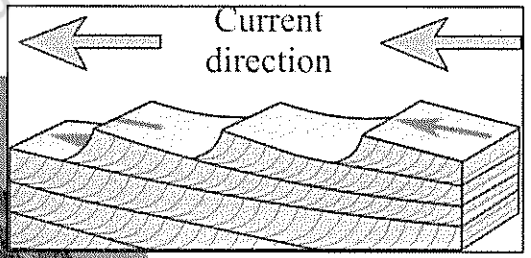


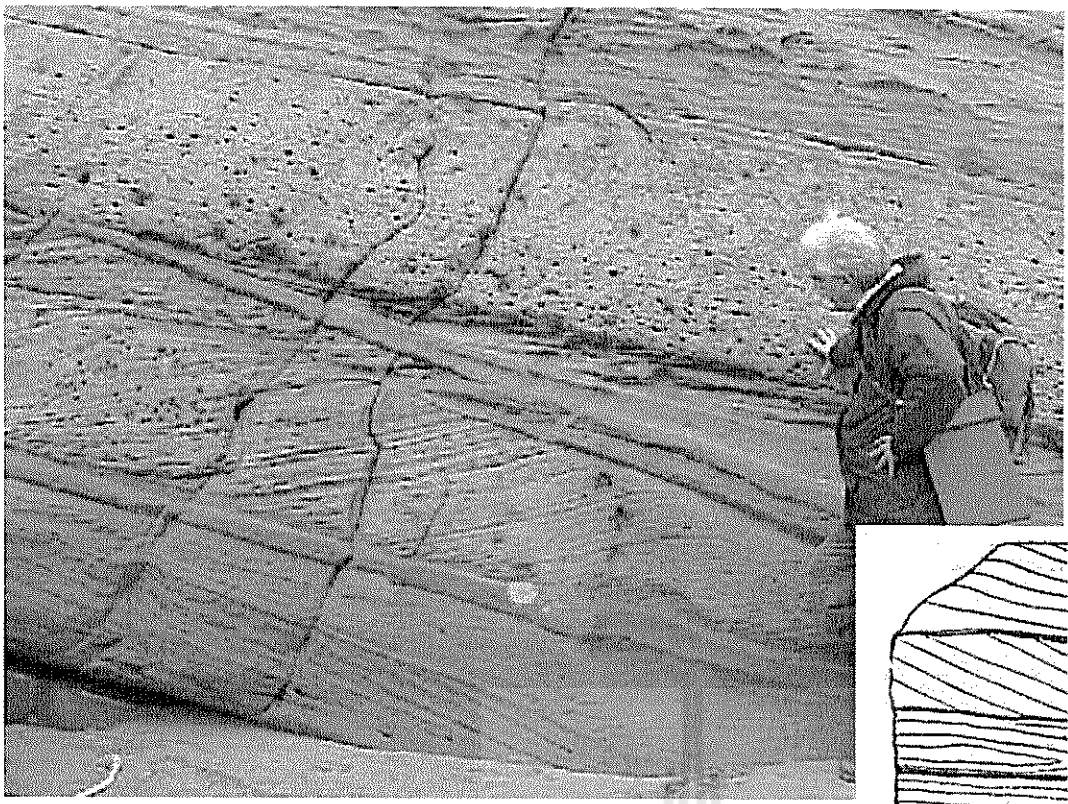
Bedding: Series of visible layers within a rock, most common sedimentary structure

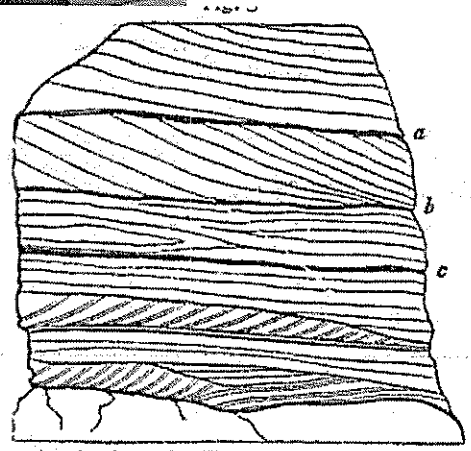


Cross-bedding: Series of thin, inclined layers within a horizontal bed of rock, common in sandstones. They can indicate the deposition in ripples, bars, dunes, deltas.







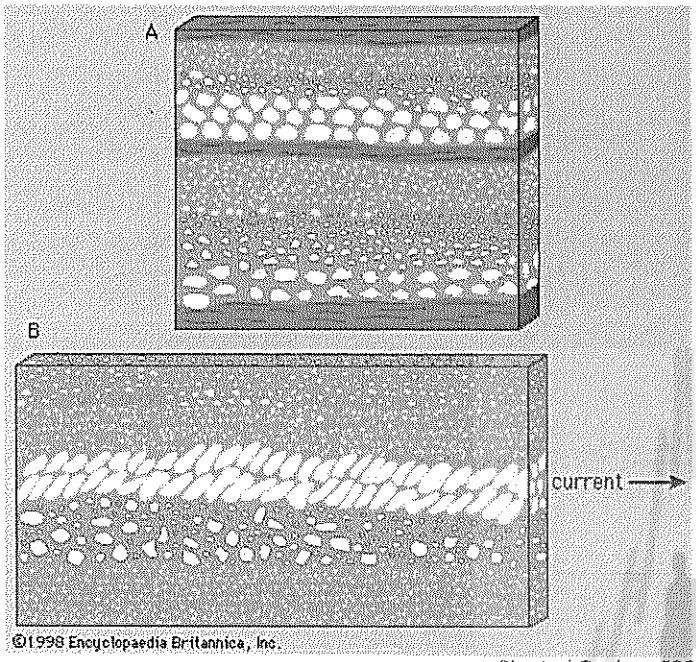


Section of sand at Sandy Hill, near Biggleswade, Bedfordshire. Height 20 ft. (Green-sand formation.)

Ripple marks: small ridges formed on surface of sediment layer by moving wind or water

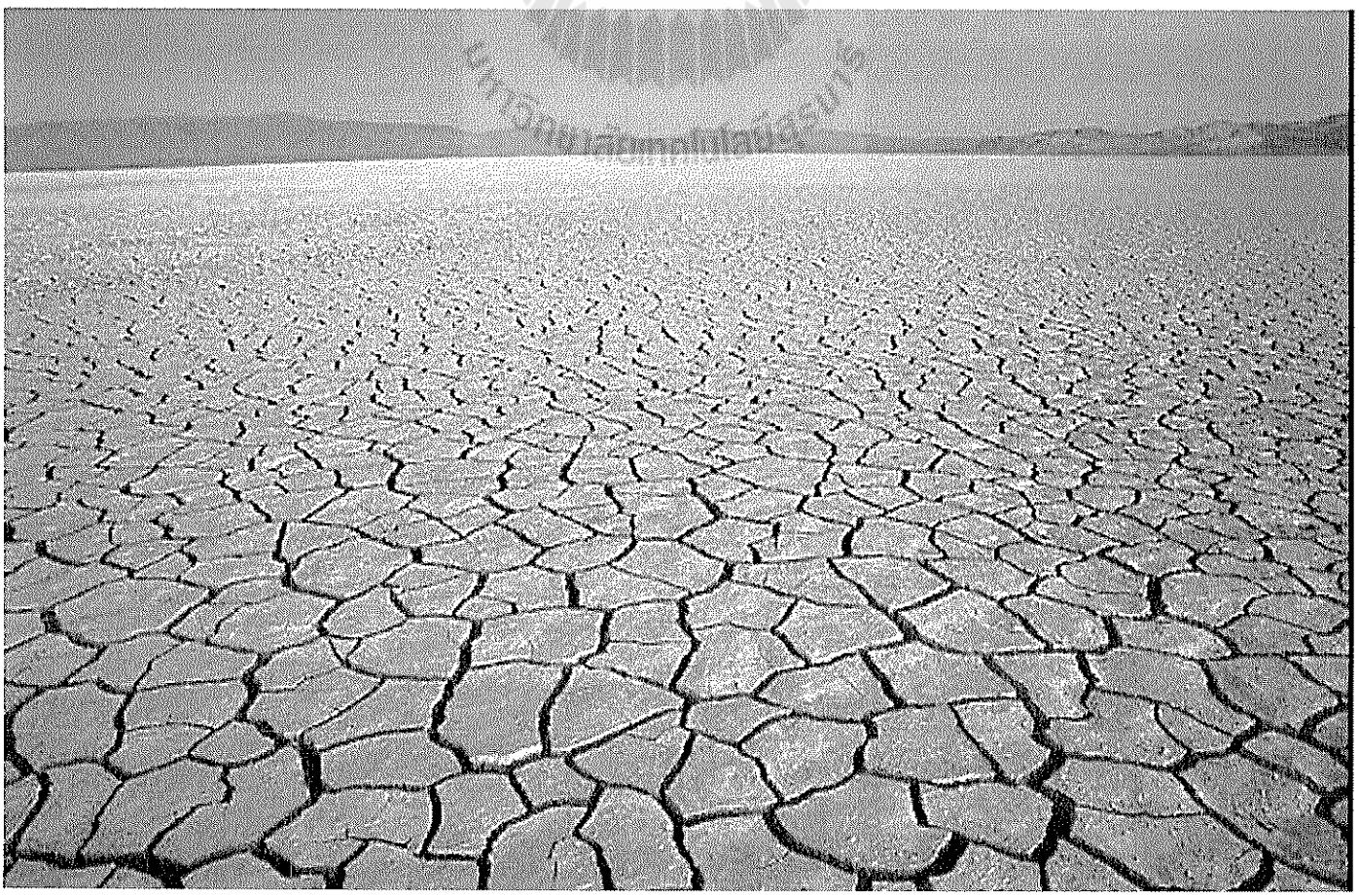


Graded bedding: progressive change in grain size from bottom to top of a bed

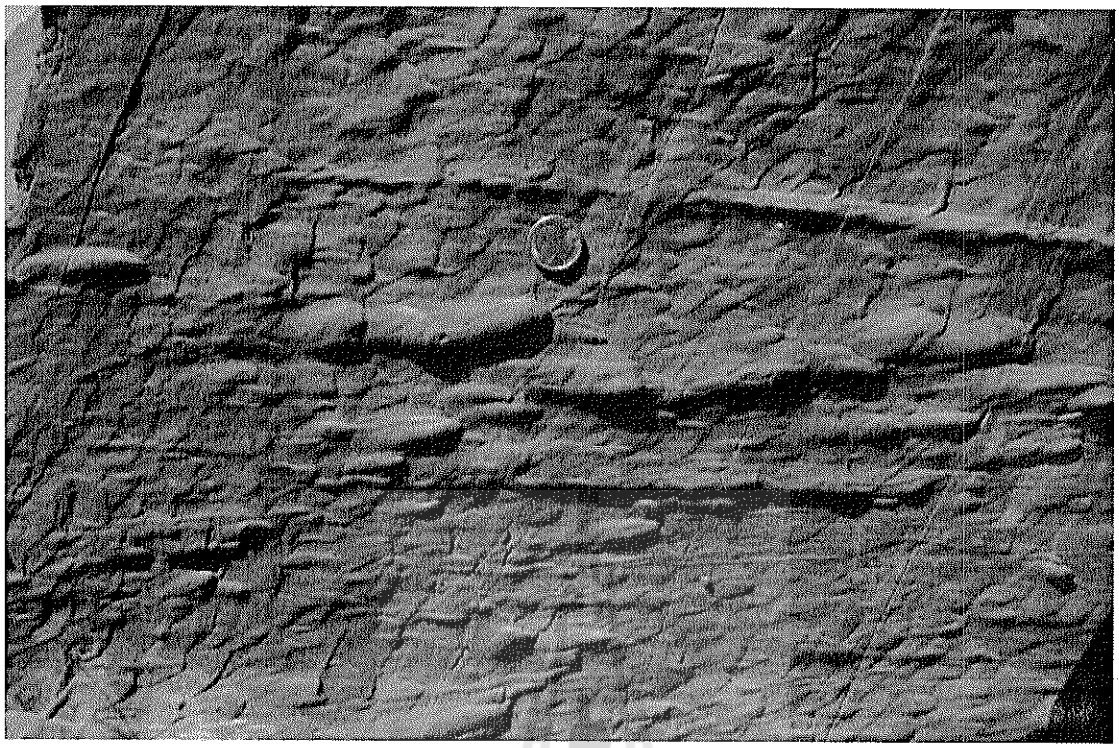




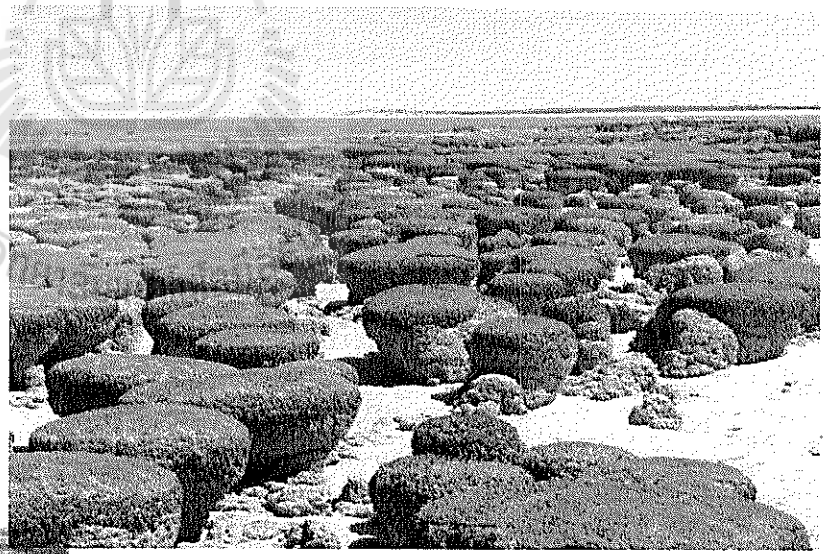
Mud cracks: polygonal cracks formed in drying mud



Sole mark: found on the bases of a strata that indicates small-scale grooves or irregularities, usually occurs at the interface of two different in lithologies and/or grain sizes.



Biological sedimentary structure

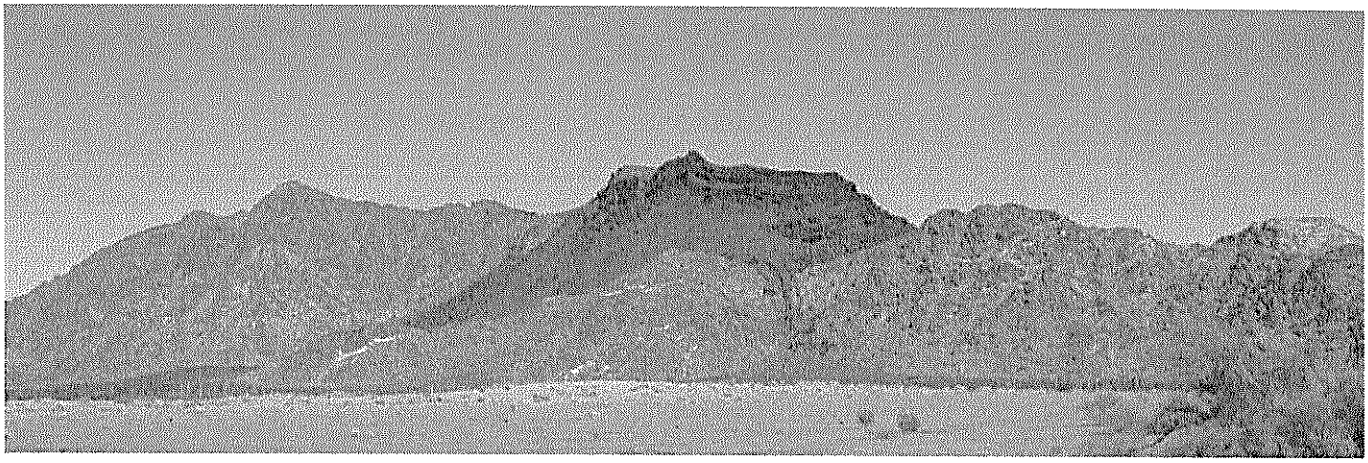




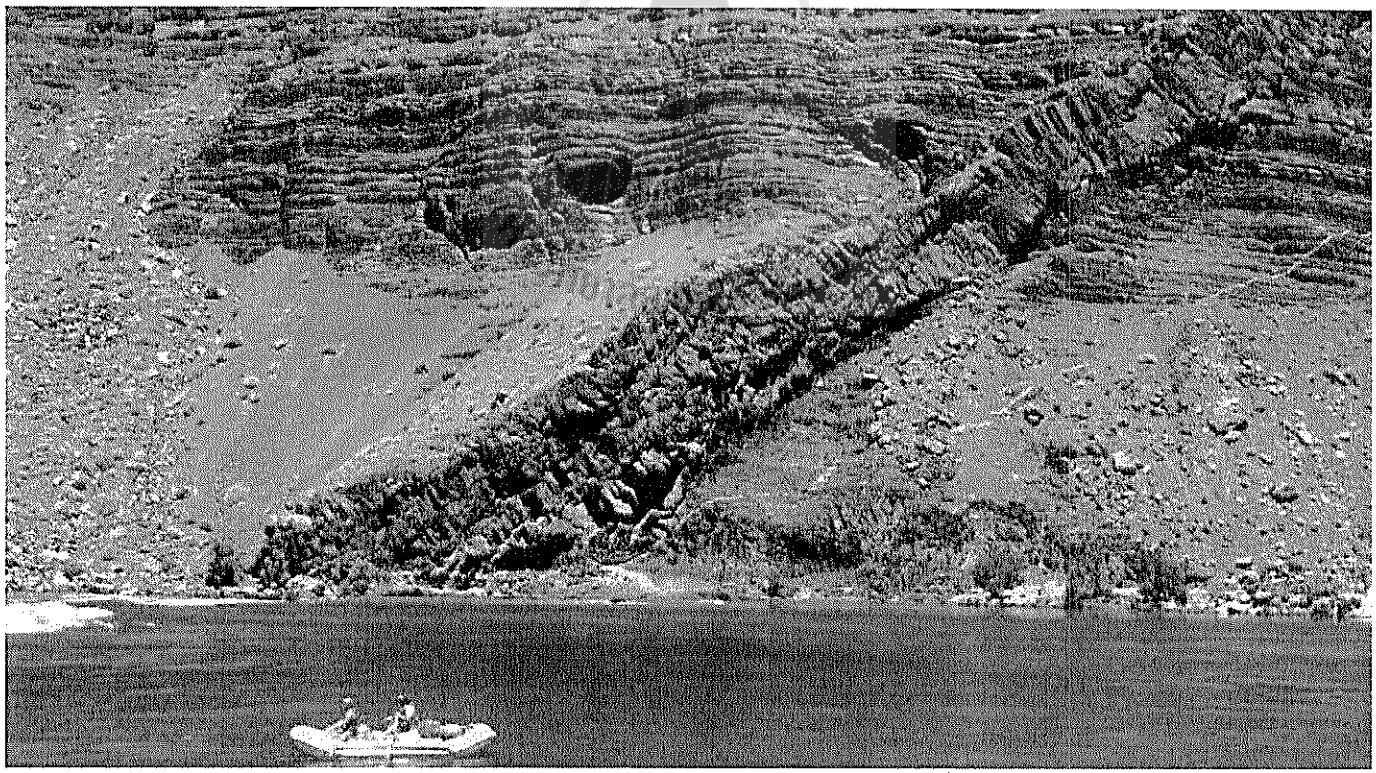


Igneous structures

- Flows
- Veins
- Dikes and sills
- Aa-aa and pahoehoe structure
- Stocks and batholiths

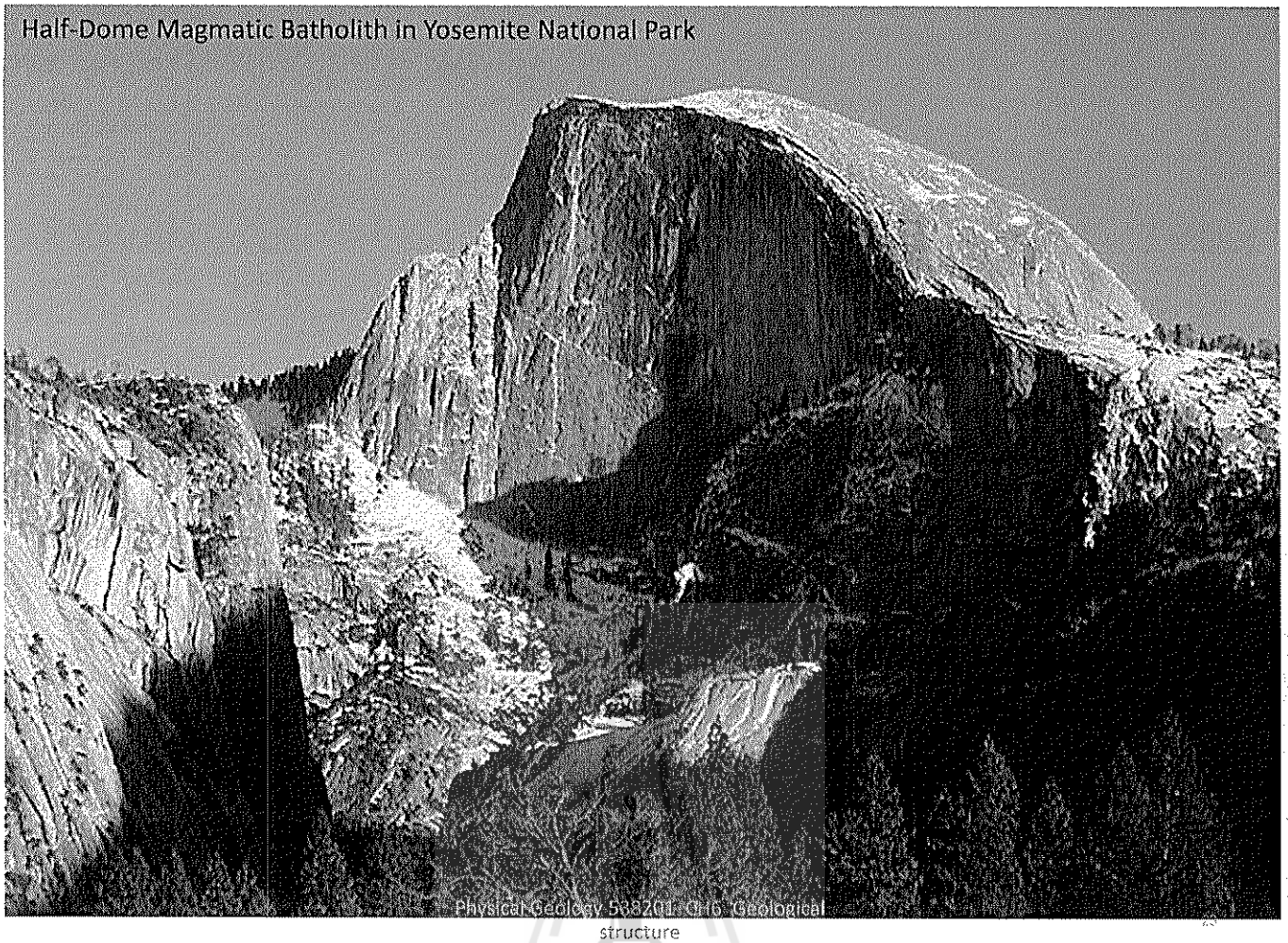


Originally non-horizontal lava flow



Grand Canyon

Half-Dome Magmatic Batholith in Yosemite National Park



Physical Geology 5332(1): Ch 15: Geological structure

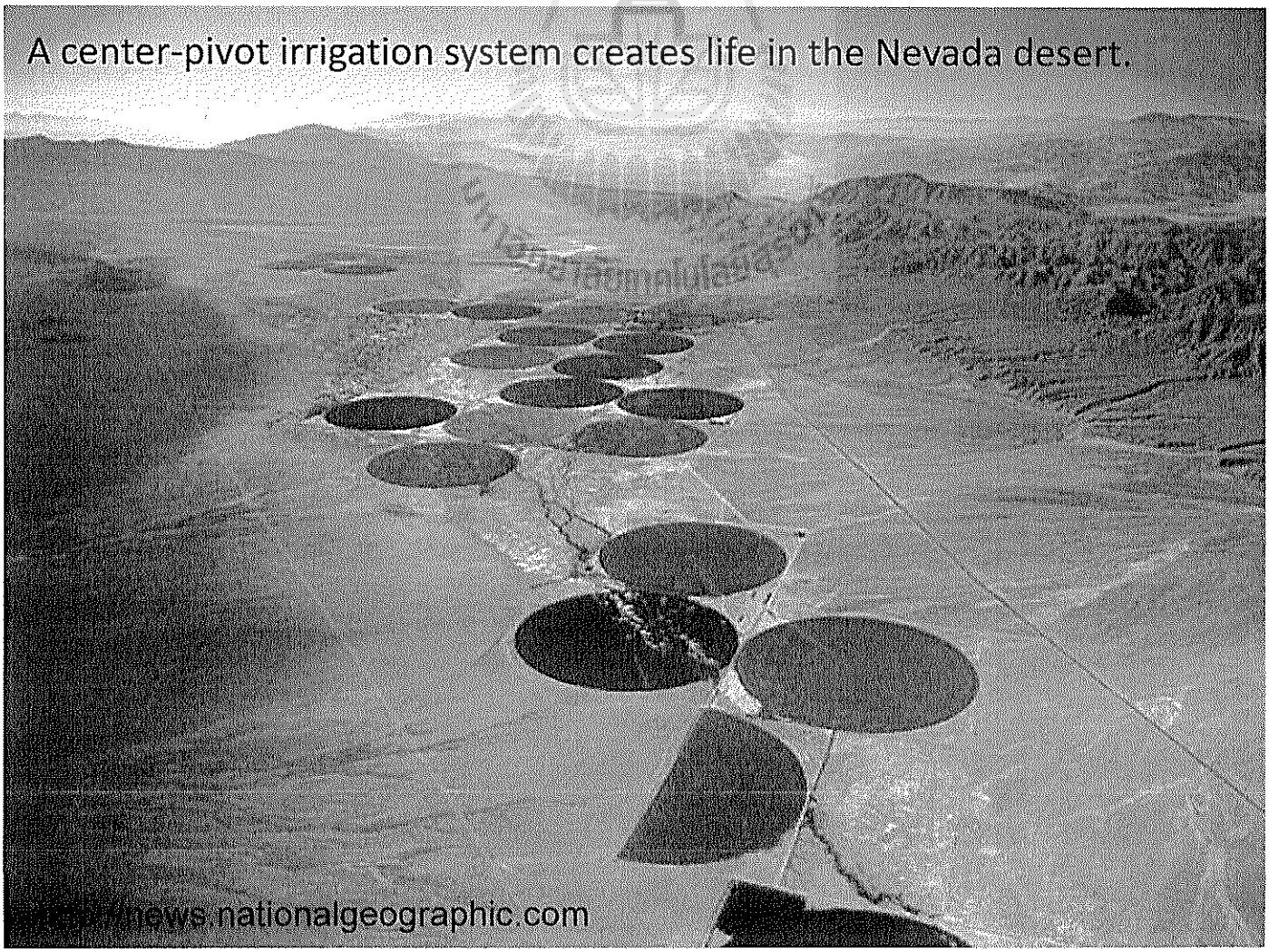


Sierra Nevada Batholith as exposed in the Yosemite Valley area and western foothills of the Sierran crest

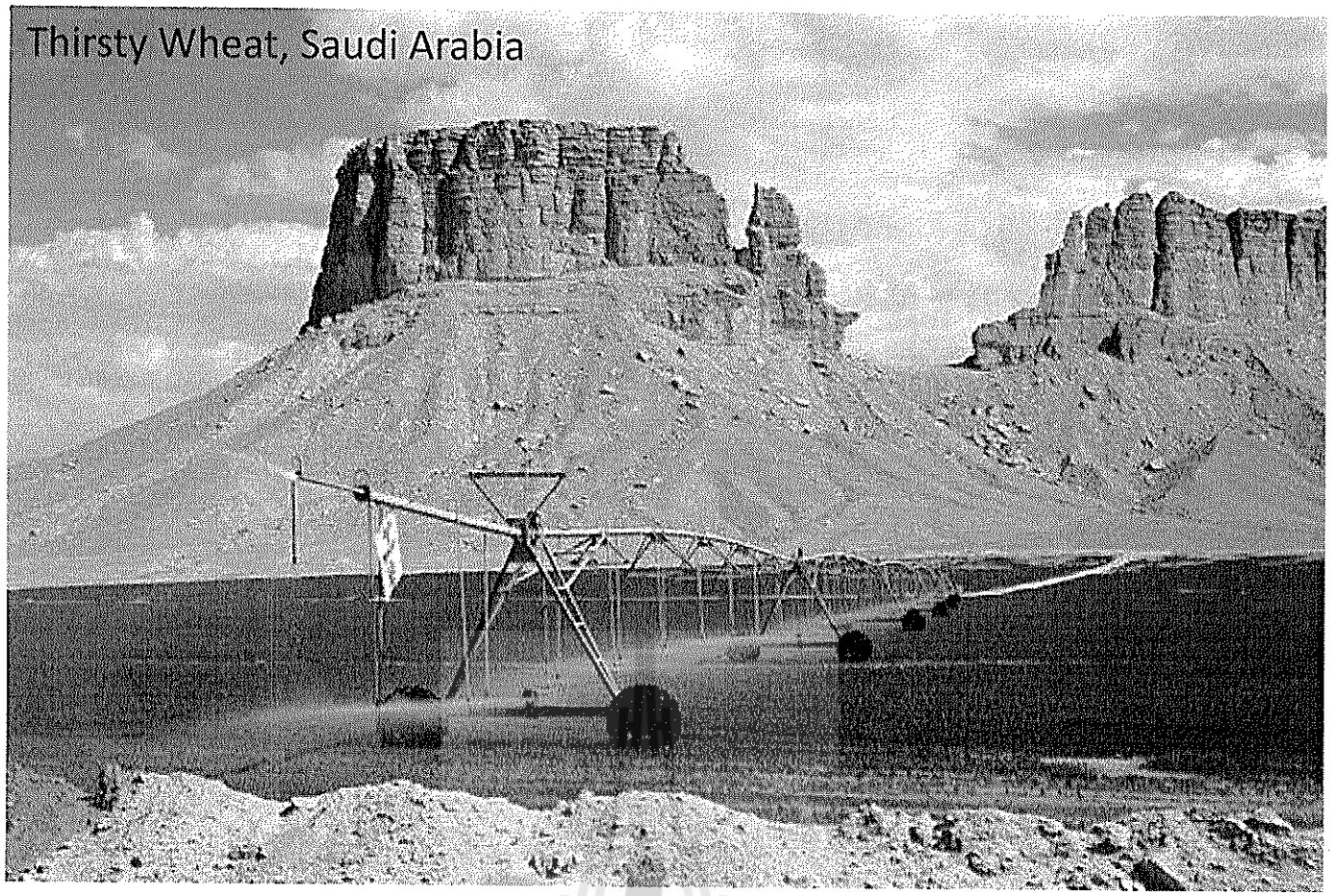


Sahara desert, oasis

A center-pivot irrigation system creates life in the Nevada desert.



news.nationalgeographic.com



มหาวิทยาลัยเทคโนโลยีสุรนารี

Chapter 7
Water & Geology

น้ำและธรณีวิทยา

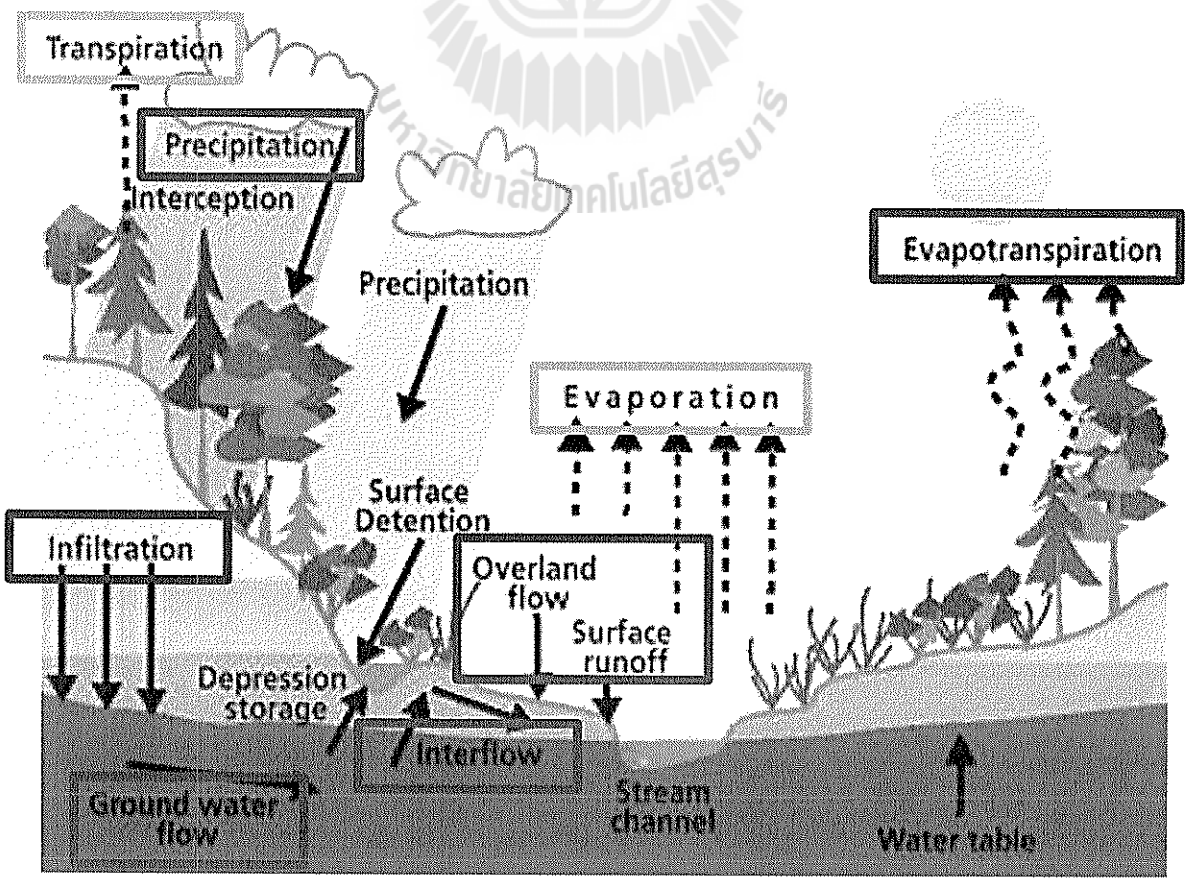
Contents

1. Hydrologic cycle
2. Surface water
3. Groundwater
4. Sea water

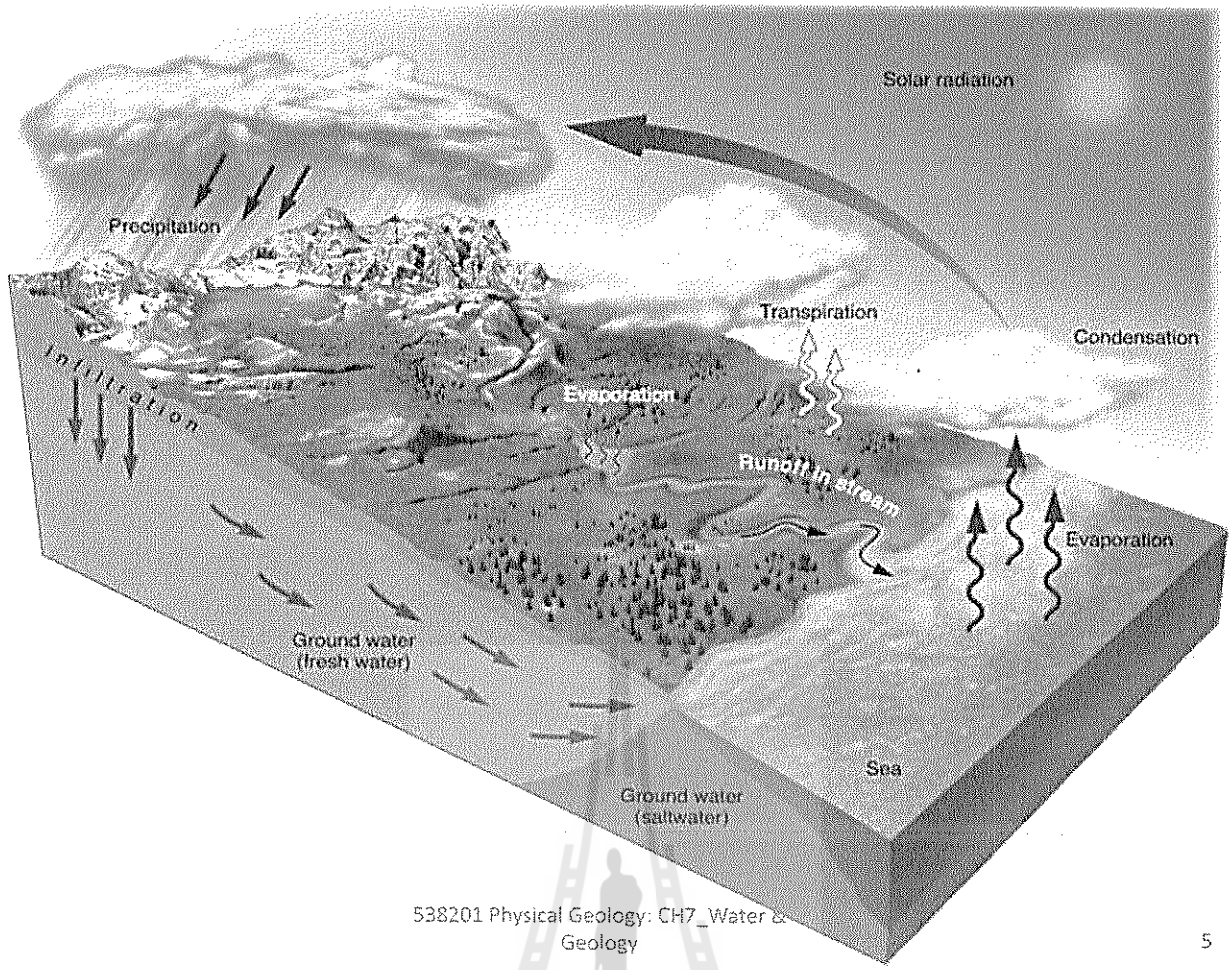
1. Hydrologic Cycle

Hydrologic cycle: the movement and interchange of water between the sea, air, and land.

The hydrologic cycle composes of several processes such as Evaporation, Precipitation, Transpiration, Runoff and Infiltration.



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2. Surface water

Contents

Terms
Drainage basin
Drainage patterns
Stream erosion and deposition
Stream valley development



Terms

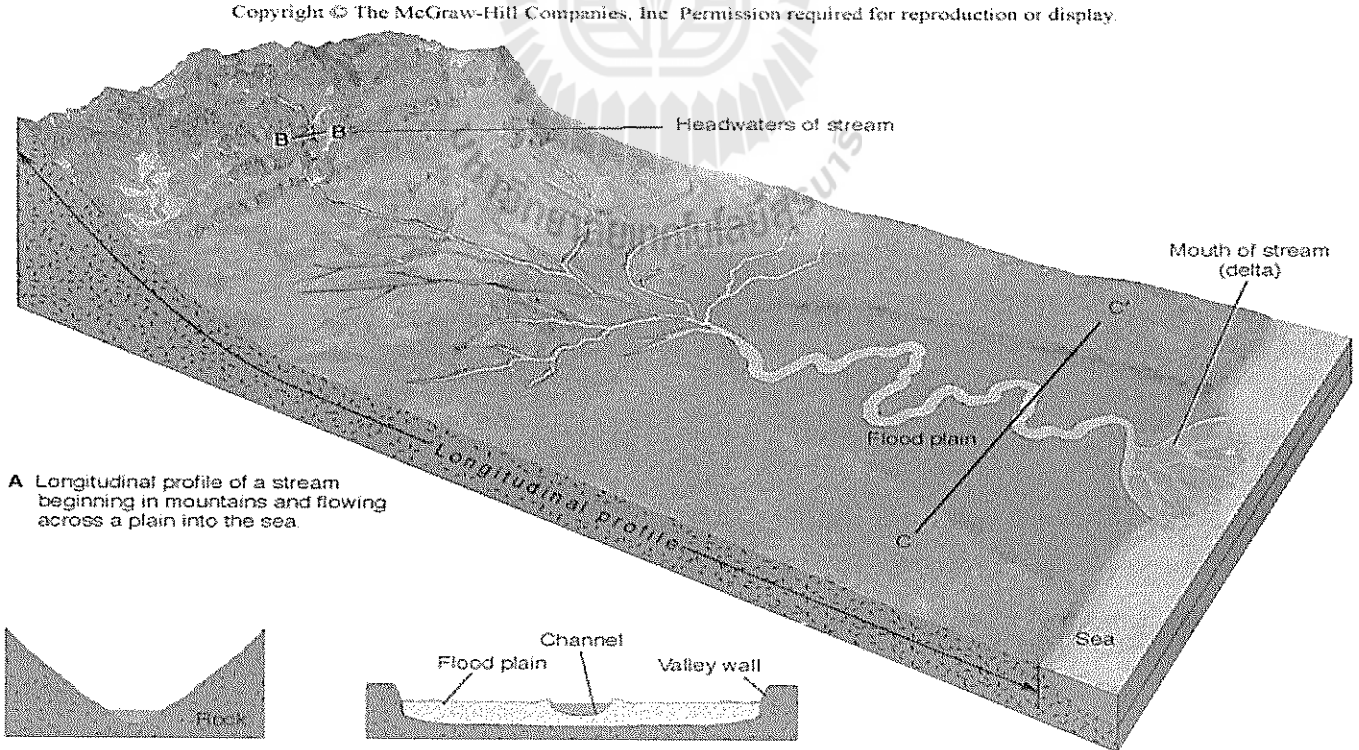
Running water: the most important geologic agent in eroding, transporting and depositing sediments.

Stream: a body of running water, confined to a channel, that runs downhill under the influence of gravity

Headwaters: upper part of stream near its source in the mountains

Mouth: place where a stream enters sea, lake or larger stream

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A Longitudinal profile of a stream beginning in mountains and flowing across a plain into the sea.

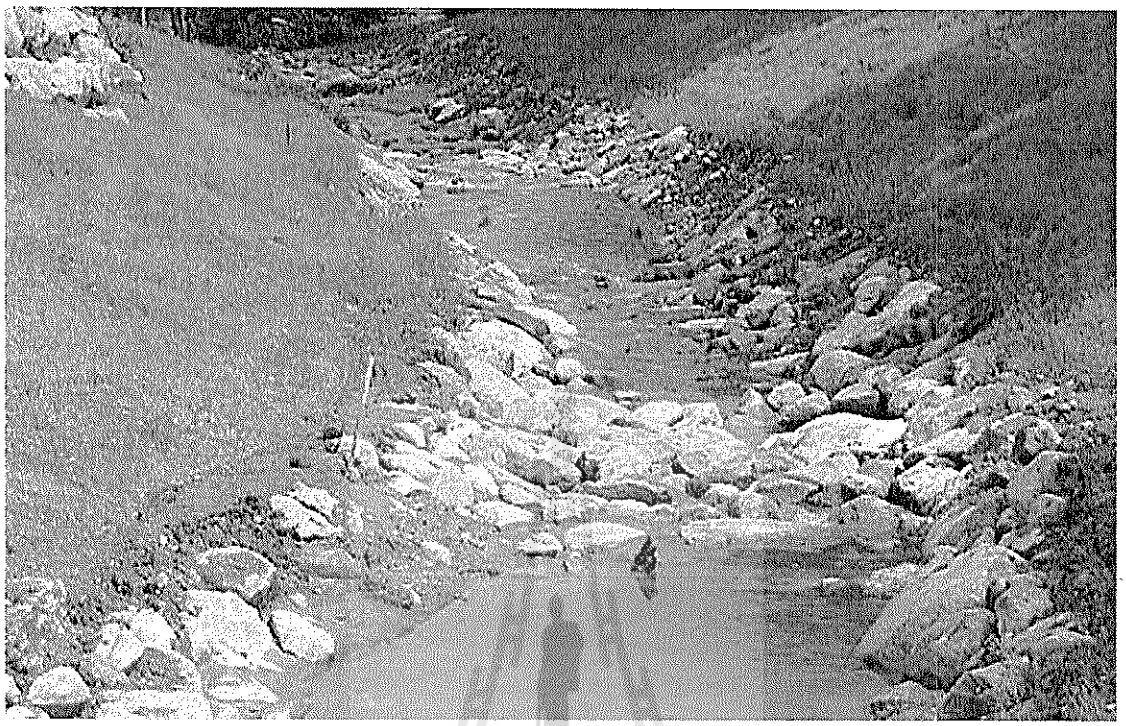
B Cross section of the stream at B-B'. The channel is at the bottom of a V-shaped valley cut into rock.

C Cross section at C-C'. The channel is surrounded by a broad flood plain of sediment.

Channel: a long, narrow depression eroded by a stream into rock or sediment

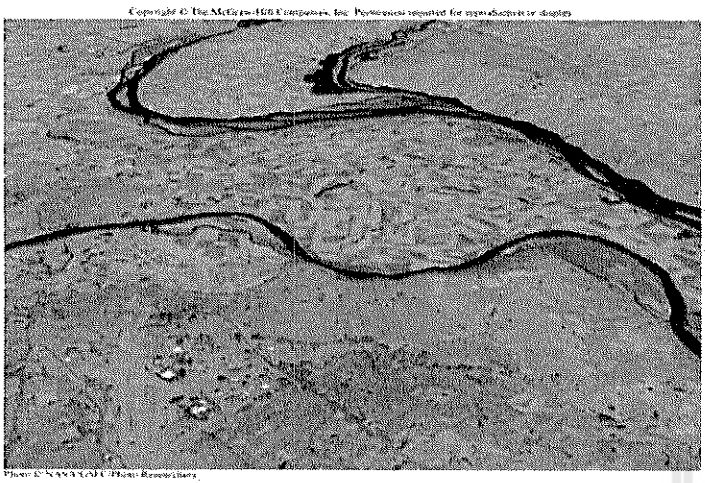
Stream banks: sides of channel

Streambed: channel bottom





Floodplain: flat valley floor composed of sediment deposited by the stream.



Before Flooding (August 14, 1991)



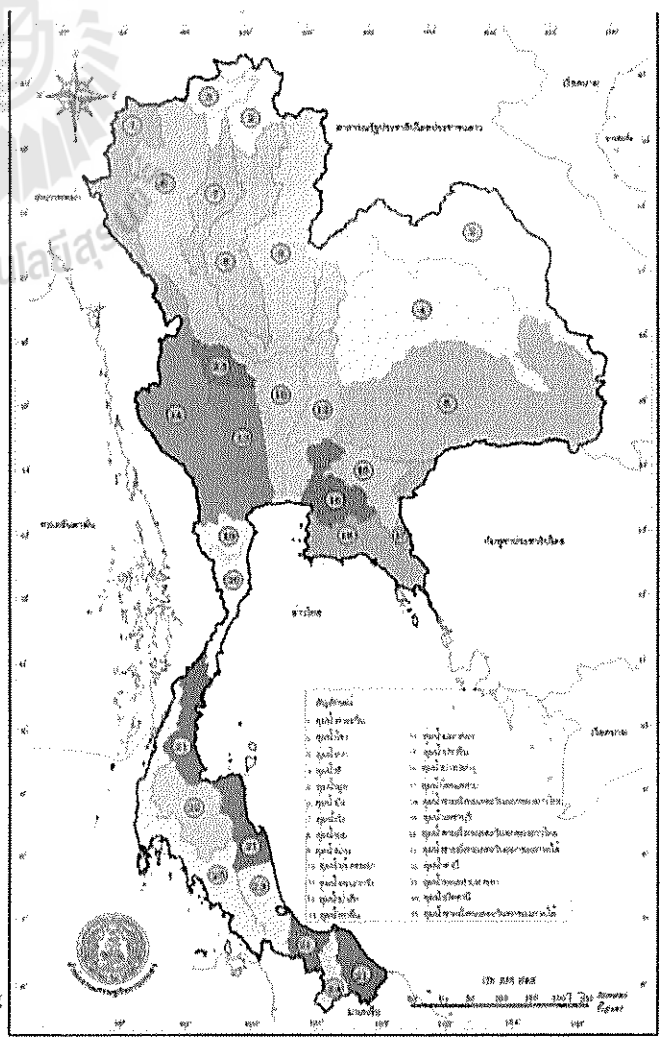
After Flooding (November 7, 1993)

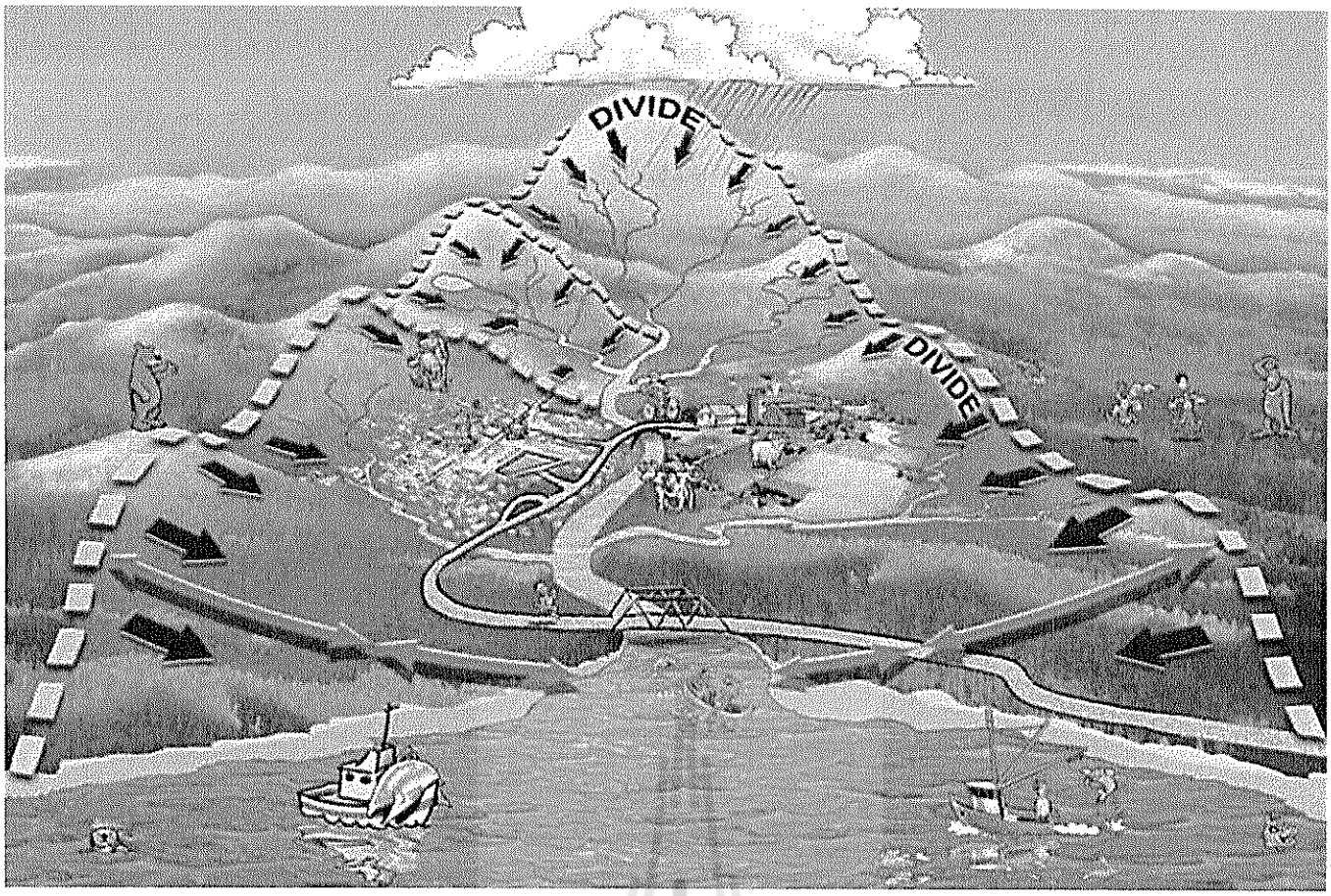
Missouri and Mississippi River spill over into floodplain.
green = vegetation, red = recently plowed fields (bare soil)

Drainage basin

Drainage basin: the total area drained by a stream and its tributaries (Tributary: a small stream flowing into a larger one).

Divide: ridge or high ground that divides one drainage basin from another.

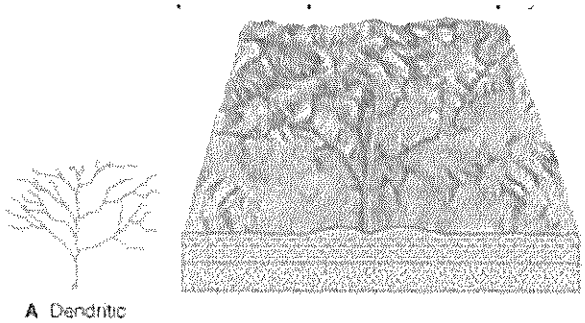




Drainage basin

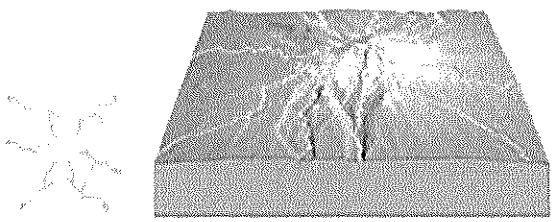
Drainage pattern

The arrangement, in map view, of a stream and its tributaries. Most tributaries join the main stream at an acute angle, forming a V or Y pointing downstream



A Dendritic

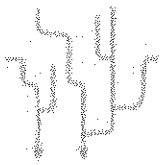
Dendritic pattern: resembling the branches of a tree.



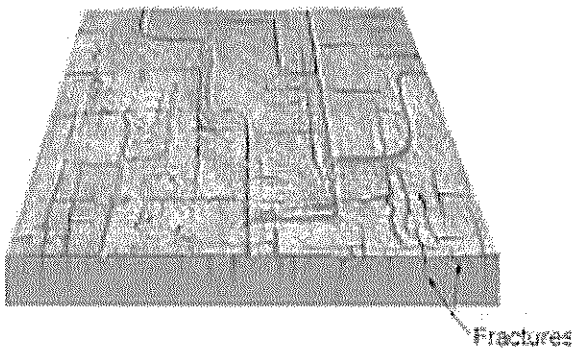
B Radial

Radial pattern: streams diverge outward like the spokes of a wheel.

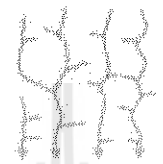
Rectangular pattern: tributaries have frequent 90° bends and join other streams at right angles



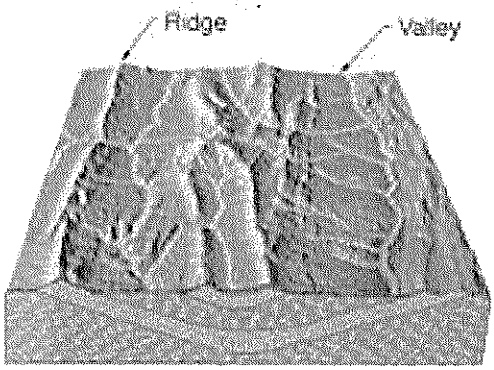
C Rectangular



Trellis pattern: parallel streams with short tributaries meeting at right angles.



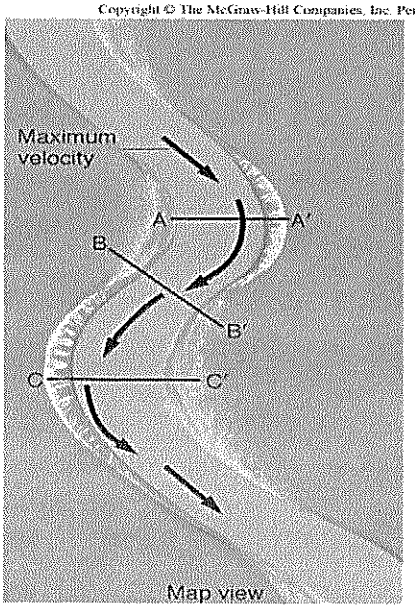
D Trellis

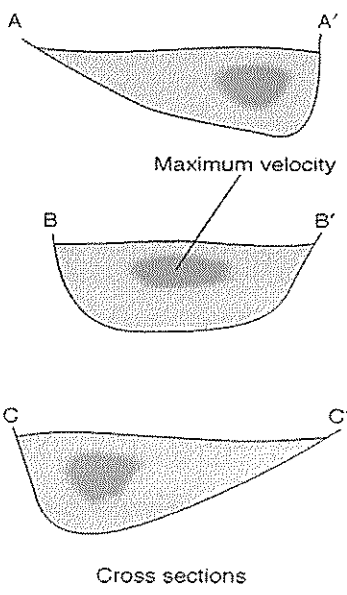


Stream erosion and deposition

Stream erosion and deposition are controlled by flow **velocity** and **discharge**.

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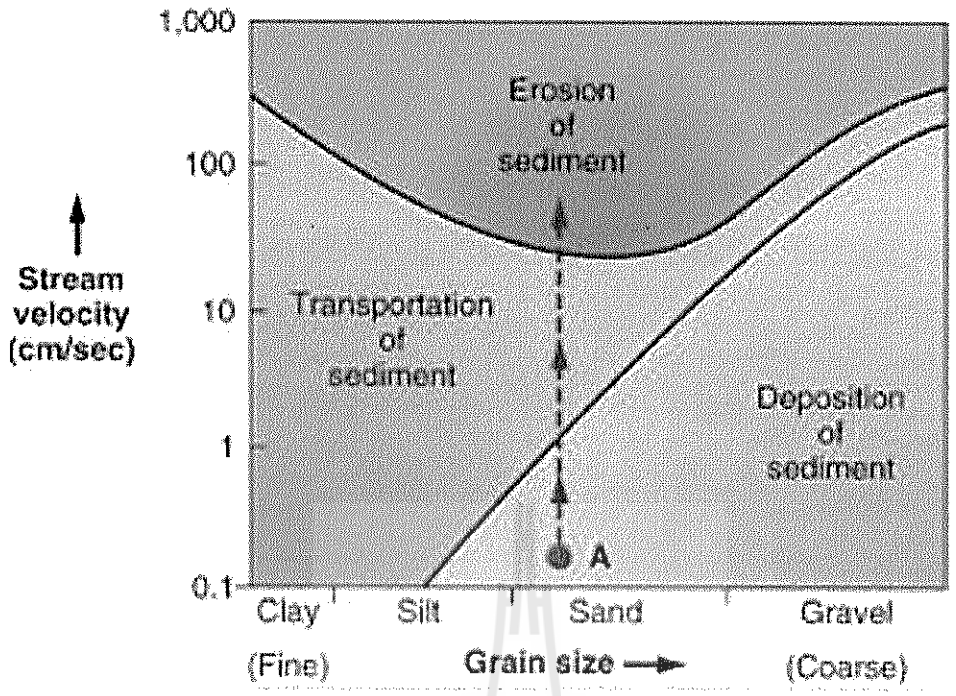




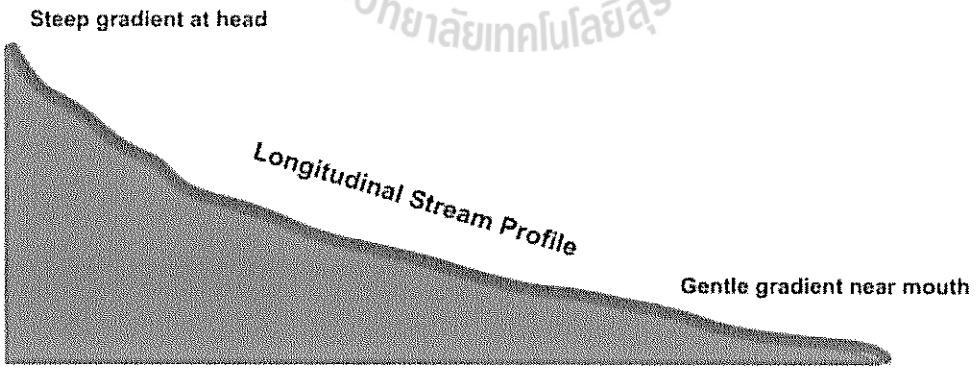
Stream velocity: controlled by **stream gradient, channel shape and channel roughness**.

Maximum velocity is near centre of channel.

Higher **stream velocities** promote erosion and transport of coarser sediments.

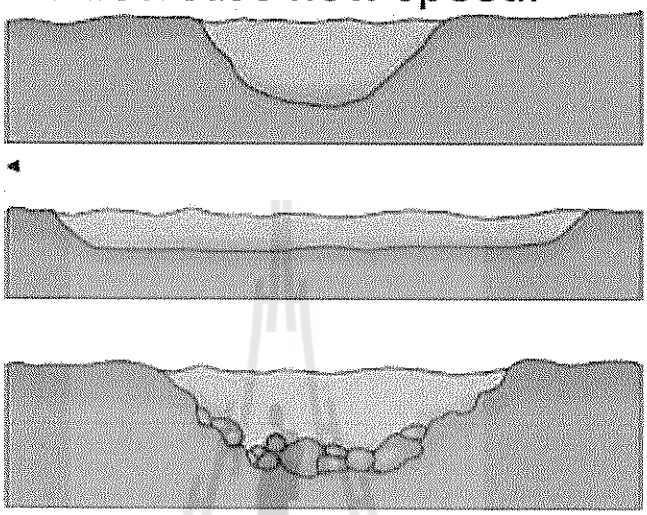


Stream gradient: the downhill slope of the streambed, usually decreases downstream



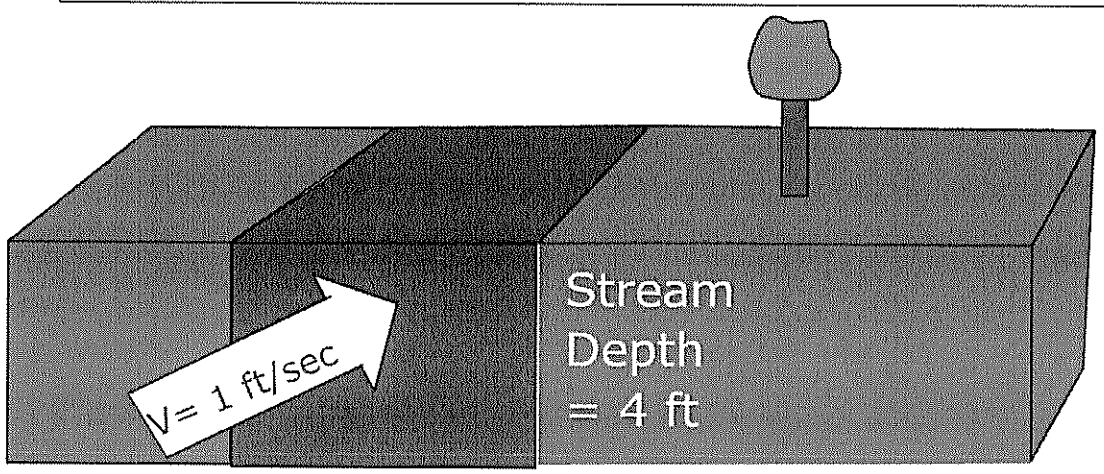
Channel shape and **roughness**

- Both effect stream velocity due to drag.
- Narrower, deeper channels allow faster flow.
- Smoother channels allow faster flow.
- Wider, shallower channels decrease speed.
- Rougher channels decrease flow speed.



Stream discharge: the volume of water flowing past a given point in a unit of time.

Discharge (cms) = average stream width (m, ft)
x average depth (m, ft)
x average velocity (m/sec, ft/sec)



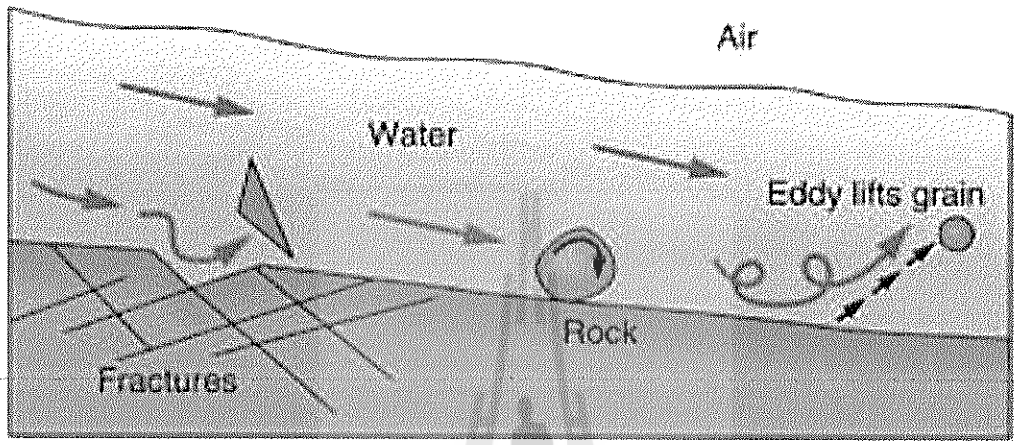
Stream Width = 5 ft

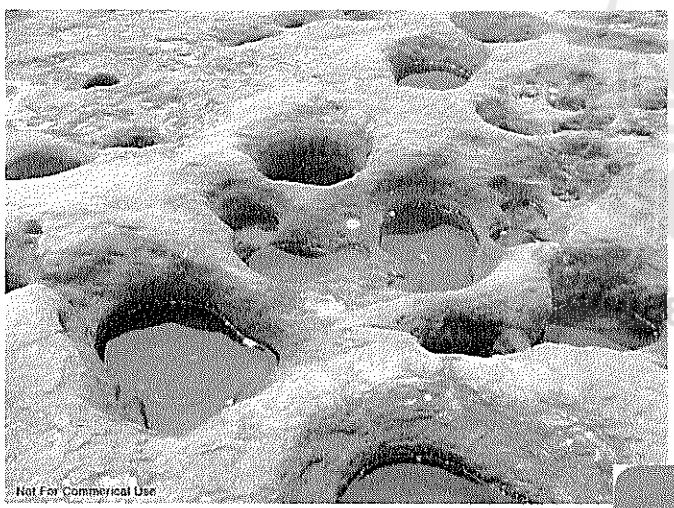
Stream erosion consists of 3 mechanisms:

Hydraulic action: ability of flowing water to pick up and move rock and sediment.

Solution: dissolving of rocks (e.g., limestone)

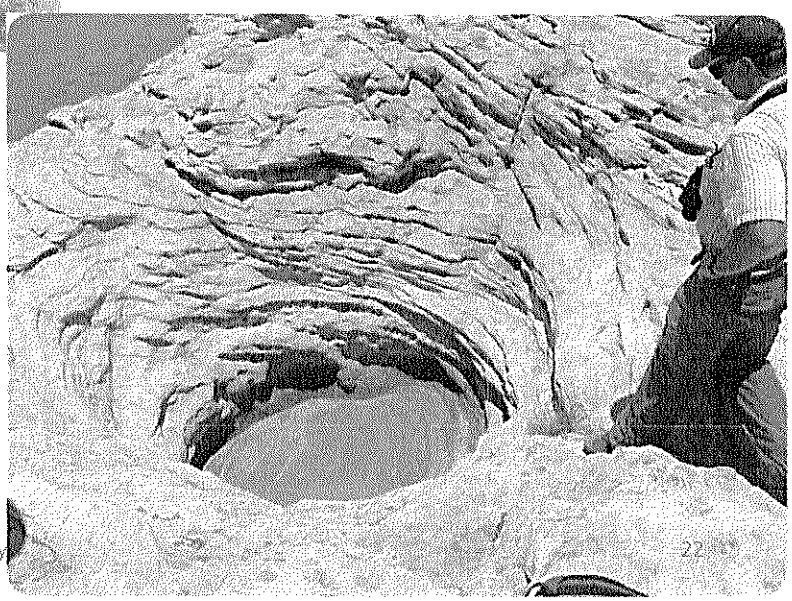
Abrasion: grinding away of stream channel by the friction and impact of the sediment load

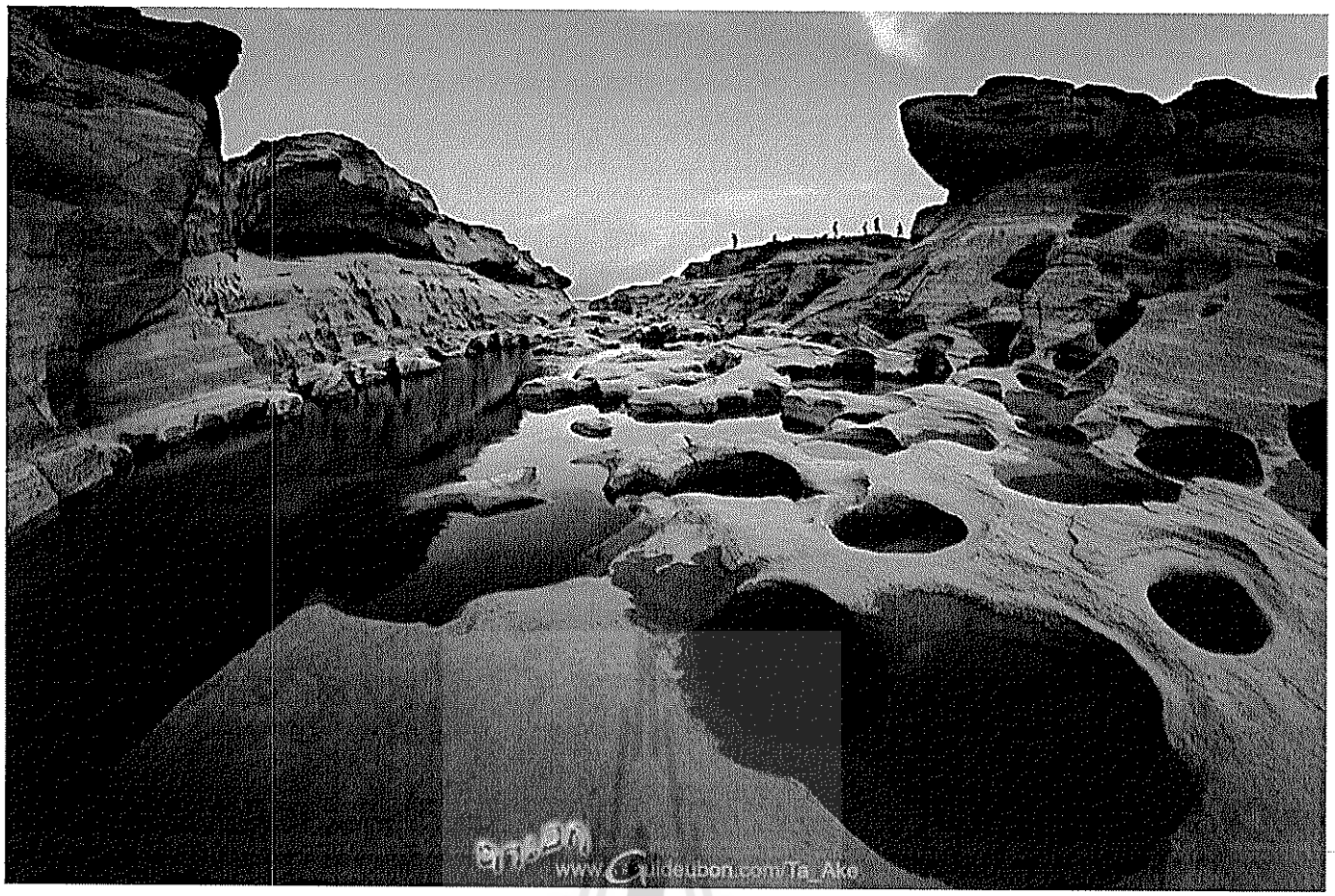




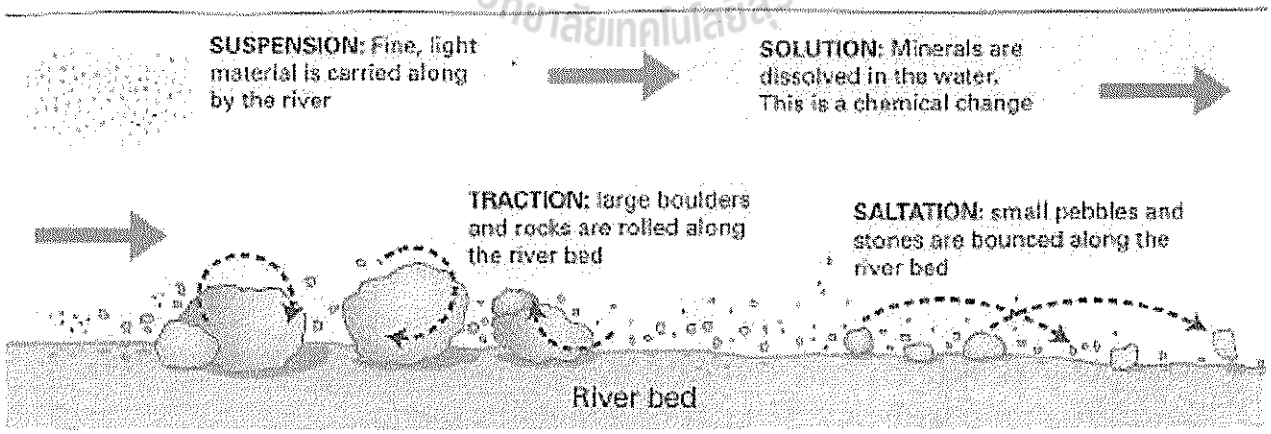
Potholes are eroded into streambed by the abrasive action of the sediment load in the stream.

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Sediment load transported by a stream can be subdivided into bed load, suspended load, and dissolved load

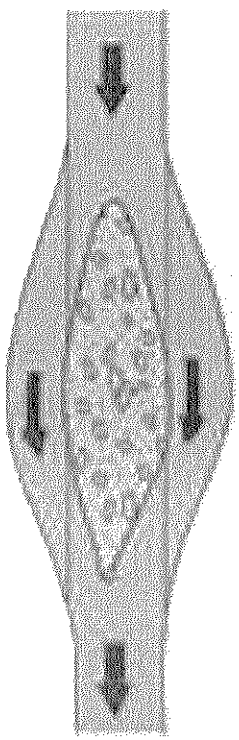


Stream deposition

Sediments are temporarily deposited along stream courses:

- Bars
- Braided streams
- Meandering streams and point bars
- Floodplains
- Deltas
- Alluvial Fans

Bars: ridges of sediment (usually sand or gravel) deposited in the middle or along the sides of a stream.

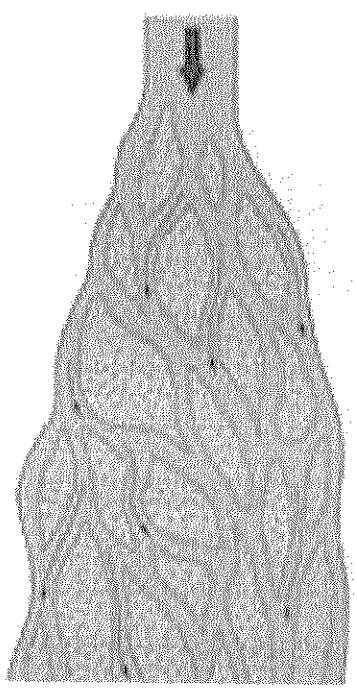






Braided streams contain sediment deposited as numerous bars around which water flows in highly interconnected rivulets (heavy sediment. shallow, wide channel).

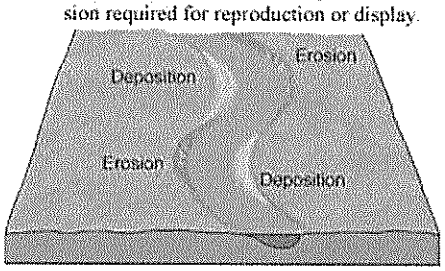
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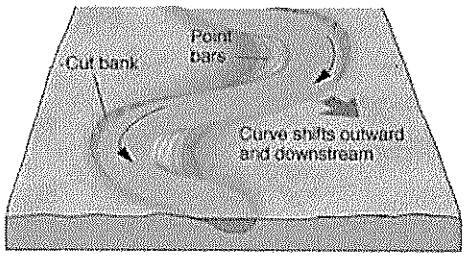


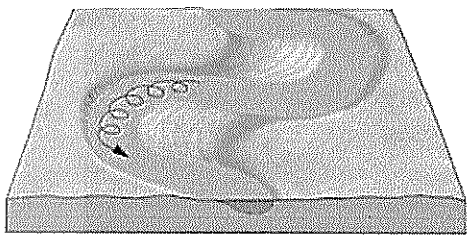


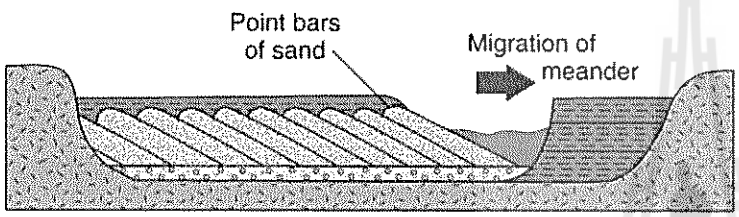
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Meandering streams flow faster along the outside of bends and more slowly along the inside, depositing point bars on the insides of the meanders.











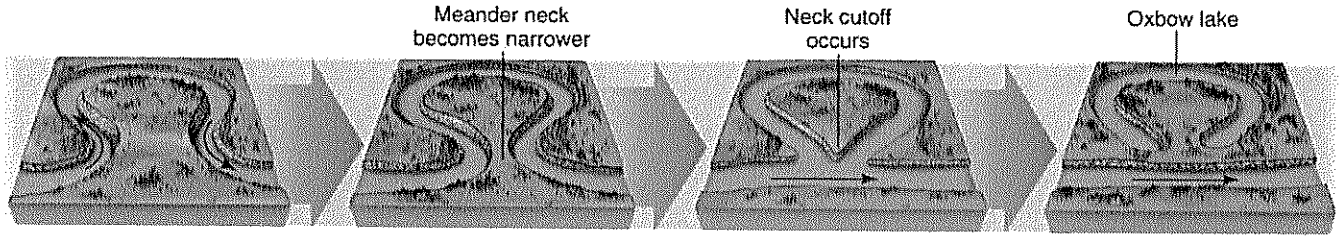
Corkscrew water motion on a curve helps cause erosion and deposition

29



30

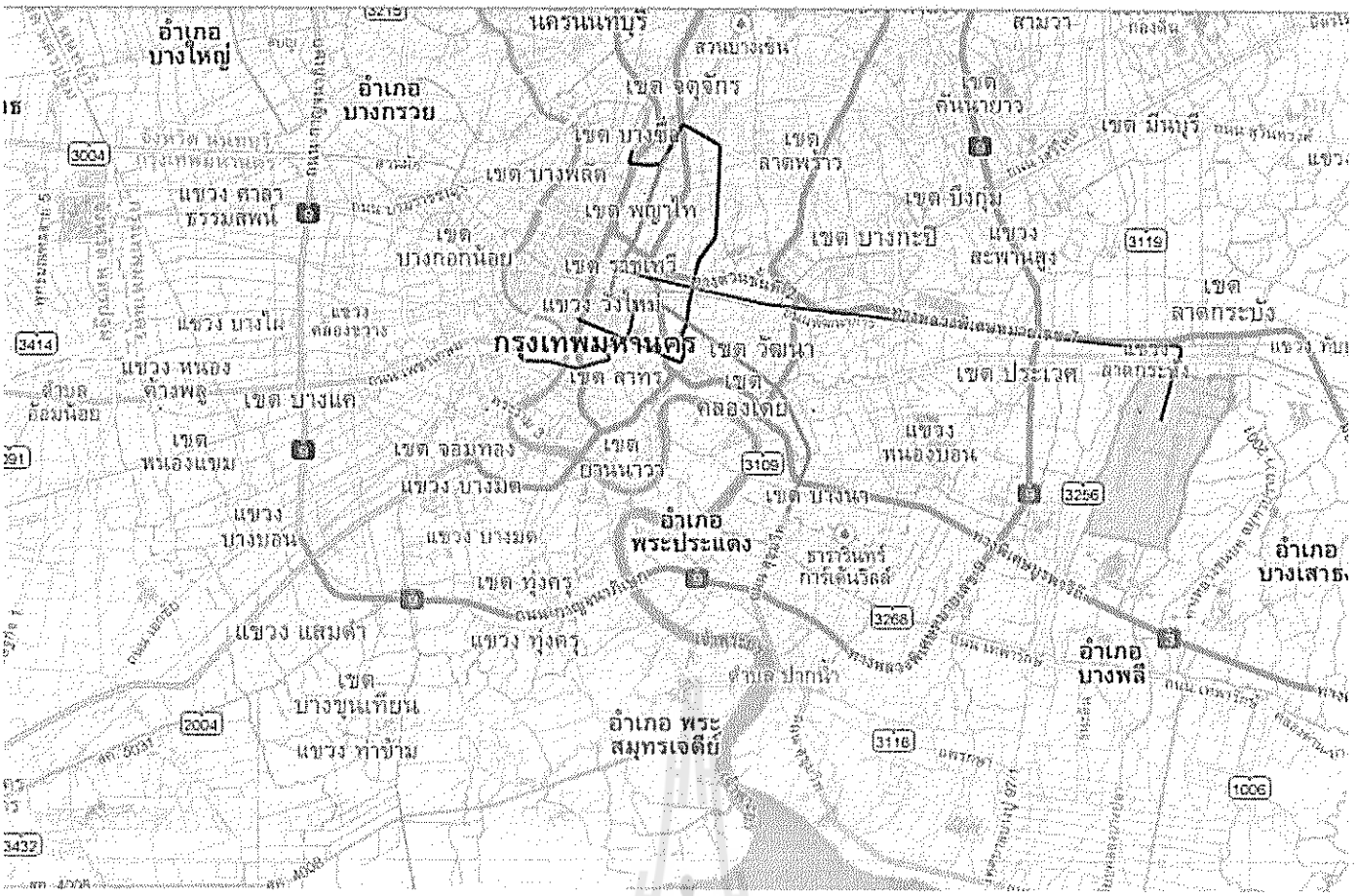
Meander cutoffs may form when a new, shorter channel is cut through the narrow neck of a meander (as during a flood).



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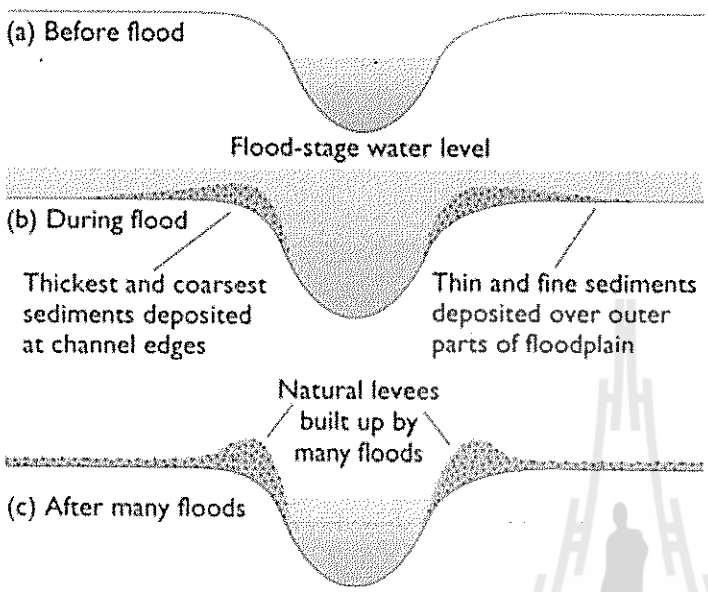


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เขต จตุจักร
เขต บางซื่อ
เขต ดินแดง
เขต ห้วยขวาง
เขต วัฒนา
เขต คลองเตย
เขต ประเวศ
เขต บางกะปิ
เขต สวนหลวง
เขต บางนา
เขต พระโขนง
เขต บางพลัด
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เขต ตลิ่งชัน
เขต ทวีวัฒนา
เขต ภาษีเจริญ
เขต หนองแขม
เขต ราษฎร์บูรณะ
เขต บางคอแหลม
เขต ยานนาวา
เขต สาทร
เขต คลองสาน
เขต ธนบุรี
เขต คลองสามวา
เขต มีนบุรี
เขต หนองจอก
เขต บางเขน
เขต หลักสี่
เขต ดอนเมือง
เขต สายไหม
เขต คันนายาว
เขต บางบอน
เขต บางขุนเทียน
เขต ทุ่งครุ
เขต บางมด
เขต จอมทอง
เขต ราษฎร์บูรณะ
เขต ยานนาวา
เขต สาทร
เขต คลองเตย
เขต วัฒนา
เขต ประเวศ
เขต บางนา
เขต บางกะปิ
เขต สวนหลวง
เขต พระโขนง
เขต ลาดกระบัง
เขต บึงกุ่ม
เขต สายไหม
เขต คันนายาว
เขต มีนบุรี
เขต หนองจอก
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เขต ภาษีเจริญ
เขต หนองแขม
เขต ราษฎร์บูรณะ
เขต บางคอแหลม

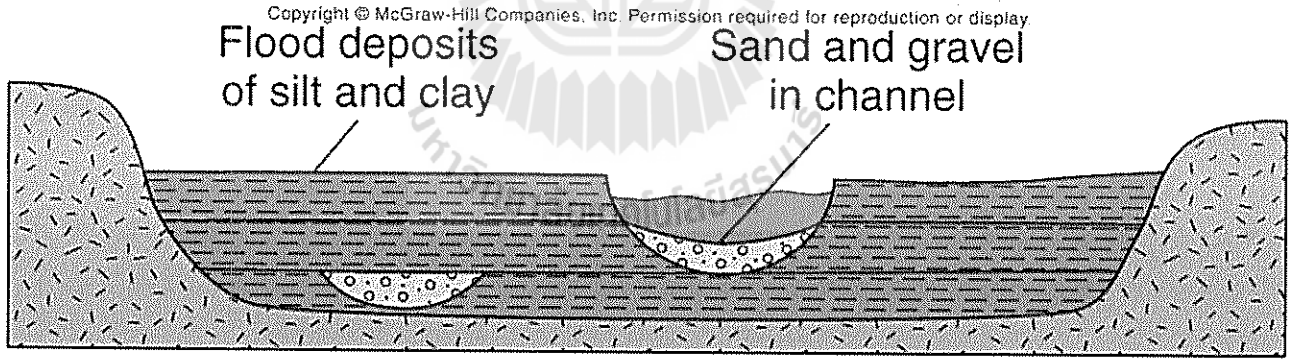
Floodplain sediments are left behind as flood waters slow and recede at the end of flood events.

Main channel has slightly raised banks with respect to the floodplain known as natural levees.



Building up the natural levees.

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Flood

When water levels rise and overtop the banks of a river, **flooding** occurs.

- Natural process on all rivers.
- Described by recurrence intervals

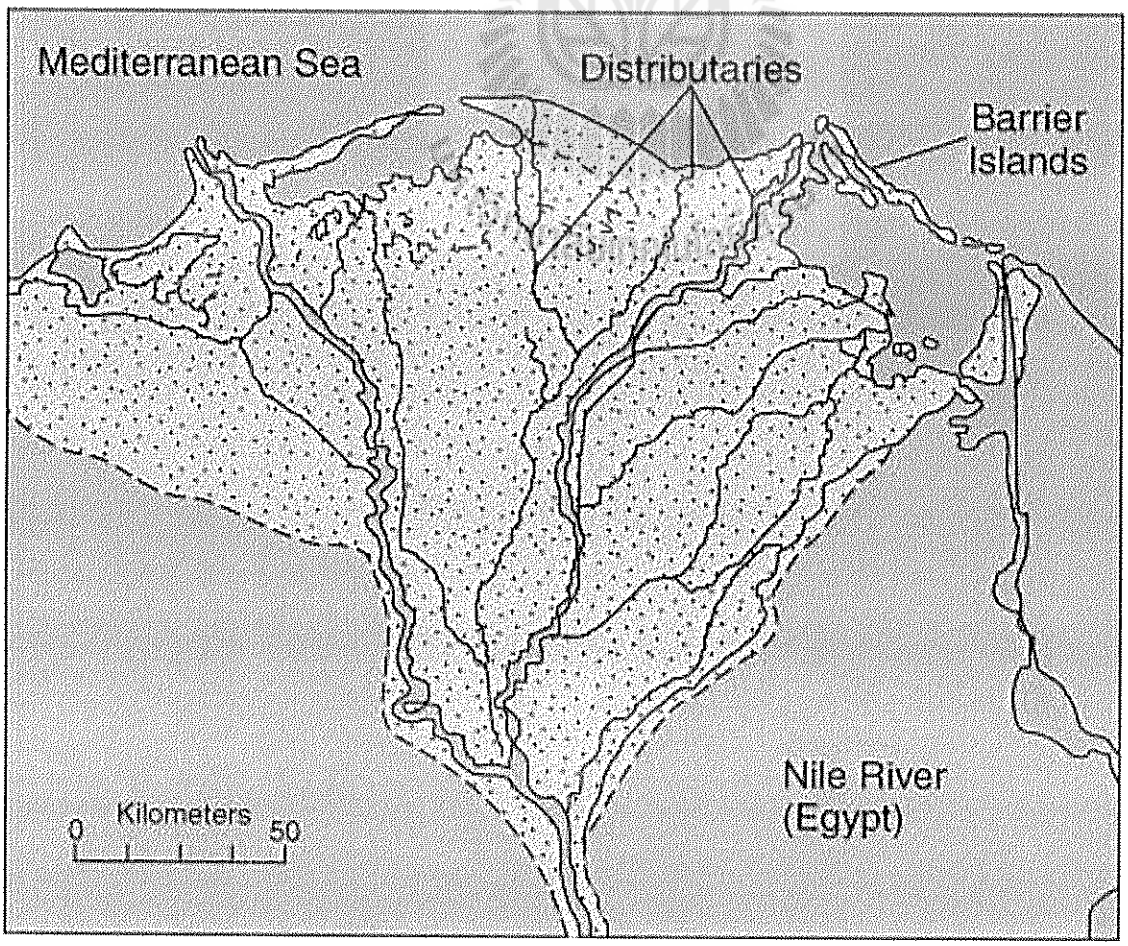
  (A 100-year flood is, on average, the size of the largest flood within a 100-year period of time).
- Can cause great damage in heavily populated areas.
- High velocity and large volume of water causes flood erosion.
- Slowing of waters as flood ends causes flood deposits (usually of silt or clay-sized particles) to be deposited in the floodplain.



Delta

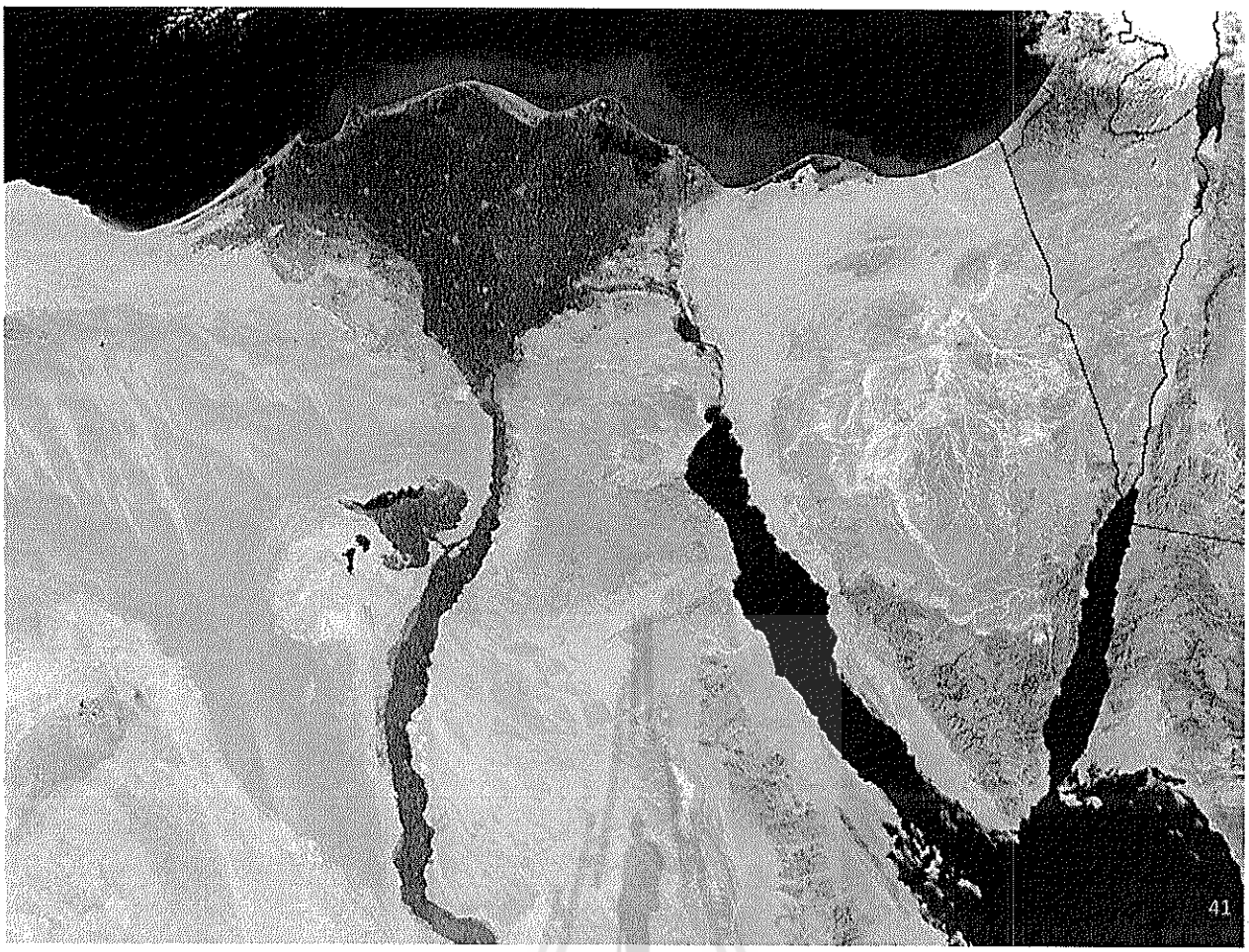
Delta: a body of sediment deposited at the mouth of a river when flow velocity decreases

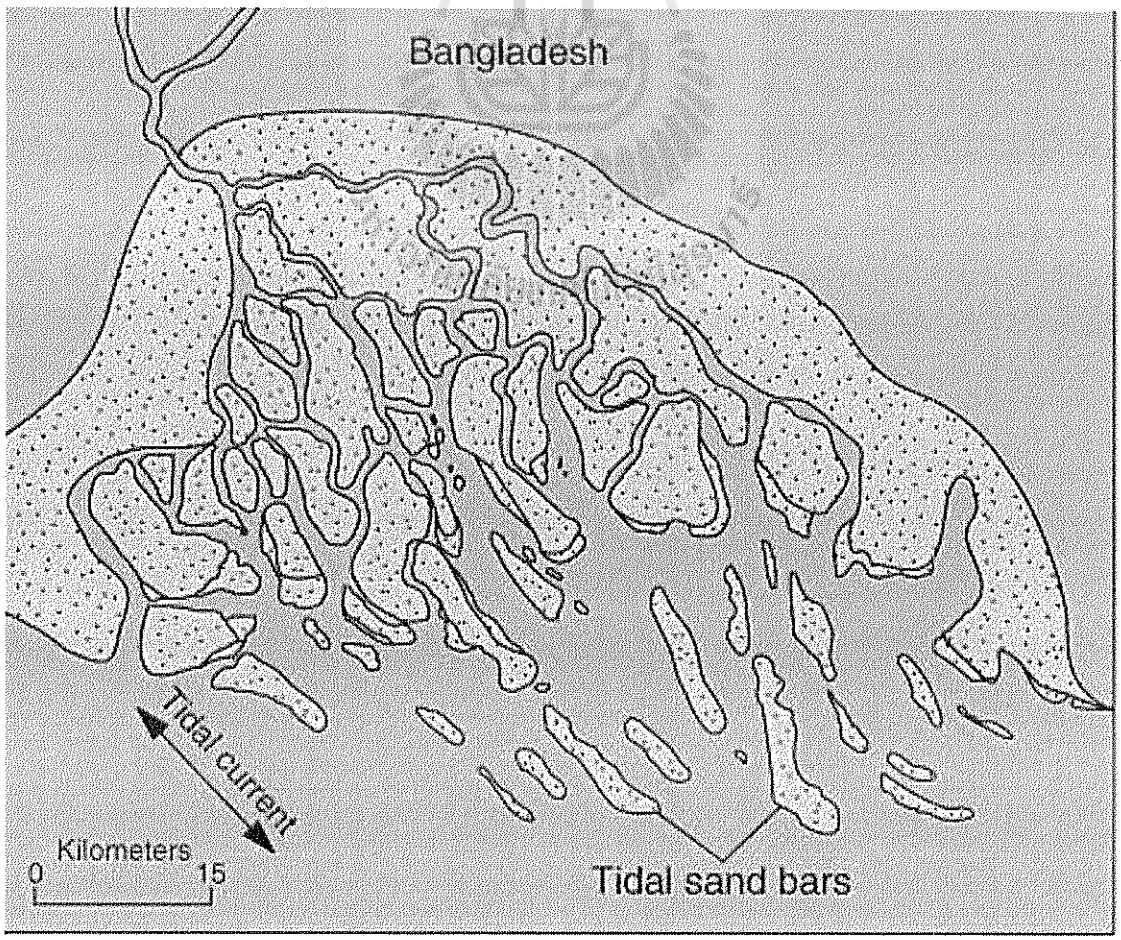
- surface marked by shifting distributaries
- shape of a delta depends on whether its wave-dominated, tide-dominated, or stream-dominated



A Wave-dominated delta

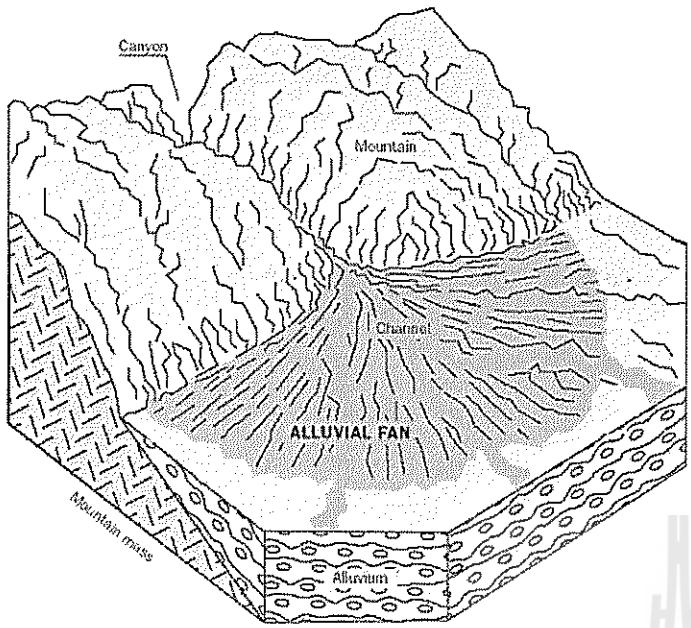
Wave dominated delta





B Tidal-dominated delta

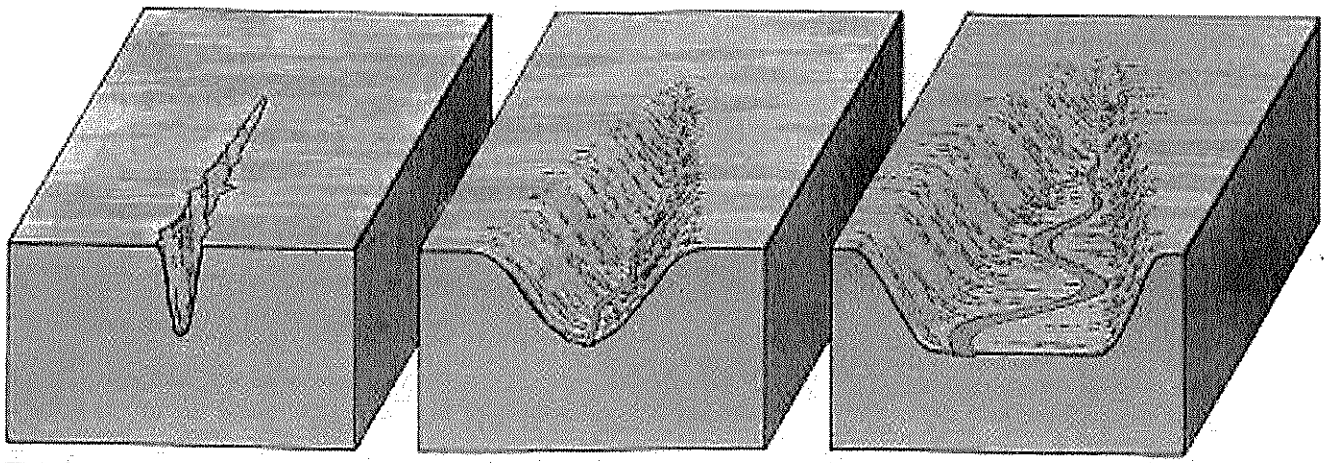
Alluvial fan



Large, fan- or cone-shaped pile of sediment that forms where stream velocity decreases as it emerges from a narrow mountain canyon onto a flat plain.

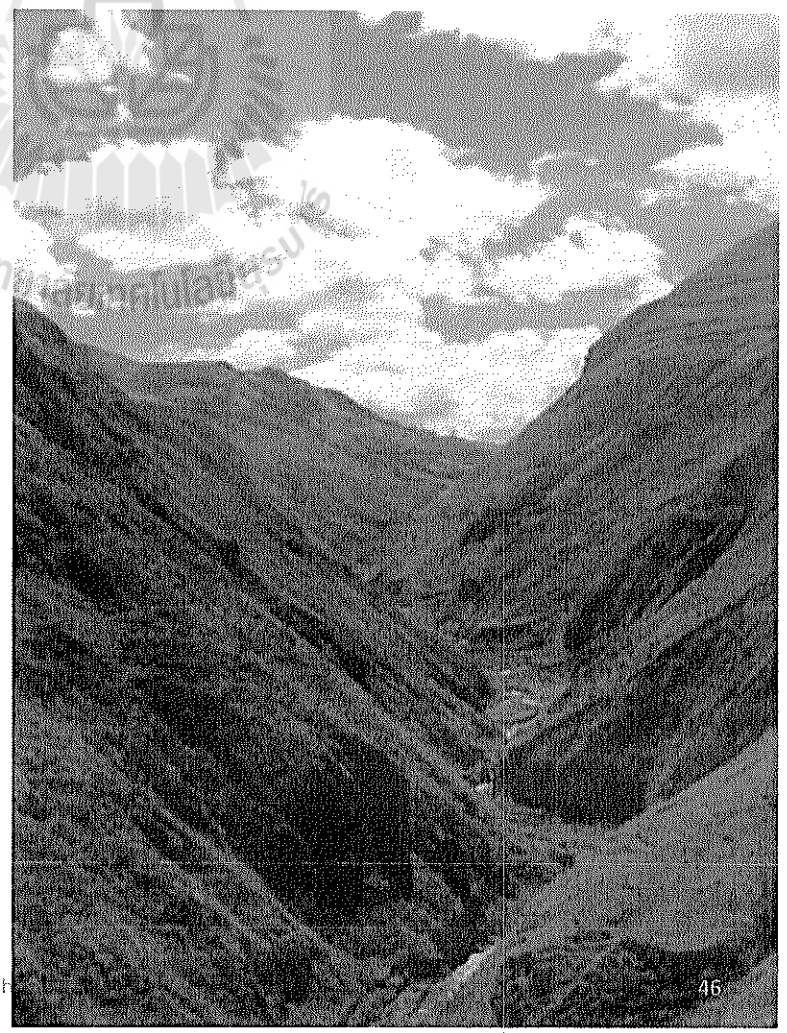


Stream valley development



Down cutting: a process of deepening a valley by erosion of the streambed.

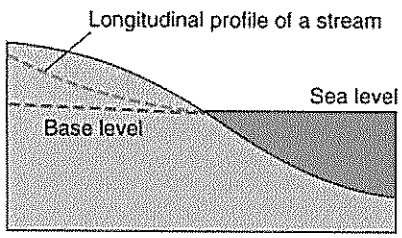
V-shaped valleys are typically form from down cutting combined with mass wasting and sheet erosion.

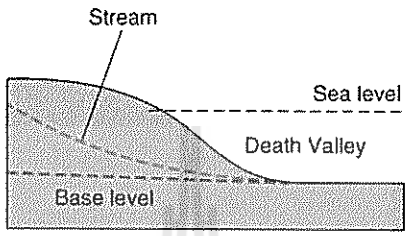


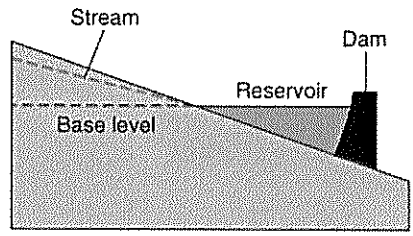
Streams cannot erode below their base level;

Basel level can be sea level, a lake, or the bottom of a closed basin.

Downcutting rate can be rapid if a stream is well above base level (e.g., Grand Canyon, AZ).

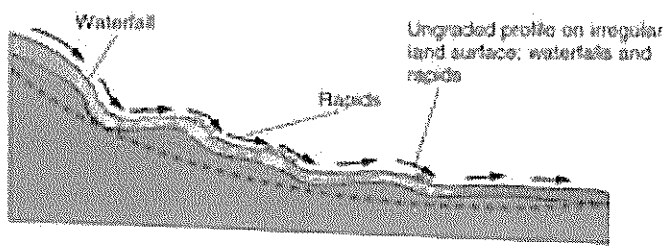


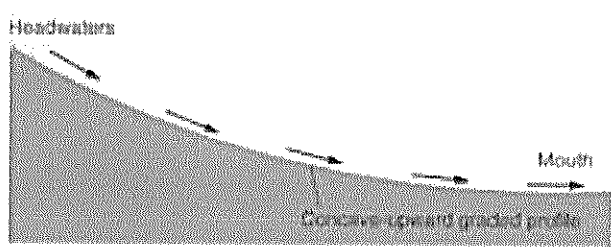


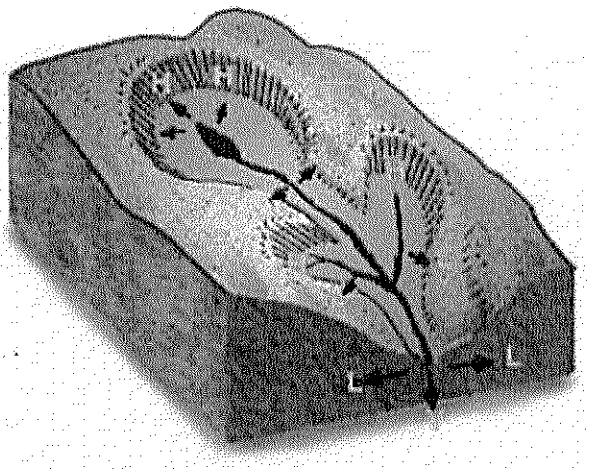


Graded streams:

- Characteristic concave-up longitudinal profile,
- Rapids and waterfalls have been smoothed out by extensive erosion over a long period of time,
- Delicate balance between available sediment load and transport capacity.







Forms and directions of erosion by running water.
H = headward erosion
V = vertical erosion
L = lateral erosion

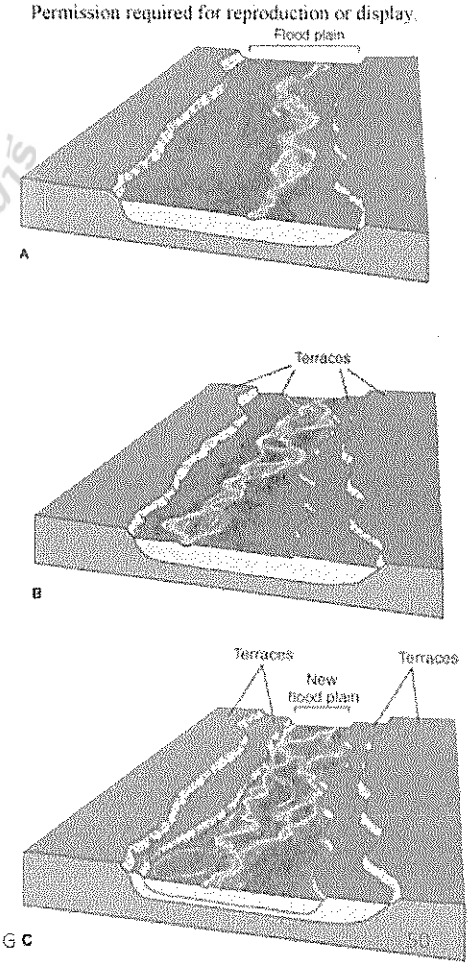
Lateral erosion widens stream valleys by undercutting of stream banks and valley walls as stream swings from side to side across the valley floor.

Headward erosion is the slow uphill growth of a valley above its original source by gullying, mass wasting, and sheet erosion.

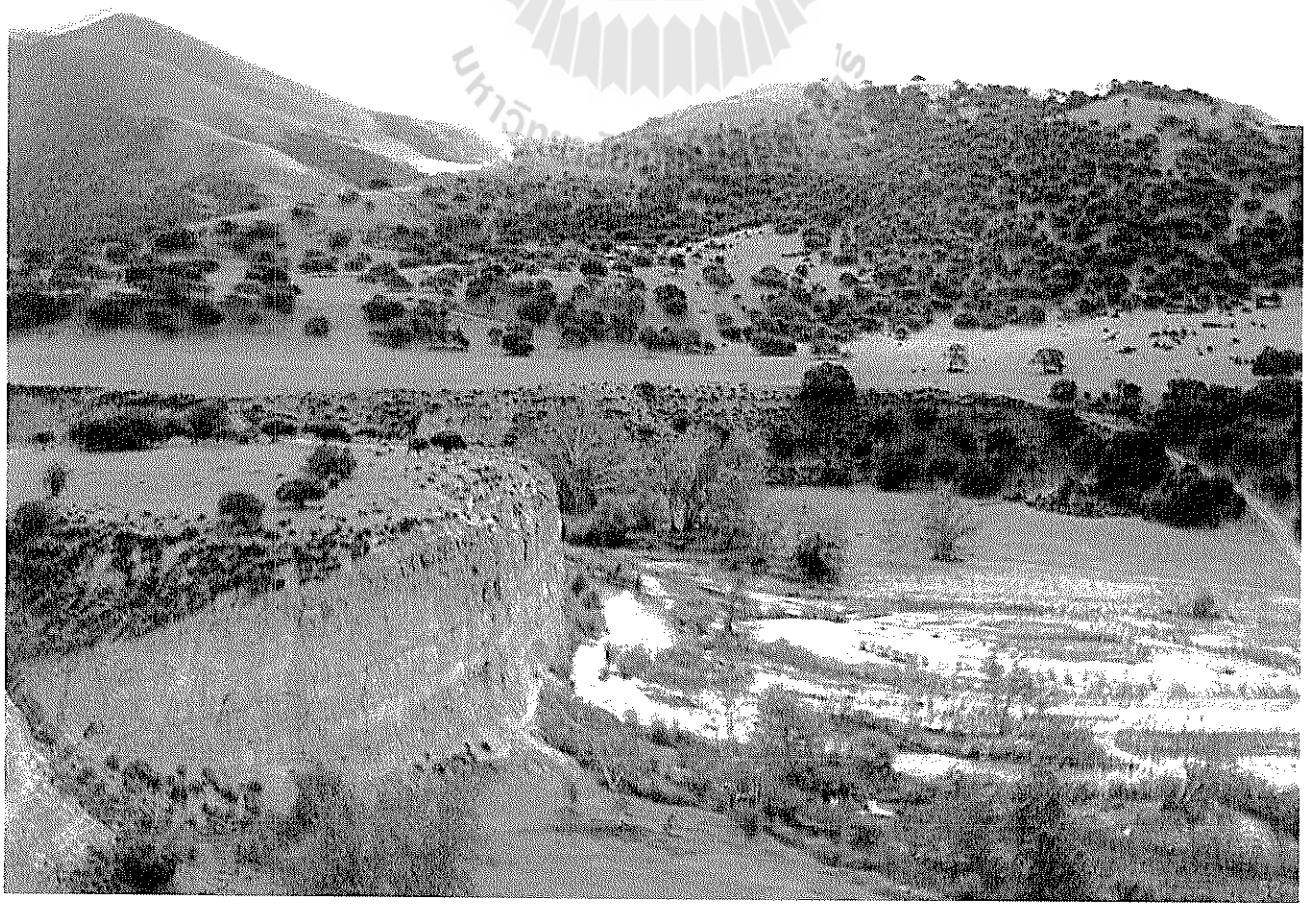
Stream terraces:

- Step-like landforms found above a stream and its floodplain.
- Occurs when river rapidly cuts downward into its own floodplain.
- Represents relatively sudden change from deposition to erosion.
- Can be caused by rapid uplift, drops in base level, or climate changes.

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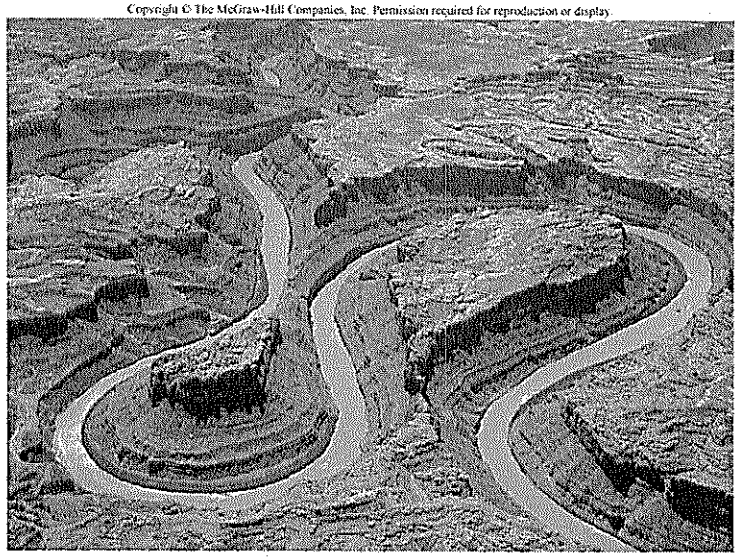




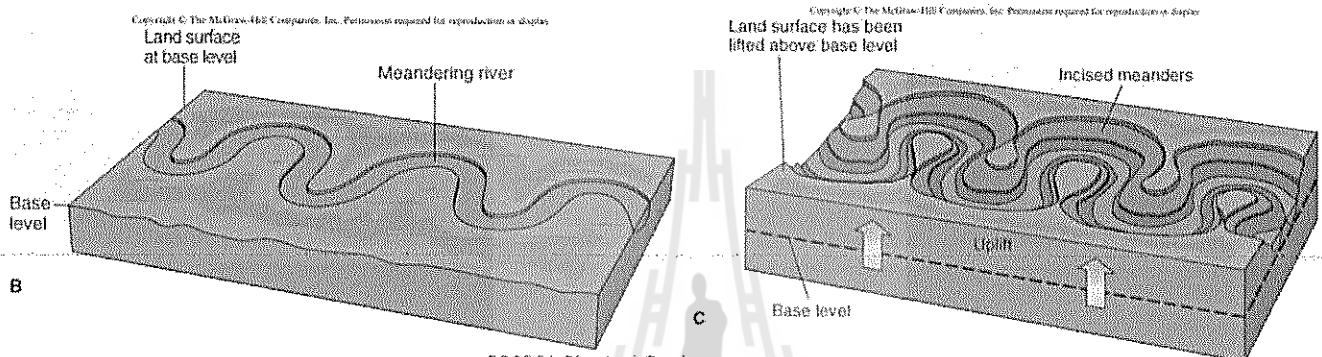
Incised meanders:

- Retain sinuous pattern as they cut vertically downward.
- May be produced by profound base level changes, as when rapid tectonic uplift occurs.

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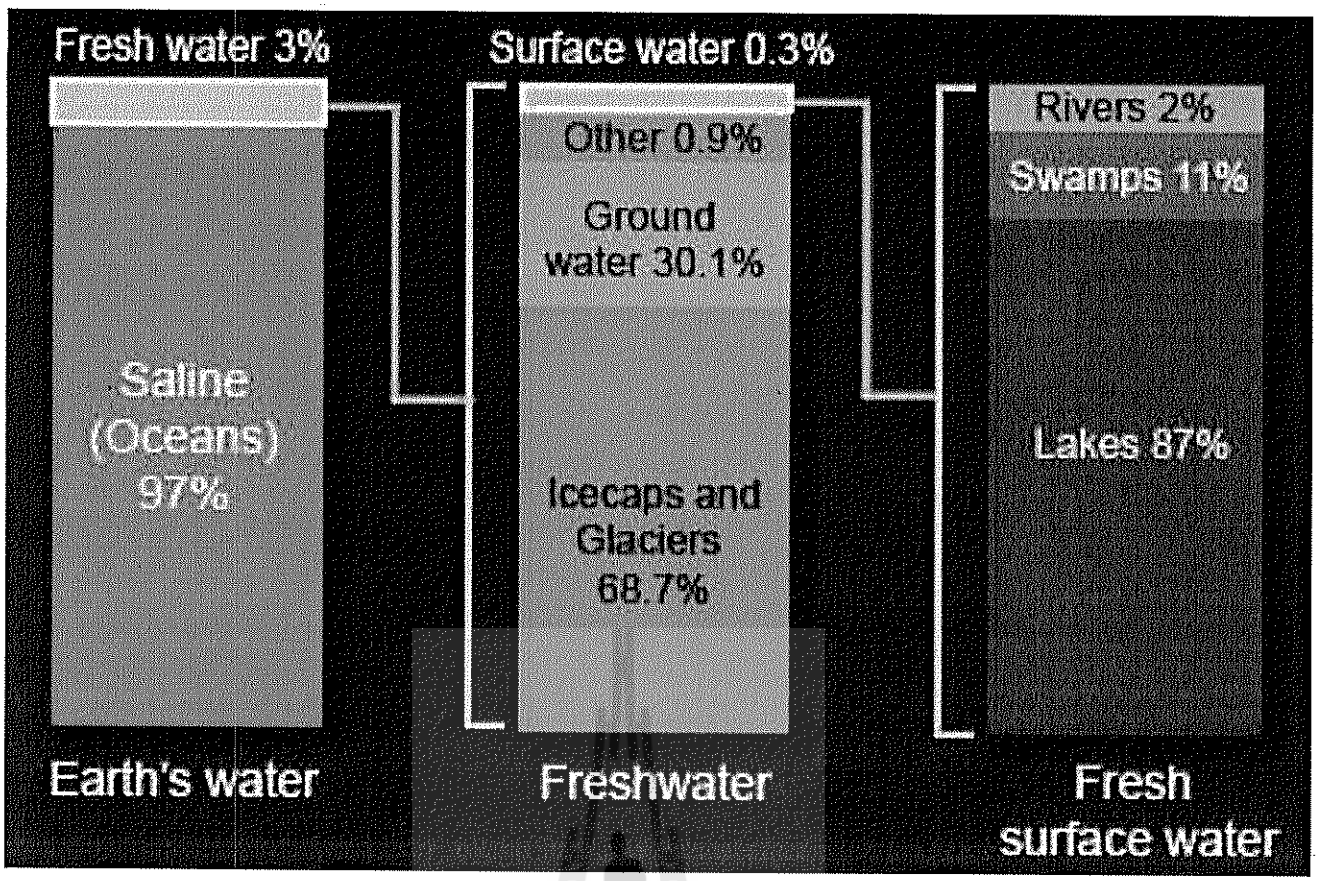
A
Photo by Frank M. Hanna



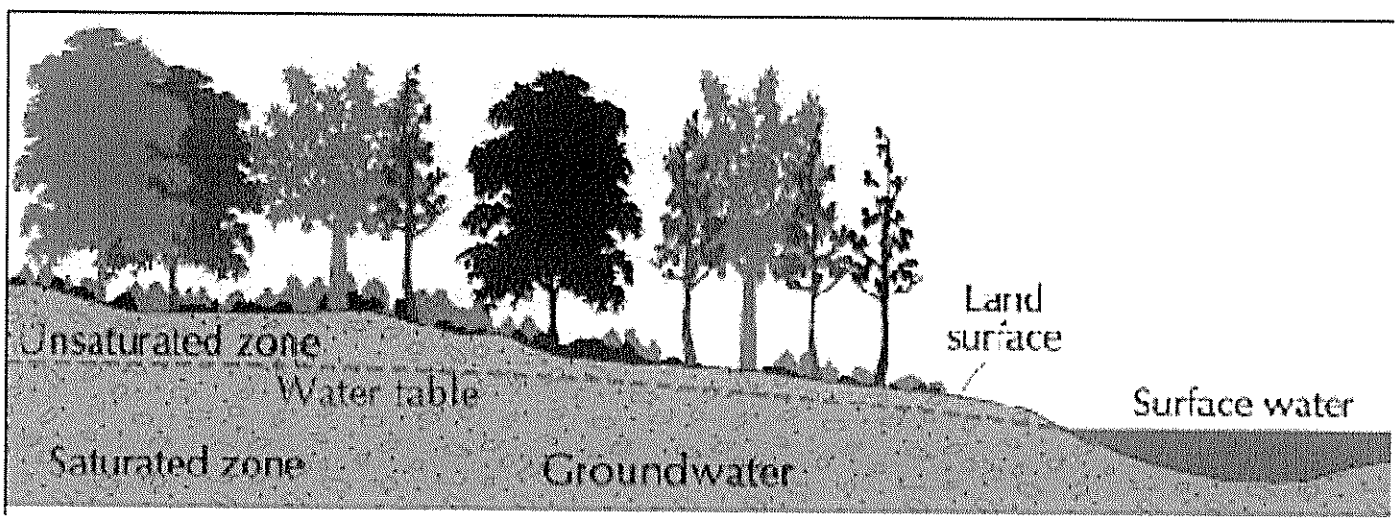
3. Groundwater

Contents

Porosity
Permeability
Saturated and unsaturated zones
Groundwater flow
Aquifers
Groundwater action

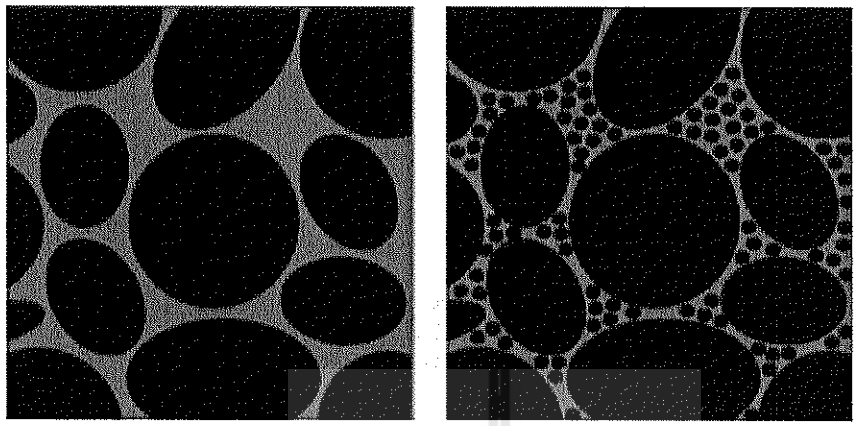


Groundwater: the water that lies beneath the ground surface, filling the pore space between grains in bodies of sediment and clastic sedimentary rock, and filling cracks and crevices in all types of rock.



Porosity

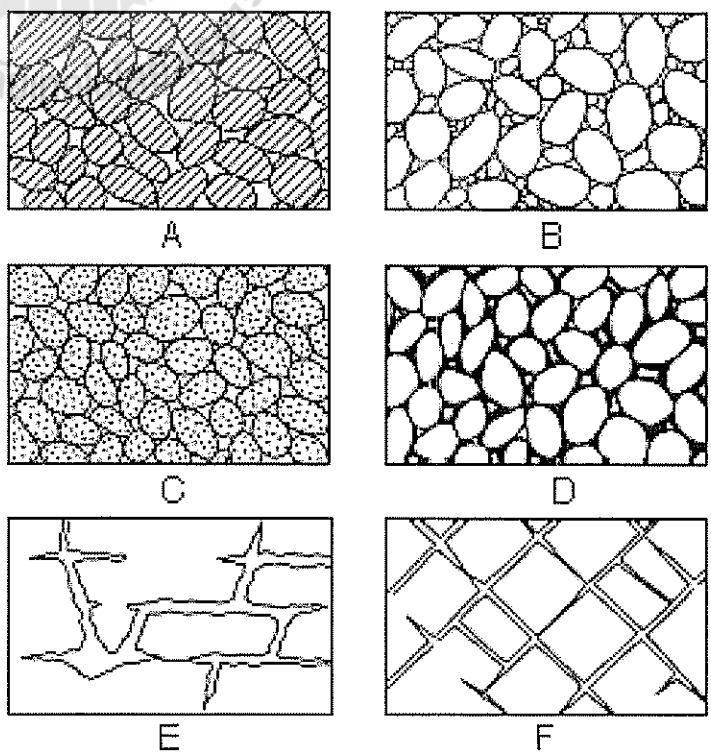
Porosity: the percentage of rock or sediment that consists of voids or openings.



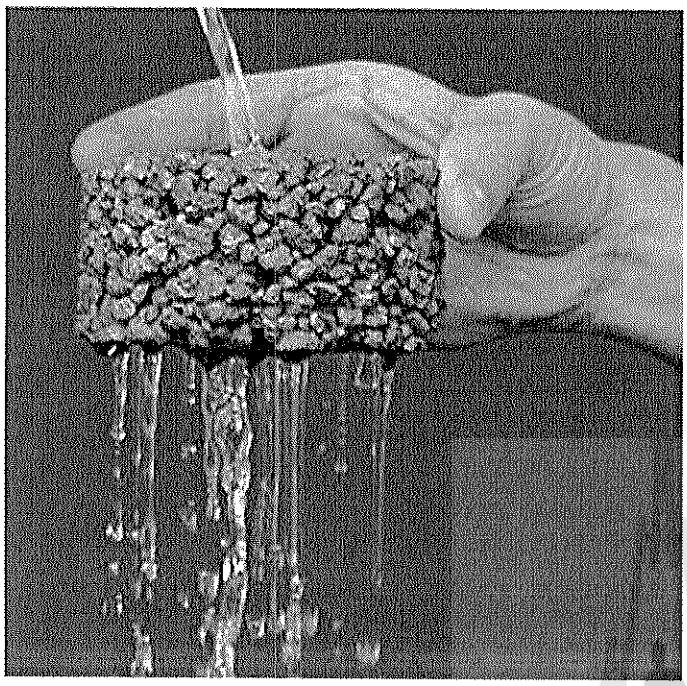
Primary porosity & secondary porosity

Sediment: Determined by how tightly packed and how clean (silt and clay), (usually between 20 and 40%).

Rock: Determined by size and number of fractures (most often very low, <5%).



Permeability: the capacity of a rock to transmit a fluid such as water or petroleum through pores and fractures.

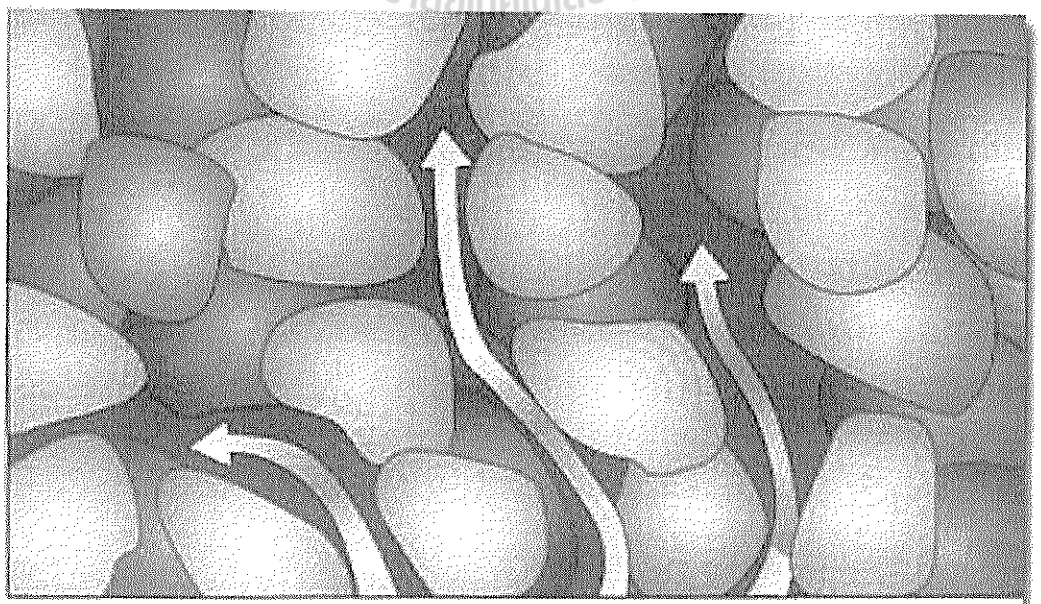


Sediment: Proportional to sediment size.

Rock: proportional to fracture size and number. Can be good to excellent.

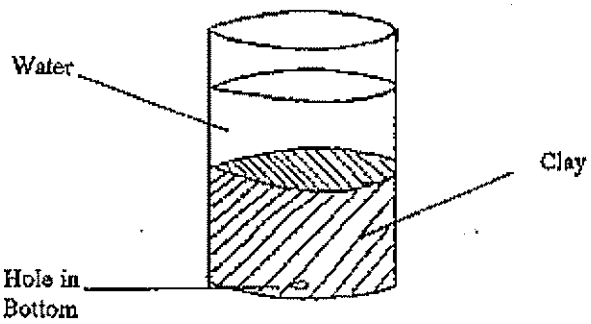
Porous rock: a rock that holds much water.

Permeable rock: a rock that allows water to flow easily through it.

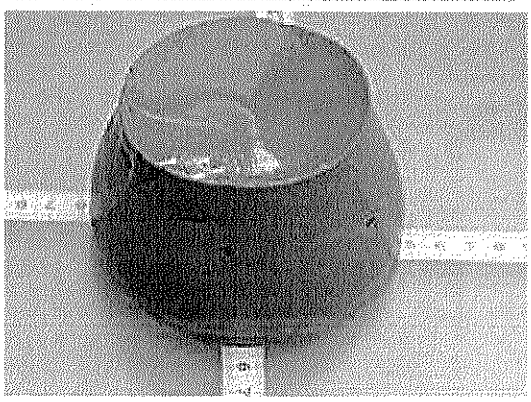


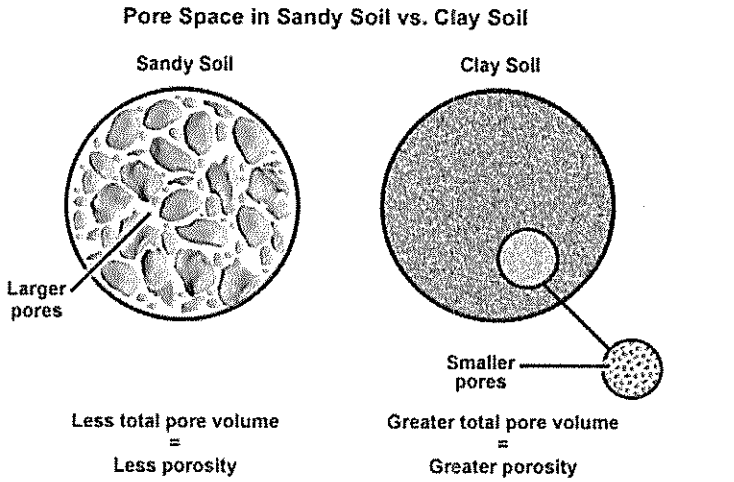
Connected pores give a rock permeability.

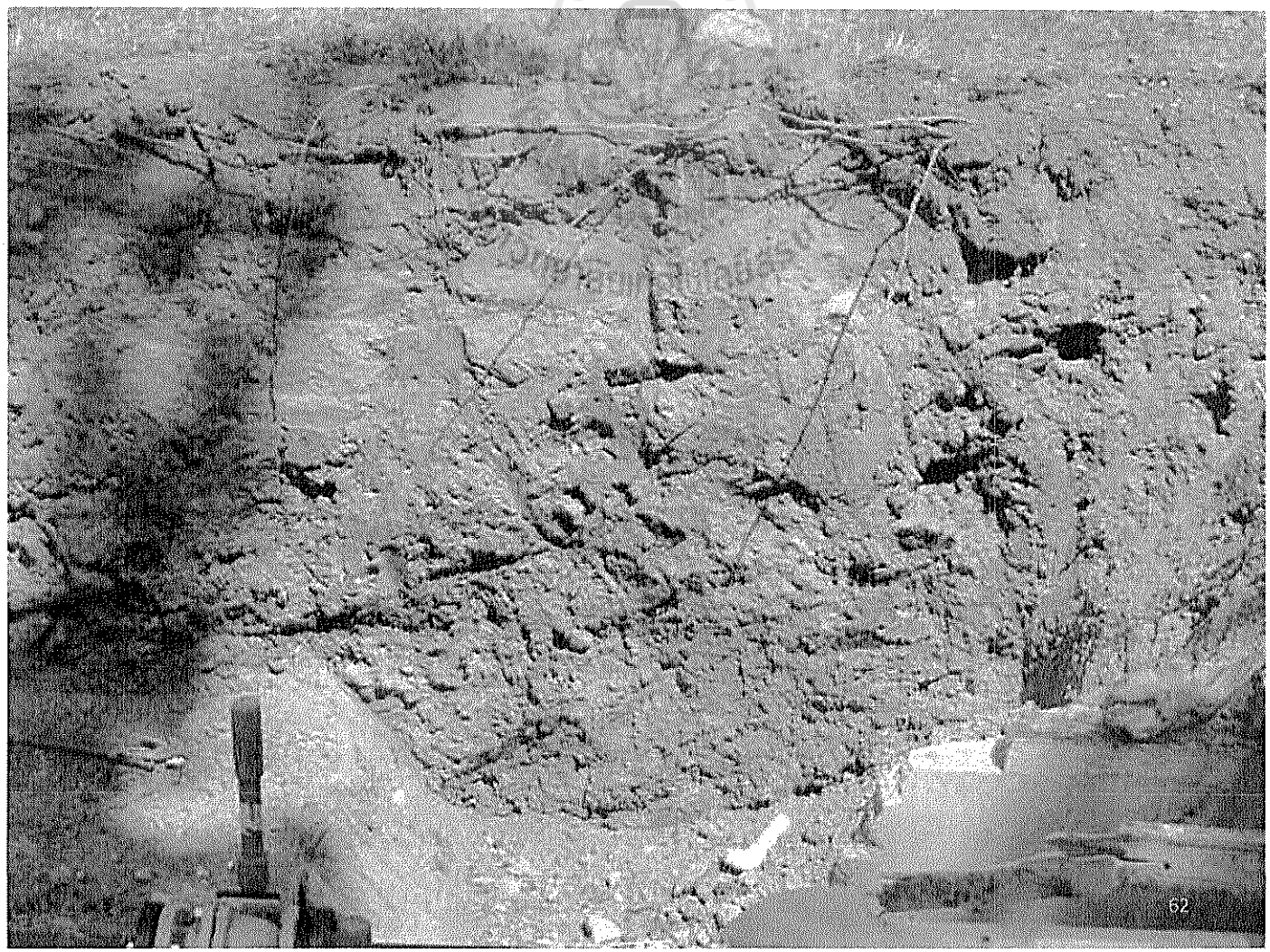
Impermeable rock: a rock that does not allow water to flow through it easily.



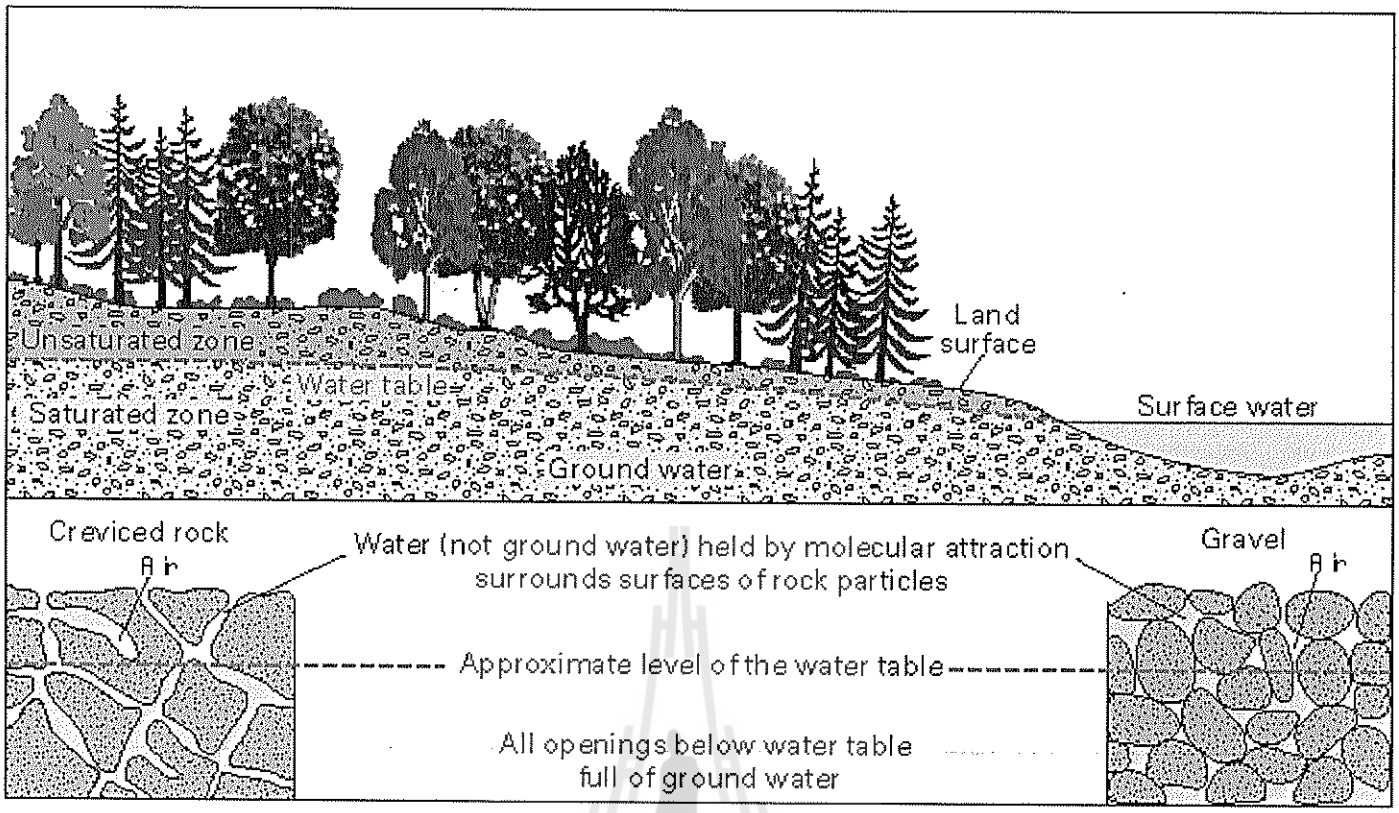
Water does not go through the hole in the bottom



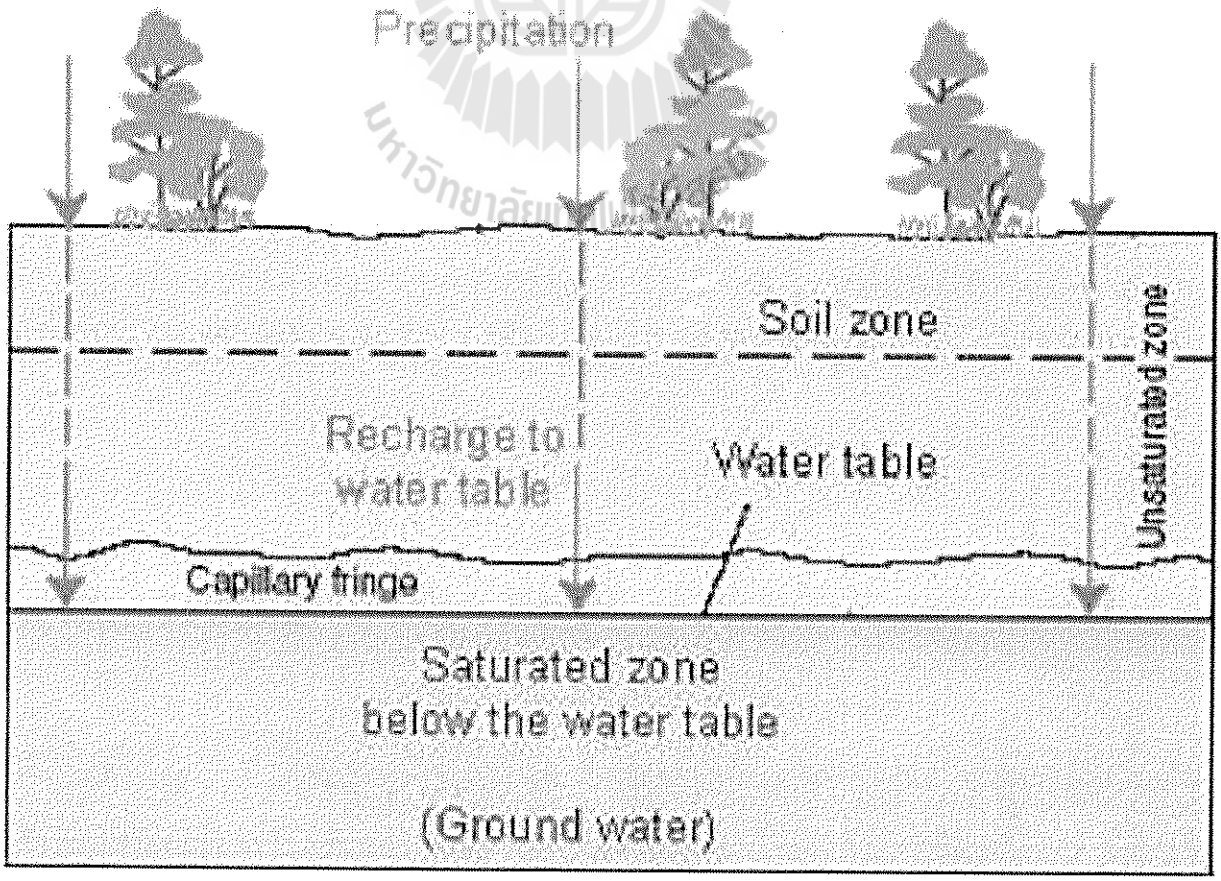




Saturated zone & Unsaturated zone



Unsaturation zone = zone of aeration

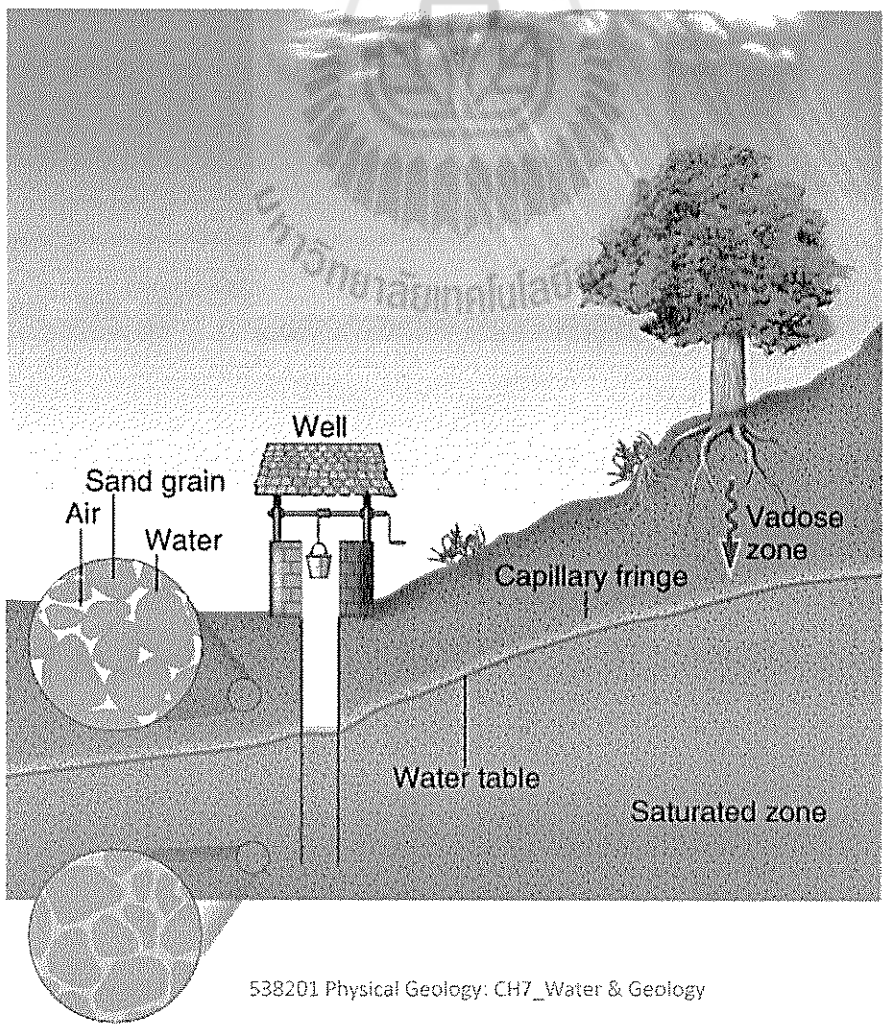


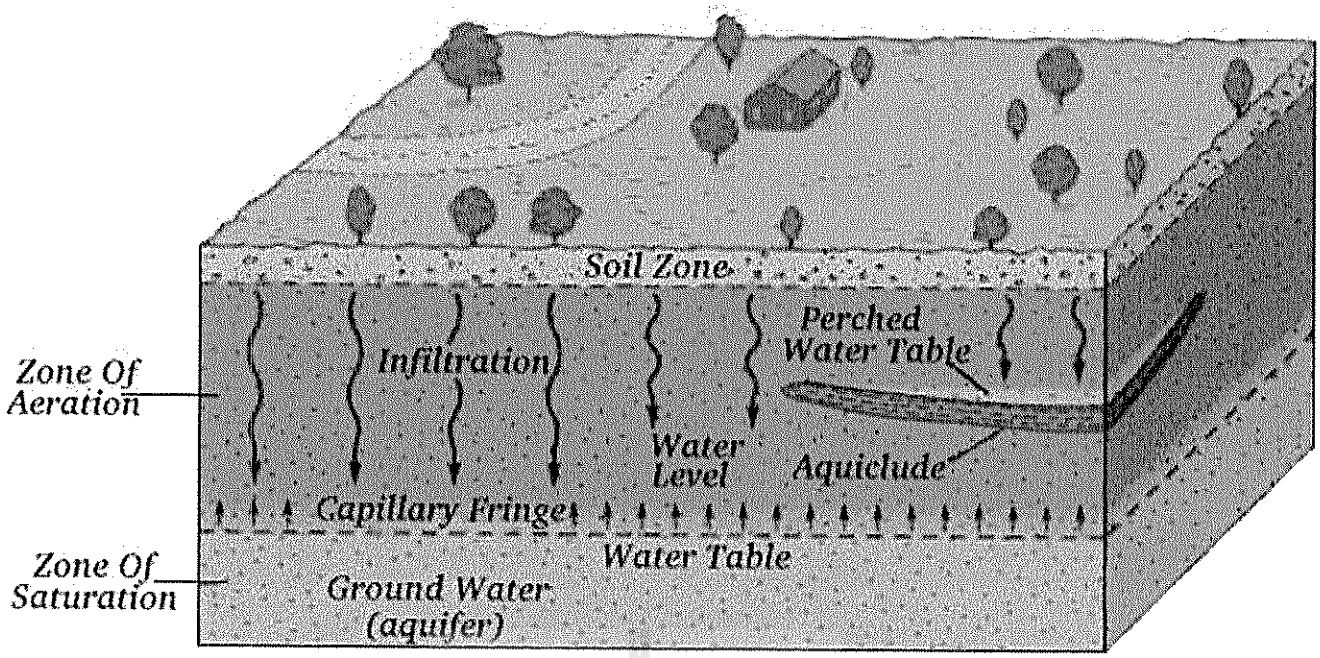
Unsaturated zone: a subsurface zone in which rock openings are generally unsaturated and filled partly with air and partly with water.

Capillary fringe: a transition zone with higher moisture content at the base of the vadose zone just above the water table.

Water table: the upper surface of the zone of saturation.

Saturated zone: the subsurface zone in which all rock openings are filled with water.

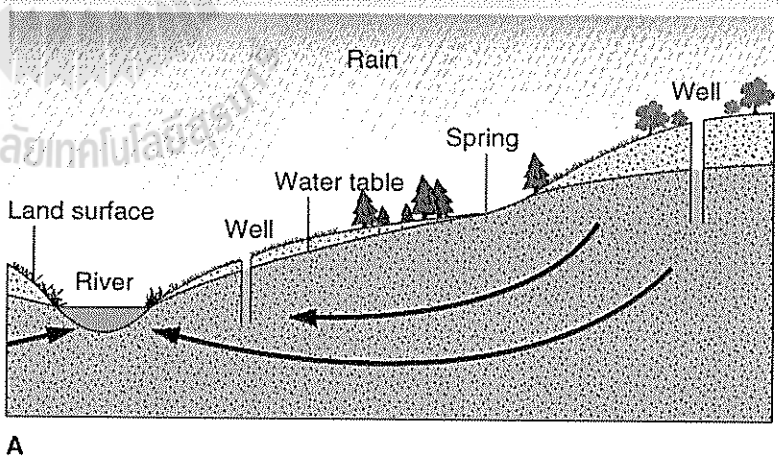




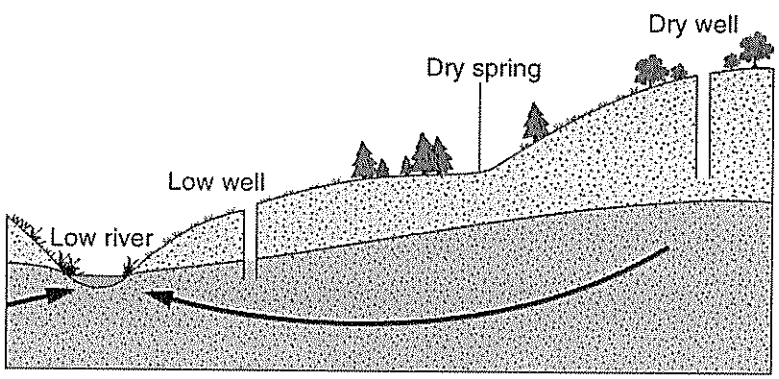
Perched water table: the top of a body of groundwater separated from the main water table beneath it by a zone that is not saturated.

Groundwater Flow

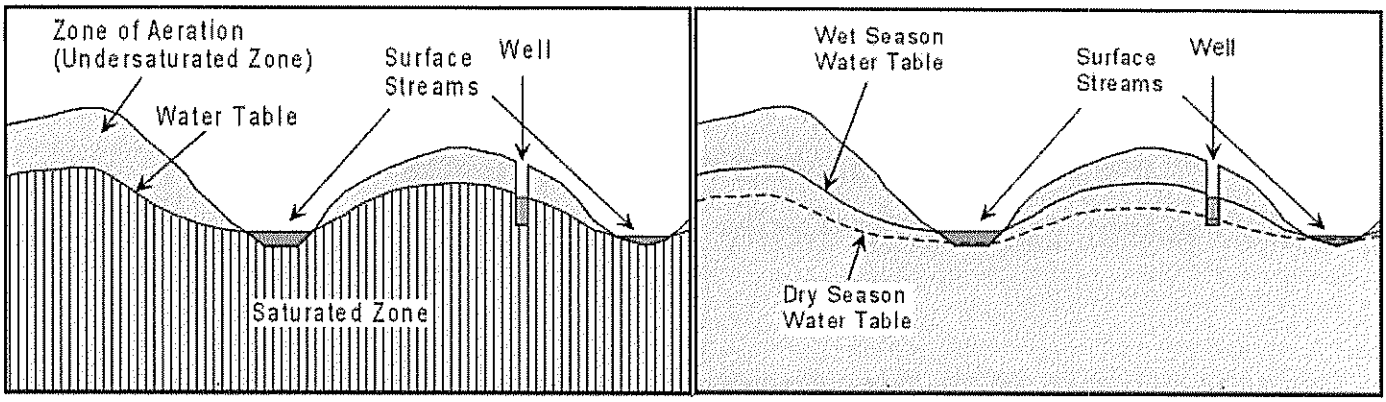
- Precipitation
- Infiltration
- Groundwater recharge
- Groundwater flow
- Groundwater discharge to
  - Springs
  - Streams and
  - Wells



A



B



Factors affecting the flow of ground water:

- the slope of the water table - the steeper the water table, the faster ground water moves.
- permeability - if rock pores are small and poorly connected, water moves slowly; when openings are large and well connected, the flow of water is more rapid.

Groundwater/ Surface-Water Interactions

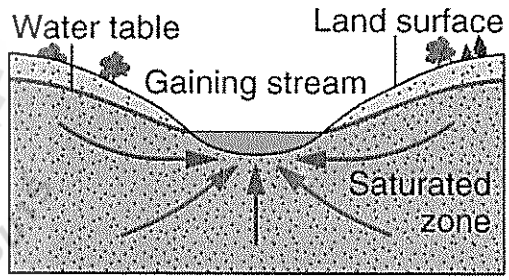
Gaining streams

- Humid regions
- Wet season

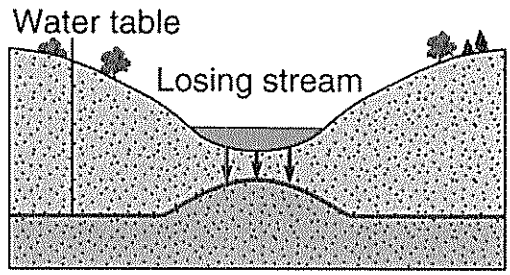
Loosing streams

- Humid regions, smaller streams, dry season
- Arid regions

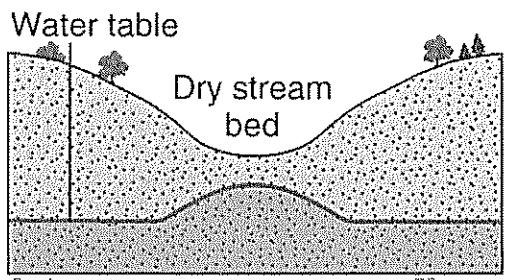
Dry stream bed



A



B



C

Aquifer

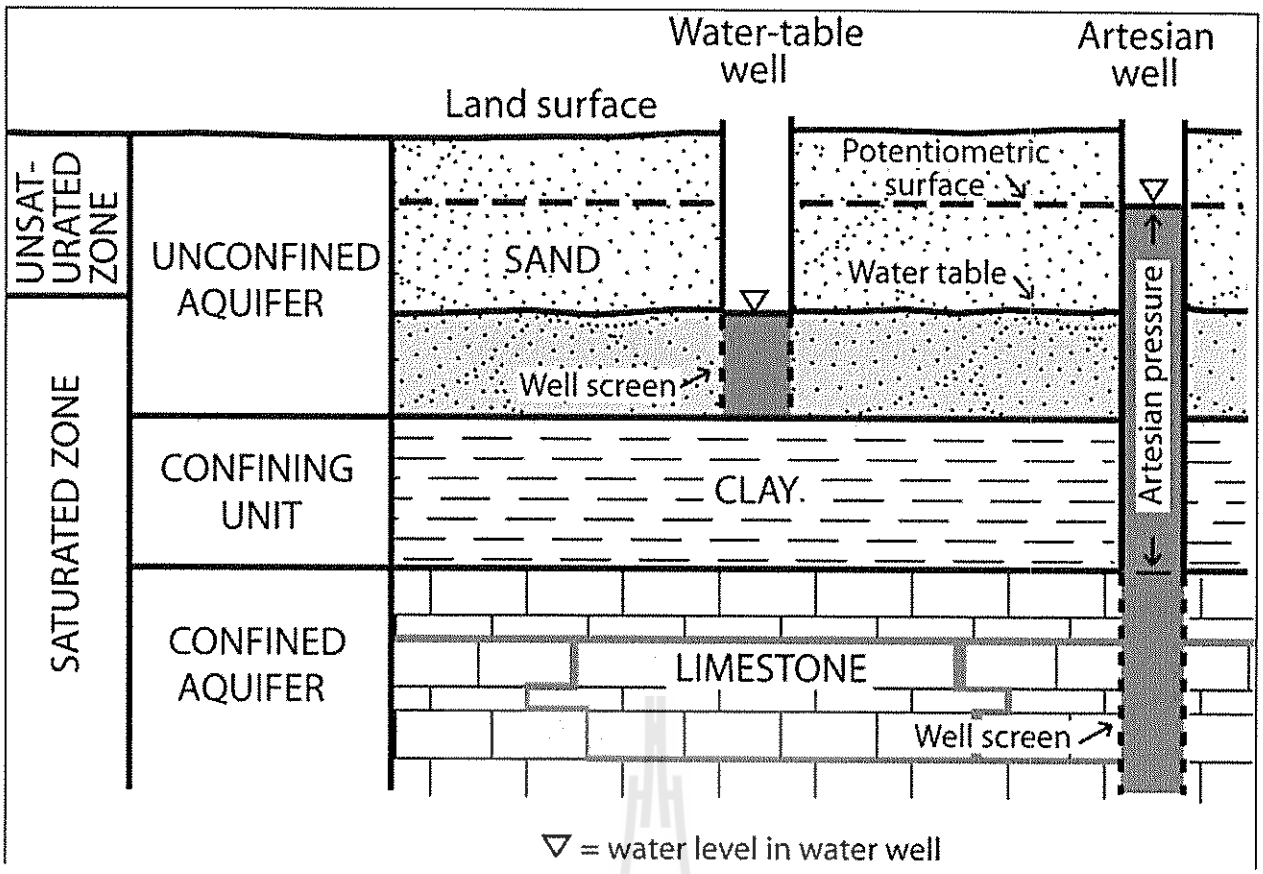
Aquifer: a body of saturated rock or sediment through which water can move easily.

Good aquifers include sandstone, conglomerate, well-joined limestone, bodies of sand and gravel, and some fragmental or fractured volcanic rocks such as columnar basalt.

Unconfined aquifer & Confined aquifer

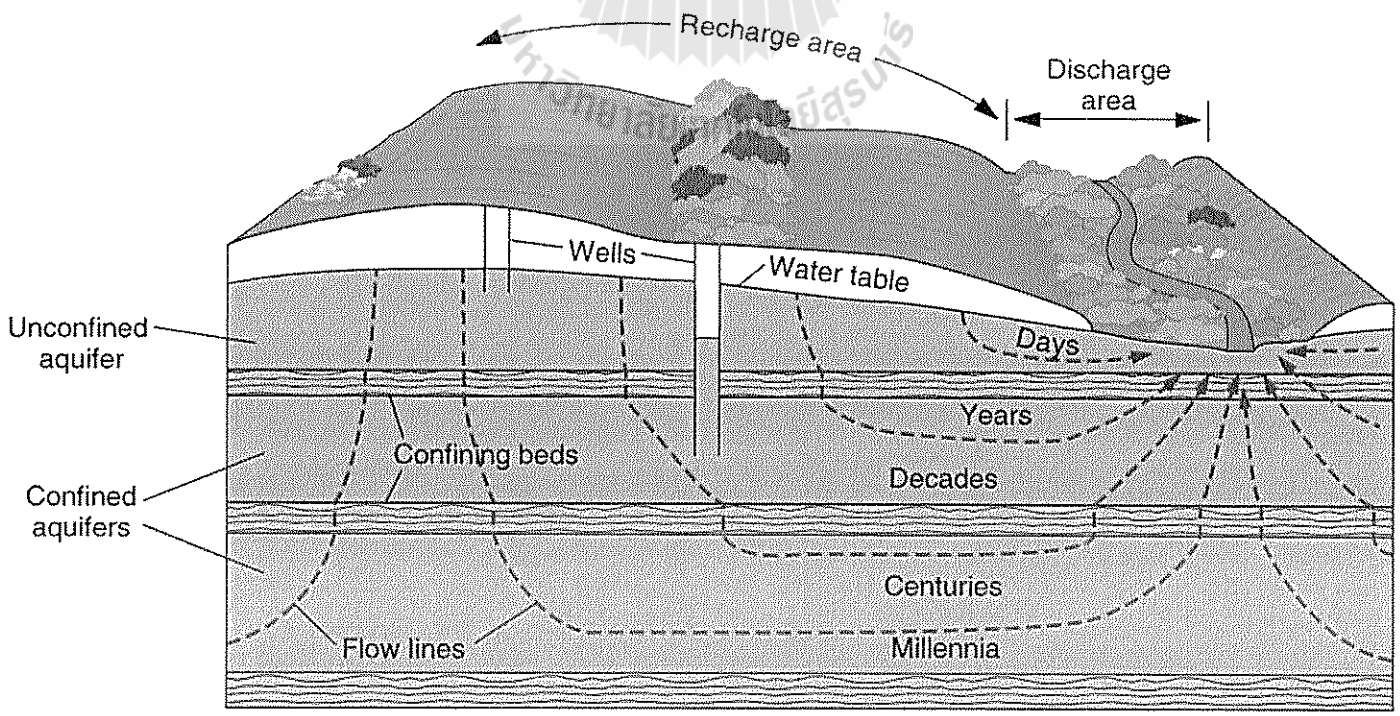
Unconfined aquifer: a partially filed aquifer exposed to the land surface and marked by a rising and falling water table.

Confined aquifer (artesian aquifer): an aquifer completely filled with pressurized water and separated from the land surface by a relatively impermeable confining bed, such as shale.



For water-table well, pore pressure = atmospheric pressure

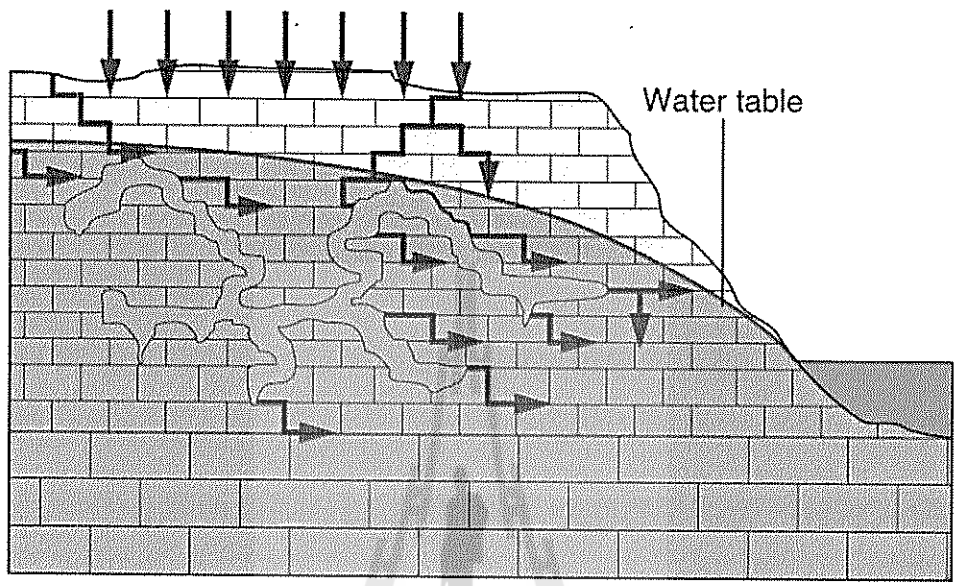
For artesian well, pore pressure > atmospheric pressure



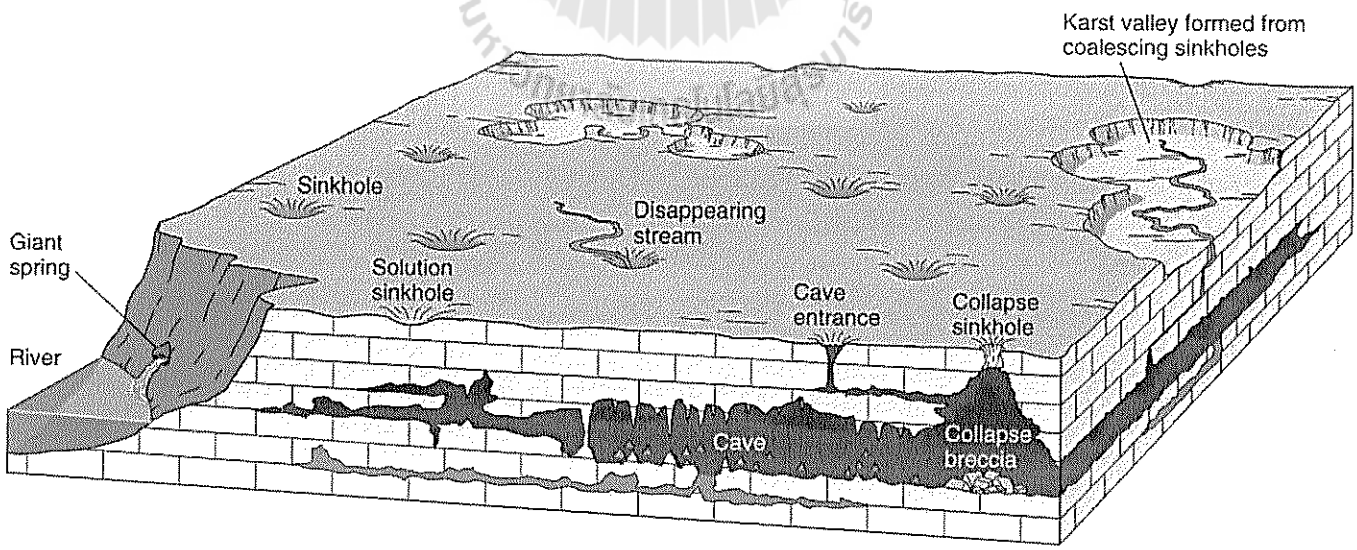
Groundwater action

Groundwater chemically weathers limestone.

- caves are formed, Permeability is increased
- caves drain, Karst Topography



75



Contents

- Landscape beneath the sea
- Sea level
- Ocean water and currents
- Tide
- Wave actions
- Sediment deposition

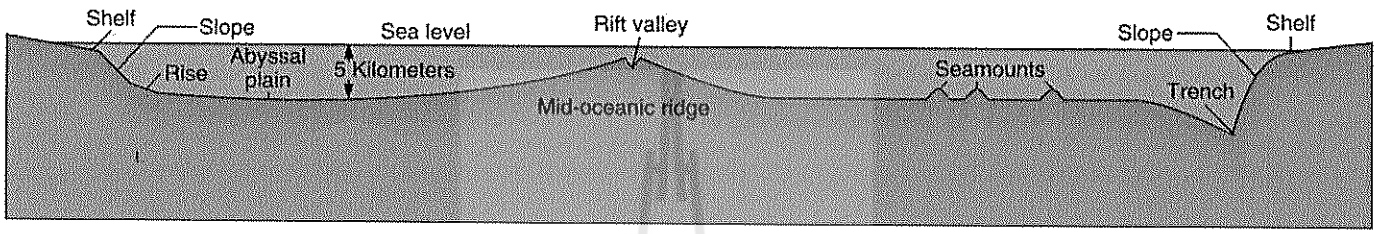
Landscapes beneath the sea

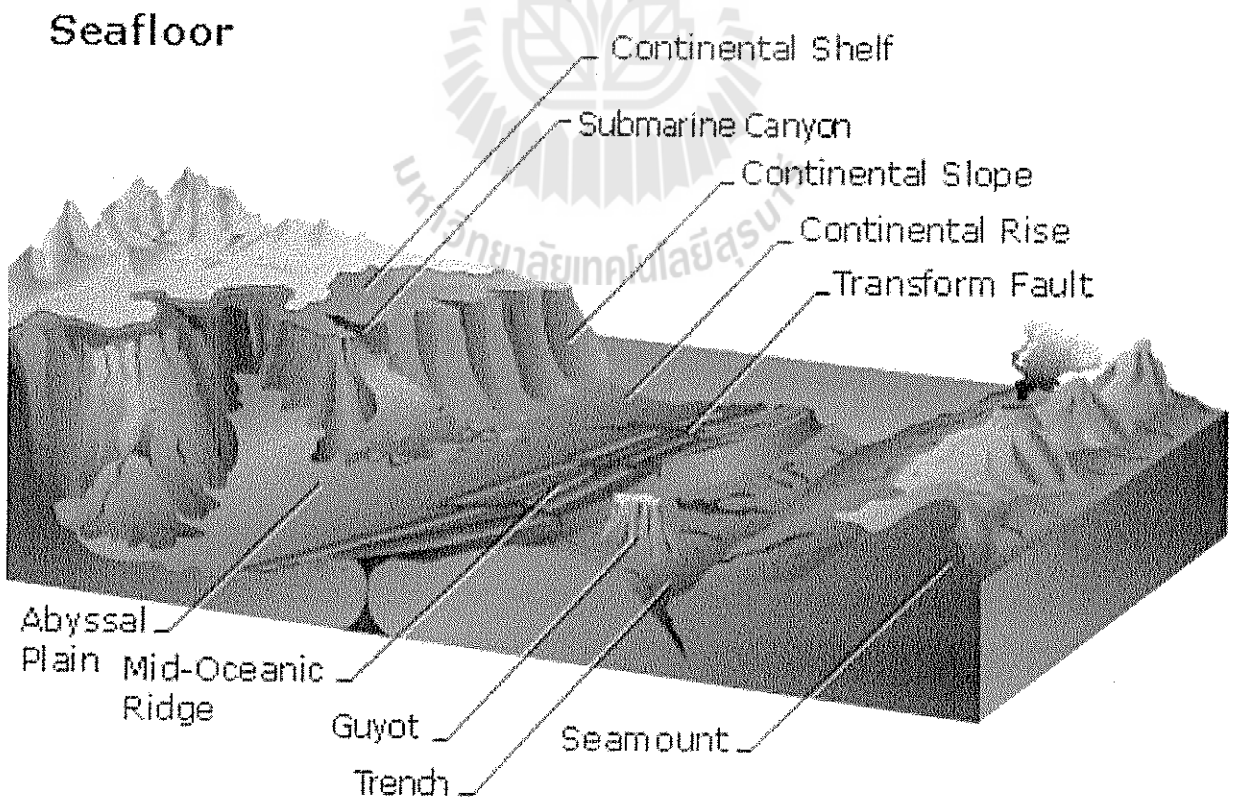
Oceanic lithosphere is denser and thinner than the continental lithosphere.

The ocean's bathymetry (variation in depth) which measured by sonar or satellites can be distinguished as



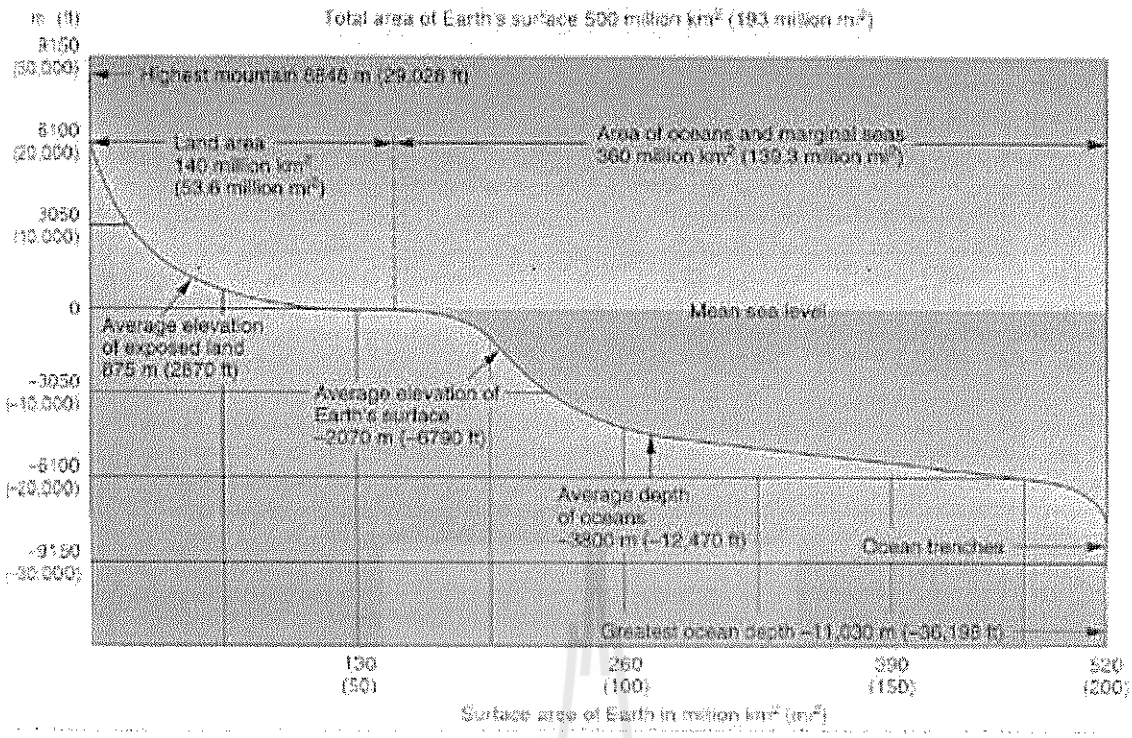
- Continental shelf (depth < 500 m, slope at 3°)
- Continental slope (depth 500 m-4 km, slope 2°)
- Continental rise (depth 4-4.5 km, angle decrease)
- Abyssal plain (depth 4.5 km)
- Seamount: oceanic hot-spot volcanoes (active and remnants) rise below sea level.



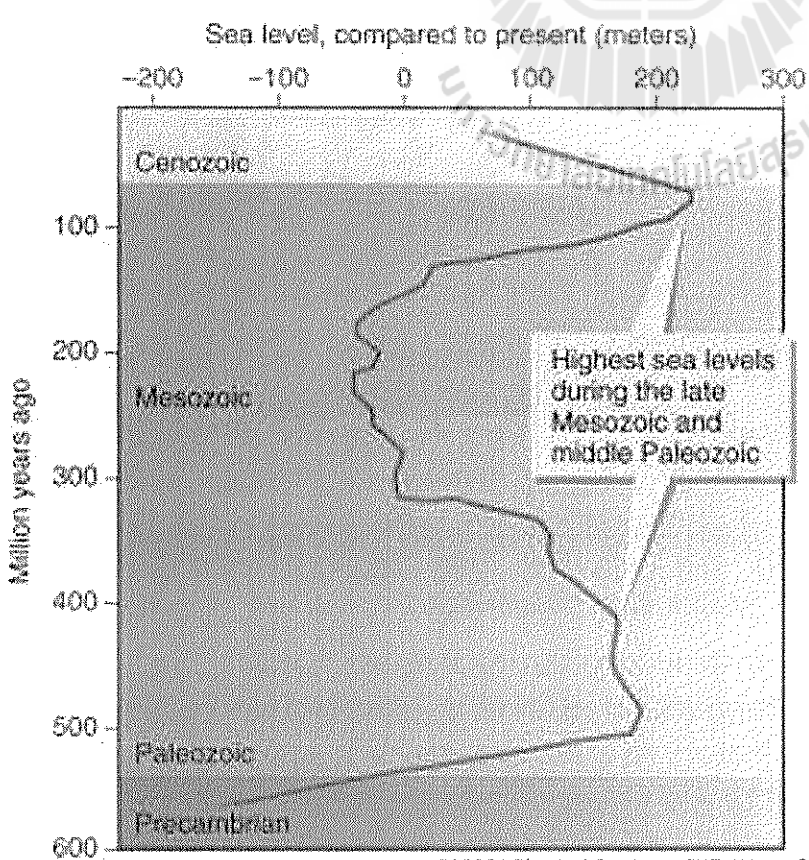


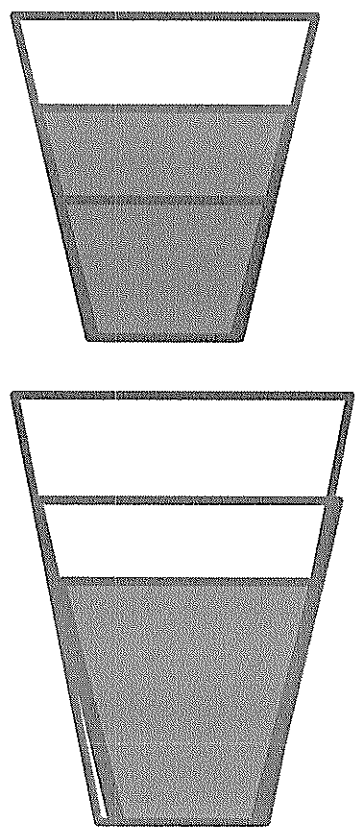
- Continental shelf (depth < 500 m, slope at 3 degree),
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- Continental rise (depth 4-4.5 km, angle decrease)
- Abyssal plain (depth 4.5 km)
- Seamount: oceanic hot-spot volcanoes (active and remnants) rise below sea level.

Sea Level



Sea level is not constant

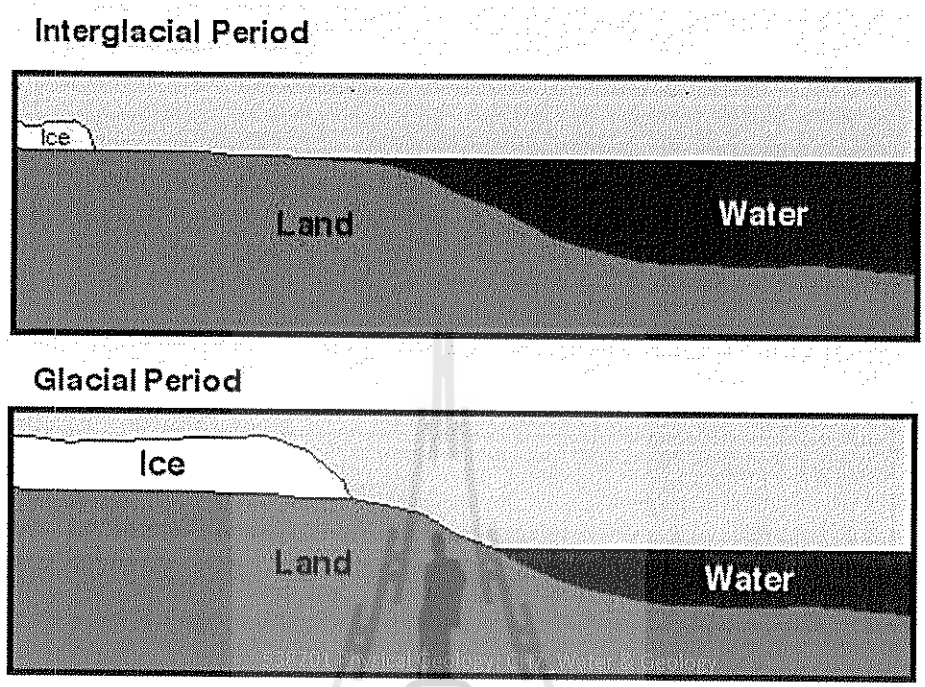


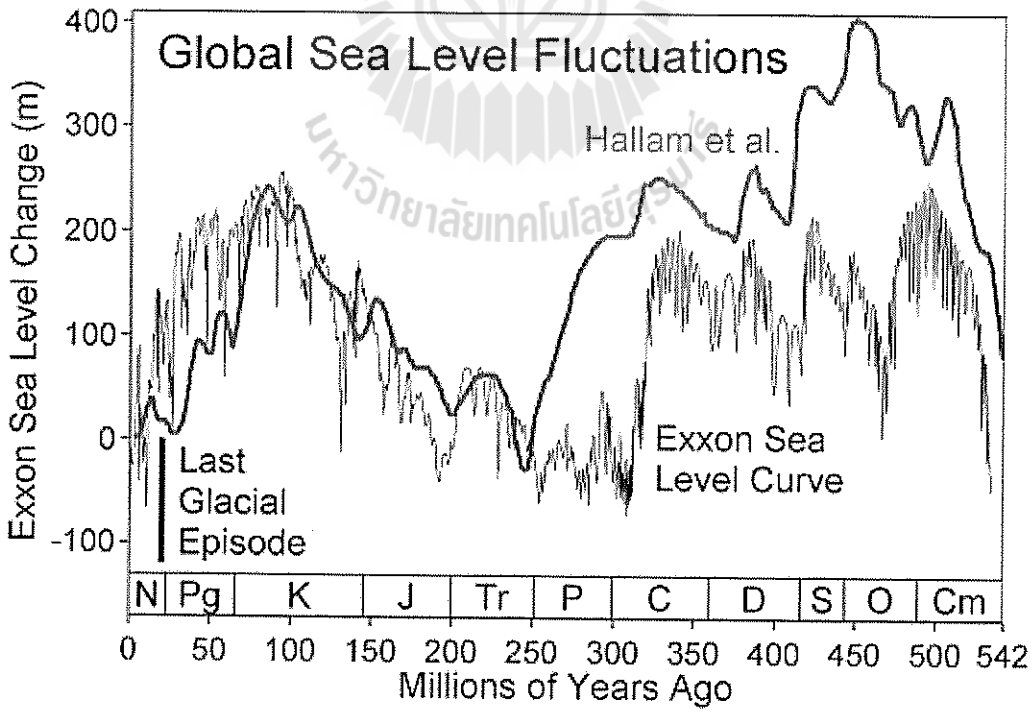


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Types of sea level change

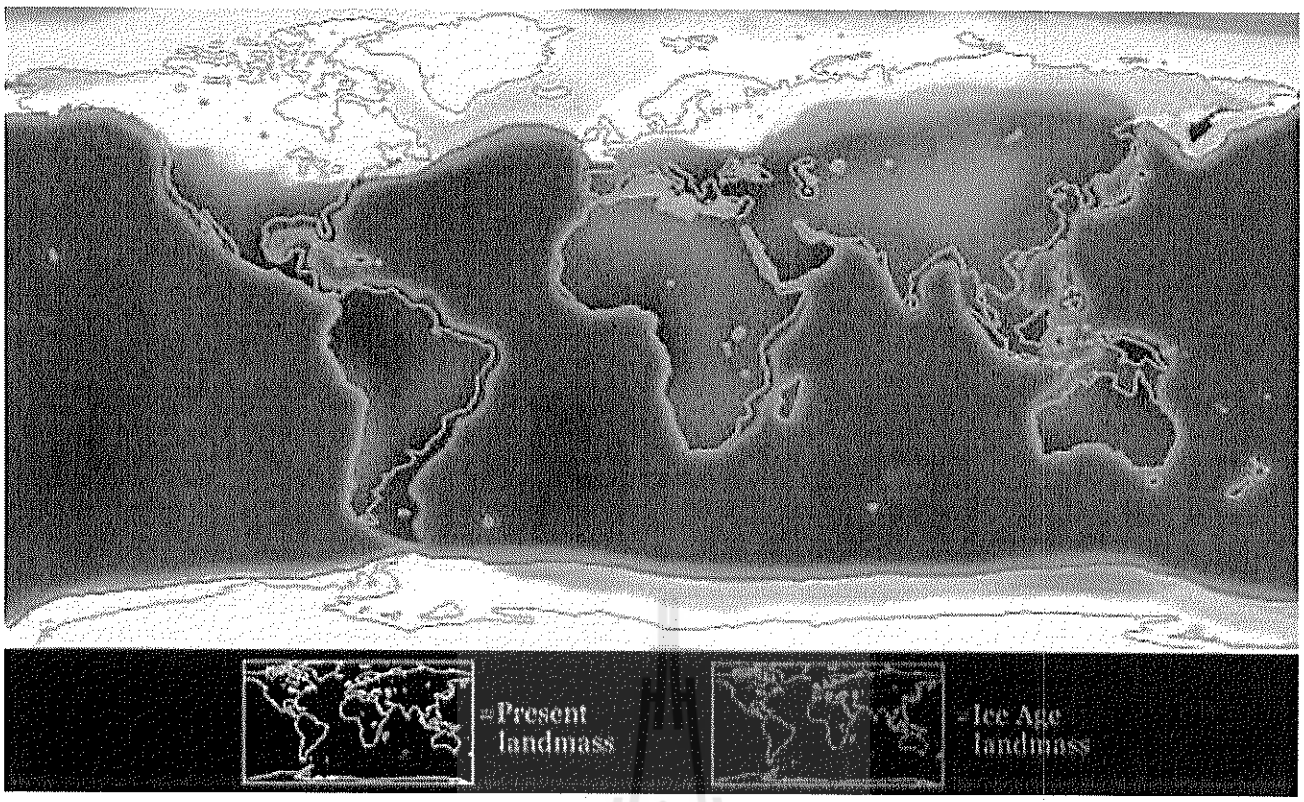
Eustatic: change in volume of liquid water worldwide. Glaciation lowers sea level by ~130 m. Exposes continental shelves to weathering and erosion.





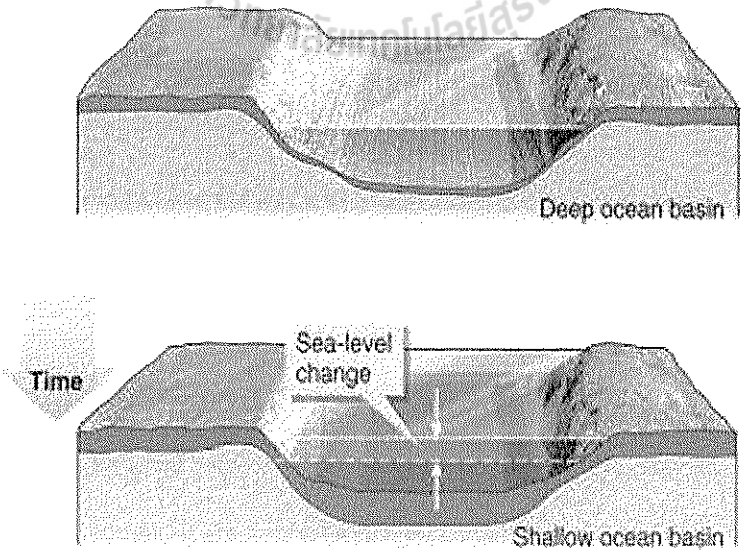
Comparison of two sea level reconstructions during the last 500 Ma. The scale of change during the last glacial/interglacial transition is indicated with a black bar. Note that over most of geologic history long-term average sea level has been significantly higher than today. http://en.wikipedia.org/wiki/Sea_level

The last Ice Age 18,000 years ago



Global warming = melting of ice = eustatic increase in sea level.

Tectonic: movement of crust relative to sea level locally. For example, uplift of region due to tectonism (e.g., Himalayas); isostatic rebound (e.g., Hudson Bay).



(b) Same volume of water covers a larger surface area if ocean basins become shallower

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Fig 13.16

Major Constituents of Sea Water (g/kg)

Chloride	Cl^-	19.35%
Sodium	Na^+	10.76%
Sulfate	SO_4^{2-}	2.71%
Magnesium	Mg^{2+}	1.29%
Calcium	Ca^{2+}	0.41%
Potassium	K^+	0.39%
Bicarbonate	HCO_3^-	0.14%
Bromide	Br^-	0.067%



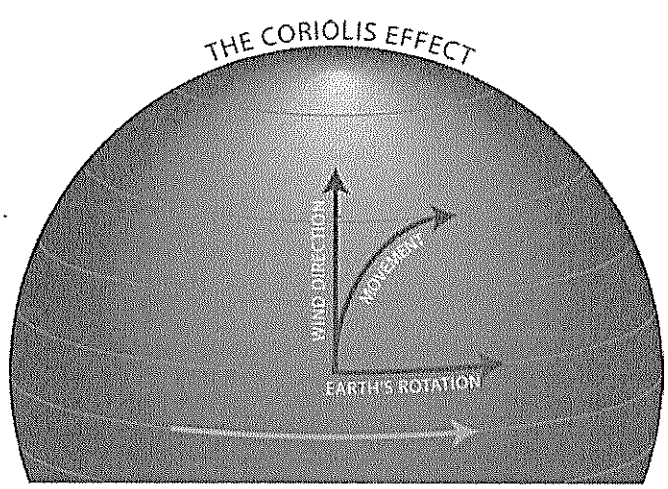
Everything Else < 0.01

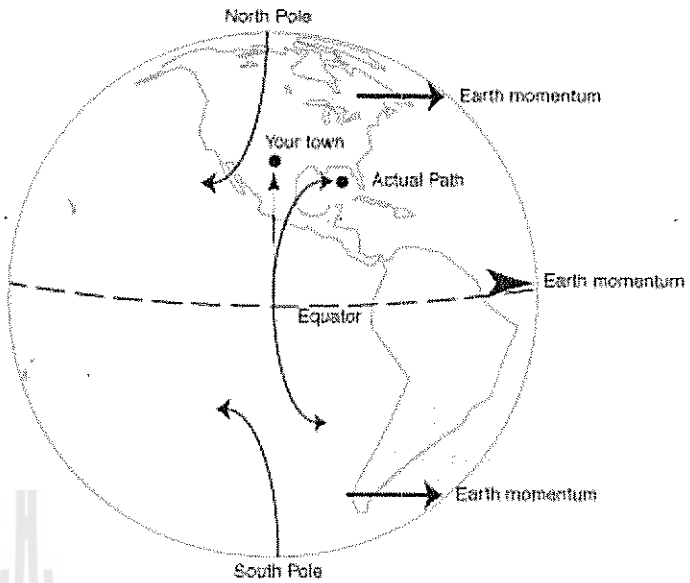
Total Dissolved Solids ~ 30.3%

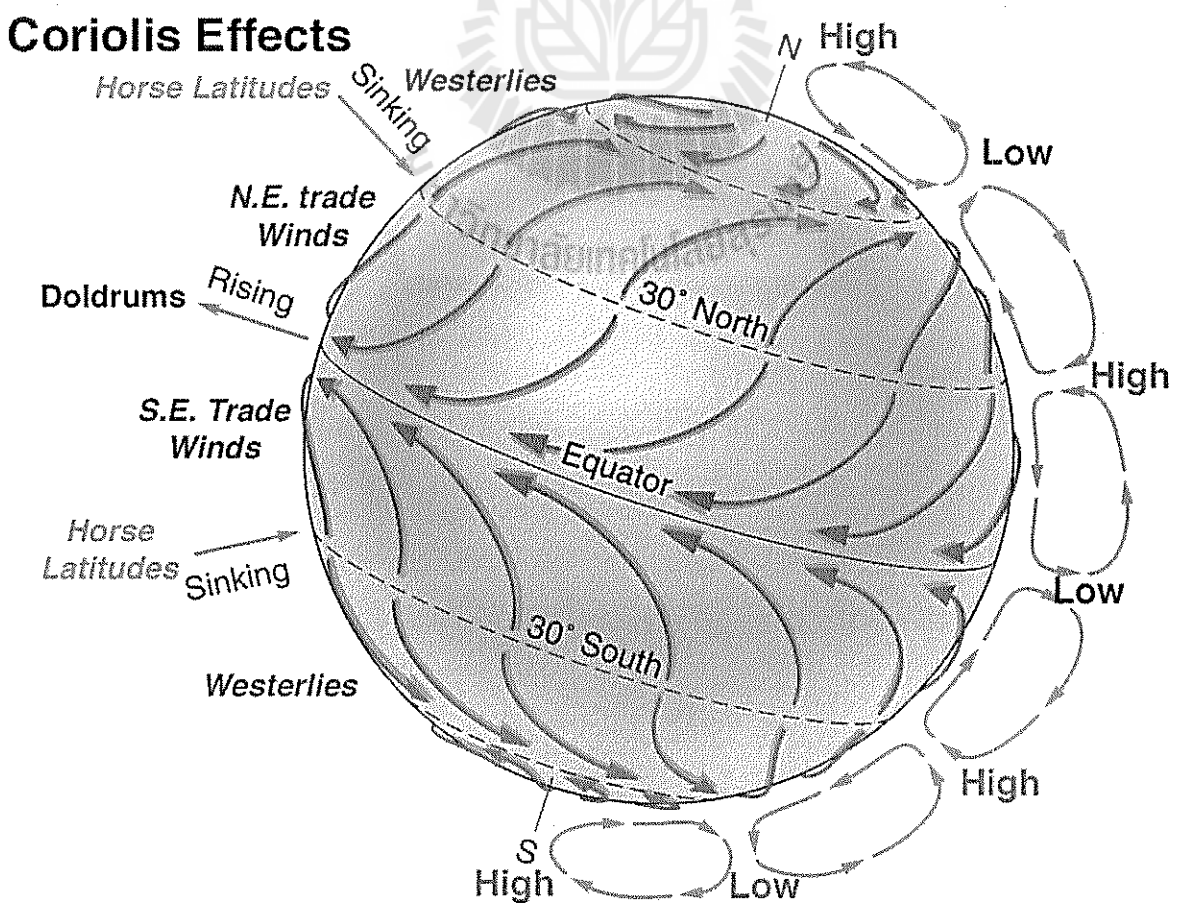
•The average global sea-surface temperature is 17 °C (near the poles) to 35 °C in tropical areas. T varies with depth.

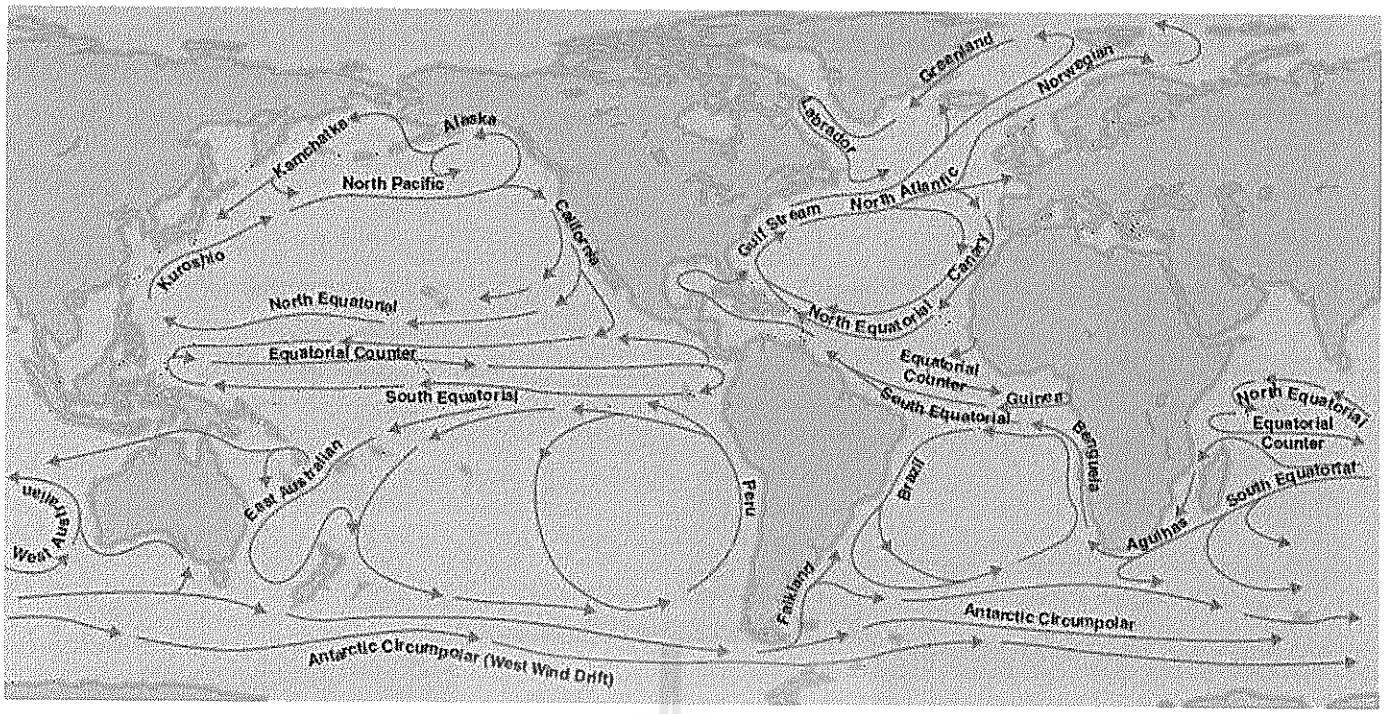
• Ocean water flows are resulted of surface currents and differences in temperature and salinity (thermoclinal circulation).

Wind Currents: worldwide patterns due to frictional drag of prevailing winds.

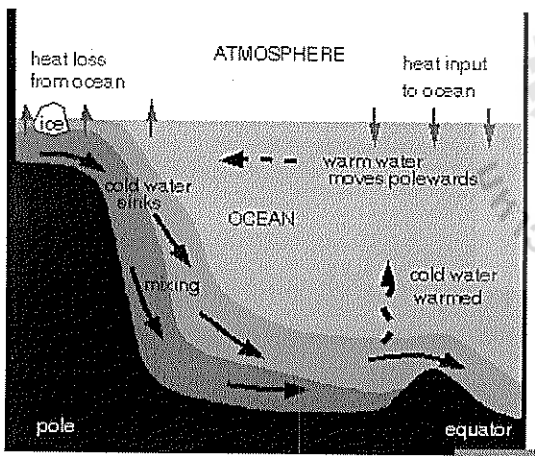








The major surface currents of the world's oceans



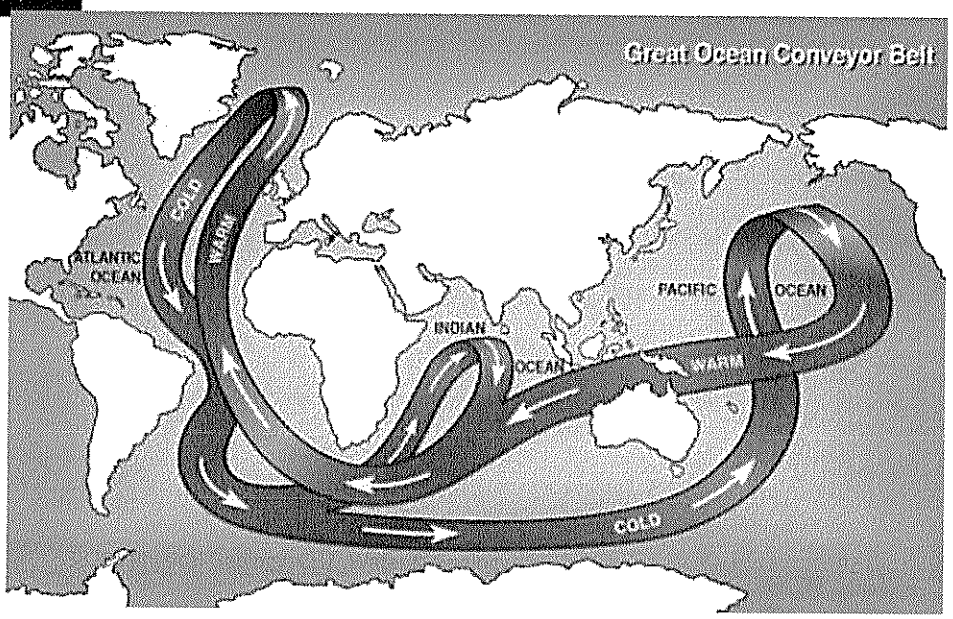
Thermoclinal circulation

Composition:

higher salinity = denser water

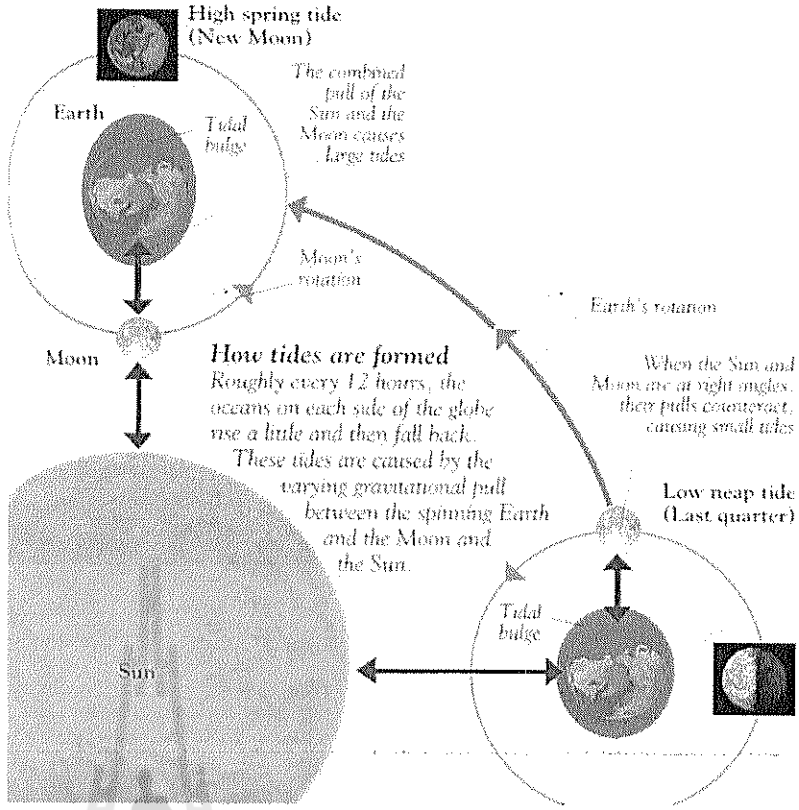
Temperature:

to 4˚C, water gets denser



Tides

Tide: Periodic rising and falling of the sea surface that results from gravitational attractions of the Moon and Sun acting on the rotating Earth.



Variability: 0.1 – 15 m.

Moon orbits the Earth every 29.5 days

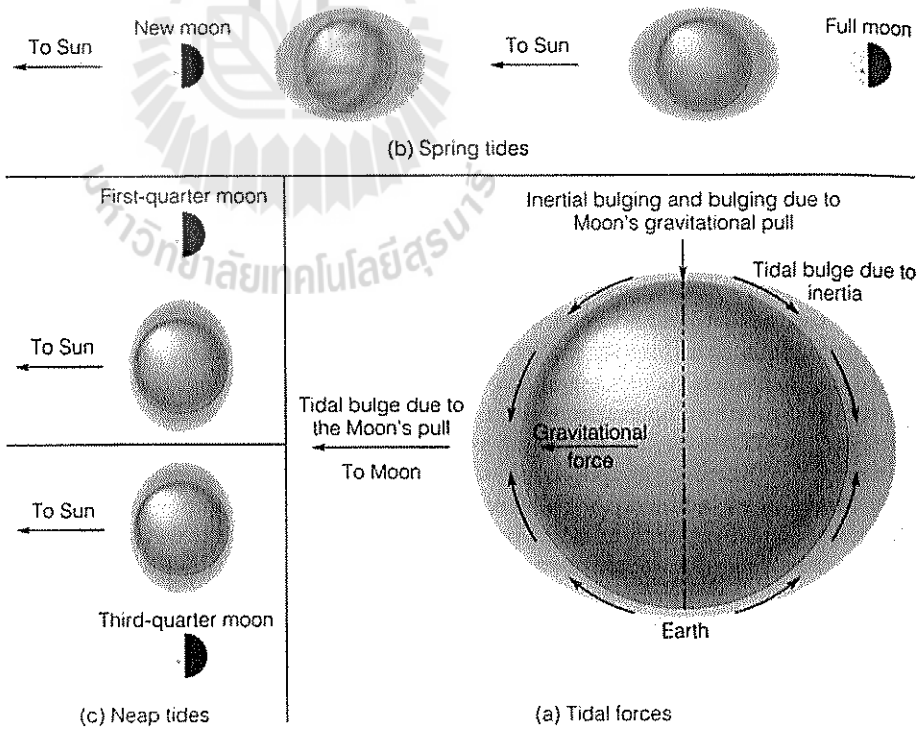


Figure 19.5
(a) Tides are caused by the gravitational pull of the Moon and, to a lesser degree, the Sun. The Earth–Moon–Sun alignments at the times of the (b) spring and (c) neap tides are shown.

When the Sun and moon are in alignment (every 2 weeks), "Spring Tides" are generated, which are ~20% higher than normal.

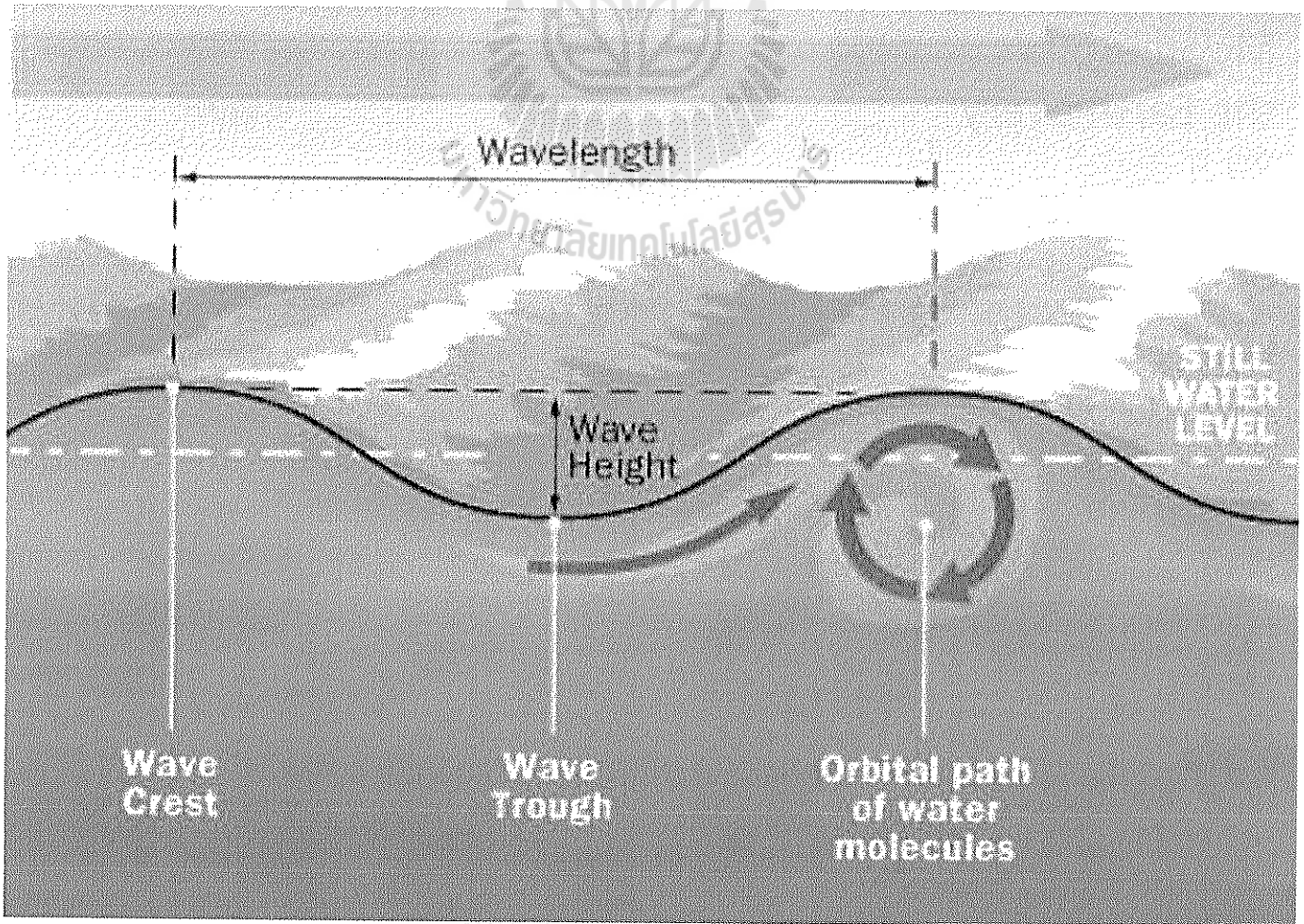
When the sun and Moon are in opposition, "Neap Tides" are generated, which are ~20% lower than normal.

Wave action

Most waves are generated by wind.

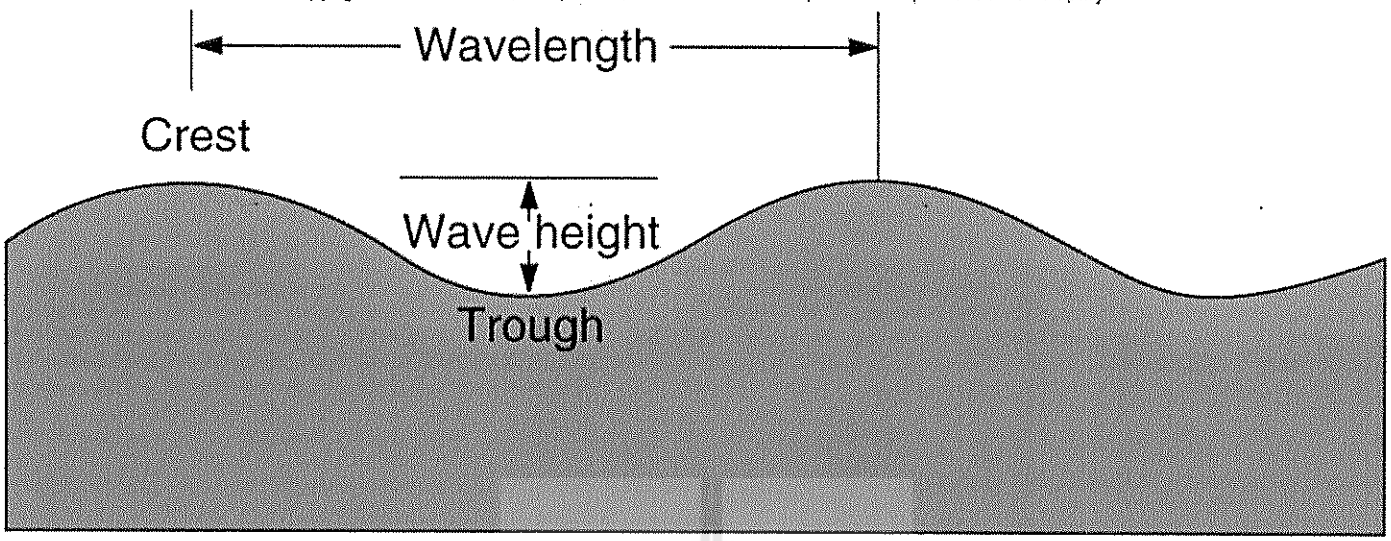
Amplitude depends on wind velocity and persistence.





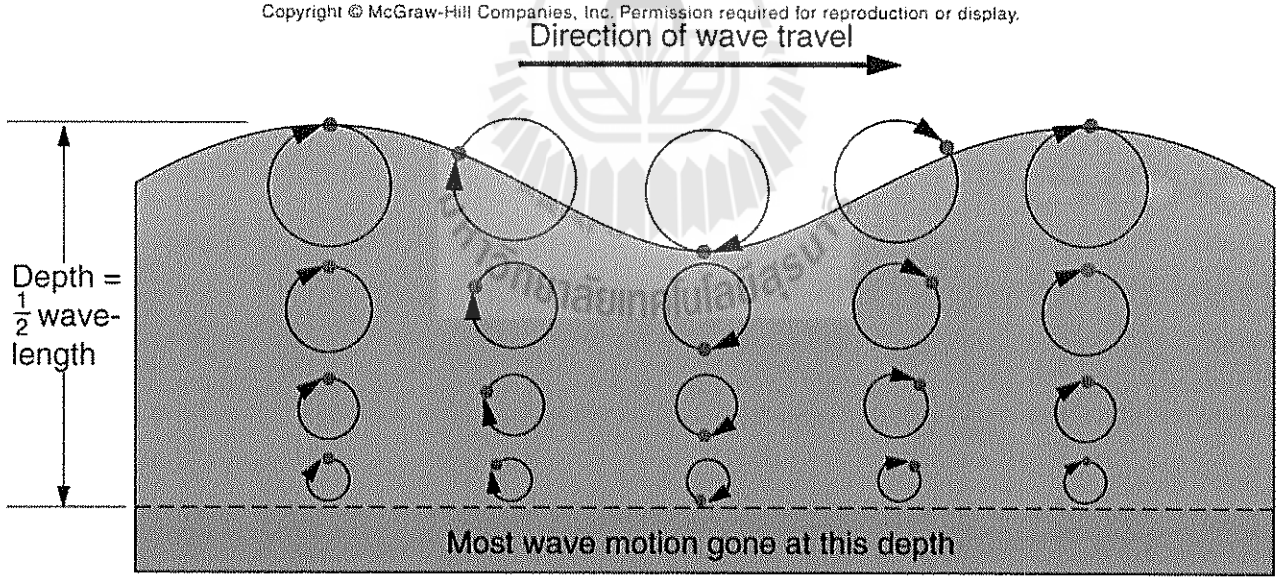
Period: time required for two successive crests or two successive troughs to pass a point in space.

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Wavelength (L): the distance between adjacent points on a wave that are in phase (i.e., moving in the same direction & displaced the same distance from the undisturbed water level.

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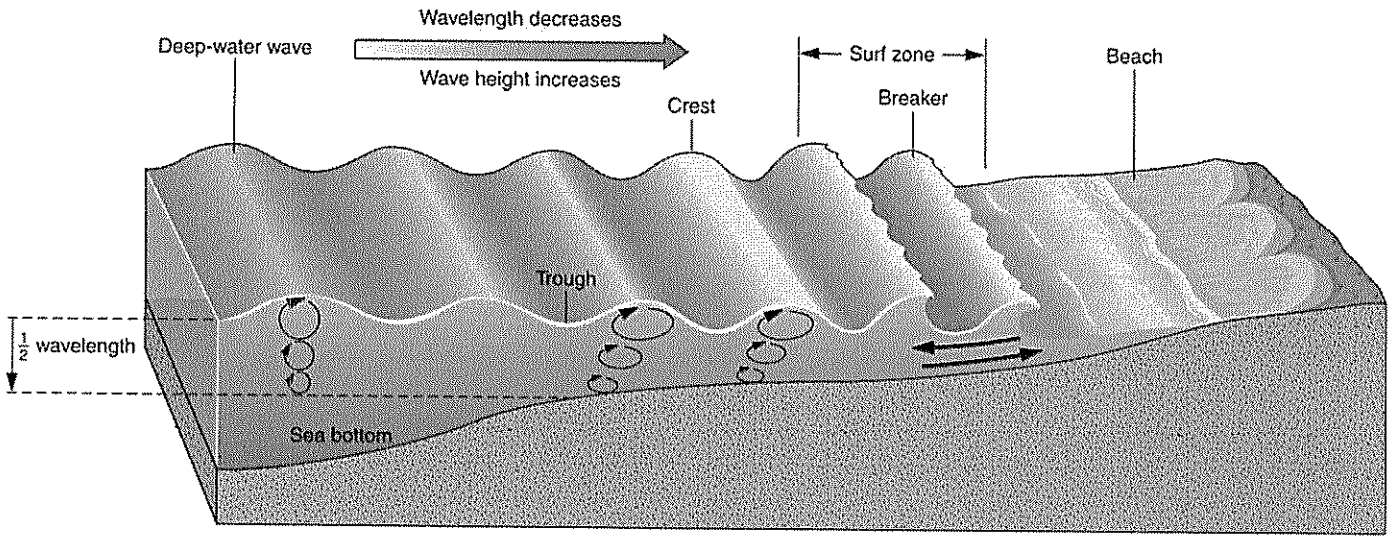


Wave motion: water is moving in an orbit, wave propagation is moving energy forward, <u>not</u> the water mass.

As wave propagates, particles move in an orbit and return to roughly the same place (objects bob up and down).

Waves "feel" only down to L/2.

Waves in water where D > L/2 = deep water waves and are unaffected by ocean floor topography. D = depth.



Waves in water with depth D < L/2 = shallow water waves and these feel the bottom topography:

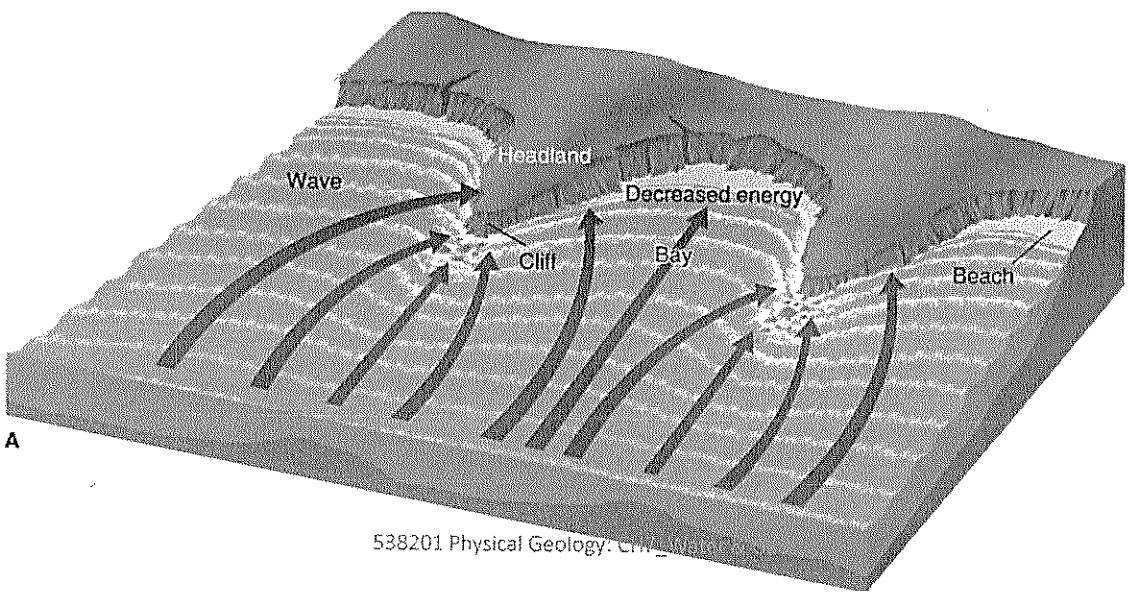
- Wave orbits are forced to become elliptical;
- Wave energy is confined to shallower depths, it builds up and breaks in the surf zone
- Waves slow down once they start to "feel" sea floor;
- Wave refraction occurs where the wave enters the shallow water obliquely.

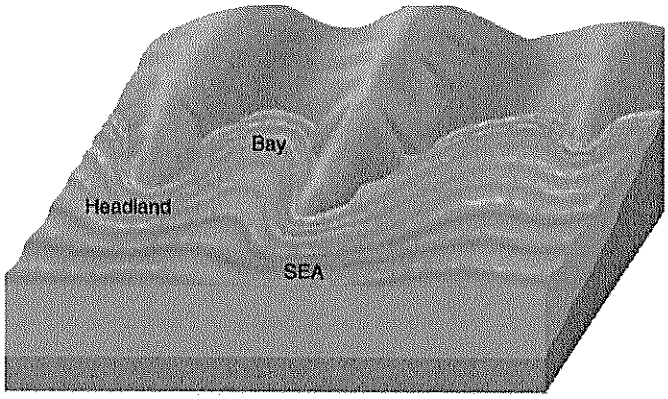
Erosion by wave

Hydraulic action: by compression of air in joints/ cracks/ planes of weakness

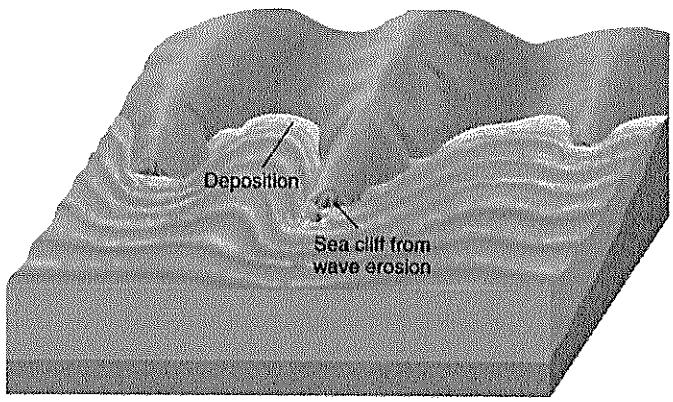
Abrasion: movement of fine particles.

Wave action tends to focus energy on cliffs and results in the erosion of **Headlands** via **Wave Refraction**.

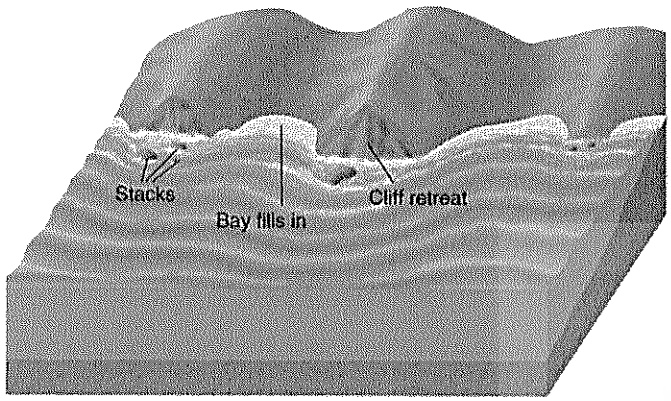




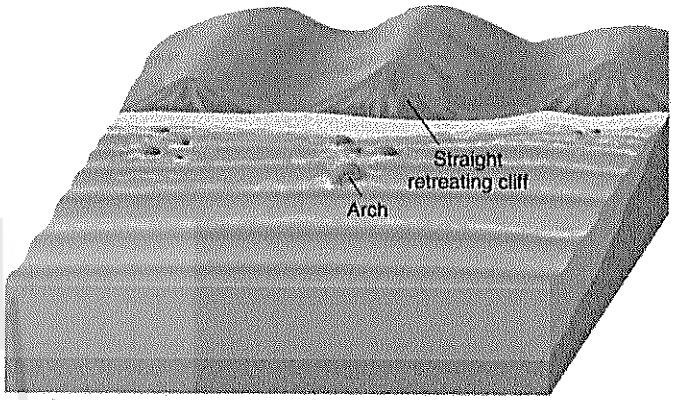
A **Stage 1**: Flooding of coast results in an irregular coast.



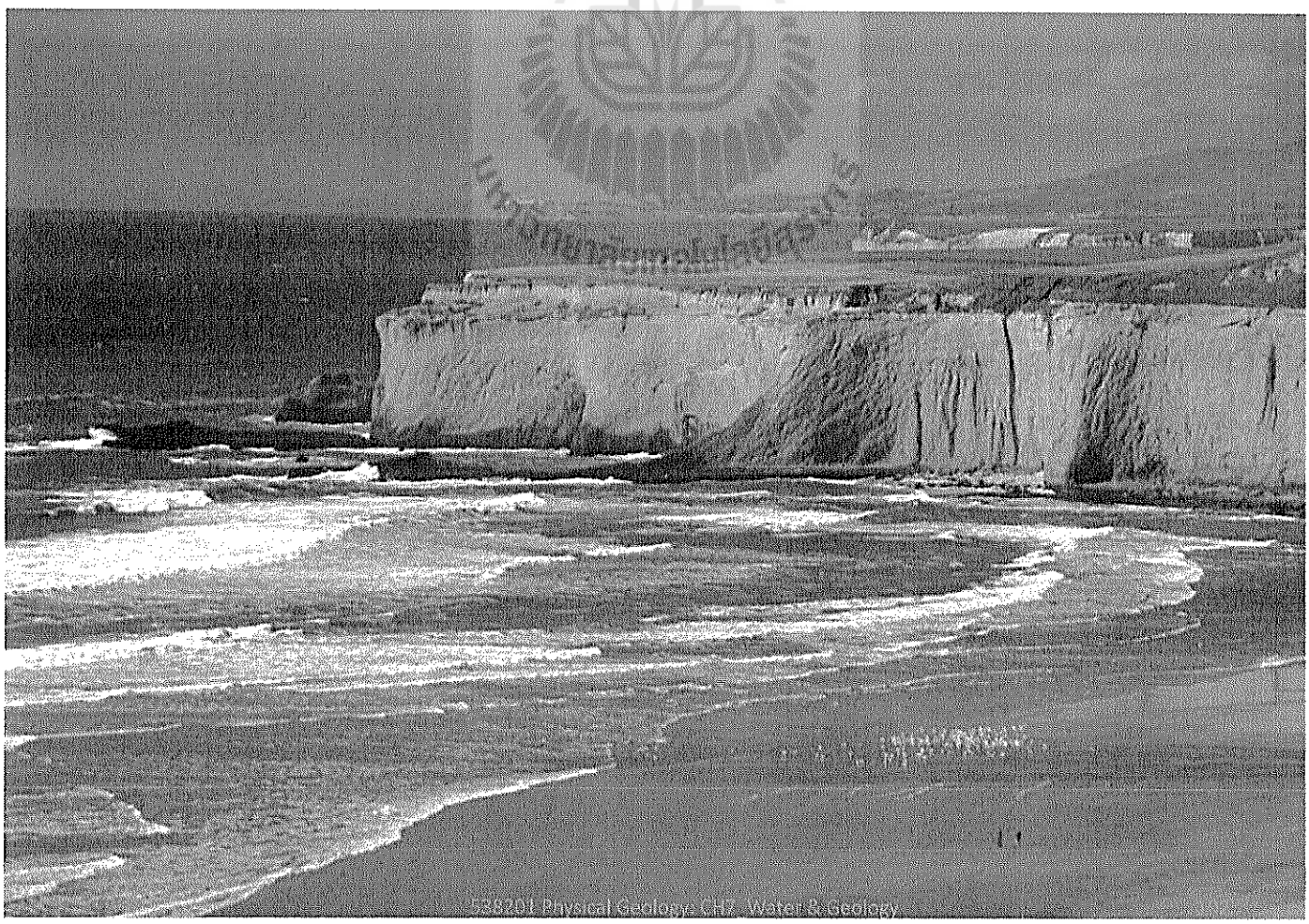
B



C **Stage 2**: Erosion of cliffs/headlands.

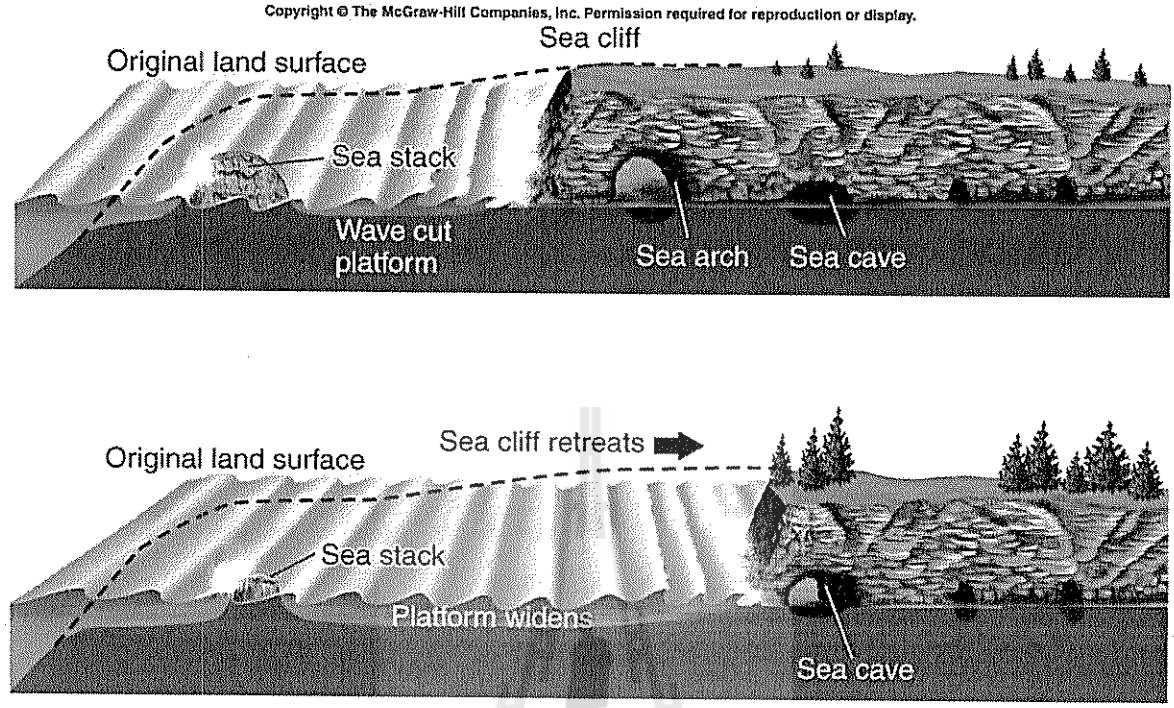


Stage 3: Straightening of beach.



Stack = isolated, pillar-like island detached from headland by wave erosion (i.e., erosional remnant of a headland).

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B

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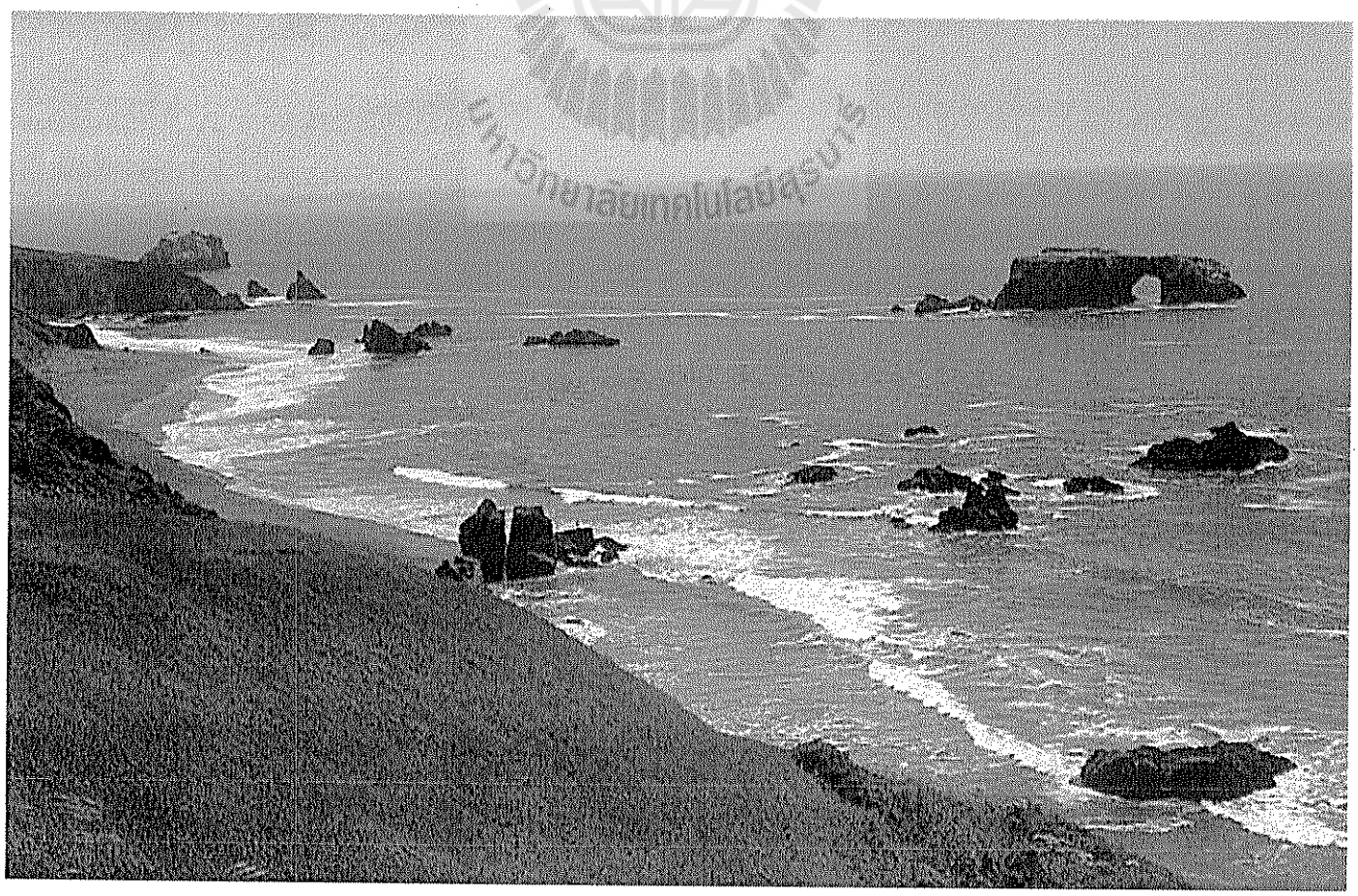


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Retreating Cliffs

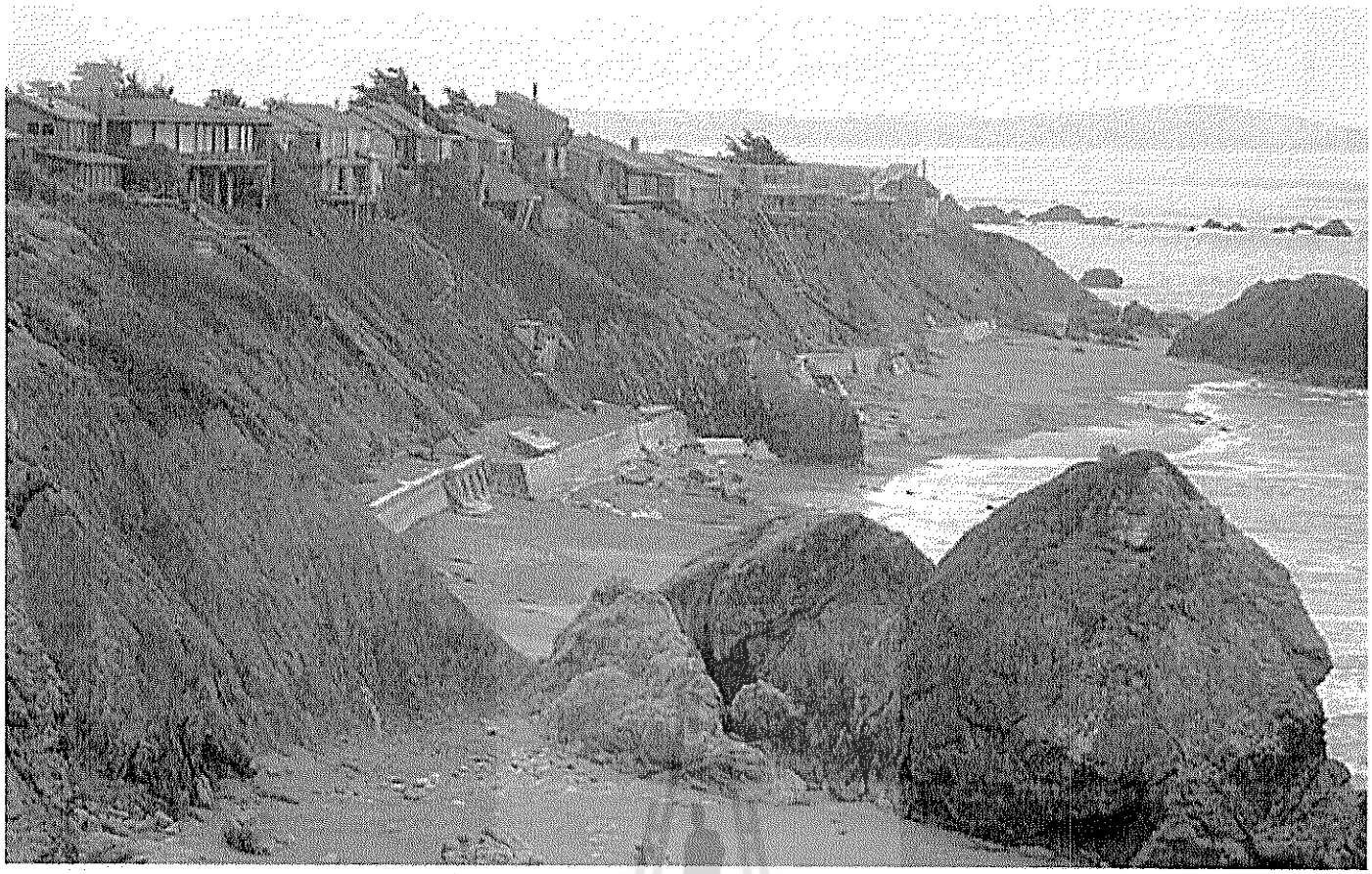
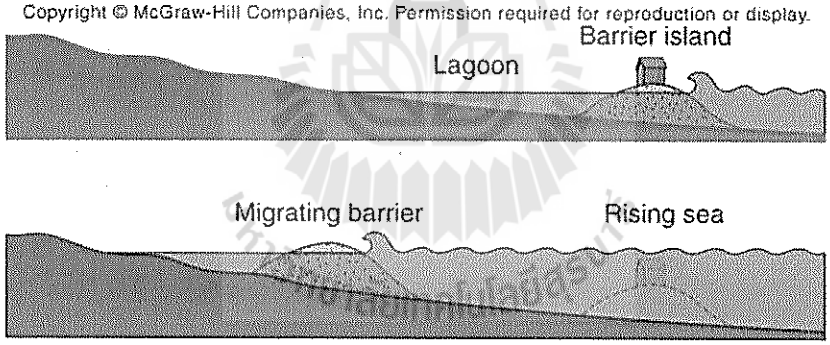
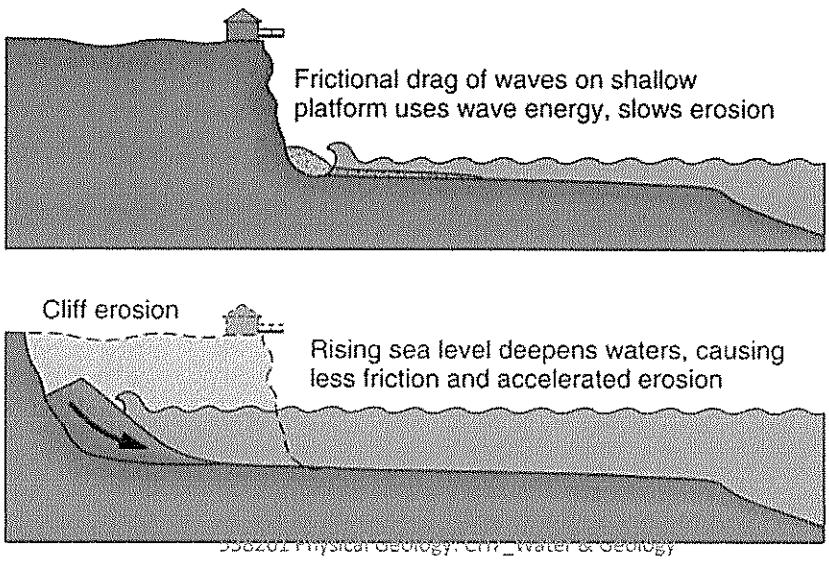


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A



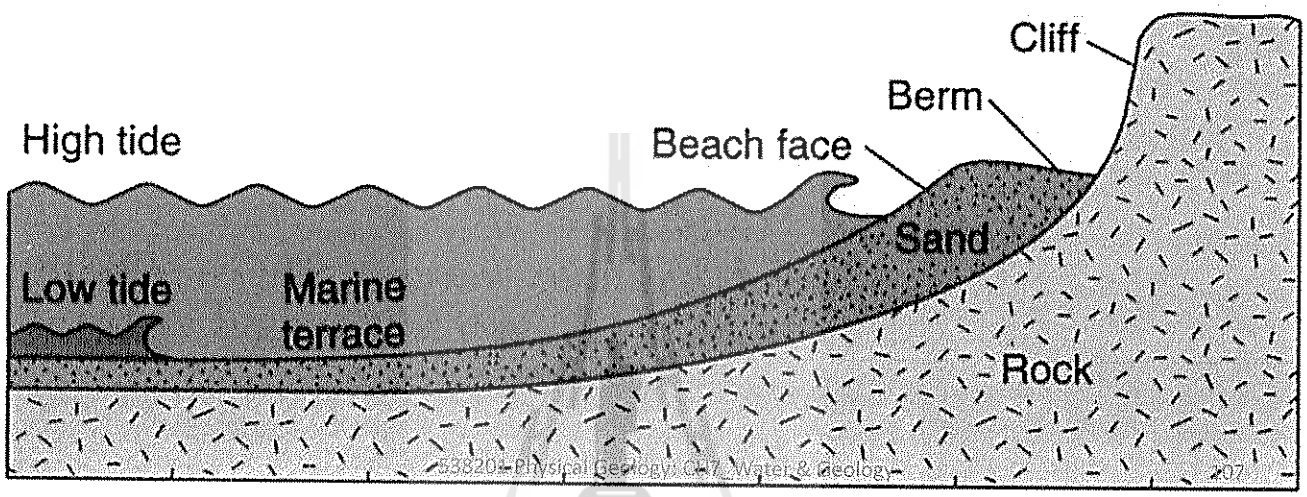
B

Sediment Deposition

Beach: strip of sediment that extends from the low-water line inland to a cliff or zone of permanent vegetation.

Beach Face: steepest part of the beach.

Berm: wave-deposited platform that is nearly flat – deposited above the usual high water line due to storms.



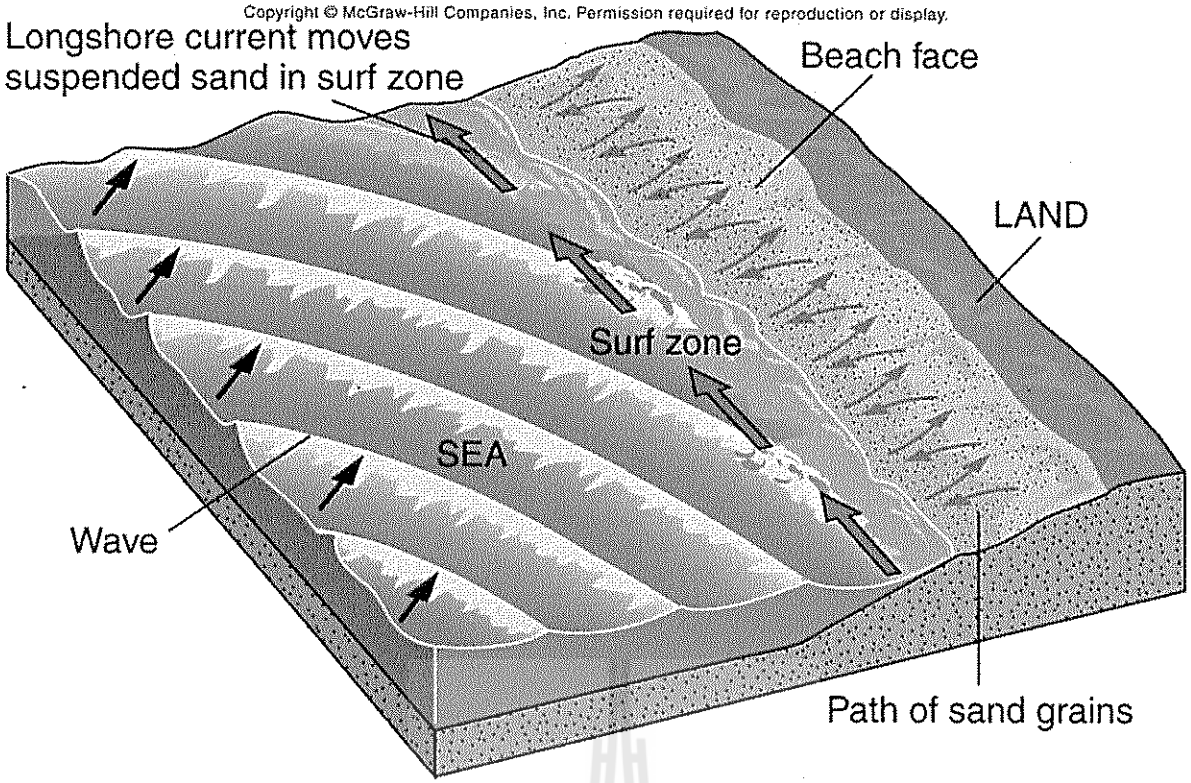
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B

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Sediments on beach are being worked by wave action, and tend to be transported by **longshore current.**

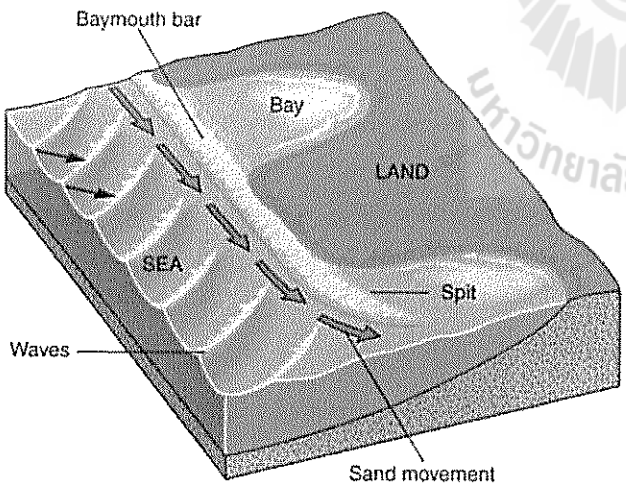


Figure 14.10*A*
Longshore drift of sand can form spits and baymouth bars.



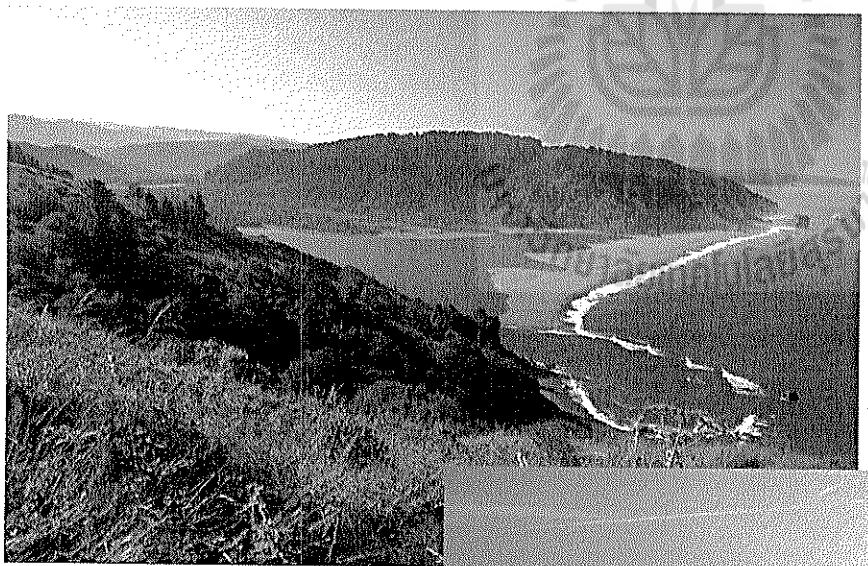
Figure 14.10*B*
Curved spit near Victoria, British Columbia.

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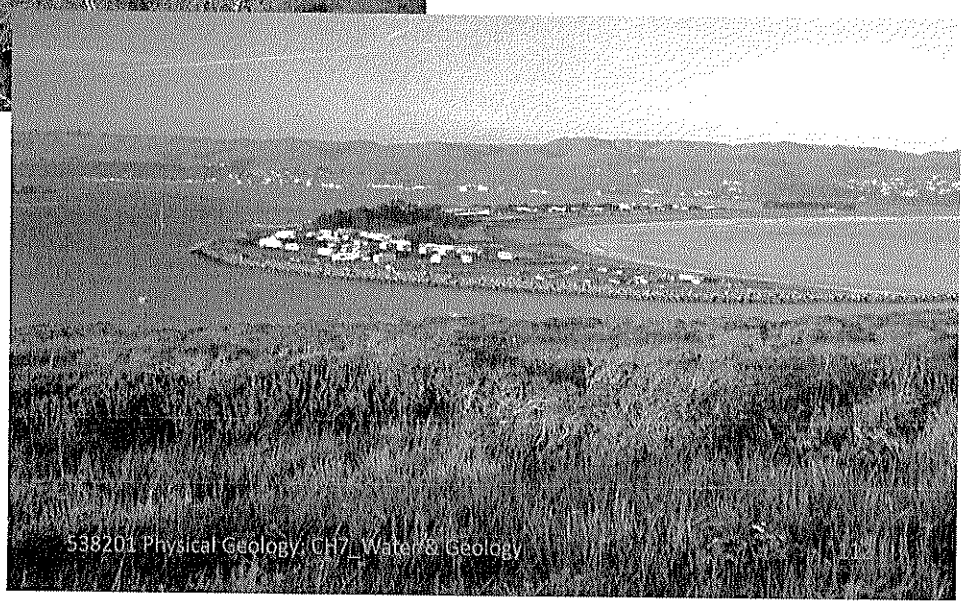


C

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Spit



Barrier Islands

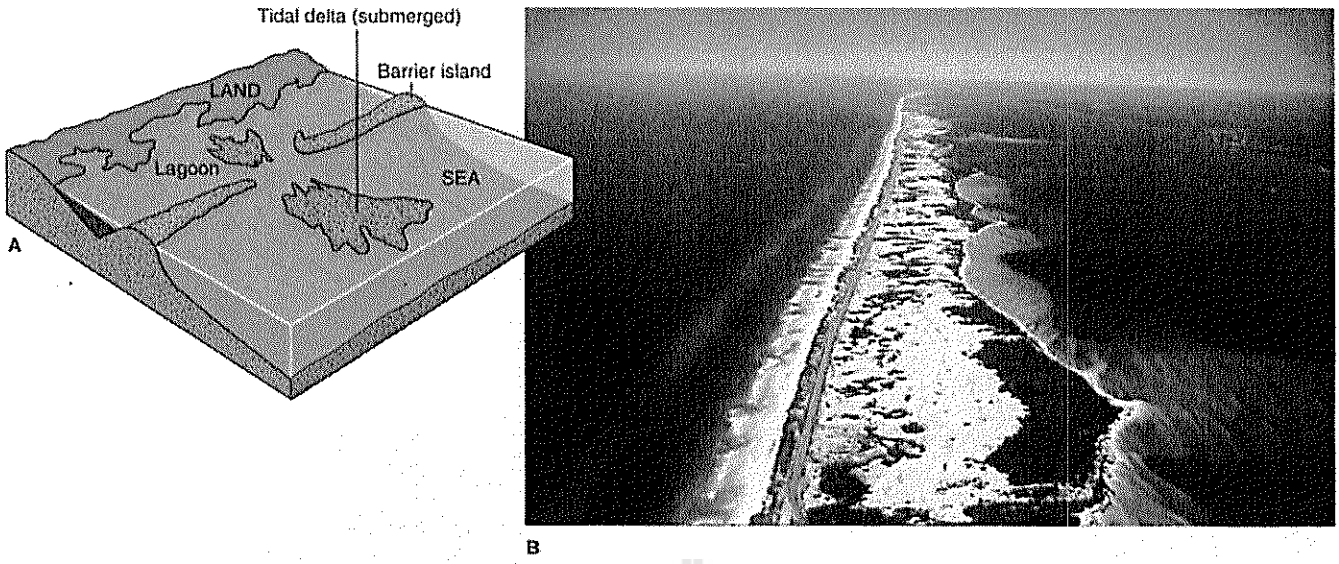


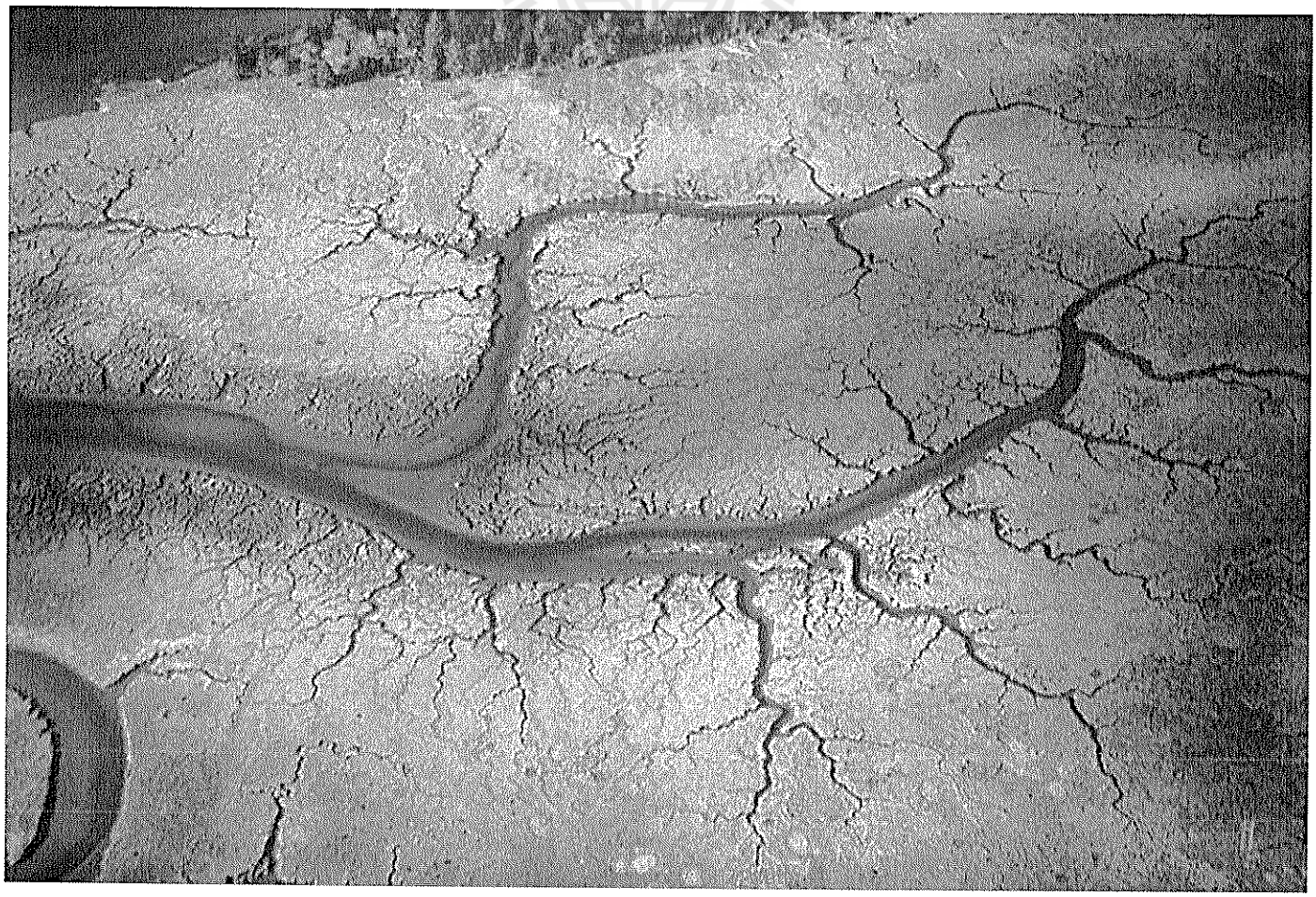
Figure 14.18

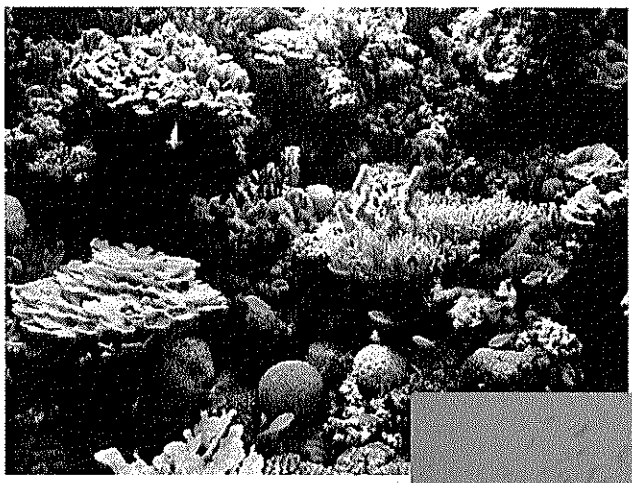
(*A*) A barrier island on a gently sloping coast. A lagoon separates the barrier island from the mainland, and tidal currents flowing in and out of gaps in the barrier island deposit sediment as submerged tidal deltas. (*B*) A barrier island near Pensacola, Florida. Open ocean to left, lagoon to right, mainland Florida on far right. Light-colored lobes of sand within lagoon were eroded from the barrier island by hurricane waves.

Tidal Deposits

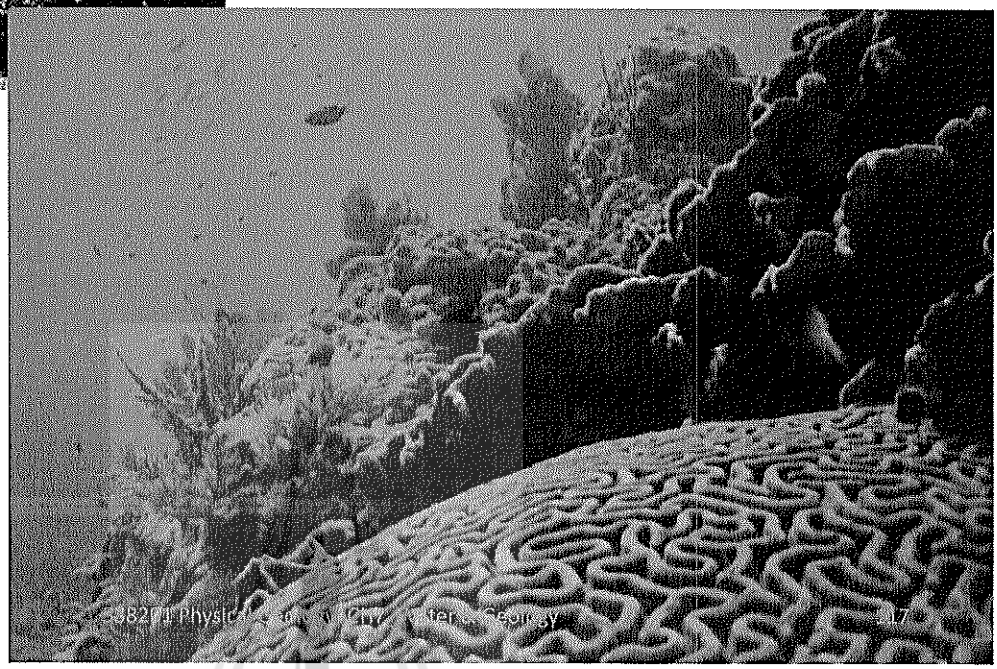


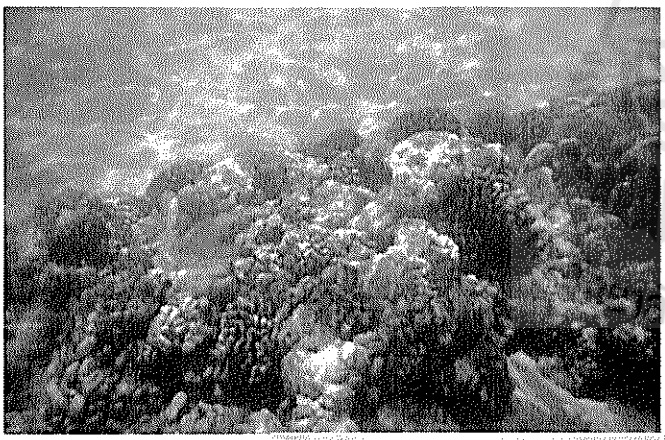


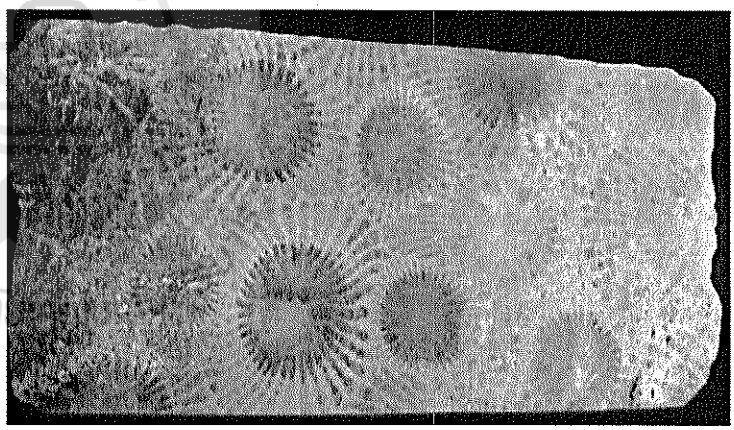


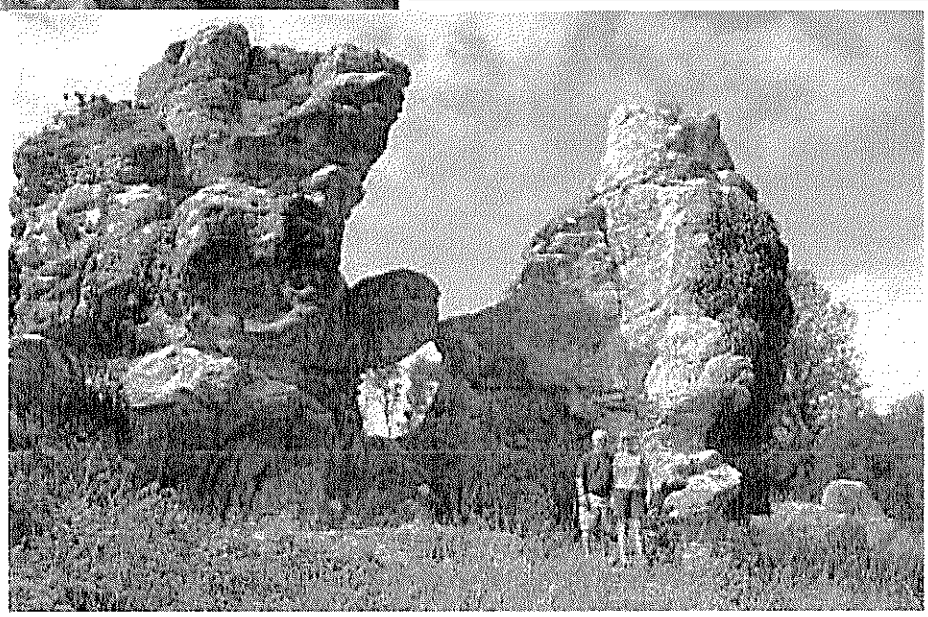


Reefs

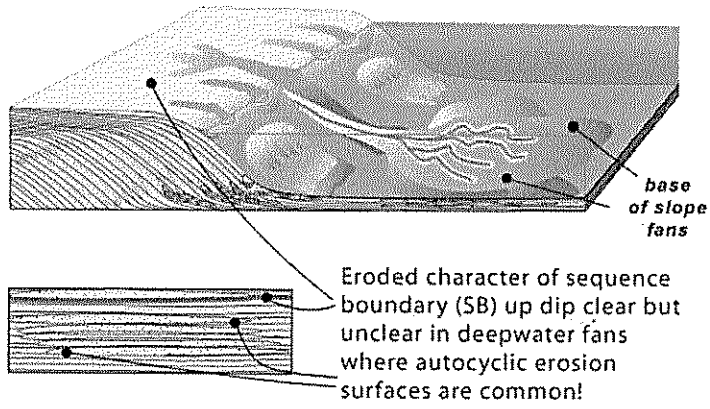




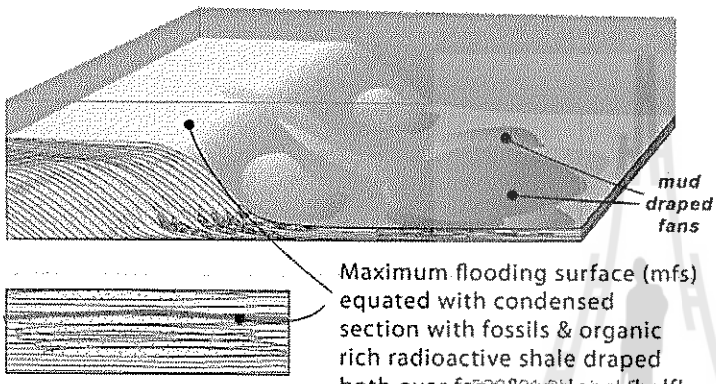




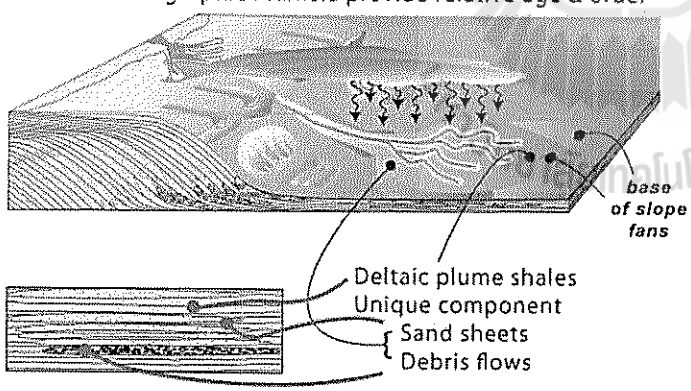
Deep water sedimentation



Maximum flooding surfaces form most useful sequence stratigraphic markers of deepwater

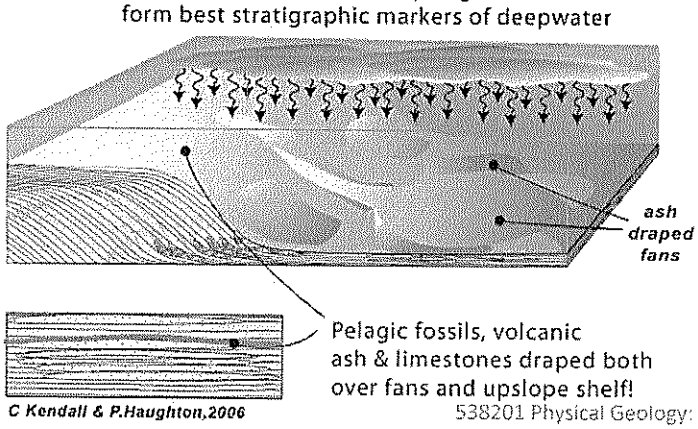


DEEPWATER ALLOSTRATIGRAPHIC MARKERS
Synchronous widespread Lithostratigraphic layers &
Biostratigraphic markers provide relative age & order



High resolution biostratigraphic
markers and seismic enhance these tools

Biomarkers, volcanic ash & pelagic limestones form best stratigraphic markers of deepwater



Chapter 8 Desert

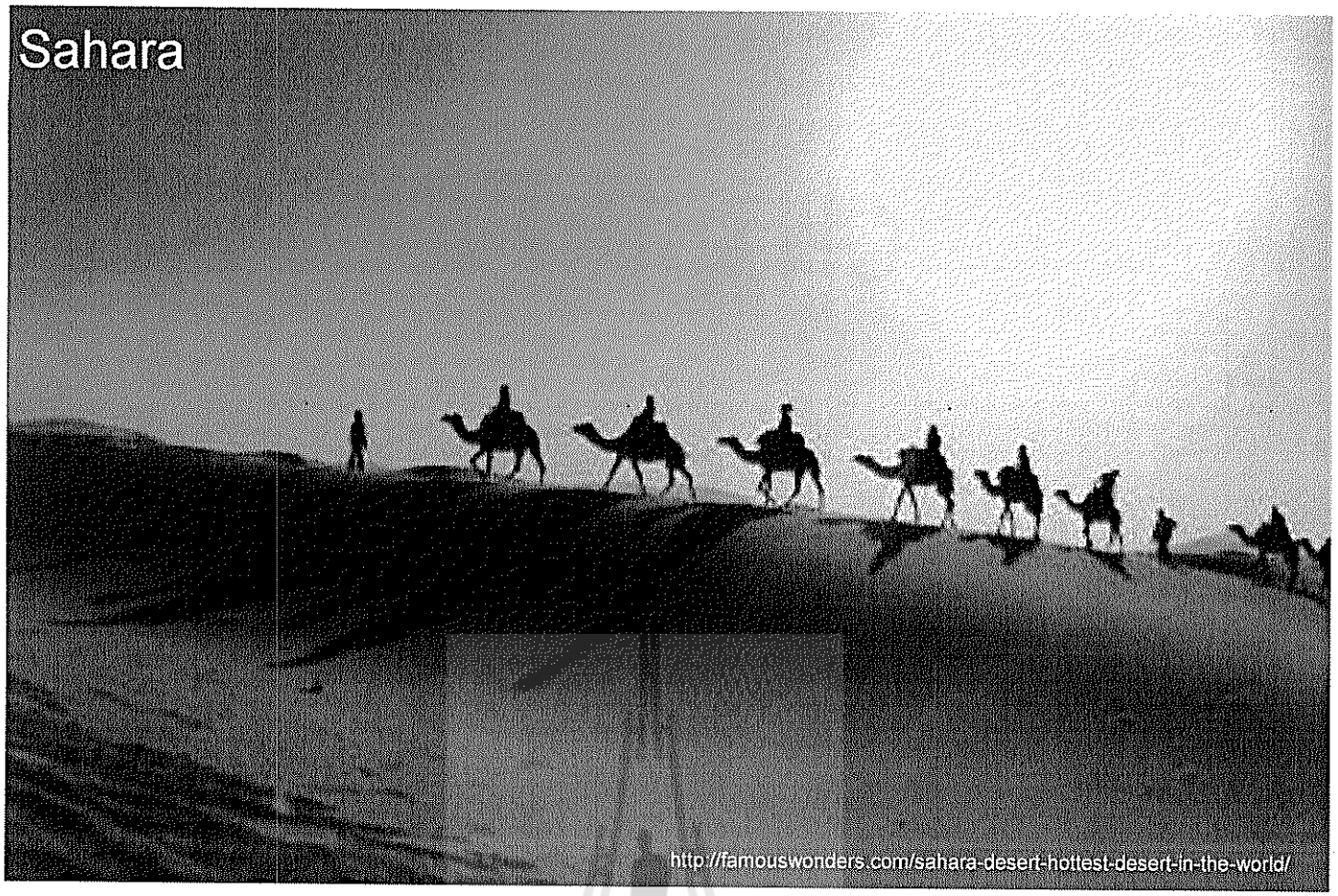
ทะเลทราย

Contents

1. Definition
2. Weathering and erosion in deserts
3. Deposition in deserts
4. Desert landscapes

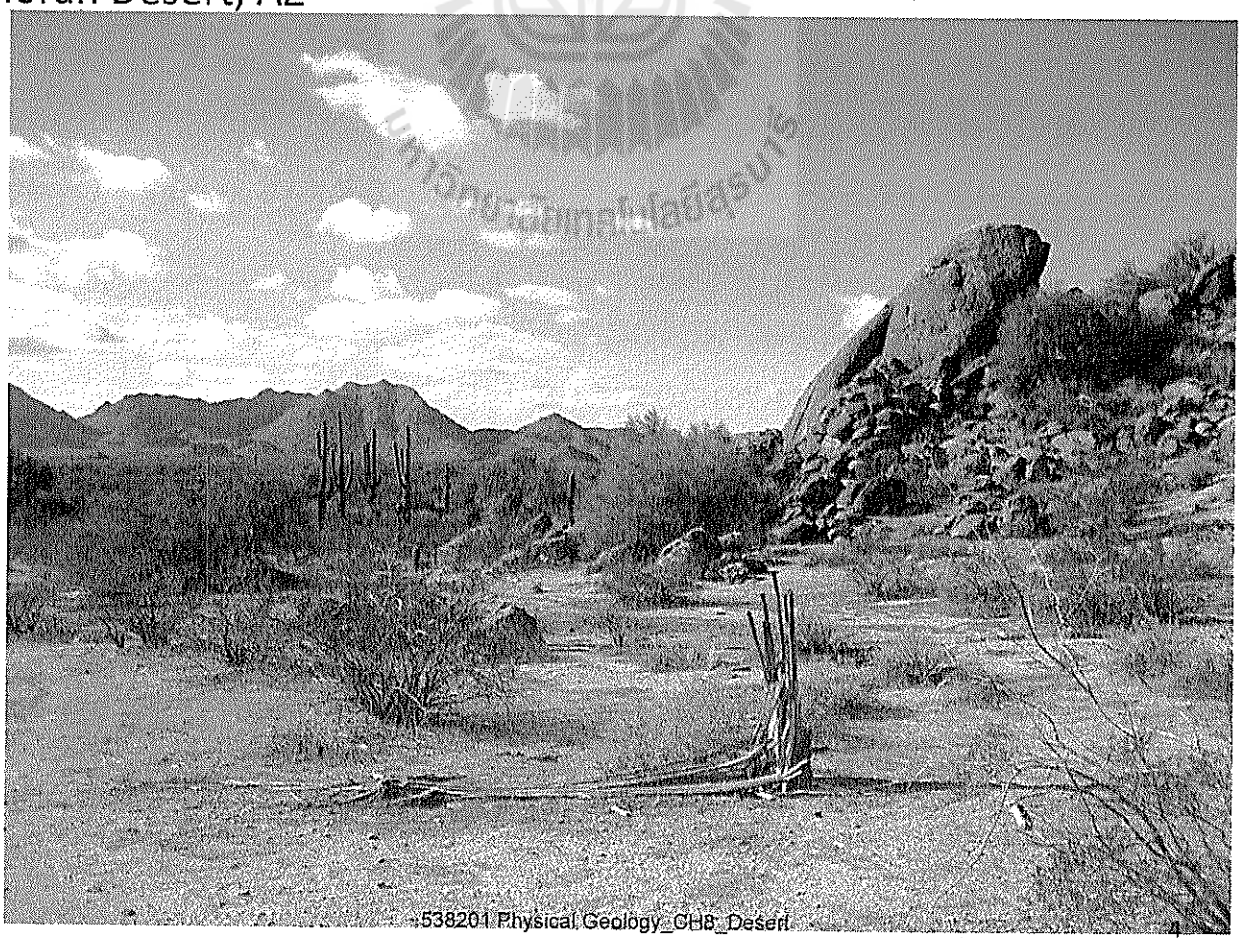
มหาวิทยาลัยเทคโนโลยีสุรนารี

Sahara



http://famouswonders.com/sahara-desert-hottest-desert-in-the-world/

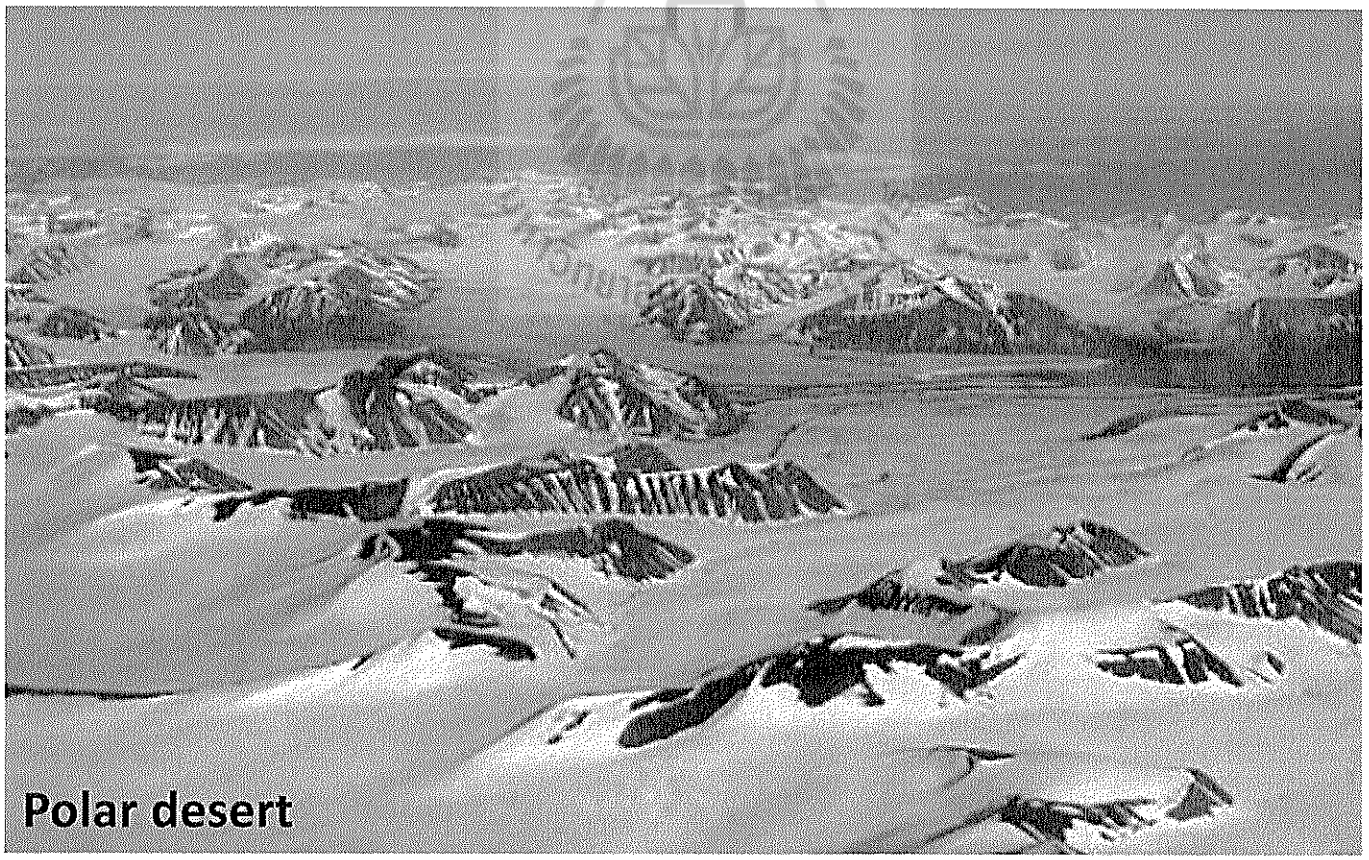
Sonoran Desert, AZ



http://commons.wikimedia.org

1. Desert definition

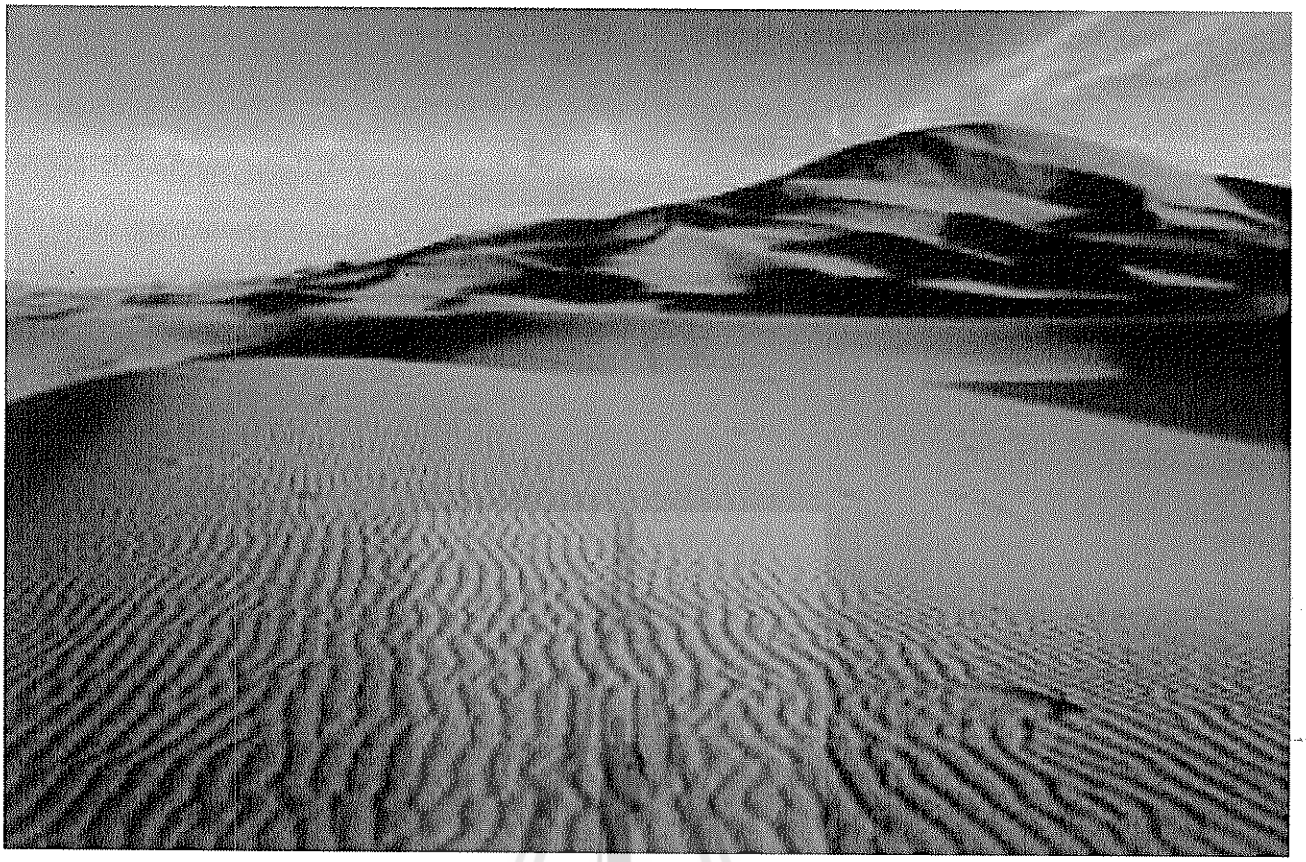
- A region which has an arid climate or where evaporation exceeds precipitation
- <15% of the surface has a cover of vegetations
- Deserts cover about 30% of the Earth's land surface (42 million km^2)



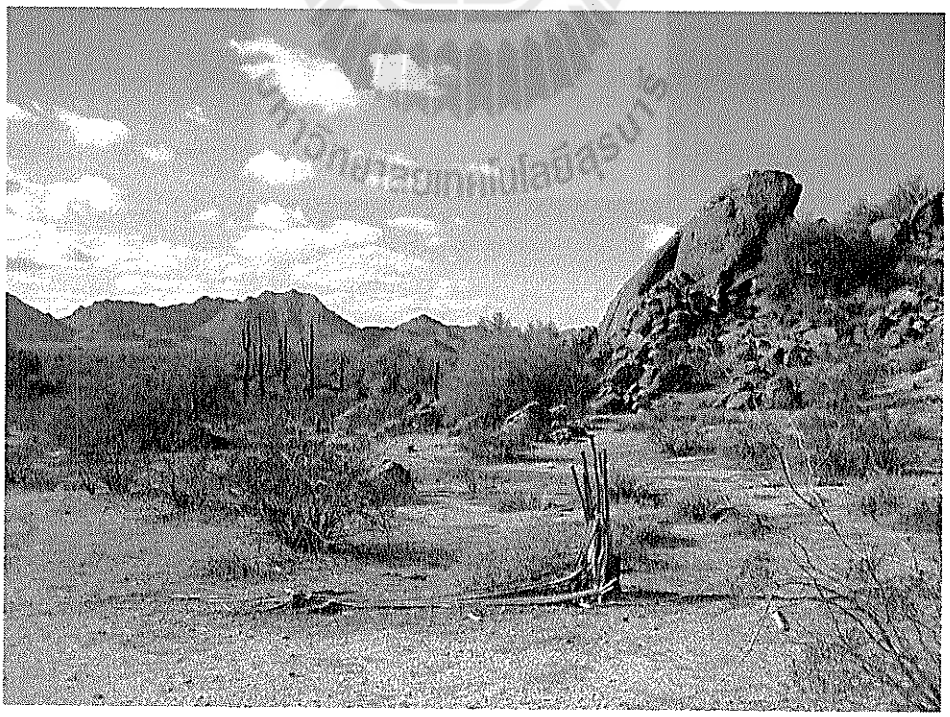
Many polar regions are deserts, covering nearly 5 million km^2 and range from bedrock to gravel plains to ice sheets. (Expansive Svalbard Arctic landscape, northern Norway) http://www.eoearth.org

True deserts are characterized by having little or no vegetation.

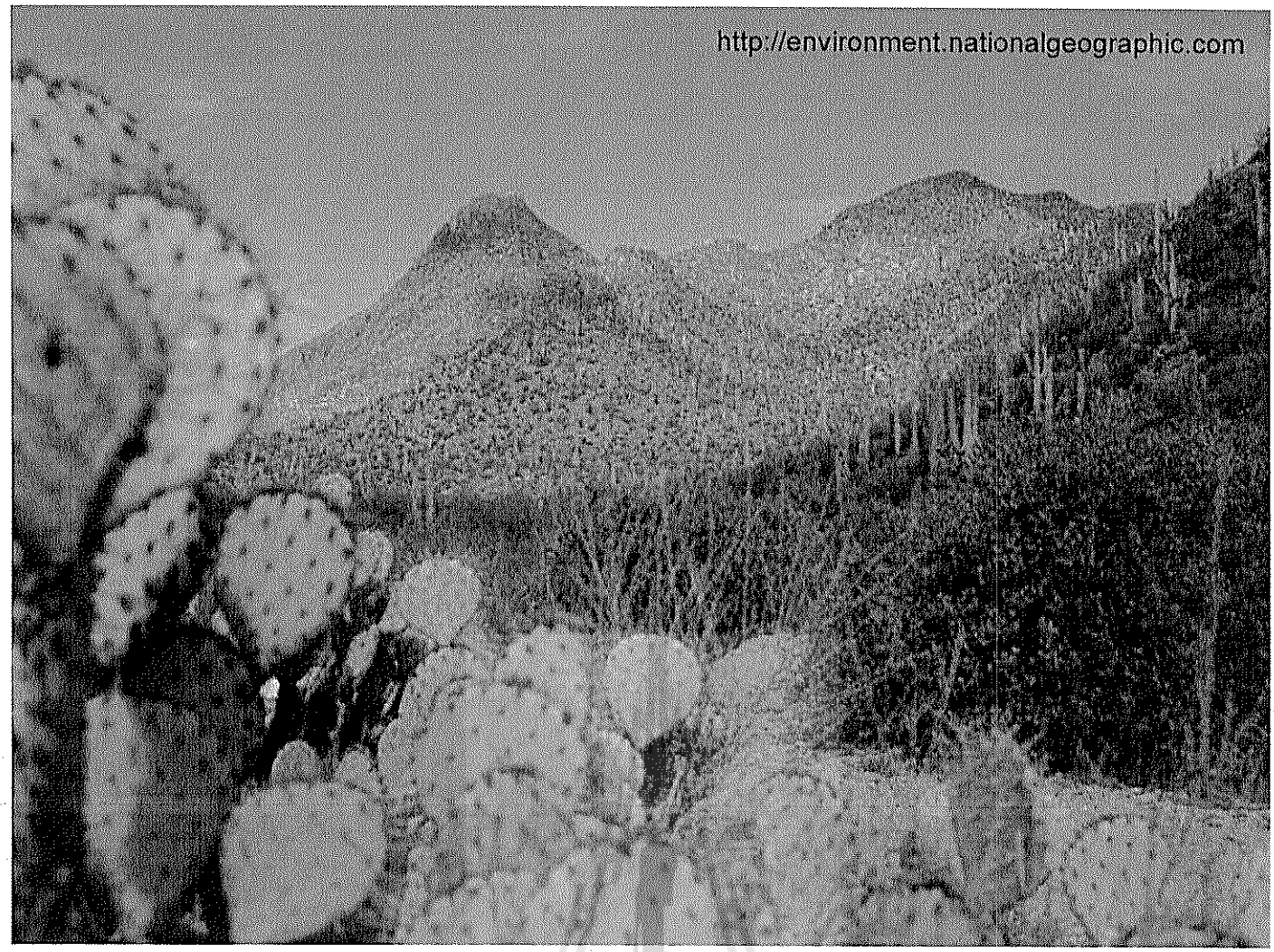
http://world-visits.blogspot.com/



Not only sand and dunes



Only 10% of the Sahara Desert is covered with sands. The sandiest desert is the Arabian Desert, which is still only 33% sands.



Semiarid, arid and deserts

Semiarid lands (steppes): precipitation rate of 250 to 500 mm/year

Arid lands: precipitation rate < 250 mm/year

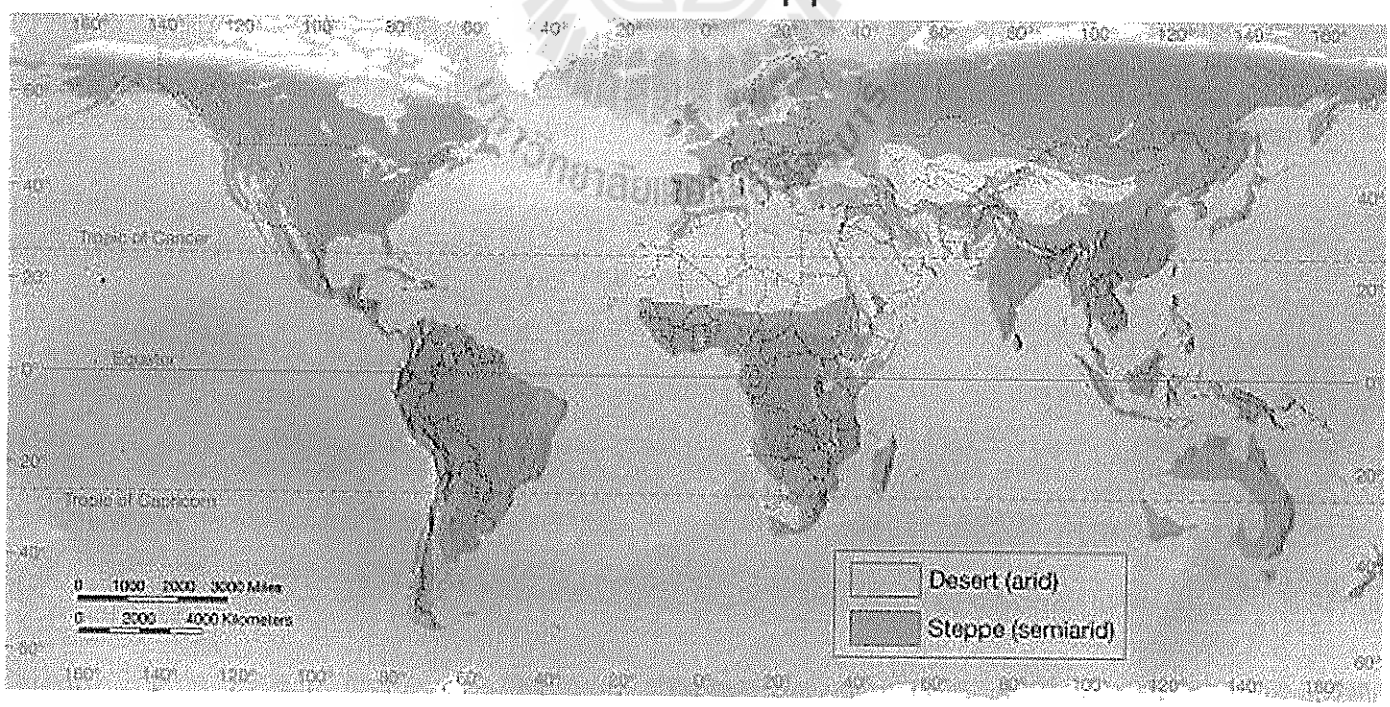
Deserts: precipitation < 100 mm/year





http://scathing-sanity.deviantart.com/art/Desert-Climate-322994520

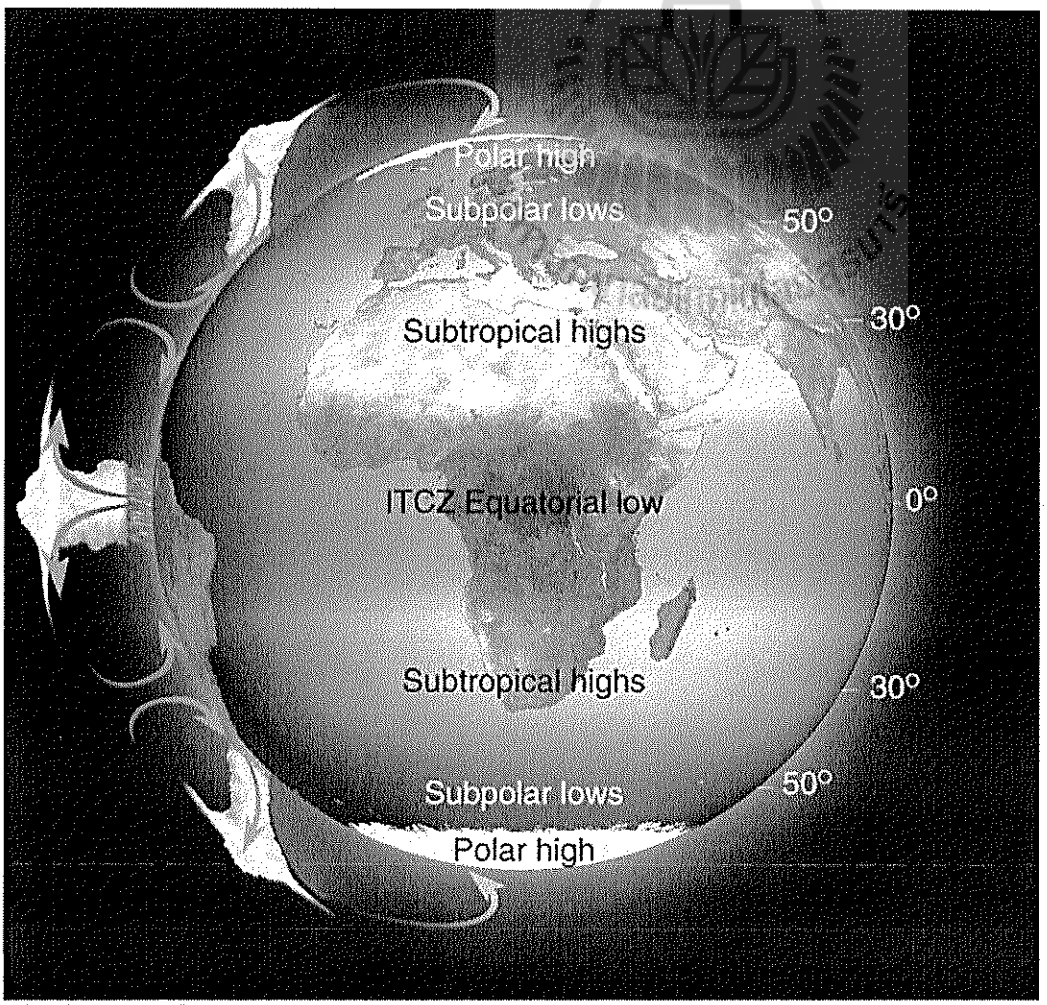
Desert and steppe areas



Deserts can be found at all altitudes and latitudes.

Four physical factors cause deserts

- Prevailing winds
- Continentality
- Cold ocean currents
- Lee side of mountains



© 2007 Thomson Higher Education

Polar

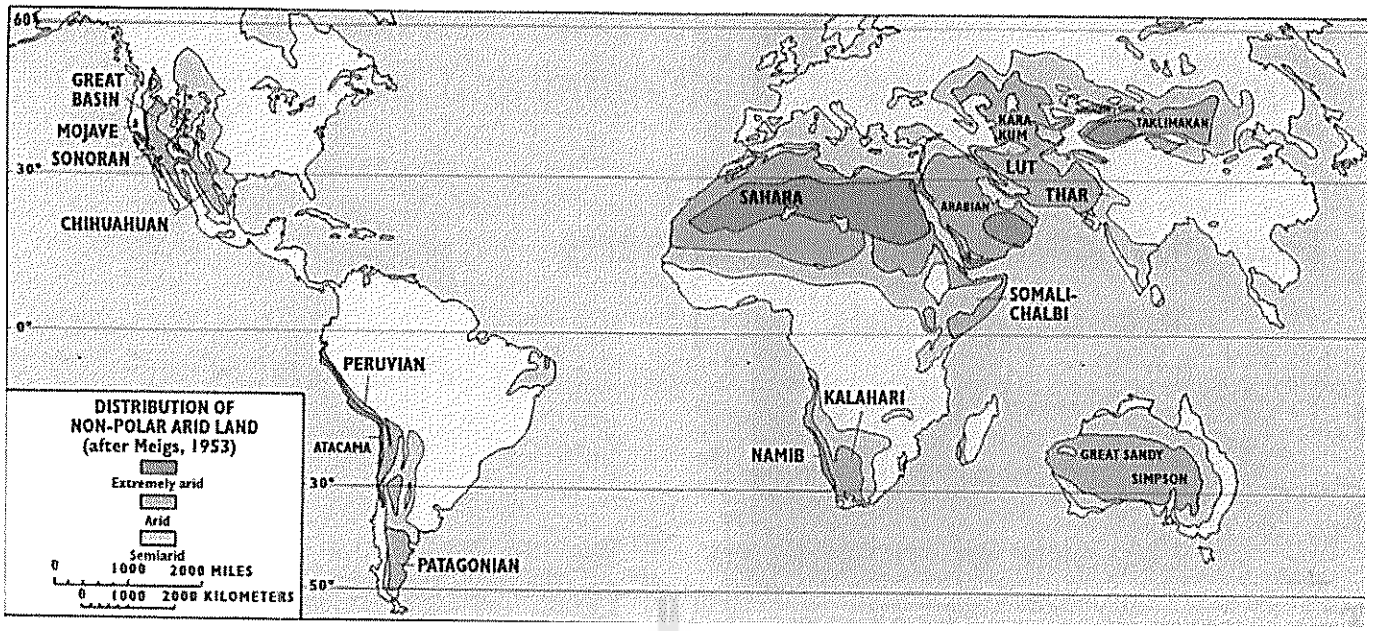
Temperate

Subtropical

Semi-arid (steppe)

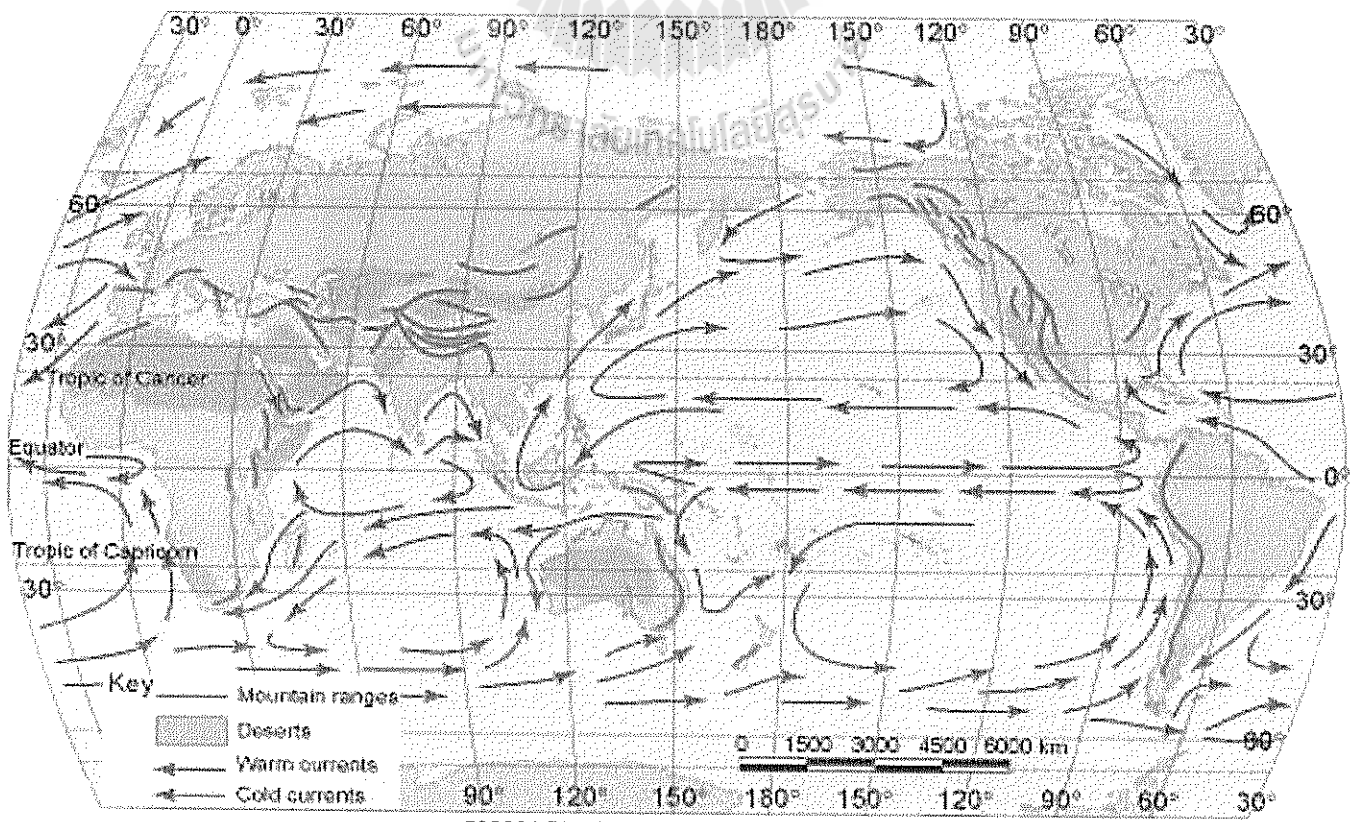
Tropical

http://apollo.lsc.vsc.edu/classes/met130/notes/chapter10/global_precip.html

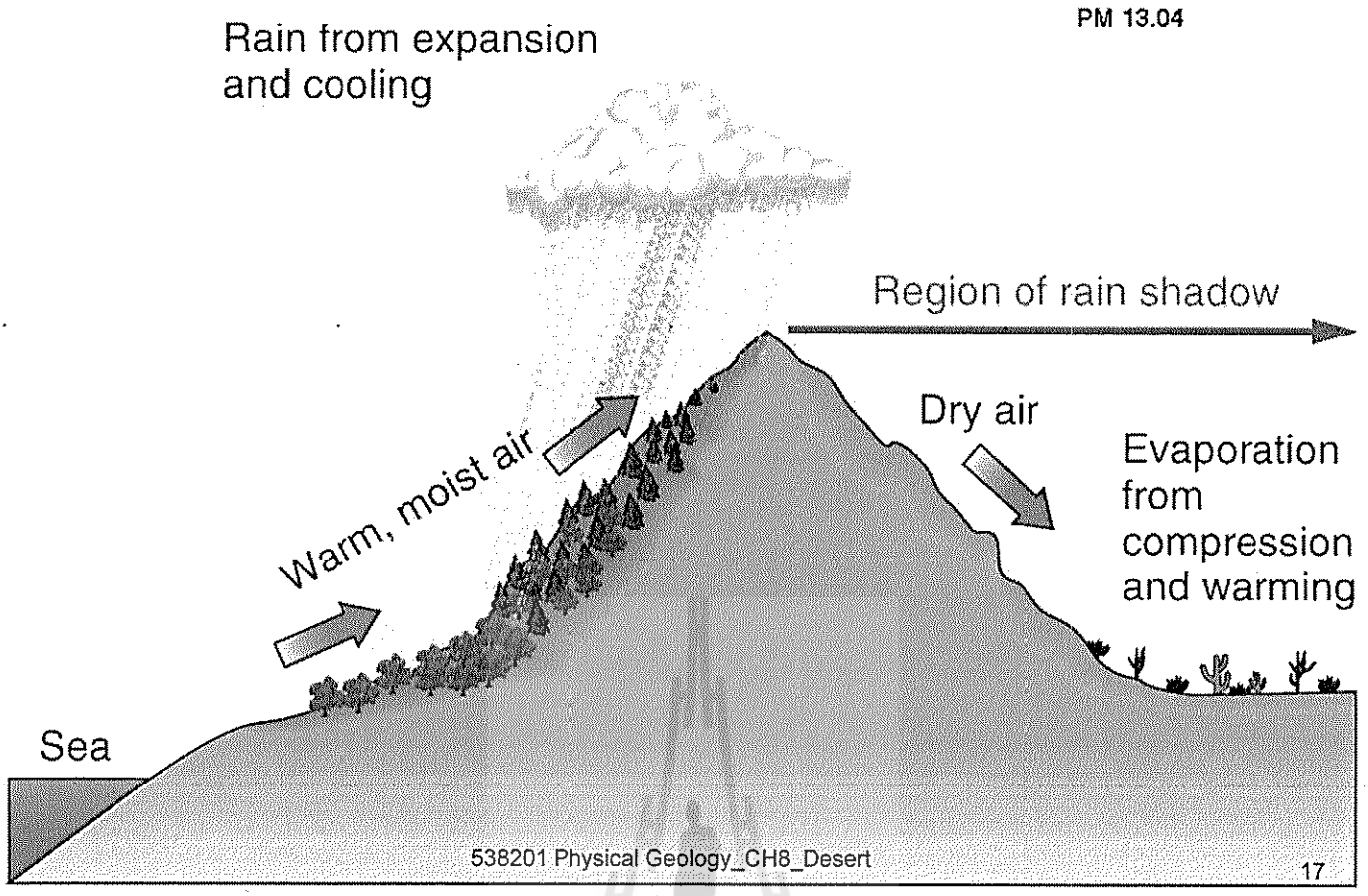


http://world-visits.blogspot.com/2012/03/sahara-desert-world-largest-hot-desert.html#.UgSYldKnCSo

Coastal locations



Lee side

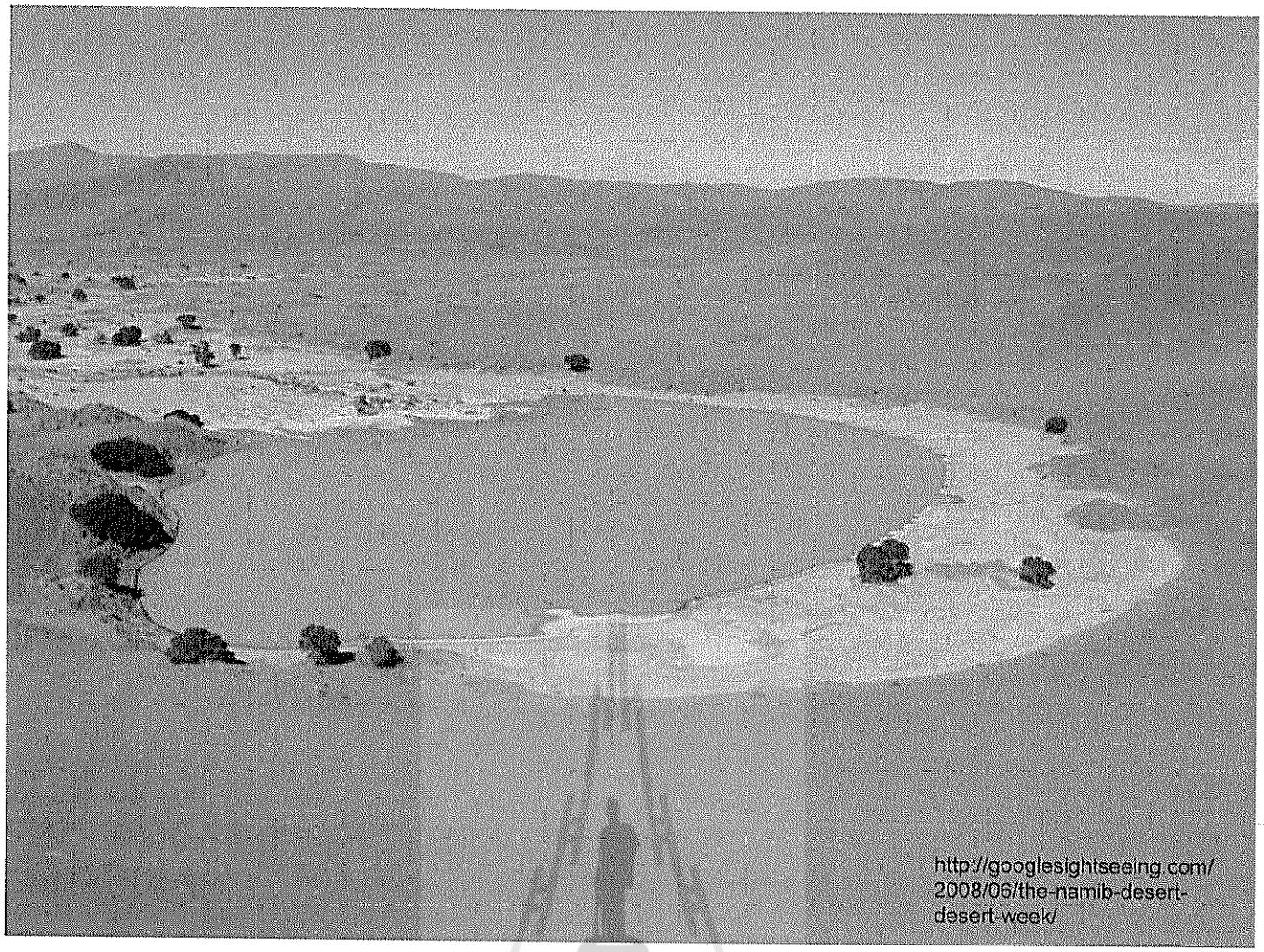


2. Weathering and erosion in deserts

Desert erosion by water

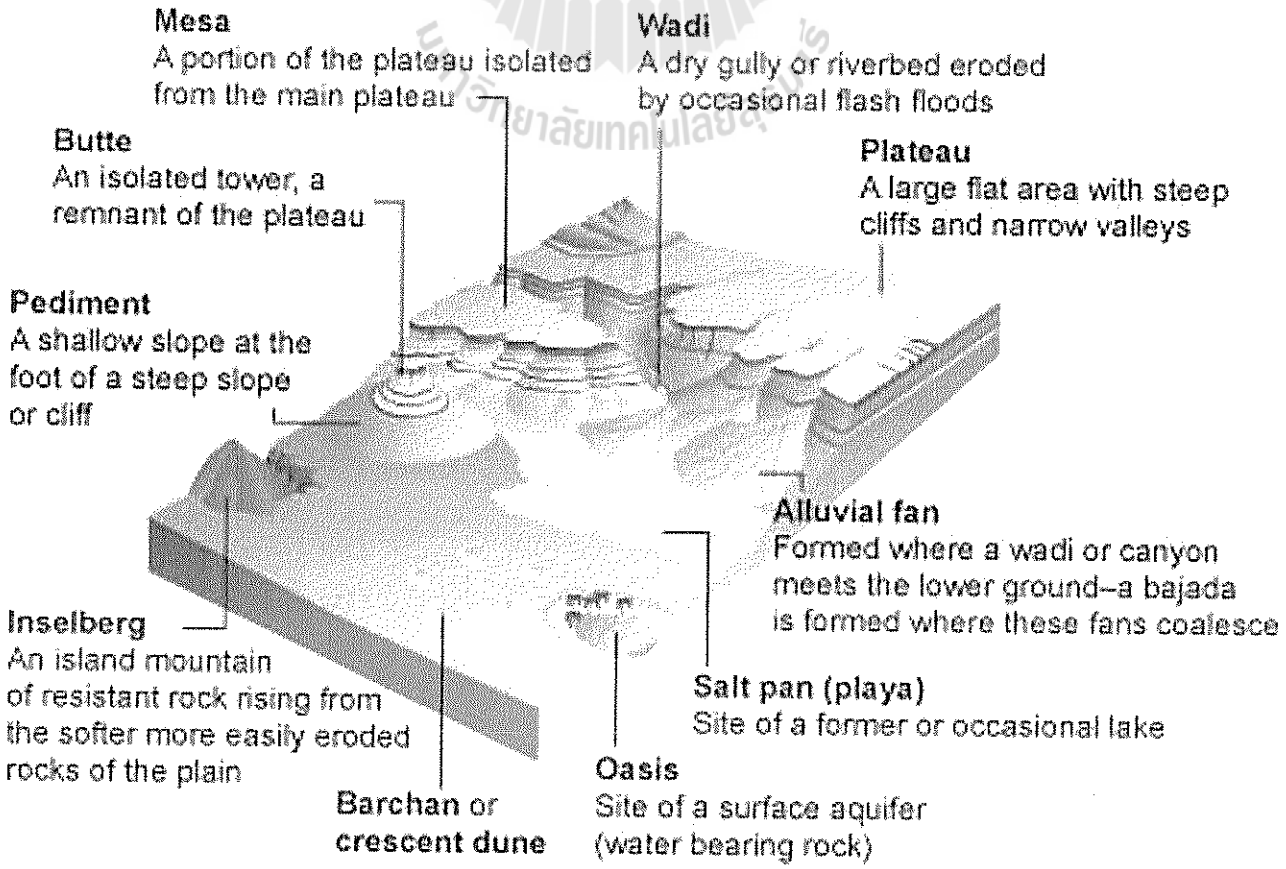
- Seldom rains in desert regions
- When it does massive downpour called a flashflood
- Dry weathered soil, and minimal vegetation to anchor the soil causes rapid erosion
- Rainwater carries sediment away and deposits it on the valley floor
- Within 10 to 20 minutes the rain is gone and the water has evaporated

http://www.youtube.com/watch?v=ORZQUlk8vxg
http://www.youtube.com/watch?v=wCh-IYPlWH4



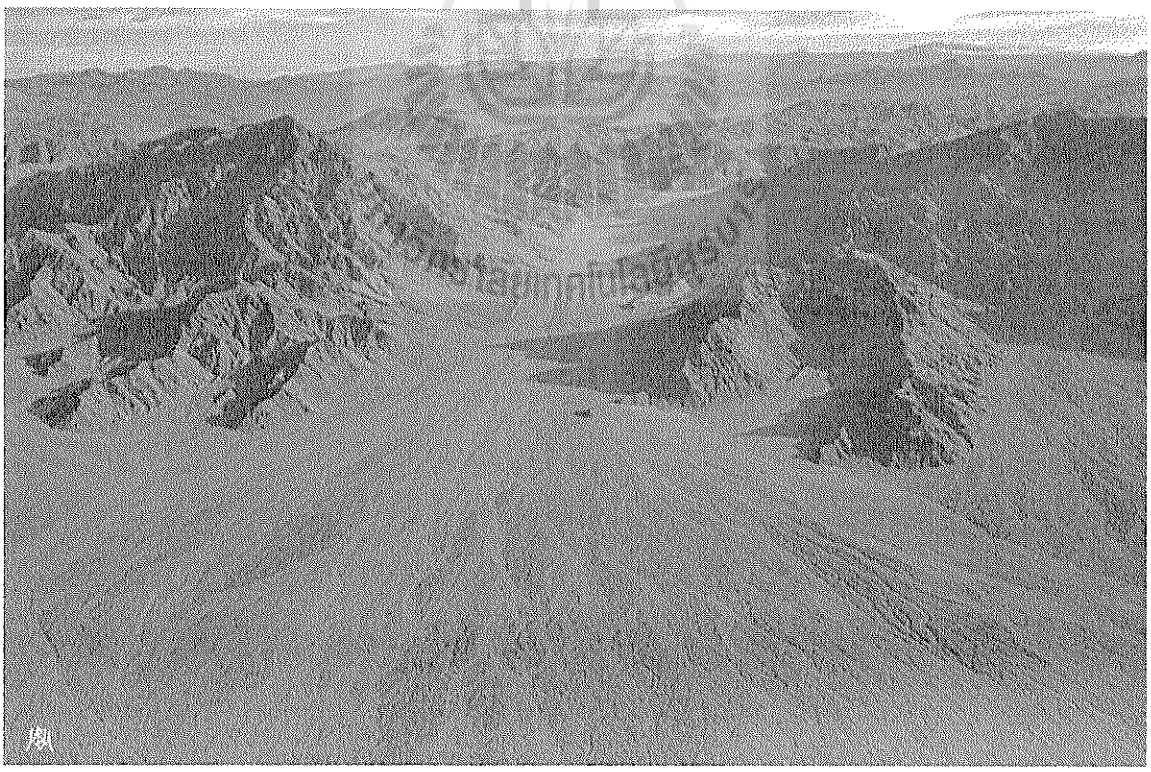
http://googlesightseeing.com/2008/06/the-namib-desert-desert-week/

Landforms created by water





http://physical-features.wikispaces.com/Process



http://www.marlimillerphoto.com/alluvialfans.html

Alluvial Fan:

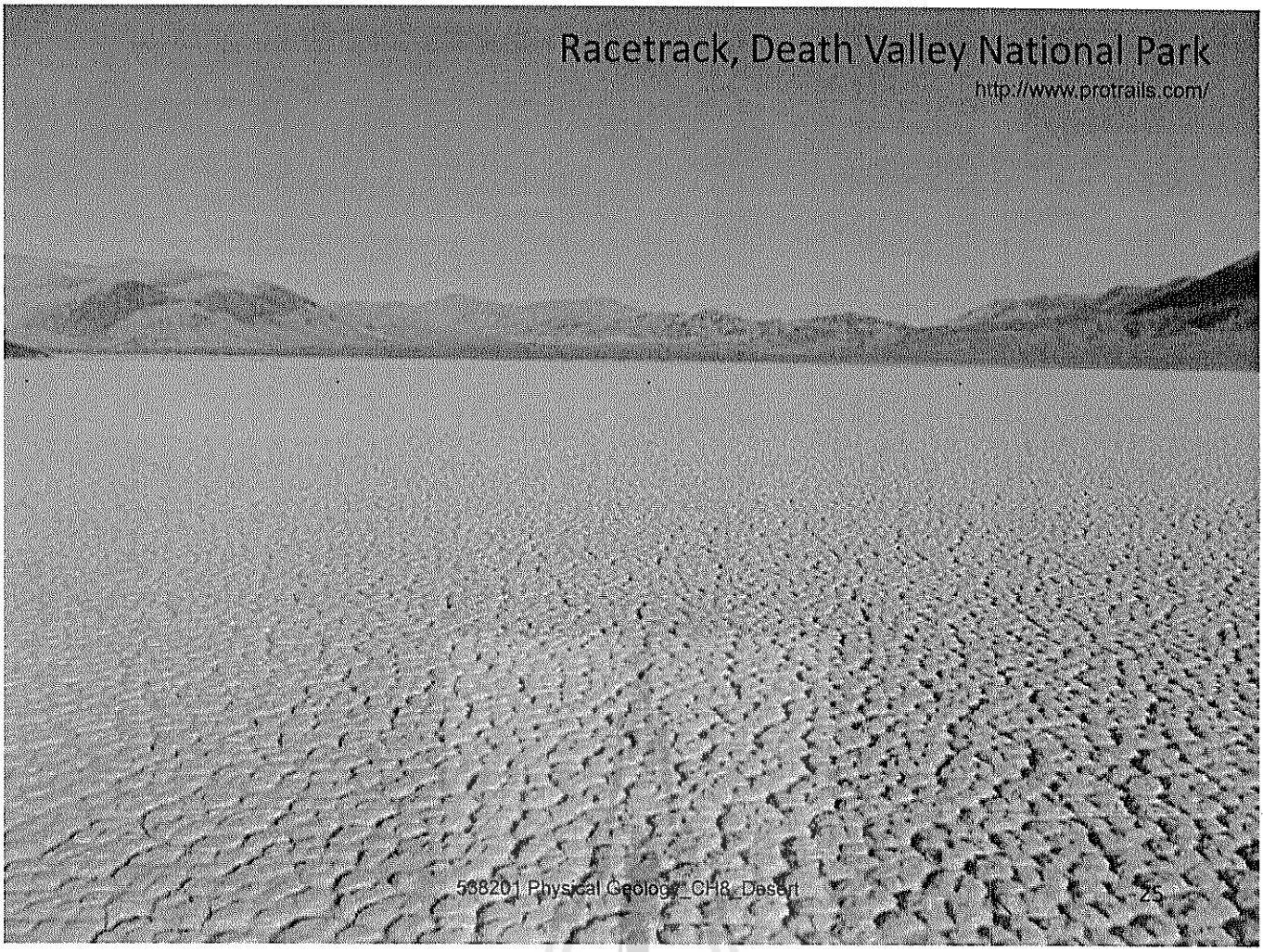
Fan shaped delta formed at the foot of mountains in a desert valley



A Bajada is an apron of sediment resulting from a coalescence of alluvial fans



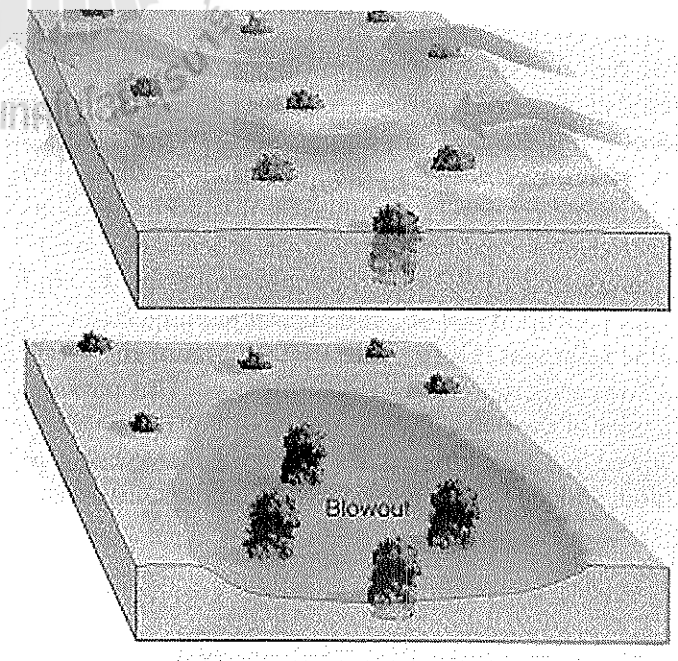
Playa Lake: a temporary shallow lake formed in the central basin of a desert during a rare downpour (a playa is the dry flat lake bed that remains http://esp.cr.usgs.gov/projects/paleo_hyd/



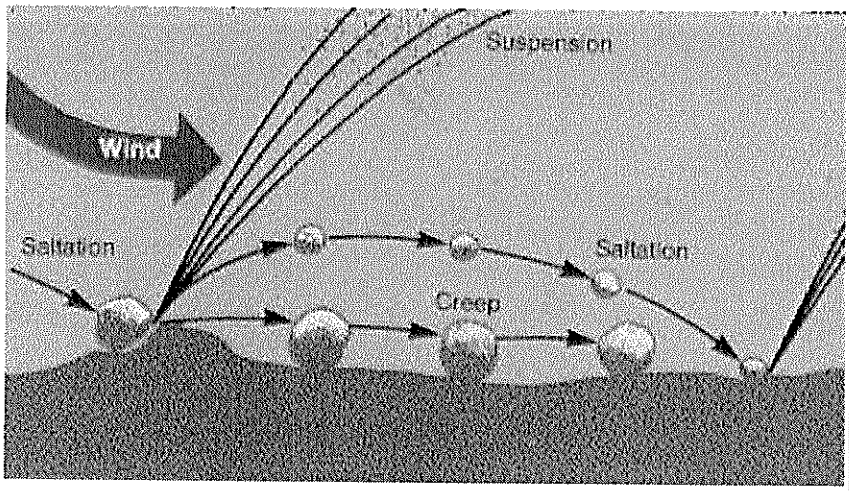
Desert erosion by wind

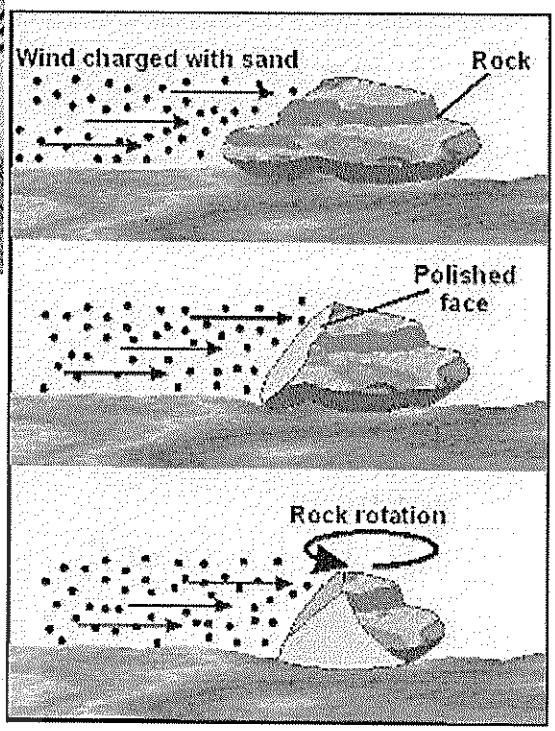
Wind erosion processes:

- Deflation: removal of rock waste from the land by the wind
- Abrasion : "sandblasting" effect on materials caused by the impact with particles carried by the wind

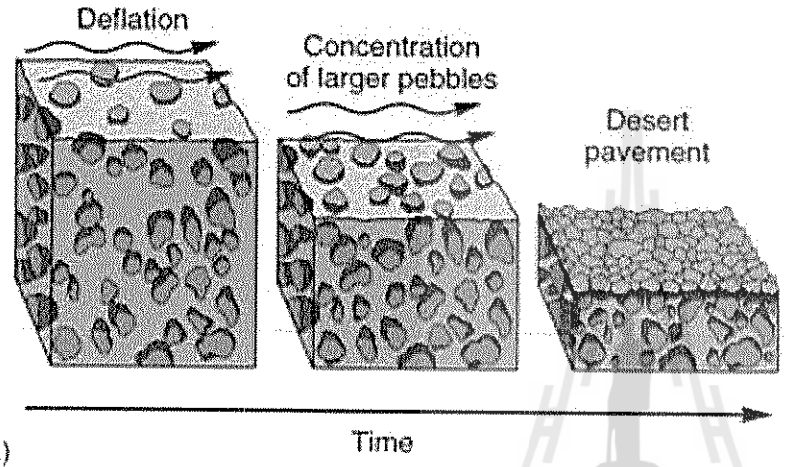


Wind erosion processes



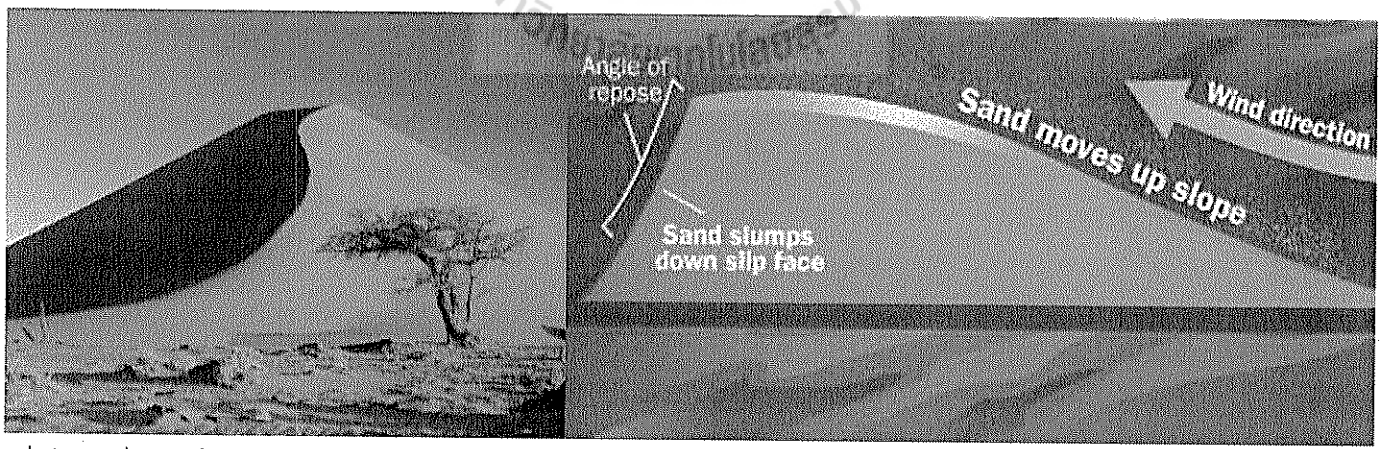


Deflation

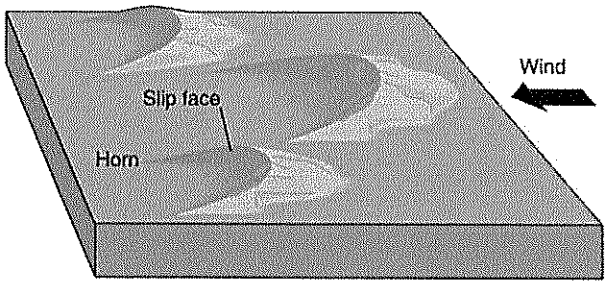


27

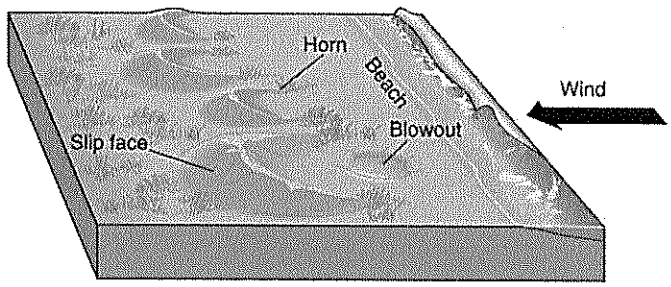
Sand Dunes: mounds of loose sand grains piled up by the wind



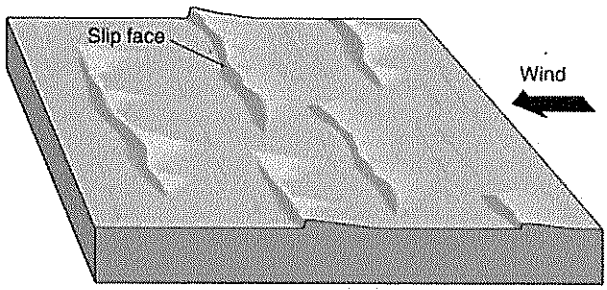
photograpghy-match.com



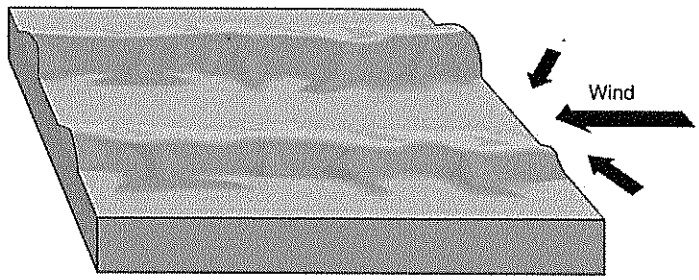
A Barchans



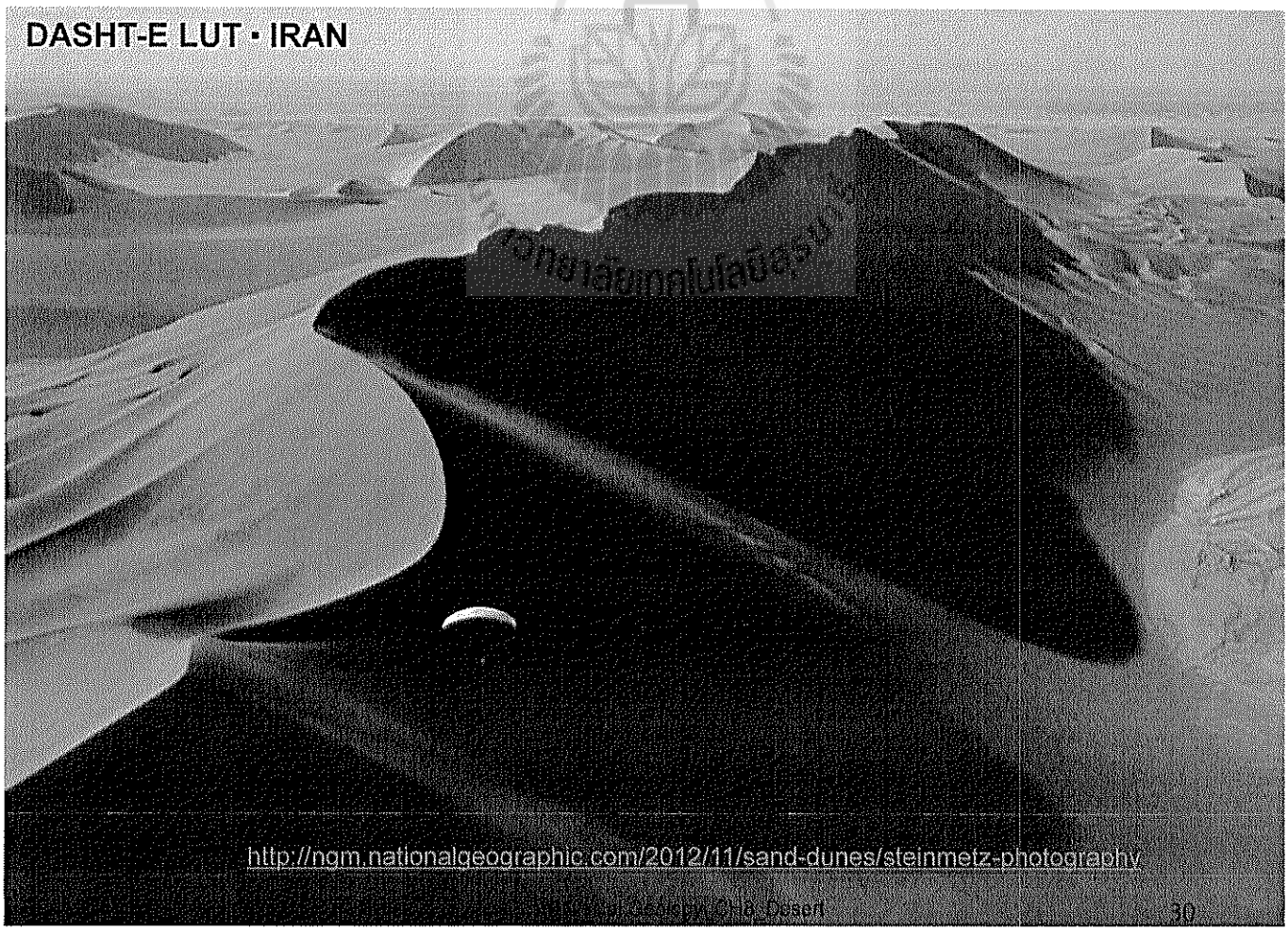
C Parabolic dunes



B Transverse dunes



D Longitudinal dunes (seifs)

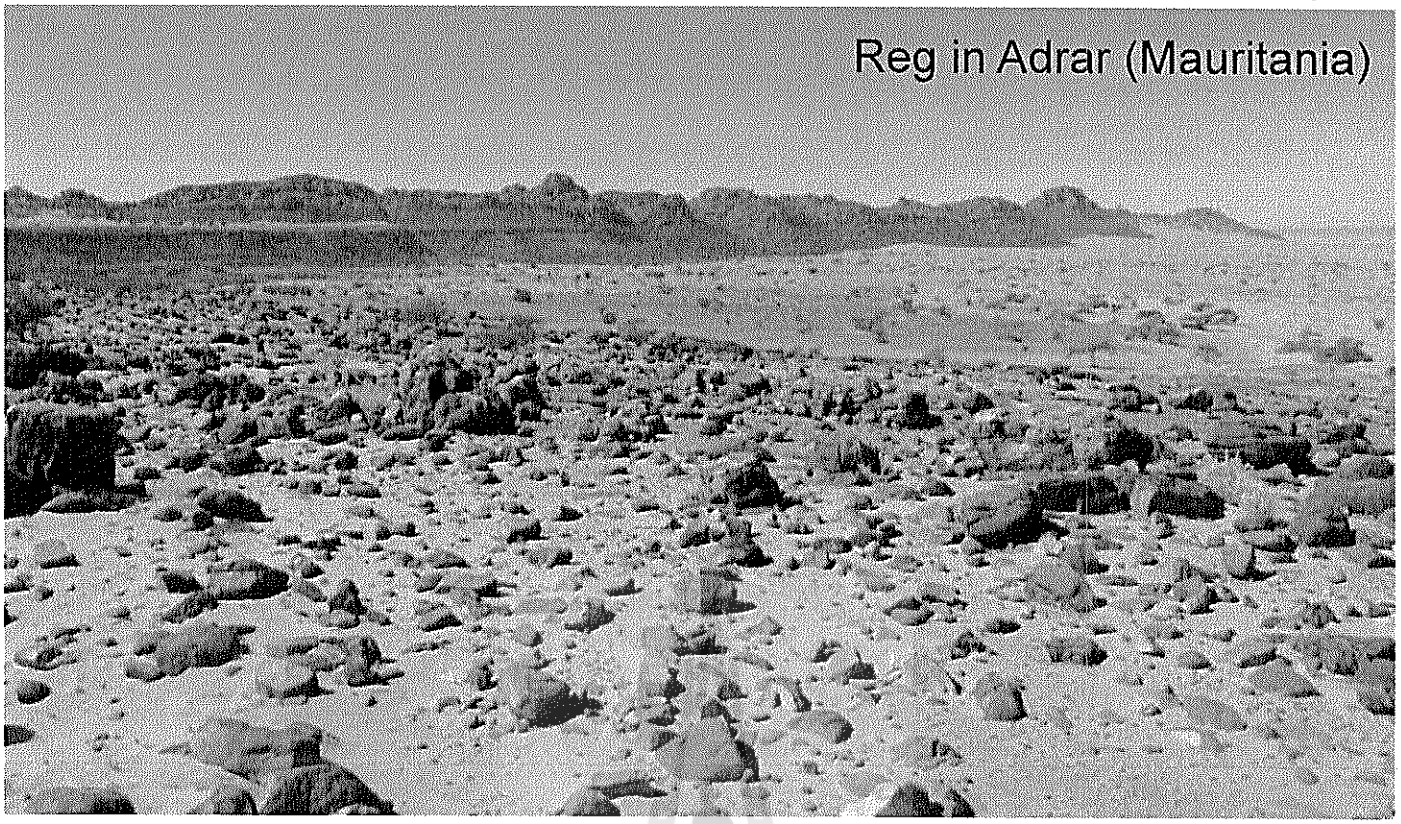


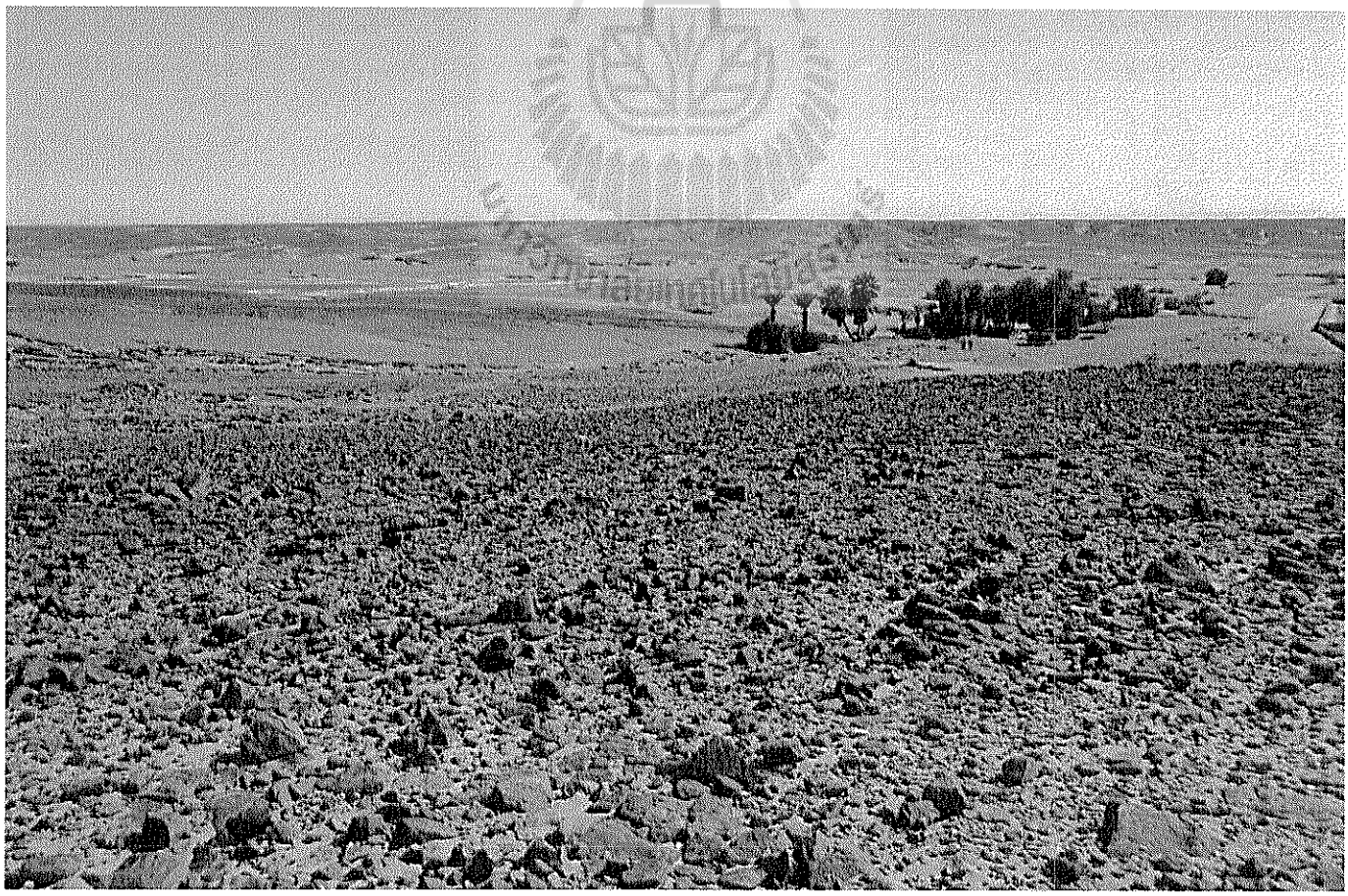

PACIFIC COAST · PERU


SAHARA · CHAD

Reg Deserts

http://commons.wikimedia.org



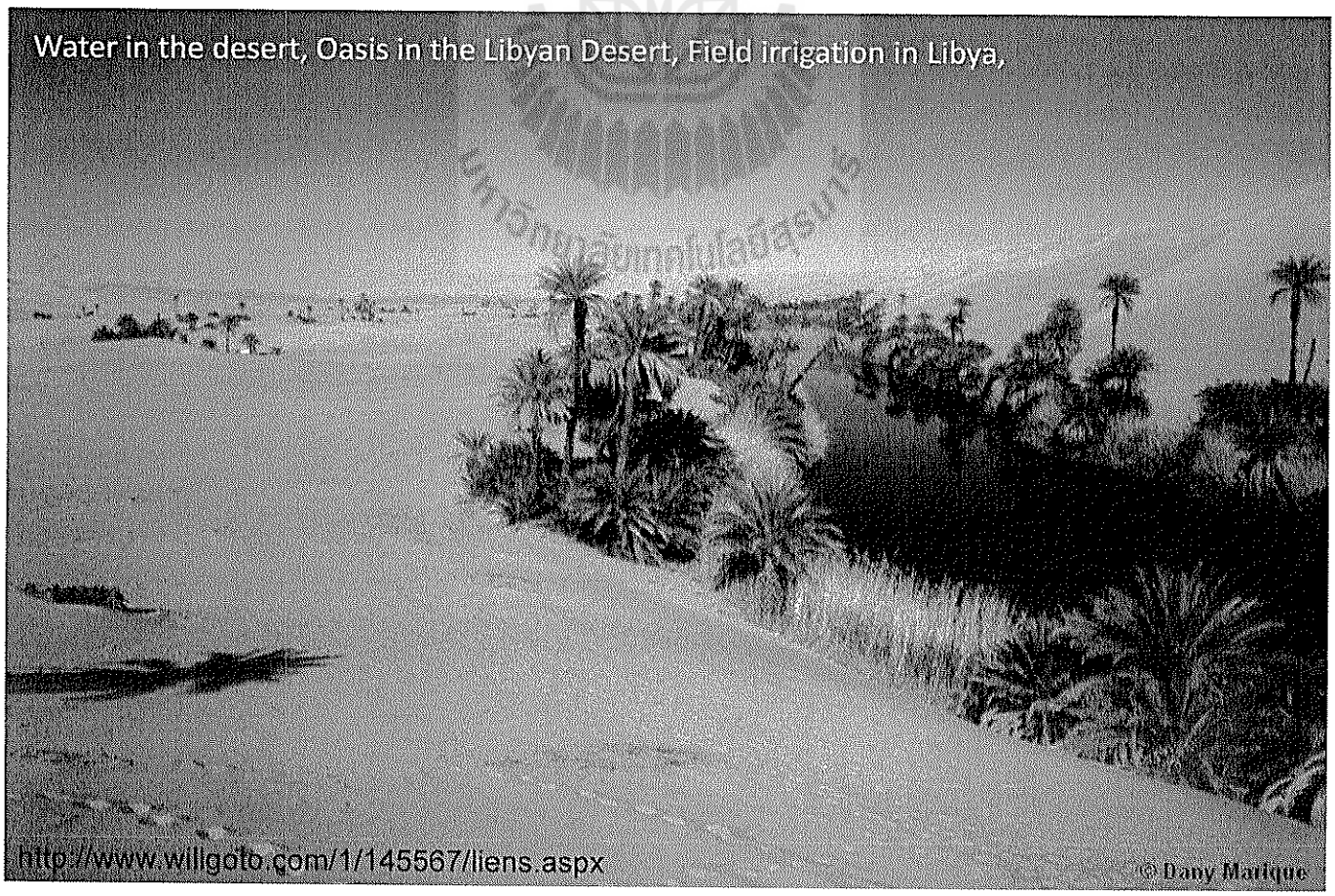


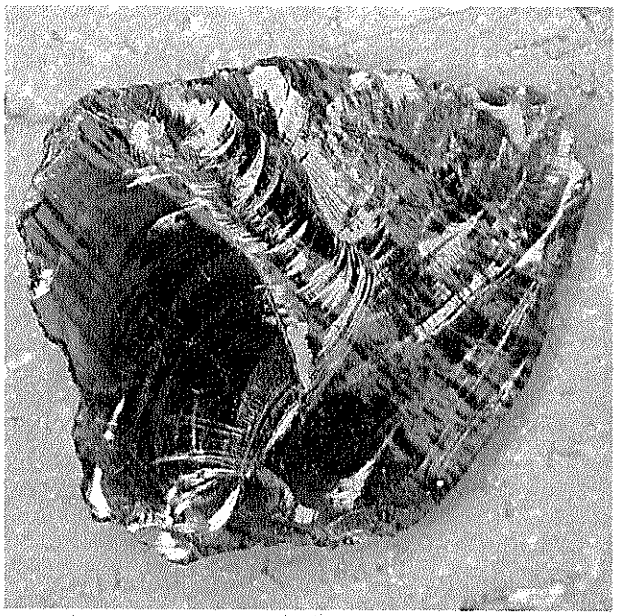
http://guatemalahola.blogspot.com/2012/05/morocco-30.html

Oasis

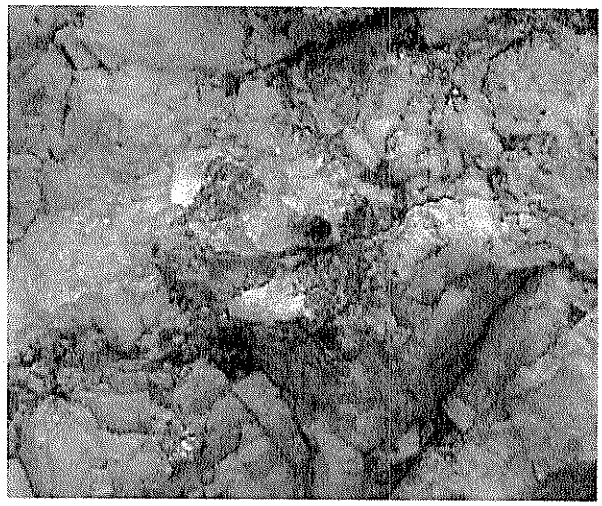
Oasis is an isolated area of vegetation in a desert, surrounding a spring or similar water source.

Oases also provide habitat for animals and even humans if the area is big enough. The location of oases has been of critical importance for trade and transportation routes in desert areas.



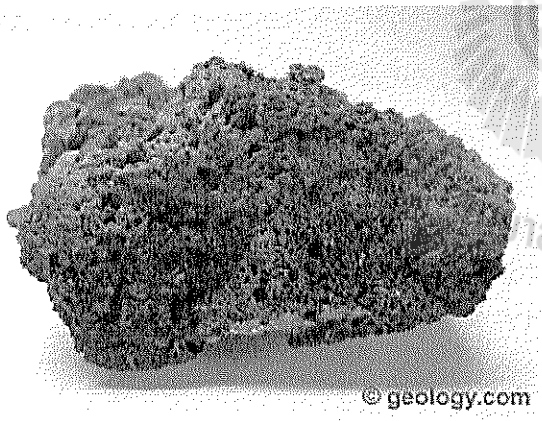


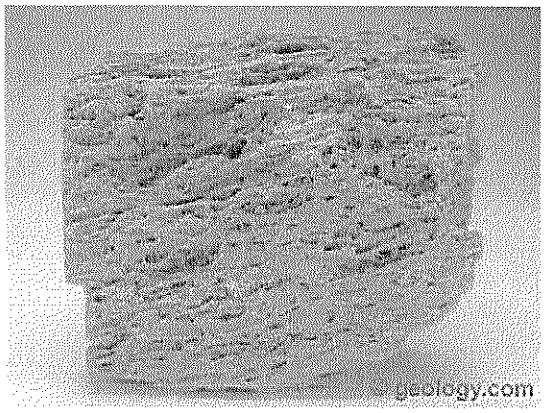
Glassy texture

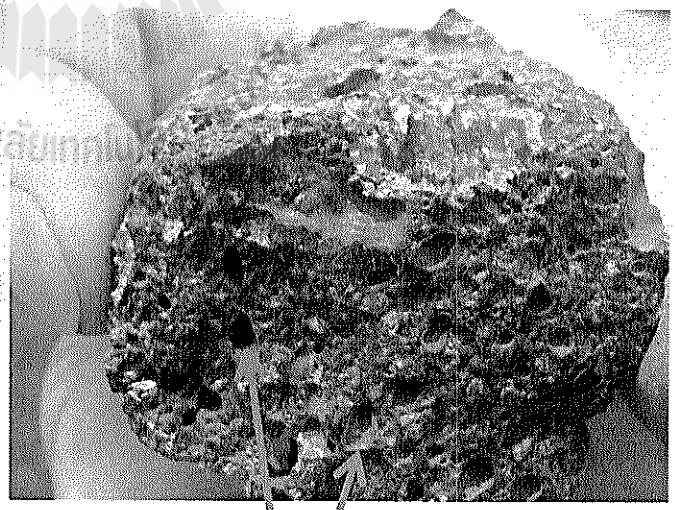


Pegmatitic texture

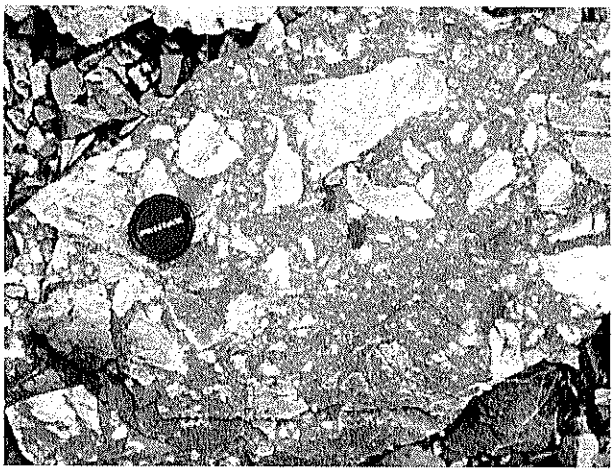
Vesicular texture





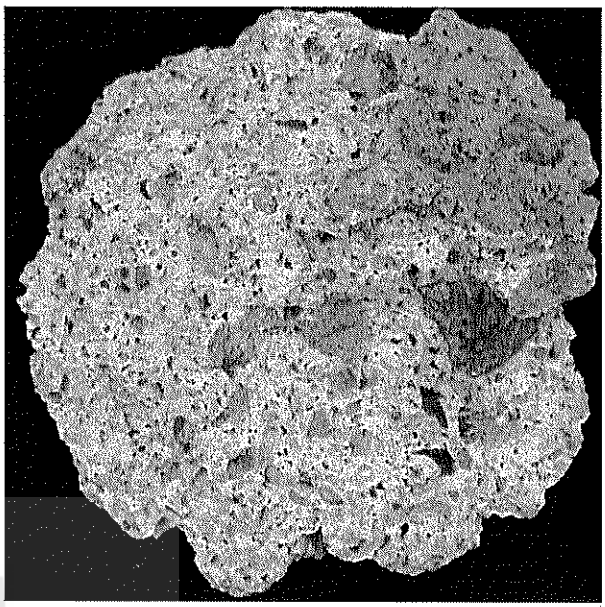


Vesicles





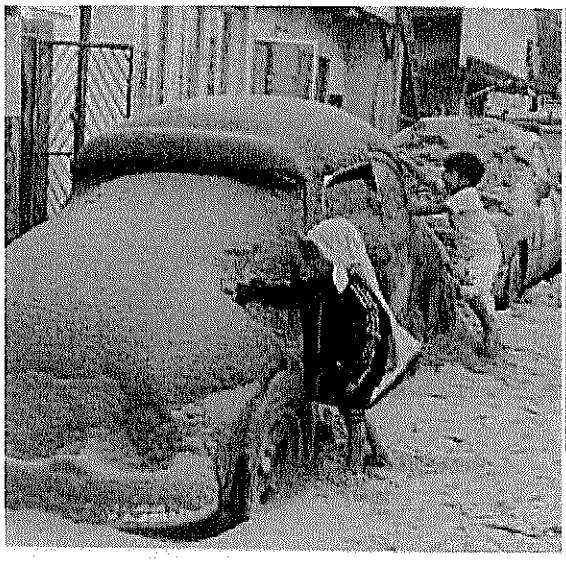
Clastic texture

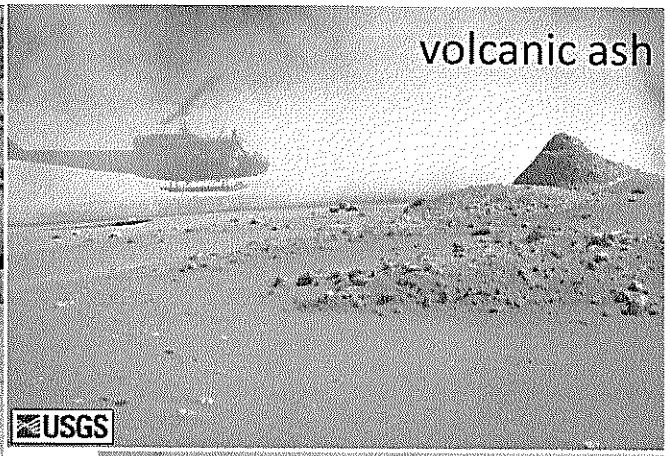


Pyroclastic rock & Tuff

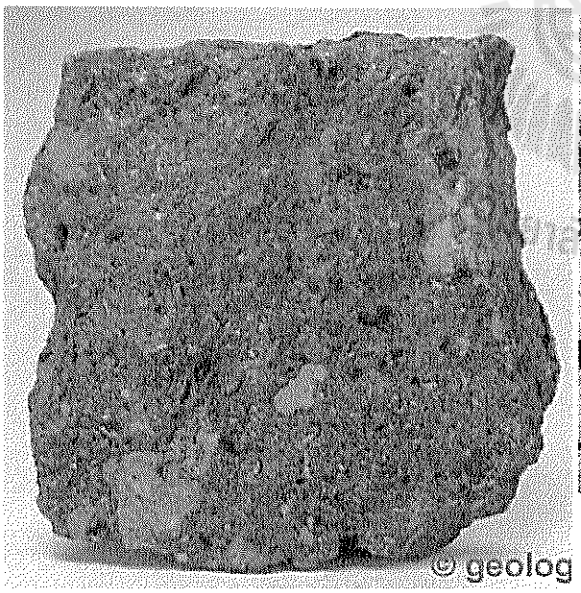
Pyroclastic rocks: rocks that are composed primarily of volcanic materials

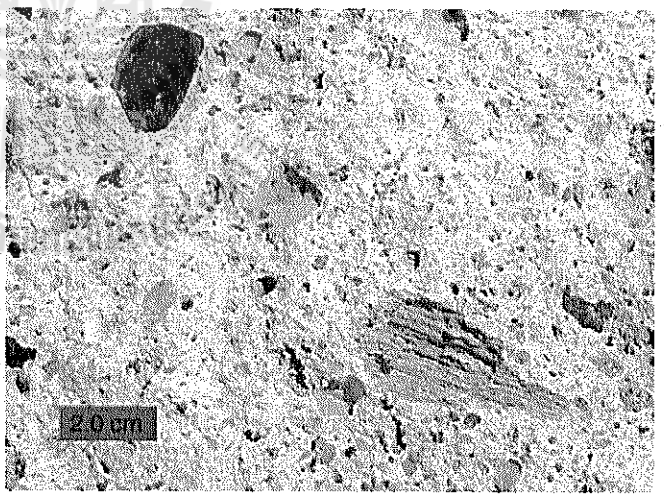
Clast size	Pyroclast	Rock name
> 64 mm	Block, bomb	Agglomerate, pyroclastic breccias
< 64 mm	Lapillus	Lapilli tuff
< 2 mm	Coarse ash	Coarse tuff
< 0.063	Fine ash	Fine tuff







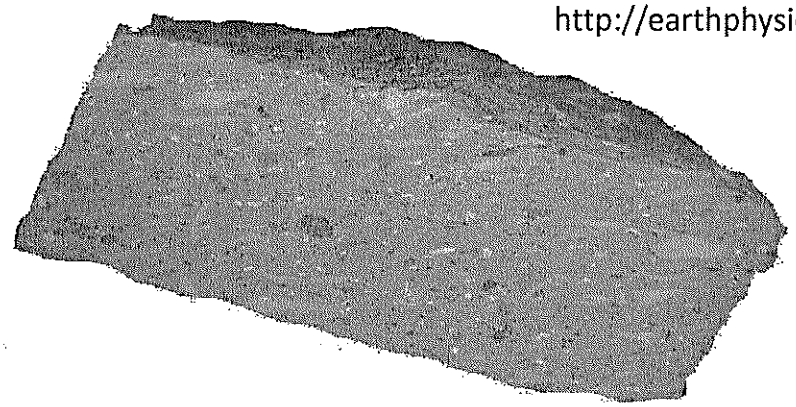




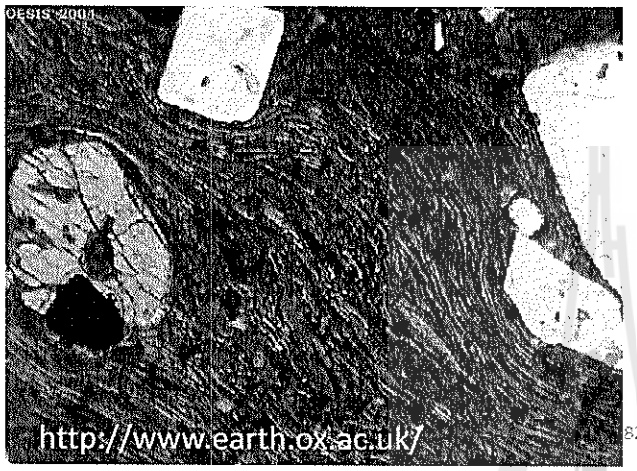
www.geology.com

Tuff: an igneous rock that contains the debris from an explosive volcanic eruption. It often contains fragments of bedrock, tephra and volcanic ash.

http://earthphysicsteaching.homestead.com/

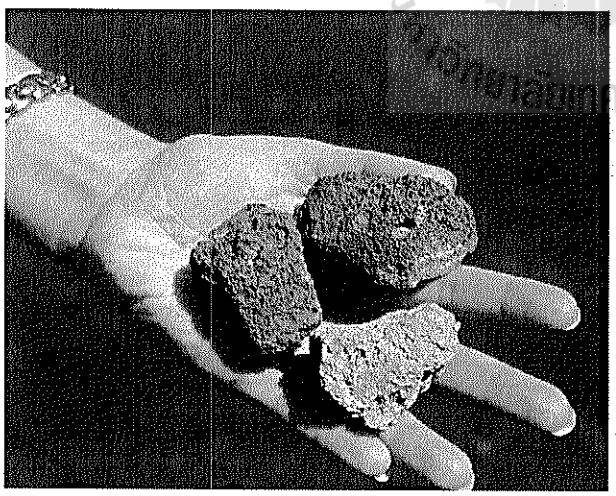


Welded tuff



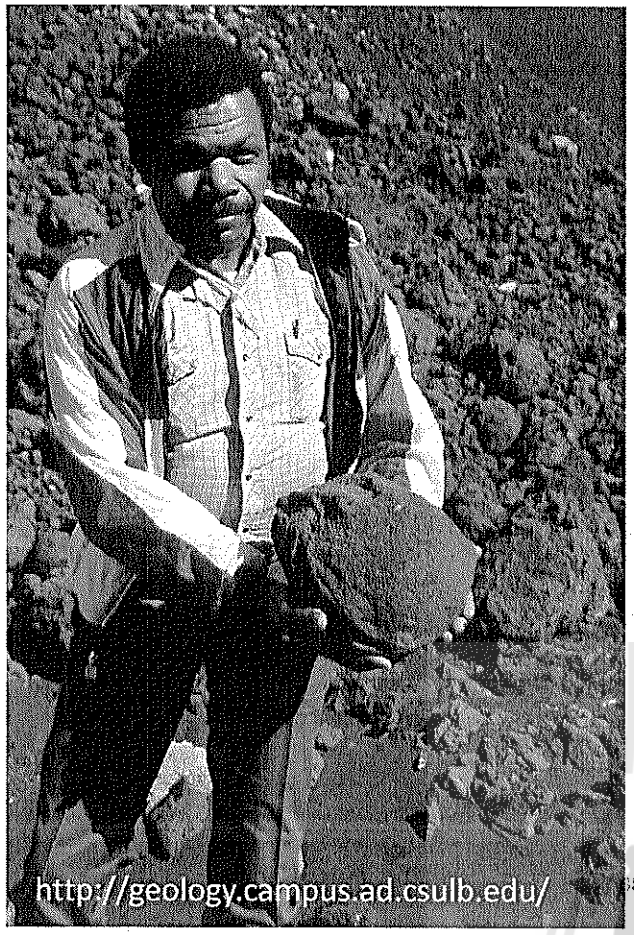
Lapilli tuff

pea to pebble-sized pyroclastic rocks

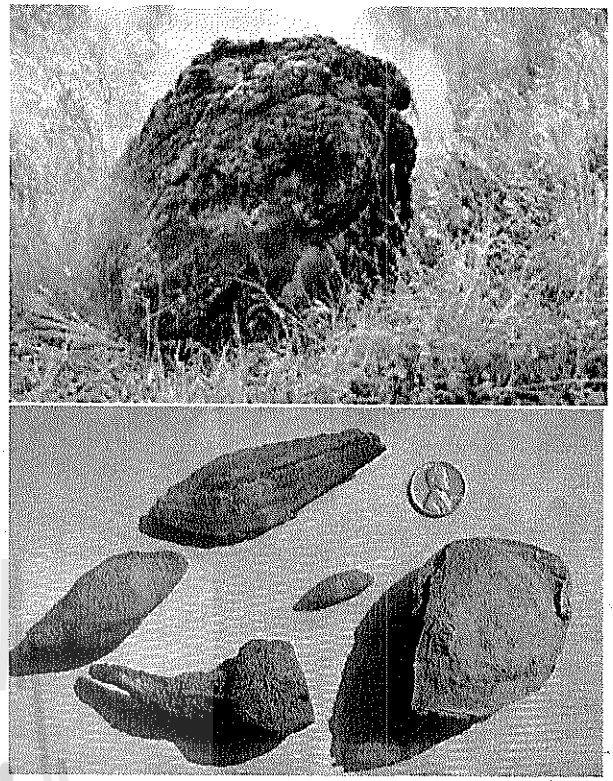




http://geology.campus.ad.csulb.edu/



Block and bomb





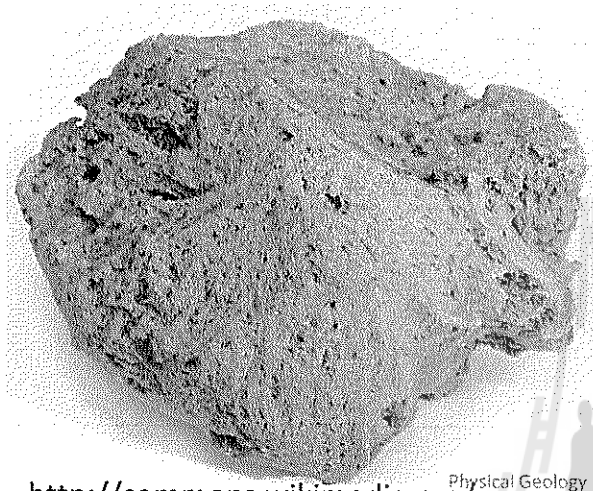
Agglomerate

http://www.landforms.eu/

Volcanic glass

Pumice

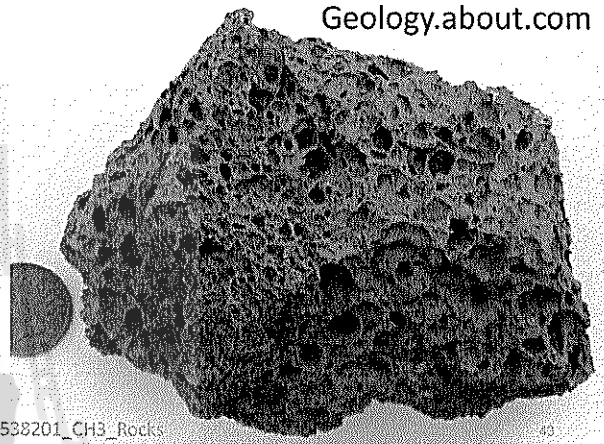
Highly vesicular
Porosity 90%
Light color
Felsic - intermediate melt



http://commons.wikimedia.org/

Scoria

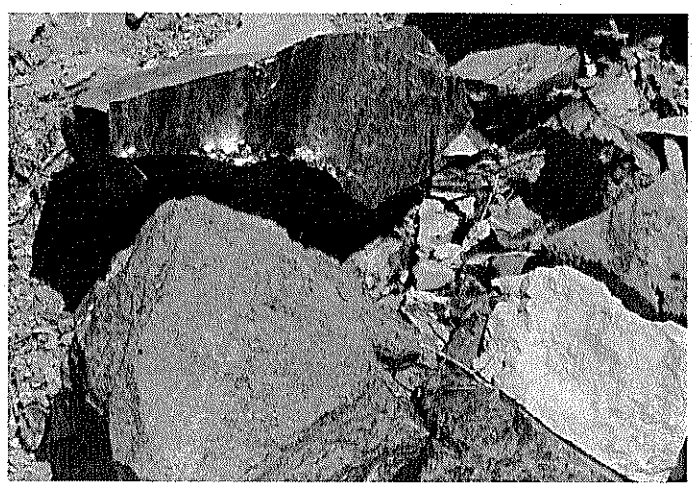
Dark color
Low viscosity magma
Denser than pumice
Large vesicles
Thick vesicle wall



Geology.about.com

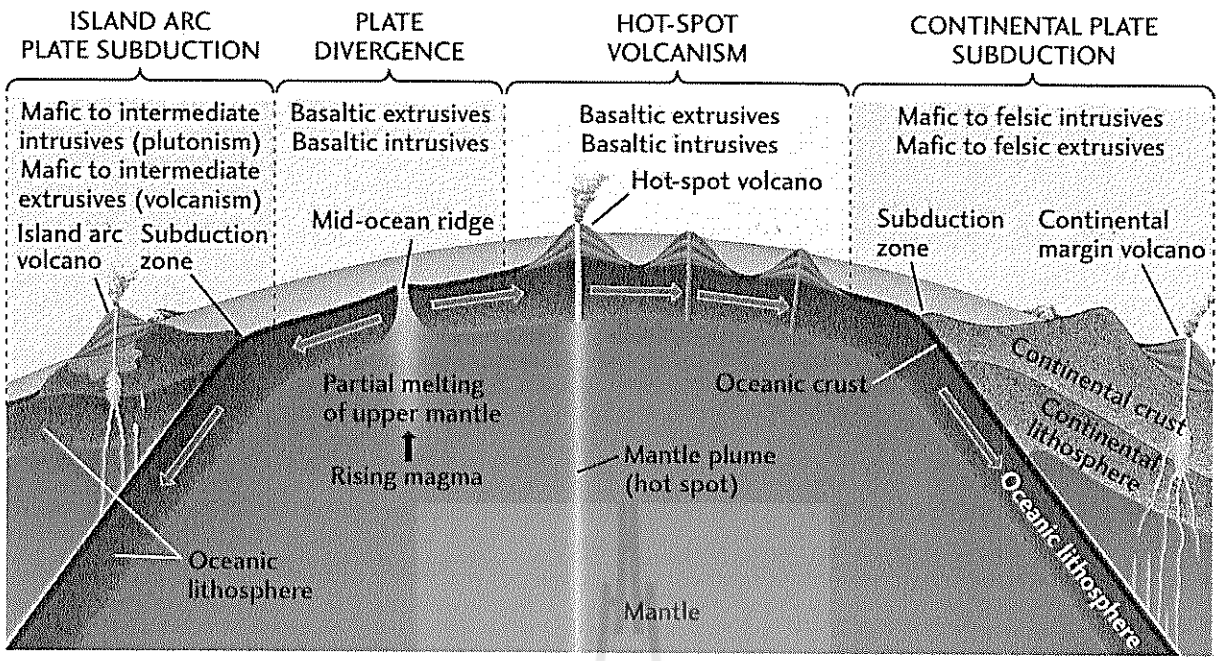
Obsidian: extrusive igneous rock which has glassy texture, formed from high silica lava (SiO_2 70-75%), having conchoidal fracture.

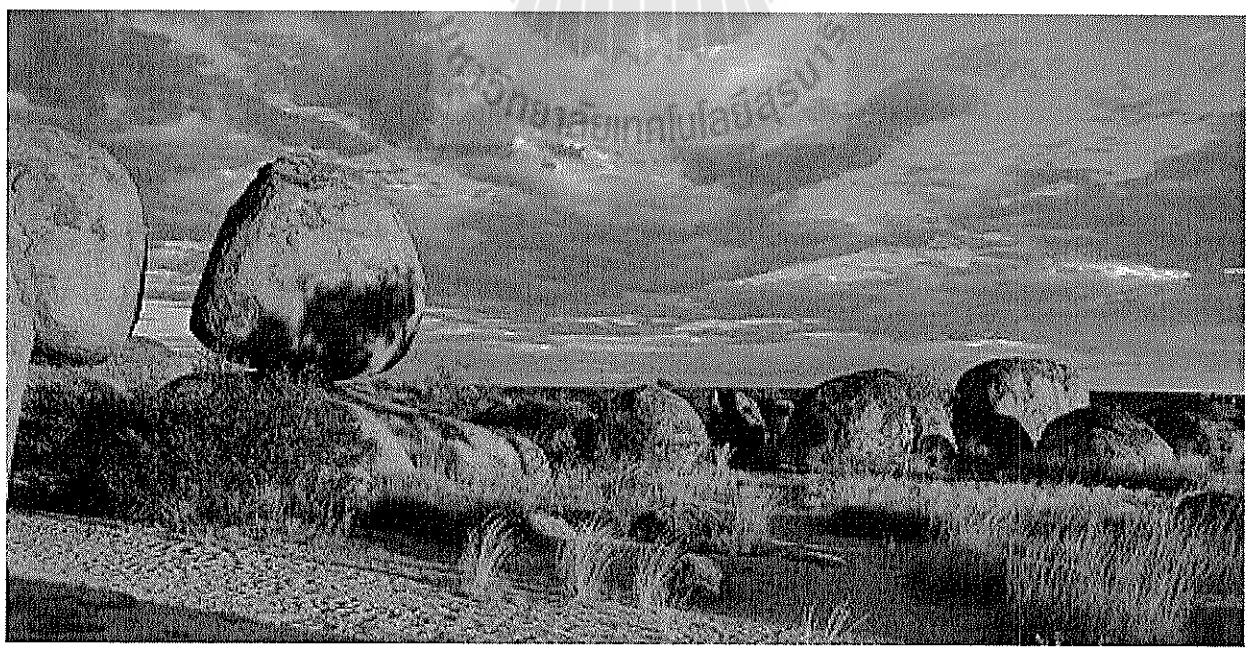




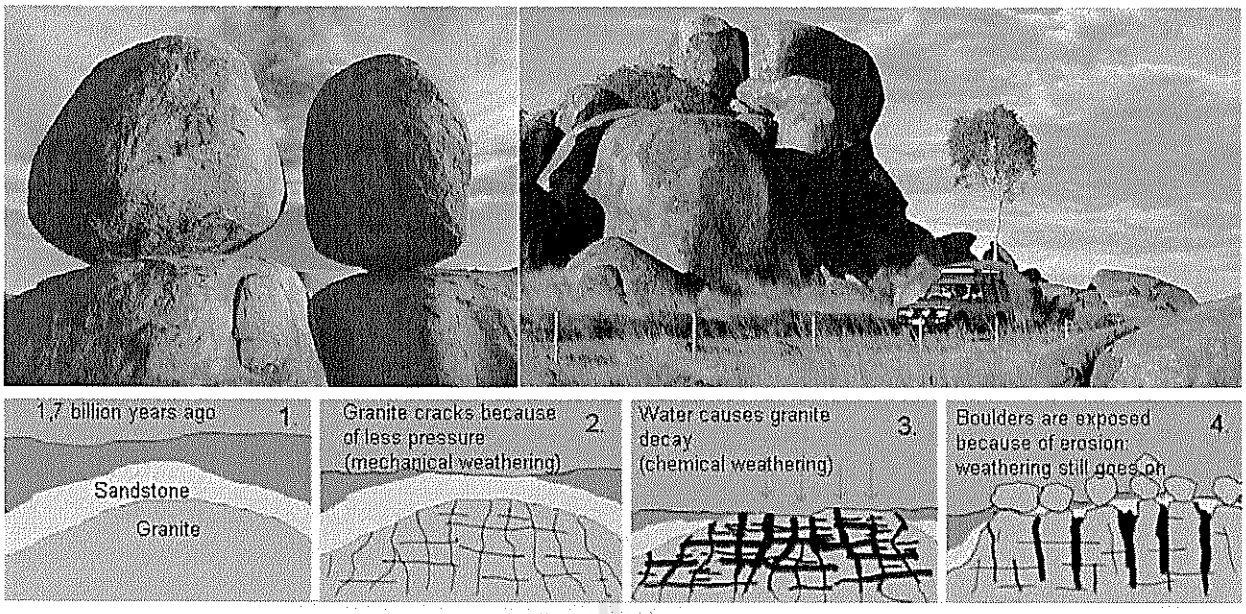
http://rockhoundblog.com/

Igneous rocks and plate tectonic





Karlu Karlu, Devil's marble, Australia



Karlu Karlu/Devils Marbles are of great cultural and spiritual signficance to local Aboriginal people.

This tradition tells of 'Arrange', the Devil Man, who came from a hill nearby and travelled through the area. Whilst walking along, Arrange made a hair-string belt (a kind of traditional adornment, worn only by initiated men). As he was twirling the hair to make strings, he dropped clusters of hair on the ground

3. Sedimentary Rocks

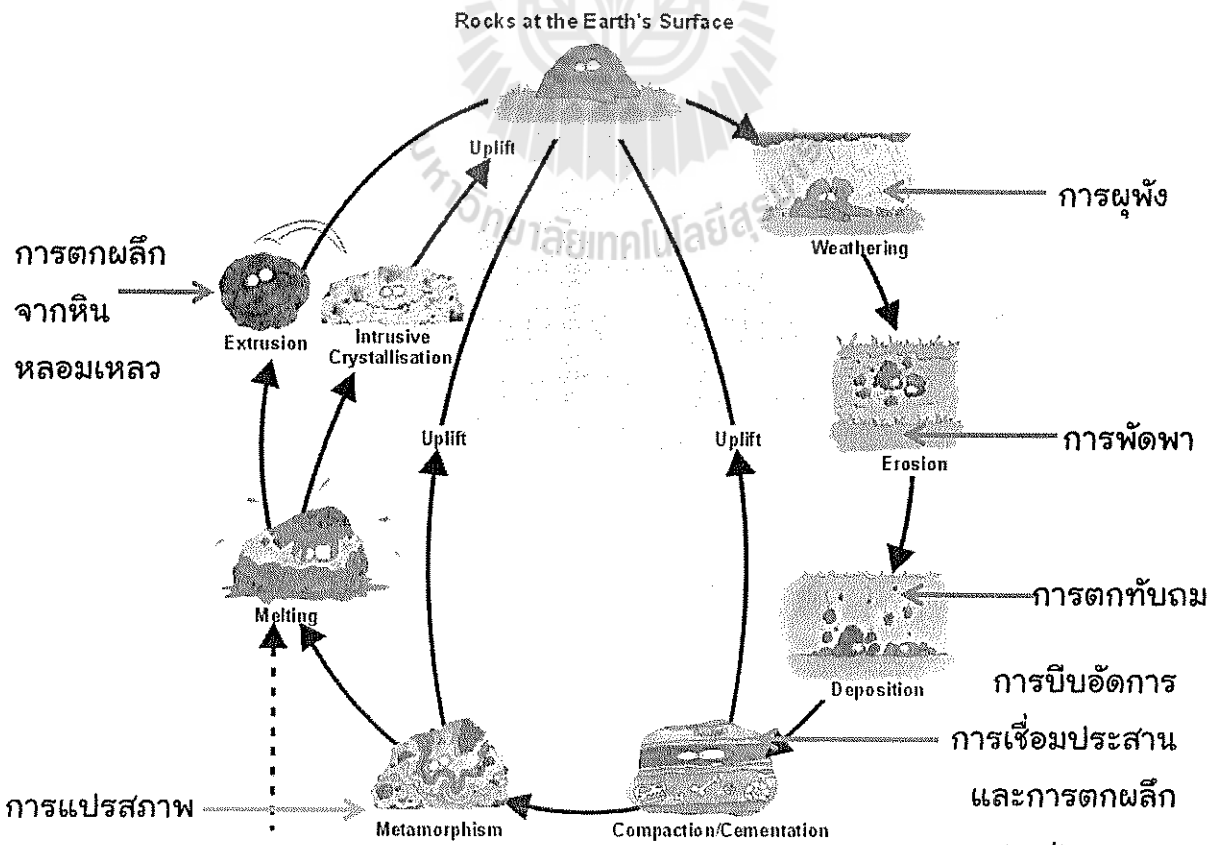
Contents

- Definition
- Classification
- Environment of deposition

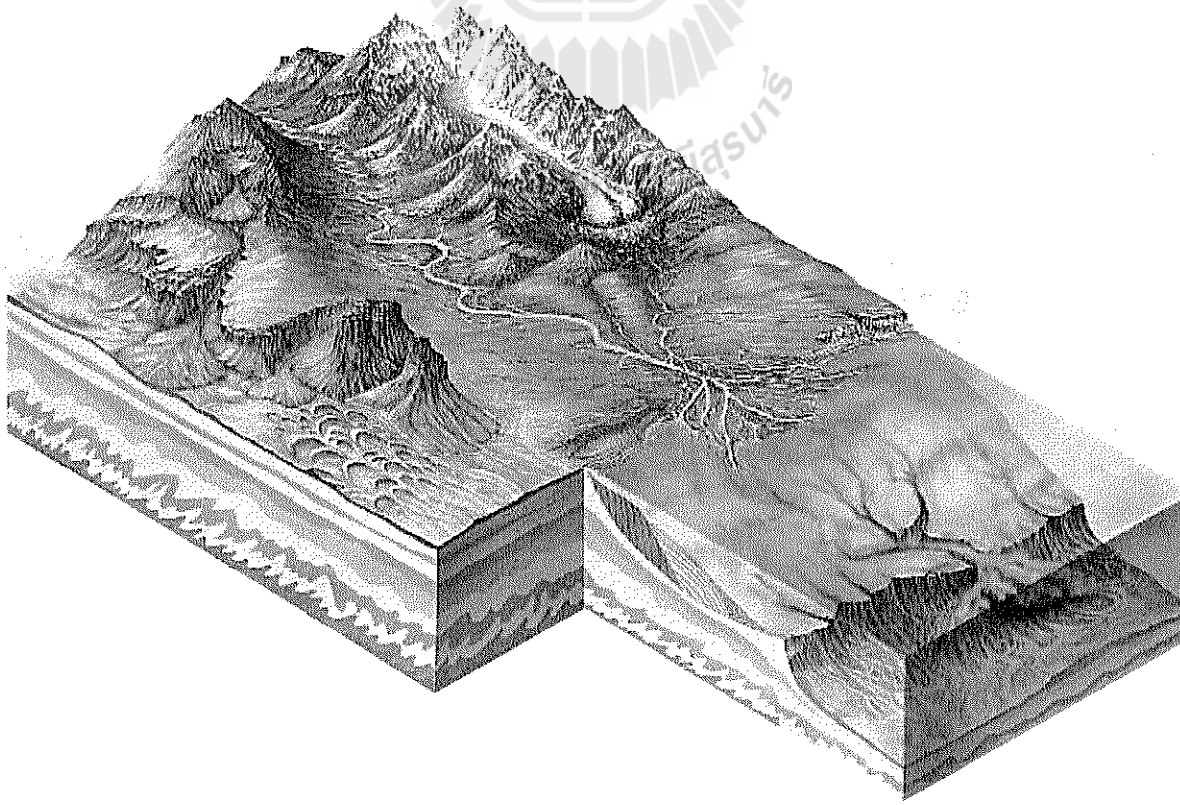


Definition

Sedimentary rocks: types of rock that are formed by the deposition of *weathering products* of pre-existing rocks or accumulated *biological matter* at the Earth's surface and within bodies of water.



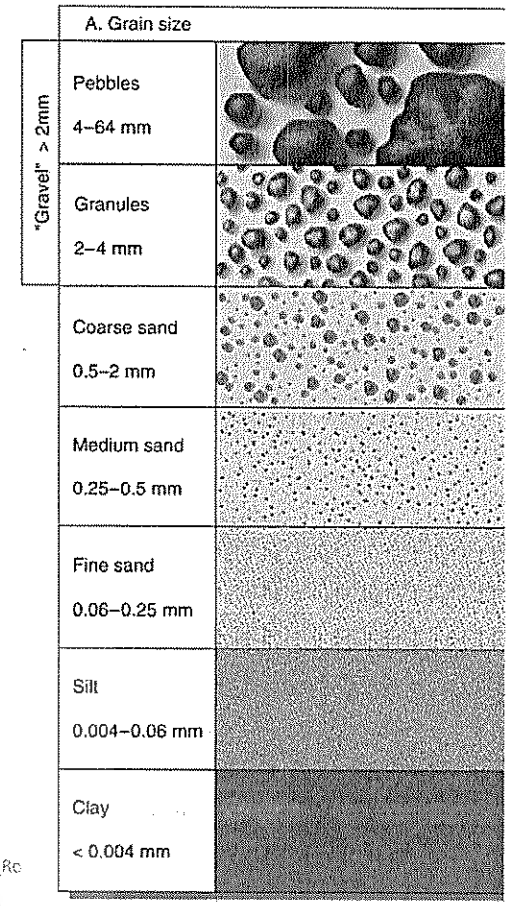




http://letslearngeology.com

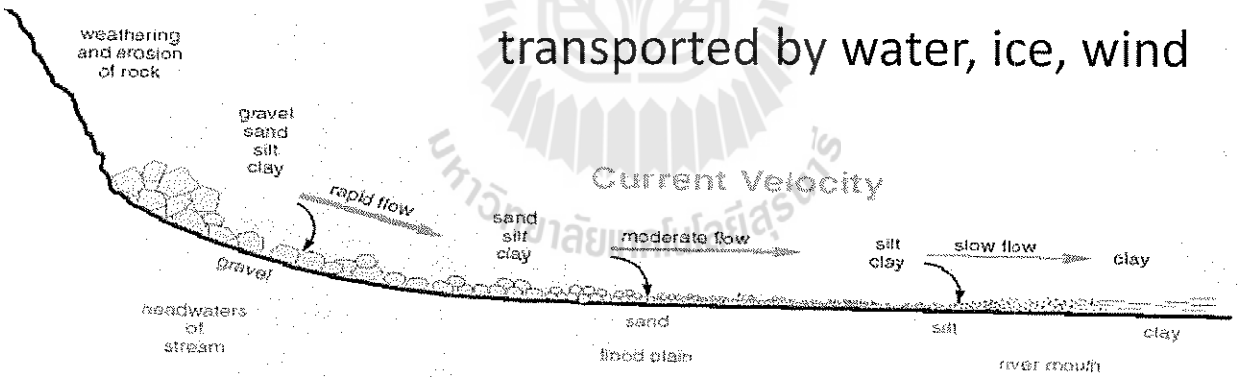
Sediments are classified by particle size

- Boulder >256 mm
- Cobble 64-256 mm
- Granule 2-4 mm
- Gravel 2-64 mm
- Sand 1/16 to 2 mm
- Silt 1/256 to 1/16 mm
- Clay <1/256 mm



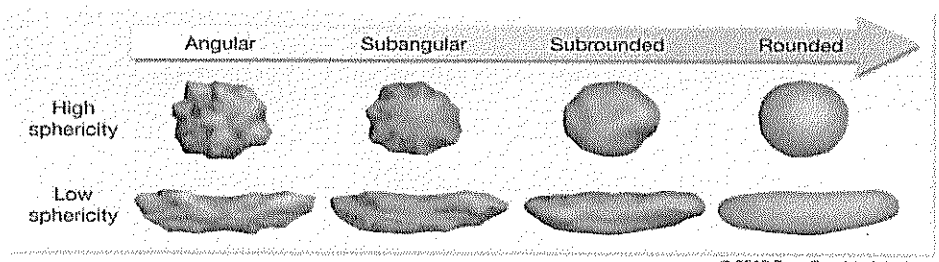
Physical Geology 538201_CH3_Rc

transported by water, ice, wind

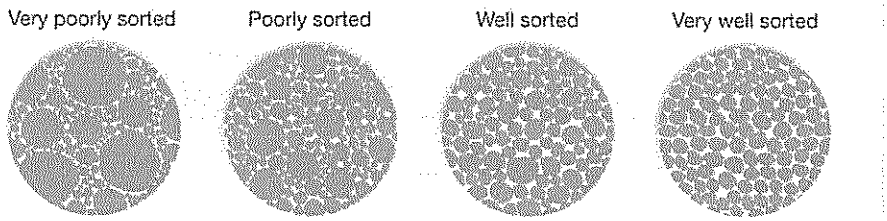


Current Velocity

Rounding



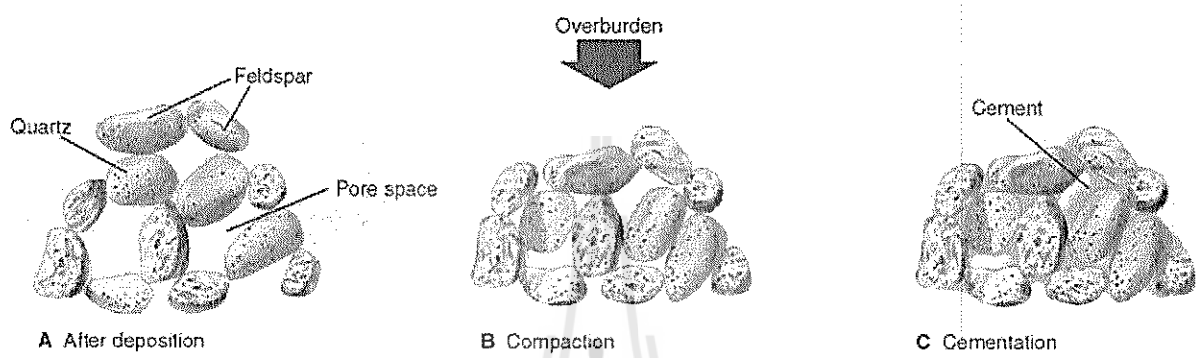
Sorting

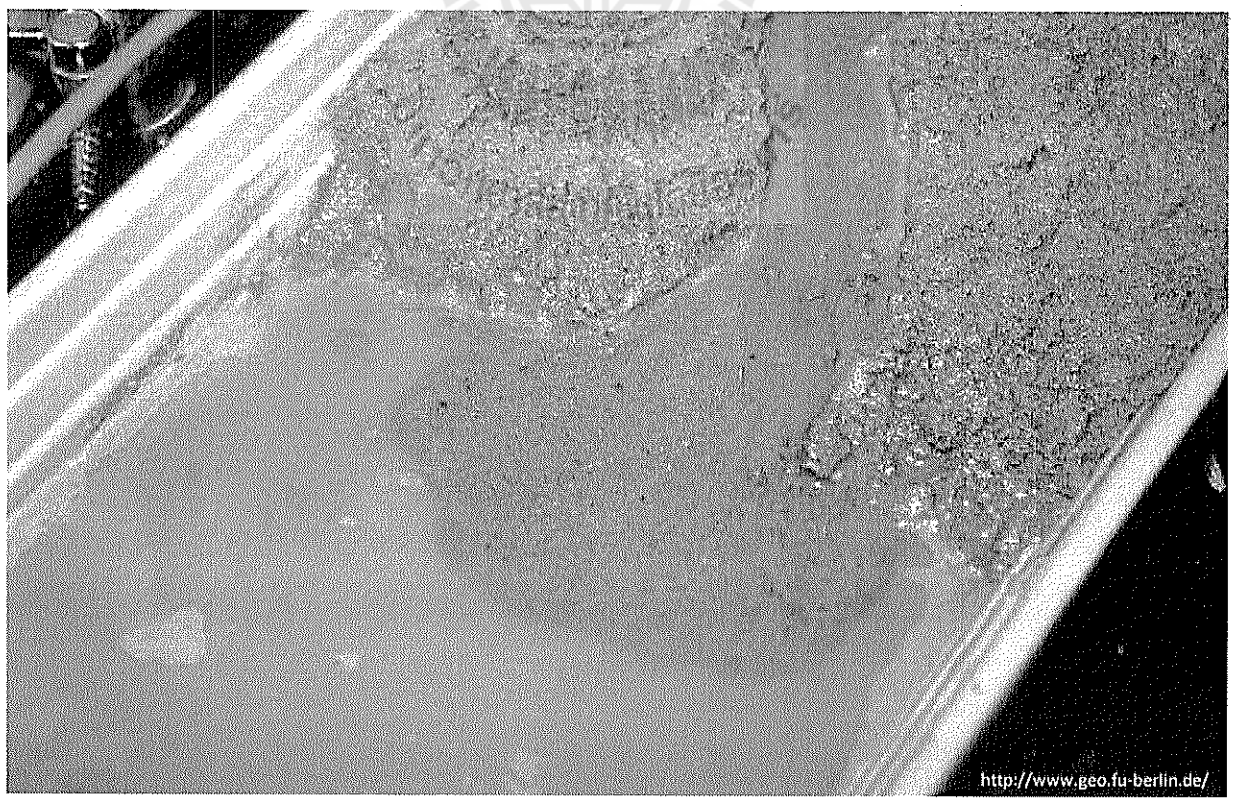


- Deposition: settling and coming to rest

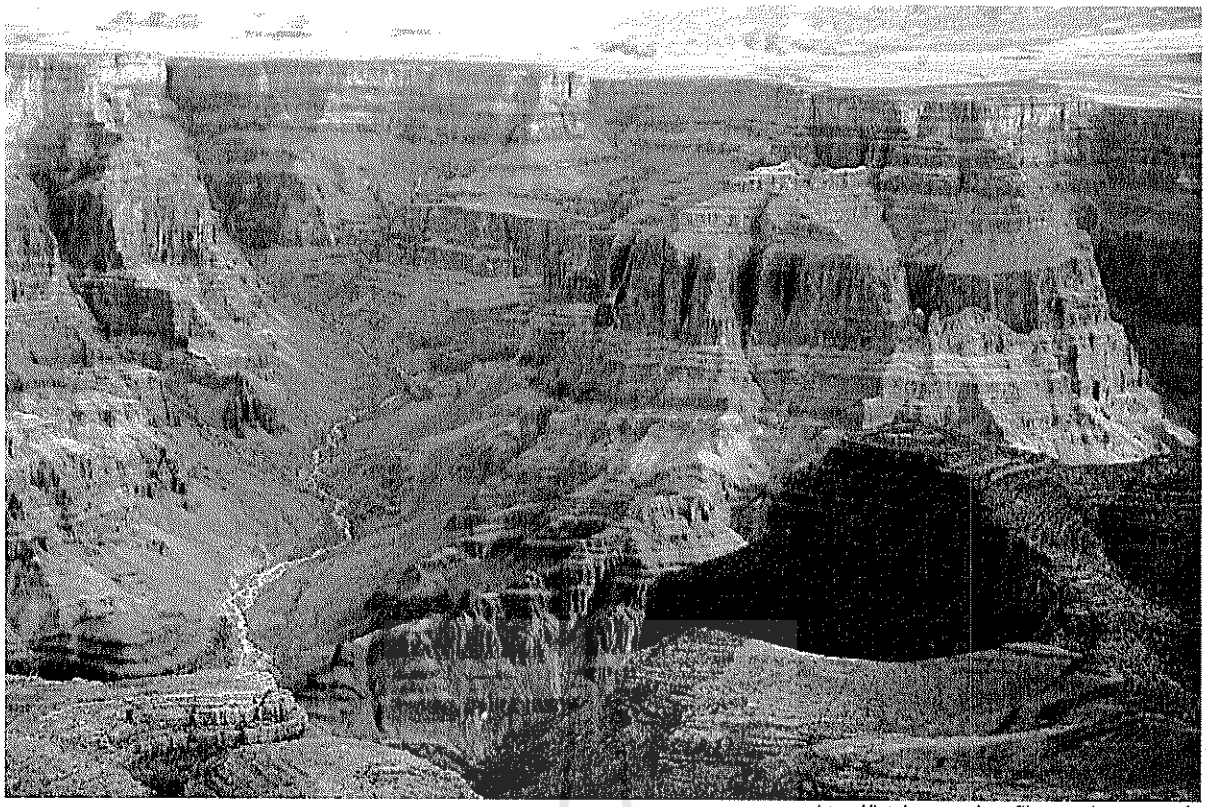
- Preservation: sediments must be preserved by burial with additional sediments

- Lithification: combination of compaction and cementation to convert loose sediment into sedimentary rock.





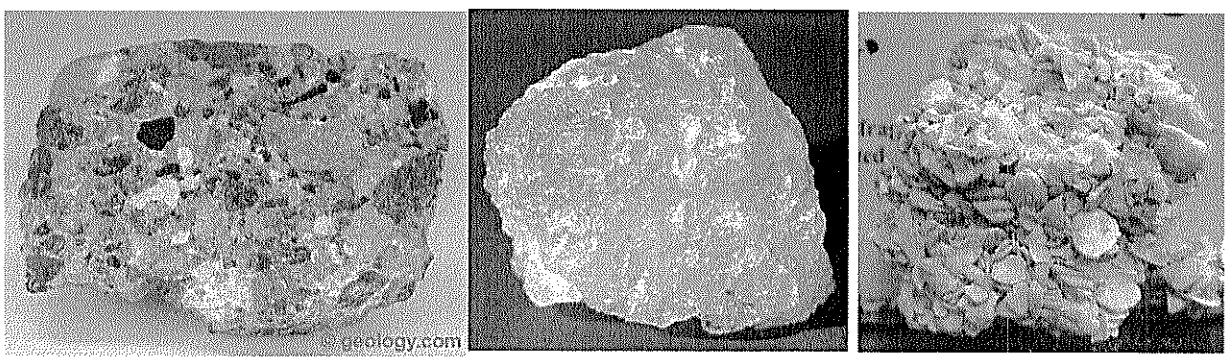
http://www.youtube.com/watch?v=Yf4YtDlA1oQ



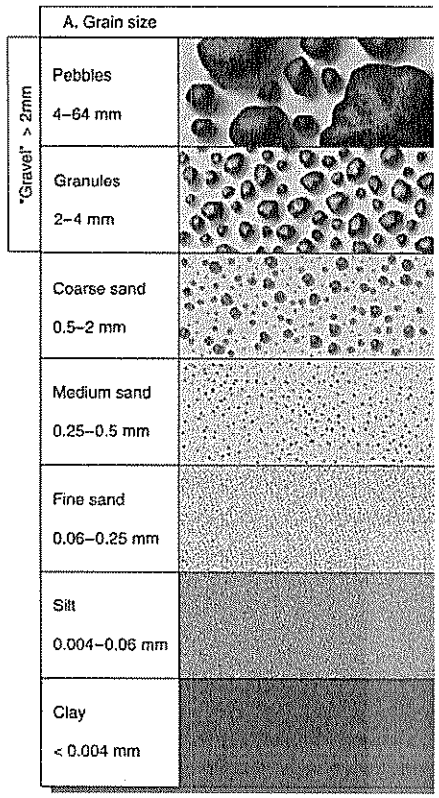
http://letslearngeology.files.wordpress.com/

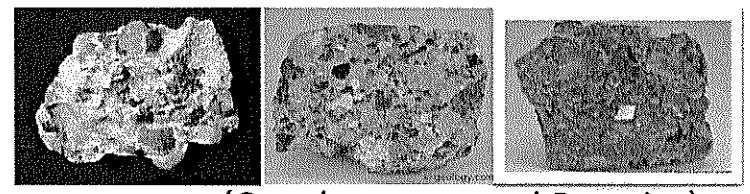
Classification of sedimentary rocks

- Clastic sedimentary rocks (detrital origin)
- Non-clastic sedimentary rocks (chemical origin)
- Biochemical sedimentary rocks (organic origin)

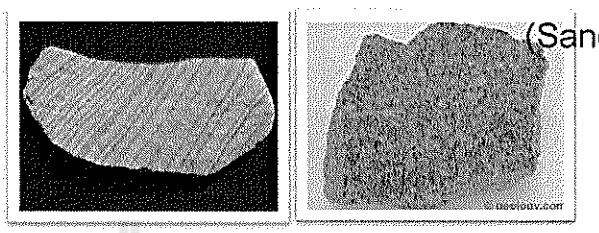


Clastic sedimentary rocks

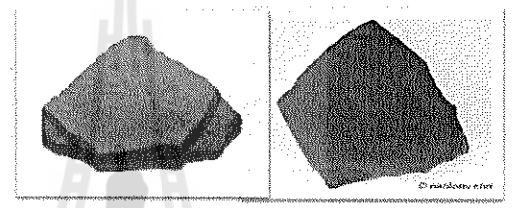




(Conglomerate and Breccias)

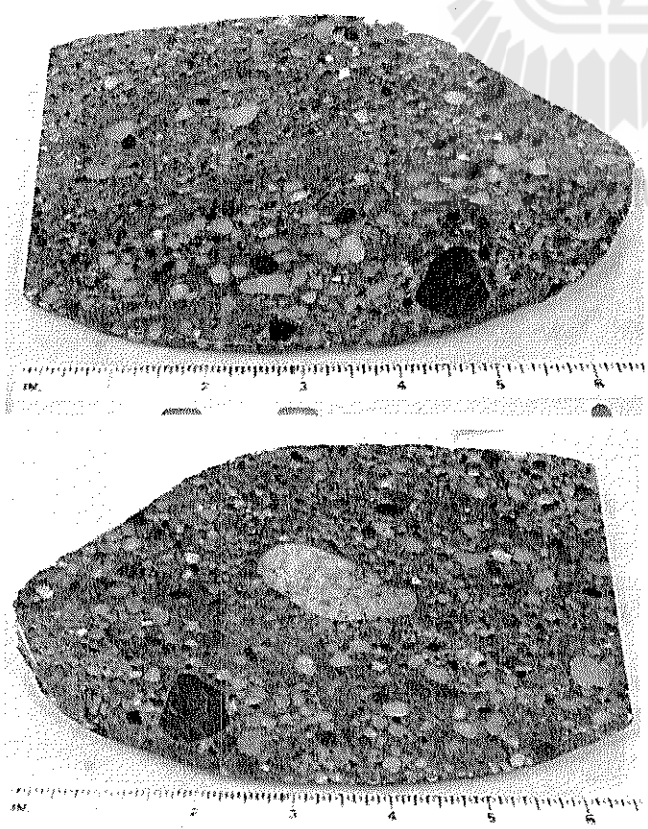


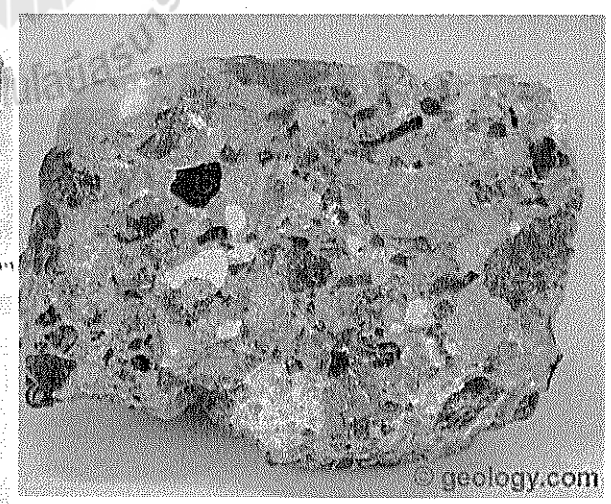
(Sandstone)



(siltstone, claystone, mudstone)

Conglomerate

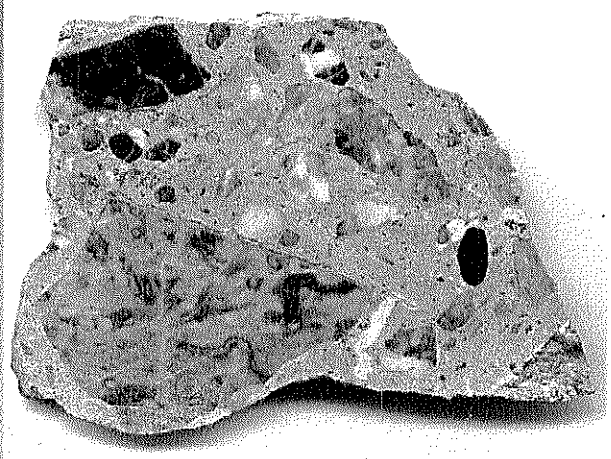




http://www.texasrockshop.com/

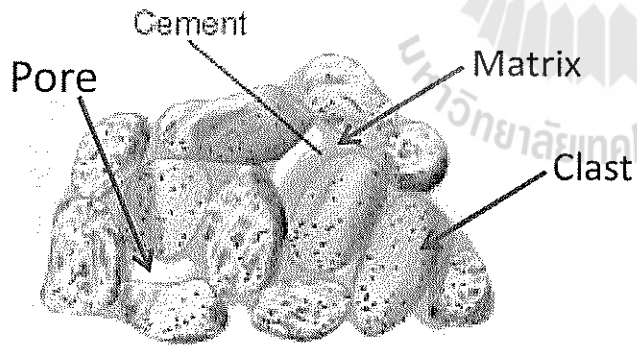
Breccias

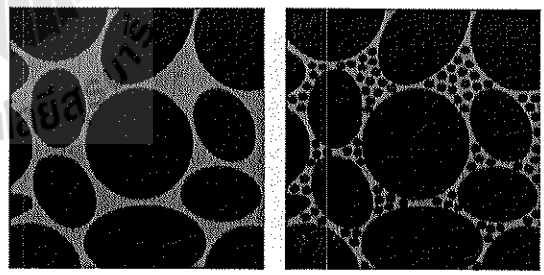




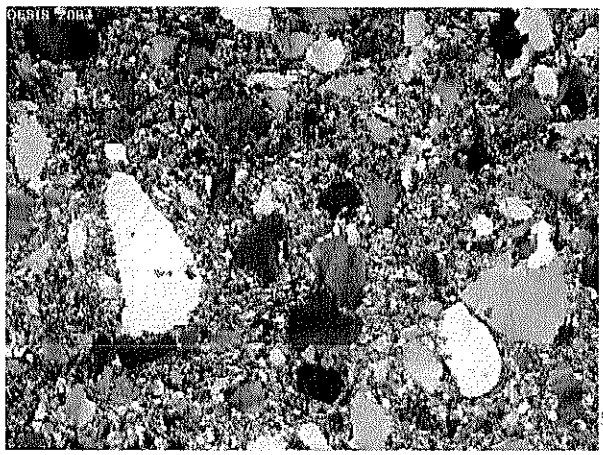
http://skywalker.cochise.edu

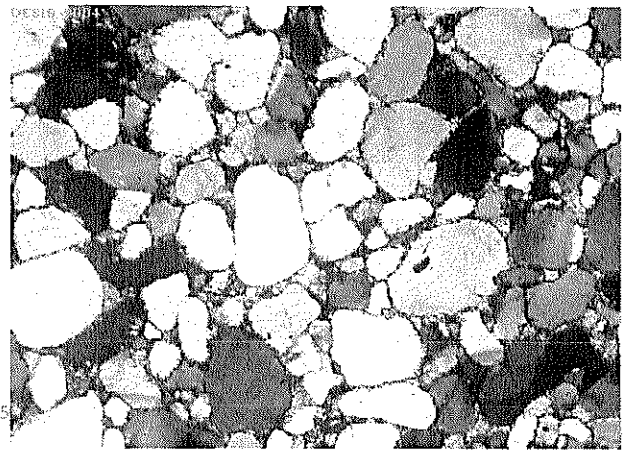
Sandstone: sand sized clastic sedimentary rock





http://www.earth.ox.ac.uk/





Shale: fine-grained clastic sedimentary rock which can splits into thin layers (fissile), composed of silt- and clay-sized grains

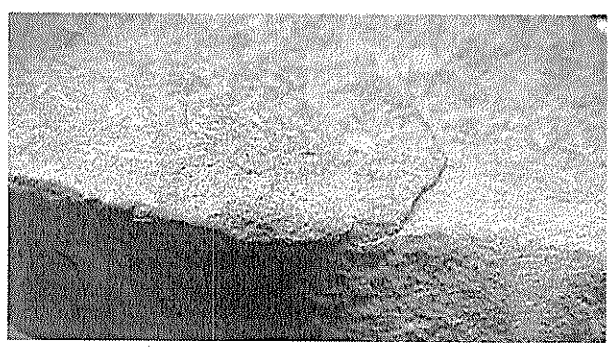
Siltstone: slightly coarser-grained than shales and lacks of fissility

Claystone: predominantly clay-sized grains; non-fissile

Mudstone: silt- and clay-sized grains; massive/blocky

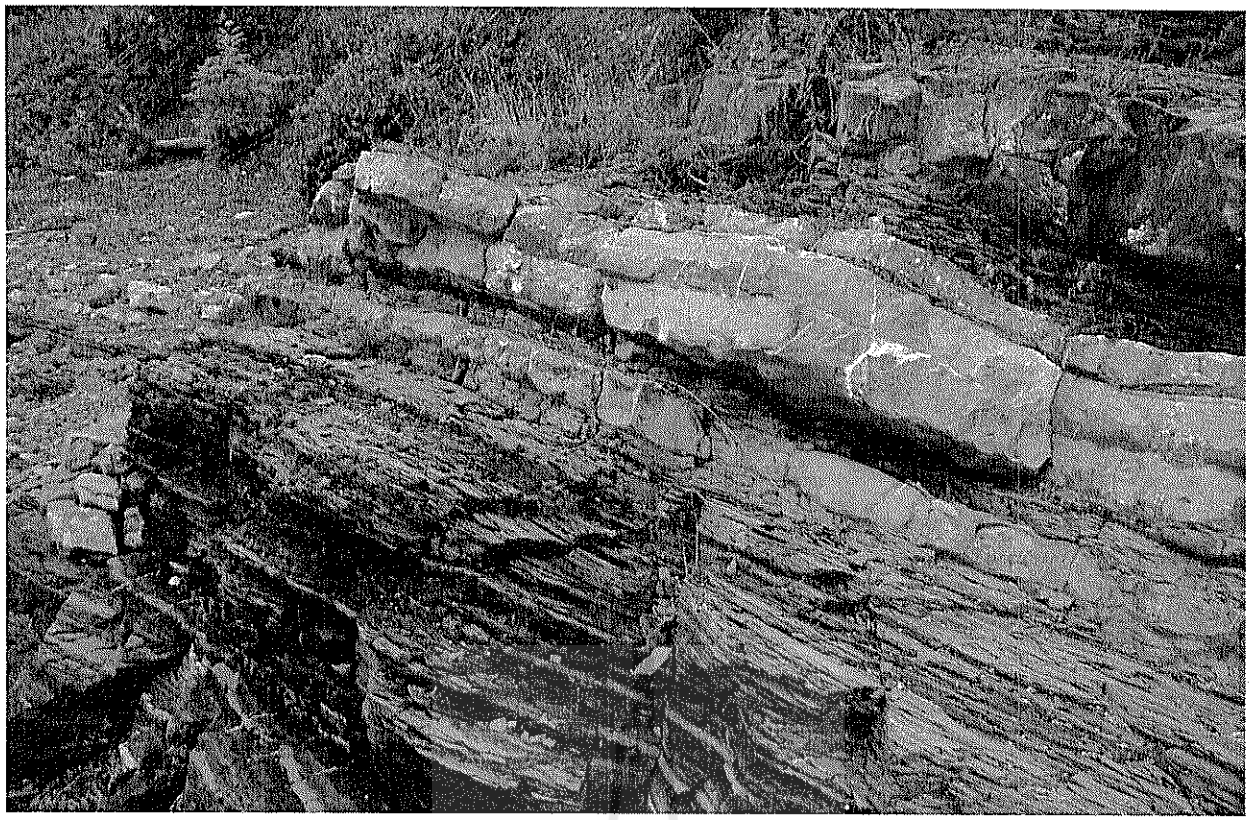








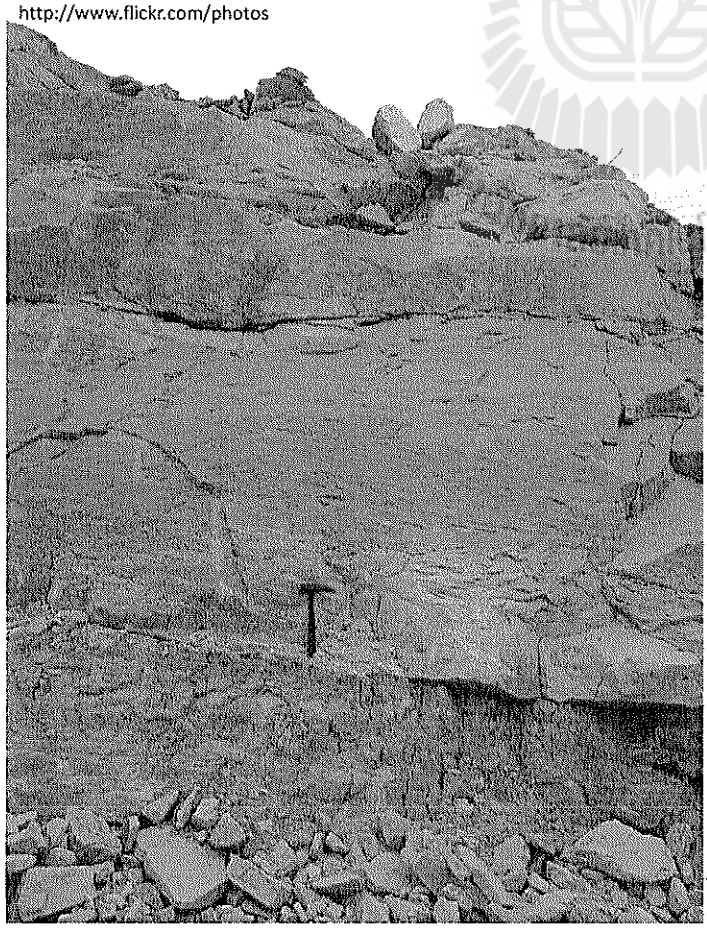
http://drannabalog.com/



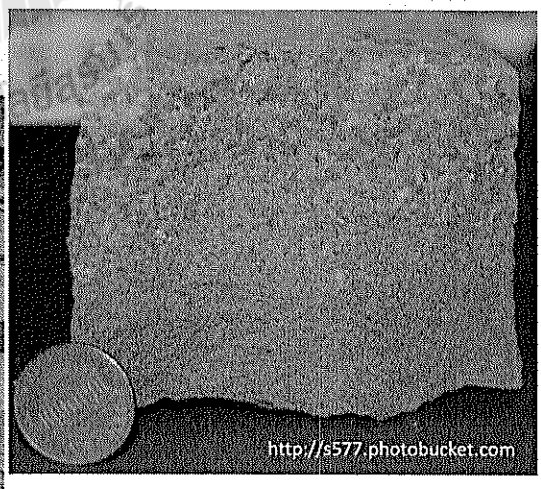
http://ucrtoday.ucr.edu

Shale interbedded with limestone

http://www.flickr.com/photos



Siltstone





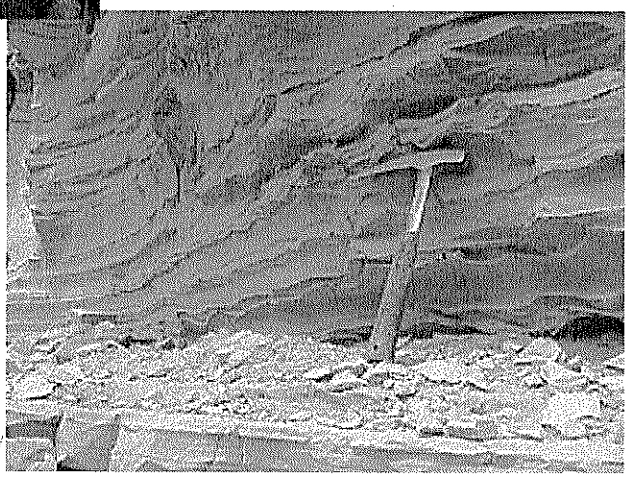
Mudstone

http://www.pitt.edu/



Claystone

http://en.wikipedia.org/wiki/Claystone



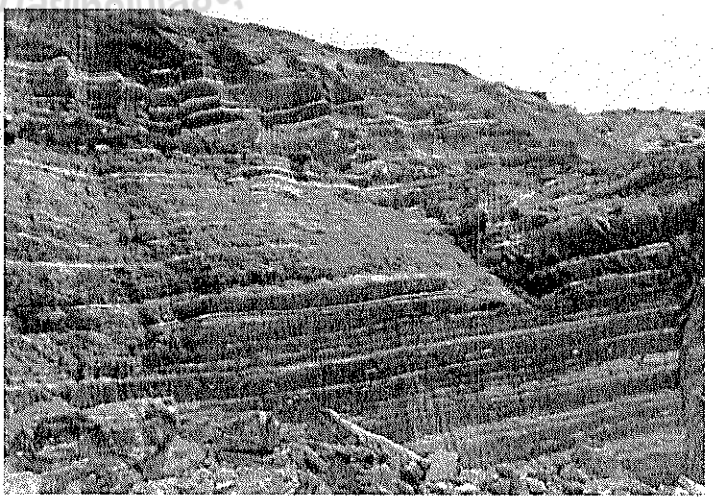
Biochemical sedimentary rocks

Biochemical sedimentary rocks: rocks which are created when organisms use materials dissolved in air or water to build their tissue.

Coal: Carbon
Limestone: Calcium carbonate
Chert: Silica
Coquina: Shell fragments

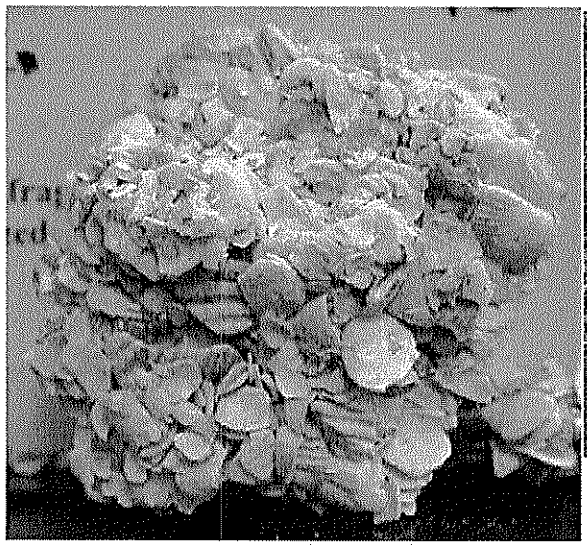
Coal: sedimentary rock forming from compaction of partially decayed plant materials (organic material deposited in water with low oxygen content)





http://www.kosovo-mining.org

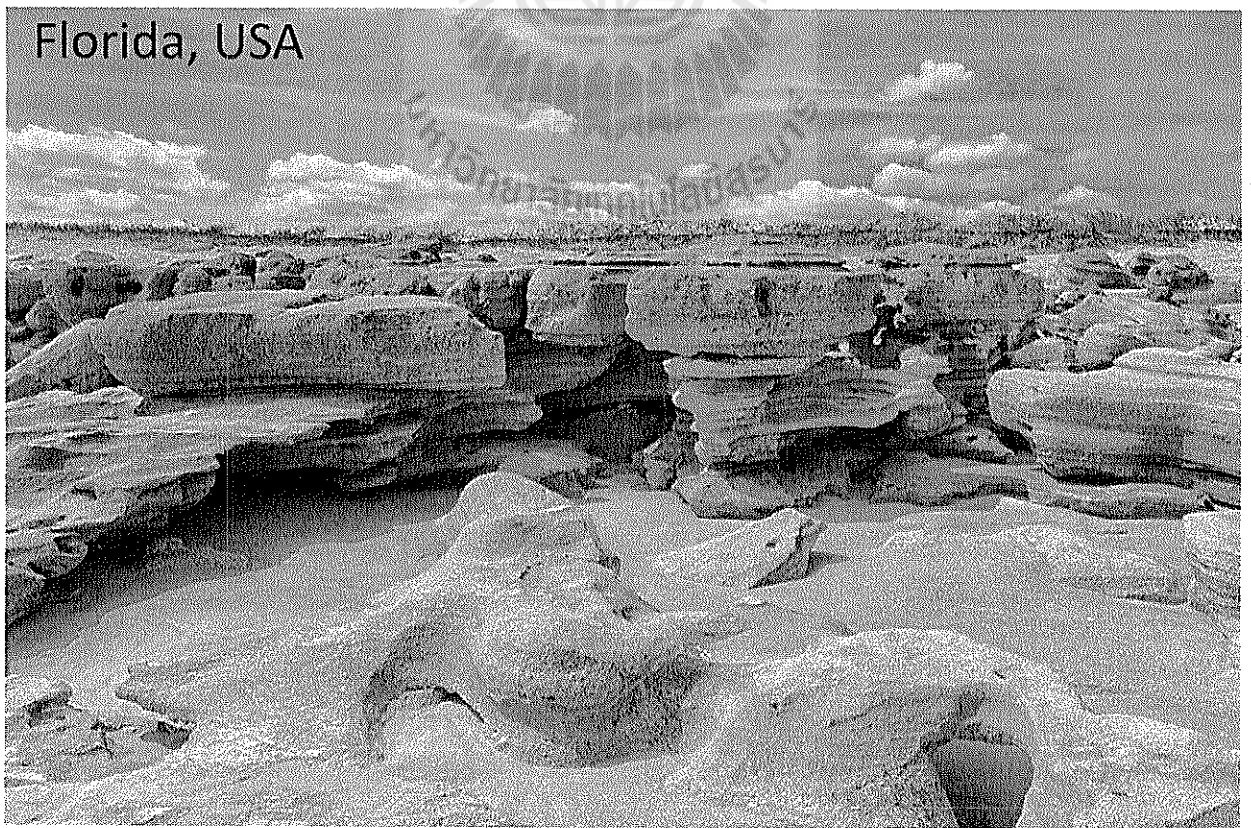




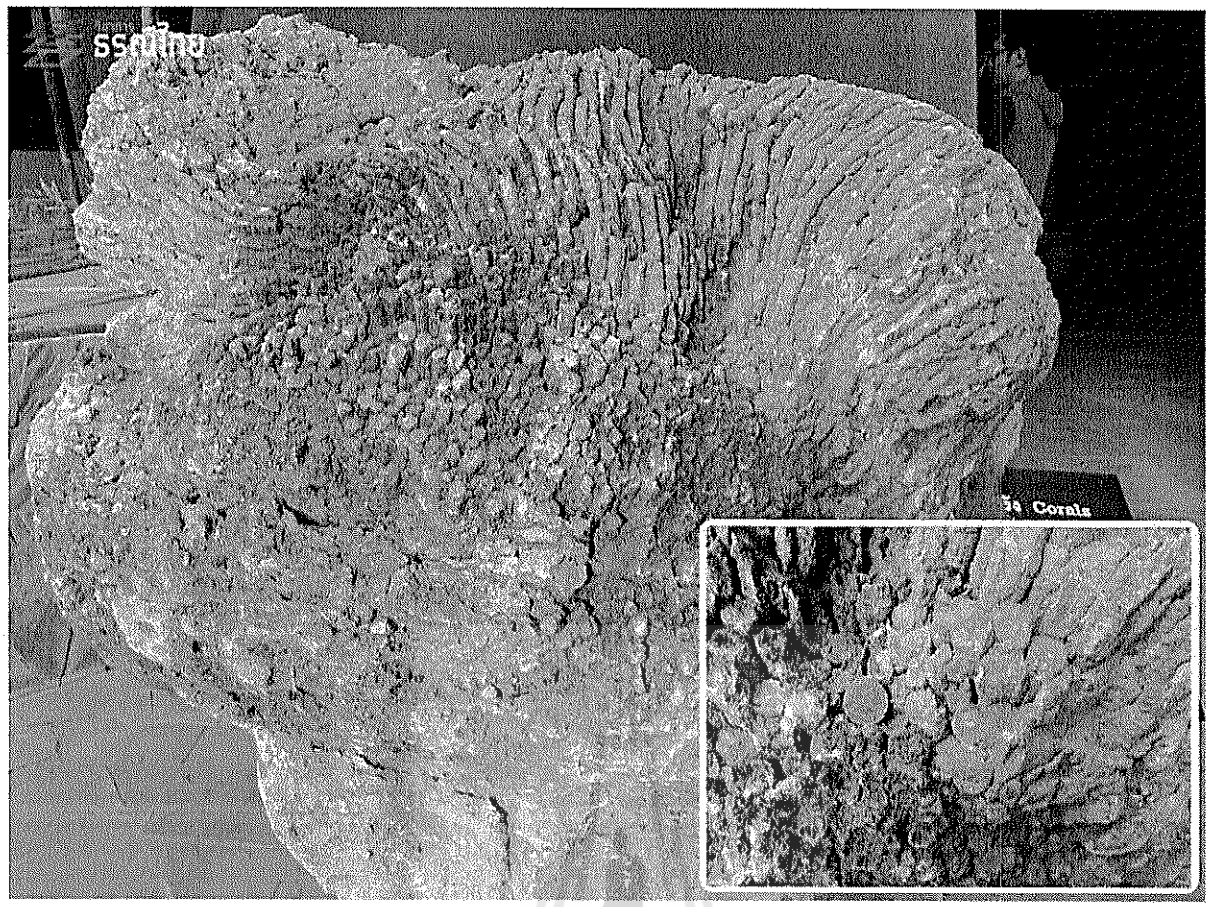


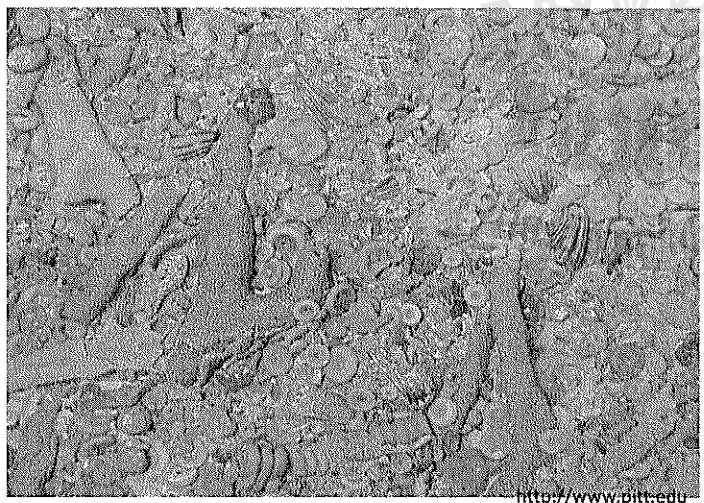
http://www.seriouslyfunnyscience.com/

Coquina: composed either wholly or almost entirely of the transported, abraded, and mechanically sorted fragments of the shells of either mollusks, trilobites, brachiopods, or other invertebrates.



http://www.imagesbyadam.com/



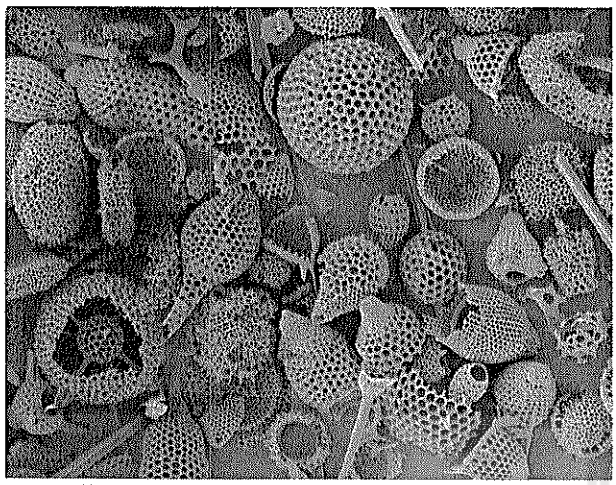


http://www.pitt.edu

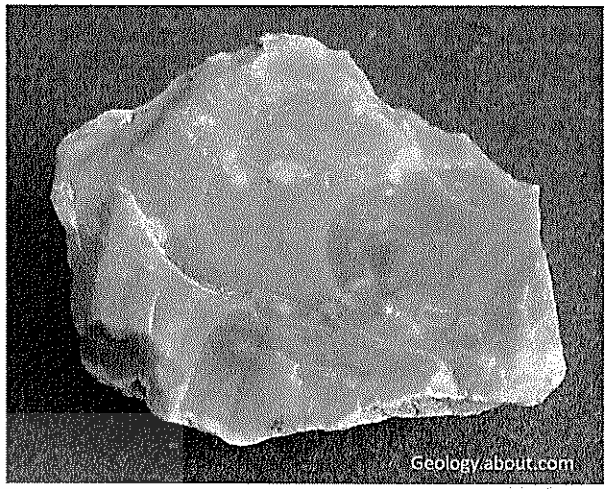
Fossiliferous limestone



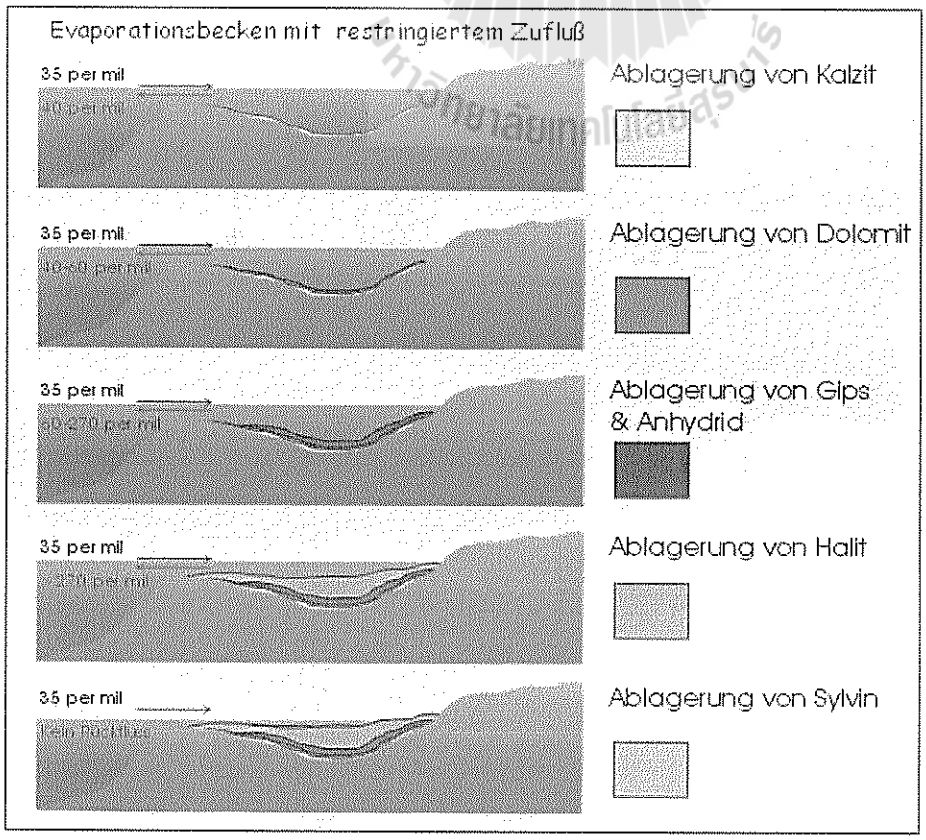
Chert: a sedimentary rock rich in silica which formed by radiolarian (protozoa) oozes.



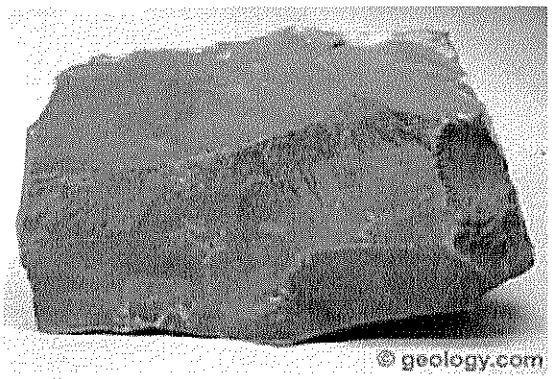
https://farm8.staticflickr.com

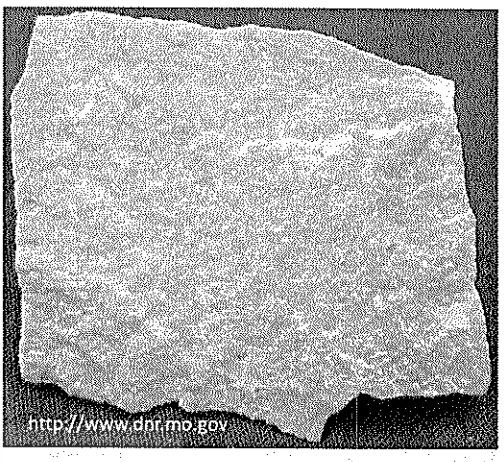


Chemical sedimentary rocks

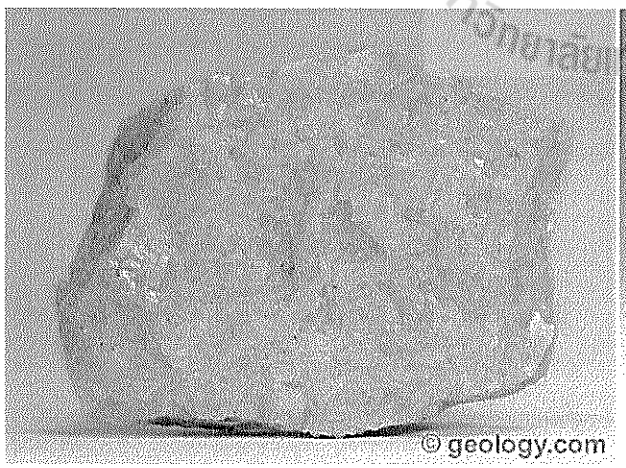


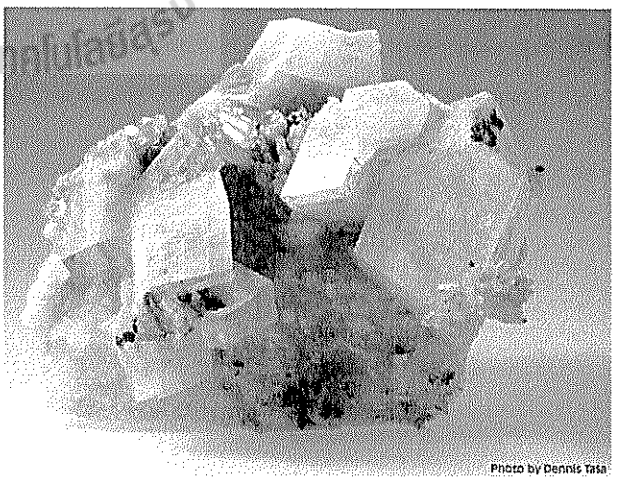
Limestones: composed mainly of calcite, most are biochemical, but can be inorganic.



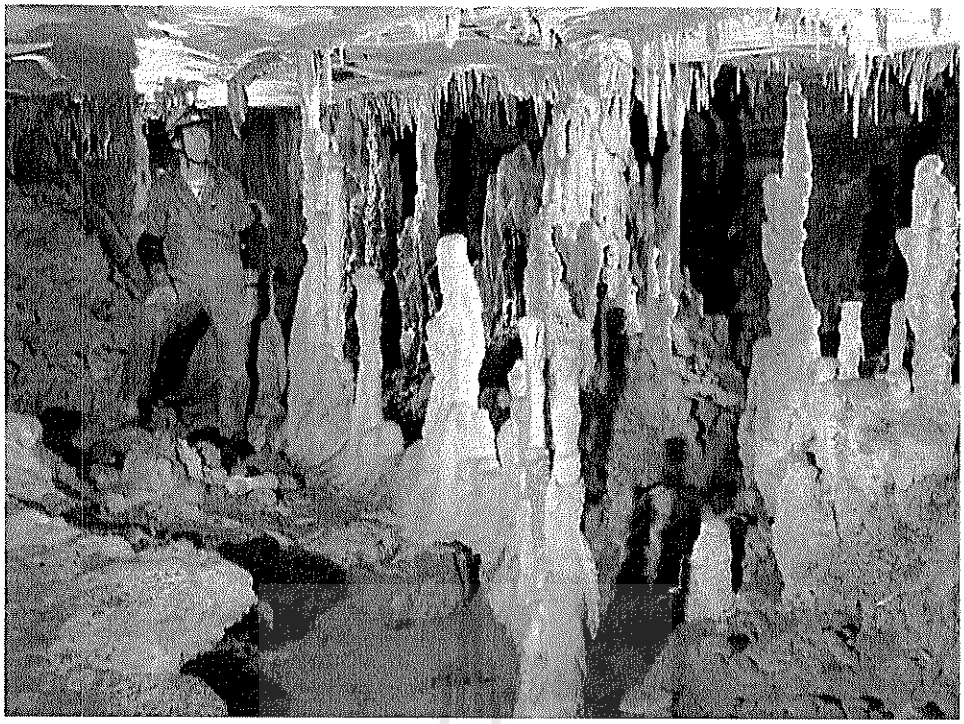


Chemical alteration of limestone in Mg-rich water solutions can produce "dolomite".



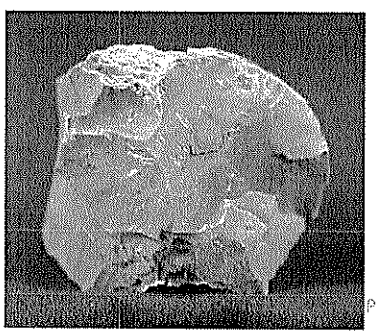


http://lovepeaceandharmony.org/



Travertine: forms as calcite-rich water drips from the ceiling of limestone cave.

Chert: hard, compact, fine-grained, formed almost entirely of silica. Chert can occur as layers or as lumpy nodules within other sedimentary rocks such as limestone.





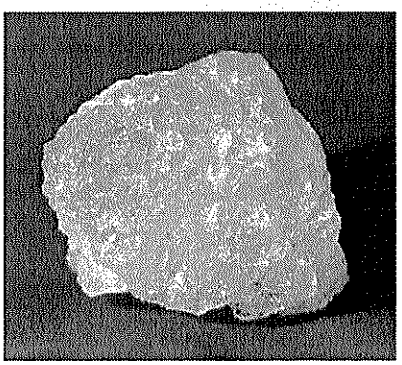
Bedded chert

Nodular chert

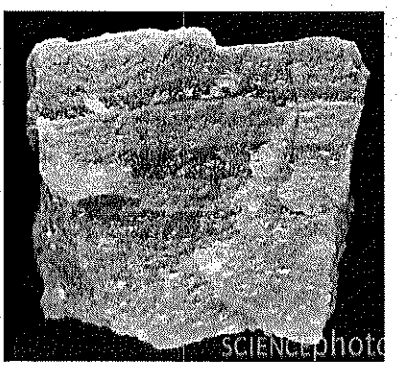


Physical Geo

Evaporites: form from evaporating saline waters (lake, ocean), common examples are rock gypsum, anhydrite, rock salt (halite, sylvite)

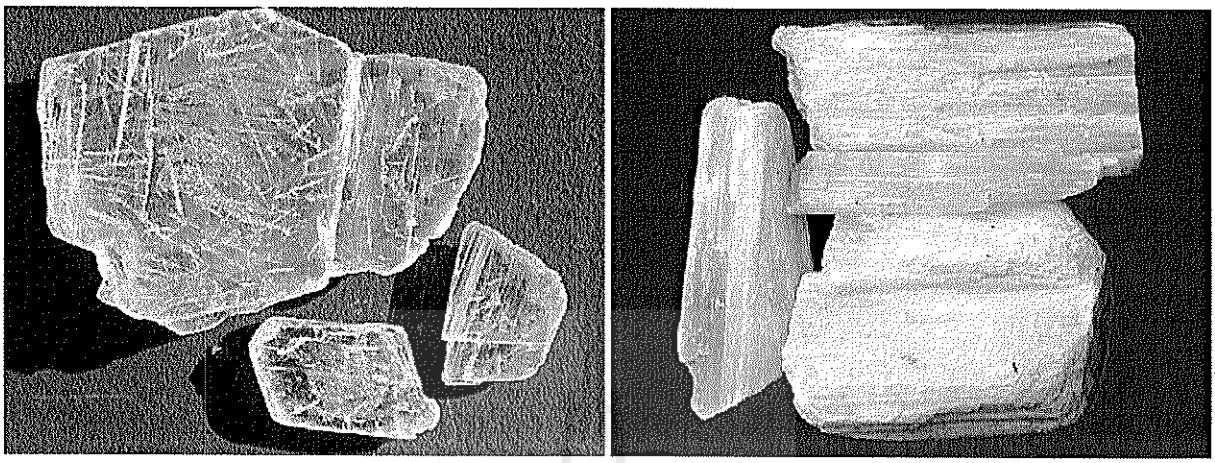






มหาวิทยาลัยเทคโนโลยีสุรนารี

Gypsum varieties:
Selenite - clear crystals, displaying one perfect cleavage
Alabaster - blocks of featureless white rock
Satin spar - silky fibrous blocks

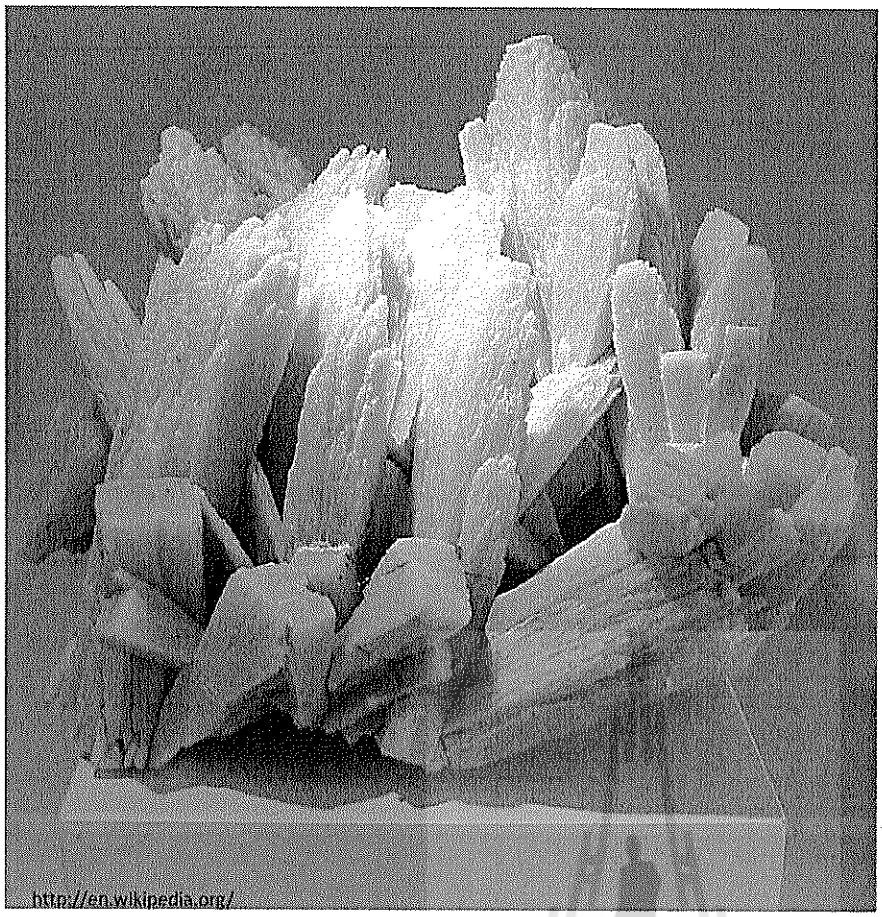


http://www.pitt.edu/



The Crystal Cave, Maxico

http://www.adventuremedicine.net/

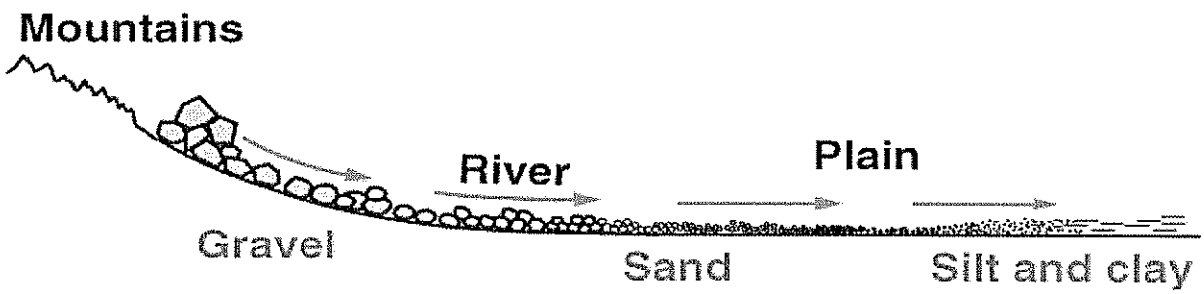


Anhydrite

Environment of deposition

In sedimentary rock interpretation, two things need to be understood,

1) Source area and 2) Depositional environment



Source area: locality that eroded and provided sediment.

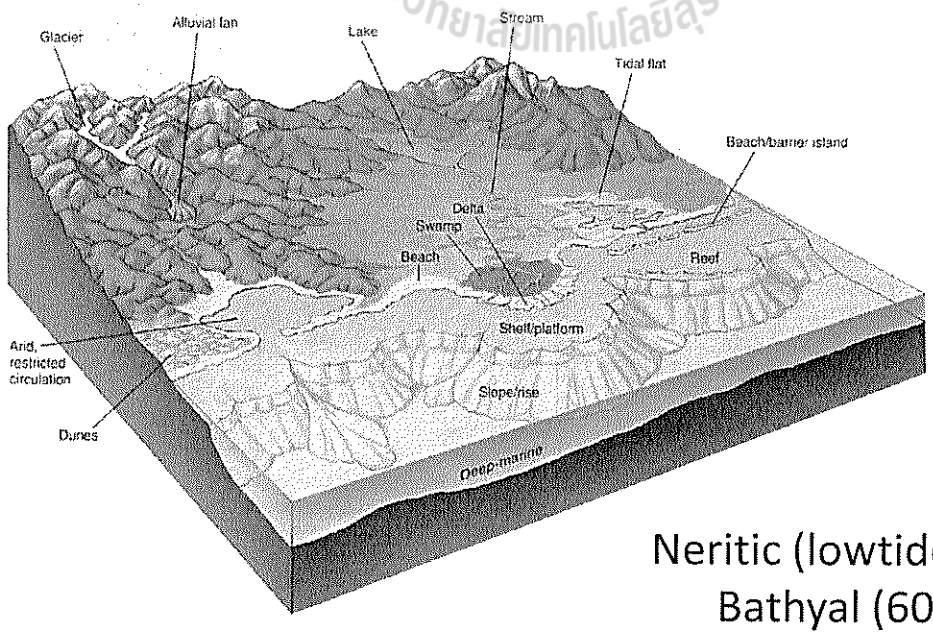
- Sediment composition, shape, size and sorting are indicators of source rock type and relative location

Depositional environment: Location where sediments came to rest.

- Sediment characteristics and sedimentary structures (including fossils) are indicators.

Continental: colluvial, alluvial, fluvial, larcustrine, desert, glacial environments

Transitional:
Deltaic
Estuarine
Lagoon
Intertidal



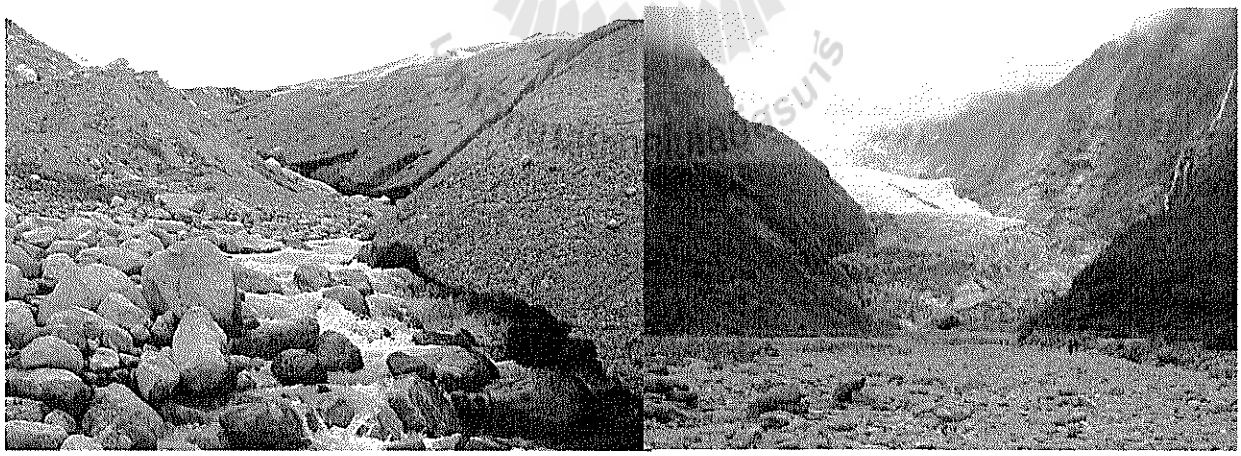
Marine:
Reef
Neritic (lowtide – 600 ft.)
Bathyal (600-6000 ft.)
Abyssal (> 6000 ft.)

Continental: on land setting caused by water, wind and glacial processes including colluvial, alluvial, fluvial, larcustrine, desert, glacial environments

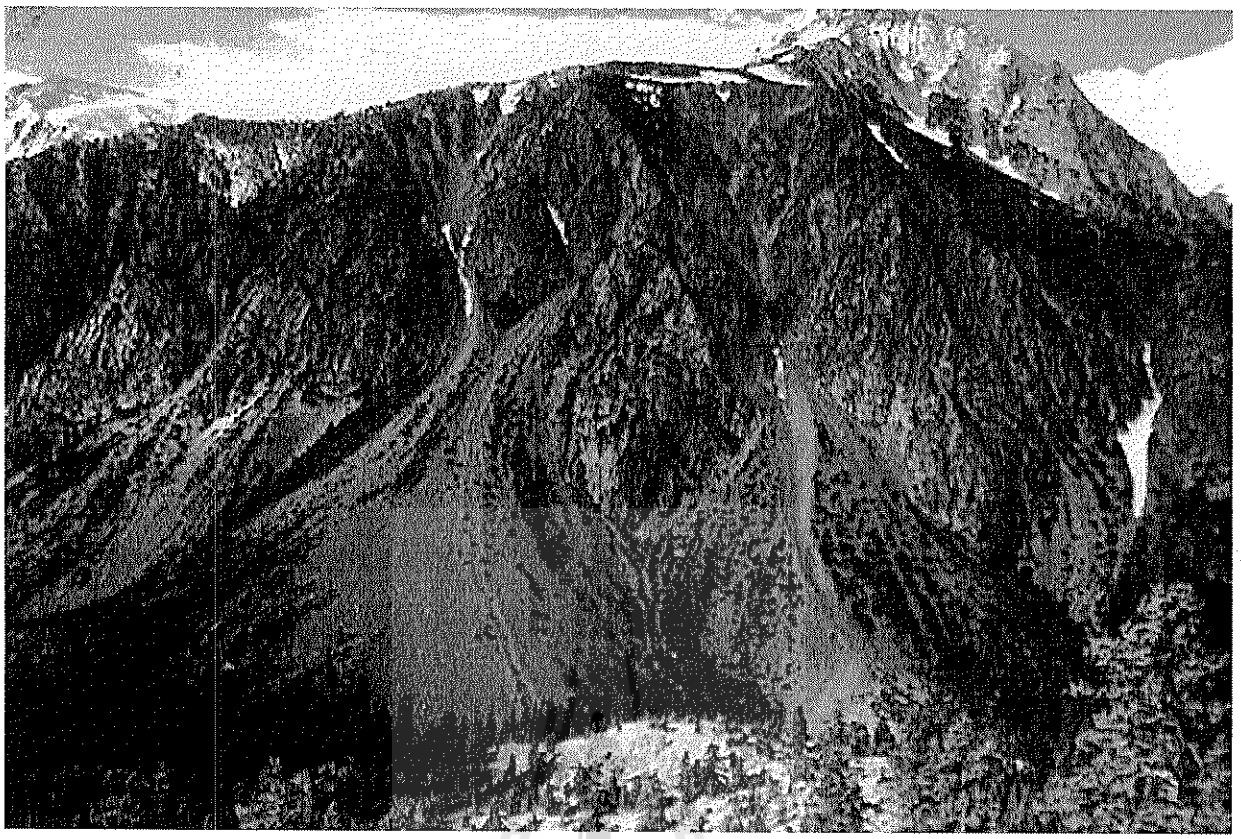
Transitional: between land and sea caused mainly by wave and tide processes includes deltaic, estuarine, lagoon, intertidal, beach environments

Marine: deposition under sea water caused by wave and gravity processes includes reef, neritic (low tide – 600 ft.), bathyal (600-6000 ft.), abyssal (> 6000 ft.) environments

Glacial deposit



Colluvial deposit





Fluvial deposit

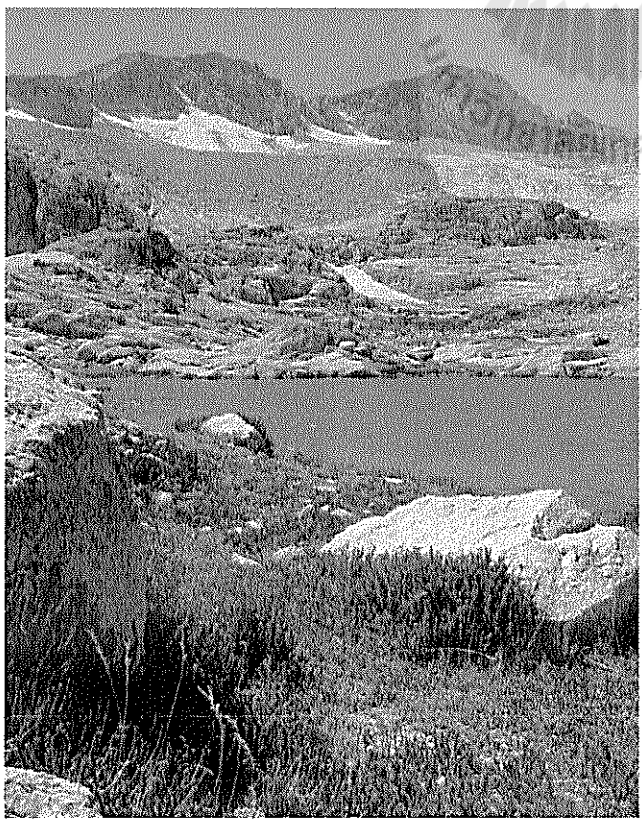


http://markgelbart.wordpress.com/



http://www.airphotona.com

Lacustrine (lake)











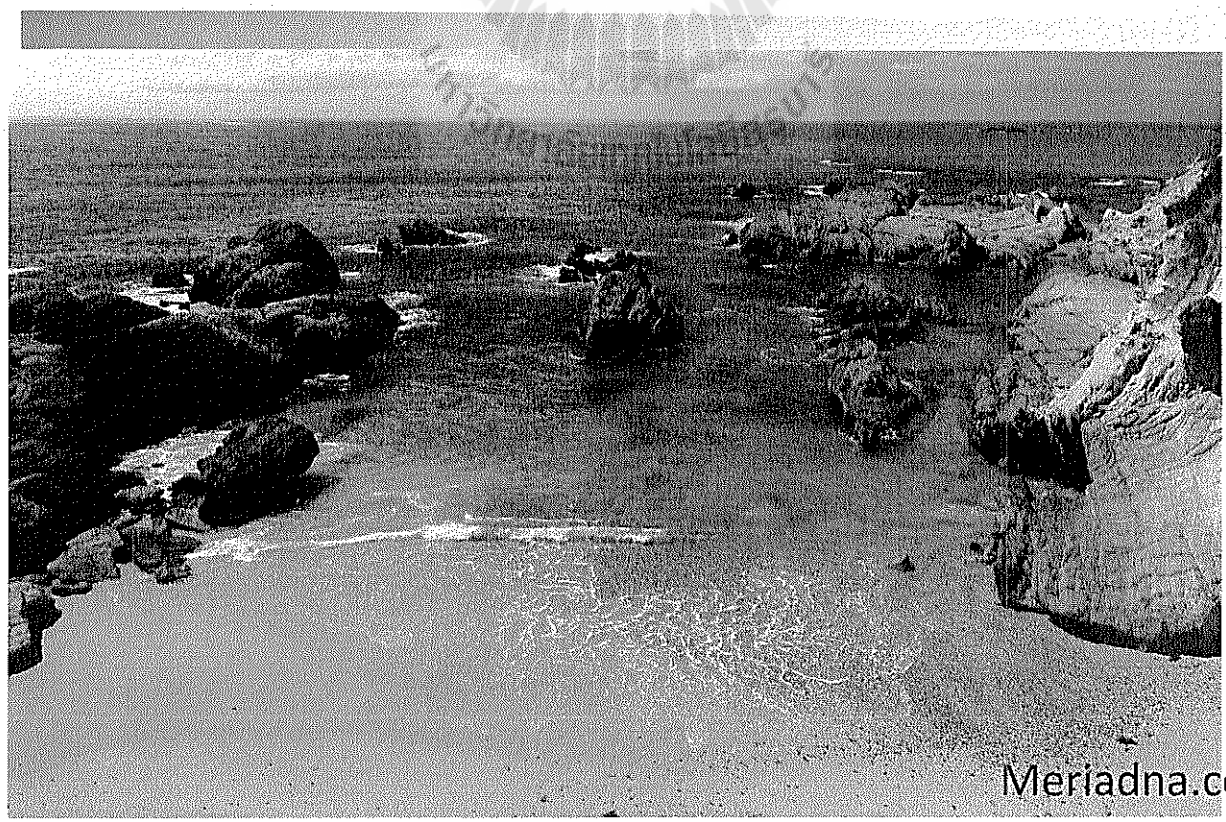
http://www.unige.ch/

Desert

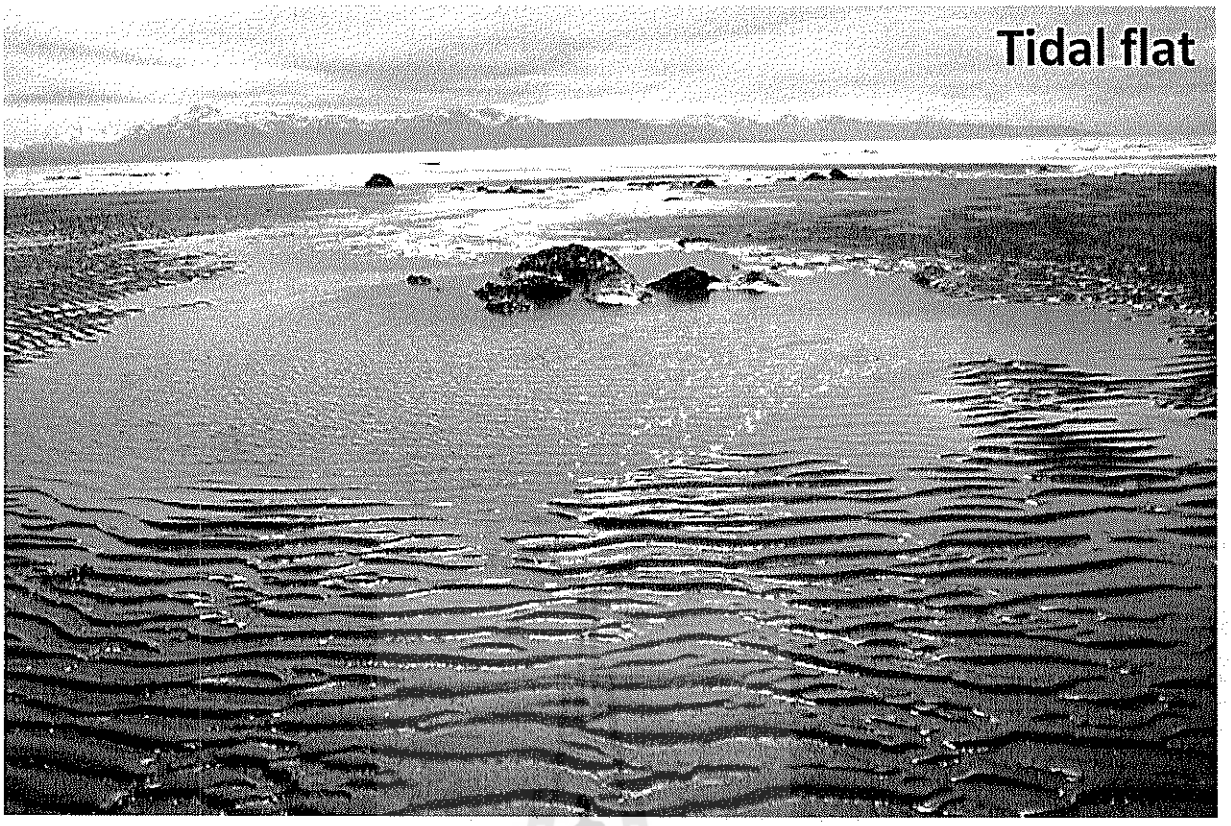




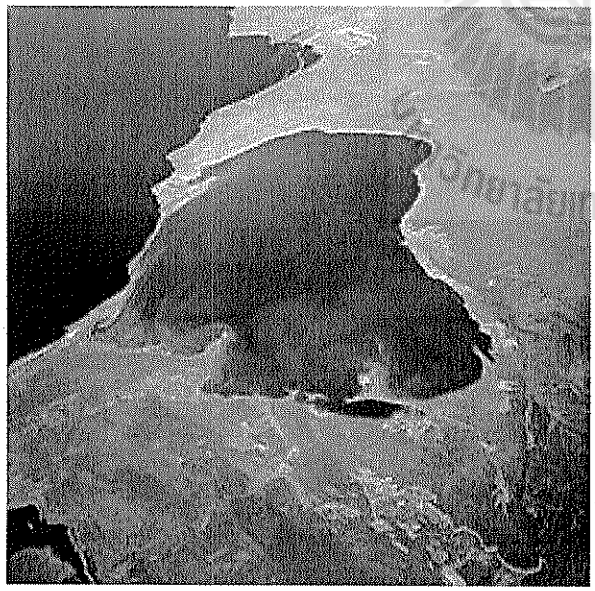
Shore zone



Tidal flat



http://www.marlimillerphoto.com/



http://en.wikipedia.org/

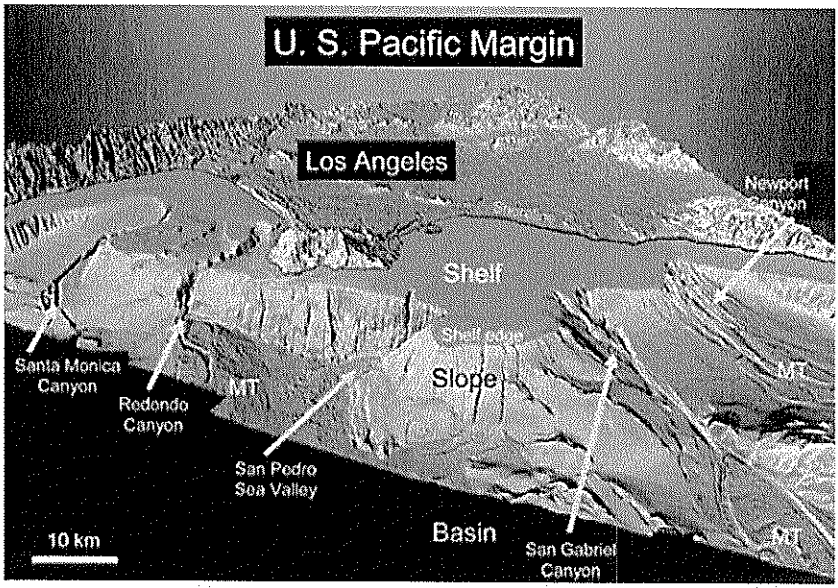
Lagoon



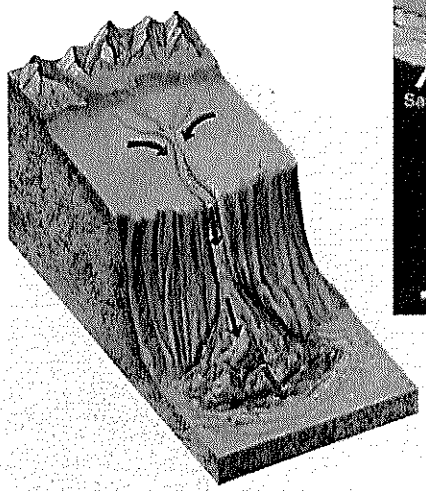
http://weknowwearecute.undebug.org



Continental slope

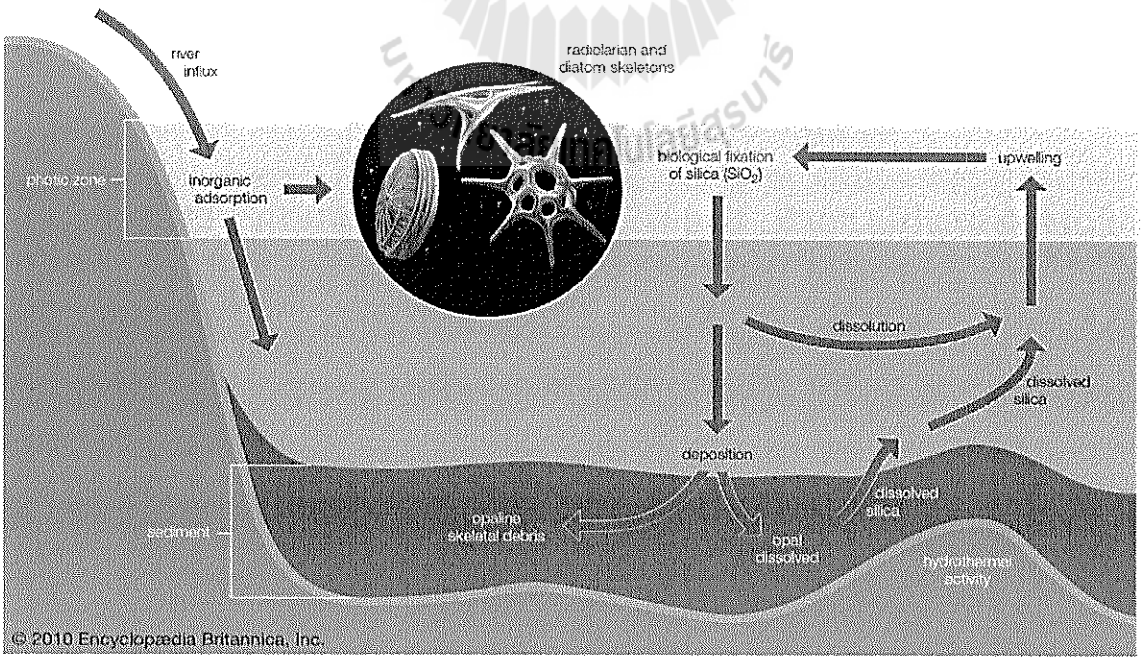


http://www.dkimages.com/



Submarine canyon
Deep sea fan

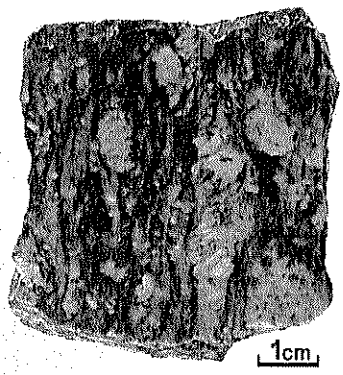
Abyssal plain

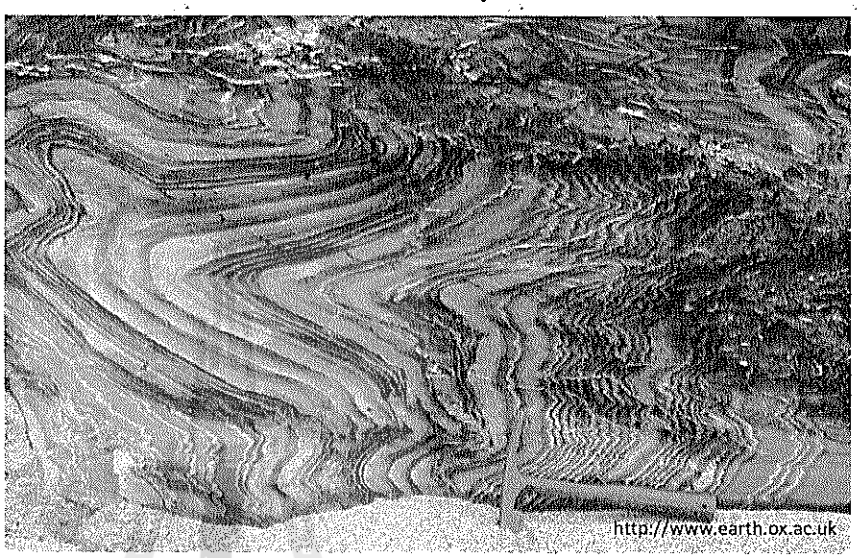


5. Metamorphic Rocks

Contents

- Definition
- Causes and results of metamorphism
- Classification of metamorphic rocks
- Environments of metamorphism



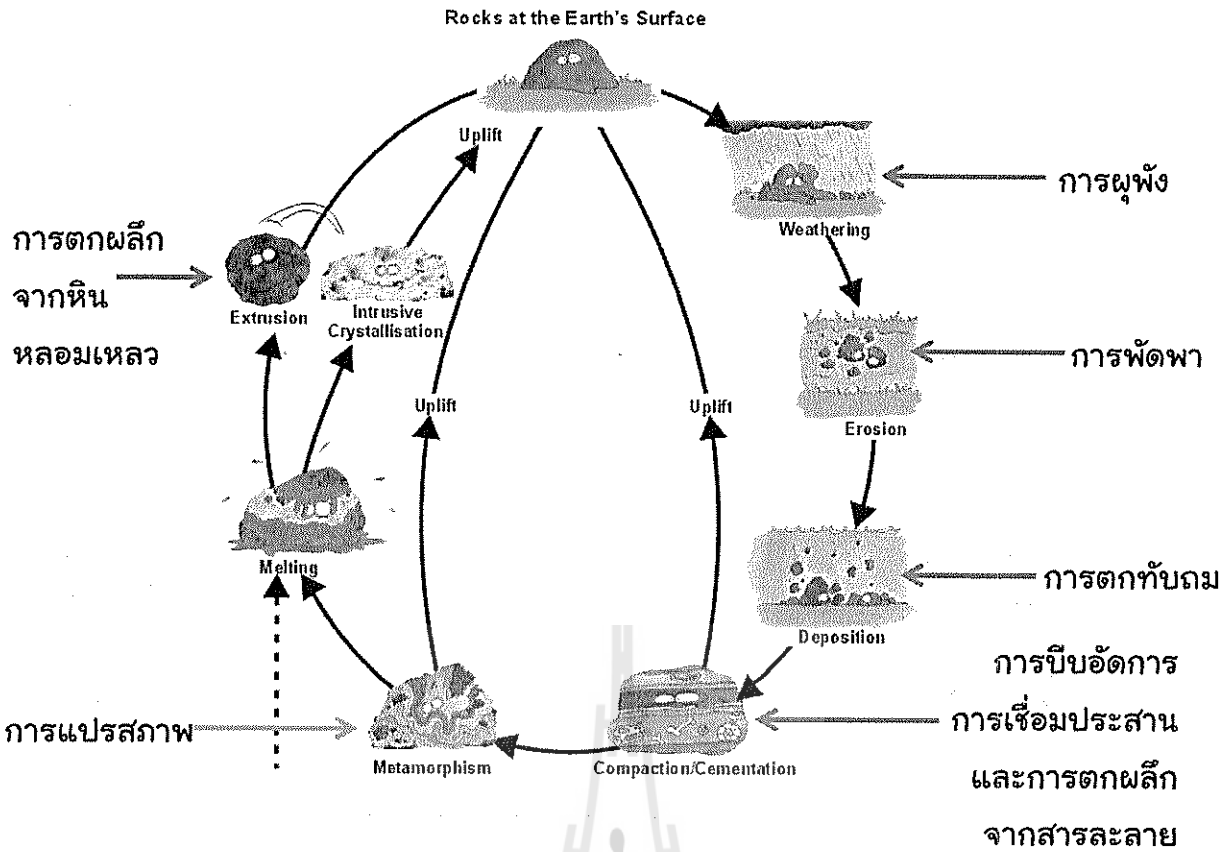


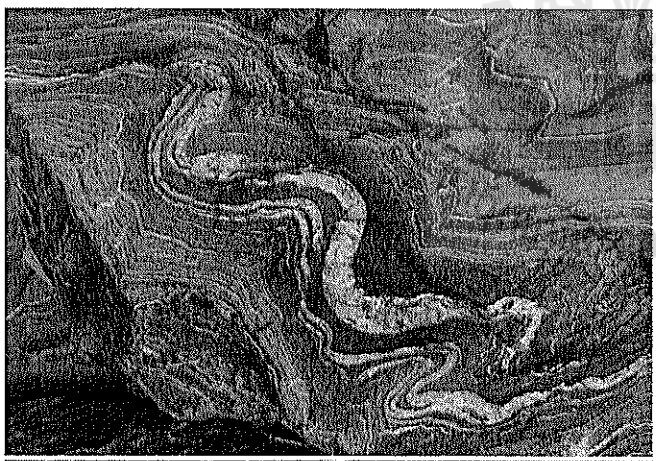
Definition

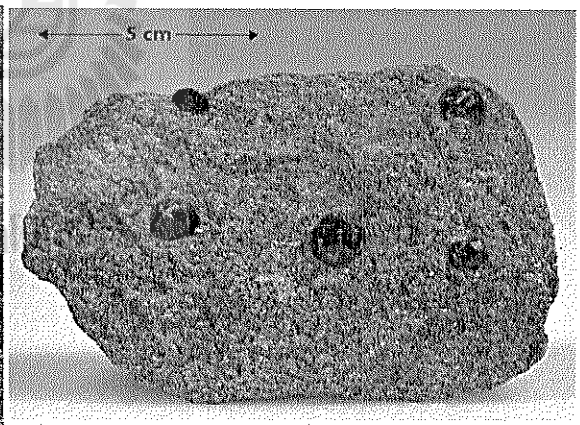
Meta (Greek) + Morphe (Greek)
(change) (form)

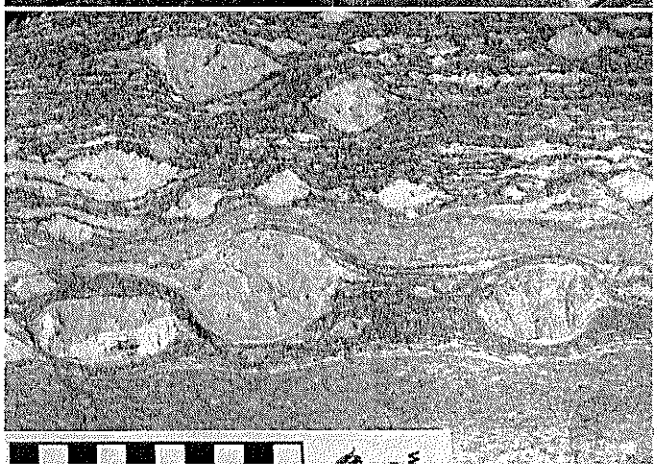
Metamorphic rock: the rock that forms when preexisting rock undergoes a solid-state change in response to changes in temperature, pressure, or differential stress or in response to interactions with hydrothermal fluids.

The process of change is called **metamorphism**.









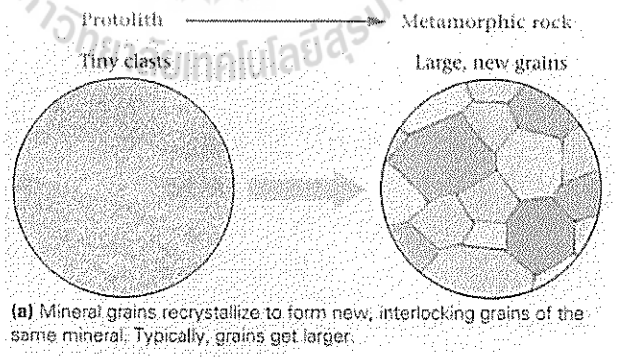
Metamorphism produces
- new minerals that did not occur in preexist rock
- a new texture (arrangement of mineral grains)

Causes and results of metamorphism

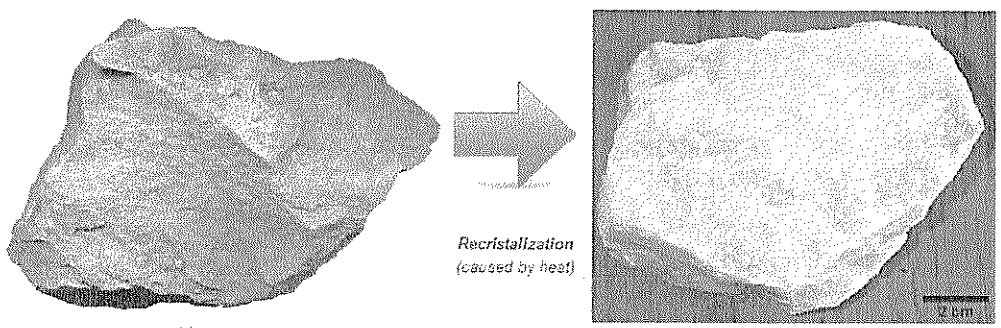
Processes of metamorphism are:

Recrystallization
Phase change
Neocrystallization
Pressure solution
Plastic deformation

Recrystallization – changes the shape and size of grains without changing the identity of the minerals.

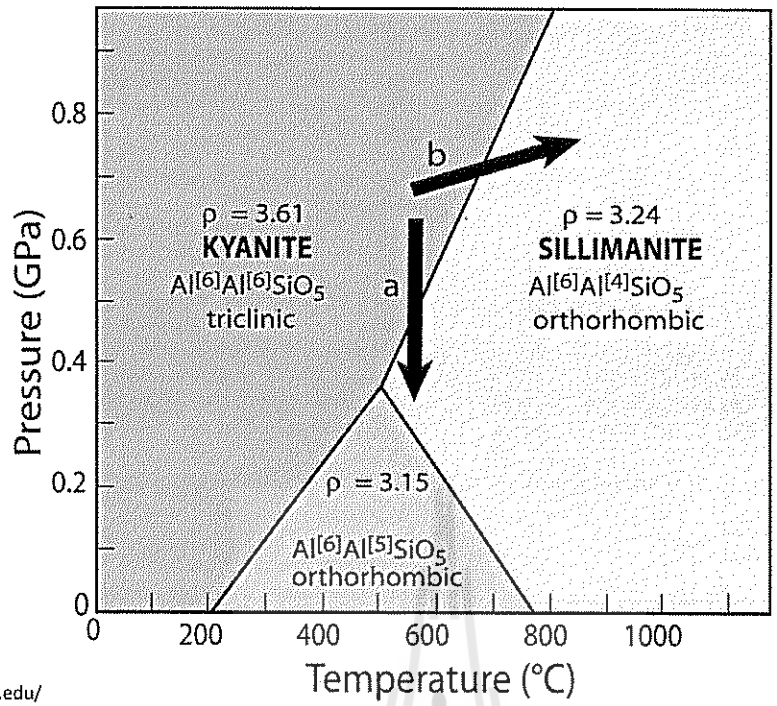


(a) Mineral grains recrystallize to form new, interlocking grains of the same mineral. Typically, grains get larger.



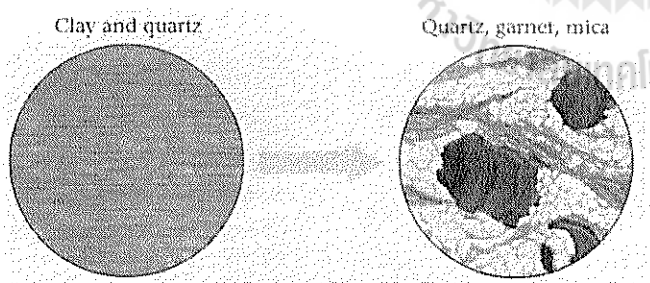
Limestone Marble

Phase change – transforms one mineral into another mineral with the same composition but different structure.

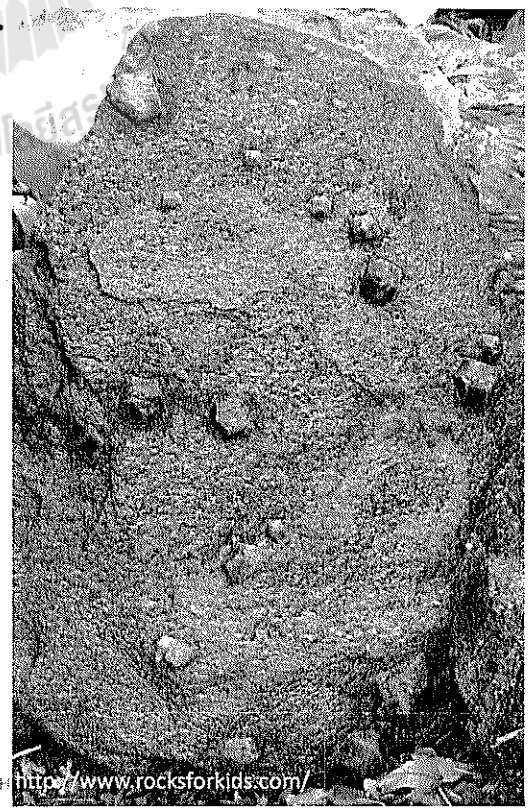


http://serc.carleton.edu/

Neocrystallization – the growth of new minerals crystals that differ from the preexist rocks.

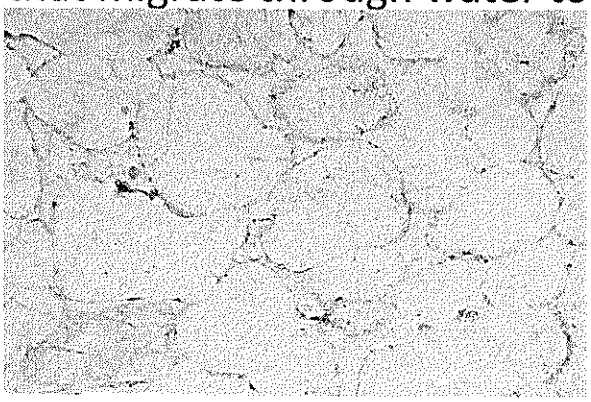


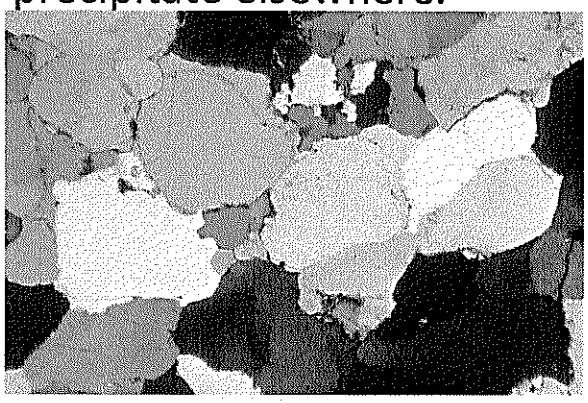
(b) Chemical reactions change the original assemblage of minerals into a new, metamorphic assemblage of minerals.



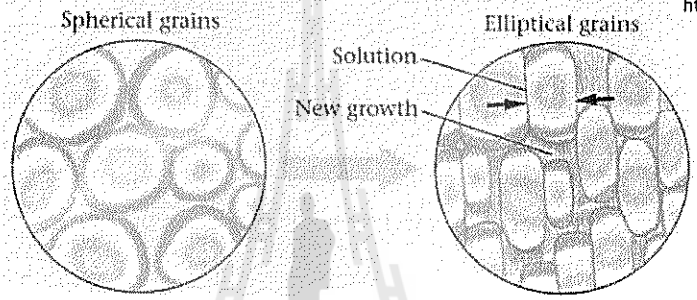
 http://www.rocksforkids.com/

Pressure solution – mineral grains dissolve where their surfaces are pressed against other grains, producing ions that migrate through water to precipitate elsewhere.



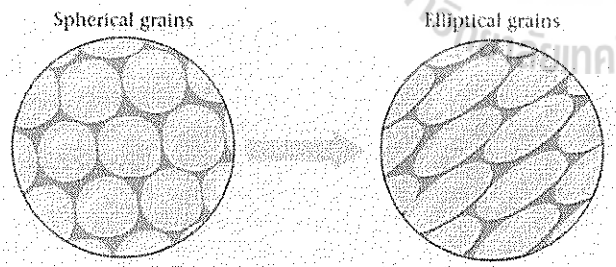


http://www.earth.ox.ac.uk

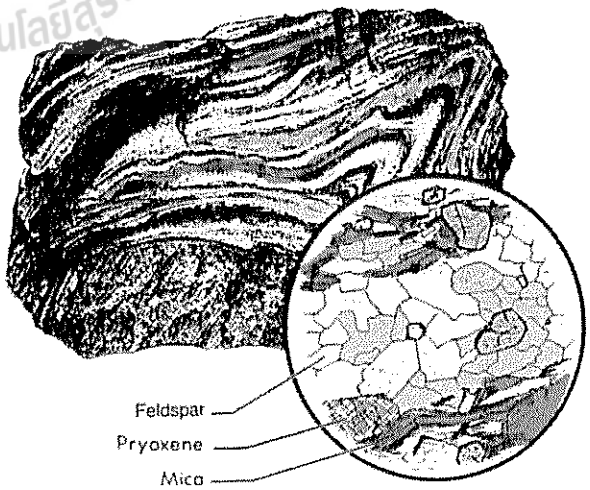


111

Plastic deformation – a rock is sheared at elevated temperatures, minerals change in shape without breaking.



(d) Plastic deformation changes the shape of grains—without breaking them—as a result of squeezing or shear at high temperatures.



http://www.explanet.info/

Classification of metamorphic rocks

Metamorphic rocks are classified to **foliated rocks** and **nonfoliated rocks**.

Foliated rocks: having foliation (the repetition of planar surfaces or layer).

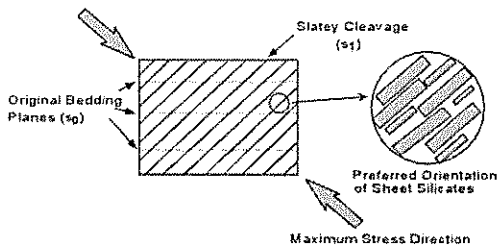
- Slate, Phyllite, Metaconglomerate, Schist, Gneiss

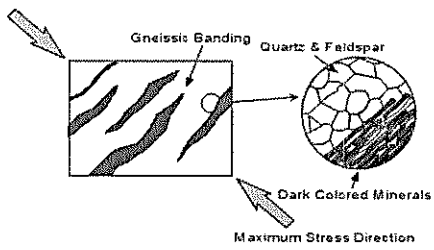
Nonfoliated rocks: containing minerals that recrystallized or grew during metamorphism, but without foliation.

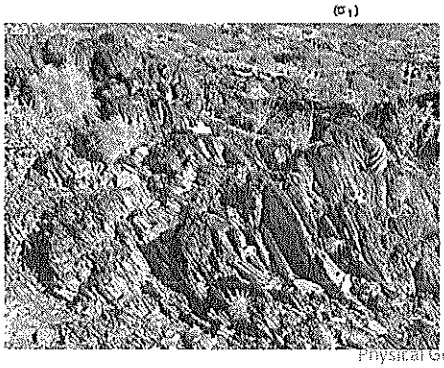
- Hornfels, Quartzite, Marble

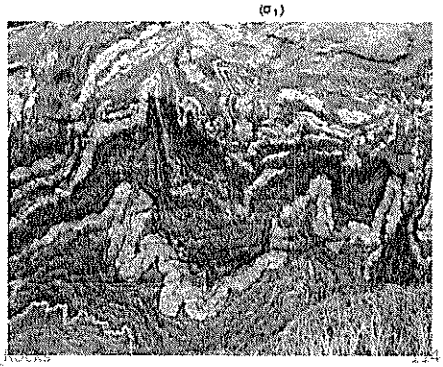
Foliated rocks: Slate, Phyllite, Metaconglomerate, Schist, Gneiss

Foliation: striped appearance in an outcrop, and/or ability to split into thin sheets.



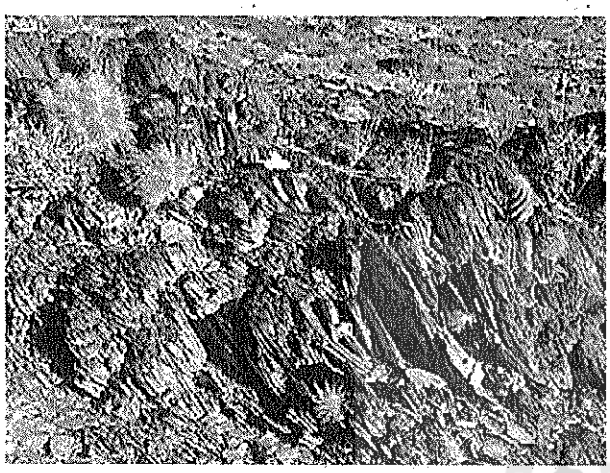


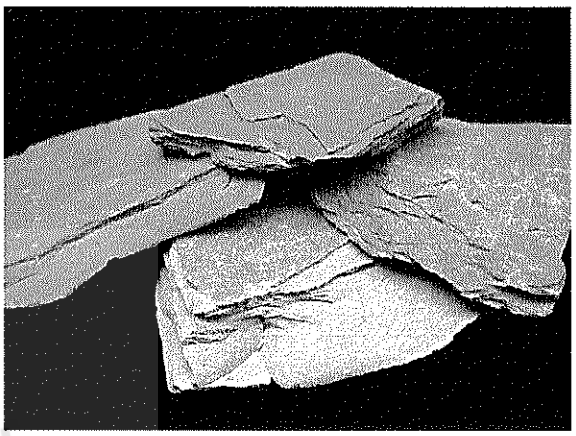




Slate: forms by metamorphism of shale or mudstone (rocks composed of clay) under low P and T.

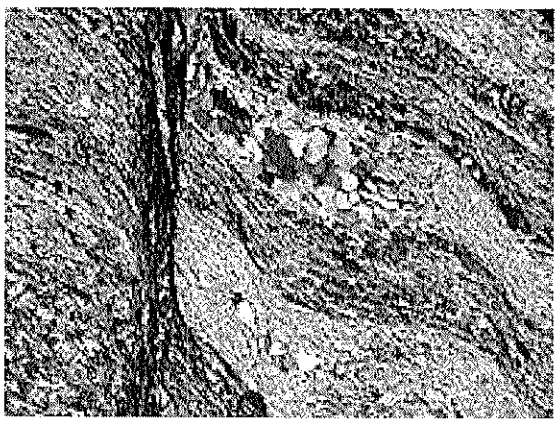
**Slaty cleavage allows it to split into thin sheets.

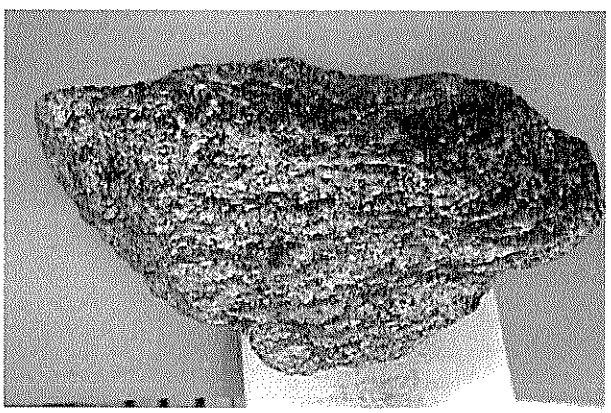




Phyllite: fine-grained metamorphic rock with foliation caused by preferring orientation of very fine-grained white mica. Temperature high enough to cause neocrystallization of white mica.

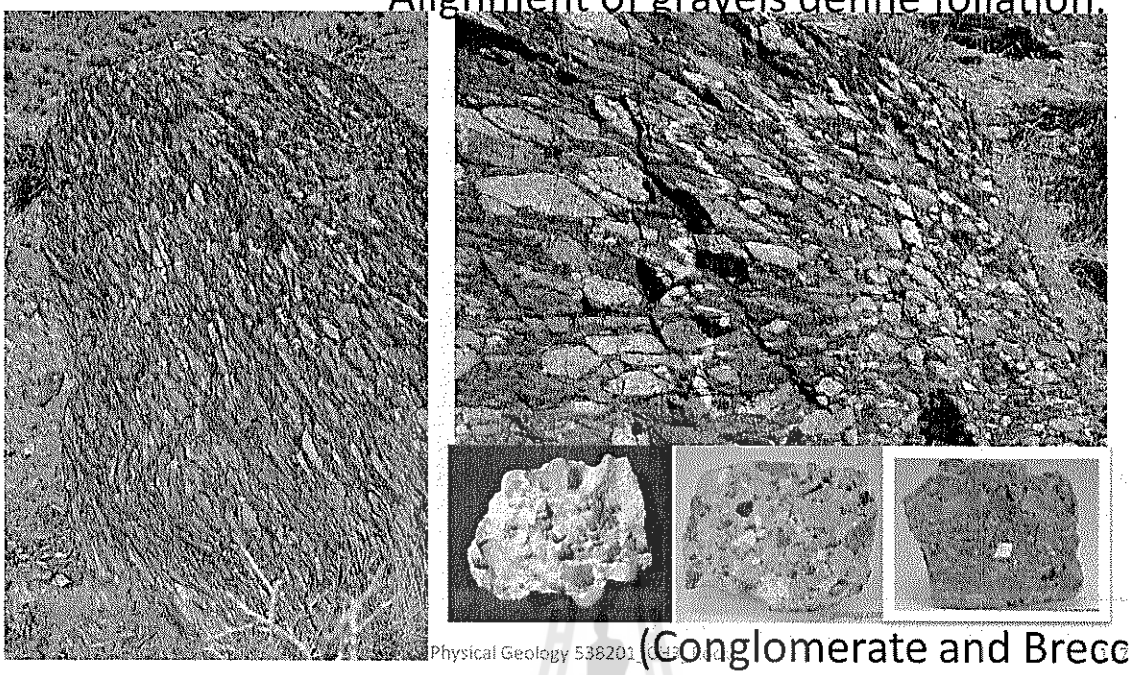
**Phyllitic luster, Phyllitic texture





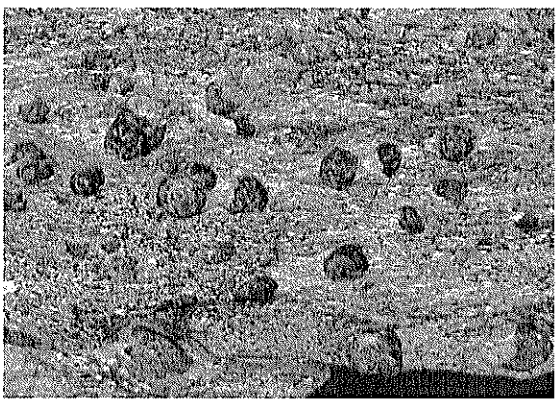
Metaconglomerate: under the conditions that produce slate or phyllite, if the preexist rock is conglomerate, it becomes metaconglomerate.

Alignment of gravels define foliation.



(Conglomerate and Breccia)

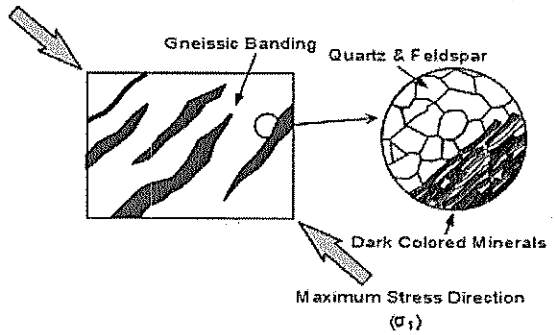
Schist: a medium- to coarse-grained metamorphic rock that process foliation called schistosity. Form at higher T than phyliite. *Schistosity: orientation of larger mica flakes (muscovite/biotite).

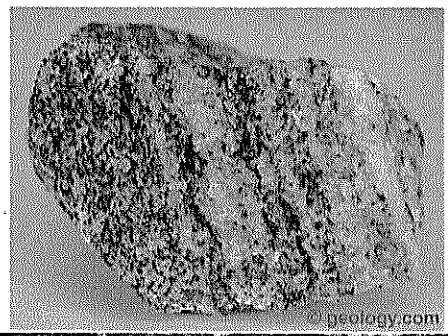


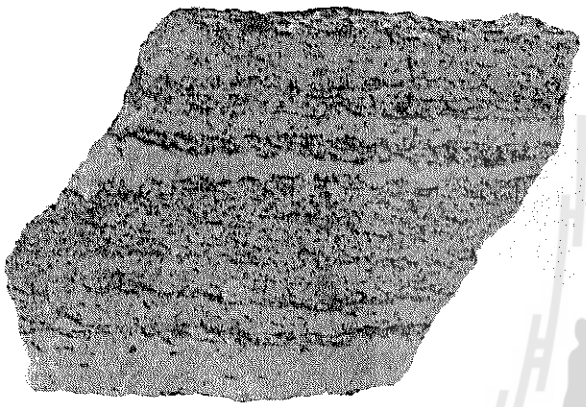


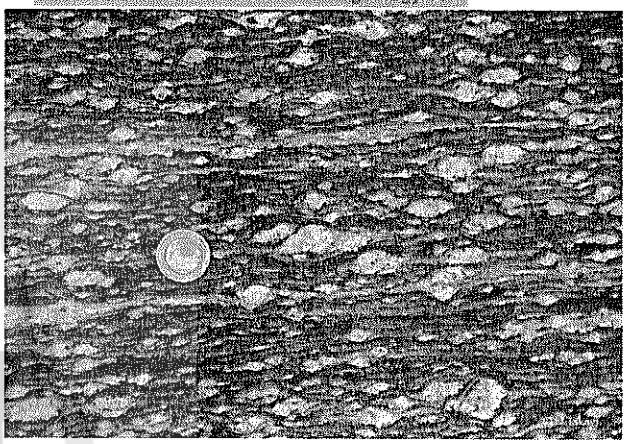
a garnet-kyanite-quartz schist. The large purple garnets look like candies. The kyanite grains are the bluish gray flat grains found here and there, especially in the top of the photo.

Gneiss: layered metamorphic rock composed of alternating dark-color and light-color layers called gneissic layering.







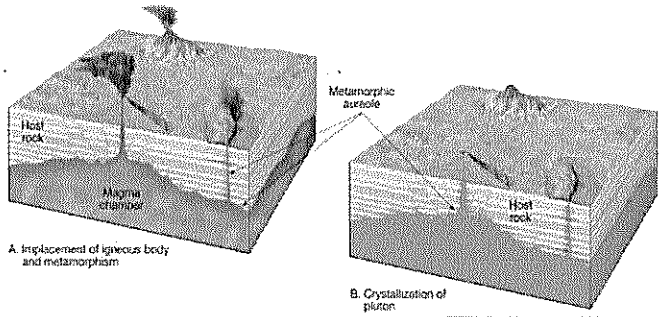


If gneiss begins to melt and produces felsic magma, then the melt freeze again before flowing out of the source area, it can produce a mixture of igneous rock with relict metamorphic rocks. It is called **migmatite**.

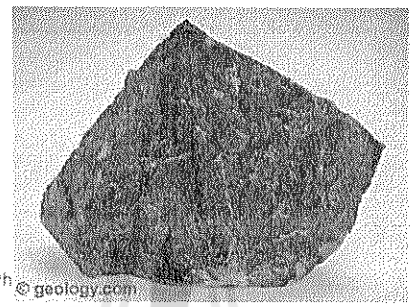


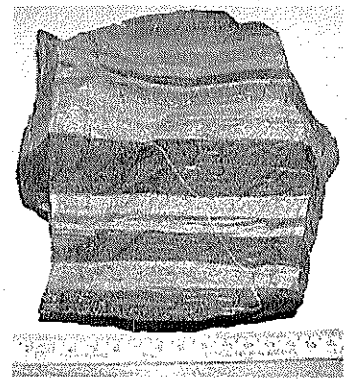
Nonfoliated rocks: Hornfels, Quartzite, Marble

Hornfels: variety of metamorphic minerals which depended on composition of preexist rock and T and P of metamorphism.

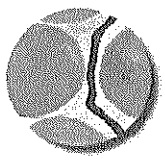


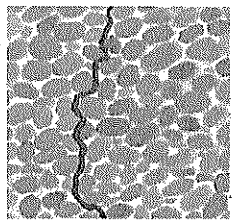


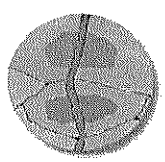


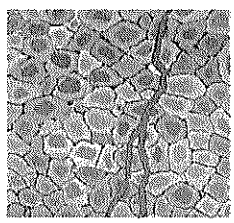


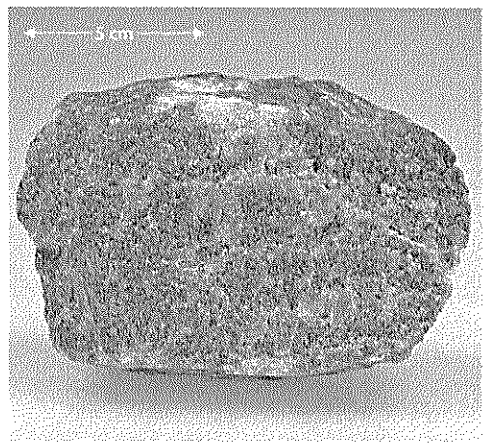
Quartzite: forms by metamorphism of pure quartz sandstone. Preexist quartz grains recrystallize create new larger grains, pore space disappears and grains become interlocking. If the rock cracks, the fracture cuts across grain boundaries.

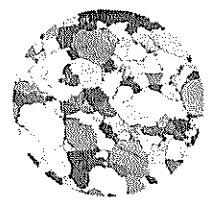






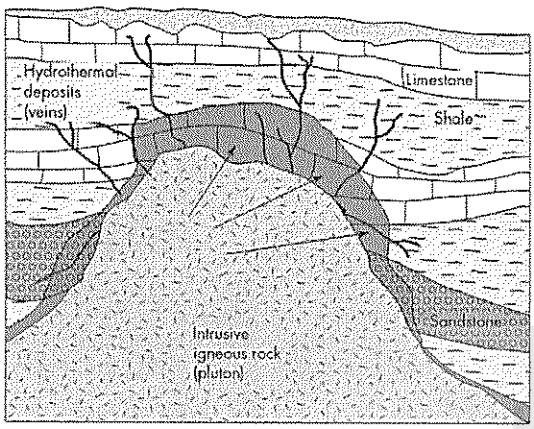


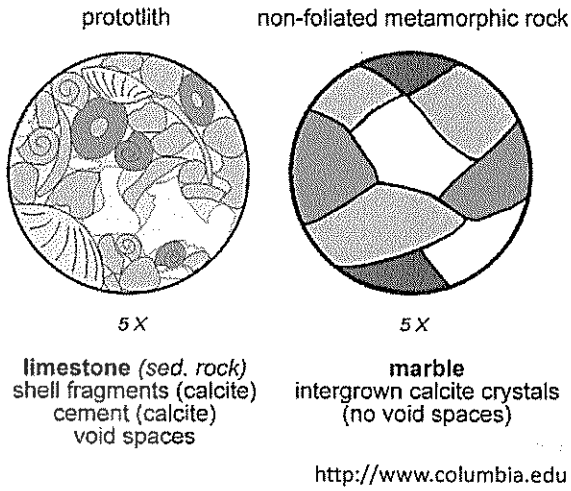




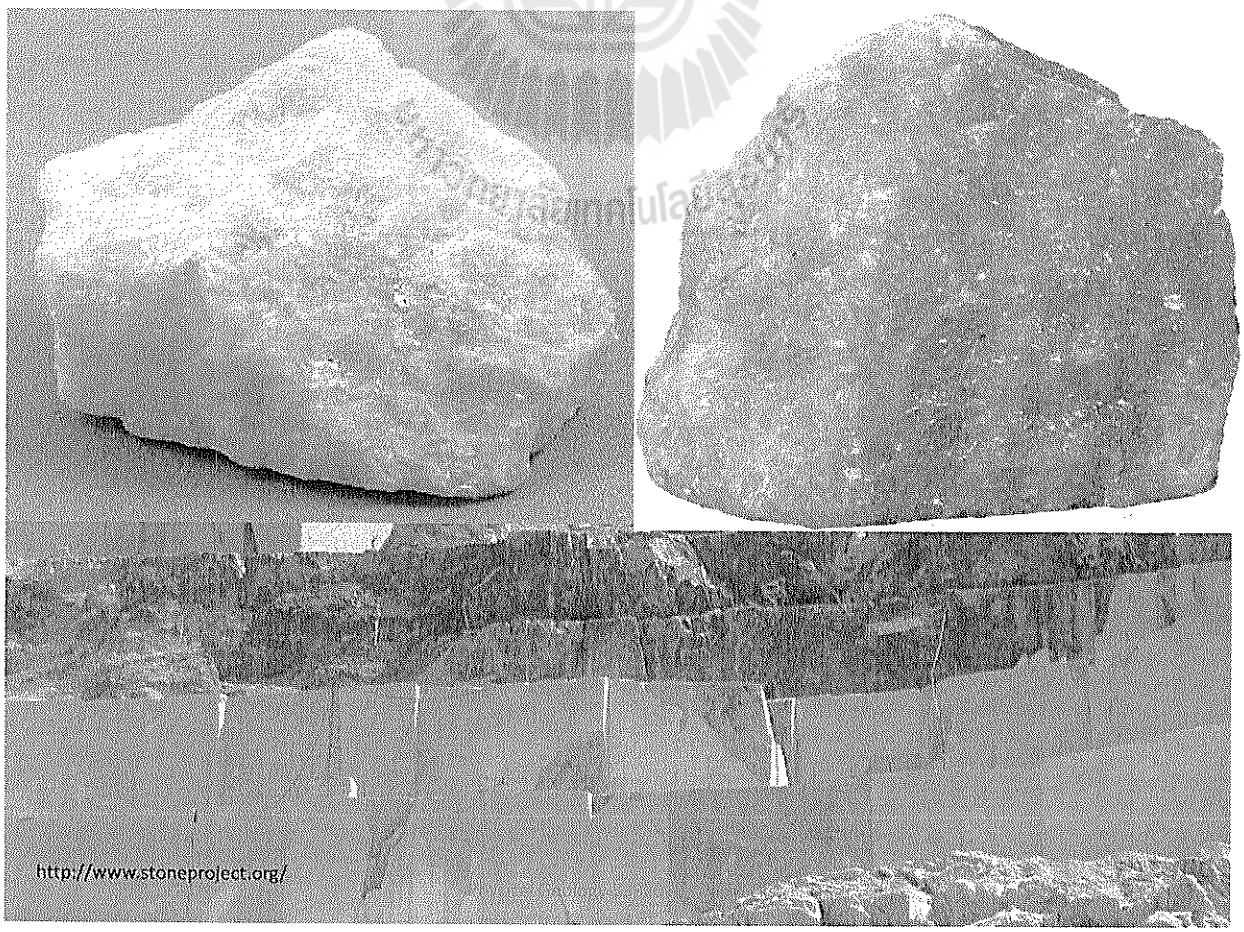
Photomicrograph (26.6x)
Sample width is 1.23 mm

Marble: forms by metamorphism of limestone. Calcite in preexist rock recrystallizes, fossils, cement and pose space disappear, showing uniform mass of interlocking calcite crystals.



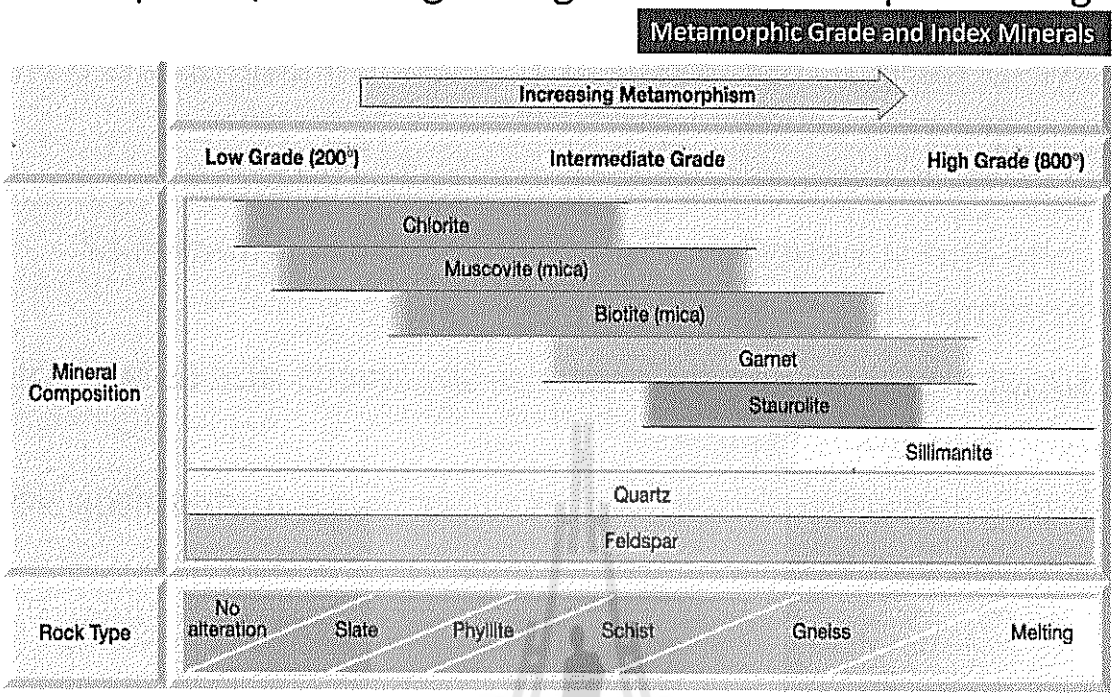


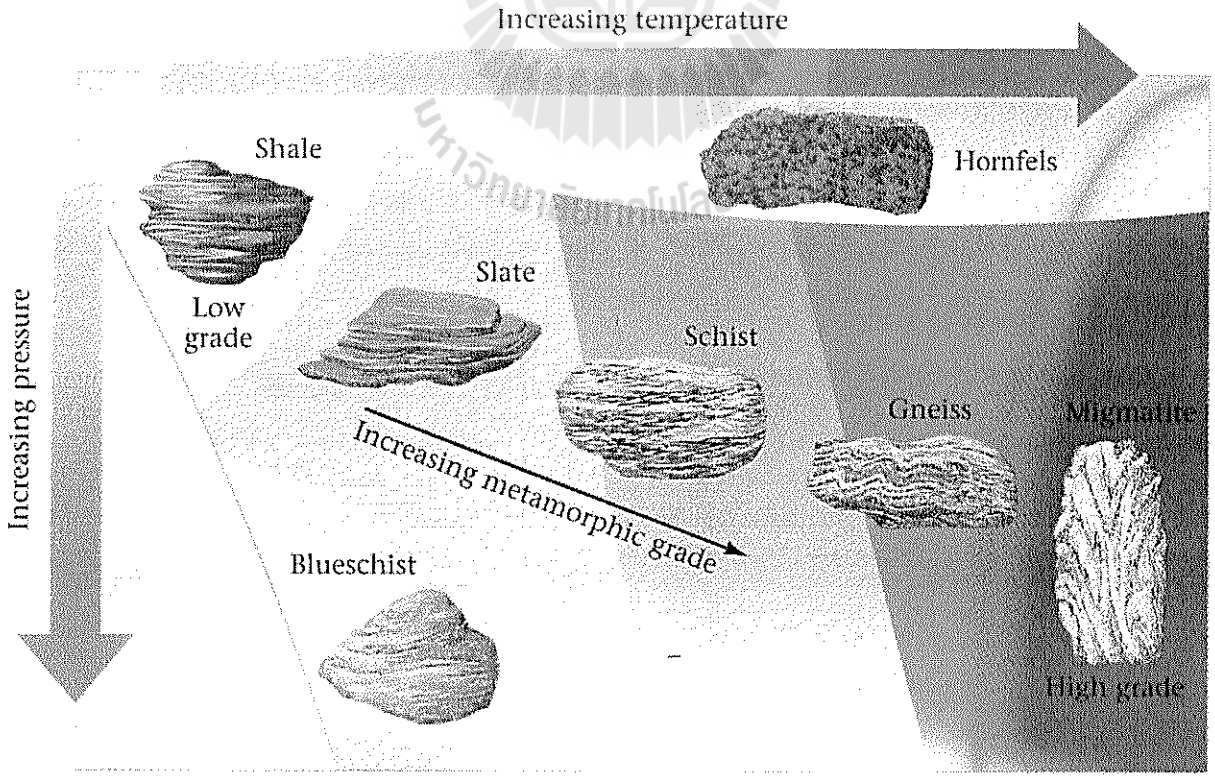
http://www.columbia.edu



Environments of metamorphism

Metamorphic grade: indication of the intensity of metamorphism, meaning in degree of metamorphic change.





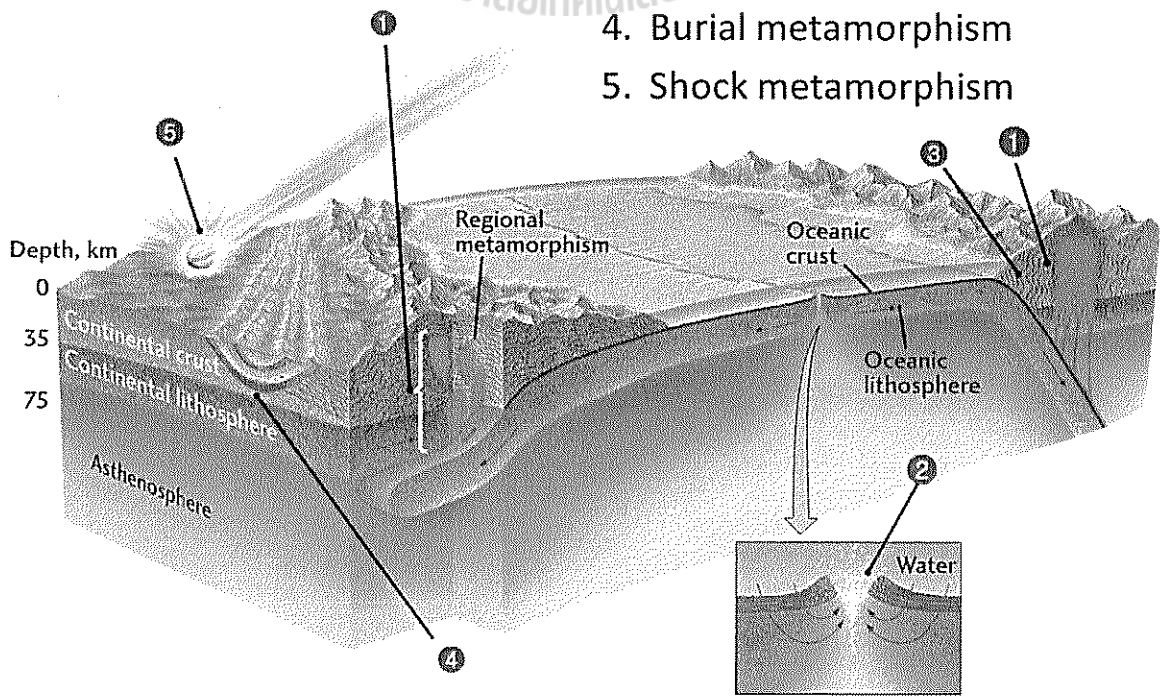
Metamorphic settings

Five types of metamorphic settings:

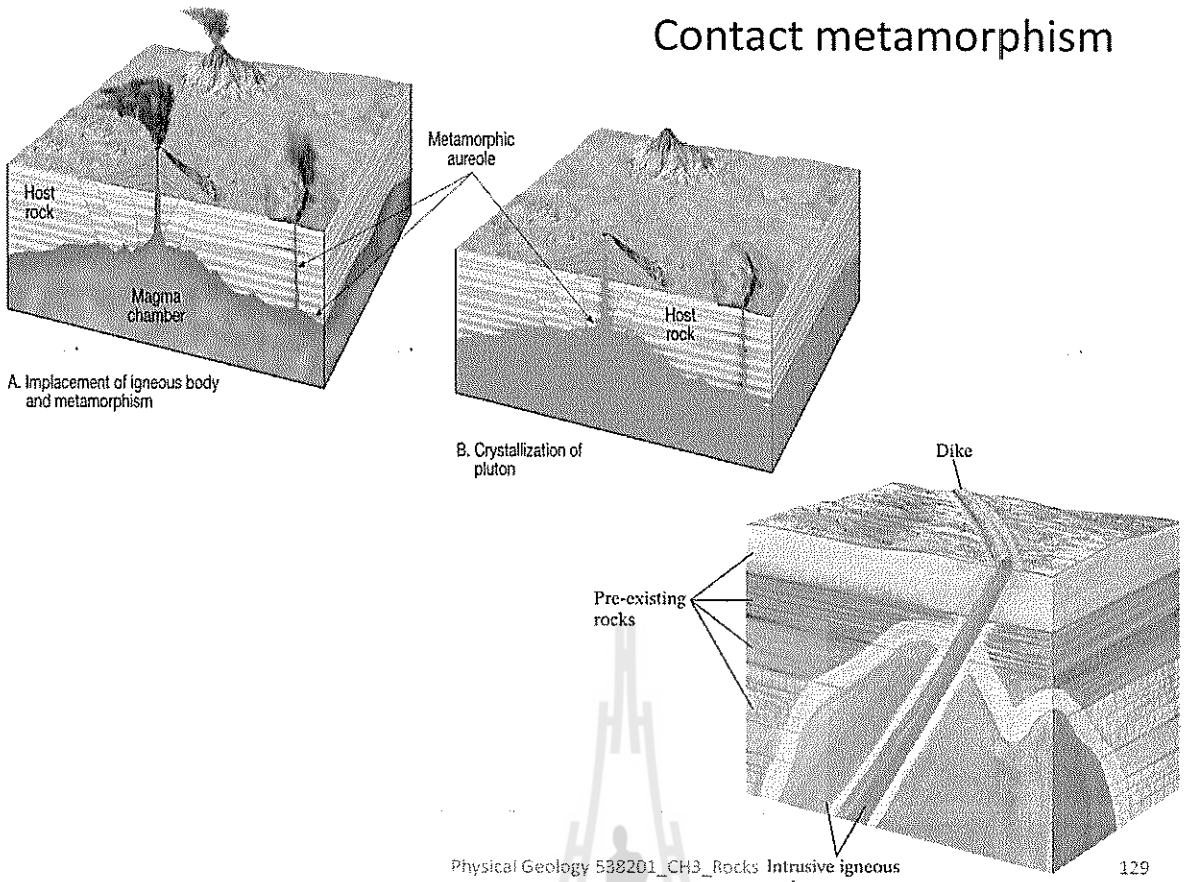
1. Contact metamorphism: due to heat from adjacent rocks
2. Hydrothermal metamorphism: chemical alterations from hot, ion-rich water
3. Regional metamorphism: occurs in the cores of mountain belts and subduction zones. Makes great volumes of metamorphic rock.
4. Burial metamorphism: pressure increases due to weight of over burden.
5. Shock metamorphism: occurs when large meteorites slam into the Earth.

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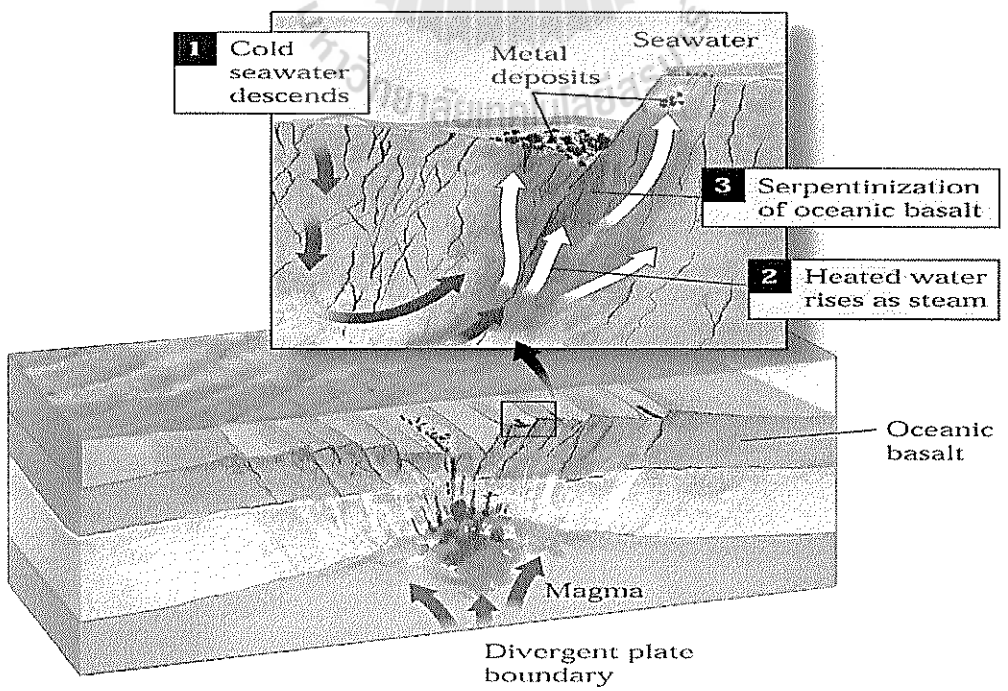
1. Contact metamorphism
2. Hydrothermal metamorphism
3. Regional metamorphism
4. Burial metamorphism
5. Shock metamorphism



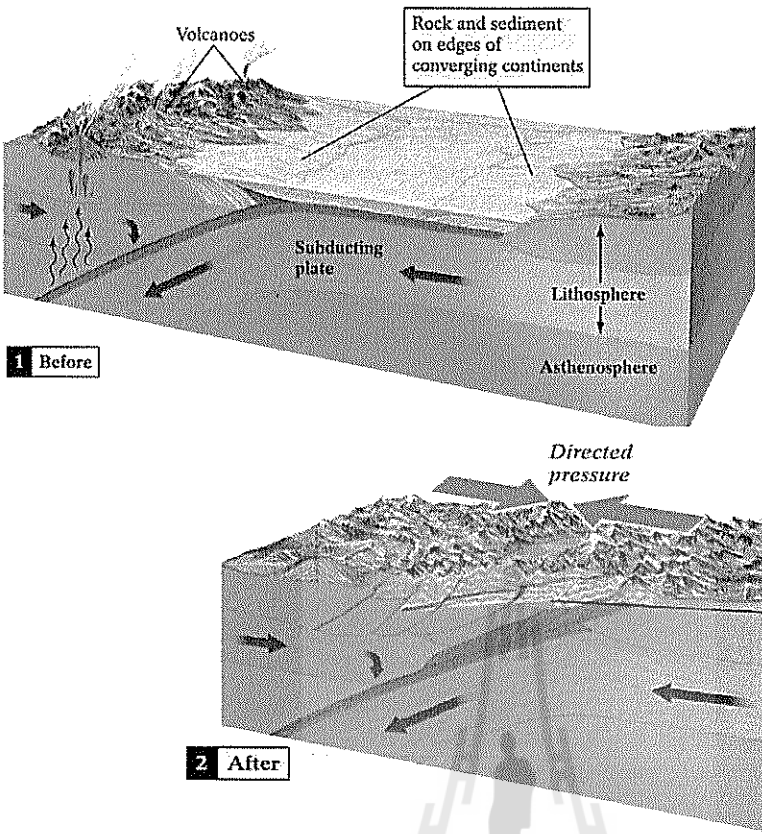
Contact metamorphism

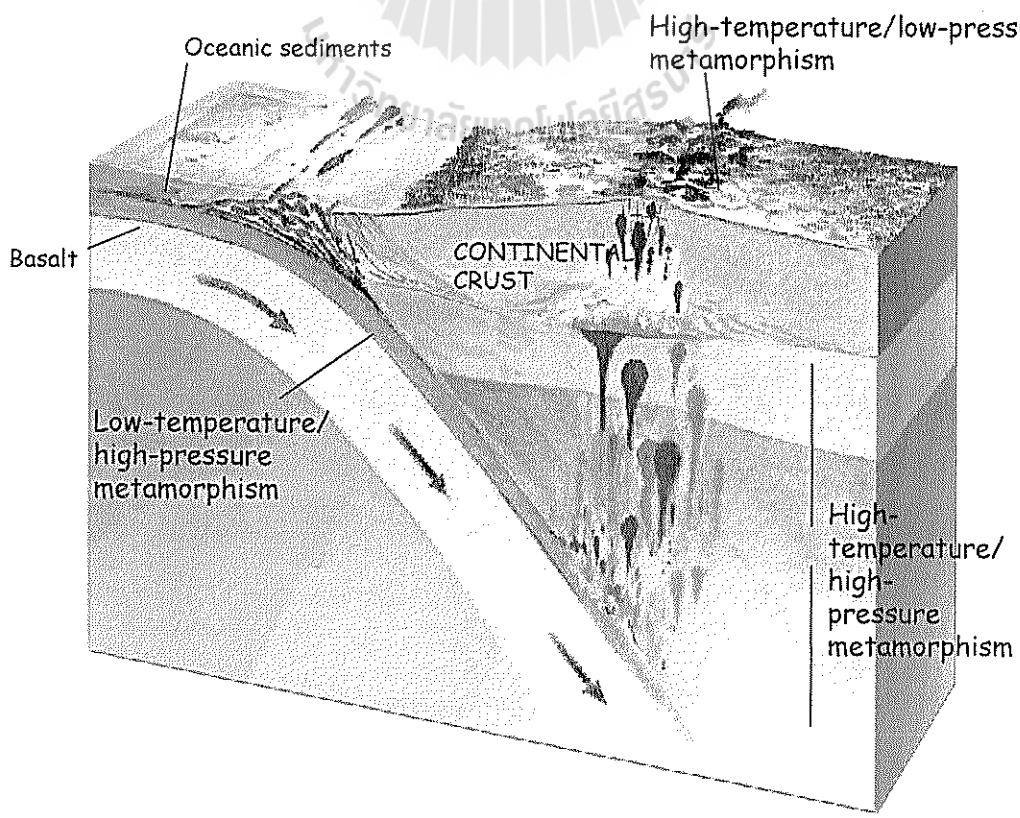


Hydrothermal metamorphism



Regional metamorphism (subduction zone)





Chapter 9 Glaciers

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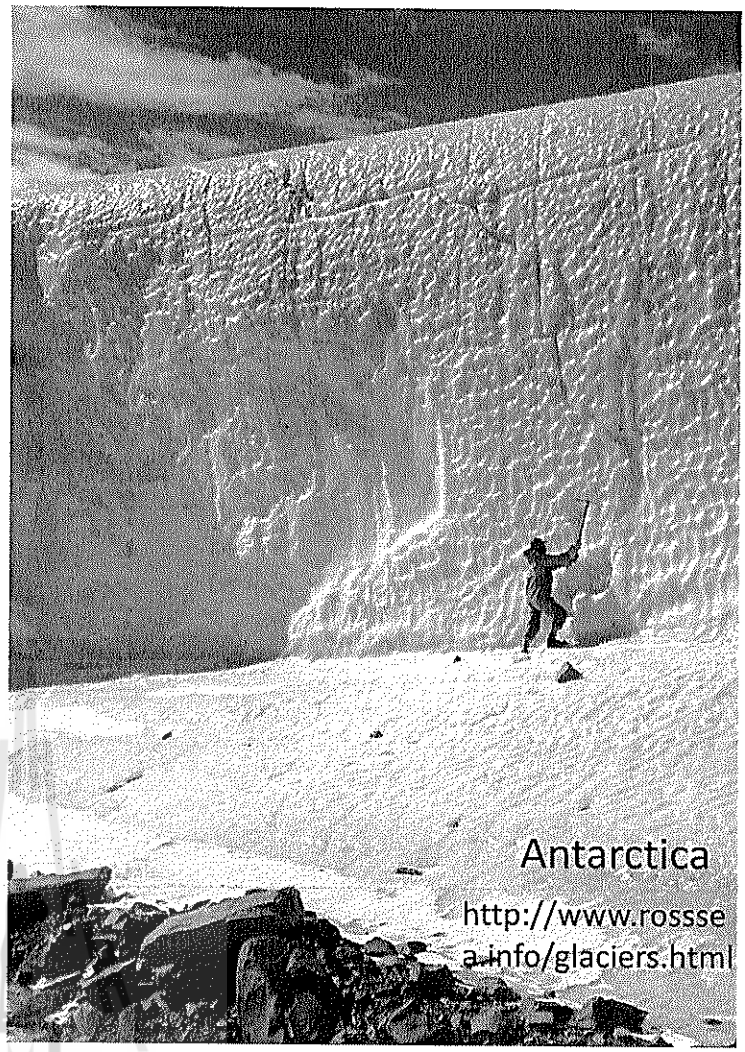
มหาวิทยาลัยเทคโนโลยีสุรนารี

Contents

1. Formation of Glaciers
2. Anatomy
3. Movement
4. Erosion
5. Landscape
6. Deposition
7. Past glaciations

Glacier

- A glacier is a large, long-lasting mass of ice, formed on land, that moves downhill under its own weight
- 75% of the world's supply of fresh water is locked up in glacial ice



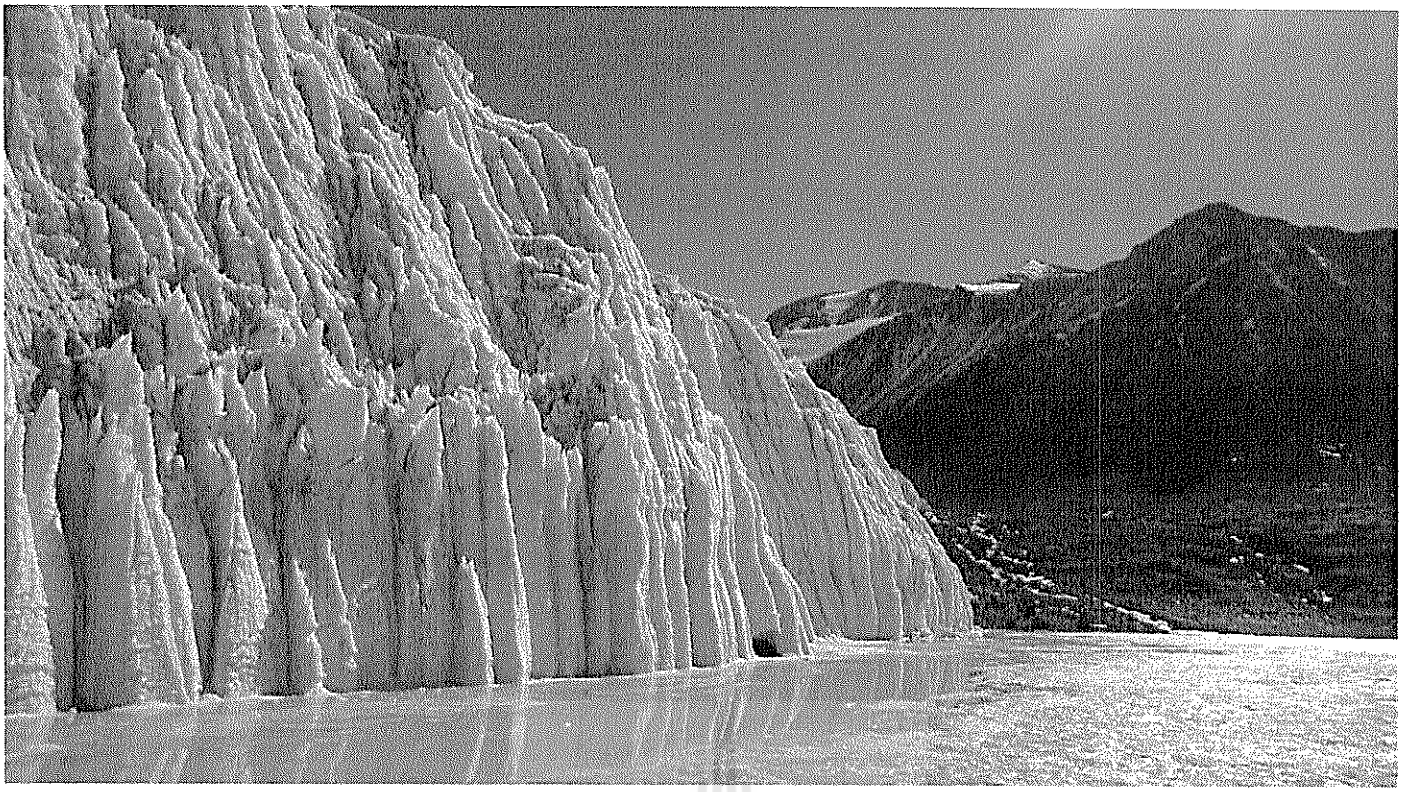
Antarctica

http://www.rossse a.info/glaciers.html



http://ak.water.usgs.gov/glaciology/black_rapids/

Black Rapids Glacier, Alaska (1986)



http://electrictreehouse.com

Glacier flowing into Lake Fryxell, Canada



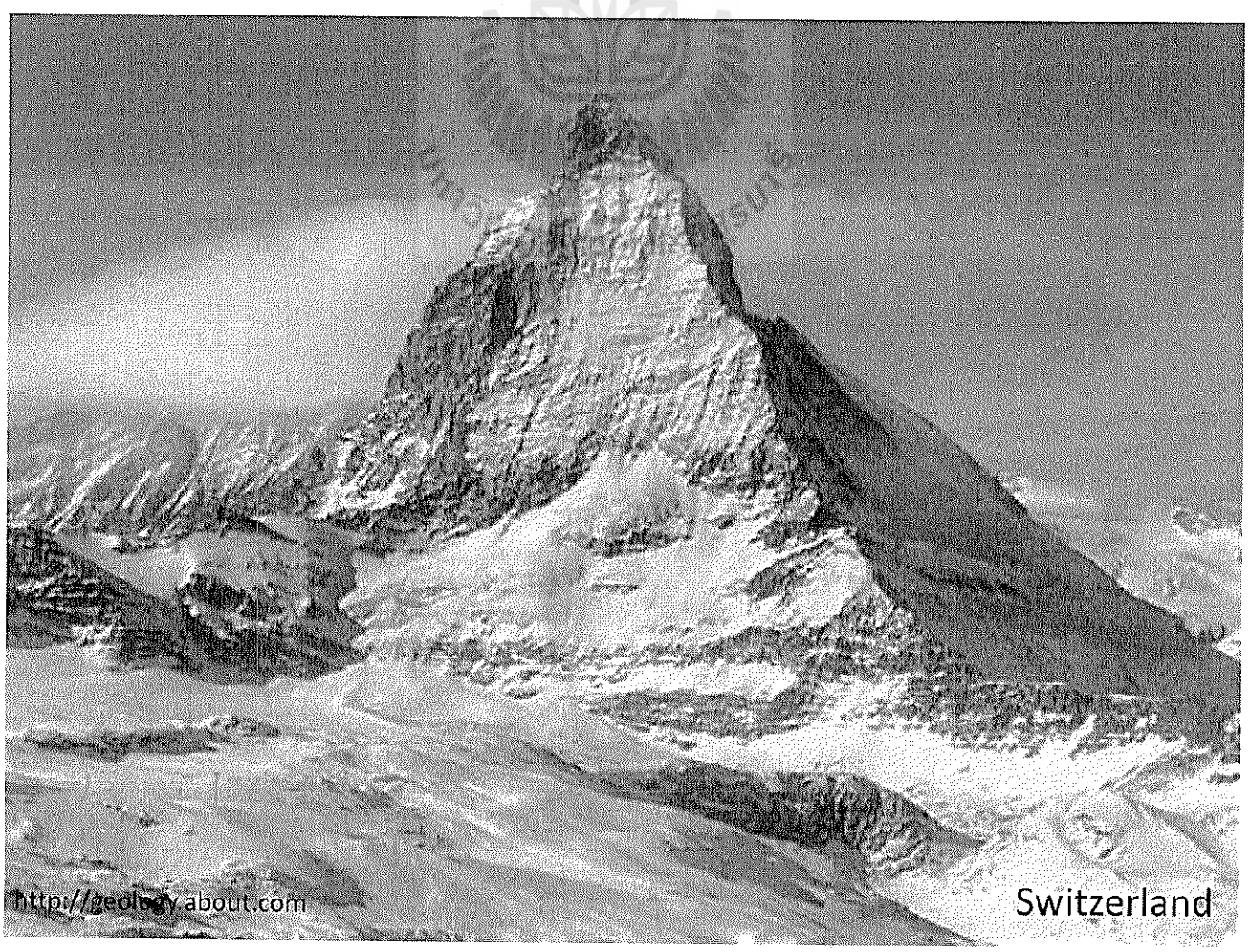
Grey Glacier, Torres del Paine National Park, Chile

http://electrictreehouse.com



Perito Moreno Glacier, Patagonia, Argentina

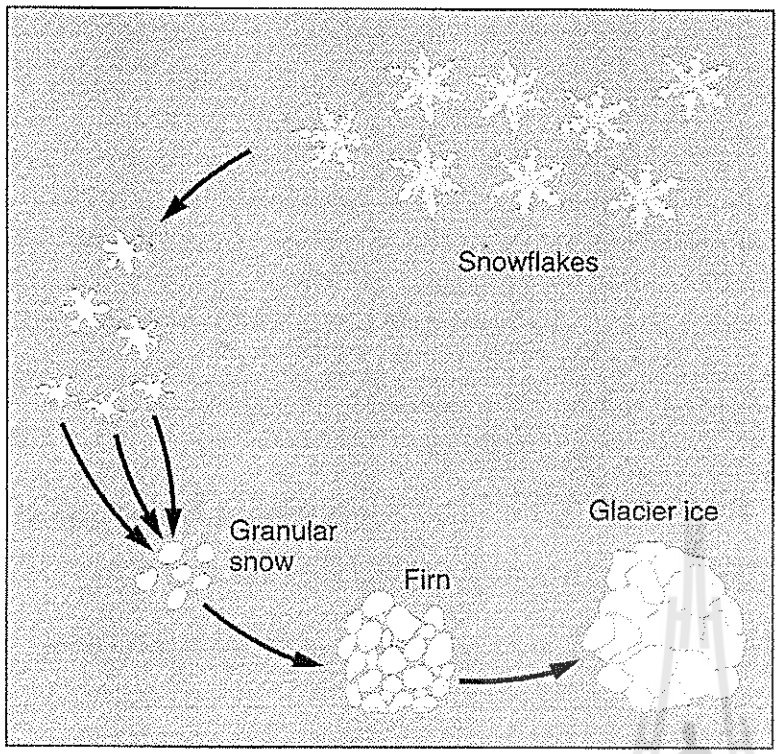
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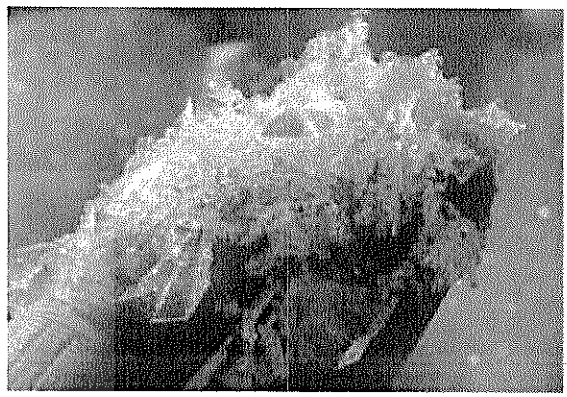
http://geology.about.com

Switzerland

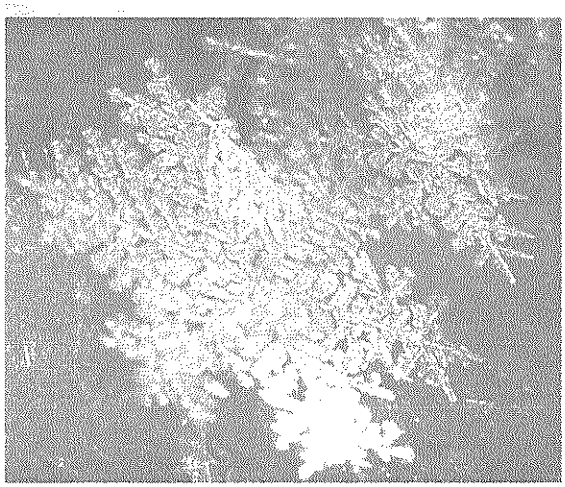
1. Formation of Glaciers

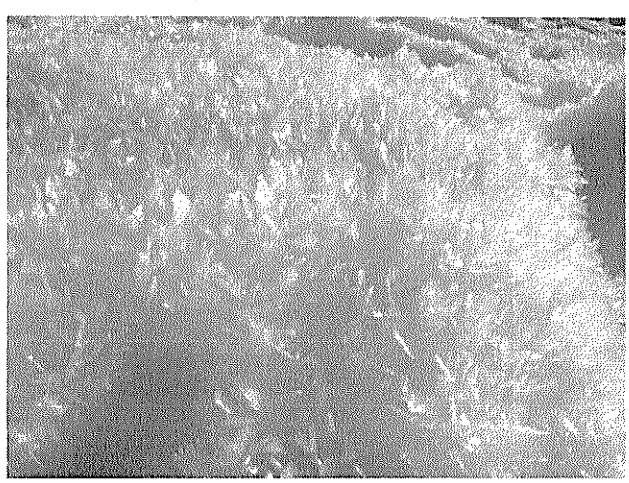


Glaciers develop as snow is compacted and recrystallized, first into firn and then glacial ice

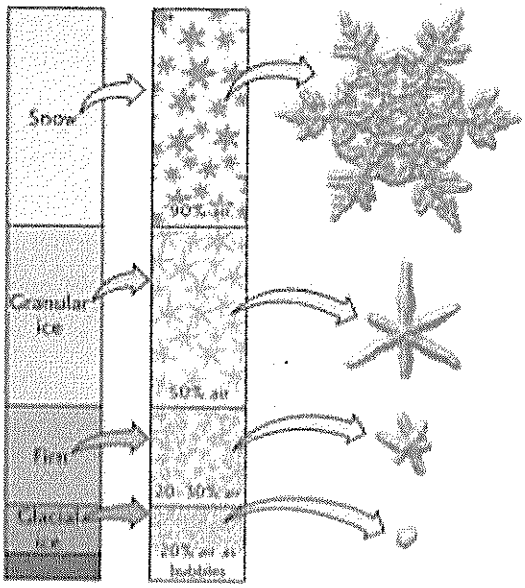












http://oncirculation.com/

A glacier can form where more snow accumulates during the winter than melts away during the spring and summer.

Two types of glaciated terrains on Earth:

1) Alpine glaciation occurs in mountainous regions in the form of <u>valley glaciers</u>

2) Continental glaciation covers large land masses in Earth's polar regions in the form of <u>ice sheets</u>

Snow can accumulate from years to years that allow the thicker and thicker glaciation.

2. Anatomy of a glacier

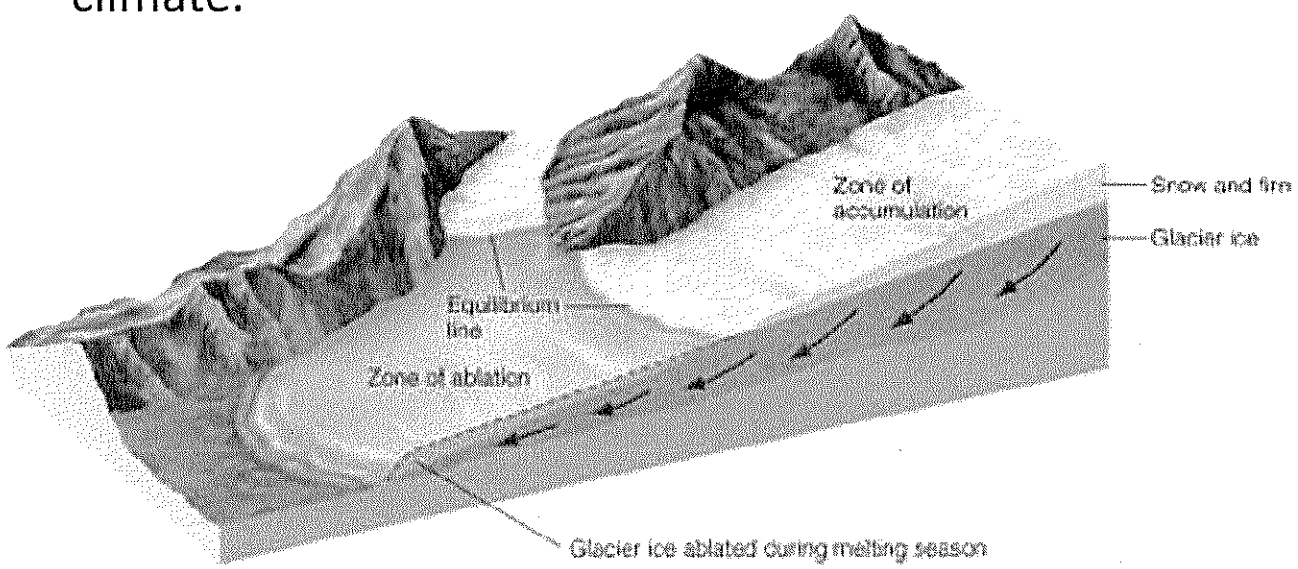


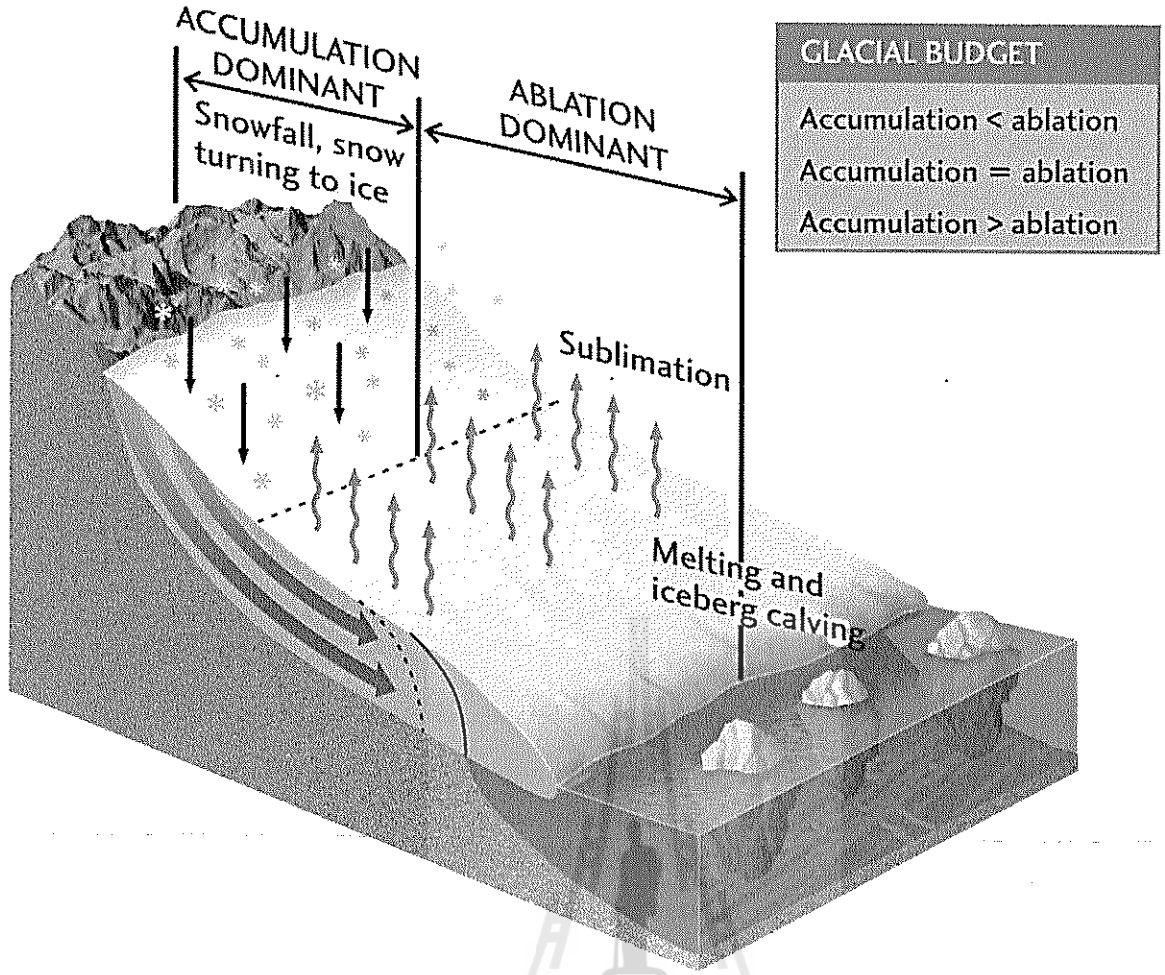
A advancing glacier has a positive budget: end or terminus of glacier advances downslope.

A receding glacier has a negative budget: terminus of glacier shrinks back upslope.

Snow is added in the zone of accumulation of glaciers, whereas melting (and calving of icebergs) occurs in the zone of ablation.

The equilibrium line, which separates accumulation and ablation zones, will advance or retreat depending on climate.

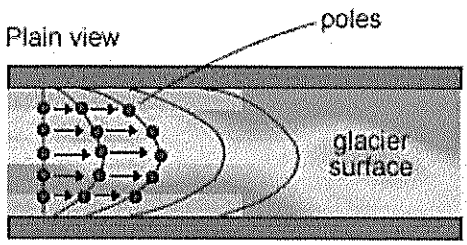




3. Movement of Glaciers

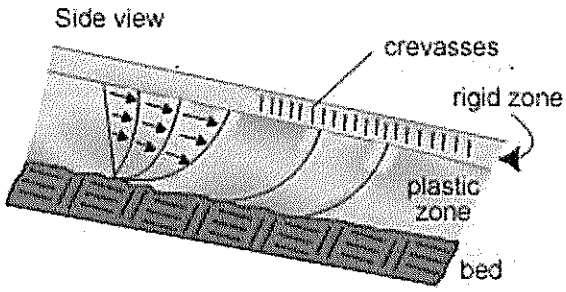


Valley glaciers and ice sheets move downslope under the force of gravity.



Fastest flow is in the centre

The sides are slowed down by friction



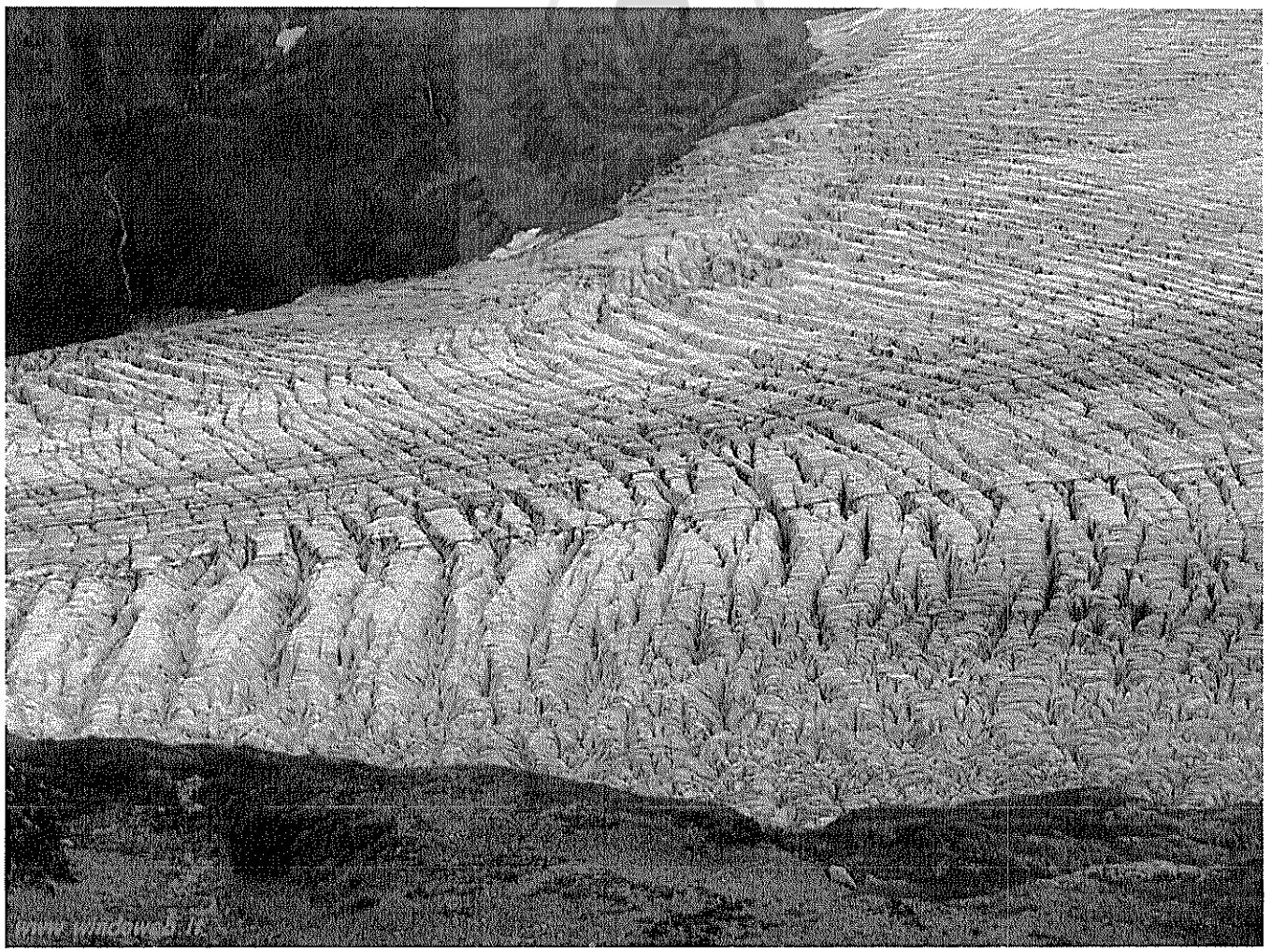
Fastest flow is a third below the surface in plastic zone

Glacial ice is slowed by friction along the bed.

http://learnthings.co.za

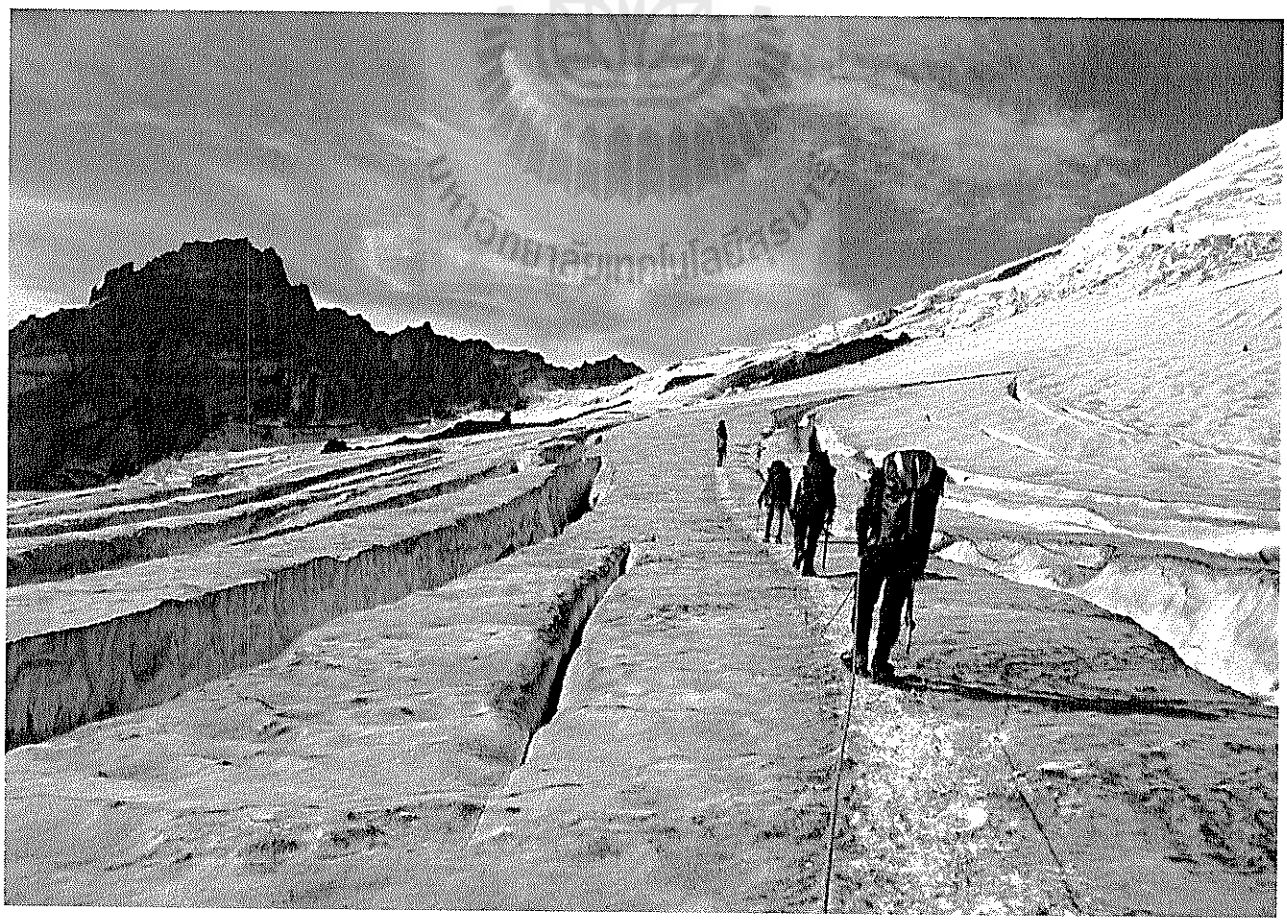
Movement occurs by basal sliding and plastic flow of the lower part of the glacier, and passive "riding along" of an overlying rigid zone.

"Crevasses" are fractures formed in the upper rigid zone during glacier flow.



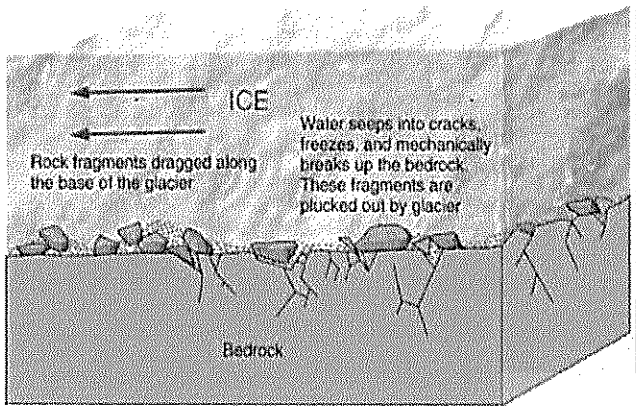


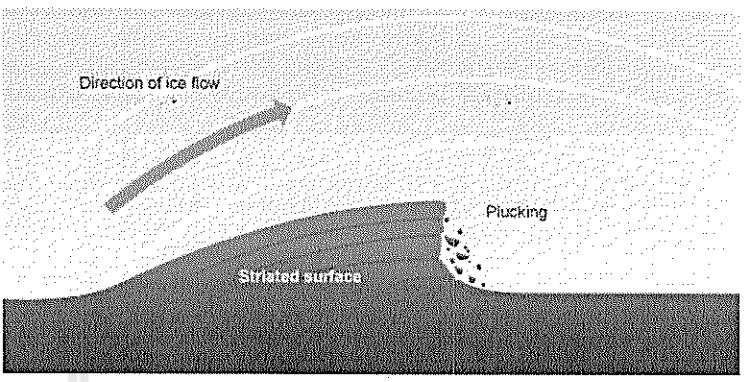
http://www.youtube.com/watch?v=Cl6pM8lKKFY



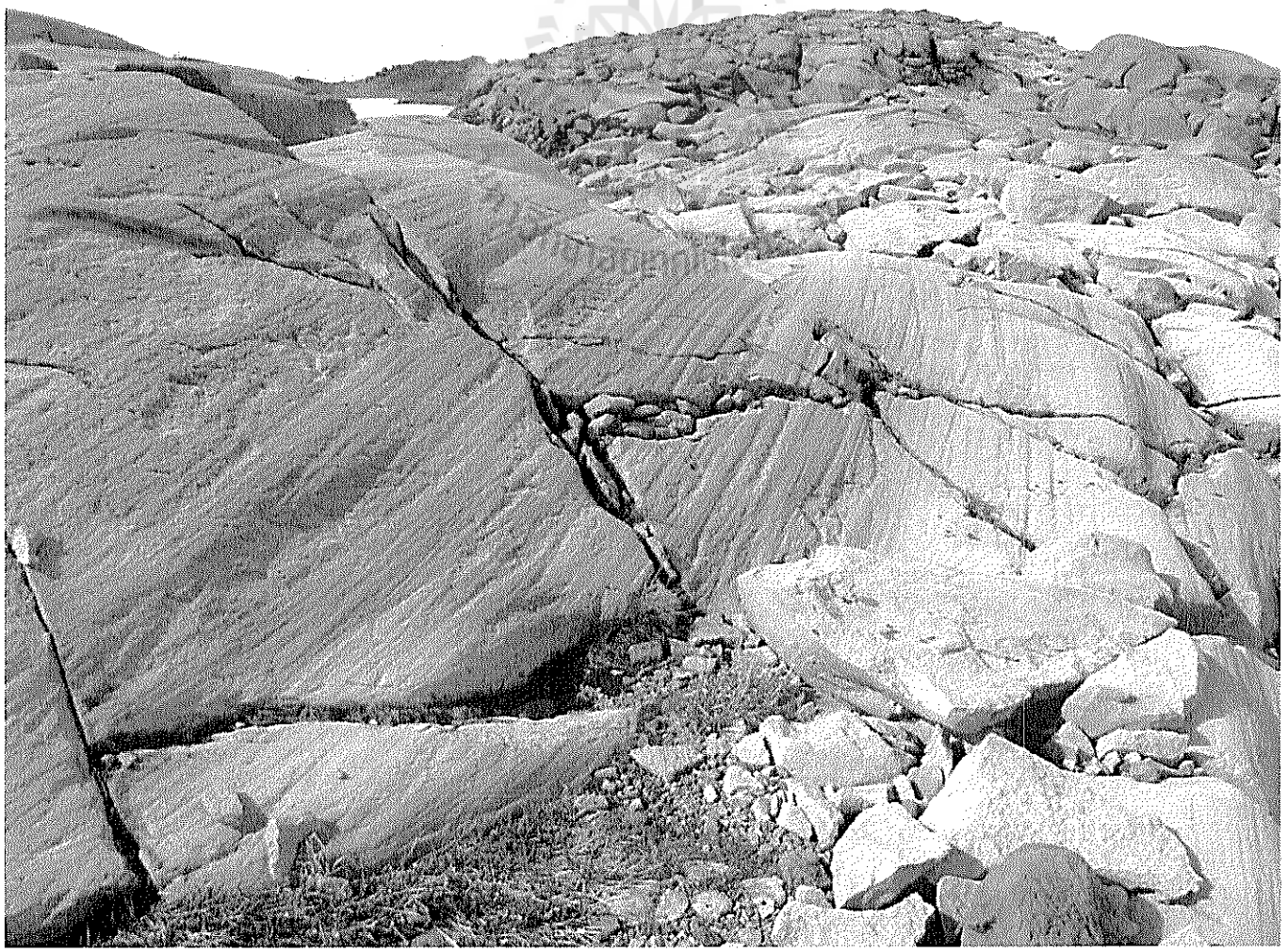
4. Glacial Erosion

Glaciers erode underlying rock by <u>plucking</u> of rock fragments and <u>abrasion</u> as they are dragged along.





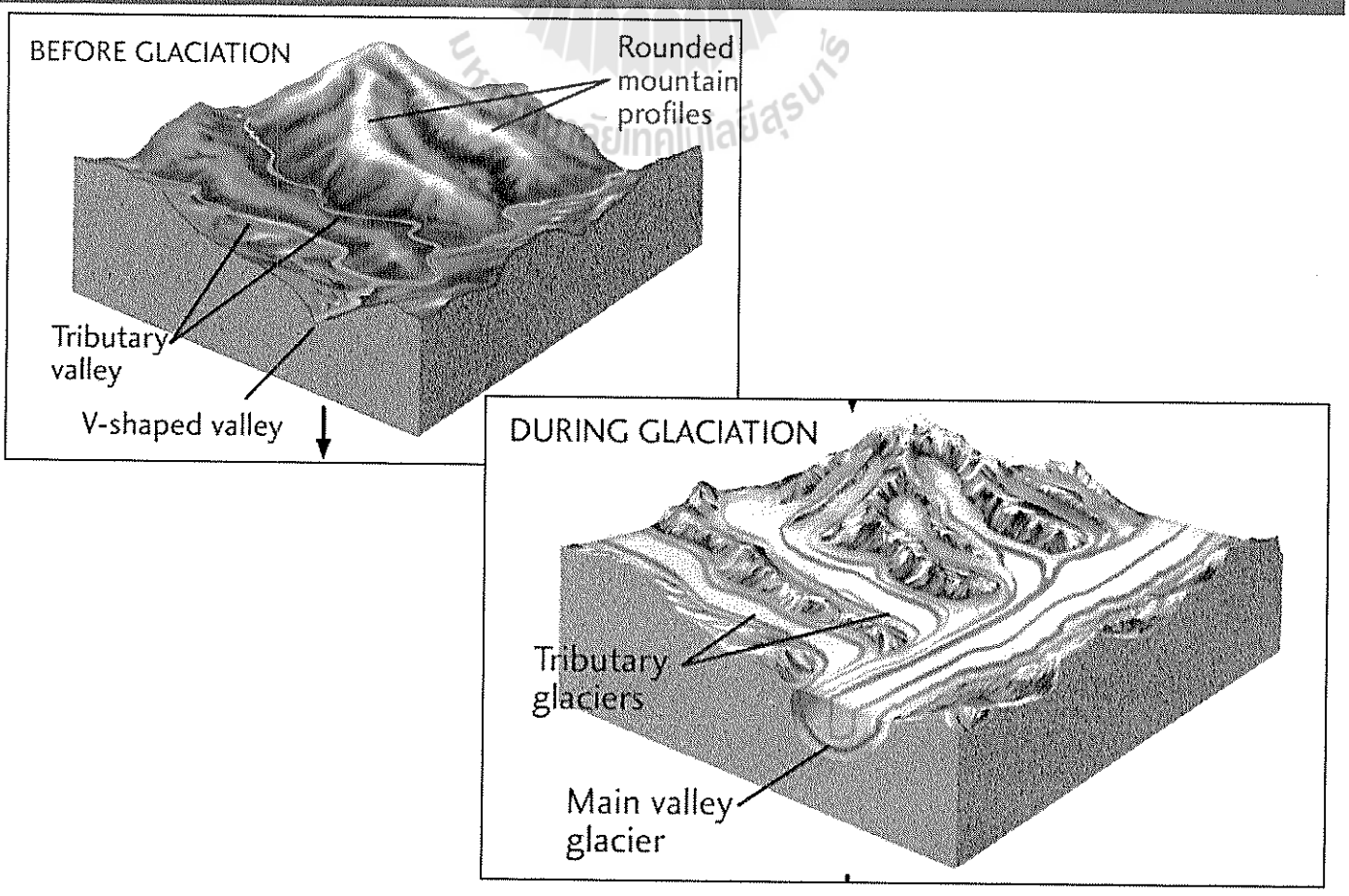
Basal abrasion polishes and striates the underlying rock surface and produces abundant fine rock powder known as rock flour.

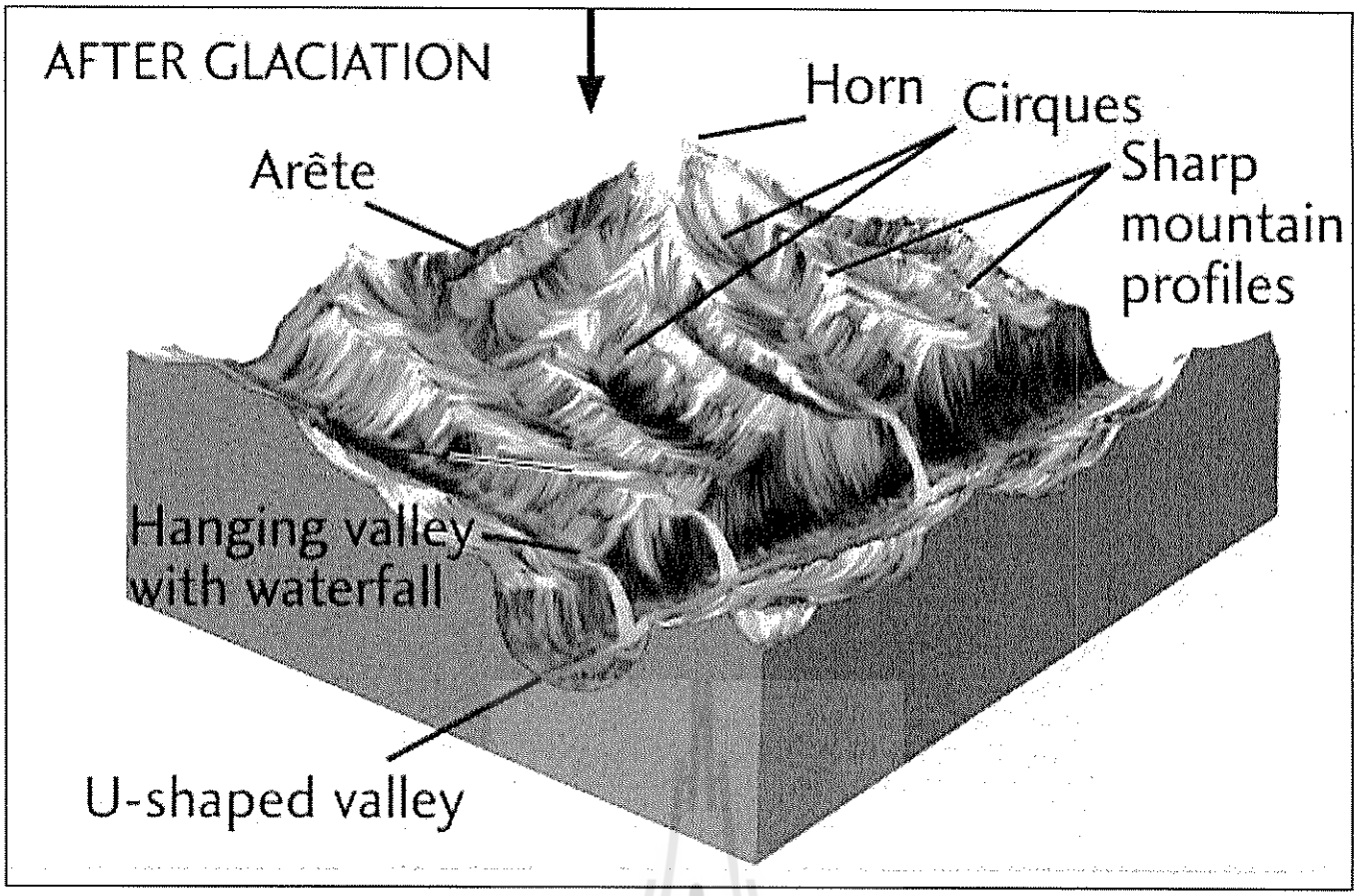




www.indiana.edu

5. Erosional Landscapes





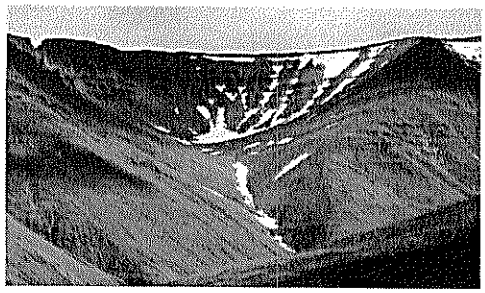
U-shaped valleys

Hanging valleys: smaller tributary glacial valleys left stranded above more quickly eroded central valleys

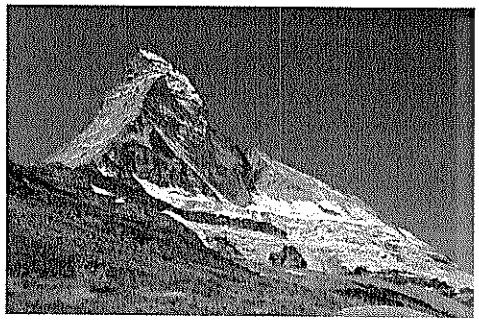
Cirques: steep-sided, half-bowl-shaped recesses carved into mountains at the heads of glacial valleys

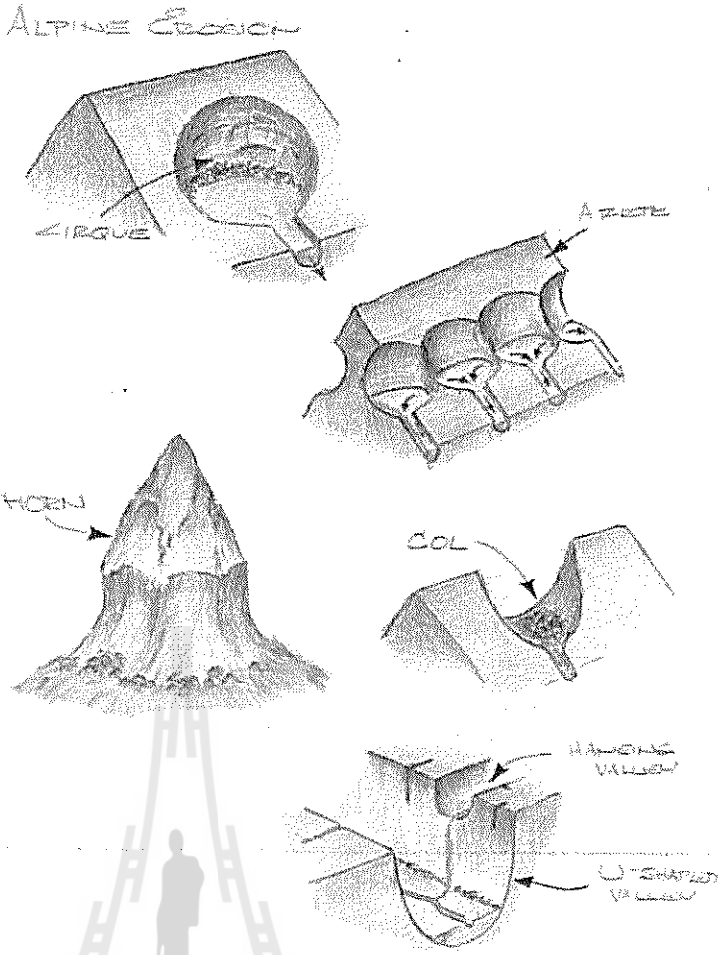
Arêtes: sharp ridges separating glacial valleys

Horns: sharp peaks remaining after cirques have cut back into a mountain on 3+ sides





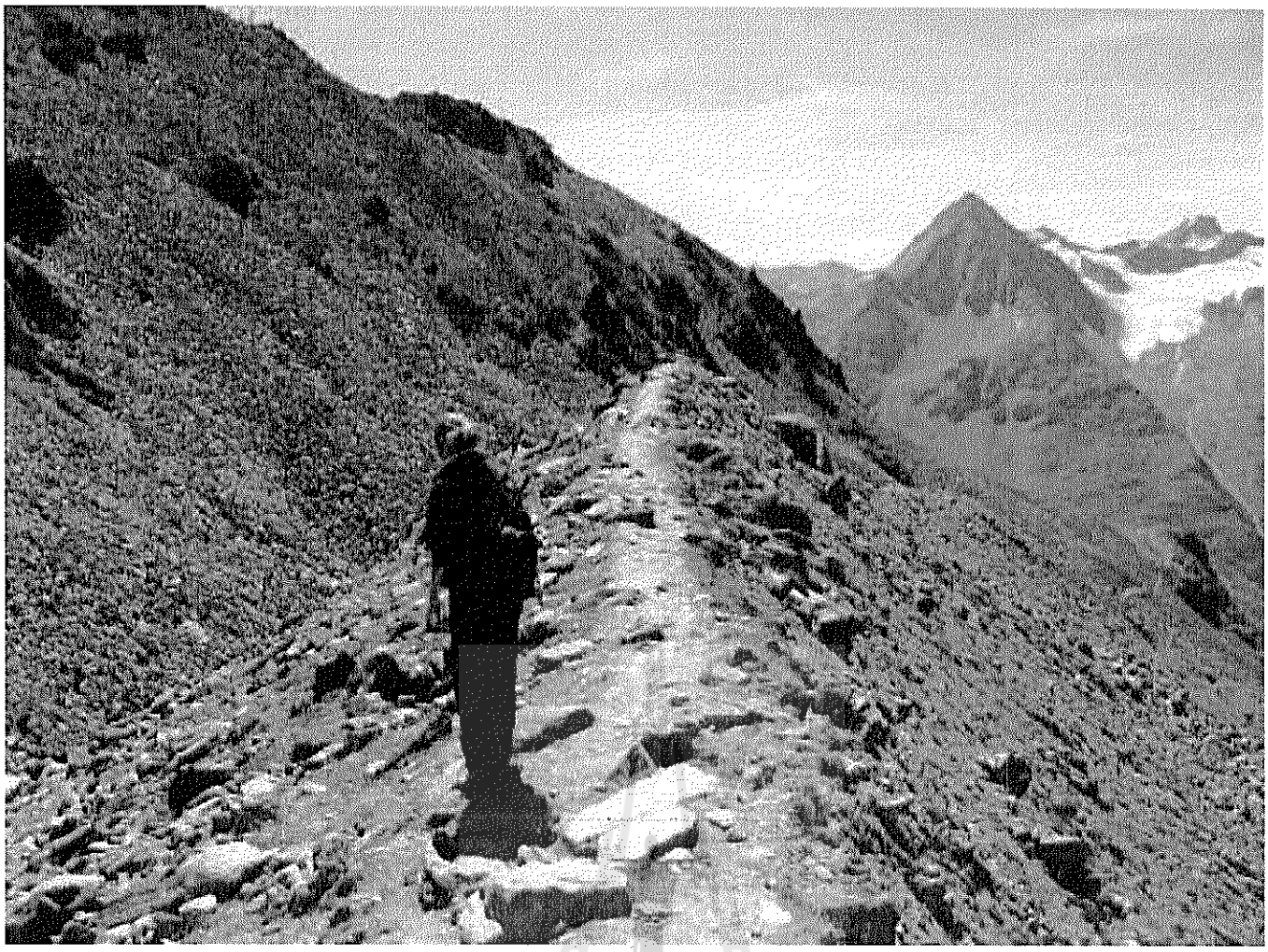




6. Glacial Deposition

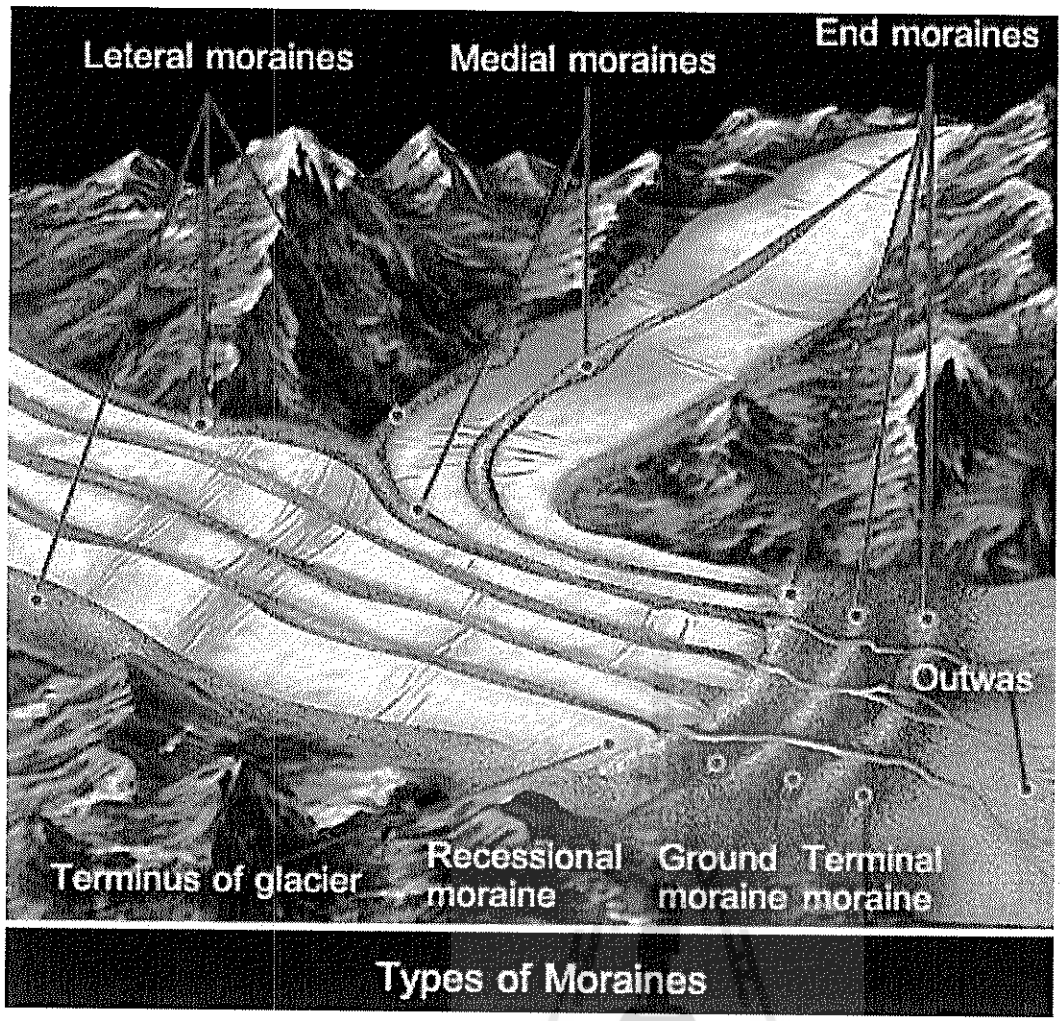


Unsorted, unlayered glacial sediment is “till” (tillite).



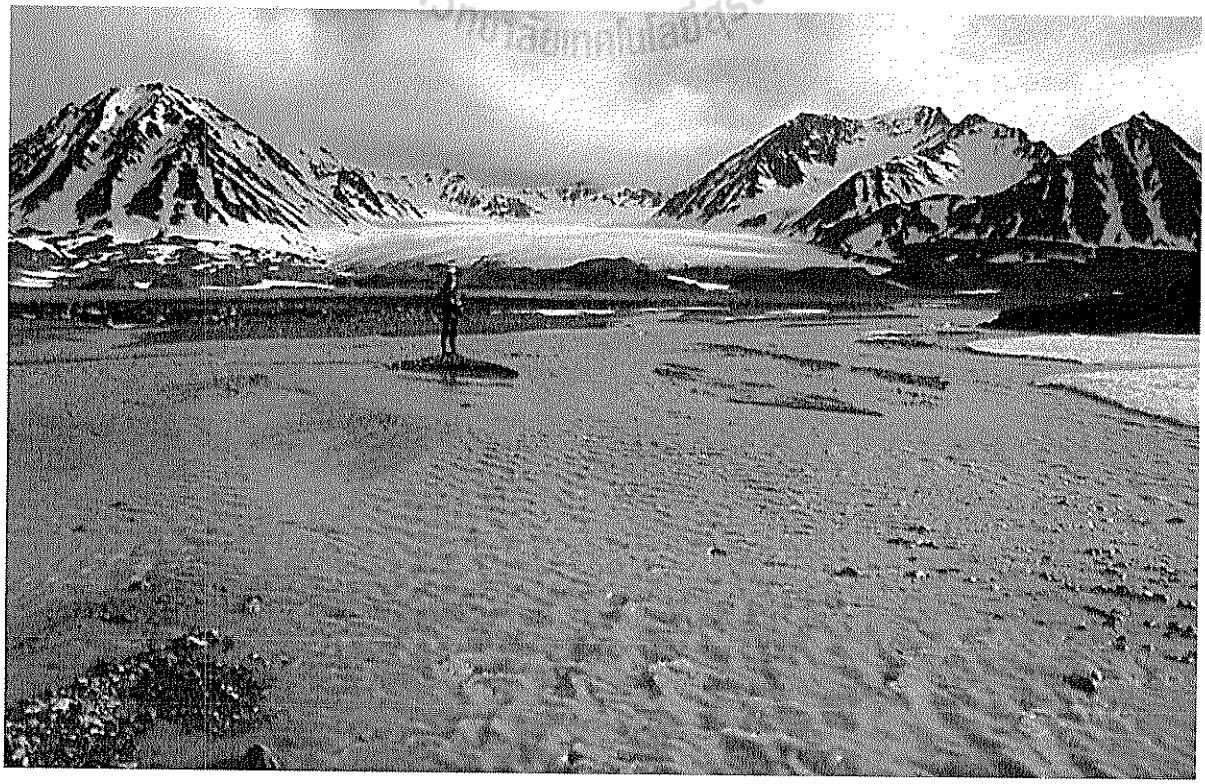


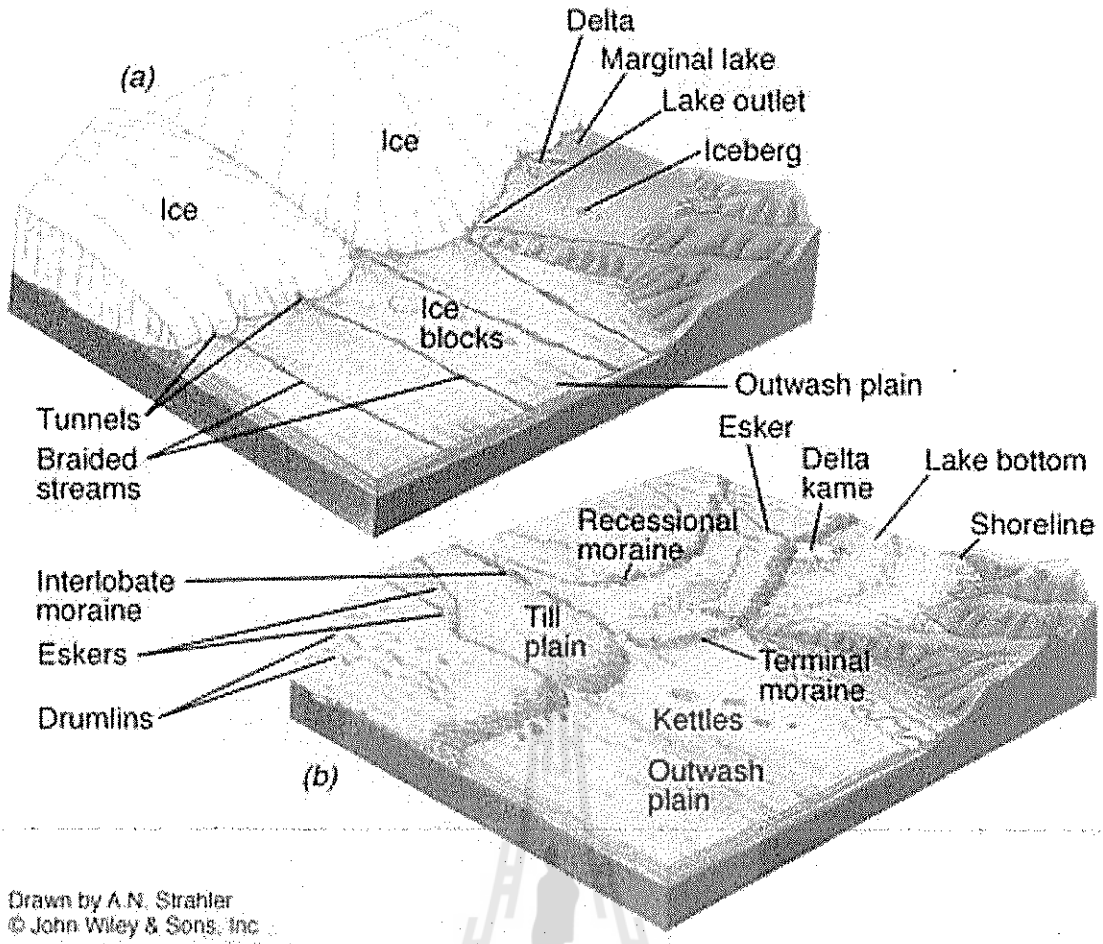
Deposits of till left behind at the sides and end of a glacier are called lateral, medial and end moraines, respectively.

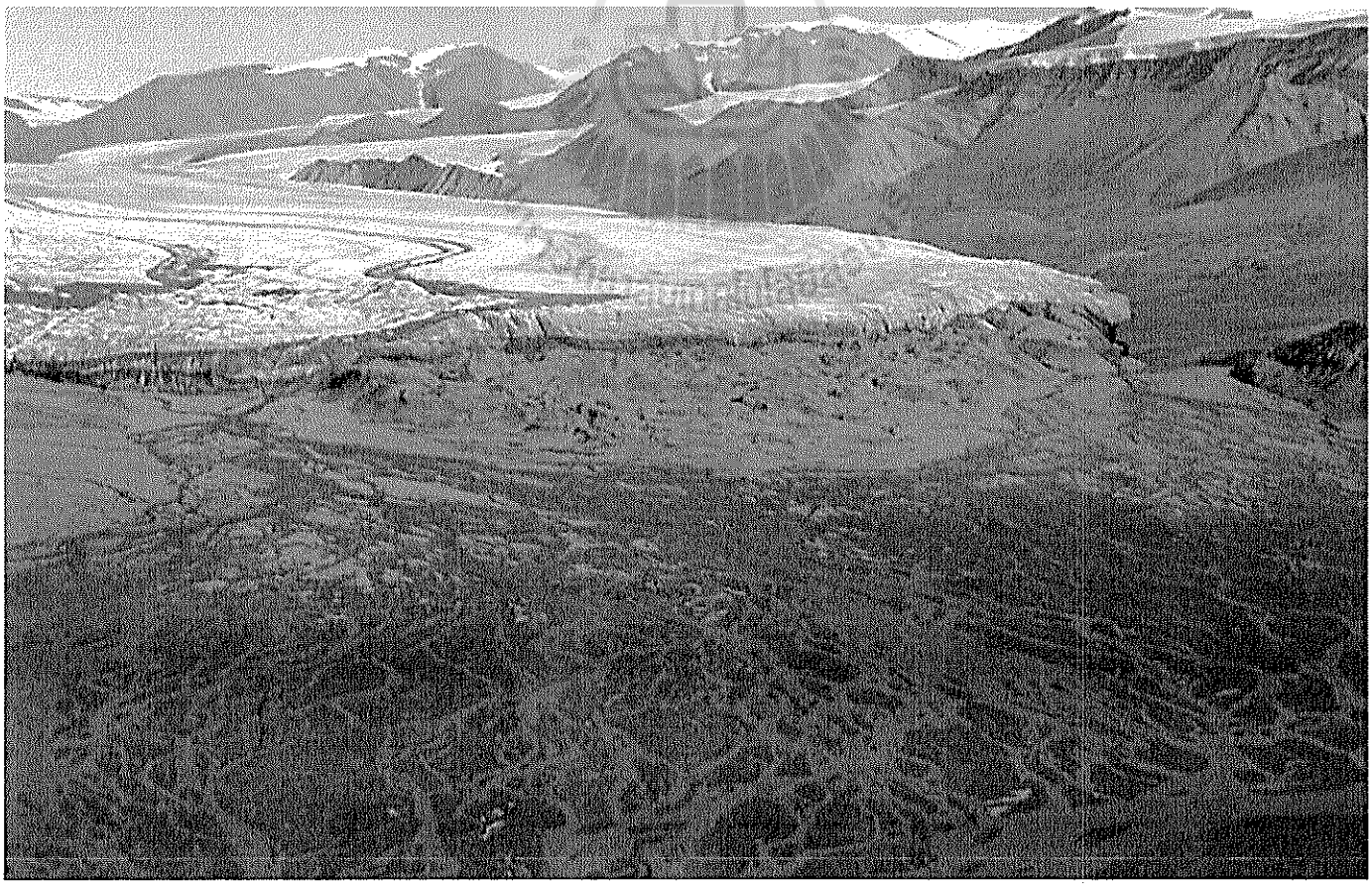


Types of Moraines

Large amounts of liquid water flow over, beneath and away from the ice at the end of a glacier. Sediment deposited by this water is known as glacial outwash.

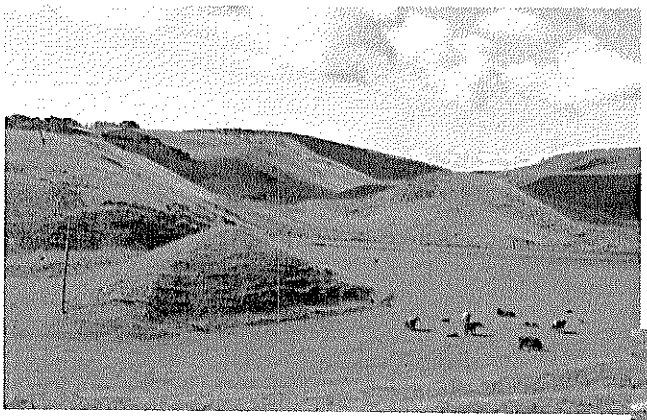


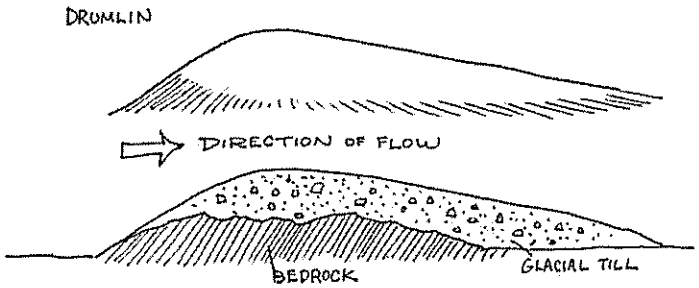


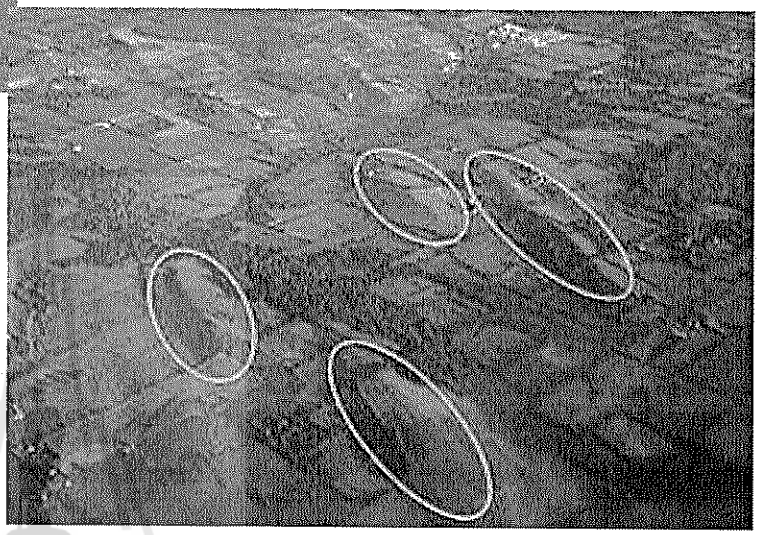


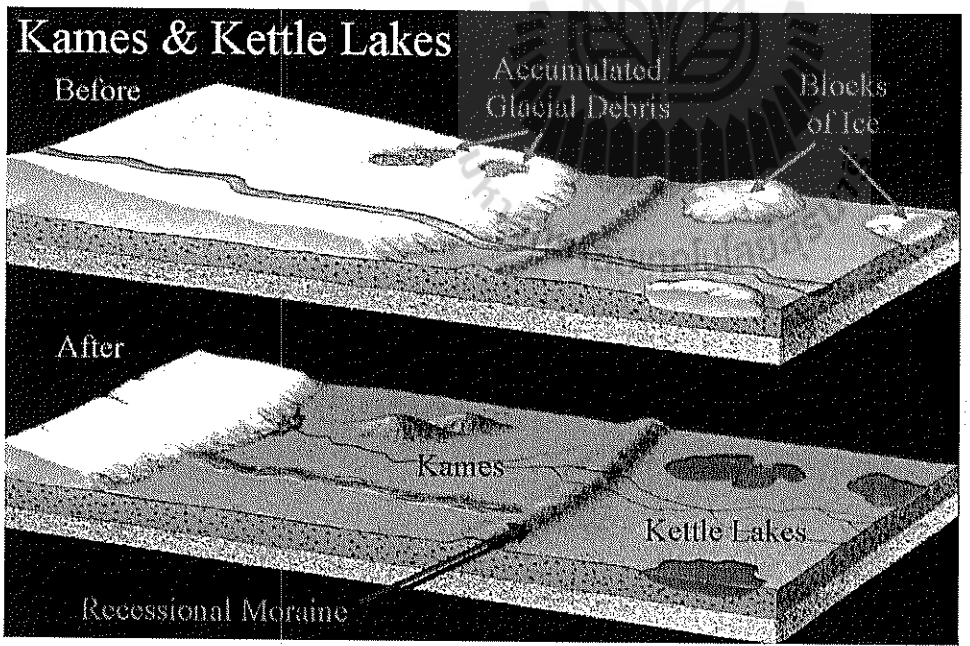
Sediment-laden streams emerging from ends of glaciers have **braided channel** drainage patterns.

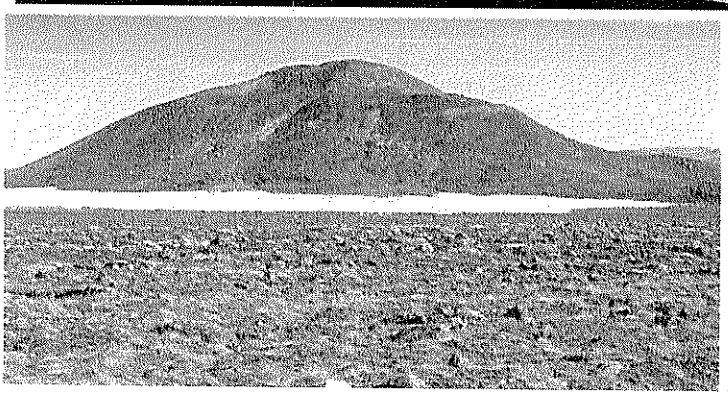
Outwash landforms include **drumlins**, **eskers**, kettles and kames.



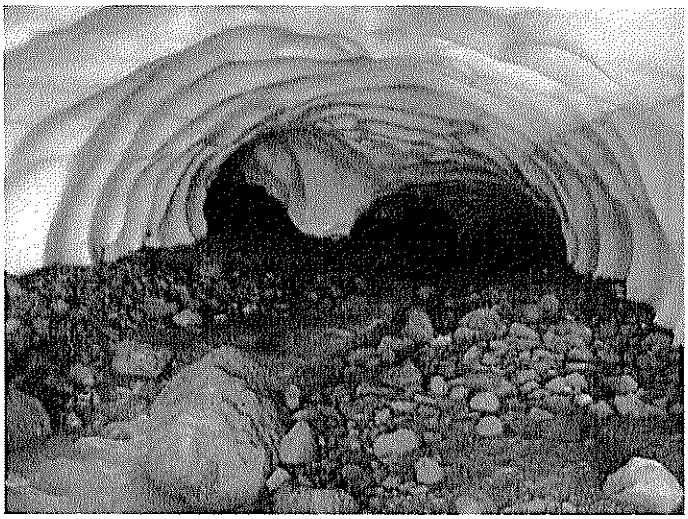


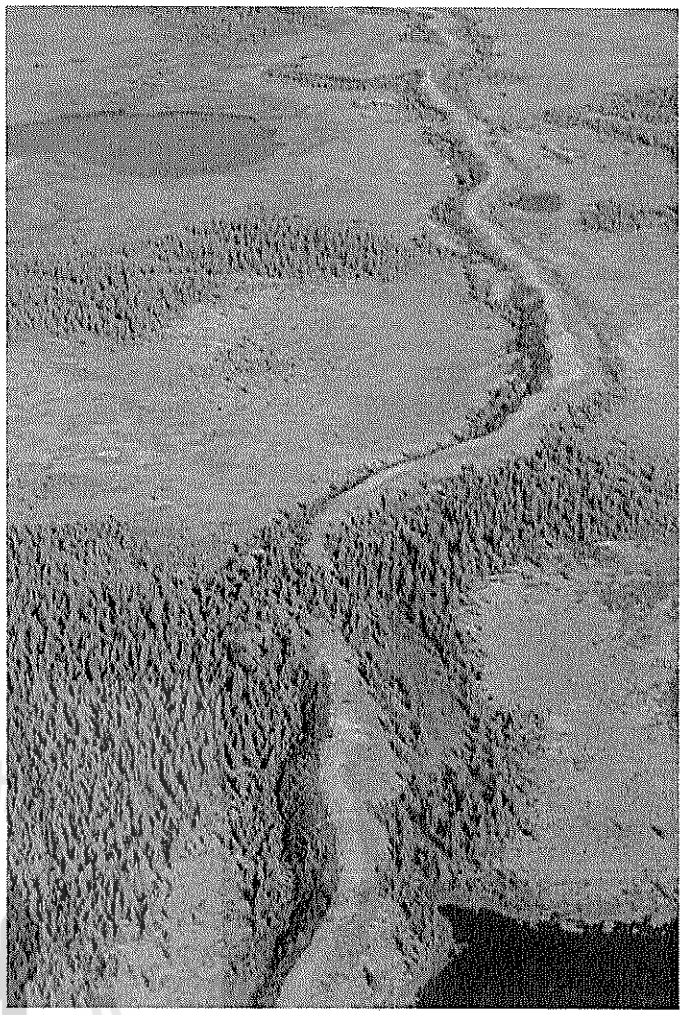




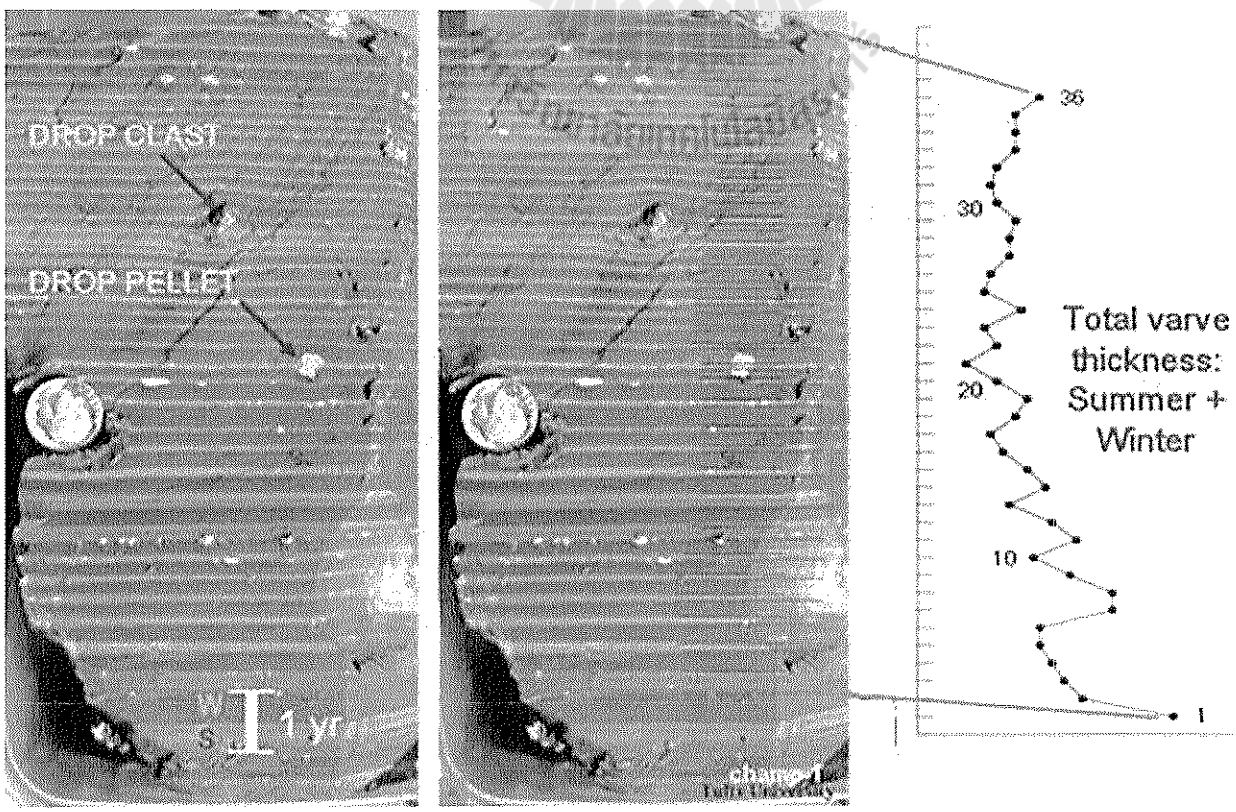








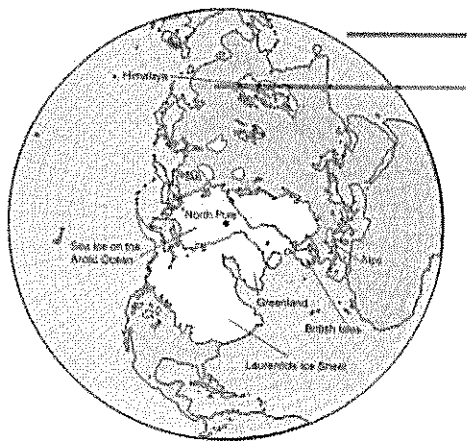
Annual sediment deposition in glacial lakes produces varves, which can be counted like tree rings.



http://eos.tufts.edu/varves/Geology/chronology.asp

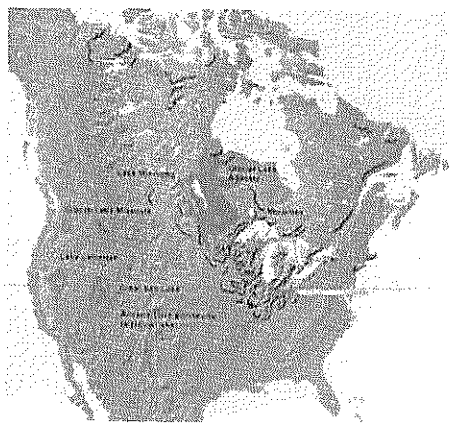
7. Past Glaciations

Direct effects of past glaciation



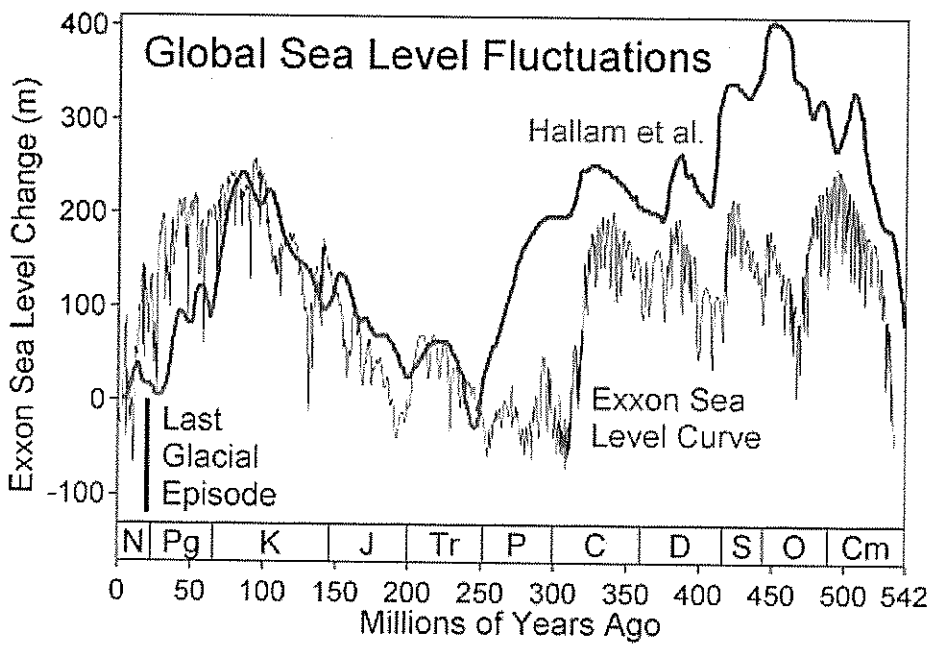
Large-scale glaciation of North America during the most recent ice age produced the following effects:

- Most of the soil and sedimentary rocks were scraped off underlying crystalline rock in northern and eastern Canada, and lake basins were gouged out of the bedrock
- Extensive sets of recessional moraines were left behind by retreating ice sheets in the upper midwestern U.S. and Canada

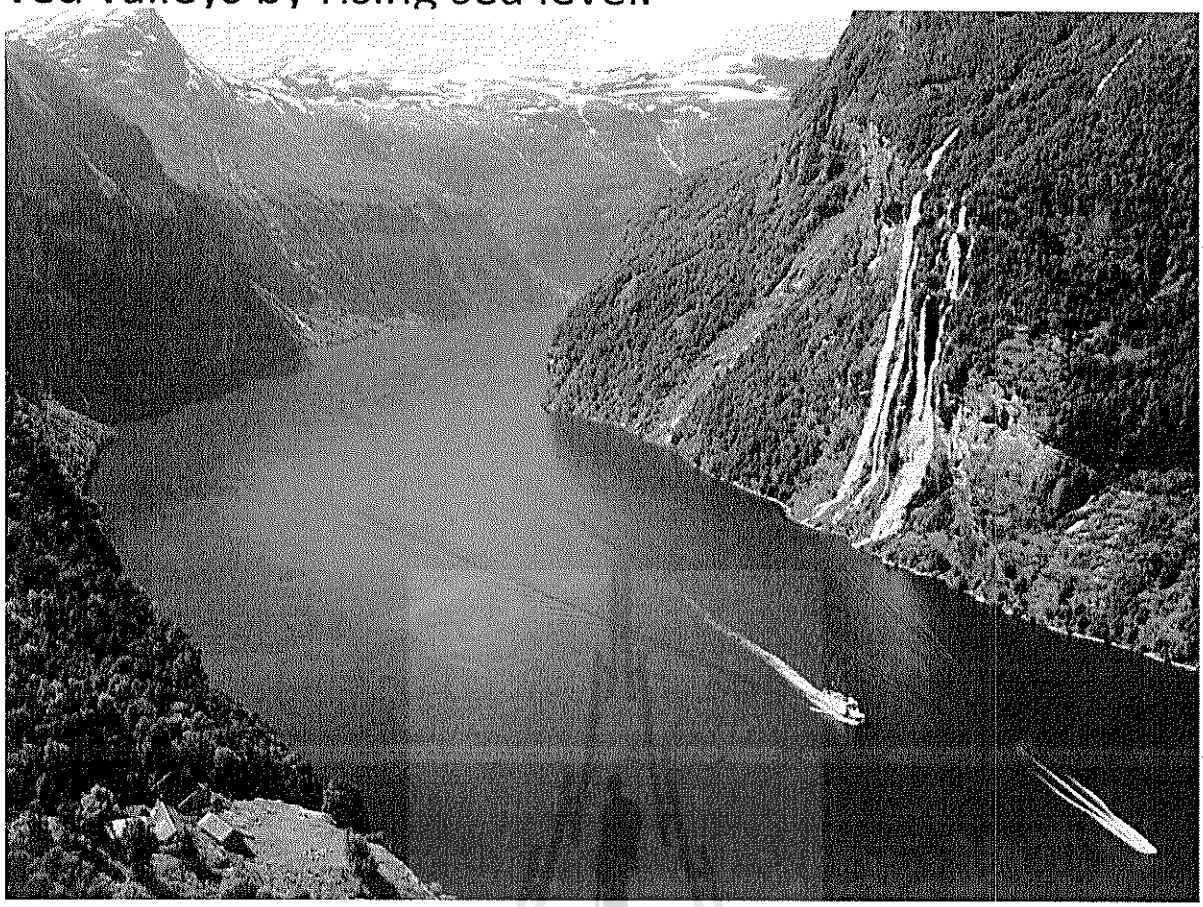


Indirect Effects of Past Glaciation

Sea level was significantly lowered by large amounts of water locked up into ice sheets, allowing stream channels and glaciers to erode valleys below present-day sea level.

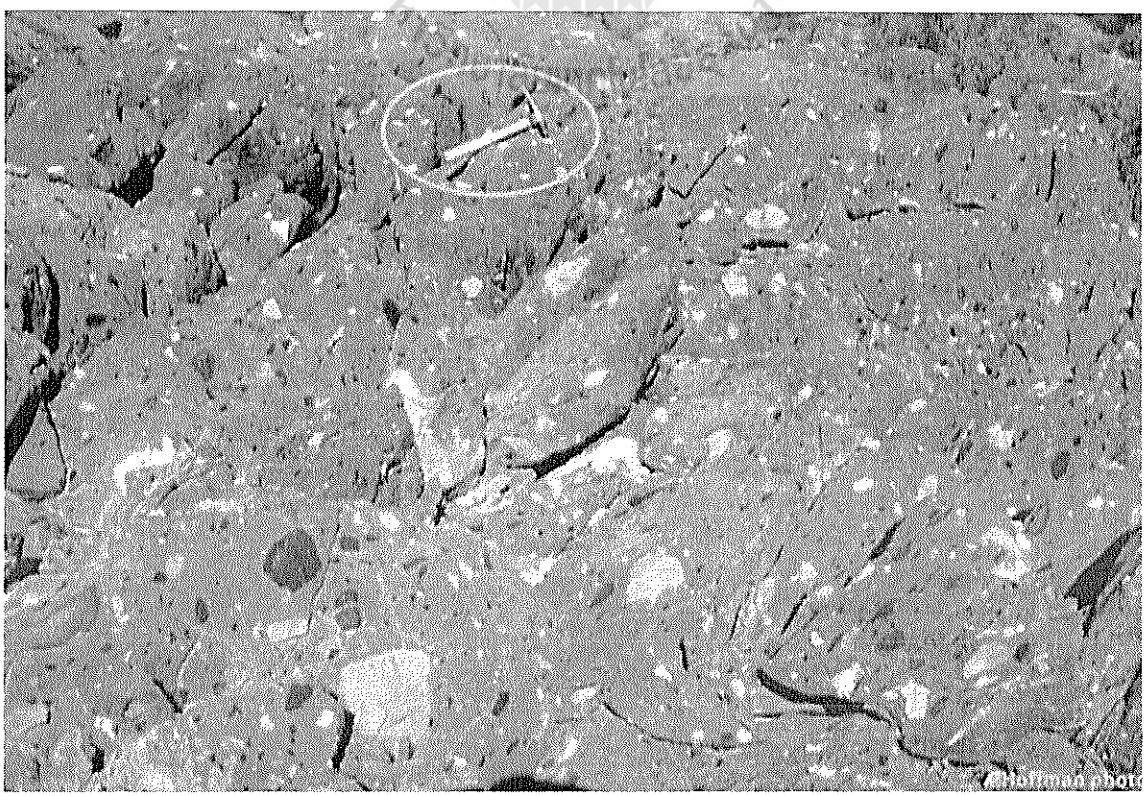


Fiords are coastal inlets formed by drowning of glacially carved valleys by rising sea level.



Evidence for older glaciations

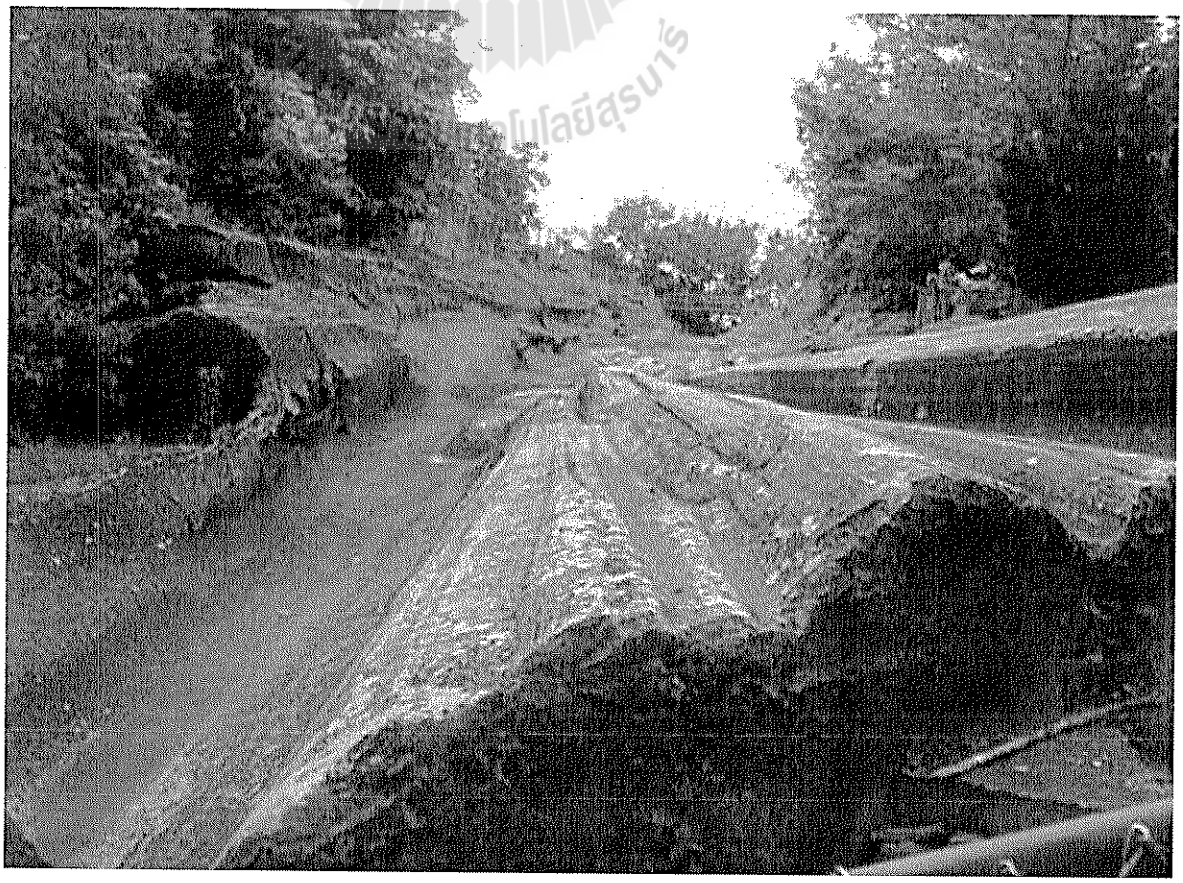
Tillites, lithified glacial till, have distinctive textures that suggest emplacement of sediments by glaciers.



Unsorted rock particles including angular, faceted and striated boulders.



Old tillites directly overlie polished and striated crystalline rocks.



Chapter 10
Maps and images for geology

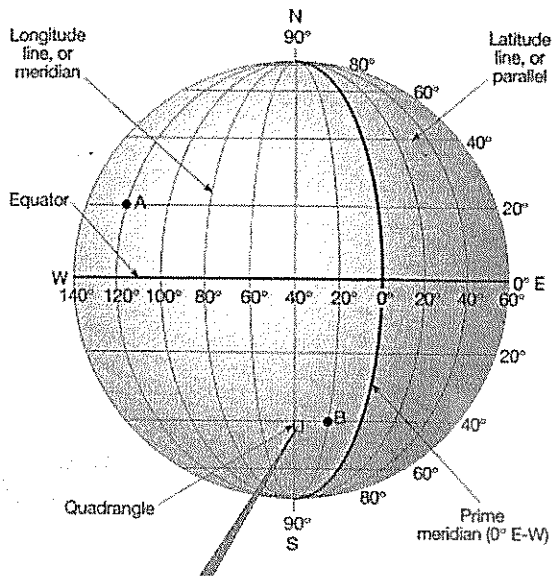
แผนที่และภาพถ่ายสำหรับธรณีวิทยา

Contents

1. Geographic coordination system
2. Topographic map
3. Geologic map
4. Arial photographs
5. Satellite Images

1. Geographic coordinate system

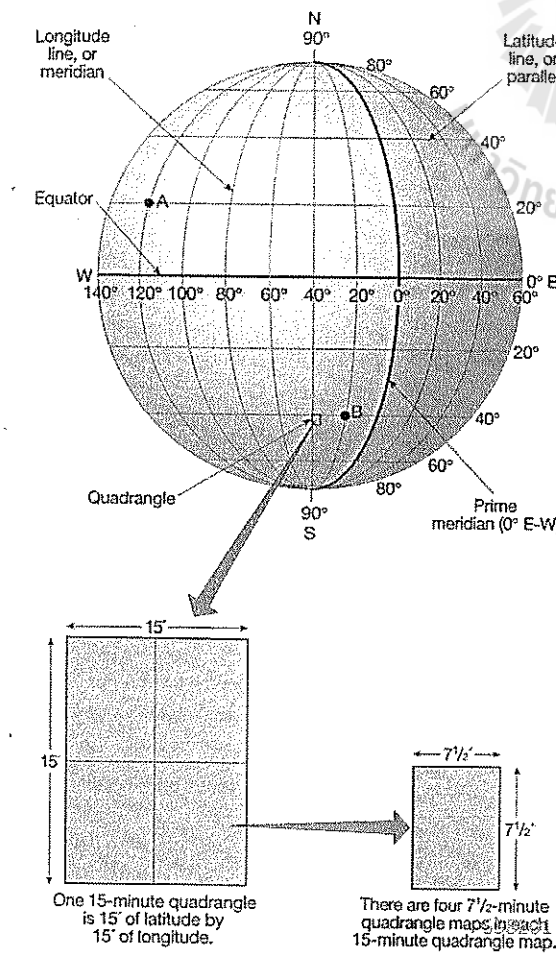
Latitude and Longitude



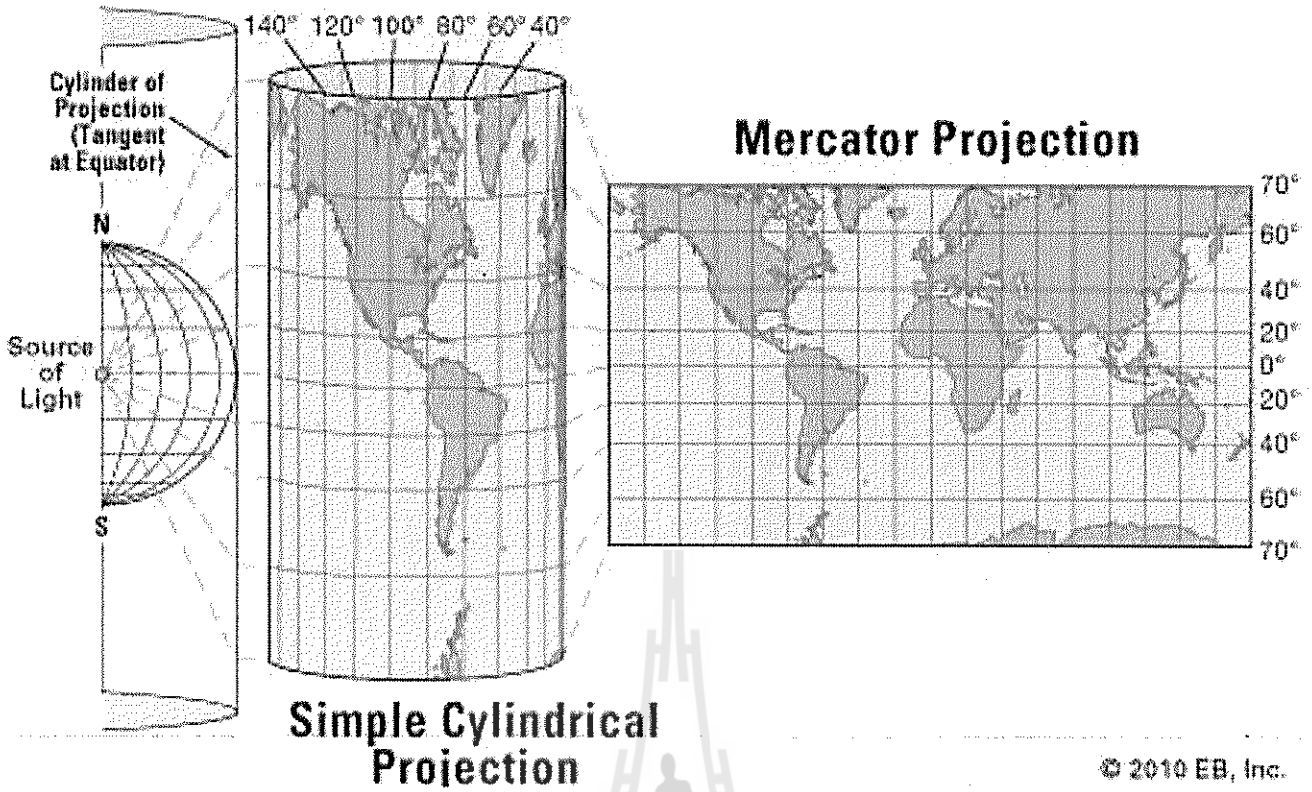
- Both are measured by degree
- Latitude is O degree at equator to 90 degree N and S.
- Longitude is measured from Prime meridian, to E and W.
- Each degree is divided into 60 minute.
- Each minute is subdivided into 60 seconds.

Topographic Quadrangles

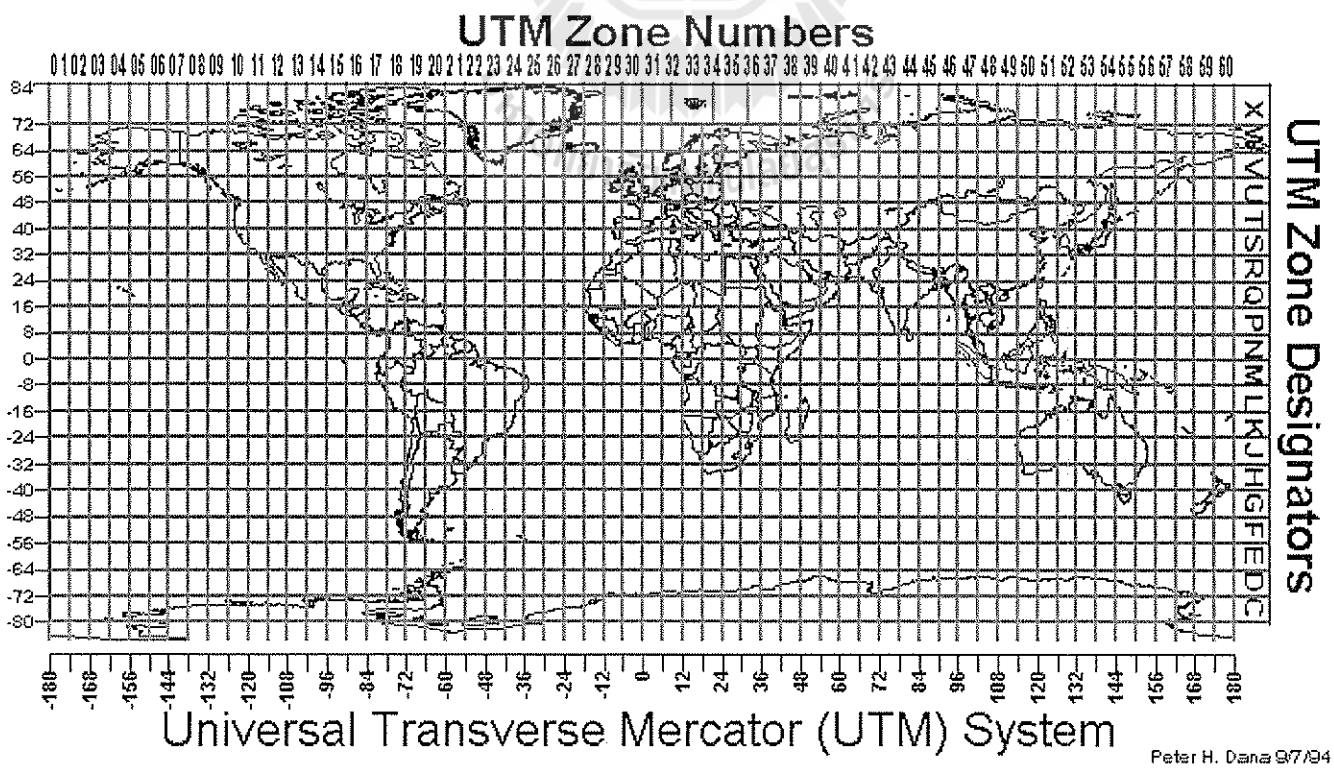
A quadrangle is a section of Earth's surface that is bounded by lines of latitude at the top (N) and bottom (S) and by lines of longitude on the left (W) and right (E).

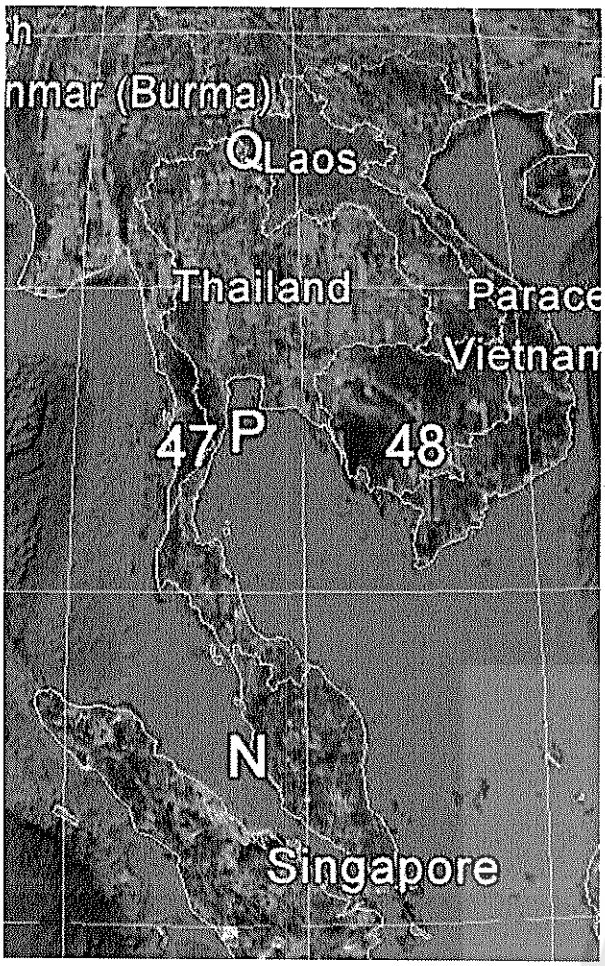


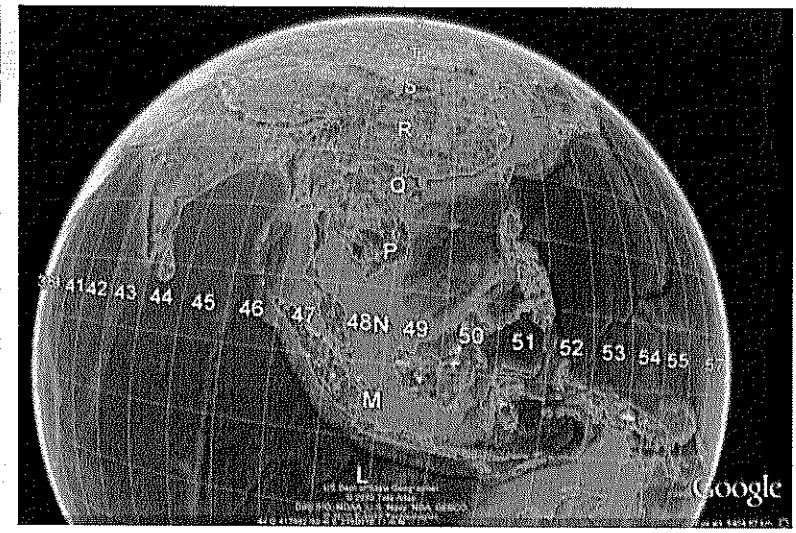
Mercator cylindrical projection



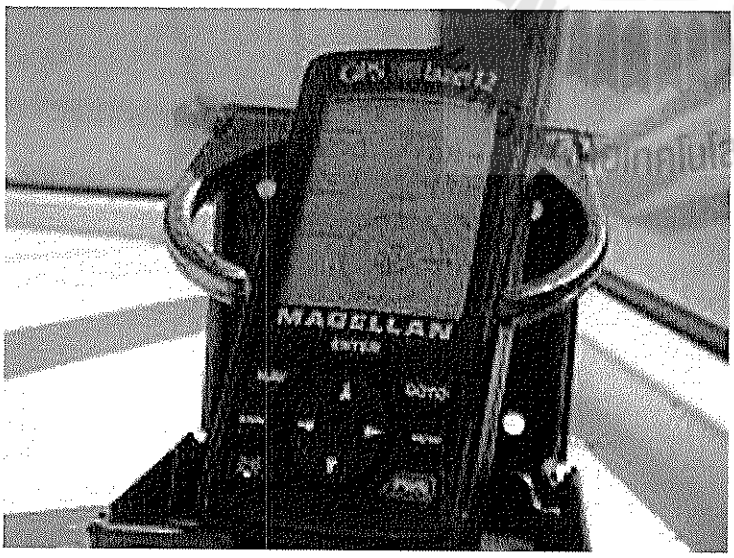
UTM-Universal Transverse Mercator System

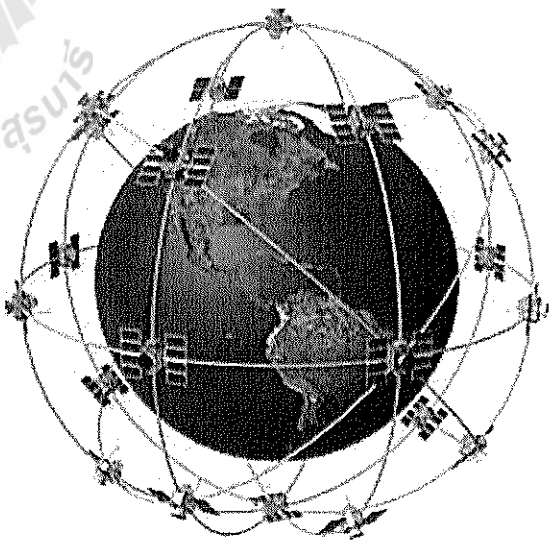






Global Positioning System

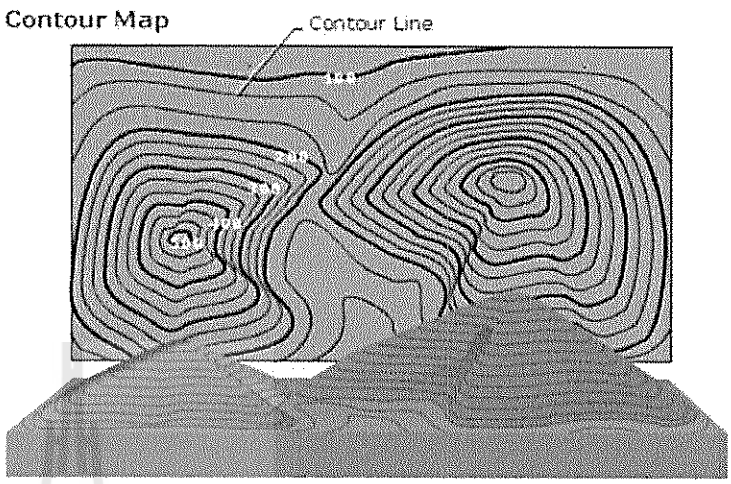




GPS navigation rely on the World Geodetic System 1984 (WGS1984). WGS 1984 is a datum based on the Universal Transverse Mercator (UTM) grid.

2. Topographic map

- A topographic map: miniature models of Earth's 3-D surface, printed on 2-D pieces of paper.

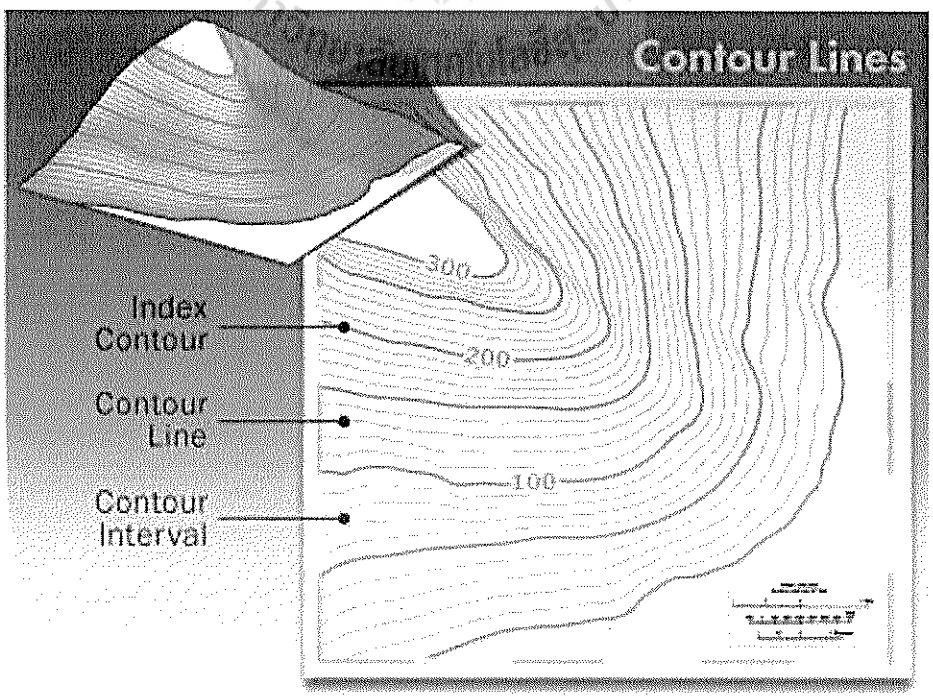


- Two dimensions are the lengths and widths of objects and landscape features.

- The third dimension, elevation (height) is shown using contour lines.

Contour lines

Each contour line connects all points on the map that have the same elevation above sea level.



Some contour line rules

- Contour lines generally should not merge or cross.

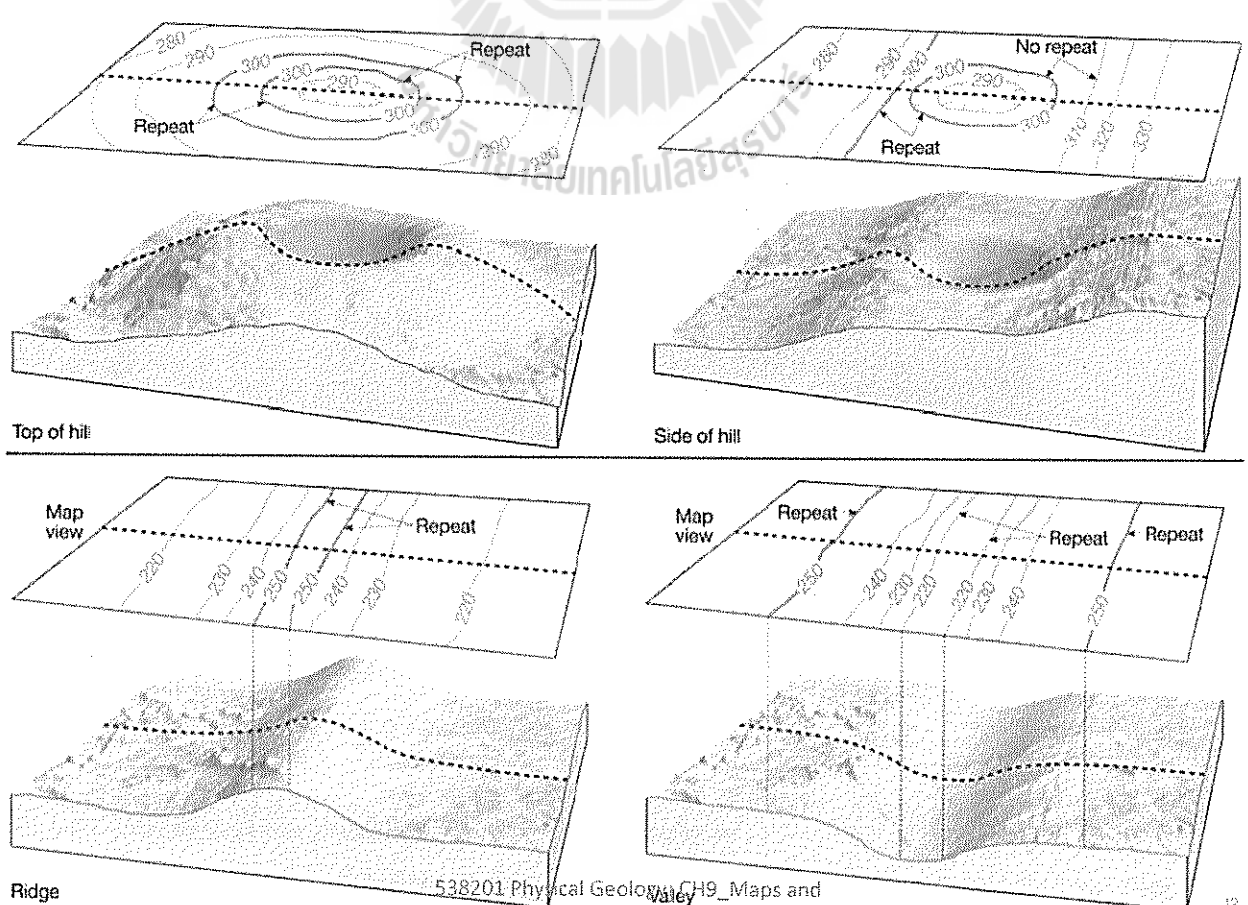
- Contours should be either closed within the map area or truncated by the edge of the map.

- Contour lines are repeated to indicate reversals in gradient direction.

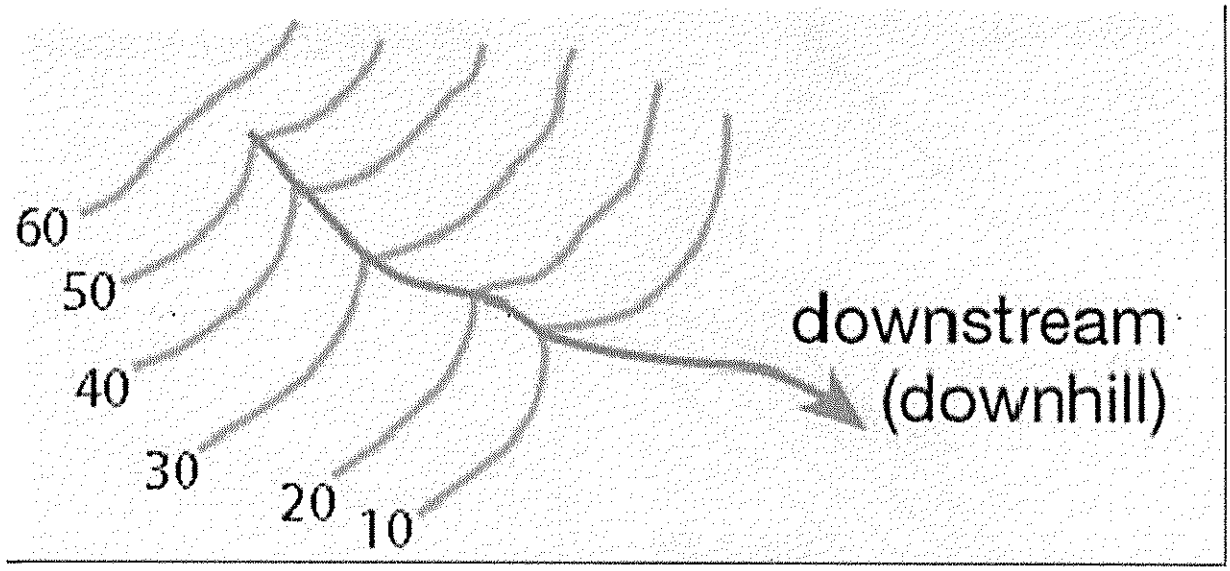
- Contours "V" point an upstream direction.

See more in a lab work sheet

Repeated contour lines

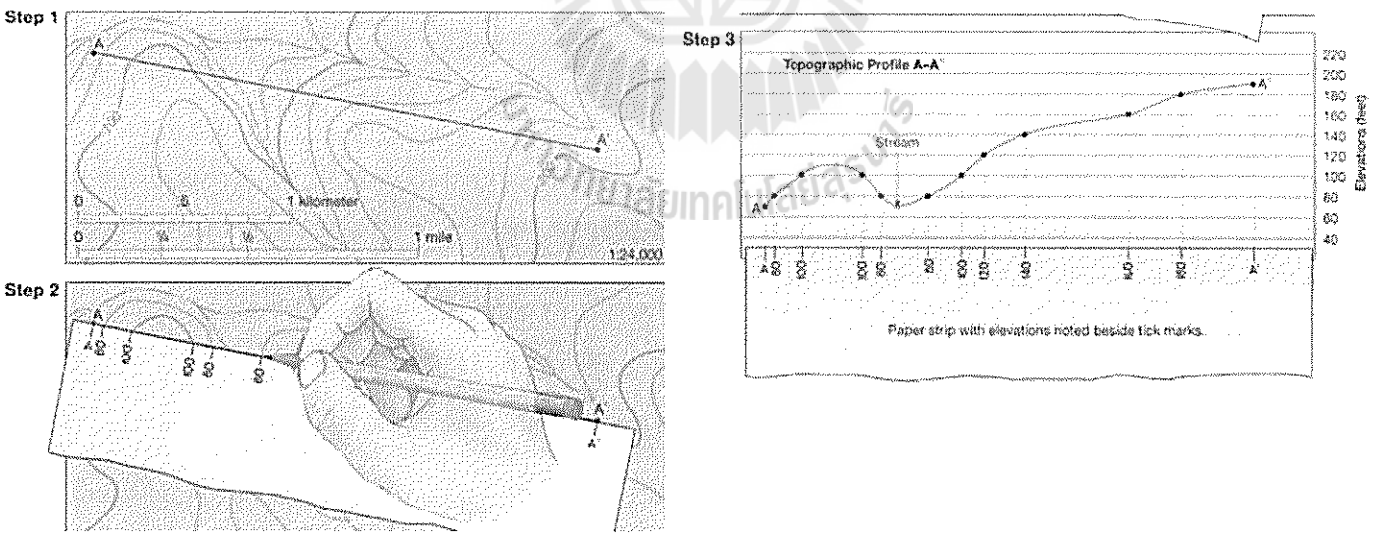


Rule of "V's"



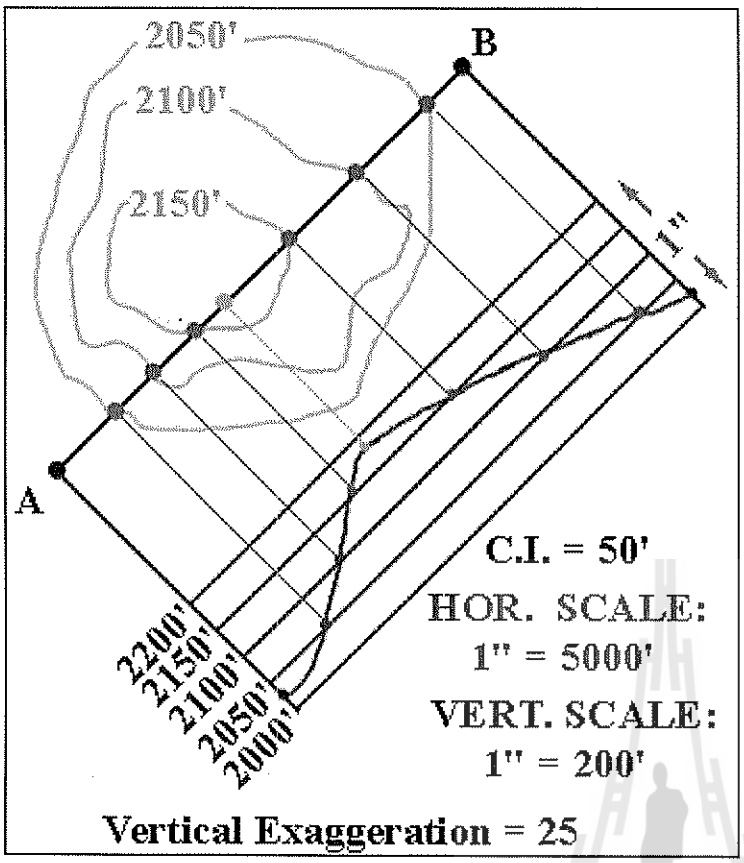
Contour lines "V" in an upstream direction where rivers or stream are present in the landscape (topography).

Topographic Profiles



To create the topographic profile, **vertical exaggeration** of the profile must be calculated.

Vertical exaggeration



VE = H scale / V scale

For a 1:50,000 topographic map

1 cm on a map = 50,000 cm = 500m in real world

1 cm = 500 m for vertical direction,

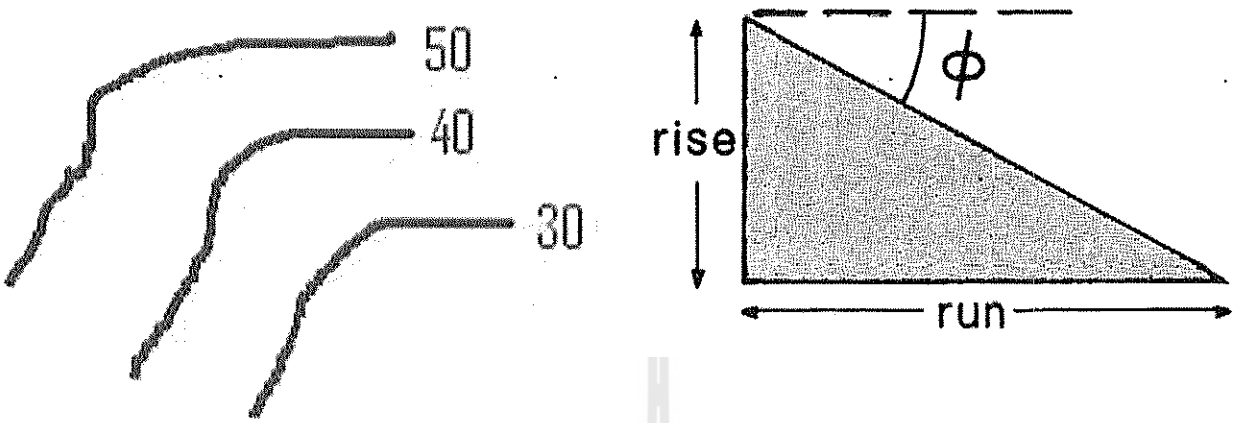
Vertical Exaggeration (VE) = H scale / V scale
= 500m / 500m
= 1x

1 cm = 250 m

VE = 500m/250m = 2x

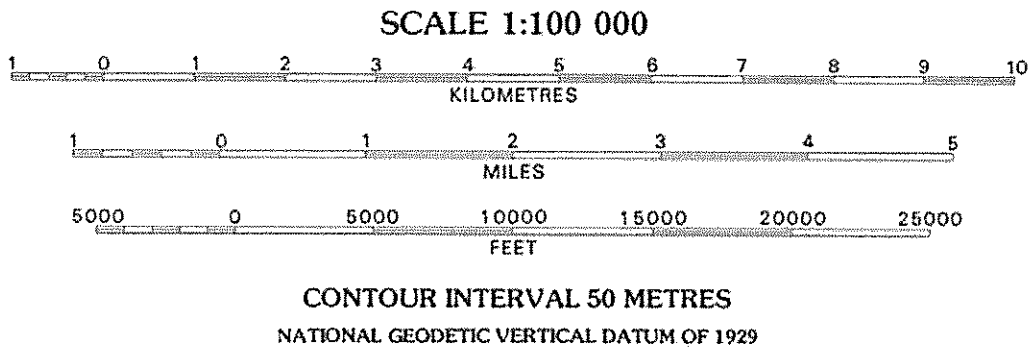
Calculating Gradient and Angle

Gradient = Relief (amount of rise) / Distance (run)



Scale of maps

Scale is the proportion by which you will reduce the real object to the model size.



The common map scales are 1:24,000, 1:15,000, 1:50,000, 1:100,000, 1:125,000, 1:250,000.

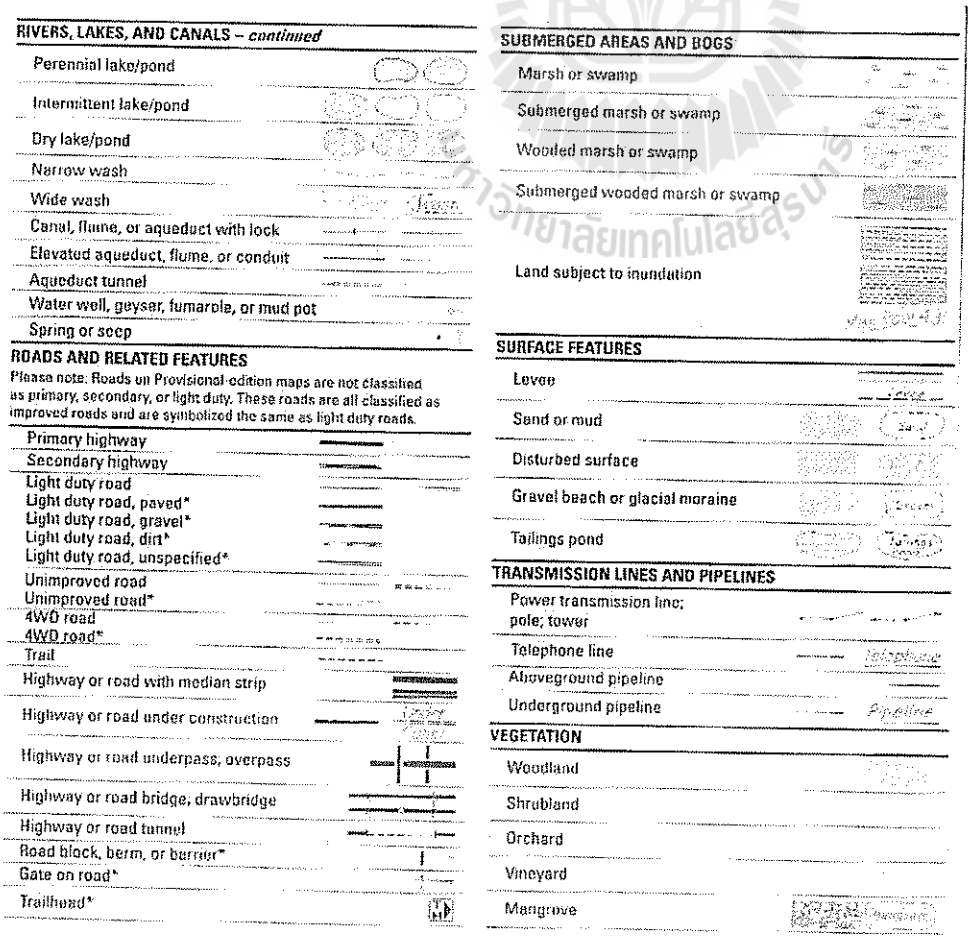
Other components on a topographic map

Sheet identification system
- Series name
- Series number
- Sheet name
- Sheet number

Indices
- Index to adjoining sheets
- Index to administrative boundaries

Diagrams
- Declination diagram
- Elevation guide

Topographic map symbols



RIVERS, LAKES, AND CANALS – *continued*
- Perennial lake/pond
- Intermittent lake/pond
- Dry lake/pond
- Narrow wash
- Wide wash
- Canal, flume, or aqueduct with lock
- Elevated aqueduct, flume, or conduit
- Aqueduct tunnel
- Water well, geyser, fumarole, or mud pot
- Spring or seep

ROADS AND RELATED FEATURES

Please note: Roads on Provisional-edition maps are not classified as primary, secondary, or light duty. These roads are all classified as improved roads and are symbolized the same as light duty roads.
- Primary highway
- Secondary highway
- Light duty road
- Light duty road, paved*
- Light duty road, gravel*
- Light duty road, dirt*
- Light duty road, unspecified*
- Unimproved road
- Unimproved road*
- 4WD road
- 4WD road*
- Trail
- Highway or road with median strip
- Highway or road under construction
- Highway or road underpass, overpass
- Highway or road bridge, drawbridge
- Highway or road tunnel
- Road block, berm, or barrier*
- Gate on road*
- Trailhead*

SUBMERGED AREAS AND BOGS
- Marsh or swamp
- Submerged marsh or swamp
- Wooded marsh or swamp
- Submerged wooded marsh or swamp
- Land subject to inundation

SURFACE FEATURES
- Levee
- Sand or mud
- Disturbed surface
- Gravel beach or glacial moraine
- Tailings pond

TRANSMISSION LINES AND PIPELINES
- Power transmission line; pole; tower
- Telephone line
- Aboveground pipeline
- Underground pipeline

VEGETATION
- Woodland
- Shrubland
- Orchard
- Vineyard
- Mangrove

3. Aerial photographs

A "bird's eye view" is very useful for map making, features obscure each other less when viewed from above than when viewed from ground level

Air photography can come from many sources such as airplanes of all types can be equipped with cameras, and also can hot air balloons, helicopters, pigeons, etc.

Contents

- Terms
- Basic camera
- Scale
- Resolution
- Flight line
- Stereo paralax
- Aligning air photos

Important terms

Focal Length: the distance between the camera lens and the film

Flying Height: the height of the plane (and therefore the camera) above the ground

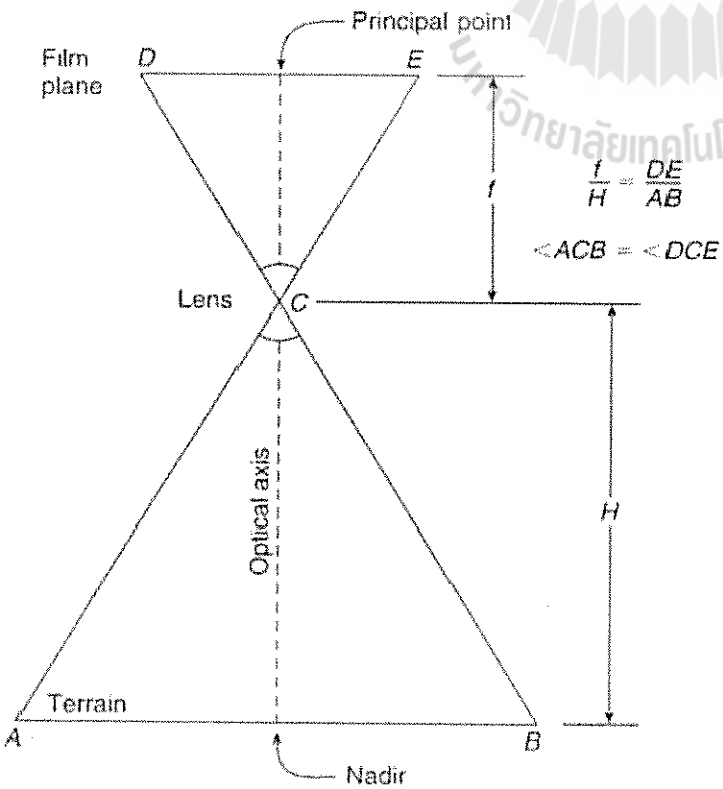
Nadir: the point on the ground directly below the camera

Flight Line: the path of the airplane over which a sequence of pictures is taken

Stereoscope: a device used to view/measure feature heights and/or landscape elevations using pairs of air photographs

Fiducial Marks: marks on photographs used to align adjacent photos for stereoscopic analysis

Basic camera



- Everything above "C" is inside the camera
- The film sits on the film plane
- f = focal length
- H = Elevation above ground
- ACB = angle of coverage

Scale: the ratio of the distance between two points on a photo to the actual distance between the same two points on the ground.

$$\frac{\text{PHOTO DISTANCE}}{\text{GROUND DISTANCE}} = \frac{4\text{ cm}}{1\text{ km}} = \frac{4\text{ cm}}{100\,000\text{ cm}} = \frac{1}{25\,000} \quad \textbf{SCALE: 1/25 000}$$

The scale can also be calculated from the ratio of focal length and the altitude of the flight.

$$\frac{\text{FOCAL LENGTH}}{\text{ALTITUDE (AGL)}} = \frac{152\text{ mm}}{7\,600\text{ m}} = \frac{152\text{ mm}}{7\,600\,000\text{ mm}} = \frac{1}{50\,000} \quad \textbf{SCALE: 1/50 000}$$

Film: most air photo missions are flown using black and white film, however colour, infrared, and false-colour infrared film are sometimes used for special projects.

Types of film

- Black and White (a.k.a. panchromatic)
- Color
- Infrared
- Color Infrared (CIR)

Resolution

- Currently, a 9 x 9 inch format digital camera would require about 400 million pixels to approach the resolution of a typical 9 x 9 inch film camera (Paine and Kaiser 2003).

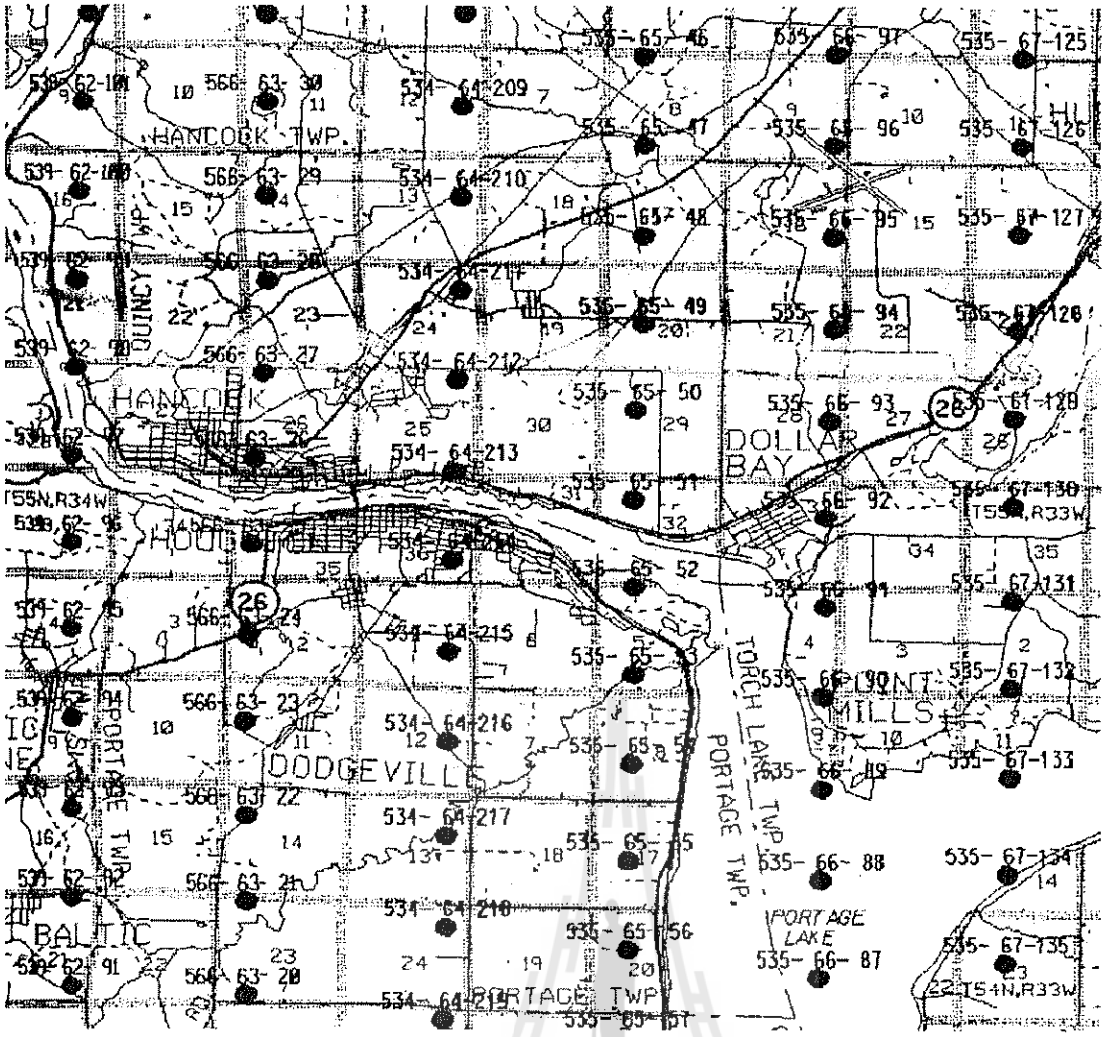
- This is roughly 2222 pixels/inch.

Flight Lines

- Successive photos on a flight line typically have ~60-65% overlap to allow stereoscopic viewing

- Adjacent flight lines typically have ~20-30% overlap

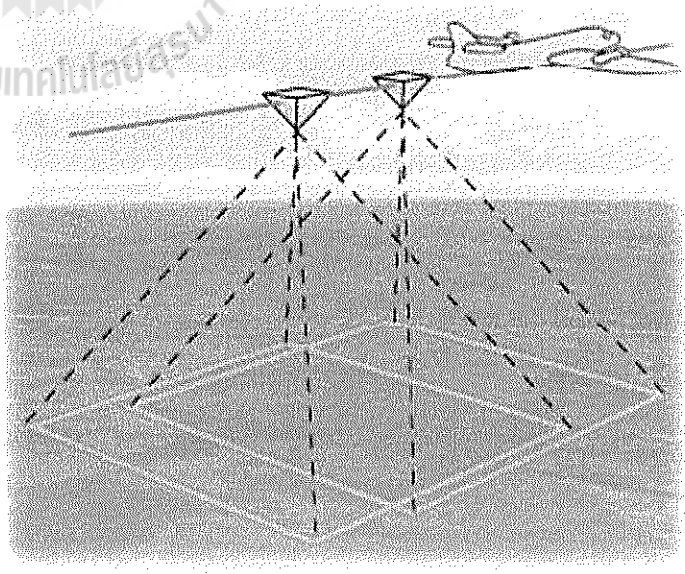
- Some location of the ground may be imaged on 3 photographs along the same flight line and 6 photographs in total

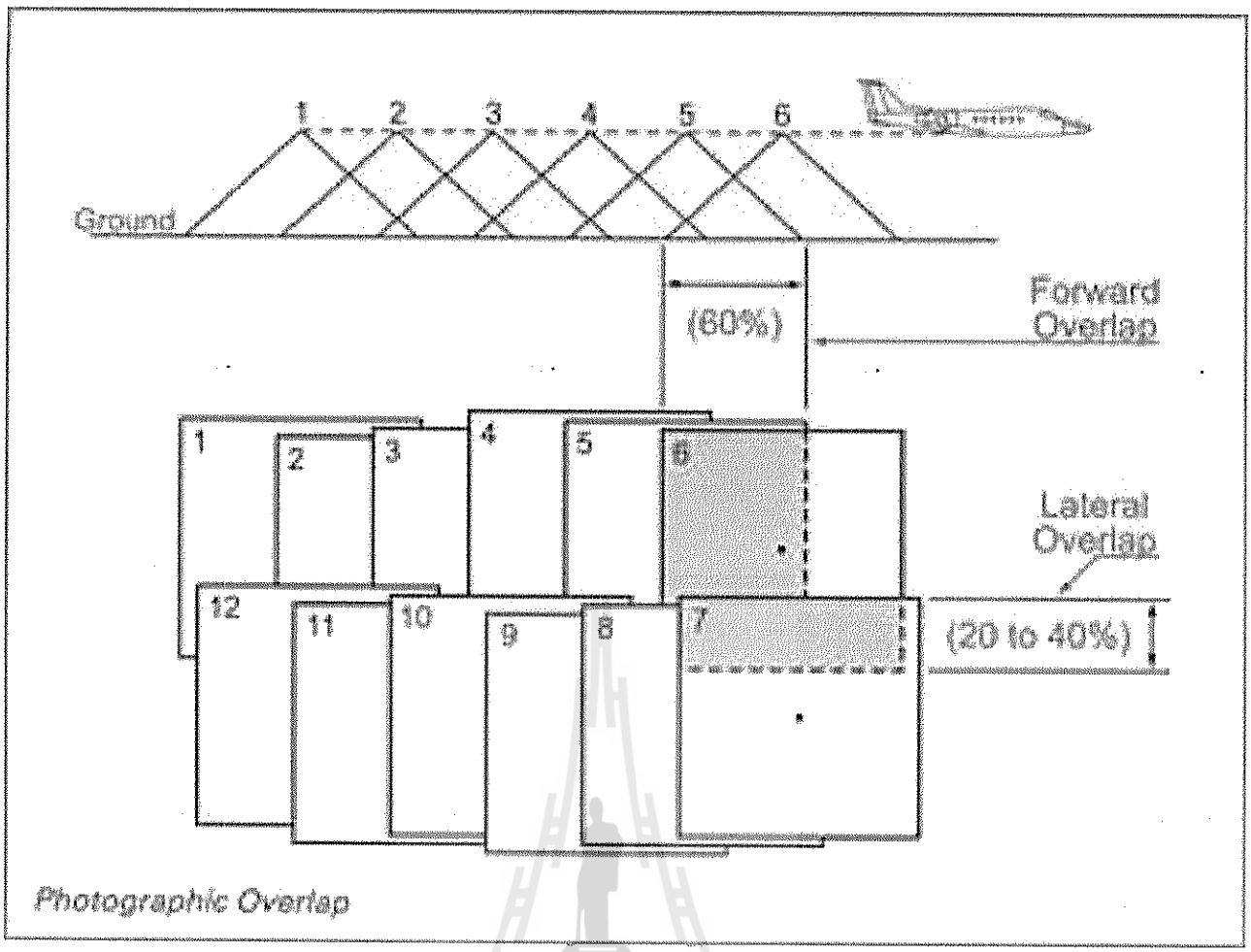


29

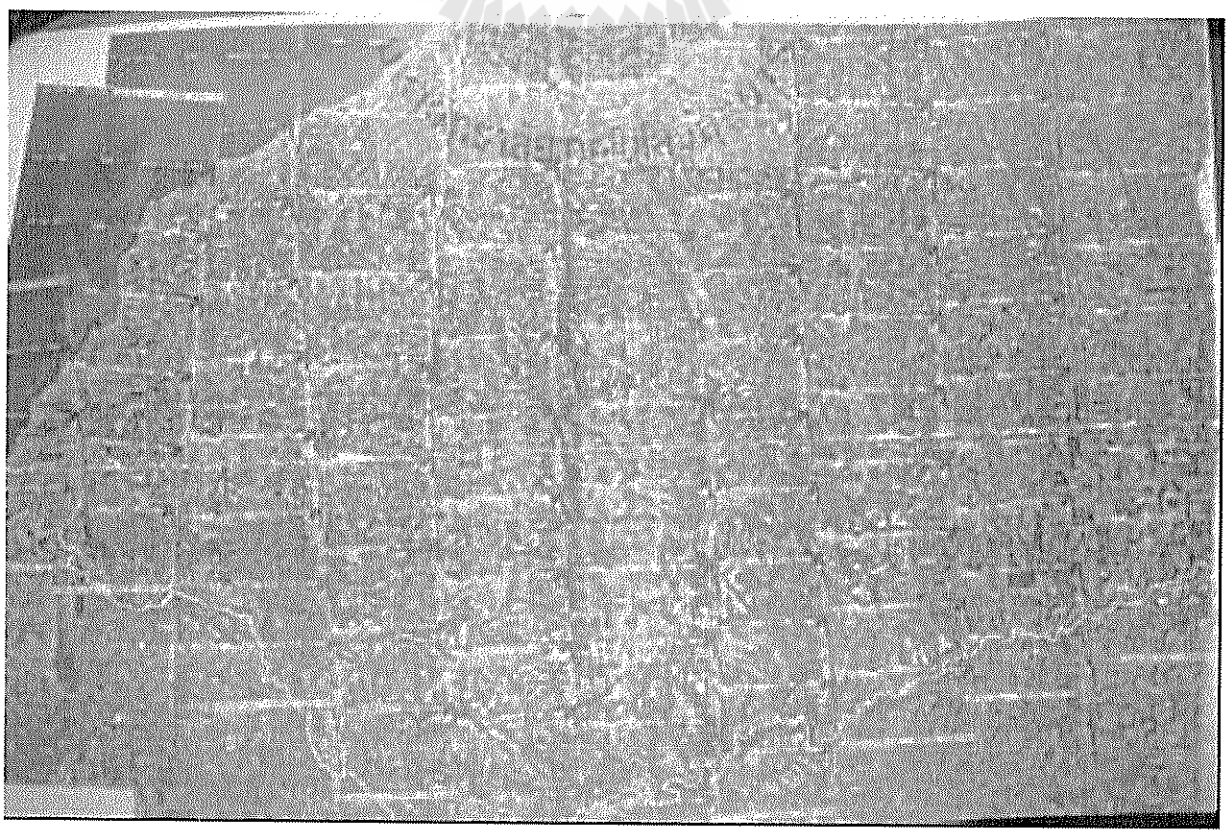
Stereoscopic Parallax

- Stereoscopic Parallax is caused by a shift in the position of observation
- Parallax is directly related to the elevation / height of features

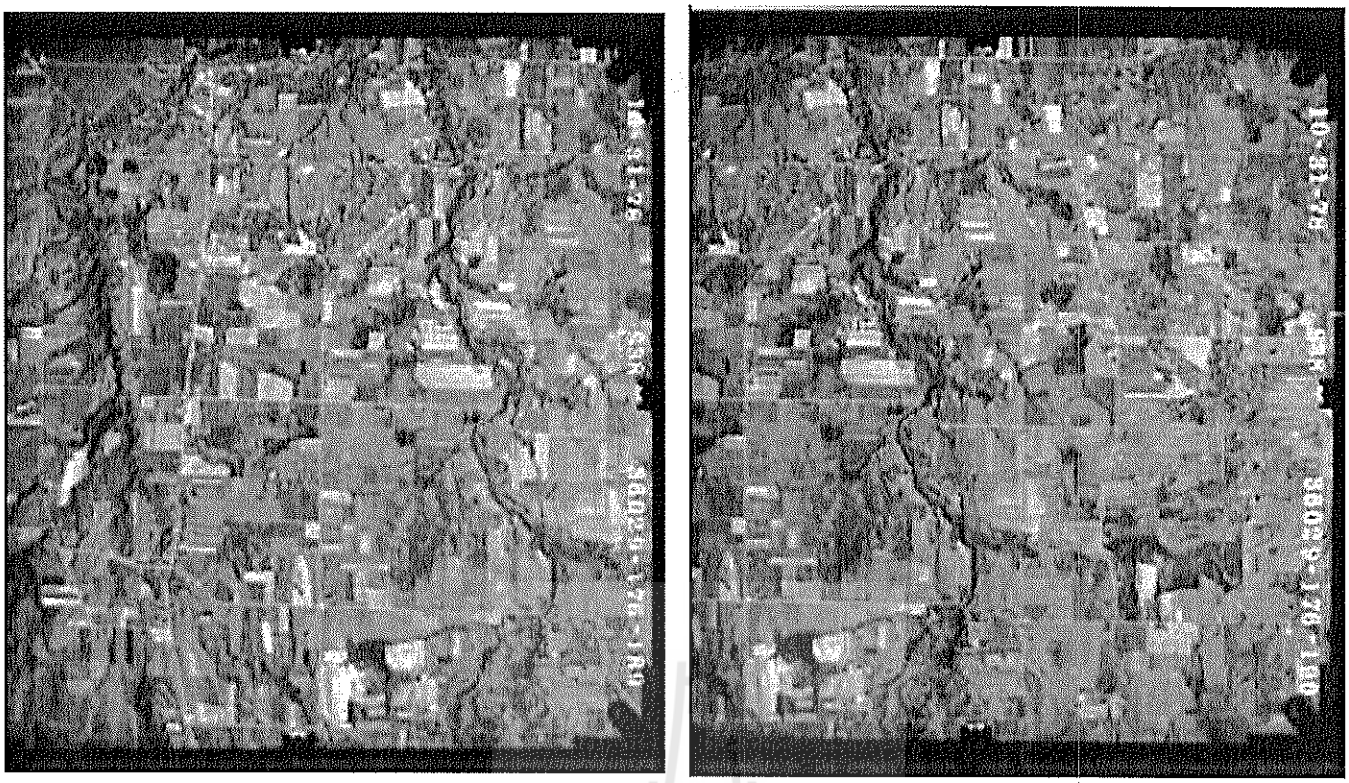




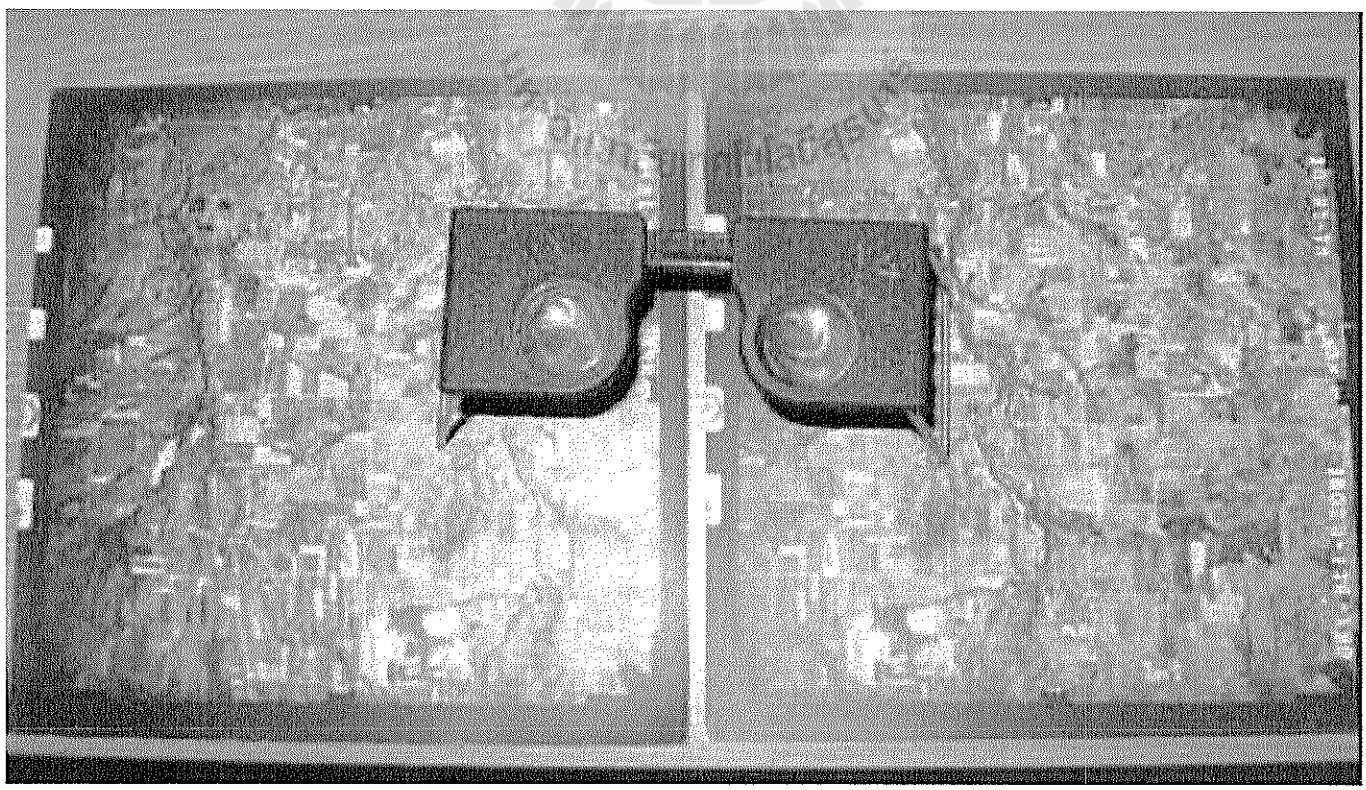
Air photo mosaic



Stereo pair



Stereoscope



Stereoscopic Coverage: the three-dimensional view which results when two overlapping photos (called a stereo pair), are viewed using a stereoscope.

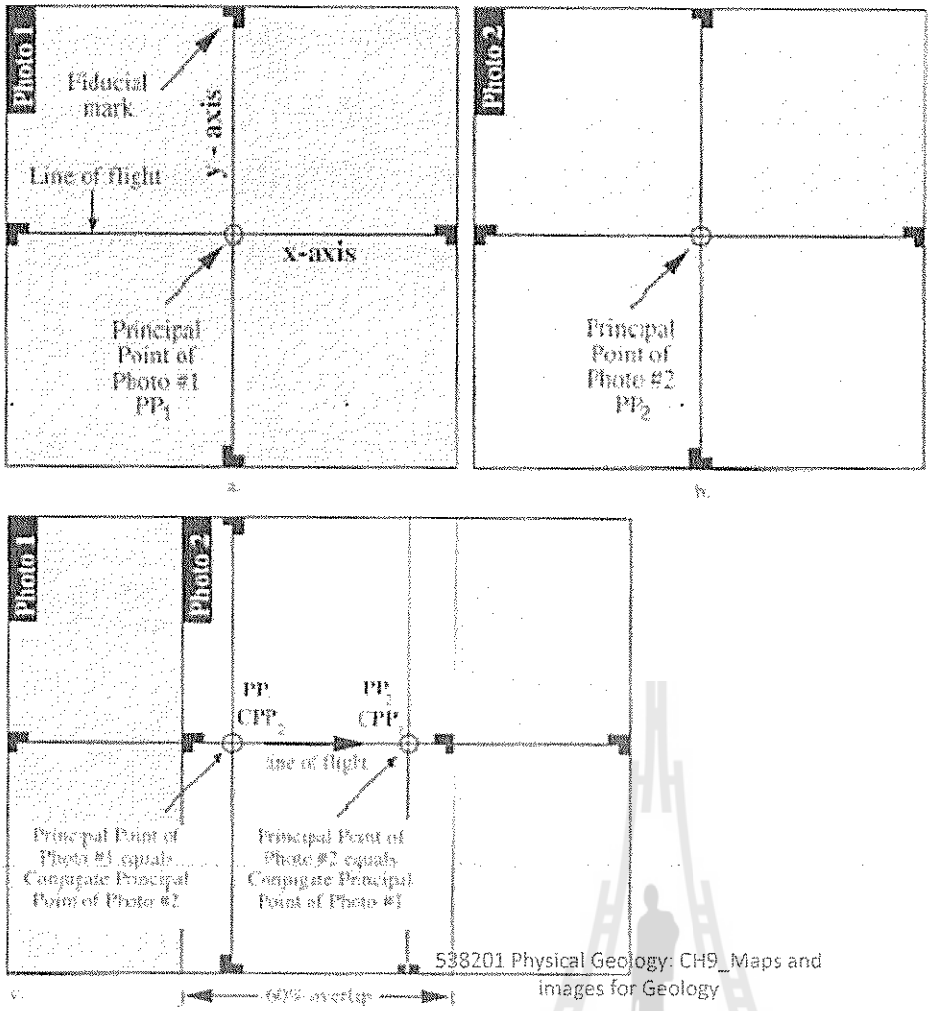
Each photograph of the stereo pair provides a slightly different view of the same area, which the brain combines and interprets as a 3-D view.

Aligning Air Photos

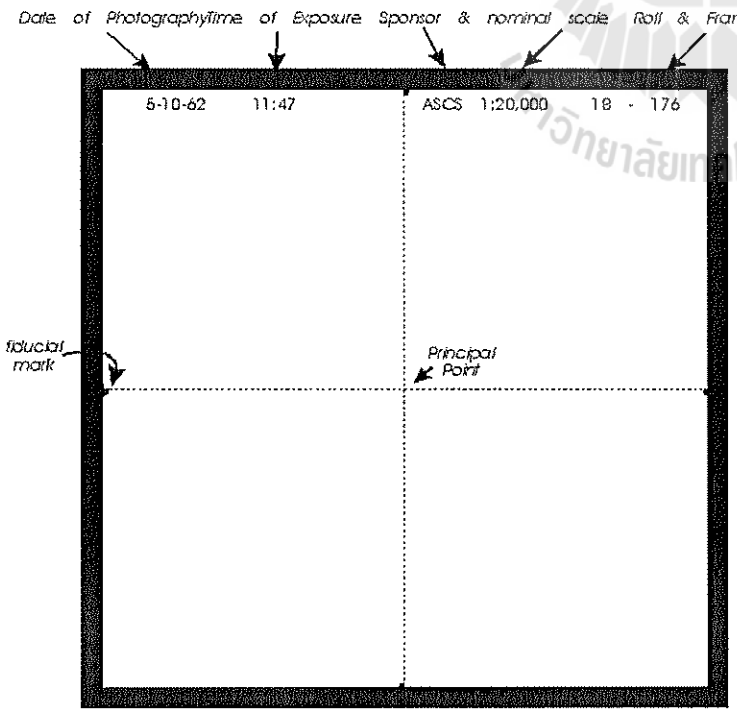
- Fiducial marks
  - Type and number vary amongst cameras
  - 4-8 marks (e.g., top, bottom, left, right, & 4 corners)

- Principal Point (PP) - the exact point at which the camera was aimed when the photo was acquired

- Conjugate Principal Point (CPP) – the principal point of an adjacent photograph in the flight line



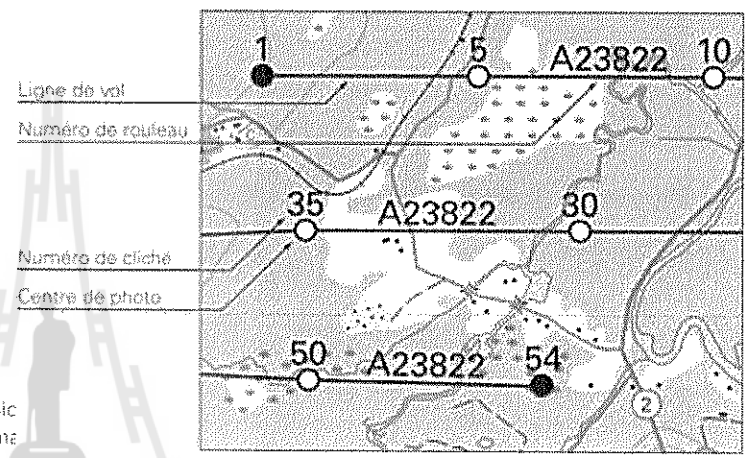
The Aerial Photo



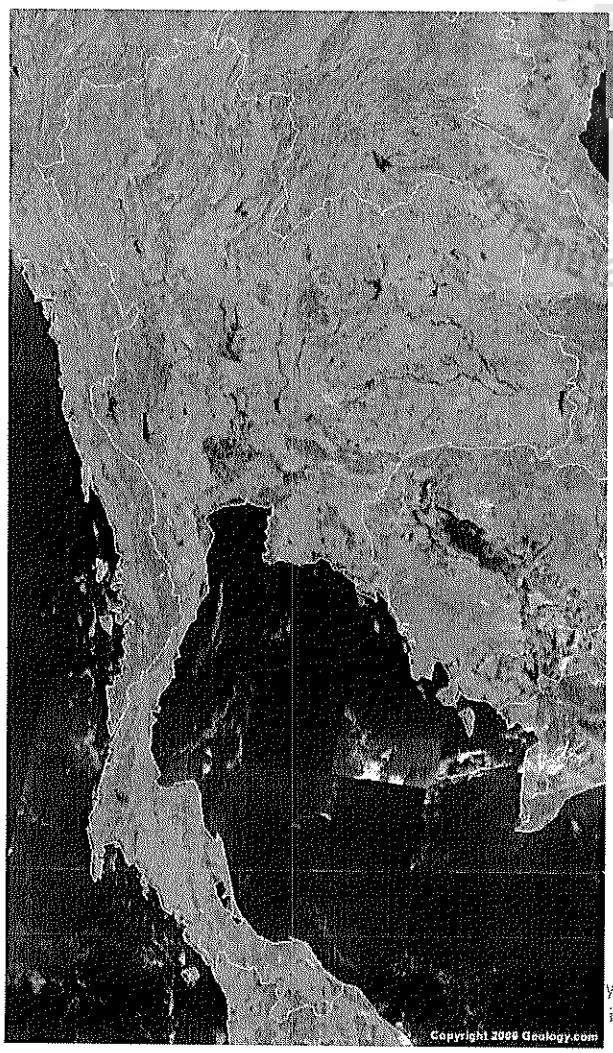
Roll and Photo Numbers:
each aerial photo is assigned a unique index number according to the photo's roll and frame.

Flight Lines and Index Maps: at the end of a photo mission, the aerial survey contractor plots the location of the first, last, and every fifth photo centre, along with its roll and frame number, on a National Topographic System (NTS) map.

Photo centres are represented by small circles, and straight lines are drawn connecting the circles to show photos on the same flight line.



538201 Physic
ima

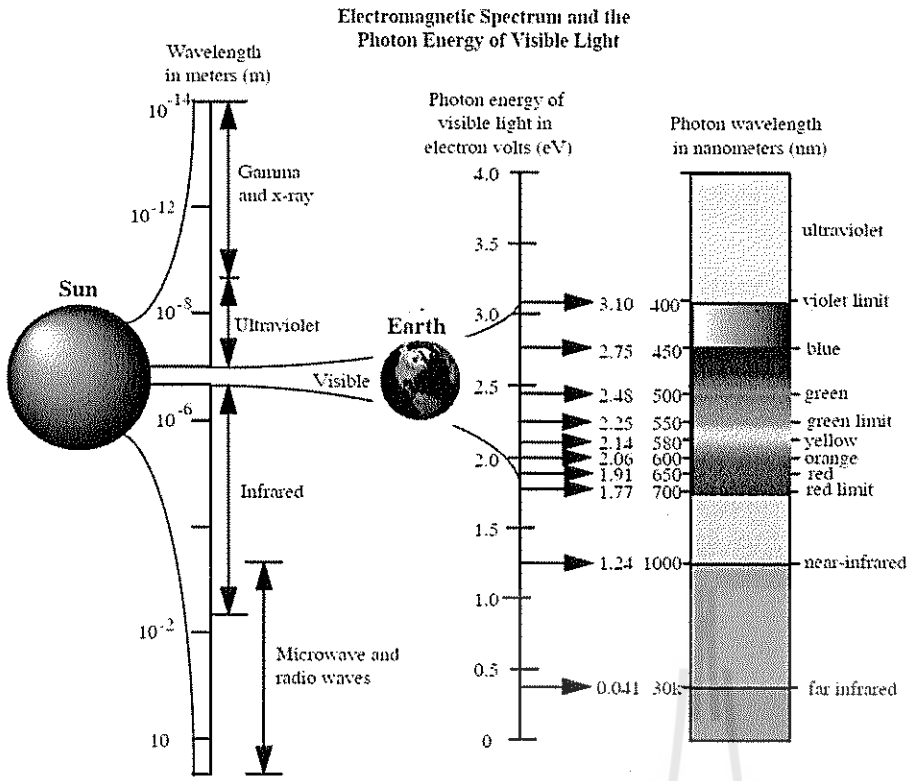


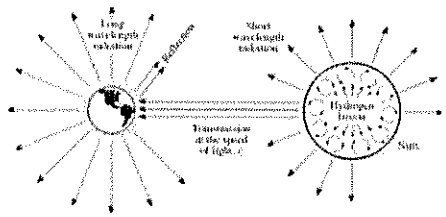
4. Satellite Image

Contents

- Electromagnetic Waves
- Remote Sensing
- Satellite Imagery
- Image display
- Satellites

The satellite image of Thailand was produced using Landsat data from NASA and the map was produced using data licensed from and copyright by Map Resources © 2008. (www.Geology.com)





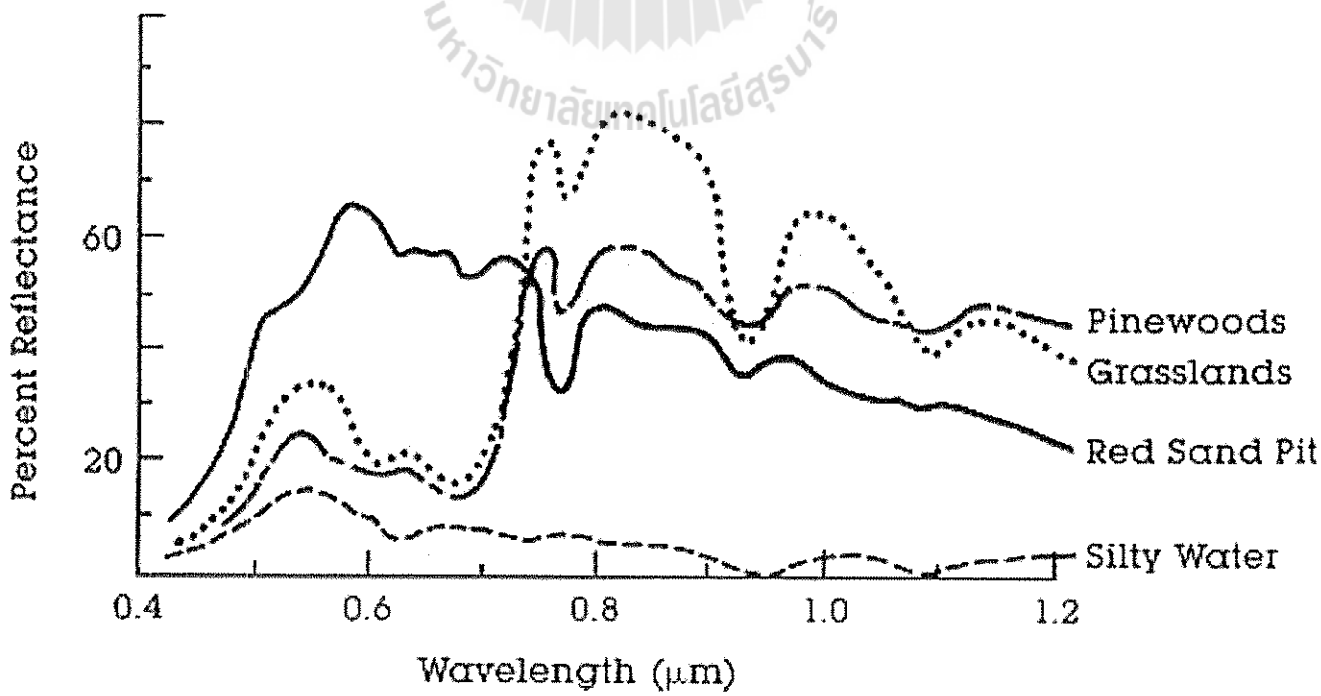
EMR energy moves at the speed of light (c):

$$c = f \lambda$$

- f = frequency: The number of waves passing through a point within a unit time (per sec)
- Energy (ε) carried by a photon: $\varepsilon = h f$ [h=Planck constant (6.626×10^{-34} Joules*seconds)]
- The shorter the wavelength, the higher the frequency, and the more energy a photon carries. Therefore, short wave ultraviolet solar radiation is very destructive (sunburns)

- The color of an object is determined by how much light it reflects of each wavelength in the visible light portion of the EM spectrum.
- Some objects emit light as well, greatly affecting their color.
- Objects reflect some wavelengths.
- Objects absorb some wavelengths.

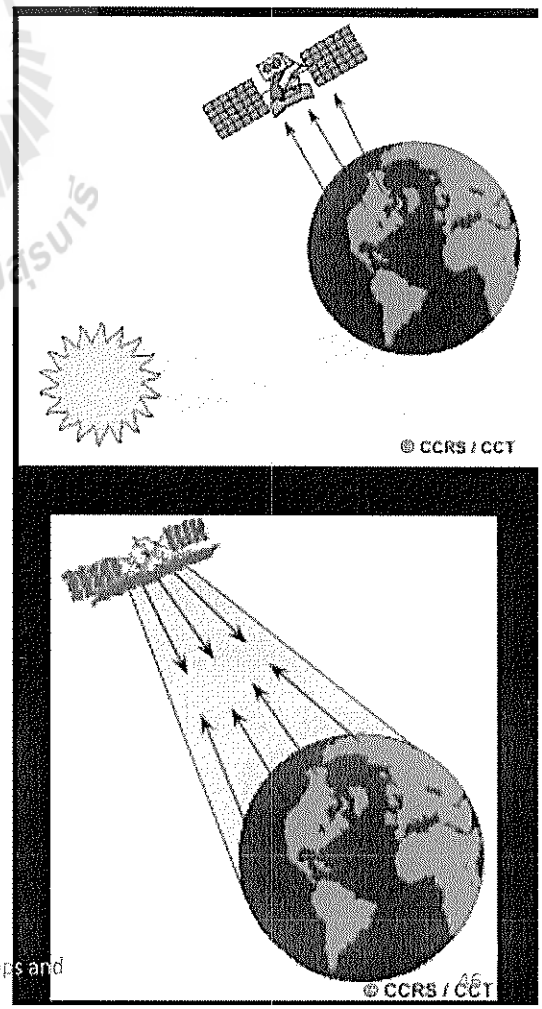
Spectral signatures



- Remote sensors are devices that sense energy from a remote location (i.e., a device not in physical contact with what it is sensing)
- Remote sensing is the science of acquiring, processing and interpreting information/data collected by remote sensors.

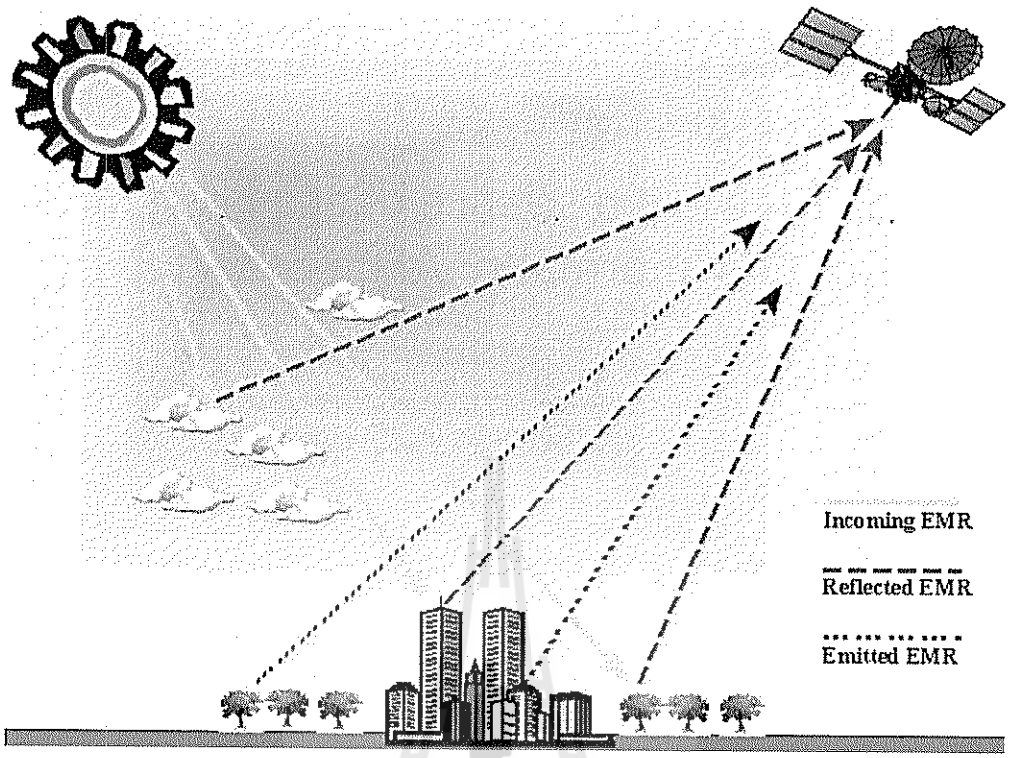
Passive: detect emitted/reflected energy from other sources
- Satellite sensors
- Air photos
- Cameras
- Video recorders

Active: emit energy and detect reflections
- Radar
- Lidar



Satellite Imagery

Digital data is obtained by sensors on satellite platforms.



Satellite imagery is described by five resolutions

Spatial resolution: area on ground represented by each pixel

Advanced Very High Resolution Radiometer (AVHRR) – 1 km

- Landsat - 30m
- SPOT – 2.5m - 20m / 2.5m - 10m
- IKONOS - 1m/4m

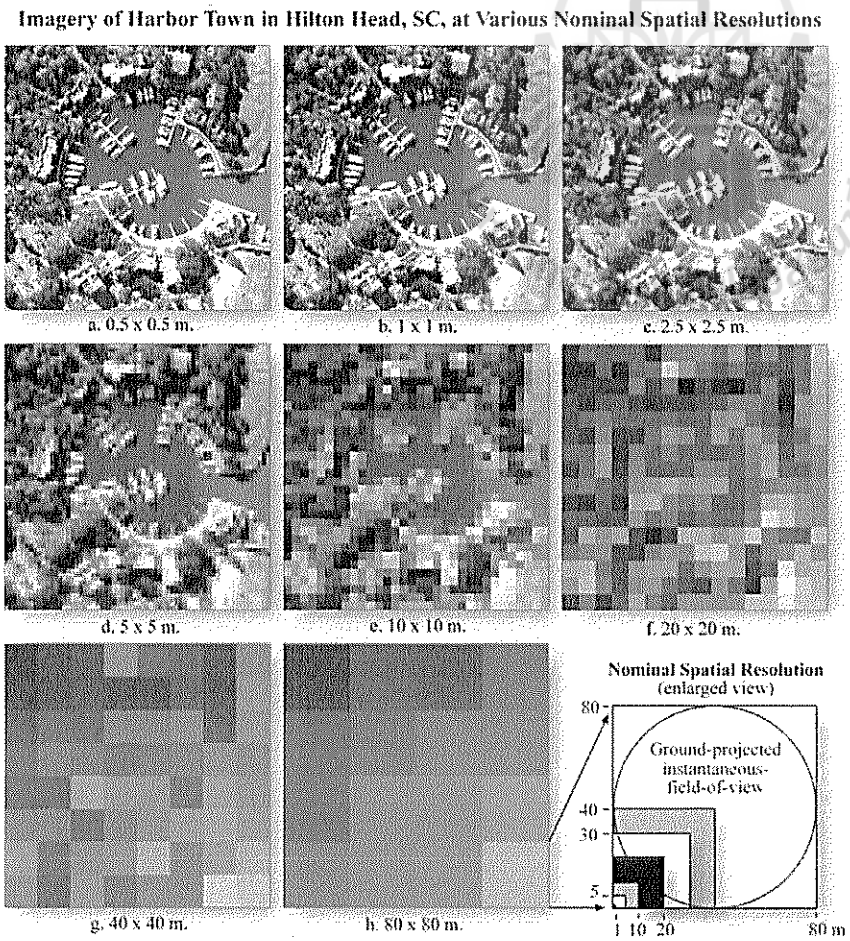
Temporal resolution: how often a satellite obtains imagery of a particular area

Spectral resolution: specific wavelength intervals in the electromagnetic spectrum captured by each sensor

Radiometric Resolution: number of possible data values reportable by each sensor (how sensitive the sensor is to changes in brightness of objects that it views)

View angle resolution: the number of angles at which the ground objects are recorded by the sensor.

Spatial resolution



Temporal Resolution

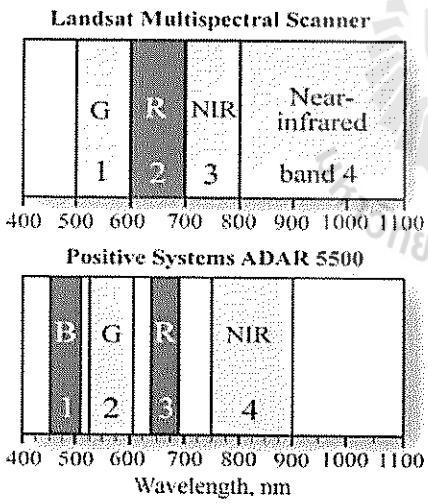
Number of days between overhead passes at the same location

- LANDSAT - 16 days
- AVHRR - daily
- IKONOS - 1 to 3 days

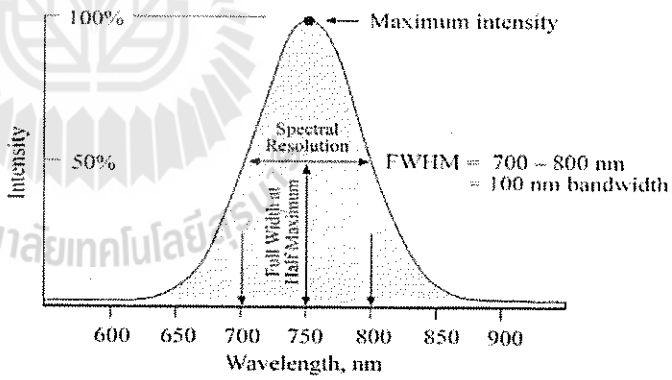
Spectral Resolution

Number, spacing and width of sampled wavelength bands

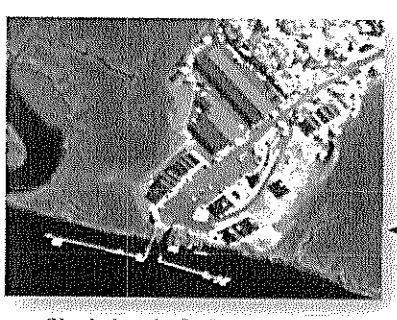
Higher resolution results in more precision in representation of spectral signatures



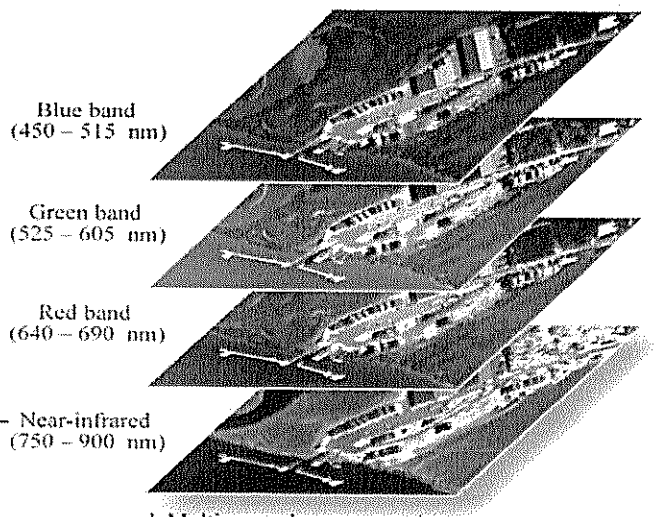
a. Nominal spectral resolution of the Landsat Multispectral Scanner and Positive Systems ADAR 5500 digital frame camera.



b. Precise bandpass measurement of a detector based on Full Width at Half Maximum criteria.



c. Single band of ADAR 5500 data.



d. Multispectral remote sensing.

- A continuum of all possible energies that radiate through space
- In remote sensing, we mainly focus on visible, infrared and microwave

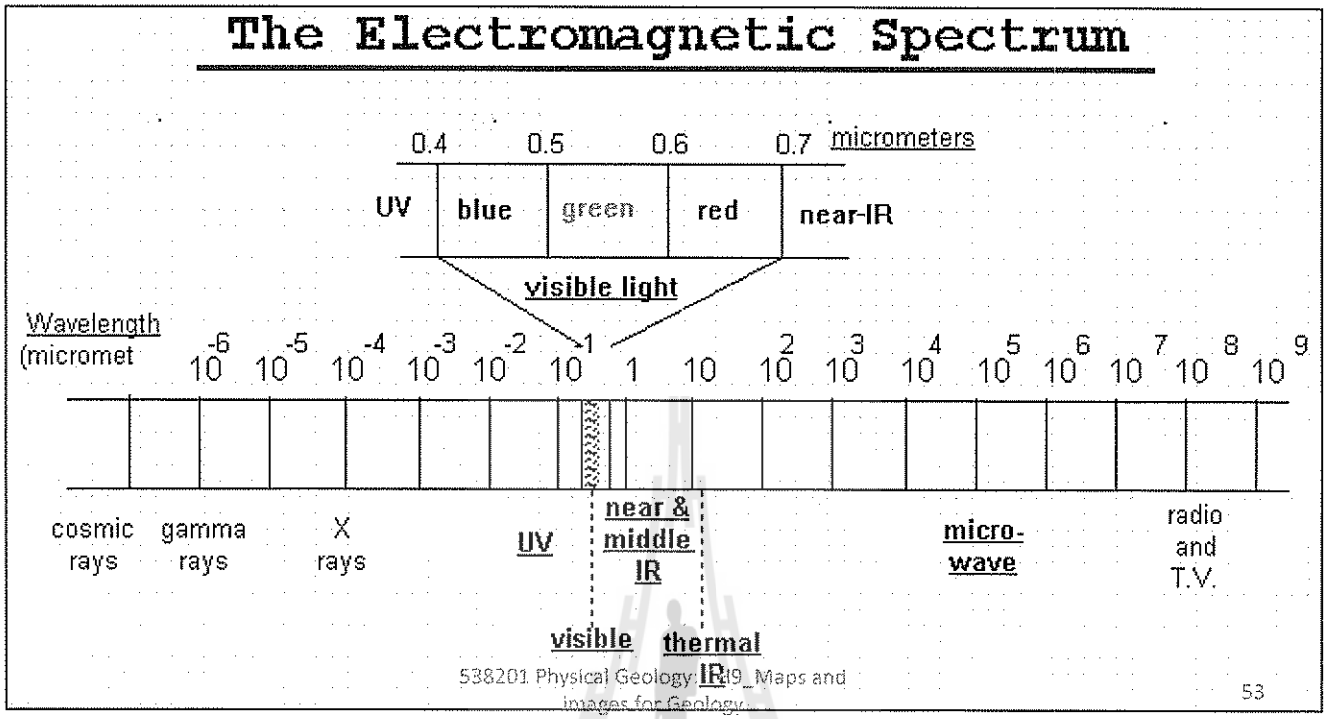


Image Display

- Graphics display devices use three color guns
  - Red, Green, Blue
  - All colors can be formed from various combinations of these 3 colors (which is why they're used in computer/TV screens)

- The brightness values (BV) to be displayed will often have an 8-bit range
  - 0 to 255
- In remote sensing, we assign one band to each color gun to give color to the image

- For a single band, the resultant color will be grayscale

Band 1	Band 1	Band 1
Red color gun	**Green color gun**	**Blue color gun**

- All three colors display the same value, so the colors are shades of gray

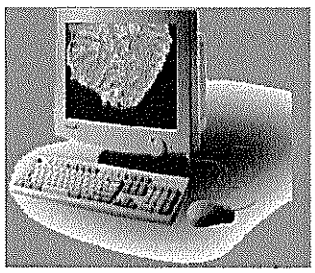
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- For a multi-band image, the resultant color will depend on which bands are assigned to which color guns

True Color Composite (321)	Red (3) Red color gun	Green (2) Green color gun	Blue (1) Blue color gun
False Color Composite (432)	Near Infrared (4) Red color gun	Red (3) Green color gun	Green (2) Blue color gun

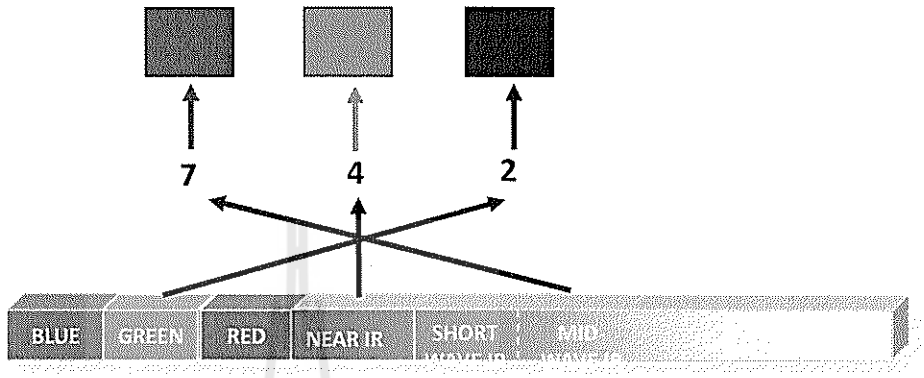
Multispectral Imagery Display

Band Composite Output =



Color Guns =

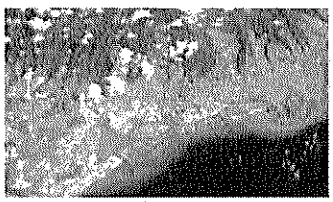
Band Combination =



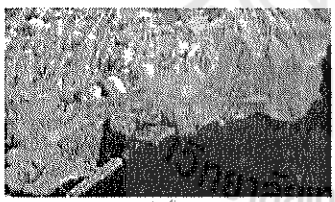
Landsat TM Band = 1 2 3 4 5 7 6

STEP #1

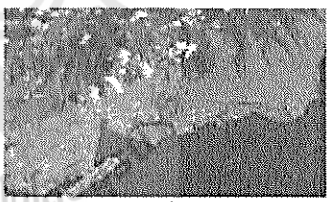
Band 2



Band 8

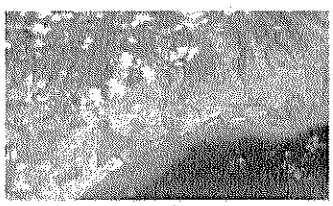


Band 10

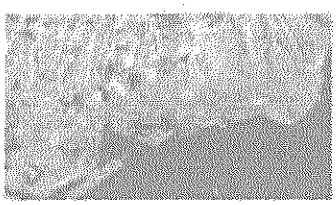


STEP #2

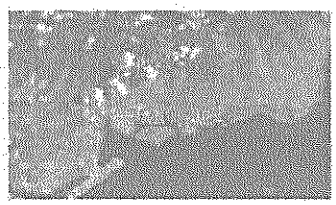
Blue color gun



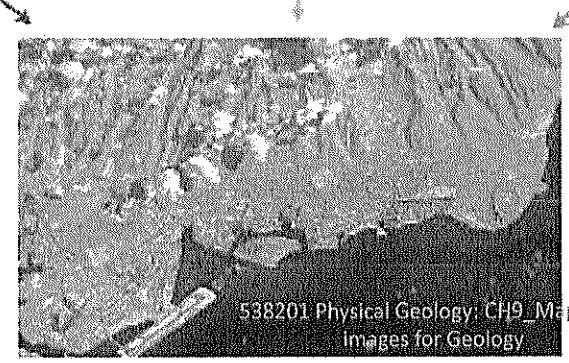
Green color gun



Red color gun



STEP #



Color composite image

Satellites

ASTER

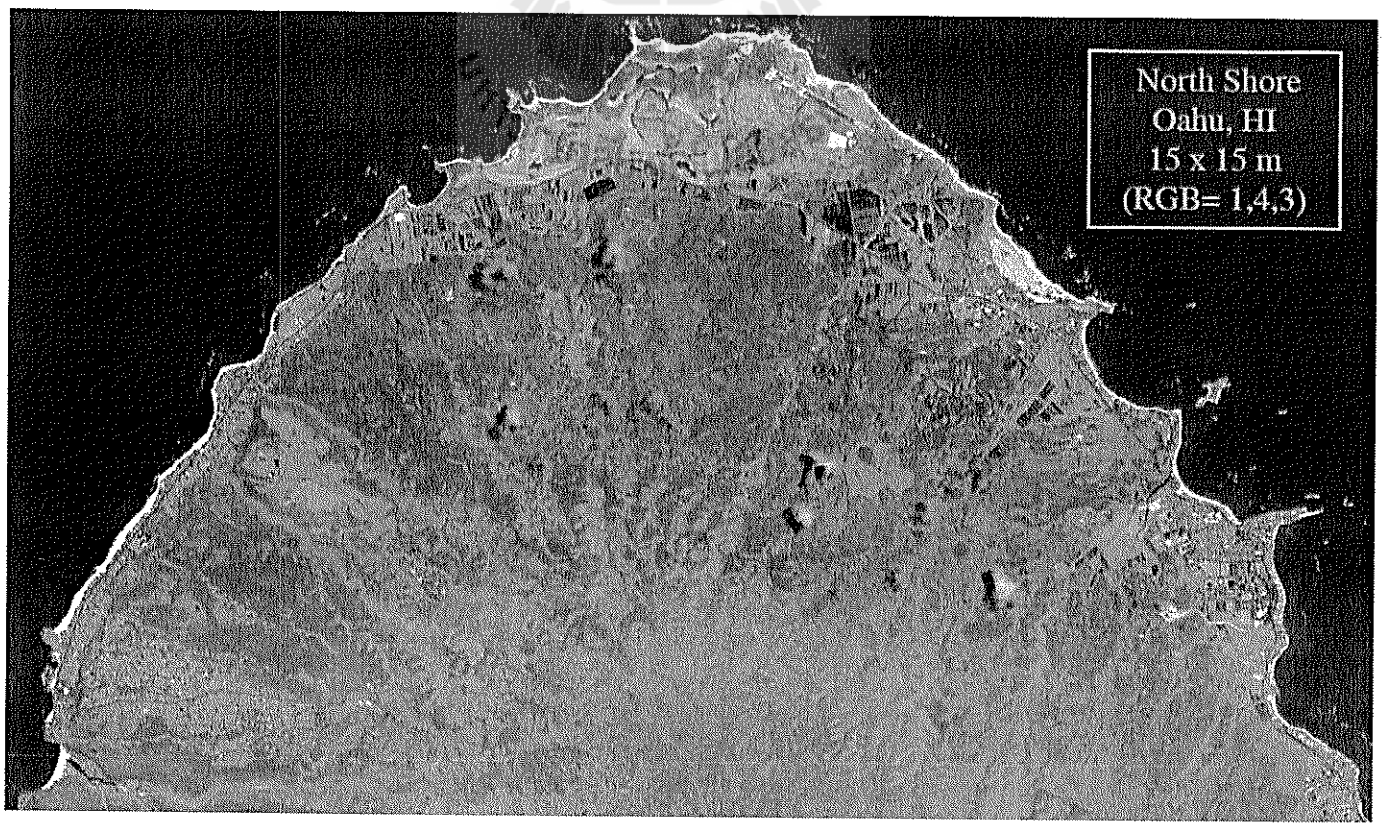
- Advanced Spaceborne Thermal Emission and Reflection Radiometer
- Launched in 1999, part of NASA's EOS
- Spatial Resolution 15m(VNIR), 30m(SWIR), 90(TIR).
- 16 day temporal resolution possible
- Per request basis



ASTER Uses

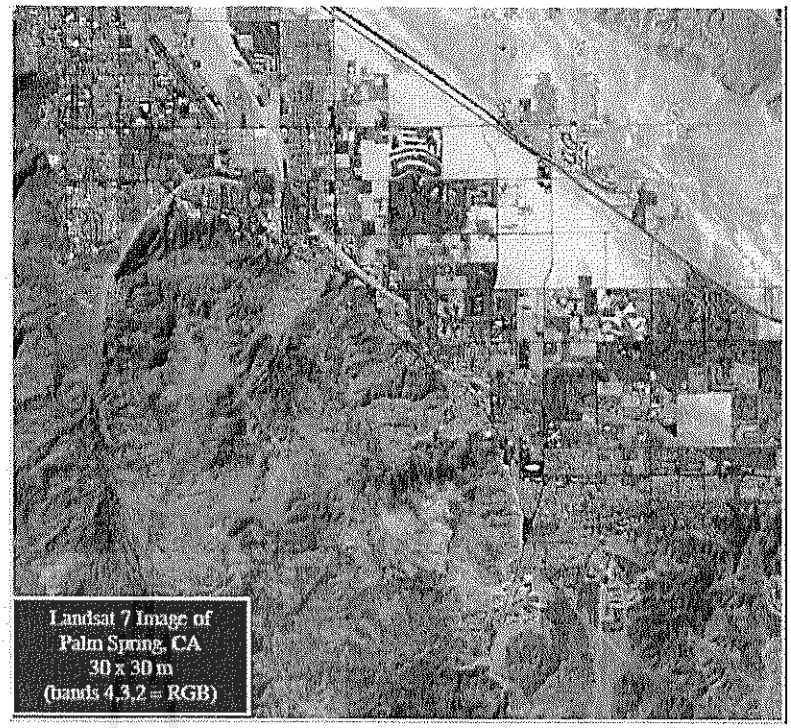
- Volcanological Studies
- Mineralogical Studies
- Hydrothermal Studies
- Forest Fires
- Glacier Studies
- Limnological Studies
- Climatology Studies
- Digital Elevation Models

ASTER



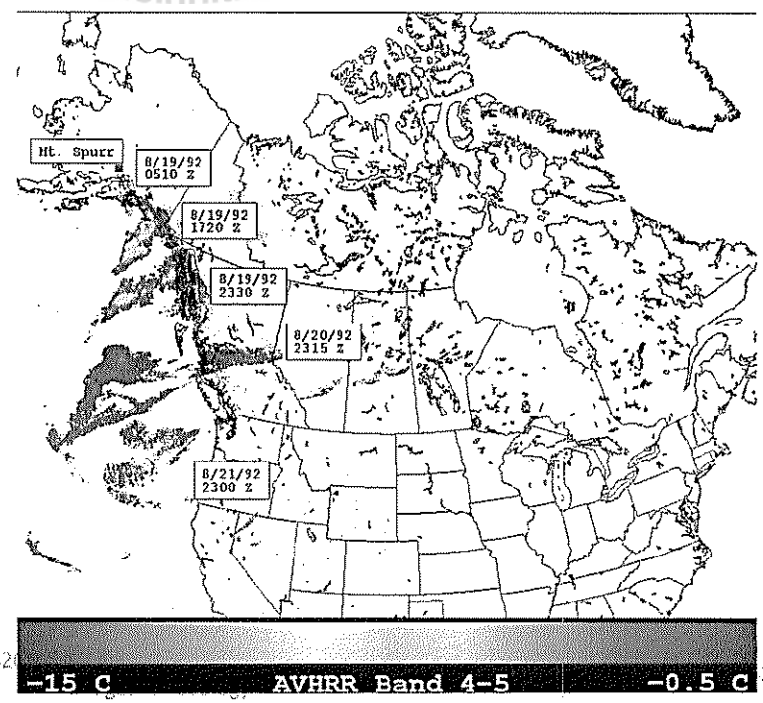
LANDSAT

- Launched in 1972, Managed by NASA and USGS
- ETM 7+ has 7 bands (30 and 60 m) and a panchromatic (15)
- Collected every 16 days
- Mapping lava flows, thermal monitoring, extrusion rates



AVHRR

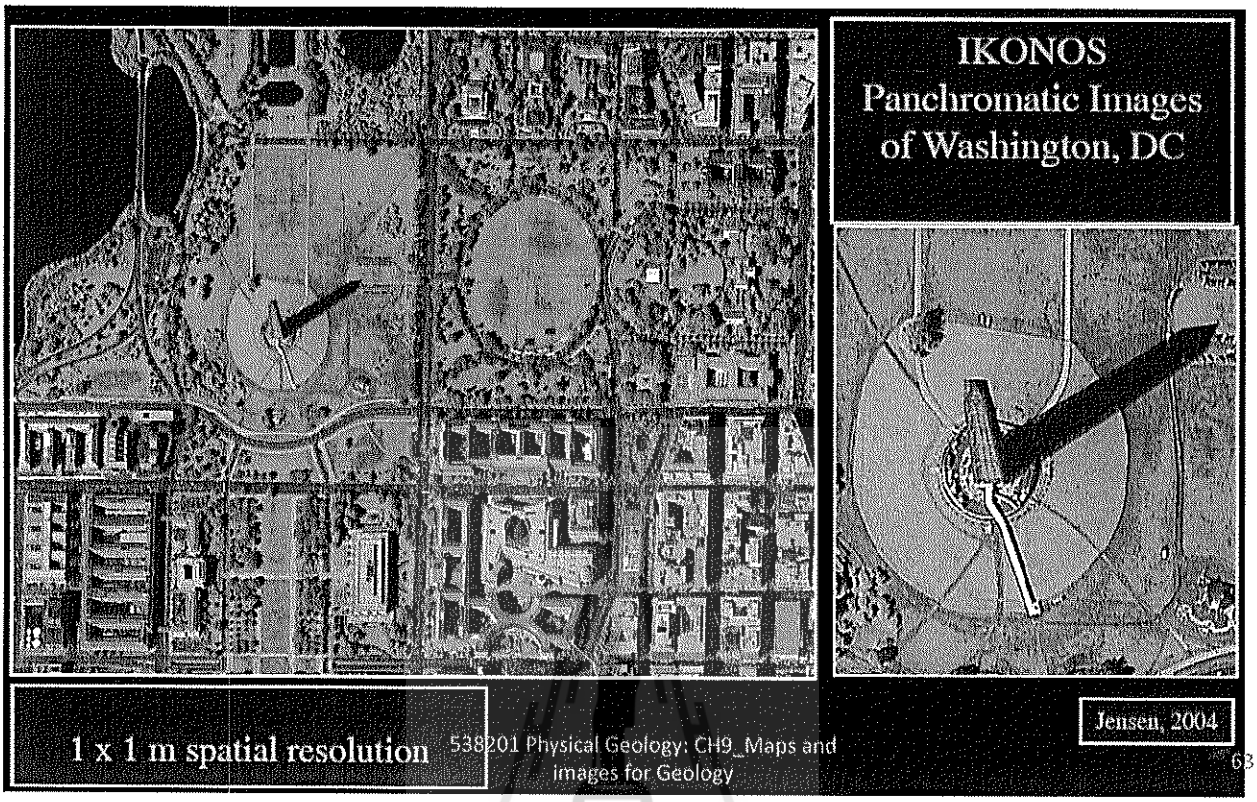
Advanced Very High Resolution Radiometer
- First launched in 1978 by NOAA
- Global coverage 4.4 km, U.S 1 km (low spatial resolution
- Collected twice a day (High temporal resolution)



Volcanic cloud movement, Mt Spurr, Alaska

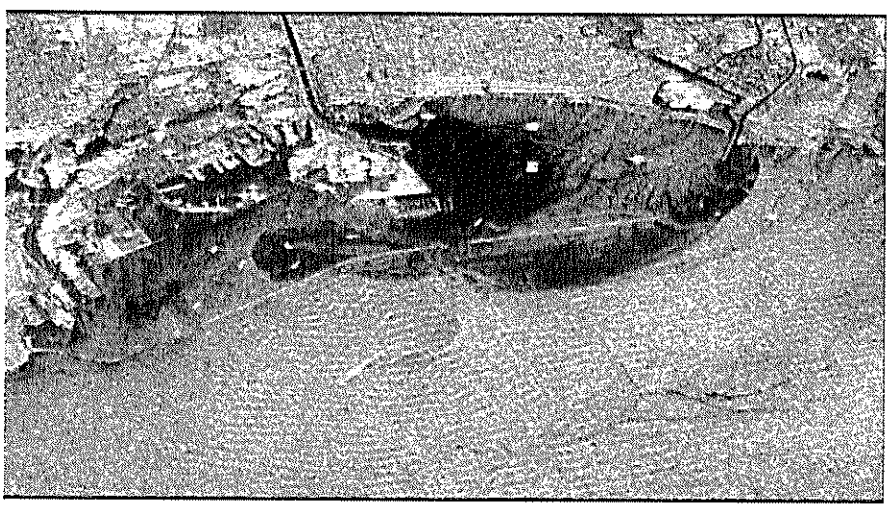
IKONOS

First satellite launched by a private company, launched in 1999, 1 meter panchromatic, 4 m visible and near infrared



RADAR

- Emits energy pulse, measure backscatter, records as a digital number
- Long wavelength-microwave
- Penetrates clouds and vegetation
- RADAR always black and white with speckled texture



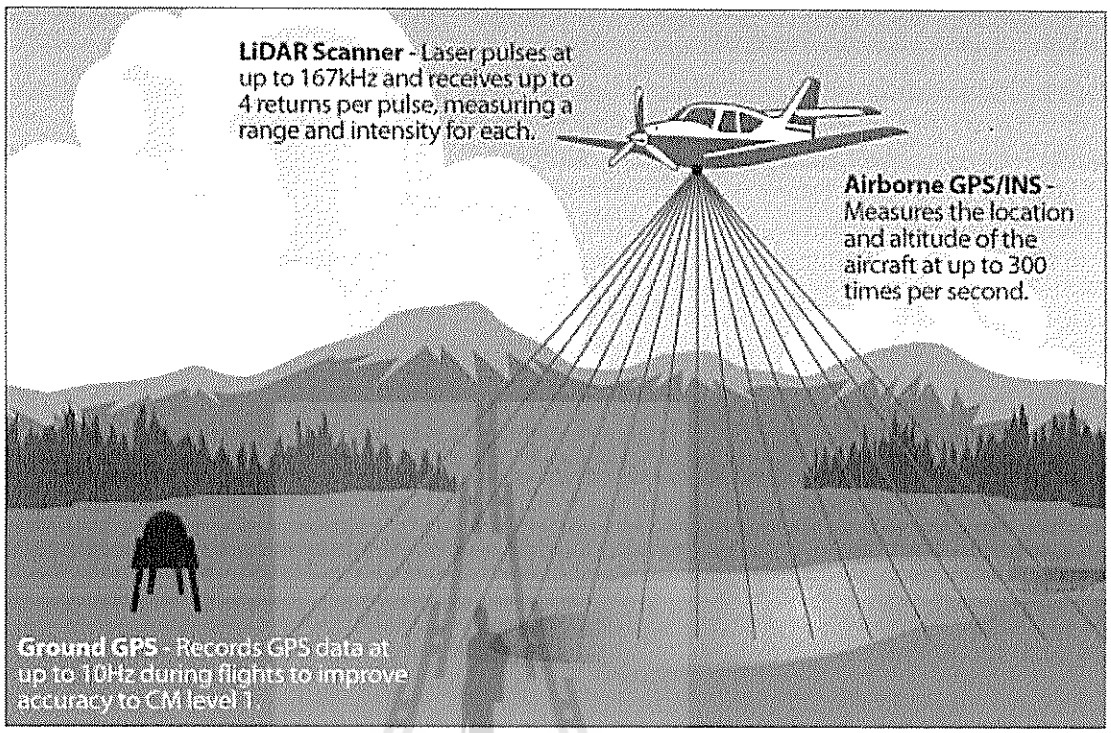
European Remote Sensing 1 satellite radar image of stormwater runoff plumes from Los Angeles and San Gabriel Rivers into the Los Angeles and Long Beach Harbors. Dec. 28, 1992.

LIDAR

Light Detection and Ranging

Transmits a laser light to target

15 cm accuracy



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Chapter 11
Geological Investigation

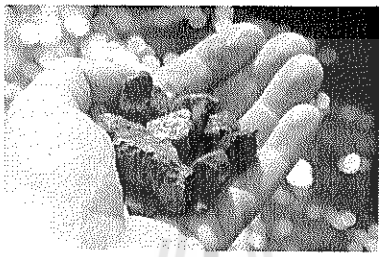
การสำรวจธรณีวิทยา

Contents

1. Investigation plan and desk study
2. Field Geology
3. Well logging
4. Sample collecting
5. Preparing a geologic report









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Geological investigation procedure

Step 1: Desk study

Step 2: Field investigation (walk over survey)

Step 3: Geophysical investigation and special excavation (if needed)

Step 4: Sample collecting

Step 5: Preparing and submitting a report

1. Investigation plan and desk study

Indicate objectives of the investigation**

↓

Design the investigation plan (time and budget)

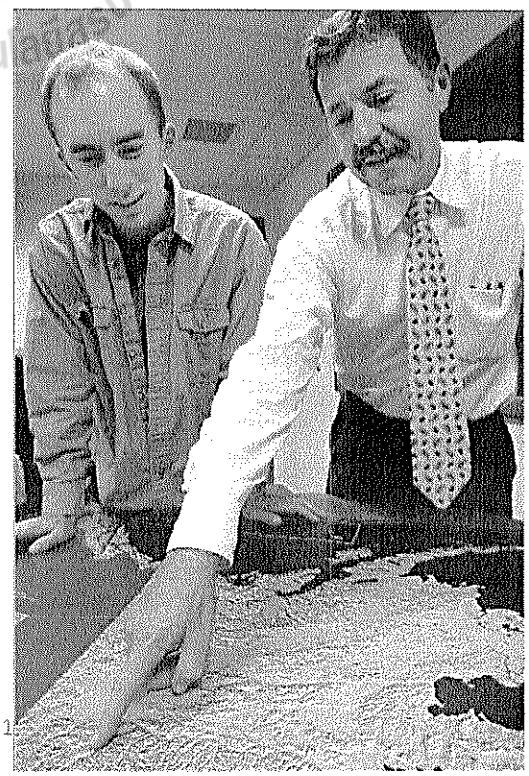
↓

Follow the plan

Desk study

- Should be carried out at the beginning of the project.
- Aimed to gather as much existing information.

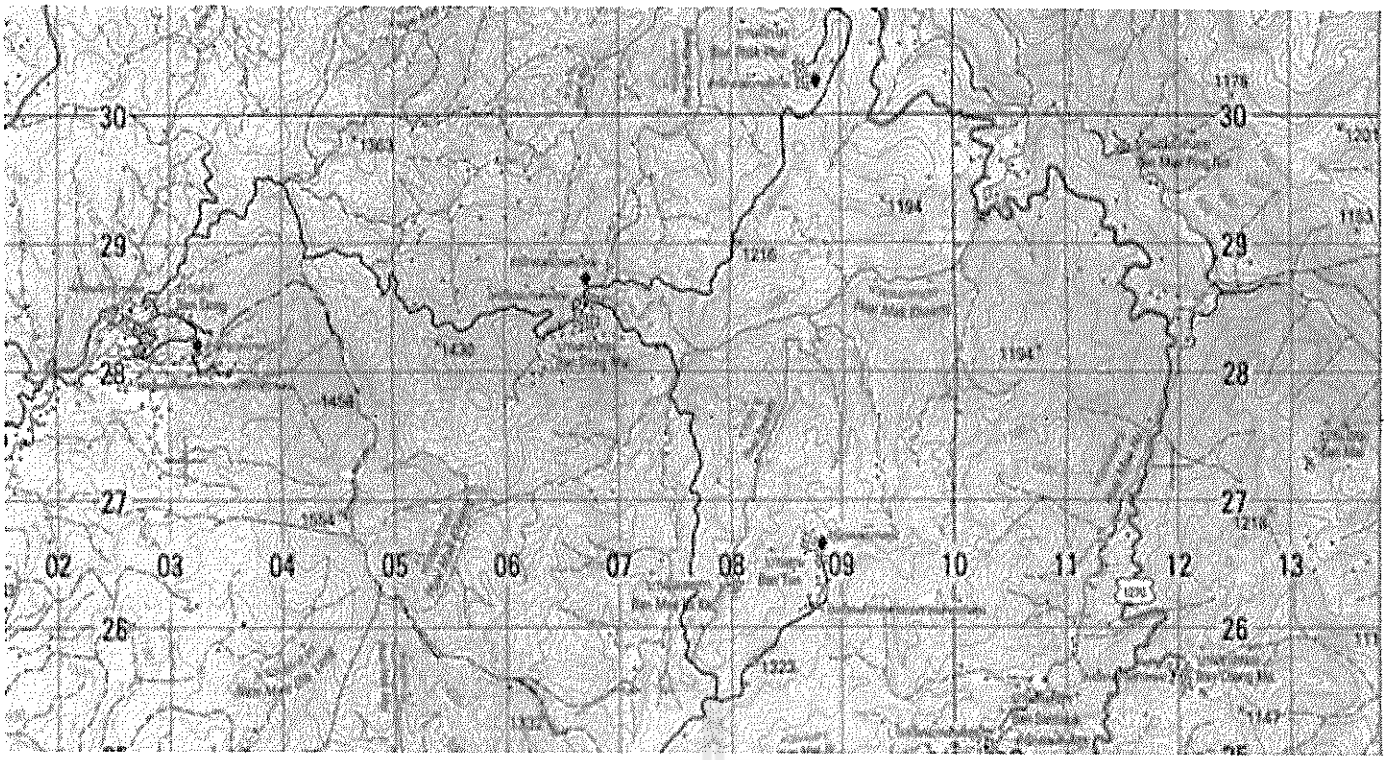
Literature reviews of
- topography
- geology
- geologic structures
- groundwater condition
- streams and rivers
- erosion and weathering
- previous studies of special interests



Where can you find information of .....

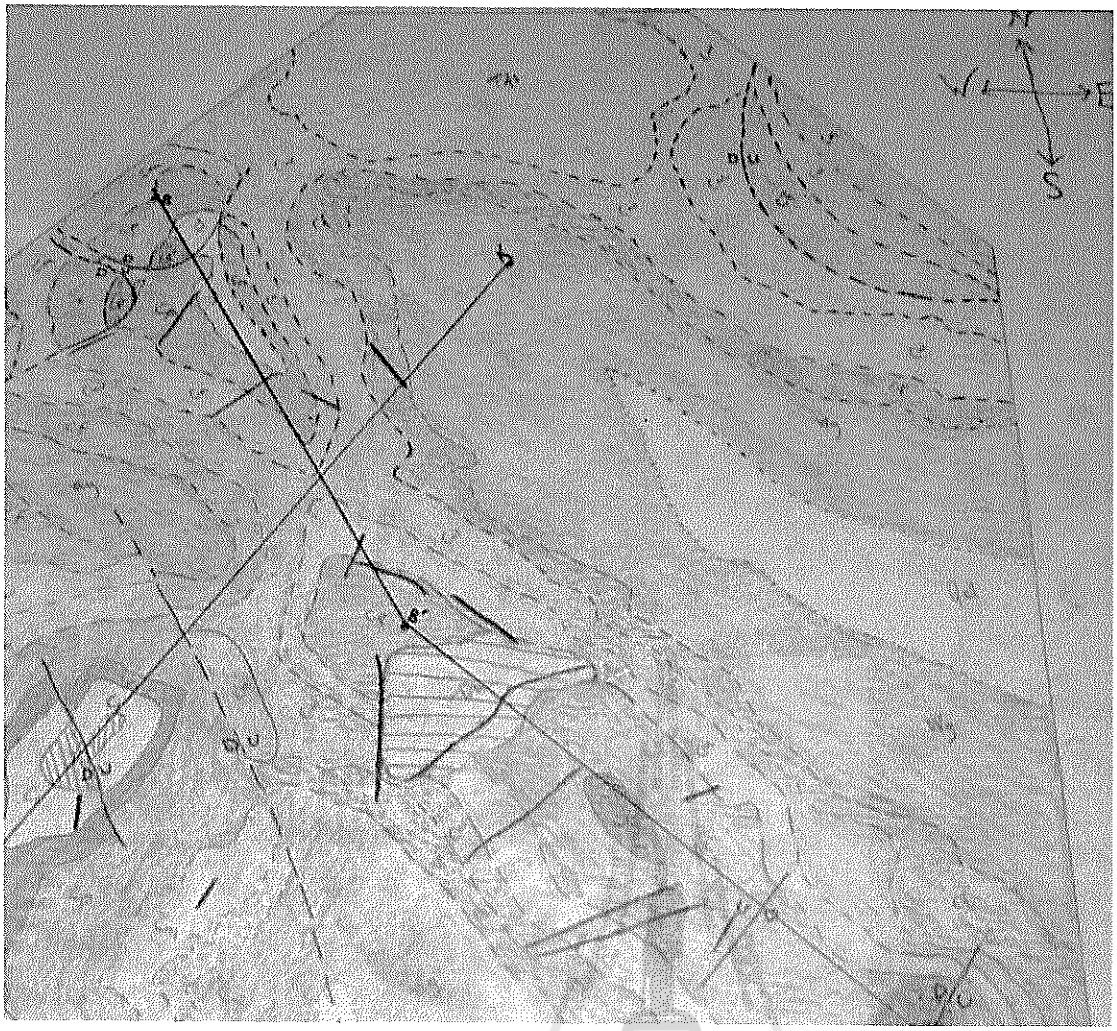
Topography ??
Geology ??
Geologic structures ??
Groundwater condition ??
Streams and rivers ??
Erosions and Weathering ??
Previous studies of special interests ??

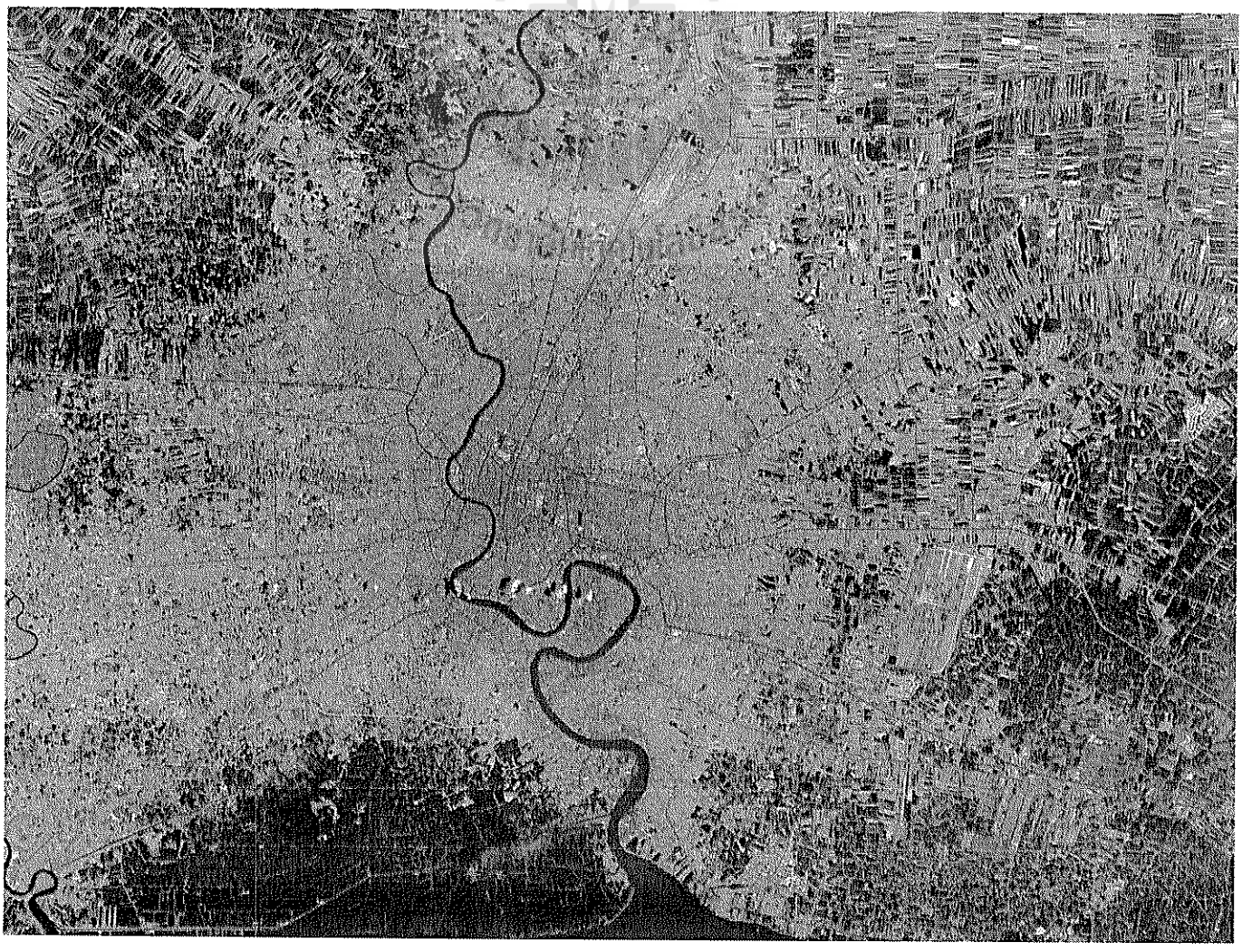
Aspect of investigation	Type of information
Topography	Topographic maps, Stereo air photographs
Geology	Geological maps, Geological publications, Air photographs, Soil survey maps and records, Previous investigation reports
Geotechnical problems and parameters	Engineering geology journals, Geotechnical journals, Civil engineering journals, Newspapers
Groundwater conditions	Topographical maps, Air photographs, Well records, Previous investigation reports
Meteorological conditions	Meteorological records, Topographical maps
Existing construction and services	Construction drawings, Plans held by utilities, Mining records, Construction press
Previous land use	Out-of-print topographical maps, Out-of-print geological maps, Air photographs, Airborne remote sensing, Archaeological society records, Mining records



538201 Physical Geology: CH11_Geological investigation







Do not forget to find a good scale of your maps.

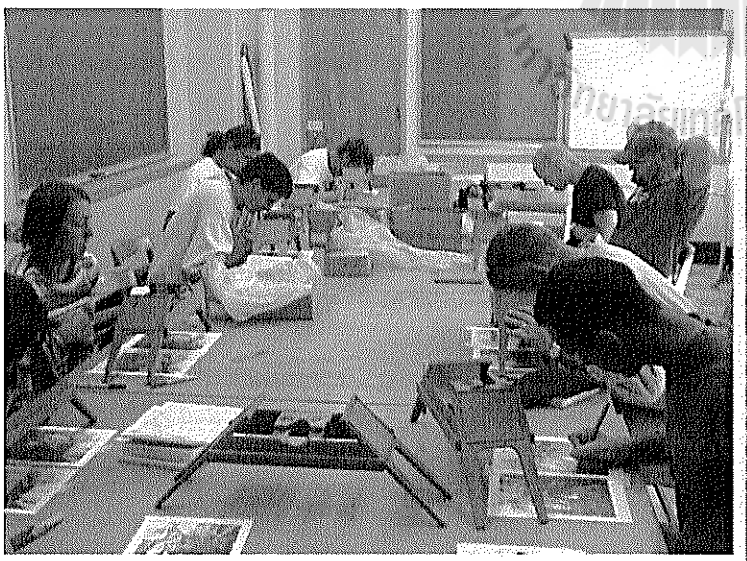
Satellite image: 1: 1,000,000, 1:500,000

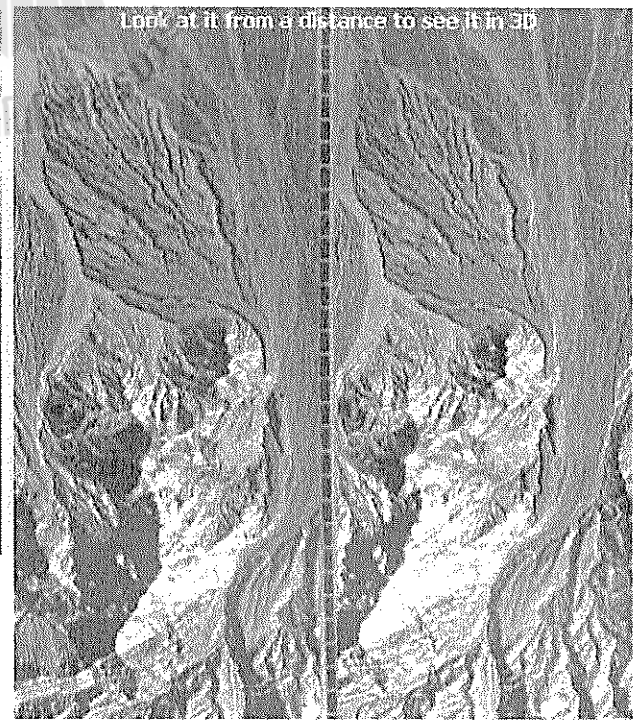
Geologic map; 1:250,000

Topographic map; 1: 250,000, 1: 50,000

Aerial photo; 1: 10,000

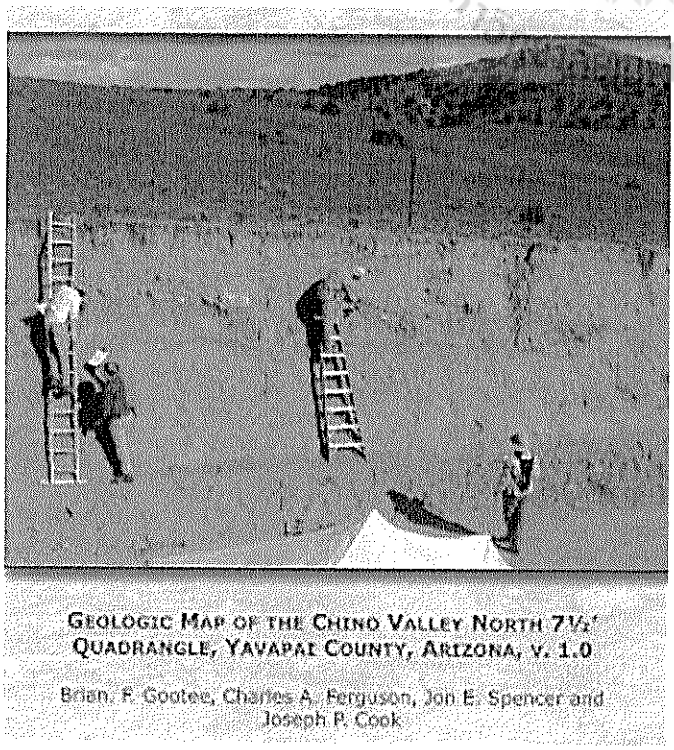
Base map; ???







Conclude and summarize the previous studies of special interests: What, where, when, why, how?



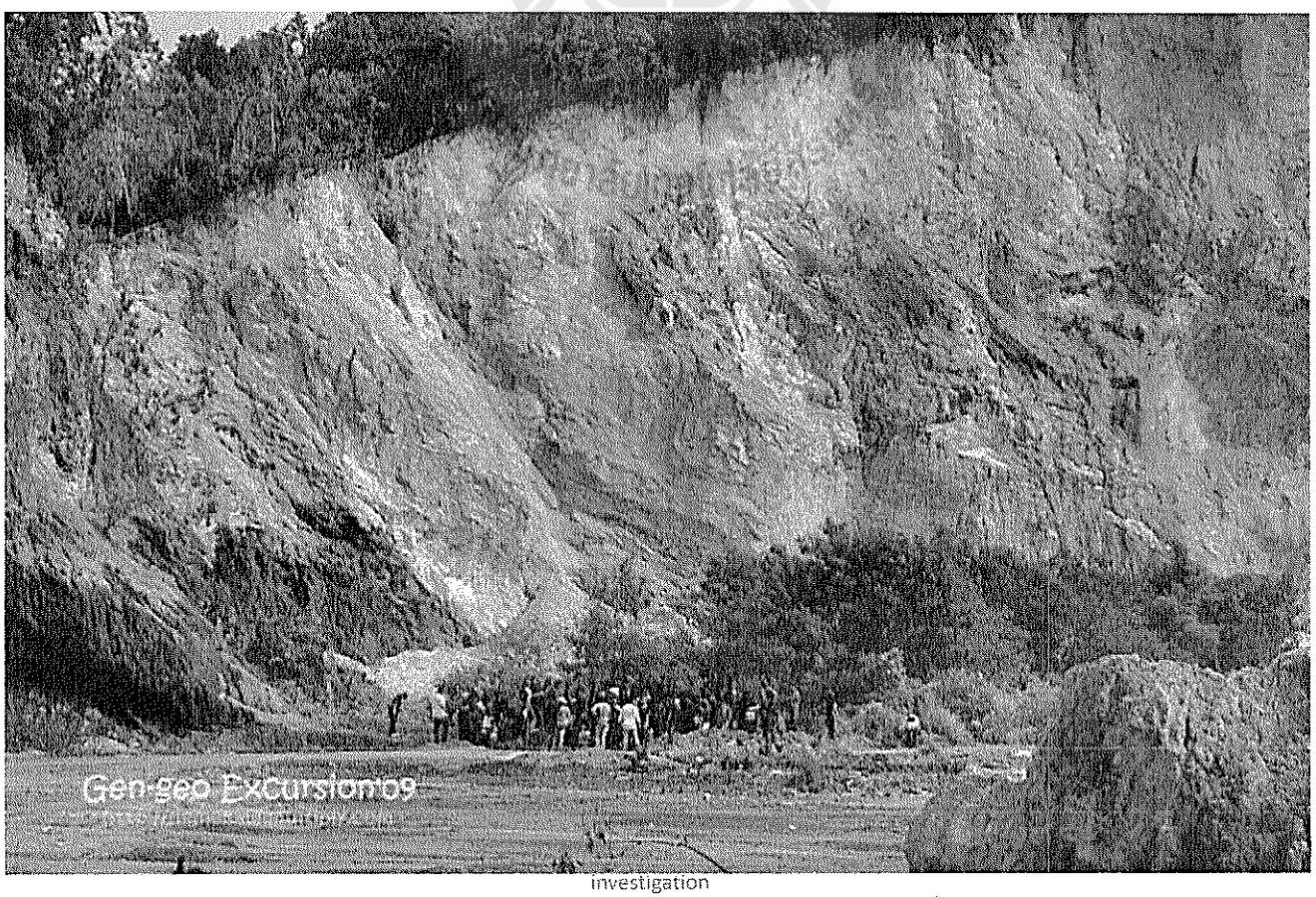
At the end of the desk study, you will know what to do next.

2. Field Geology

Contents

- Geologic reconnaissance and mapping
- Geophysical exploration
- Surface excavation
- Boring

Geologic reconnaissance and mapping

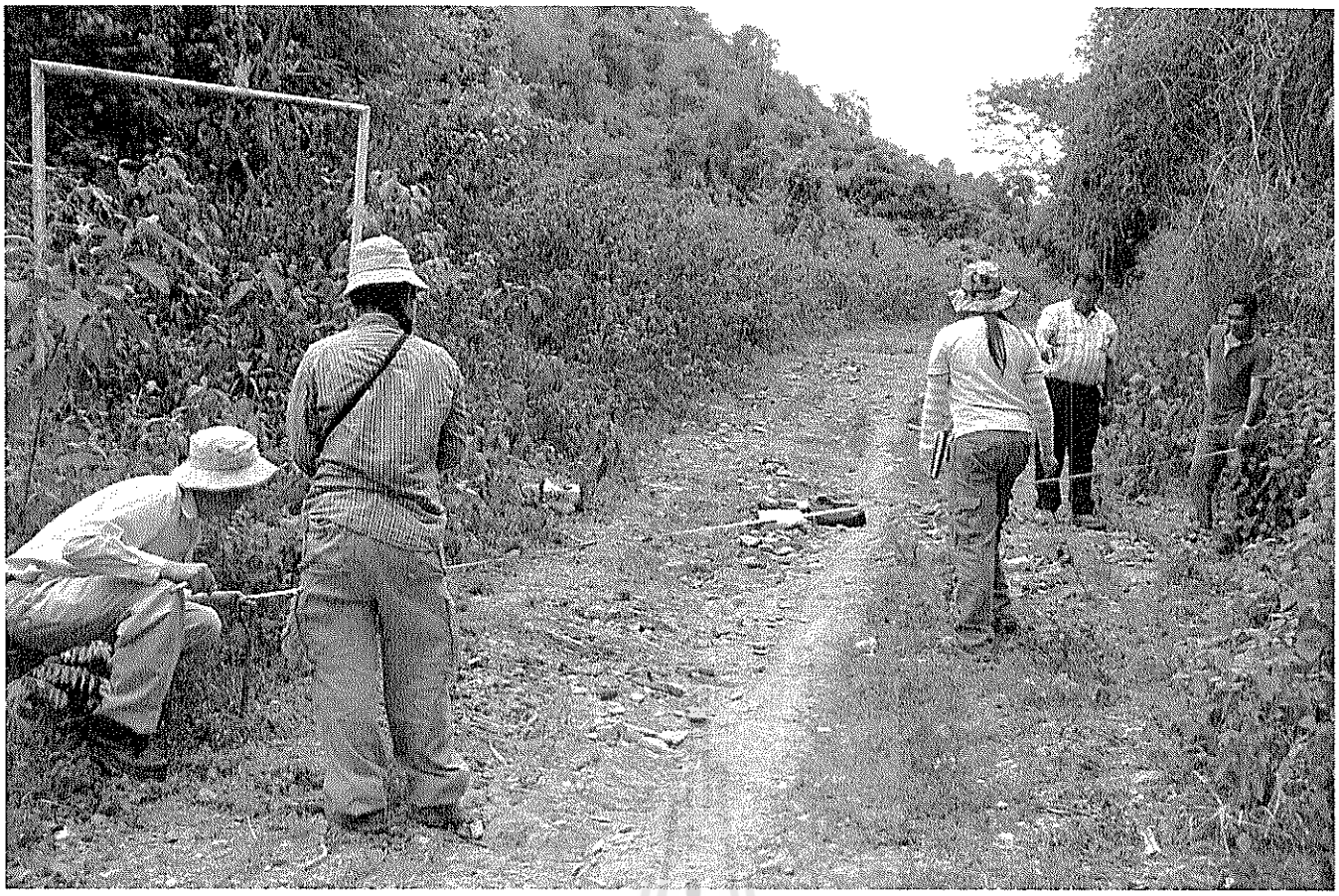


Geological field equipment



What to do

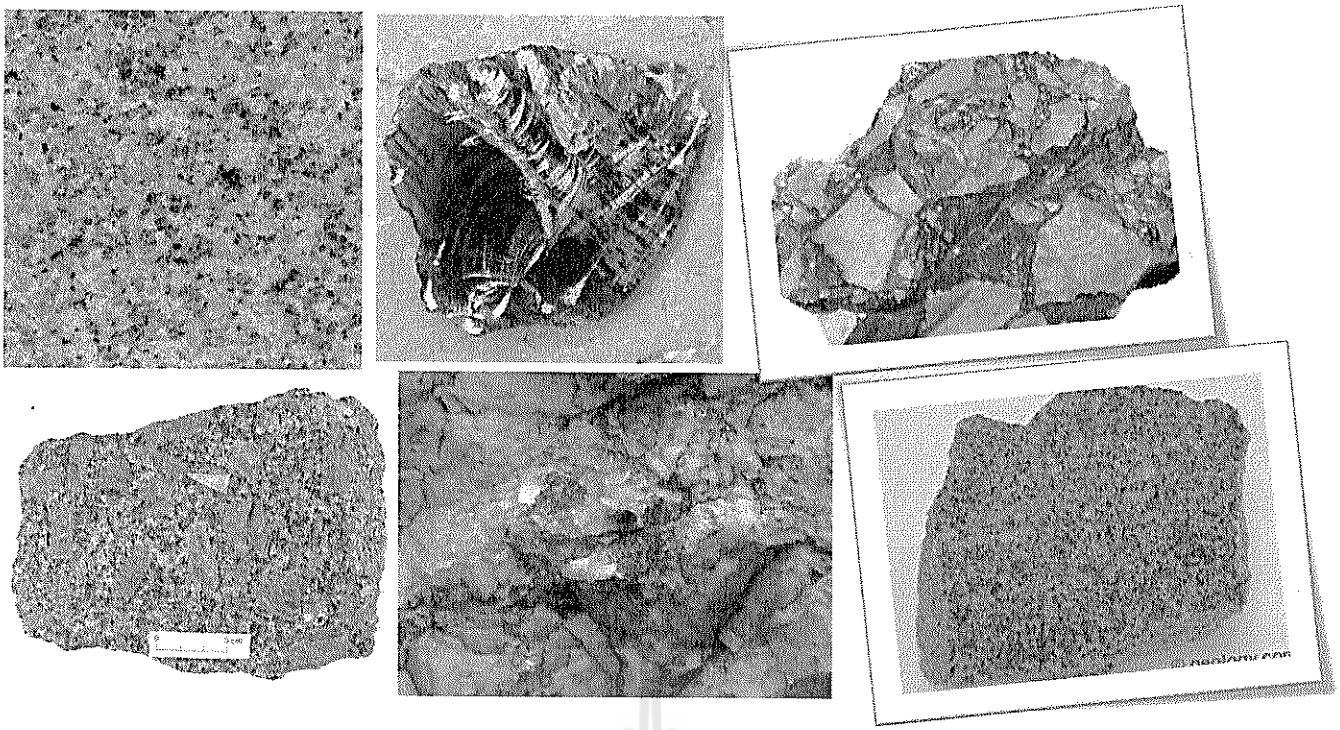
- Walking over to record geologic data
- Tracing the geologic contacts
- Describing rocks at the outcrops
- Measuring geologic structures (bedding attitudes)
- Collecting rock samples



Traverse

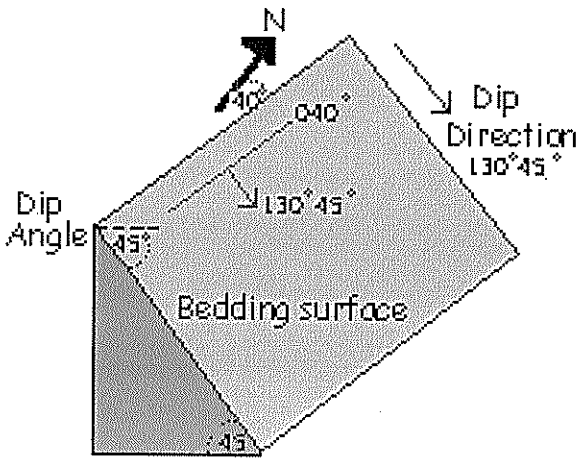


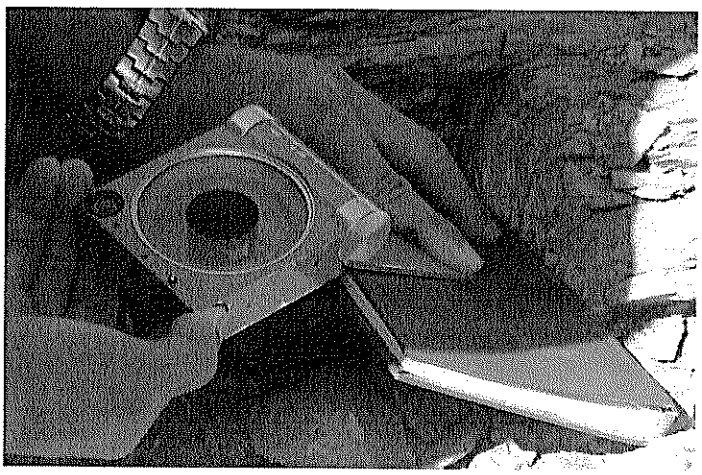
Mapping contact relationships

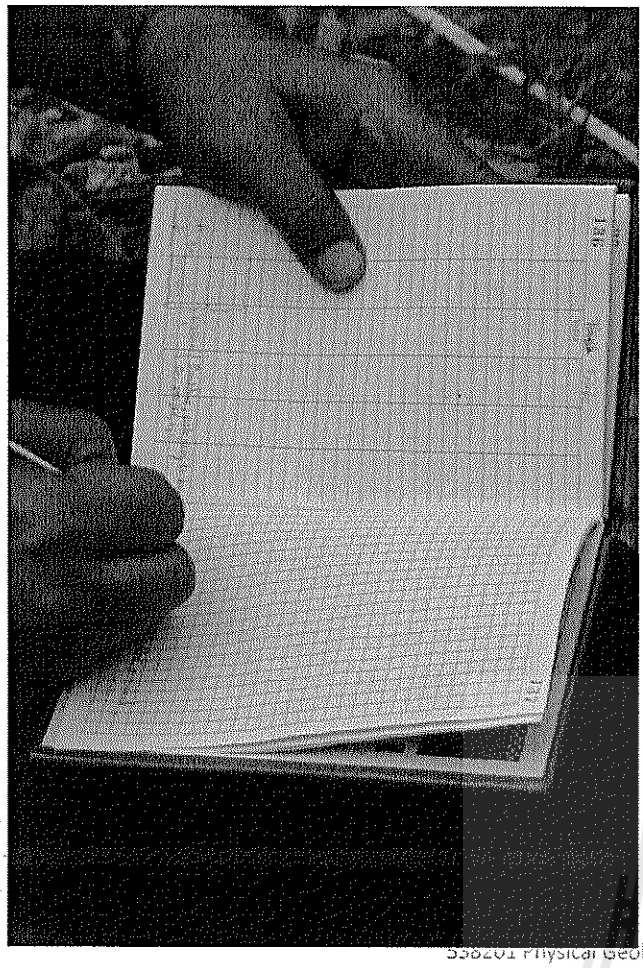


Describing rocks: texture, color, composition, size, rock name

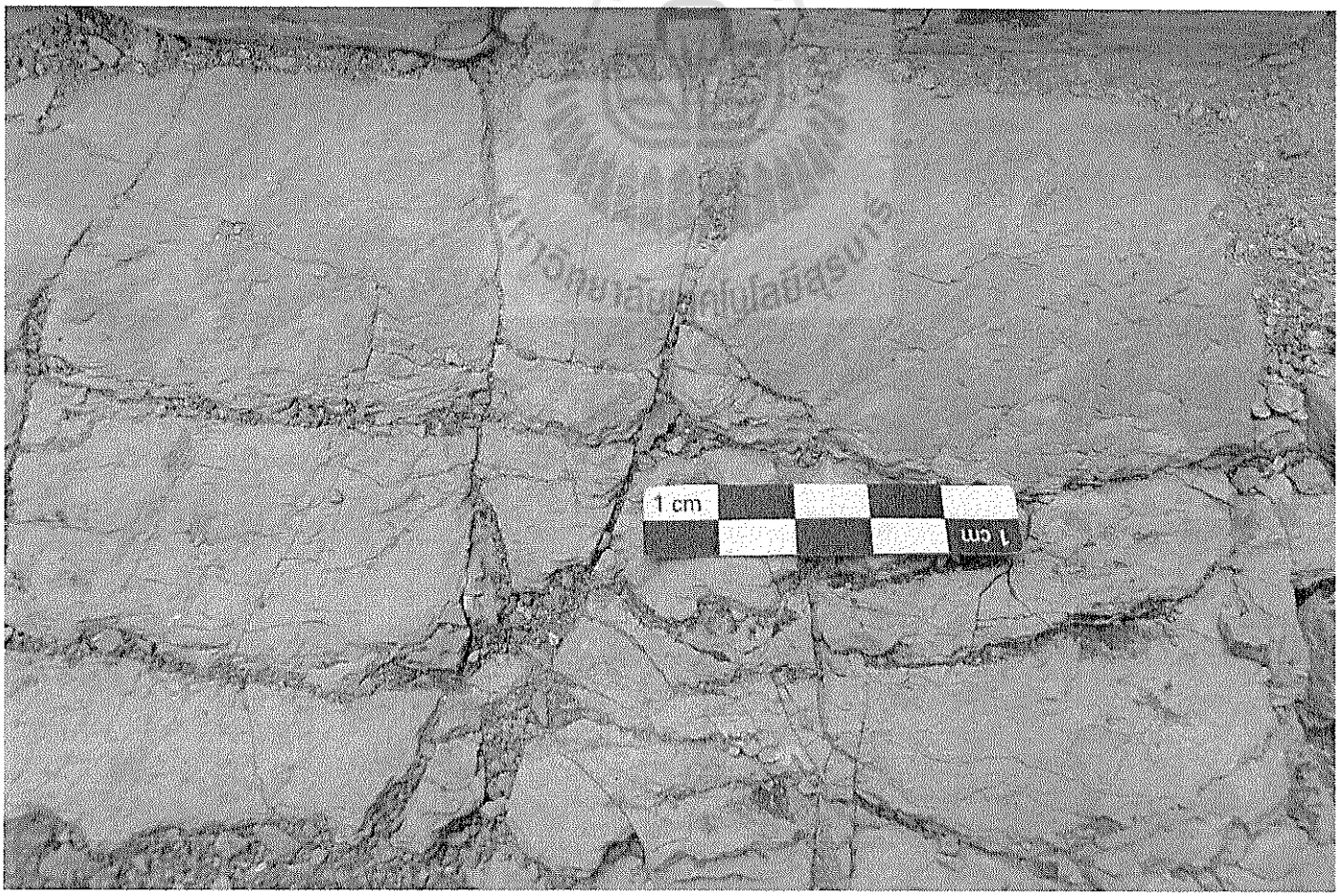
Measuring geologic structures: Strike-dip of a bedding, cleavage, foliation, axial plane, fault, joint.

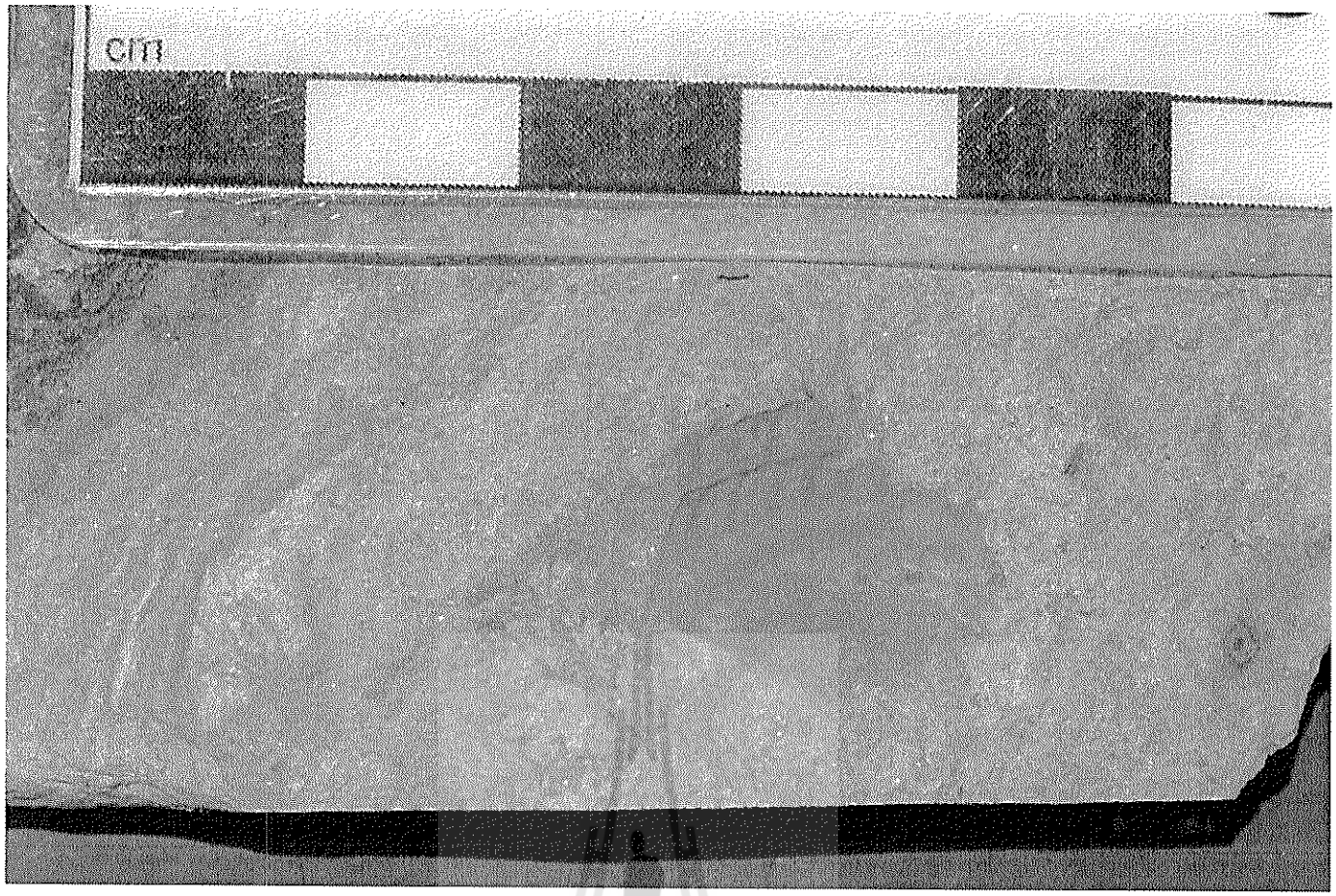


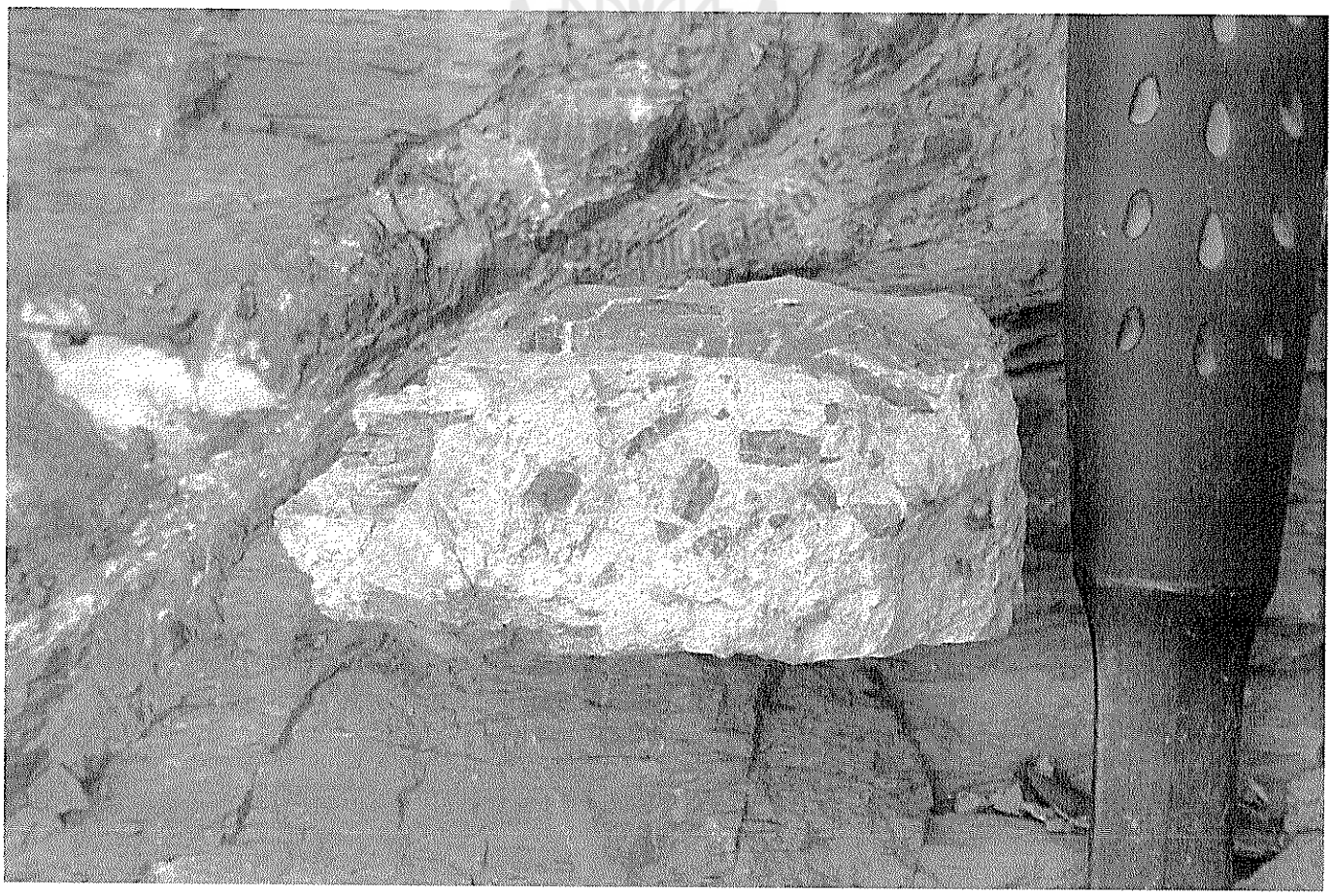


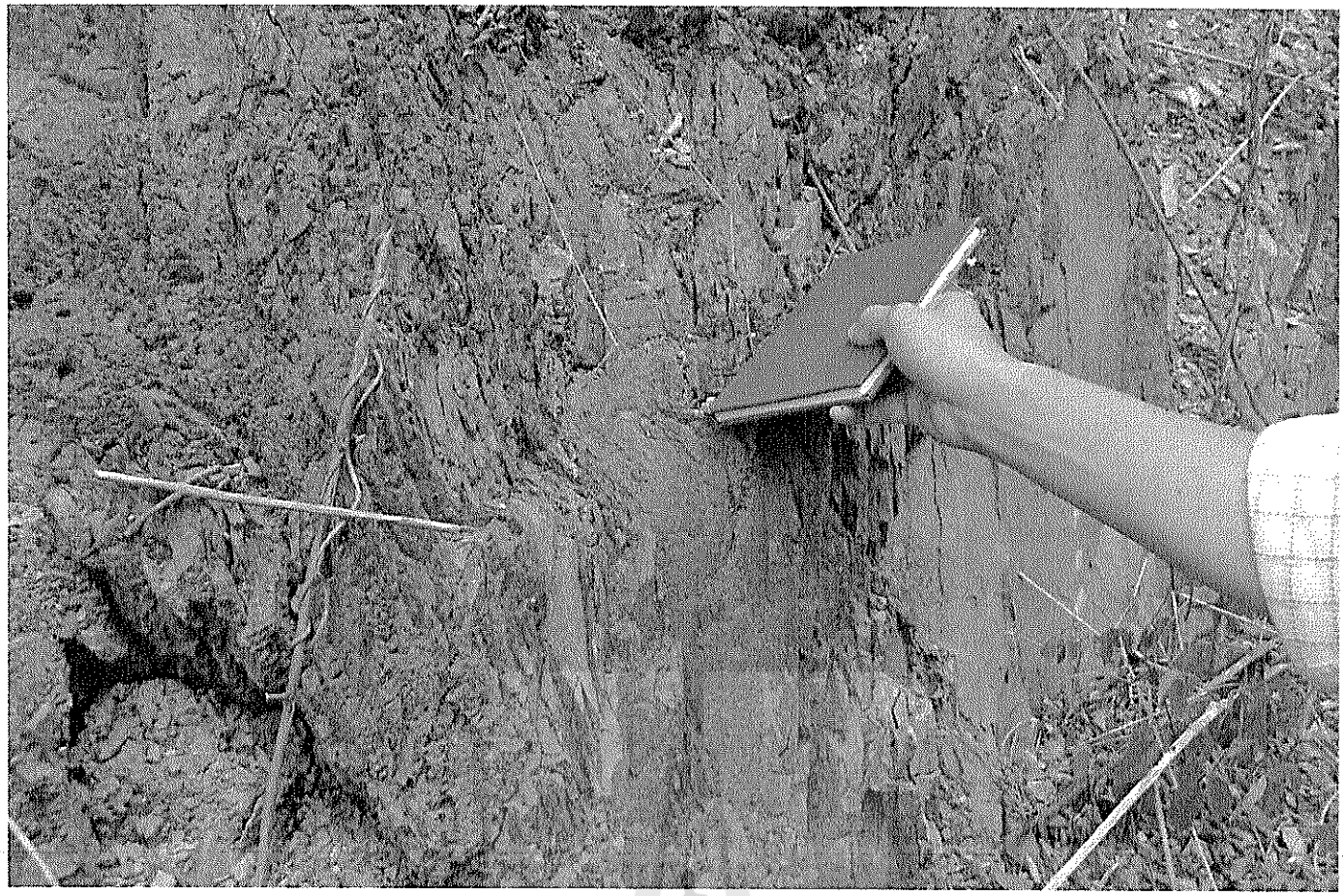




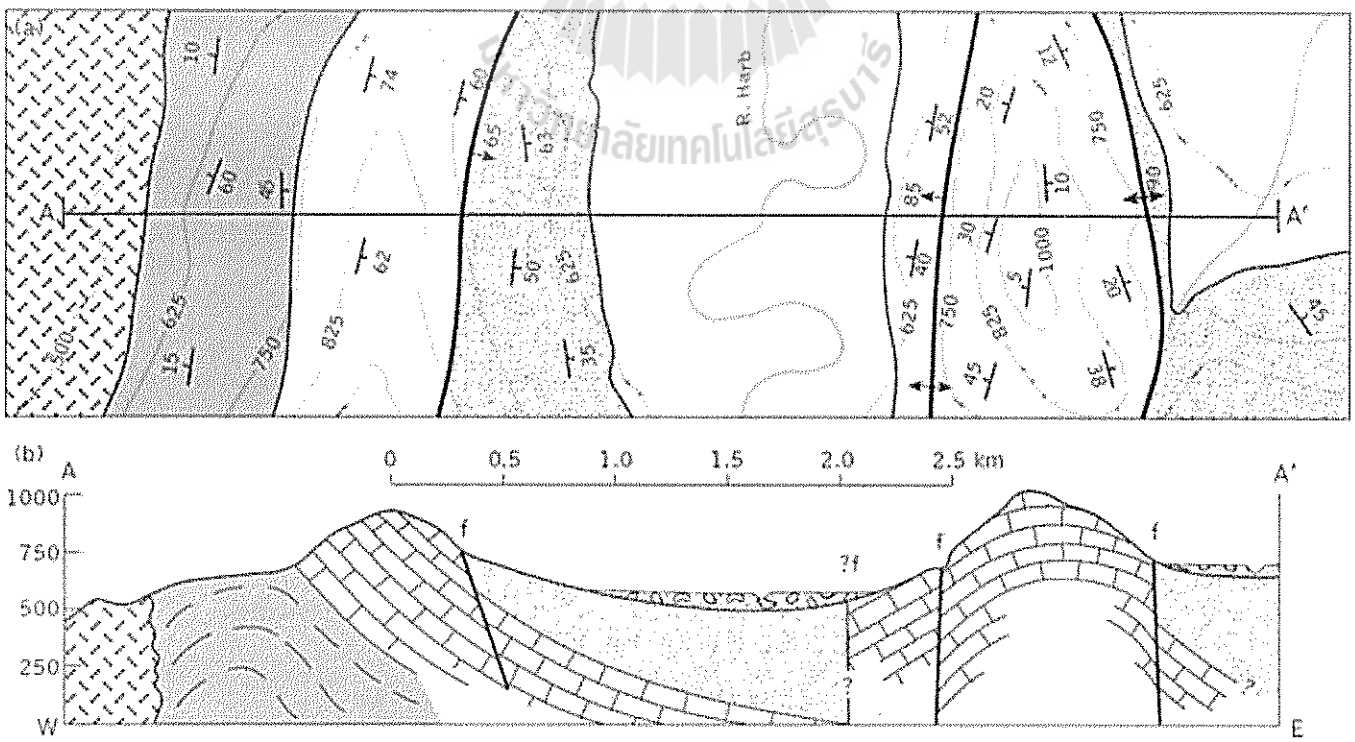

1 cm


cm



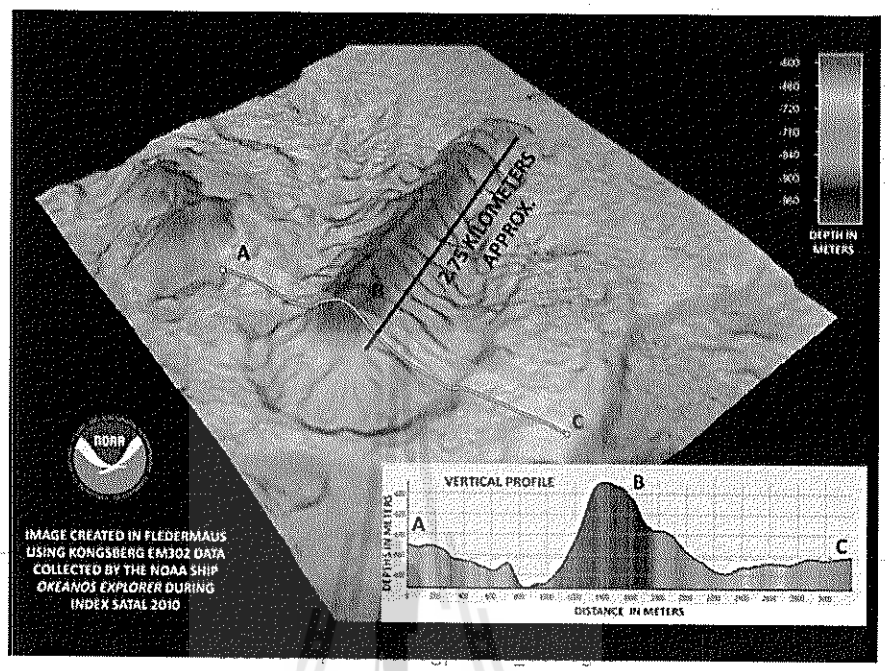


Result of field investigation



Geophysical exploration

An indirect method of obtaining generalized sub-surface geologic information by using special instruments to make certain physical measurements.



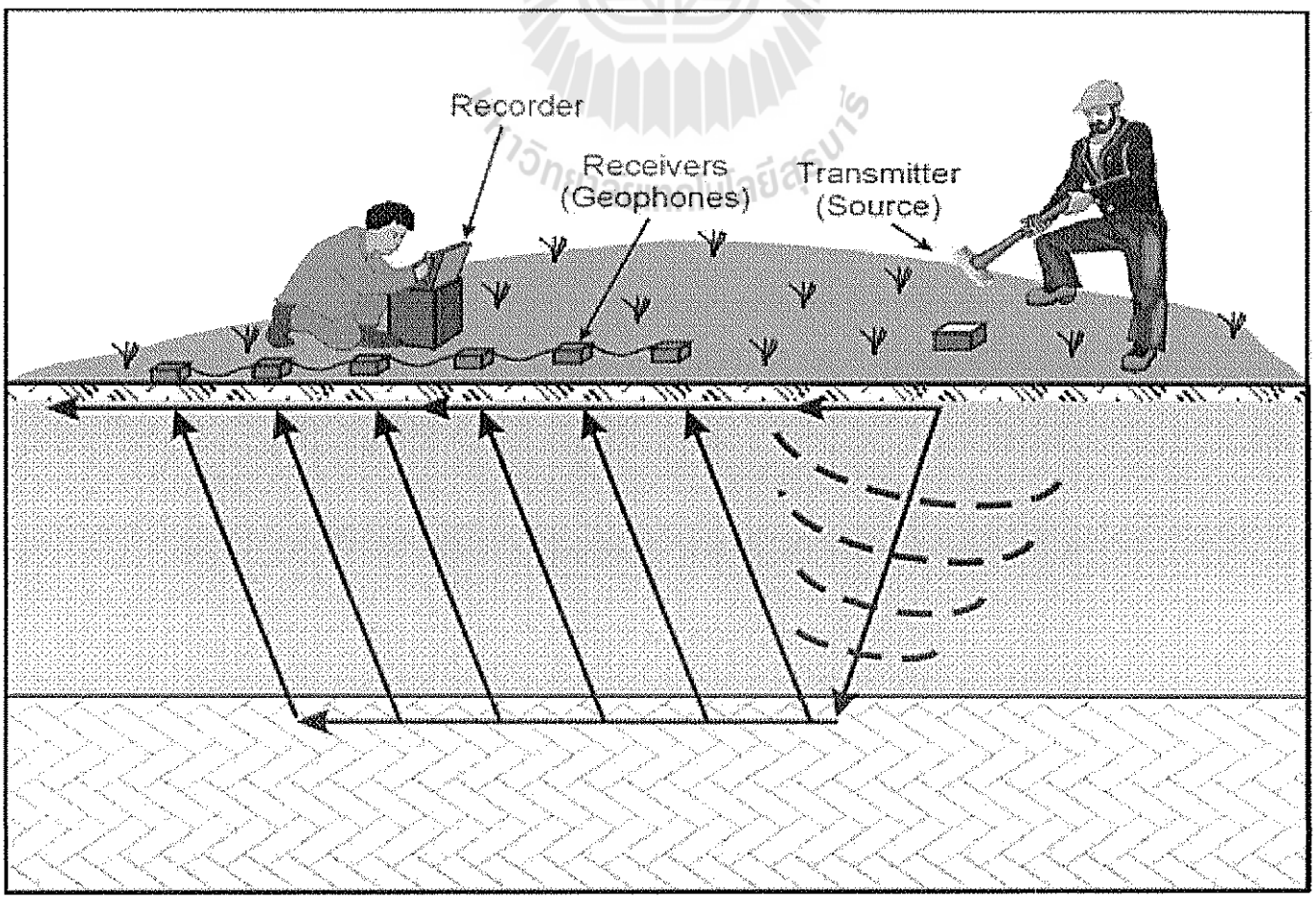
investigation

วิธีการสำรวจ	ค่าที่วัด	สมบัติทางกายภาพ
คลื่นไหวสะเทือน (Seismic)	เวลาที่ใช้ในการเดินทางของคลื่นไหวสะเทือน	ความหนาแน่นและสมบัติความยืดหยุ่น
ความโน้มถ่วง (Gravity)	การเปลี่ยนแปลงความเข้มสนามแรงโน้มถ่วงของโลก	ความหนาแน่น
แม่เหล็ก (Magnetic)	การเปลี่ยนแปลงความเข้มสนามแม่เหล็กโลก	ค่าความสามารถในการเป็นแม่เหล็กและแม่เหล็กคงค้าง
ความต้านทานไฟฟ้า (Resistivity)	ความต้านทานไฟฟ้า	ความสามารถในการนำไฟฟ้า
การเหนี่ยวนำโพลาไรเซชัน (Induced polarization)	ความต่างศักย์ของการเหนี่ยวนำโพลาไรเซชันหรือความต้านทานไฟฟ้าของพื้นดินที่ขึ้นกับความถี่	ความสามารถในการเก็บไฟฟ้า
ศักย์ไฟฟ้าธรรมชาติ (Conductivity)	ค่าความต่างศักย์ไฟฟ้า	ความสามารถในการนำไฟฟ้า
แม่เหล็กไฟฟ้า (Electromagnetic)	ค่าตอบสนองต่อสนามแม่เหล็กไฟฟ้า	ความสามารถในการนำไฟฟ้าและการเหนี่ยวนำ
กัมมันตรังสี (Gamma ray)	การแผ่รังสีแกมมา	ความสมบูรณ์ของนิวเคลียสที่แผ่กัมมันตรังสี

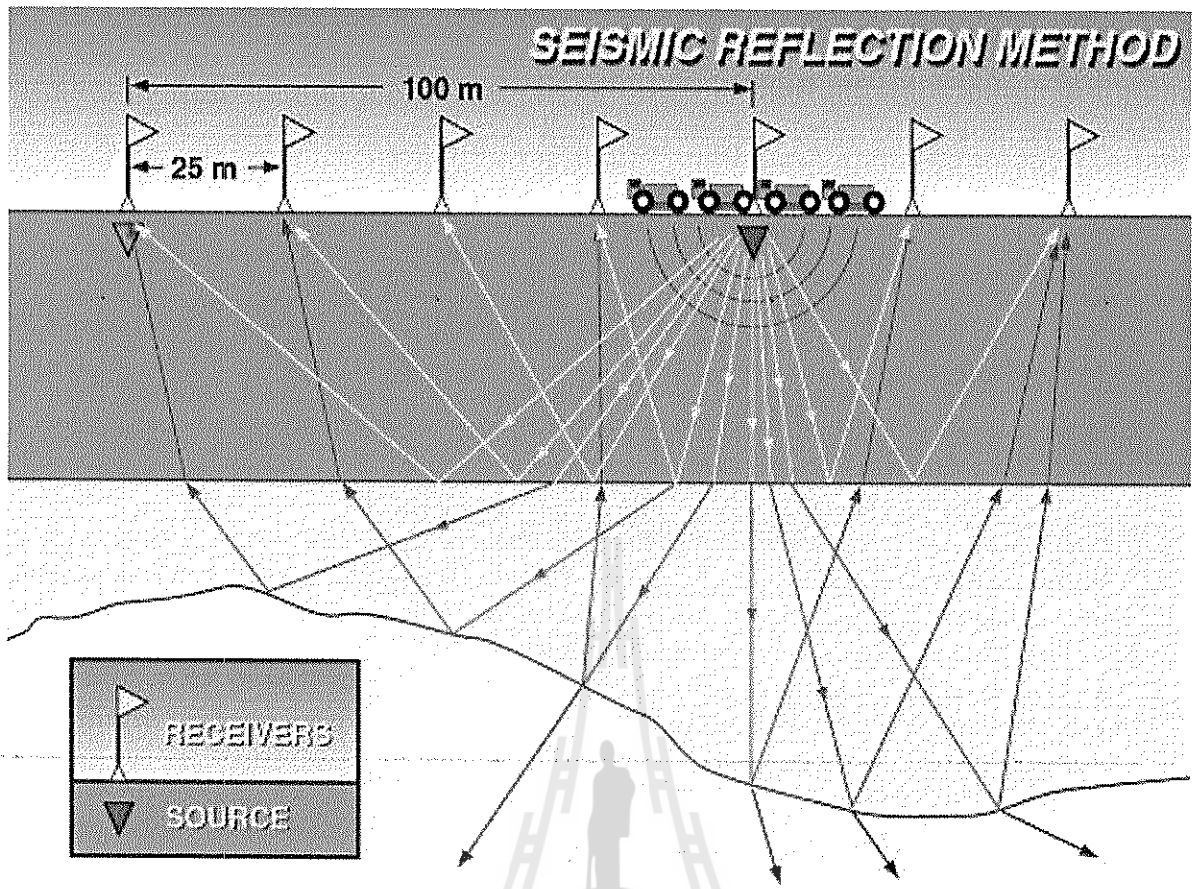
Uses of geophysical investigation

Applications	Geophysical methods
Hydrocarbon reservoir	Seismic, Electromagnetic
Metal resources	Magnetic, Electromagnetic, Resistivity, Conductivity, Induced polarization
Industrial mineral resources	Seismic, Resistivity
Groundwater	Resistivity, Seismic

Seismic Refraction Method

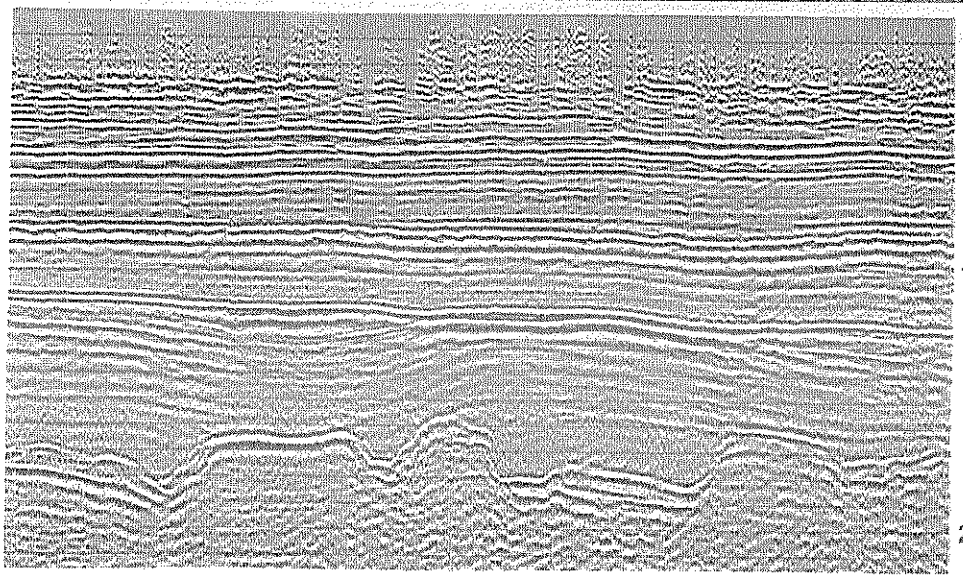


Seismic Reflection Method









(b)

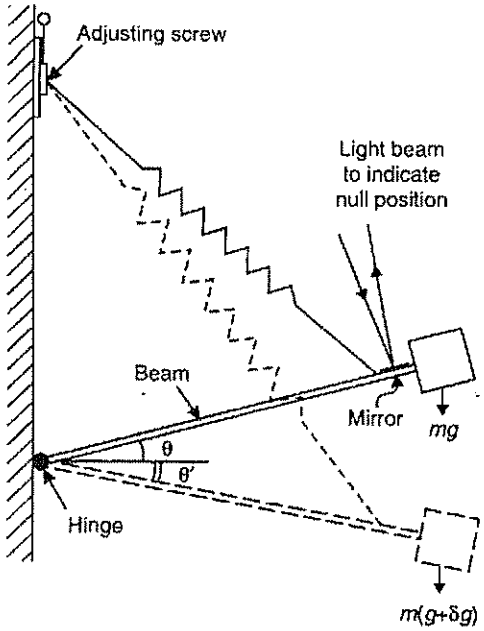
Underground soil condition obtained by geophysical exploration

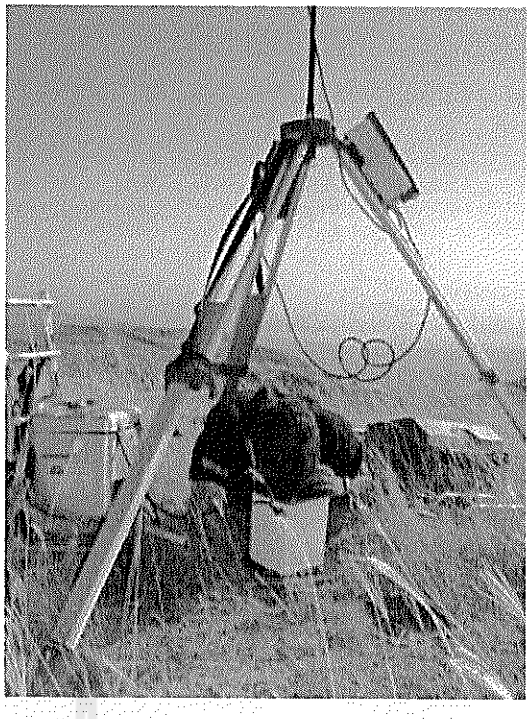
Seismic method

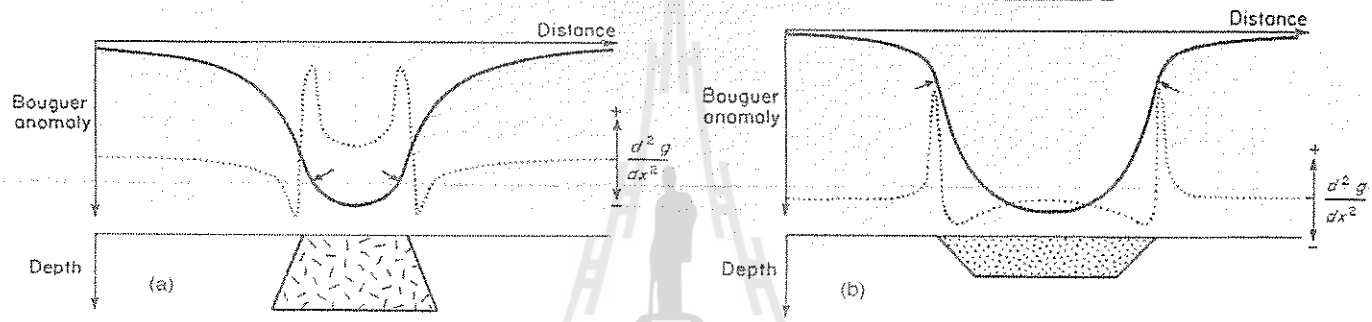
Material property obtained from seismic methods	Slow ← Seismic velocity → Fast
Underground condition	Soft ← Stiffness → Hard
	Weak ← Strength → Strong
	Strong ← Weathering → Weak
	Many ← Cracks → Few
	Little ← Water contents → Much
	Low ← Pressure → High

Gravity Method

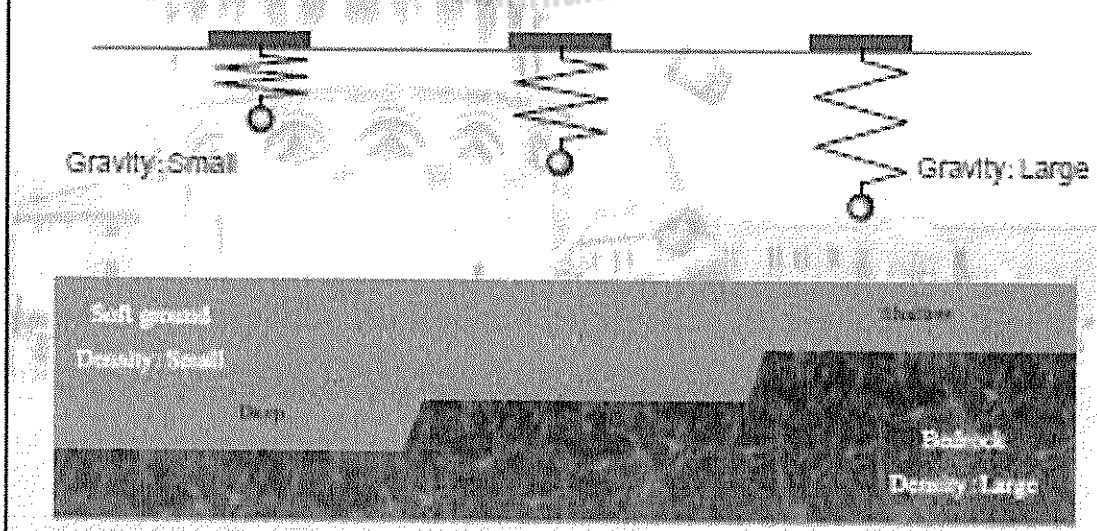
Material type	Density range (Mg/m^3)	Approximate average density (Mg/m^3)
Sedimentary rocks		
Alluvium	1.96–2.00	1.98
Clay	1.63–2.60	2.21
Gravel	1.70–2.40	2.00
Loess	1.40–1.93	1.64
Silt	1.80–2.20	1.93
Soil	1.20–2.40	1.92
Sand	1.70–2.30	2.00
Sandstone	1.61–2.76	2.35
Shale	1.77–3.20	2.40
Limestone	1.93–2.90	2.55
Dolomite	2.28–2.90	2.70
Chalk	1.53–2.60	2.01
Halite	2.10–2.60	2.22
Glacier ice	0.88–0.92	0.90
Igneous rocks		
Rhyolite	2.35–2.70	2.52
Granite	2.50–2.81	2.64
Andesite	2.40–2.80	2.61
Syenite	2.60–2.95	2.77
Basalt	2.70–3.30	2.99
Gabbro	2.70–3.50	3.03
Metamorphic rocks		
Schist	2.39–2.90	2.64
Gneiss	2.59–3.00	2.80
Phylite	2.68–2.80	2.74
Slate	2.70–2.90	2.79
Granulite	2.52–2.73	2.65
Amphibolite	2.90–3.04	2.96
Eclogite	3.20–3.54	3.37



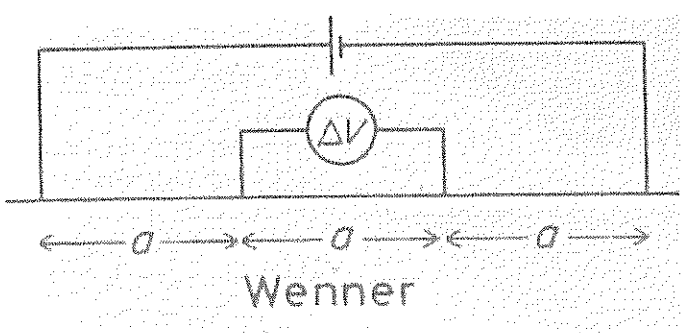




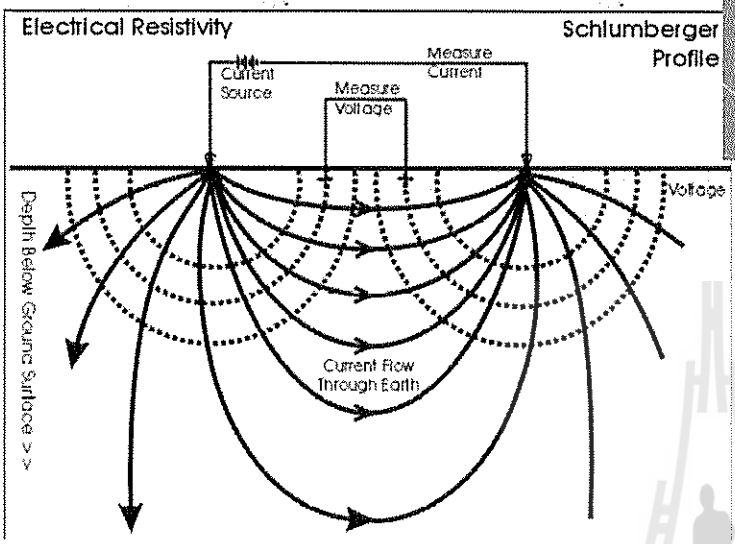
Delineating underground structure by gravity



Electric Resistivity



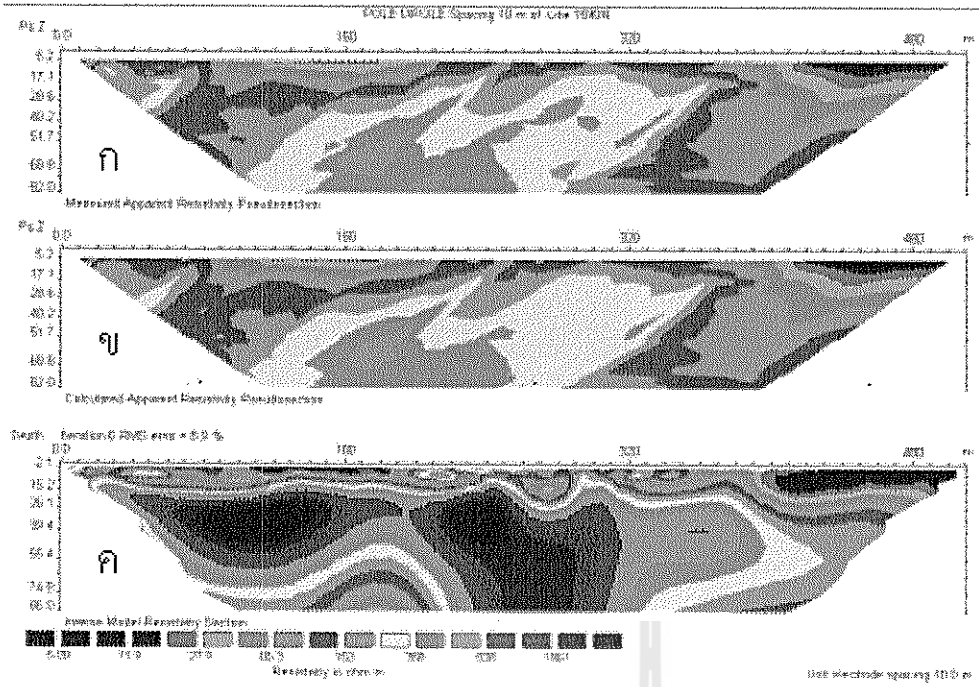




Underground soil condition obtained by geophysical exploration

Resistivity method

Material property obtained from resistivity methods	Low ← Resistivity → High
Underground condition	Low ←Water resistivity → High
	High ← Saturation → Low
	Strong← Alteration → Weak
	Much ← Clay contents → Little
	High ← Temperature → Low



รูปที่ 4 ผลการสำรวจวัดค่าสภาพต้านทานไฟฟ้า
ก.) ข้อมูลจากการวัดในสนาม
ข.) ค่าที่ได้จากการคำนวณแบบ inversion ด้วยโปรแกรม RES2DINV
ค.) ผลการแปลความหมายแสดงขอบเขตของสายแร่ทองคำเป็นสีแดงเข้ม

Surface excavation



Pit

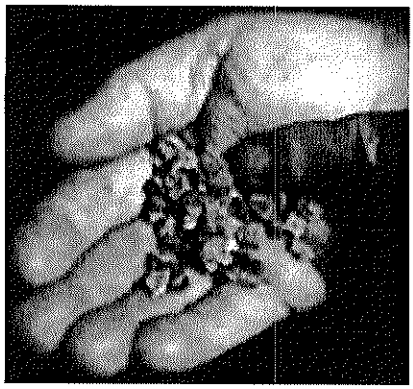
Trench



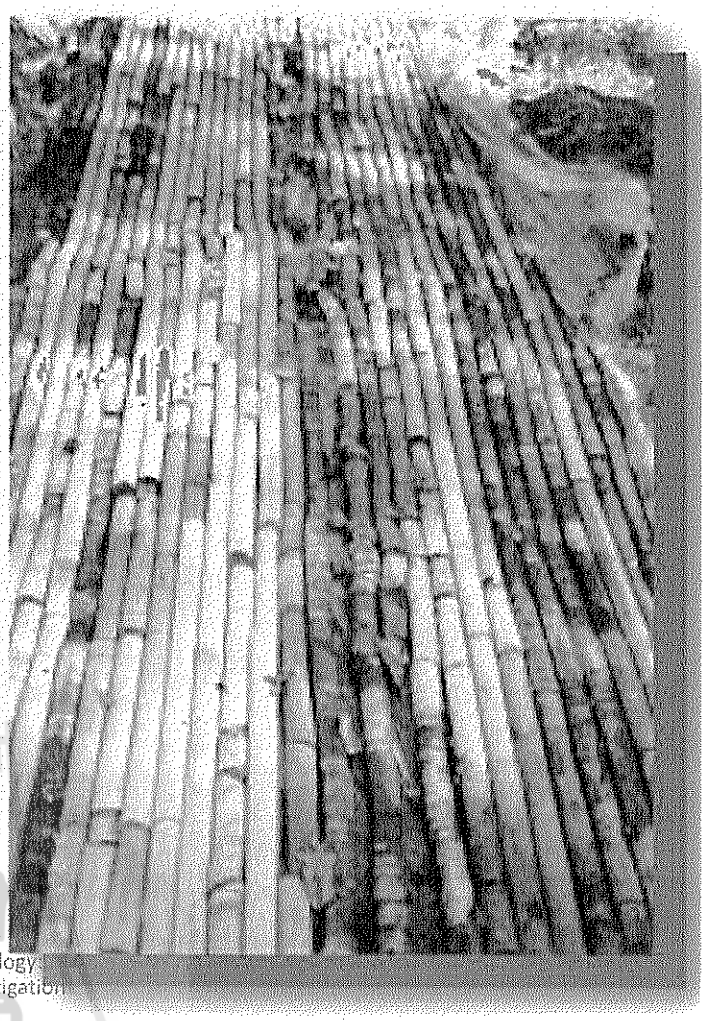
Borings

- Borings are the most practical and accurate method of obtaining sub-surface information.





Cuttings



Cores

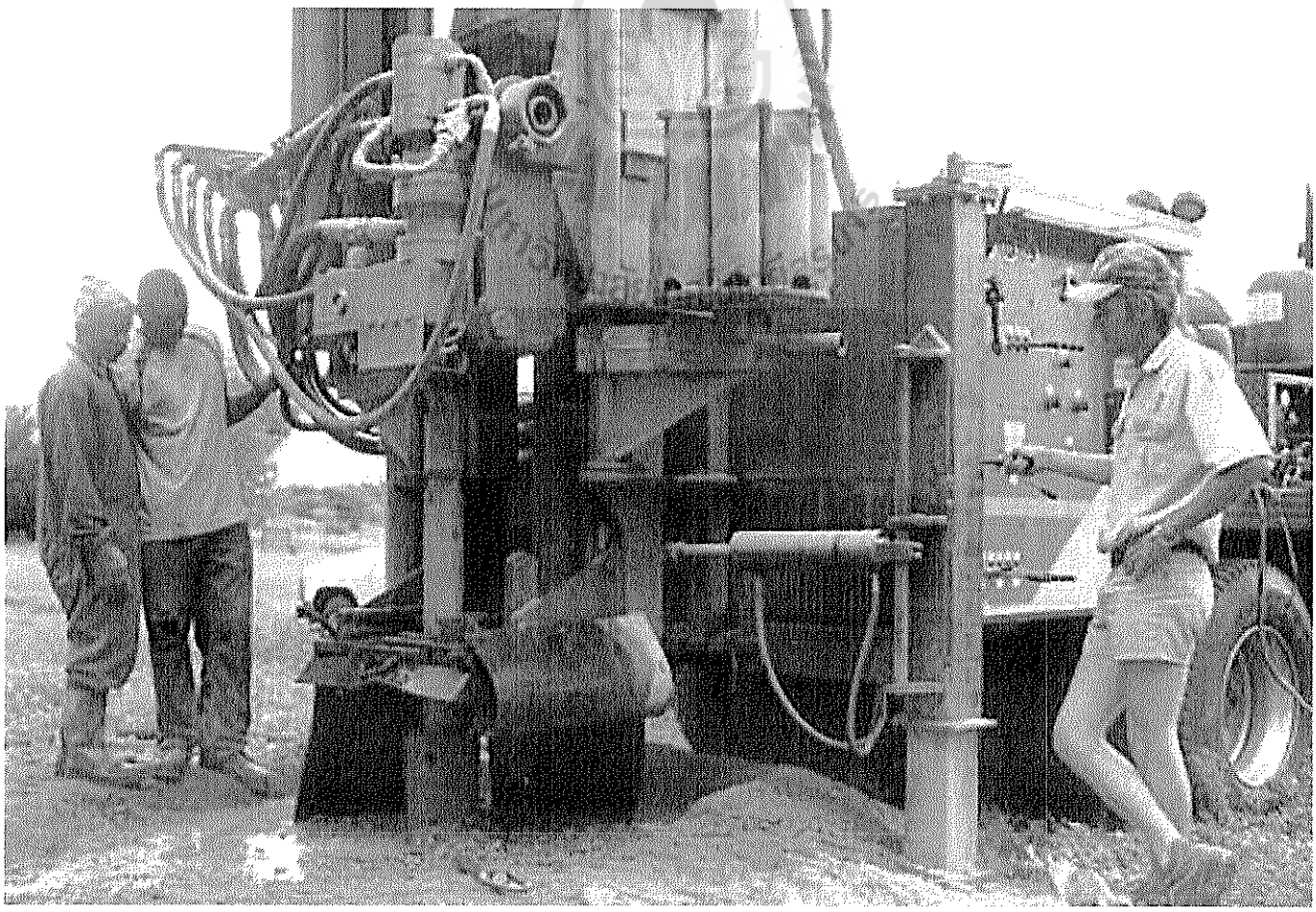
538201 Physical Geology
investigation

Percussion drilling



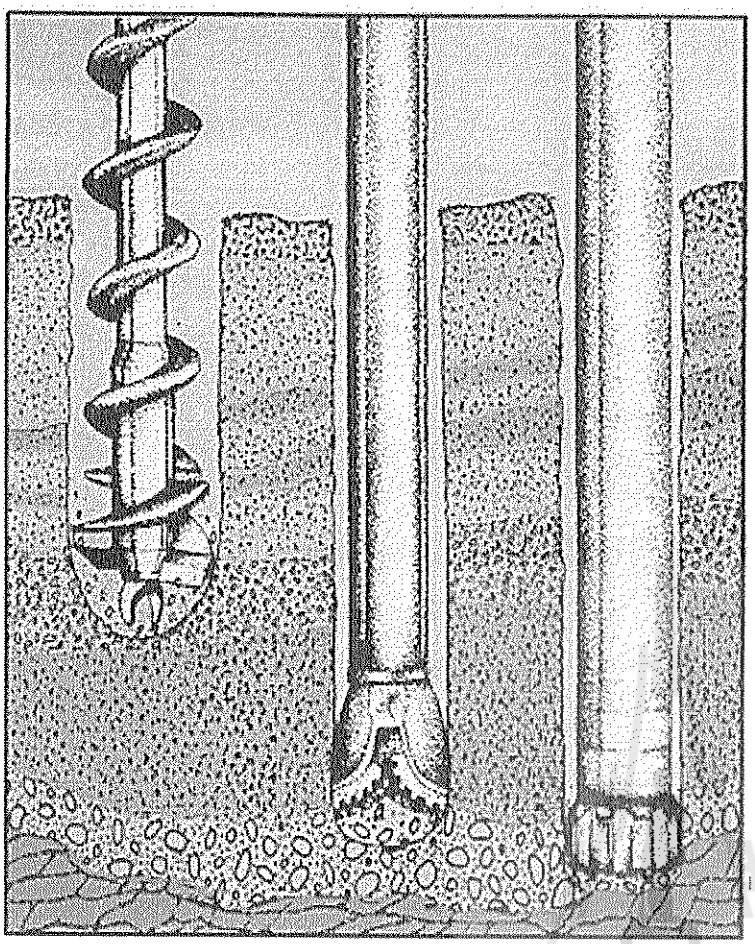
Percussion Drilling

- Depth limited to about 300 - 500 ft.
- Pneumatic or hydraulic drive.
- Air or water circulation for cuttings removal.
- Samples relatively fine cuttings.
- Works best in competent and dry rock.
- Good sample quality above water table.
- Below water table, poor to fair quality.



538201 Physical Geology: CH11_Geological investigation

Rotary drilling



- A hollow stem auger used for drilling in unconsolidated material, primarily on environmental and geotechnical projects
- A mud/air rotary drilling in overburden using a tri-cone roller bit
- A down-the-hole hammer bit used in rotary percussion (air rotary) drilling in bedrock.

Rotary Drilling

- Most commonly a tricone bit.
- Generally faster and cheaper than percussion.
- Greater depths, up to about 2000 ft.
- Air or drilling mud circulation.
- Fine-grained cuttings.
- Fair sample quality for mud drilling.
- Good sample quality for air drilling.

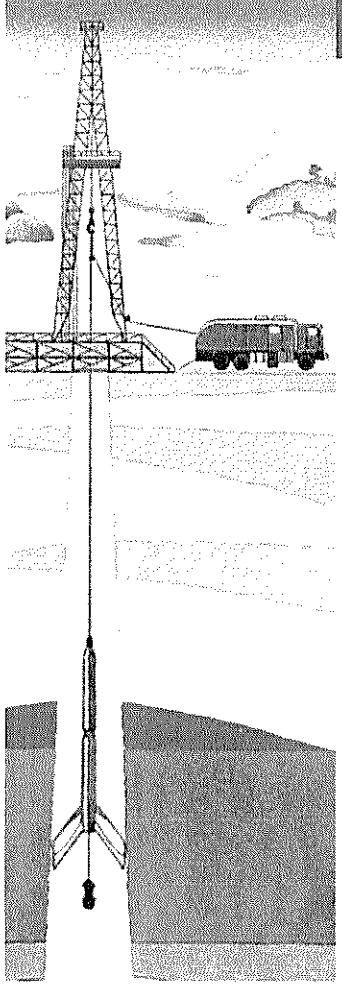
Cuttings: should normally be of a size that allows for identification of certain rock characteristics (e.g., rock type, grain size, mineralogy).

Cores: every 1 foot interval, size depends on objectives, Samples should be wrapped by plastic film.

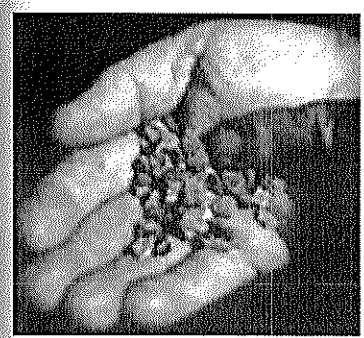
Well logging

Contents

- Core and cutting logging
- Wireline Logging

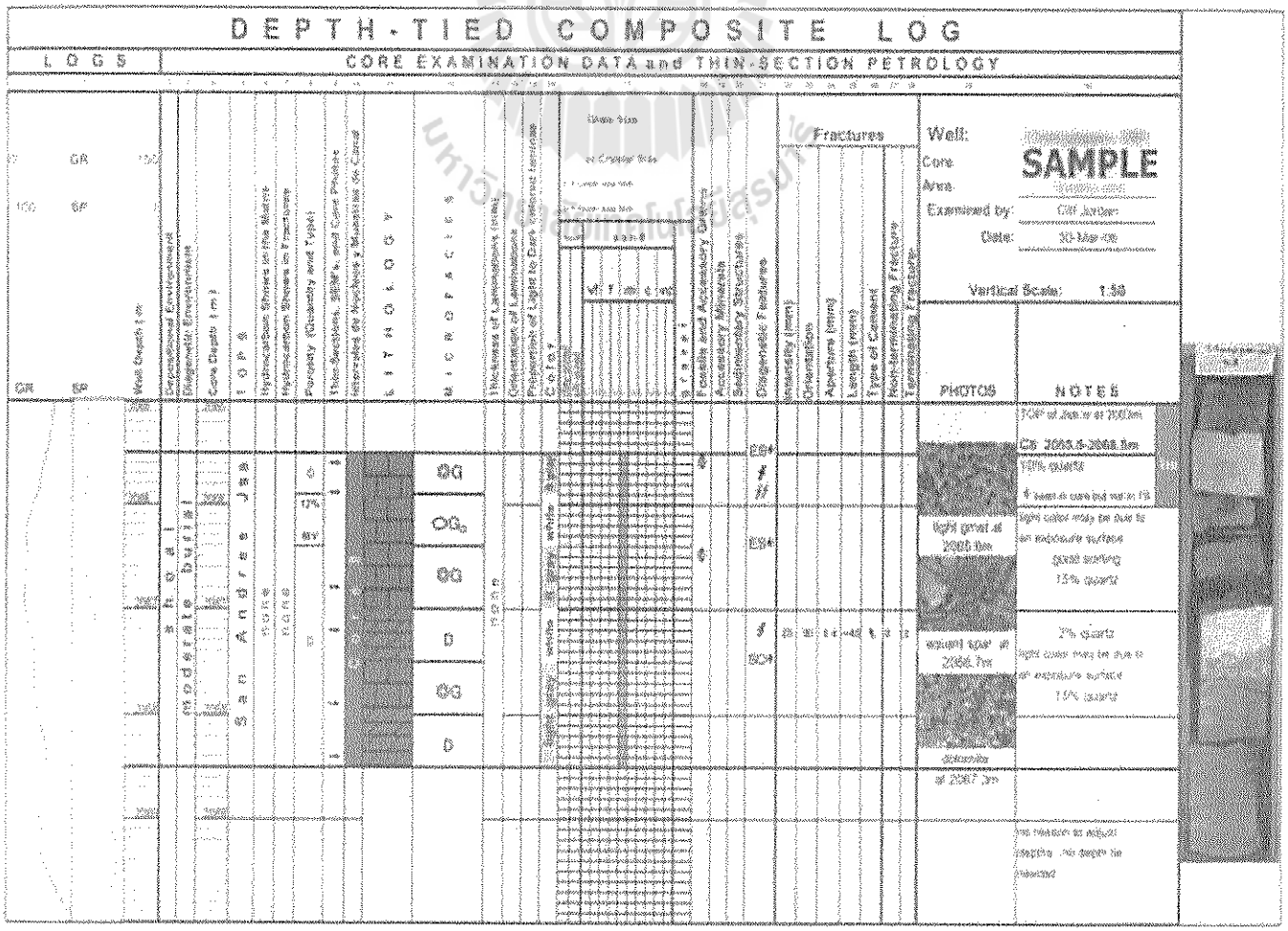


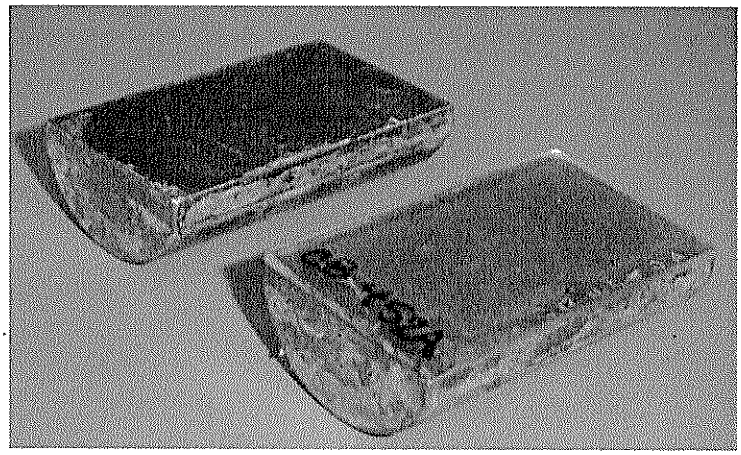




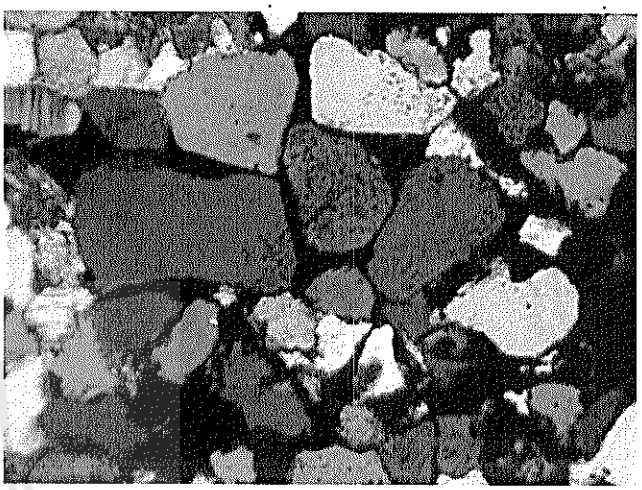
Core and cutting logging

Examination of Well Cuttings
Thin-Section Analysis
Insoluble Residues
Petrologic Analyses
Differential-Thermal Analysis
Electron-Microscopic Analysis
Micropaleontological
Water Analysis





Thin section analysis



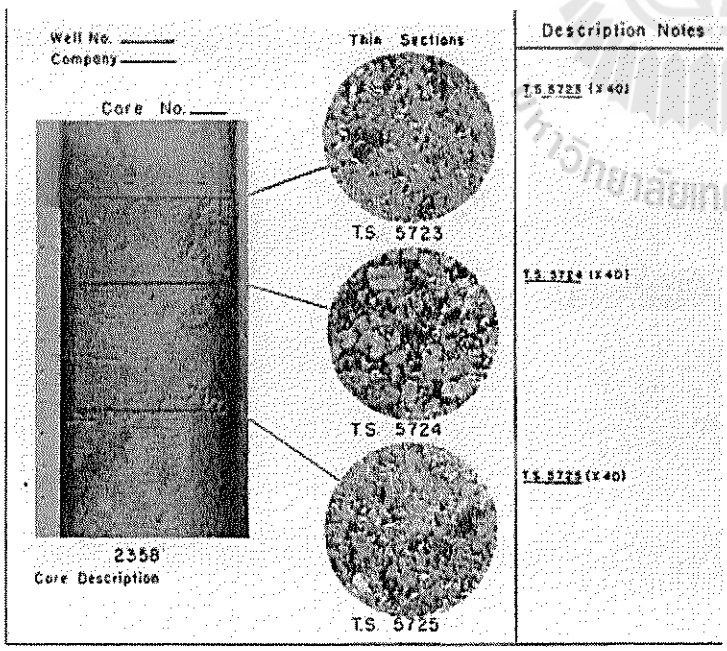
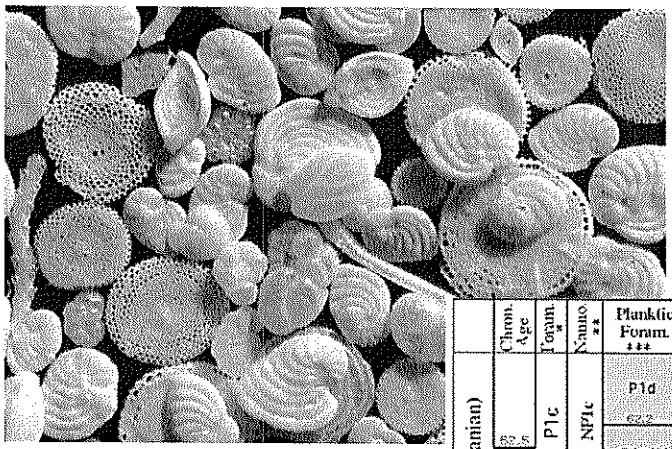
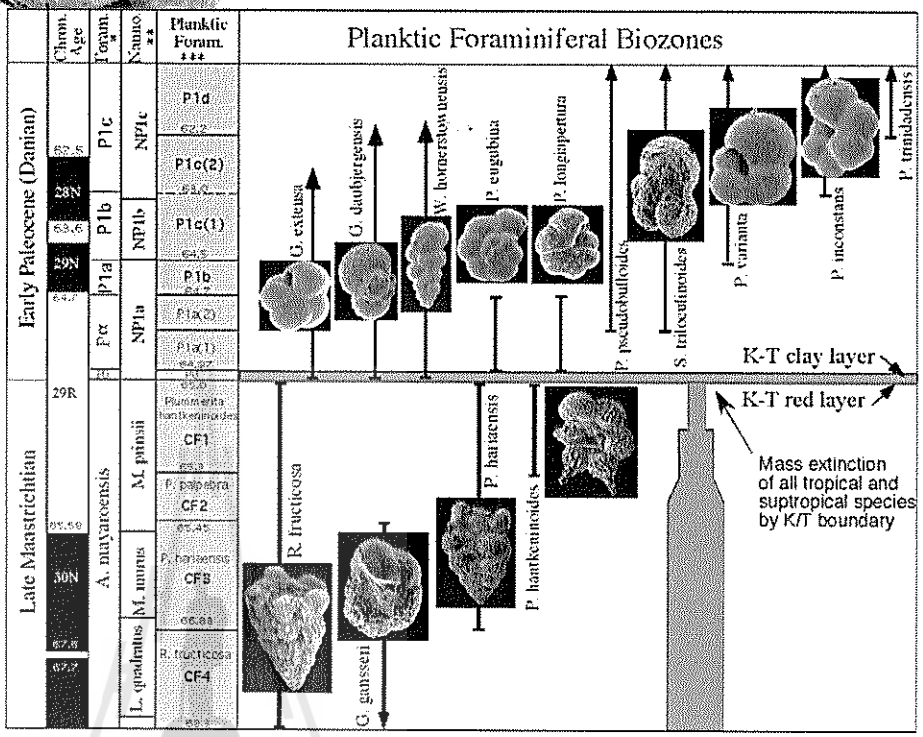


FIGURE 4-4. Example of photographic record of core and thin sections.

Correlation

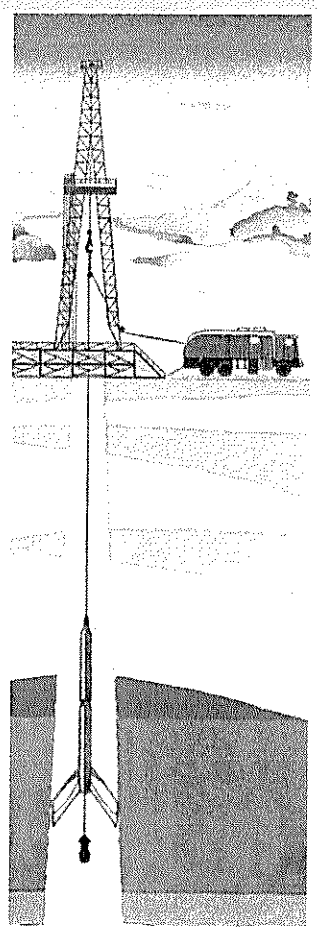
- Lithofacies studies
- Cement sersus matrix
- Amount of interstitial Material
- Kind of cement
- Rock composition
- Grain-size
- Diagenetic changes
- Metamorphic changes



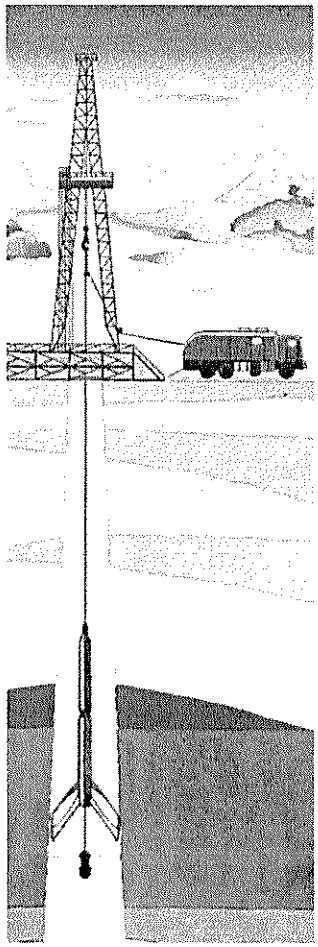


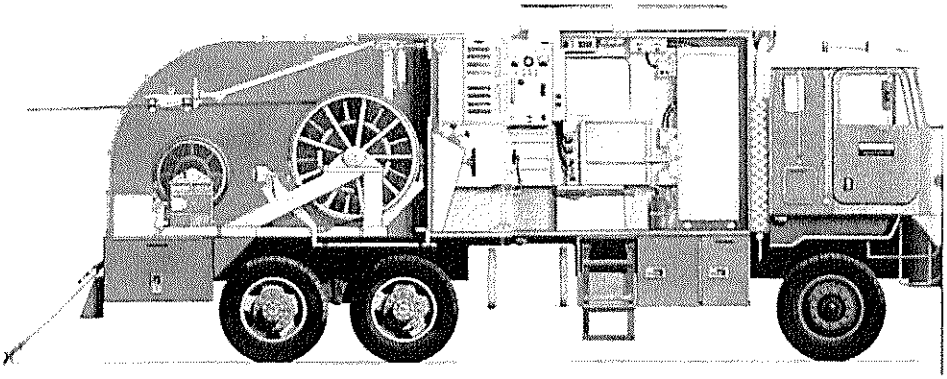
Wire line logging

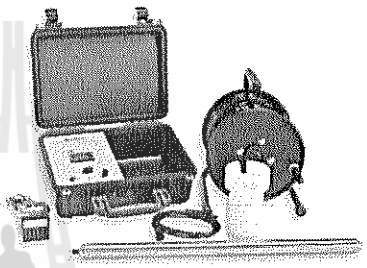
Electric Logging
Radioactivity Well Logging
Caliper and Temperature Logging
Mud and Cuttings Logging
Drilling Time Logging
Dipmeter Surveys
Permeability Surveying Methods
Continuous Velocity Logging
Magnetic Well Logging



มหาวิทยาลัยเทคโนโลยีสุรนารี







S N

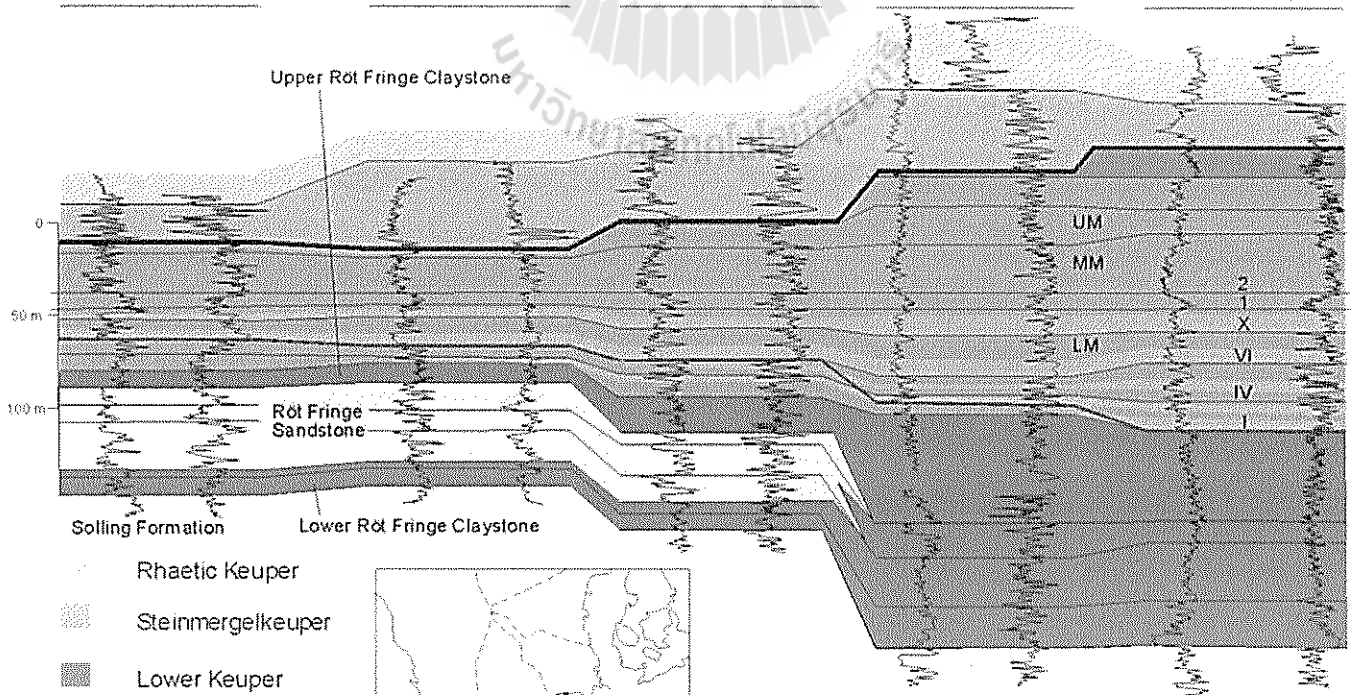
Strijen - West - 1 (NAM; 1987)
Gamma - Ray API Sonic µs/ft

Capelle - 1 (NAM; 1985)
Gamma - Ray API Sonic µs/ft

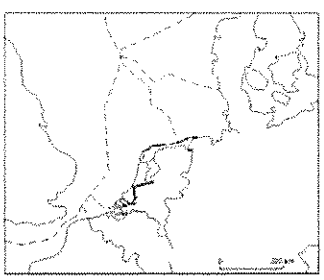
Moerkapelle - 14 (NAM; 1984)
Gamma - Ray API Sonic µs/ft

Woubrugge - 1 (NAM; 1966)
Gamma - Ray API Sonic µs/ft

Ermelo - 1 (NAM; 1972)
Gamma - Ray API Sonic µs/ft



Rhaetic Keuper
Steinmergelkeuper
Lower Keuper
Muschelkalk
Röt



Sandstone
Carbonate
Lithostratigraphic boundary between Muschelkalk and Röt formations

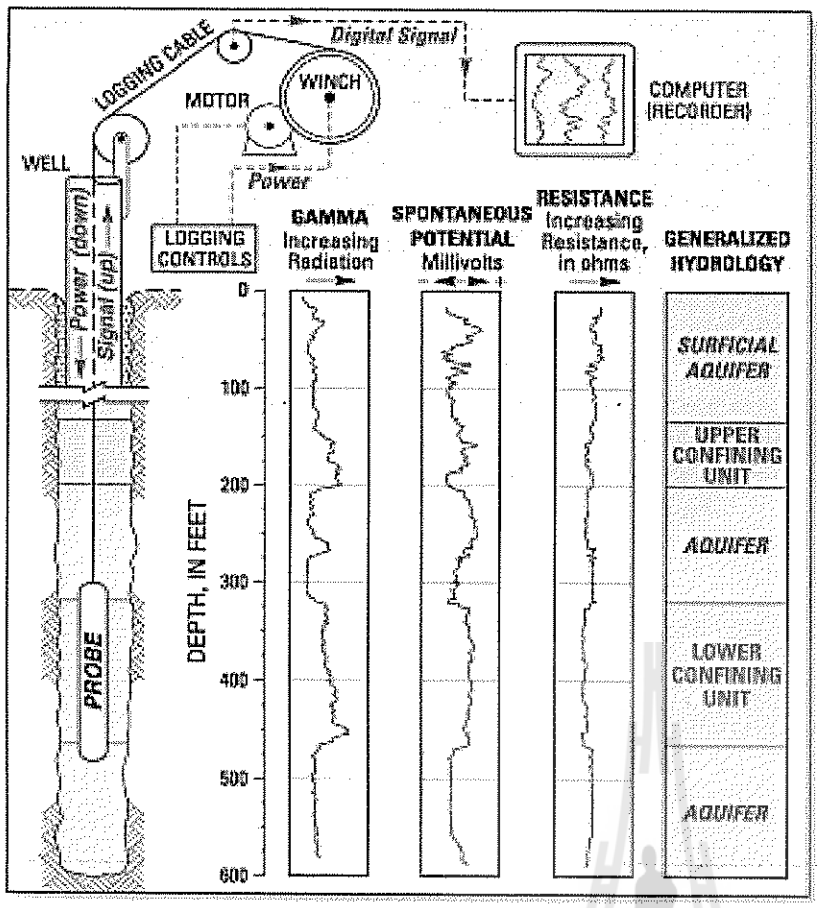
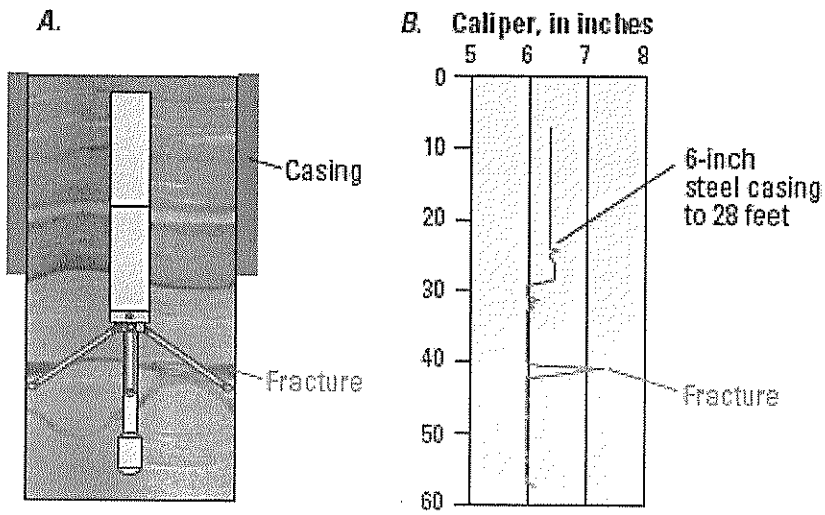


Diagram of geophysical well-logging equipment and recorded logs with generalized hydrologic units

Caliper Log

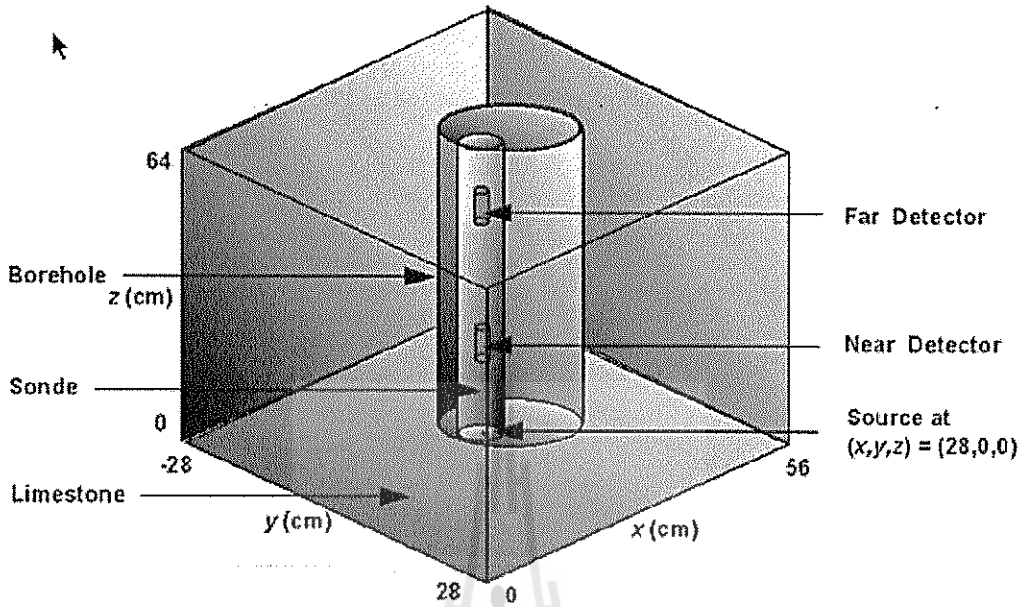
กราฟของ Caliper จะบอกขนาดเส้นผ่าศูนย์กลาง และสภาพผนังของหลุมเจาะ ถ้ากราฟของ Caliper เป็นลักษณะเส้นตรงเรียบๆแสดงถึงผนังหลุมเจาะที่มีสภาพดี ไม่มีโพรง ซึ่งหมายถึงการจับประสานตัวของชั้นดิน-หินใน Formation นั้นๆดีไม่พังทลายได้โดยง่าย



(A) As the caliper tool crosses a fracture, the arms open slightly, creating the inflection on the caliper log *(B)*. This example log shows a fracture at about 42 feet below land surface.

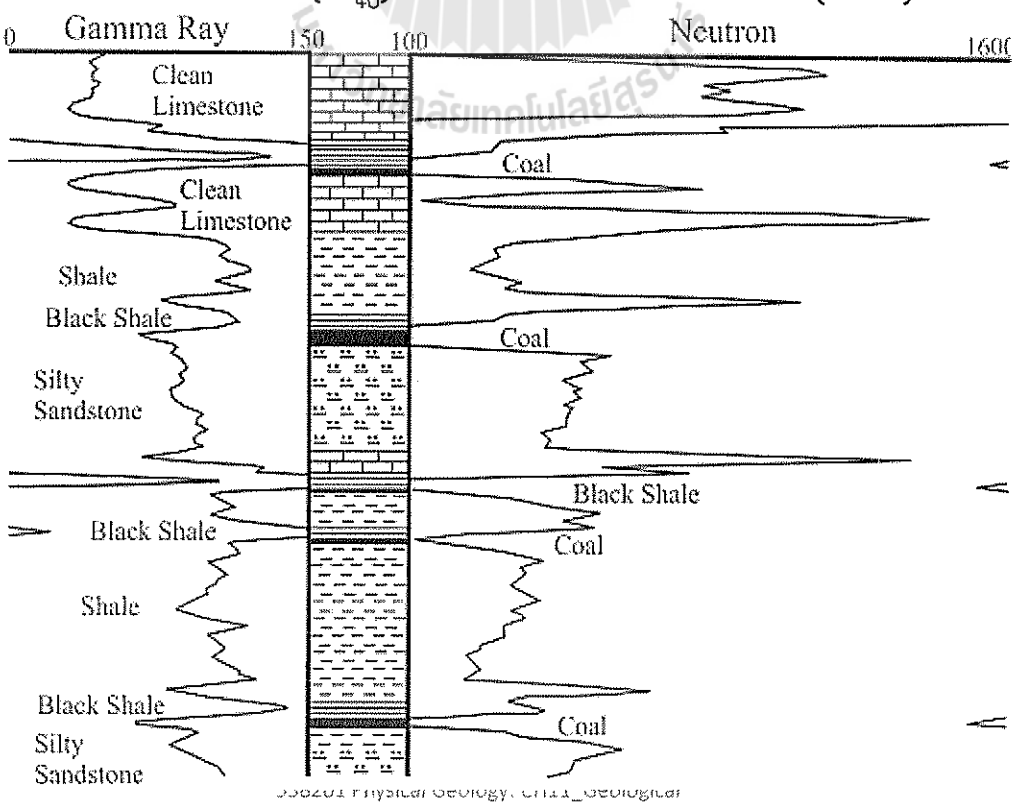
Density Log

Density Tools ได้แก่ แหล่งกำเนิดของรังสี (Radioactive Source) ซึ่งปกติใช้ธาตุ Cesium137 และมีตัวรับรังสี (Detector) ซึ่งจะเป็นตัววัด Electron Density และมีระยะระหว่าง Source และ Detector แตกต่างกันออกไปตามลักษณะการใช้งาน หากชั้นตัวอย่าง (Bed) น้อยกว่าระยะห่างระหว่าง Source และ Detector จะไม่สามารถตรวจวัดได้



Gamma Ray Log

เป็นการวัดค่า Natural Gamma ที่แผ่กระจายออกมาจากการสลายตัวเองของสารที่มีในชั้นดิน-หิน สารที่ให้ Gamma ได้แก่ โปแตสเซียม (K^{+}_{40}) ซึ่งมักจะพบว่าเป็นชั้นหินดินดาน (Shale)



Neutron Log

ลักษณะการทำงาน คล้ายคลึงกับ Density Log โดยที่การสลายตัวของธาตุกัมมันตภาพรังสีทำให้เกิดรังสีนิวตรอนซึ่งจะกระจายและถูกจับไว้โดยนิวเคลียสของอะตอมหนัก เช่น Silicon, Hydrogen พลังงานที่ได้รับจาก Detector จะแสดงอัตราส่วนของจำนวน Hydrogen ในชั้นนั้นๆ โดยปกติ Coal และ Oil Shale จะมี Hydrogen สูง โดยเฉพาะ Pore ของ Coal หรือ Lignite จะมีน้ำเข้าไปสะสมตัวทำให้การวัดค่า Neutron Log จะมีค่าต่ำ เนื่องจากถูกจับไว้ Neutron Log มักจะใช้วัด Porosity เช่น ในชั้นหินทรายเป็นต้น

Resistivity Log

การวัดค่า Resistivity ของชั้นหินเป็นการวัดการไหลของกระแสไฟฟ้าระหว่าง Electrode ในเครื่องมือที่ตรวจวัดได้จากชั้นหินกับค่า Resistivity ของ Ground ปกติ Resistivity Log ถูกใช้เพื่อการเทียบสัมพันธ์ชั้นหิน เนื่องจากใช้งานง่าย ชั้น Shale จะอ่านค่าได้ต่ำที่สุด ทั้งนี้ถ่านและหินทรายก็สามารถอ่านค่าความต้านทานได้ต่ำเช่นเดียวกัน จึงอาจจะเกิดความสับสนได้

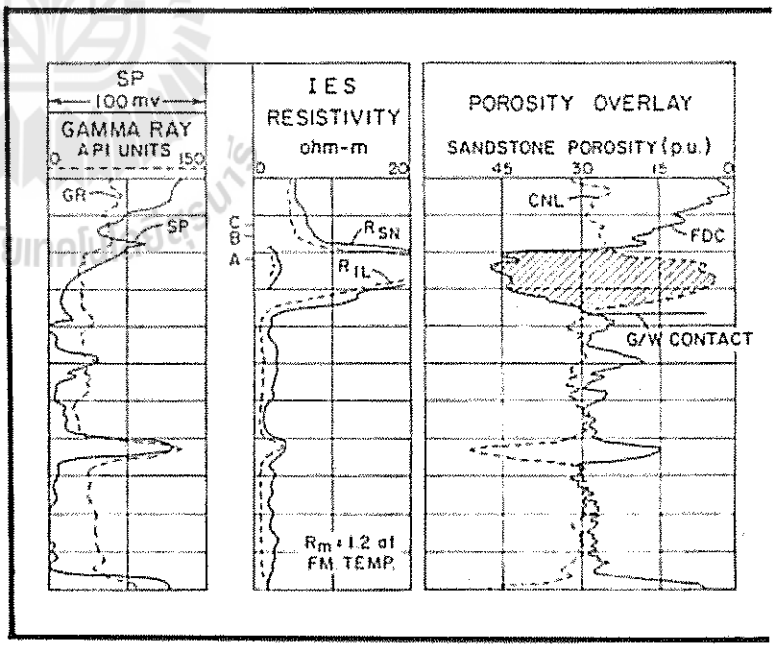
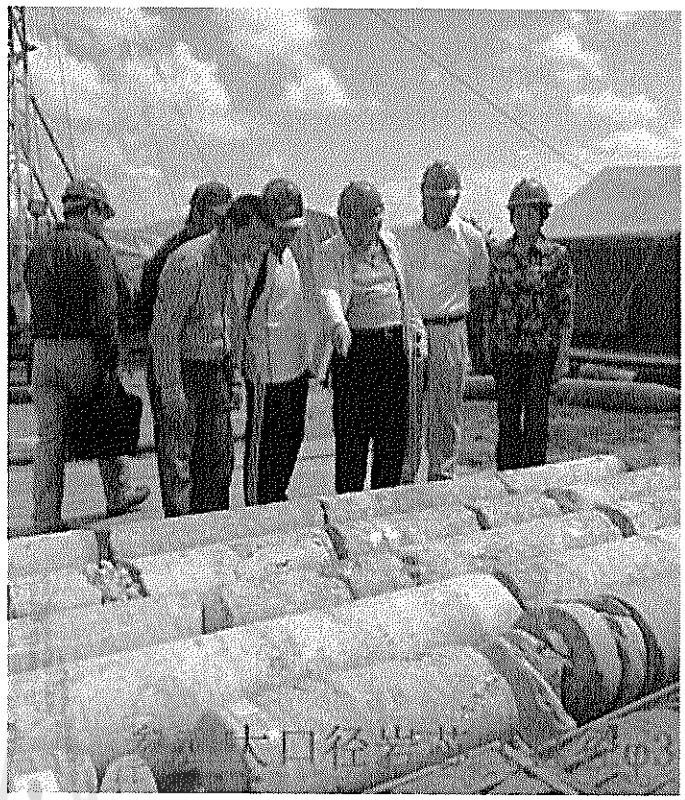


Fig. 3-4 — CNL-FDC overlay showing gas zone in cleaner part of sand. As shown by Gamma Ray the upper part of the interval is shaly. (From Ref. 1, courtesy of SPWLA.)

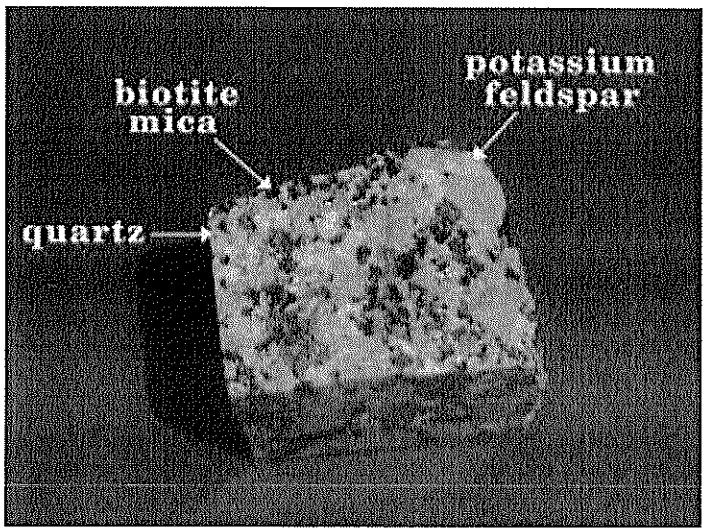
4. Sample collecting

- Surface outcrop sampling
- Channel sample in underground working
- Drilling



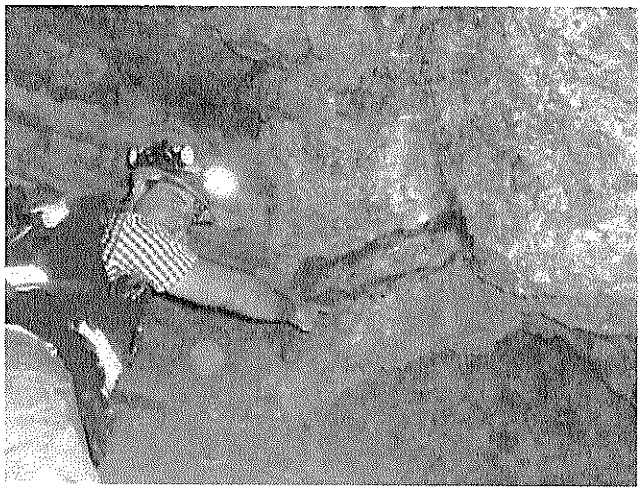
Surface outcrop sampling

Systematic sampling
Random sampling



- Identification
- Thin section study
- Chemical analysis

Channel sample in underground working



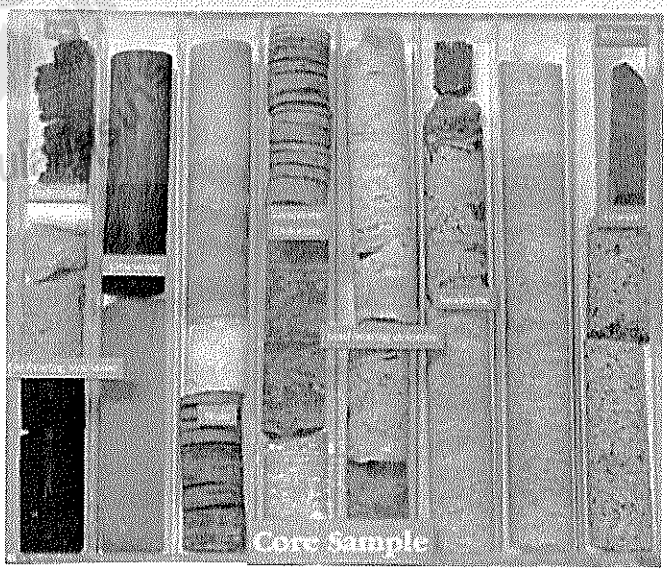
•Channel samples consist of cuttings collected from a grove cut into the rock about 4 inches wide and 0.75 in deep.

•Various tools such as a hammer and moil or a pneumatic chisel can be used to cut the sample.

•Rock fragments are collected on a canvas tarp on the floor and sent for assaying.

Continuous Core Drilling





- Site name or project
- Drill hole number
- Drilling date(s)
- Core depth interval represented in each box (e.g., 50-60 ft)
- Box number and total number of boxes in the entire core sample (e.g., box 2 of 5)

Contents of a geologic report

Introduction
- Significance of studying
- Objectives
- Study area: general information, location, geological data, maps

Literature reviews

Methodology

Results of geologic investigation
- Rock units
- Structural geology
- Geophysical surveys
- Historical geology
- Petrology
- Geochemical study (lab study)
- Geologic map and cross sections

Conclusions and recommendations