Third stage
First course
structural geology

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What Is The Structural Geology

It is that branch of geology that deals with architecture of the rocks insofar as it has resulted from deformation,

Deformation: is the process that change the shape or form of a rock body. in other word, the process responsible for the formation of **geological structures**

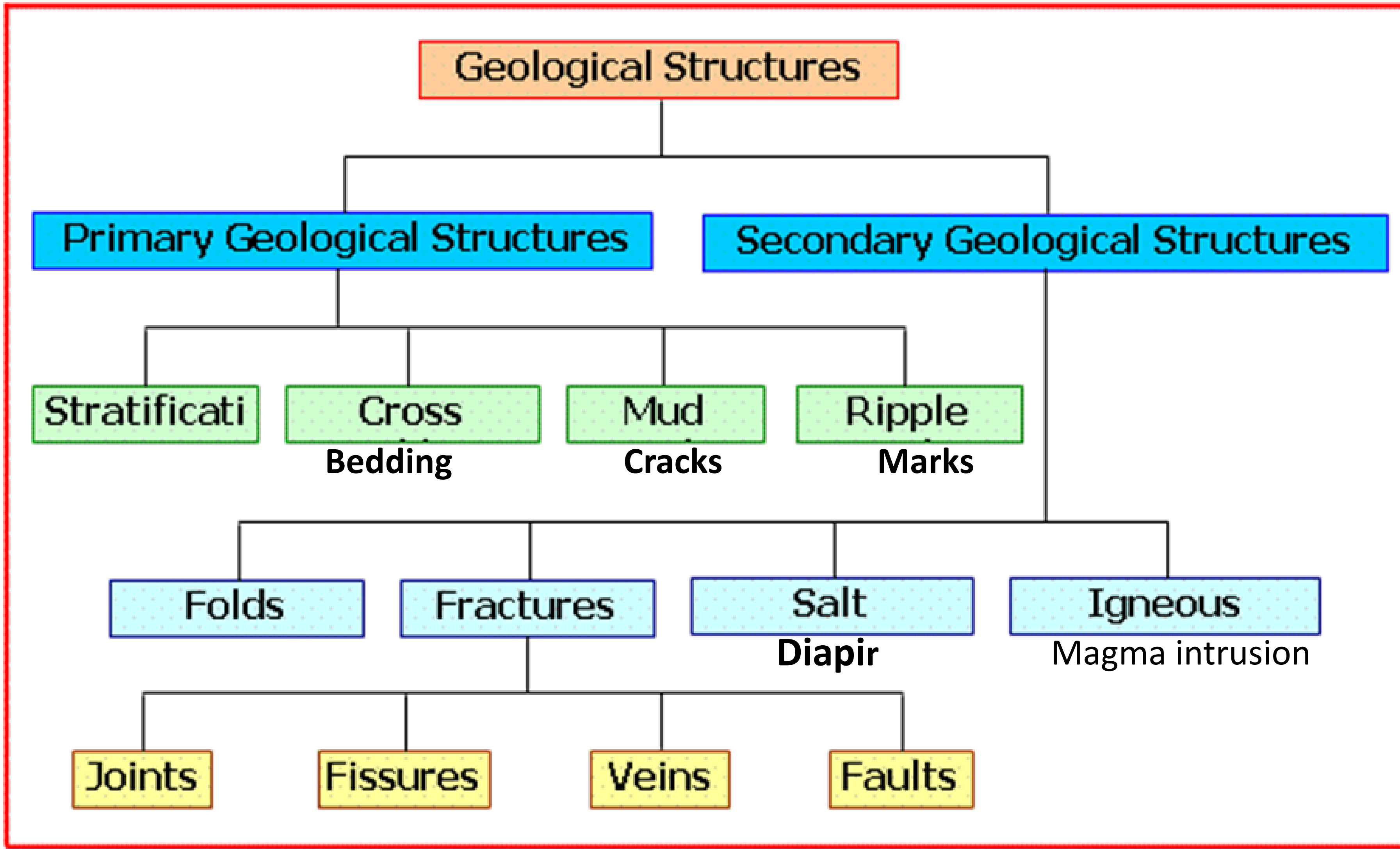
A geologic structure is a geometric configuration of rocks, and structural geology deals with the geometry, distribution and formation of structures

It should be added that structural geology only deals with structures created during rock deformation, not with primary structures formed by sedimentary or magmatic processes. However, deformation structures can form through the modification of primary structures, such as folding of bedding in a sedimentary rock

The closely related word **tectonics** comes from the Greek word tektos, and both structural geology and tectonics relate to the building and resulting structure of the Earth's lithosphere, and to the motions that change and shape the outer parts of our planet. We could say that tectonics is more closely connected to the underlying processes that cause structures to form:

Tectonics deals with the forces and movement that produced the structure.

also we could say that Structural Geology deals with the study of deformation at a scale ranging from submicroscopic to the regional whereas the Tectonics predominantly deals with a regional to global scale or large scale structures.


Geological Structures
Primary Geological Structures
Secondary Geological Structures
Stratificati
Cross
Bedding
Mud
Cracks
Ripple
Marks
Folds
Fractures
Salt
Diapir
Igneous
Magma intrusion
Joints
Fissures
Veins
Faults

Objective of Structural Geology:

The structural geologist is concerned with three major problems:

1- What is the Structure?

2-When did it develop?

3-under what physical condition did it form?

In general, the first question must be answered first. it is essential to determine the shape and size of rock bodies.

Geological field work is indispensable(لاغني عنه) to many such investigations, and it is this fact that distinguishes (يميز) most phase of geology from other sciences.

laboratory investigations are supplementary(ساندة) means to attain this primary objective.

Field (direct)observations of deformed rocks and their structures represent the most direct and important source of information on how rocks deform, and objective observations and careful descriptions of naturally deformed rocks are the key to understanding natural deformation

Because the correct location of outcrops is of the utmost importance (اهمية قصوى) , accurate maps are essential.

Indirect observations of geologic structures by means of various remote sensing methods, including satellite data and seismic surveying, are becoming increasingly important in our mapping and description of structures and tectonic deformation.

A second objective (When did it develop) of structural geologist is to relative the structure to some chronology**.**

One phase of this study is to determine the sequence in which the structural features developed .for example ,he may found an anticline. a fault and a dyke. What are their relative ages?

The structural geologist is interested not only in the sequence of events in the area in whic he is studying but he also wants to fit them into the geological history of the whole earth. this can be done by paleontological methods or by radiogenic dating.

A third objective (under what physical condition did it form?)of structural geologist is to determine the physical process that produced the observed structure. What was the temperature and pressure at the time of the structural feature formed, and what was the stress distribution?

- Experiments performed in the laboratory give us valuable knowledge of how various physical conditions, including stress field, boundary condition, temperature or the physical properties of the deforming material, relate to deformation.

- Numerical models, where rock deformation is simulated on a computer, are also useful as they allow us to control the various parameters and properties that influence deformation

The scope study of structural geology divided into two branches:

FIRST is <u>Pure Structure</u> which deals with geological structures in Geometric and Genetic studies, therefore it is divided into:

<u>Geometric Analysis</u>: include measurement of shape , size, orientation, location and type of structure and it is relation with other structures.

We can say it is interested in answering on (what and where) questions.

<u>Genetic Analysis</u>: comprise two type of analysis , (Kinematics analysis and Dynamic analysis),we can say it is interested in answering on (How ,why and When) questions.

<u>Kinematics Analysis</u>: which concerns how rock particles have moved during deformation i.e. It is interested in strain study.(the Greek word *kinema* means movement).

<u>Dynamic Analysis</u>: is the study of <u>forces</u> that cause motion of particles (*kinematics)*. dynamic analysis seeks to reconstruct the orientation and magnitude of the stress field by studying a set of structures, typically faults and fractures. It is interested in stress study.

Applying stress to syrup gives a different result than stressing a cold chocolate bar: the syrup will flow, while the chocolate bar will break. We are still dealing with dynamic analyses, therefore dynamic analysis divided into two parts

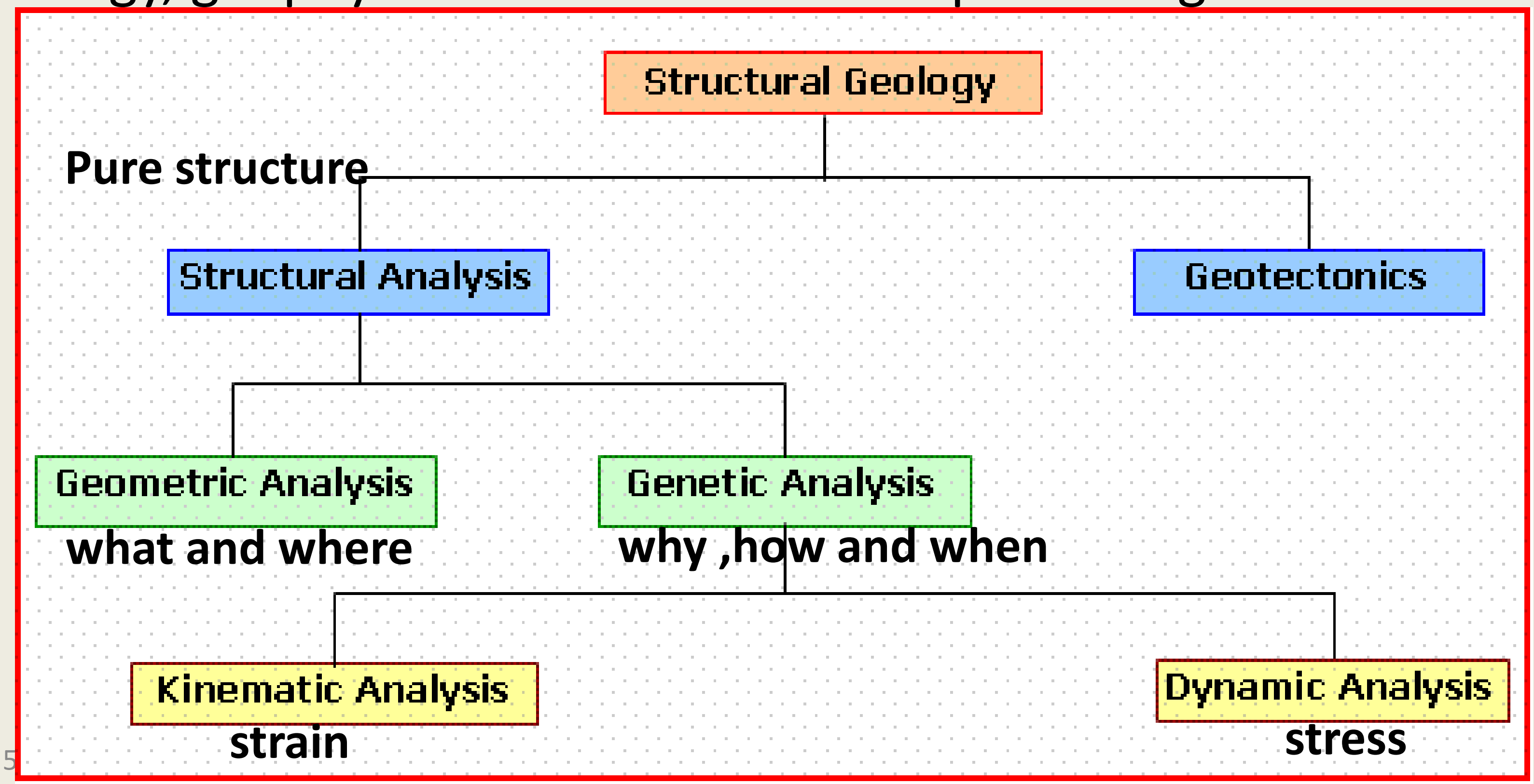
Rheologic Analysis: part of dynamics related to the flow of rocks under applied stress, The name derives from the Greek word "*rheo*", which means "to flow".

Mechanical Analysis: part of dynamics related to the study of how rocks (or sugar) break or fracture under applied stress.

SECOND (Geotectonics)

the subject of geotectonics essentially covers large-scale structural geology that is the study of large scale earth structures such as mountain belt and sedimentary basin.

Tectonic analysis involves dynamic, kinematic and geometric analysis at the scale of a basin or orogenic belt. This kind of analysis may therefore involve additional elements of sedimentology, paleontology, petrology, geophysics and other sub disciplines of geoscience.



Structural Analysis and Scales of Observation

For the results of a structural analysis to be interpretable, the scale of our analysis must be taken into account. For example, a bed of sandstone in a single outcrop in a mountain may appear to be undeformed.But the outcrop may display only a small part of a huge fold that cannot be seen unless you map at the scale of the whole mountain. Structural geologists commonly refer to these relative scales of observation by a series of subjective prefixes

Micro refer to feature that are visible optically at the scale of thin sections, or that may only be evident with the electron microscope; the latter is sometimes referred to as submicroscopic

Meso refers to features that are visible in a rock outcrop, but cannot necessarily be traced from outcrop to outcrop

Macro refers to features that can be traced over a region encompassing several outcrops to whole mountain ranges

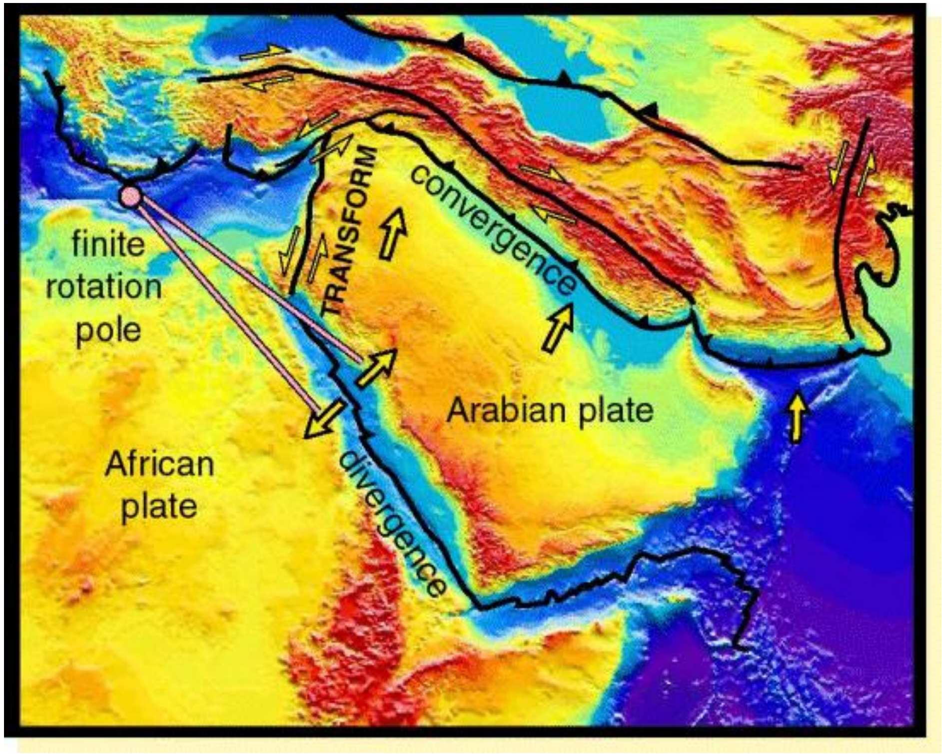
In some circumstances, geologists use the prefix **mega** to refer to continental-scale deformational, such as the movements of tectonic plates over time.

Of course there are no sharp boundaries between these scales, and their usage will vary with context, but a complete structural analysis tries to integrate results from several scales of observation.

Each scale of observation has its own set of tools.For example, optical and electron microscopes are used for observations on the microscale, and satellite imaging may be used for observations on the macroscale. **The mesoscopic recognition and Description of rocks and their structures are of fundamental importance to field analysis, which requires a set of eyes, a hammer, a compass, and a hand lens**

Neotectonics

is concerned with recent and ongoing crustal motions and the contemporaneous stress field.
Neotectonic structures are the surface expression of faults in the form of fault scarps, and important data sets stem from seismic information from earthquakes (such as focal mechanisms and changes in elevation of regions detected by repeated satellite measurements.



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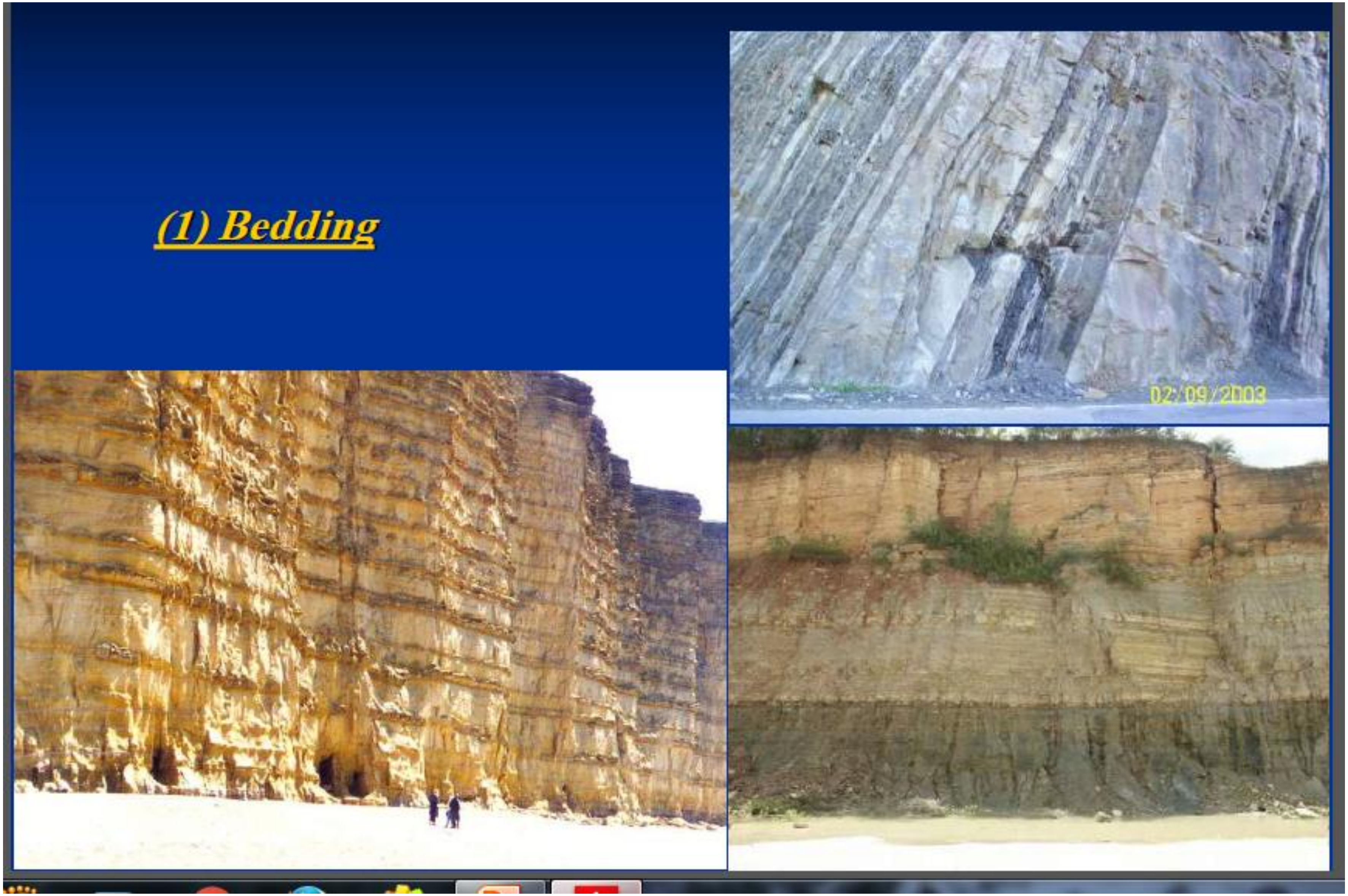
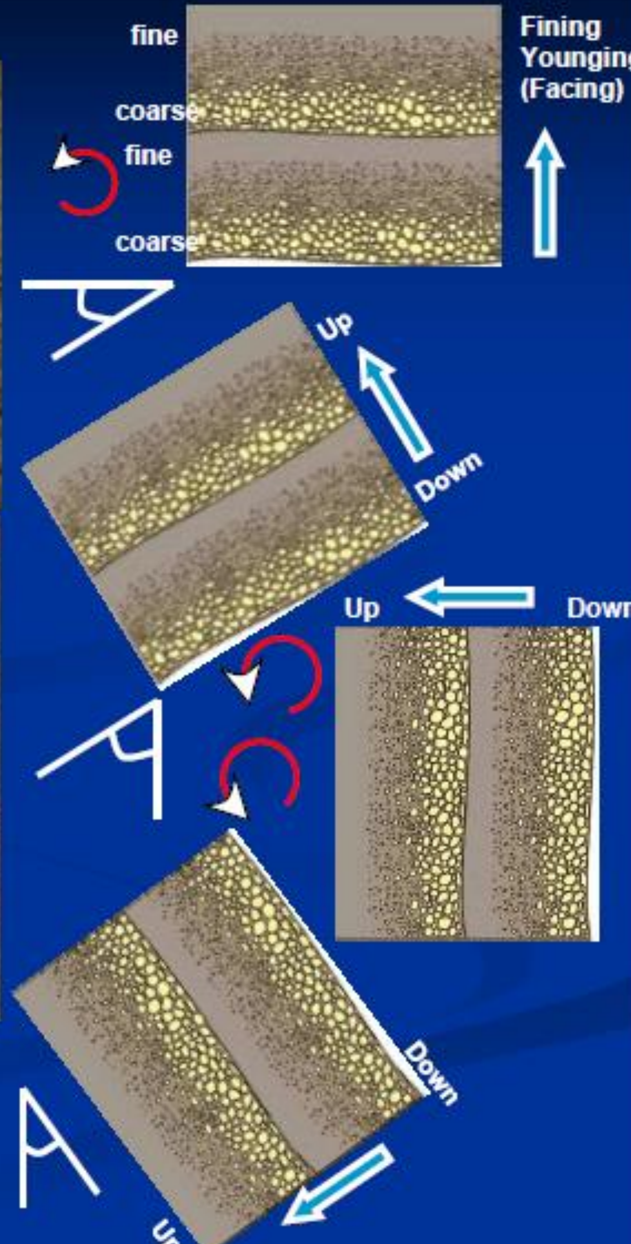
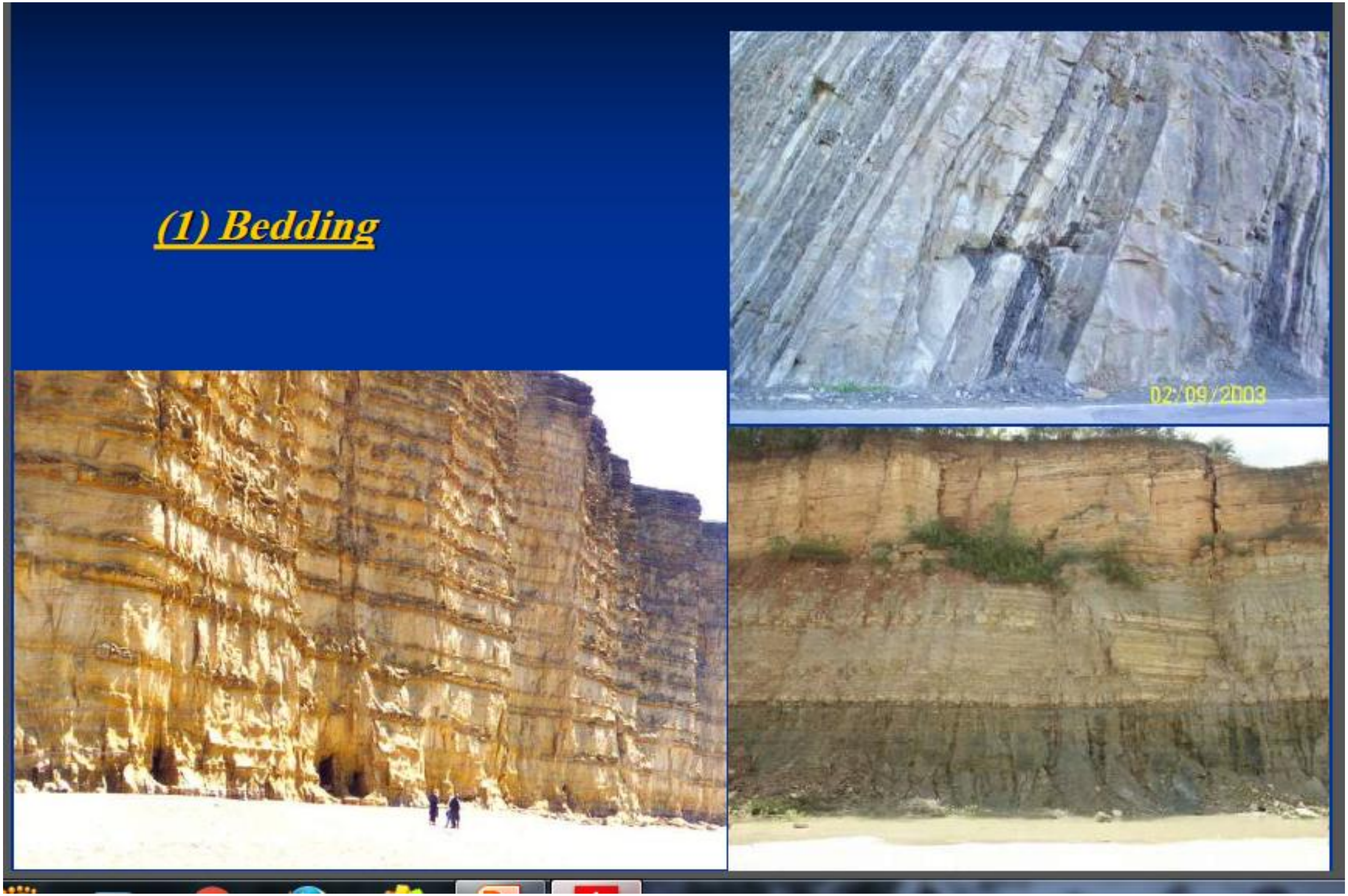
Primary (Non Tectonics) Sedimentary Structures



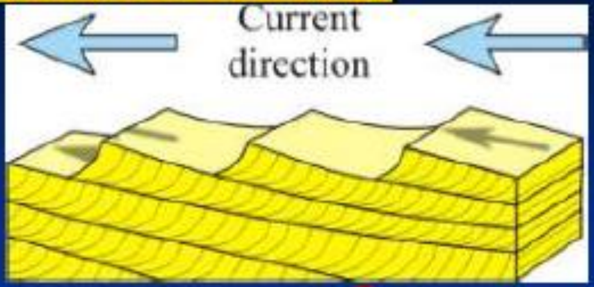
(2) Graded bedding

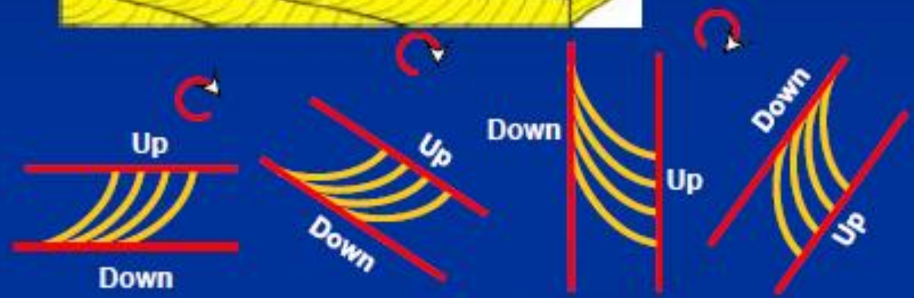


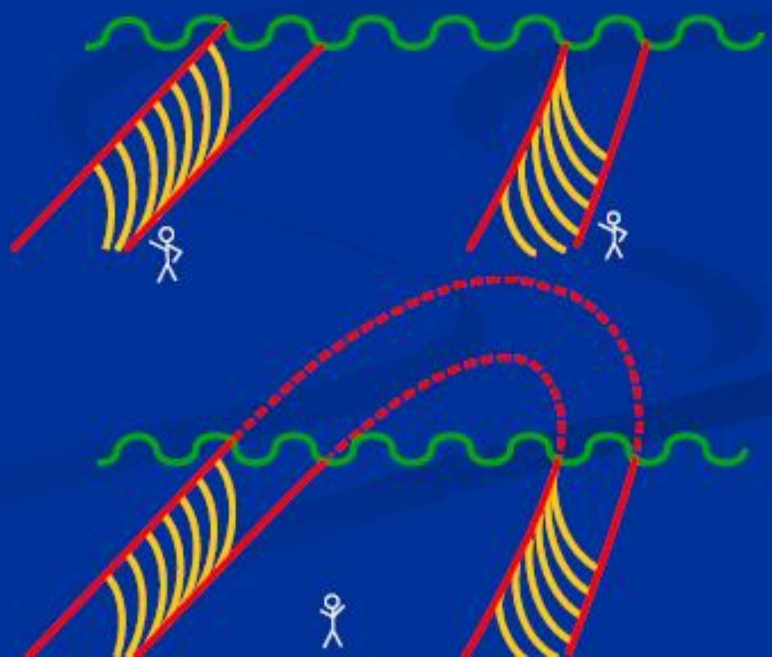
Primary (N0n Tectonics) Sedimentary Structures



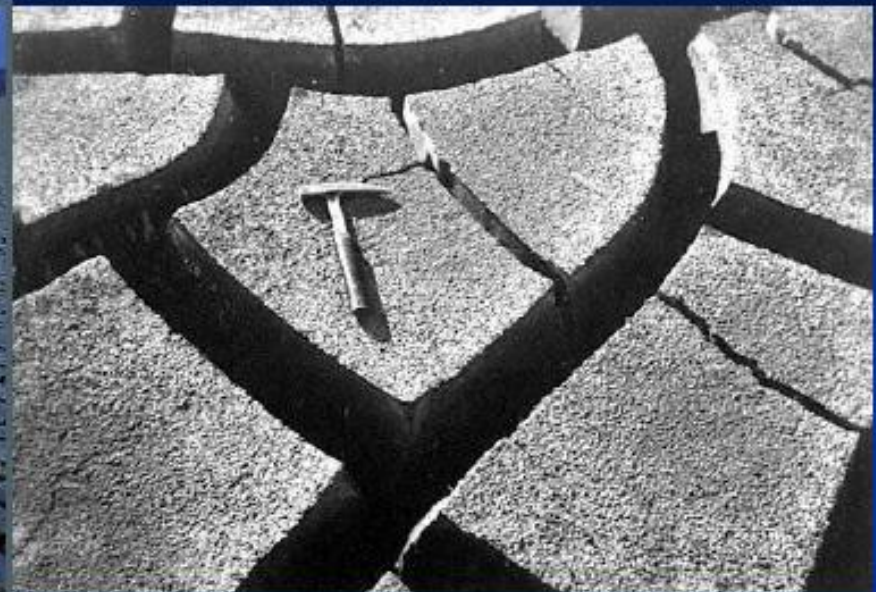
(3) Cross bedding (stratification)

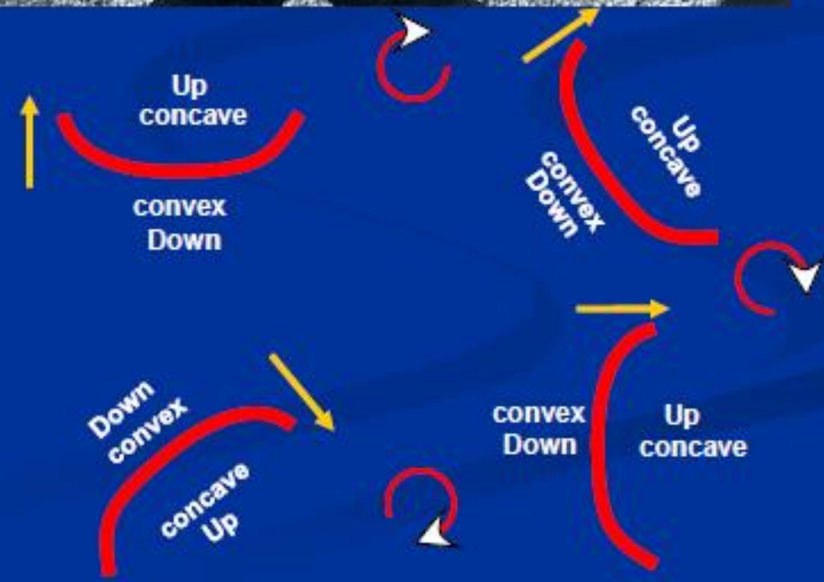




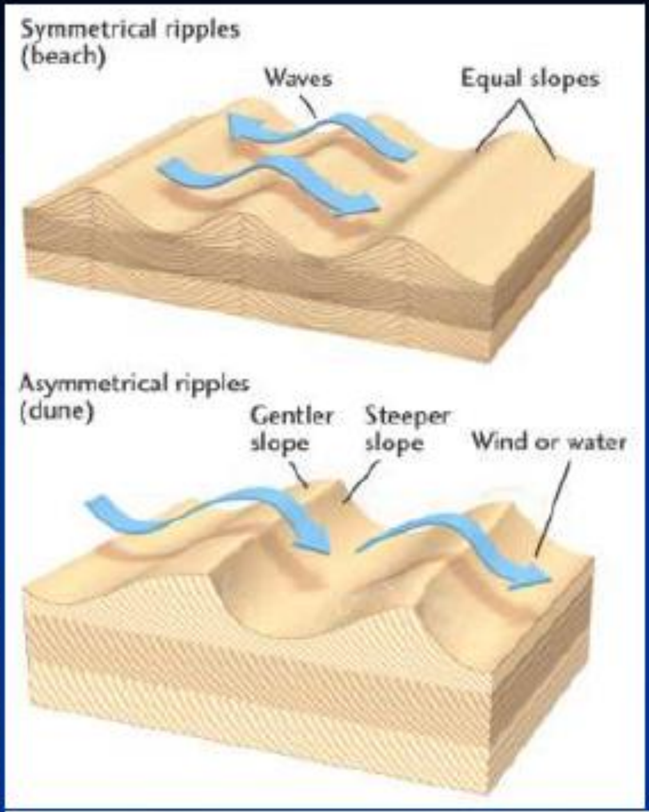


(4) Mud cracks (desiccation)





(5) Ripple marks



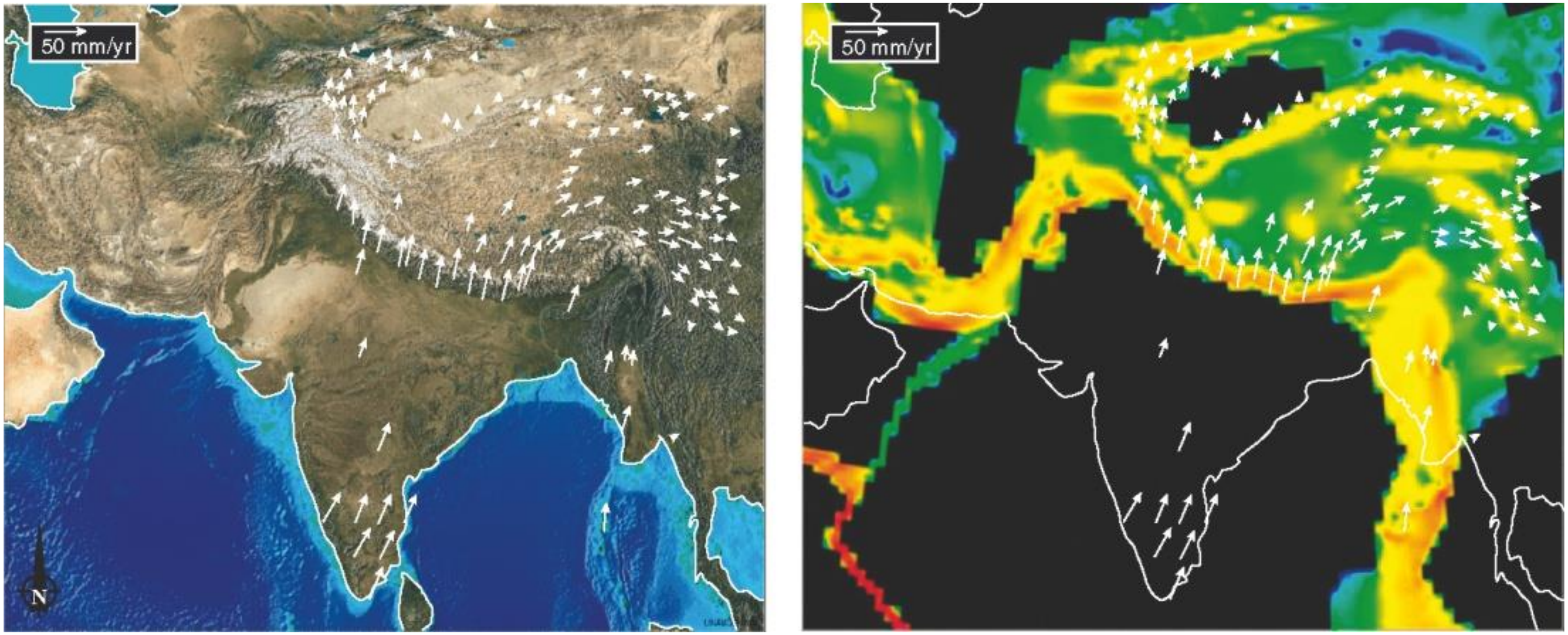
(6) Tracks and trails

Recent camel and seagull tracks

Three toed dinosaur tracks

Amphibian and Cenozoic cat tracks

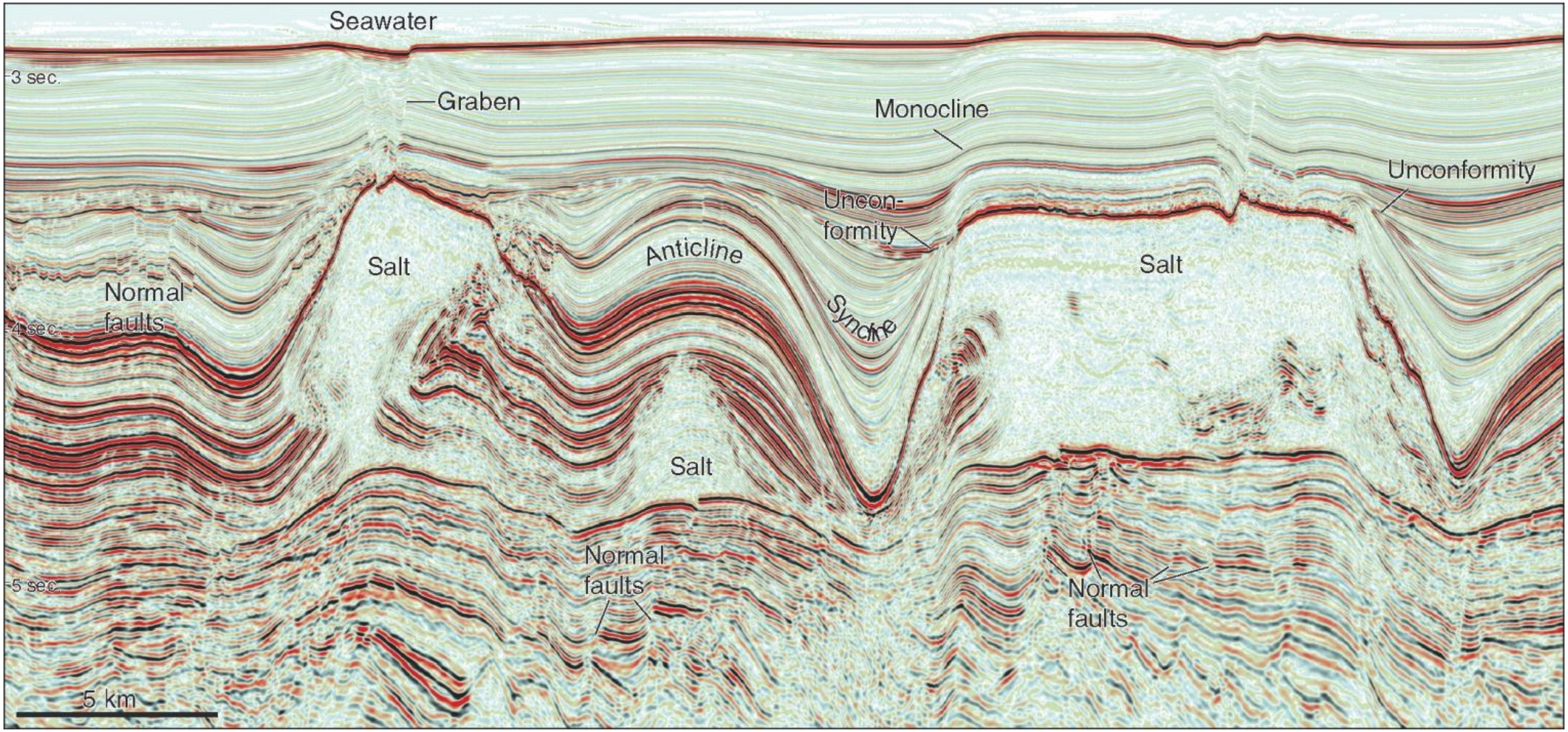
(7) Sole marks, Flute casts



Use of GPS data from stationary GPS stations worldwide over time can be used to map relative plate motions and strain rates.

(Left) White arrows (velocity vectors) indicating motions relative to Europe. The vectors clearly show how India is moving into Eurasia, causing deformation in the Himalaya–Tibetan Plateau region.

(Right) Strain rate map based on GPS data



Seismic 2-D line from the Santos Basin offshore Brazil, illustrating how important structural aspects of the subsurface geology can be imaged by means of seismic exploration. Note that the vertical scale is in seconds. Some basic structures returned to in later chapters are indicated. Seismic data courtesy of CGGVeritas

Experimental work in 1887, carried out by means of clay and a simple contractional device. This and similar models were made by H. M. Cadell to illustrate the structures of the northwest Scottish Highlands.
With permission of the Geological Survey of Britain.

(a) Satellite image of the Canyonlands National Park area, Utah. The image reveals graben systems on the east side of the Colorado River. An orthophoto (b) reveals that the grabens run parallel to fractures,

and a high-resolution satellite image (c) shows an example of a graben stepover structure. Source: Utah AGRC.

Fundamental concepts

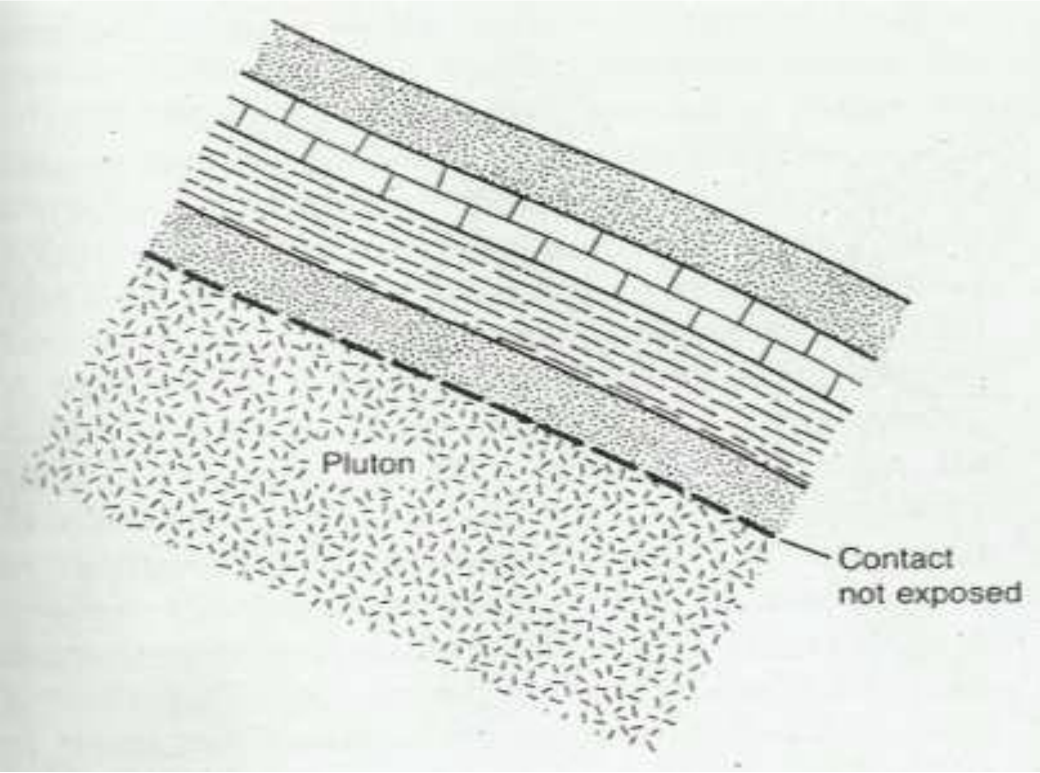
Before going through structural geology, there are some fundamental concepts a structural geologist should be aware of :

(1) Law of Uniformitarianism

“The present is the key to the past”

James Huton

(2) Law of multiple working hypotheses



**According to this law, The contact between
the igneous body and the overlying sedimentary rocks can be :**

(1) An intrusive contact

(2) A fault contact

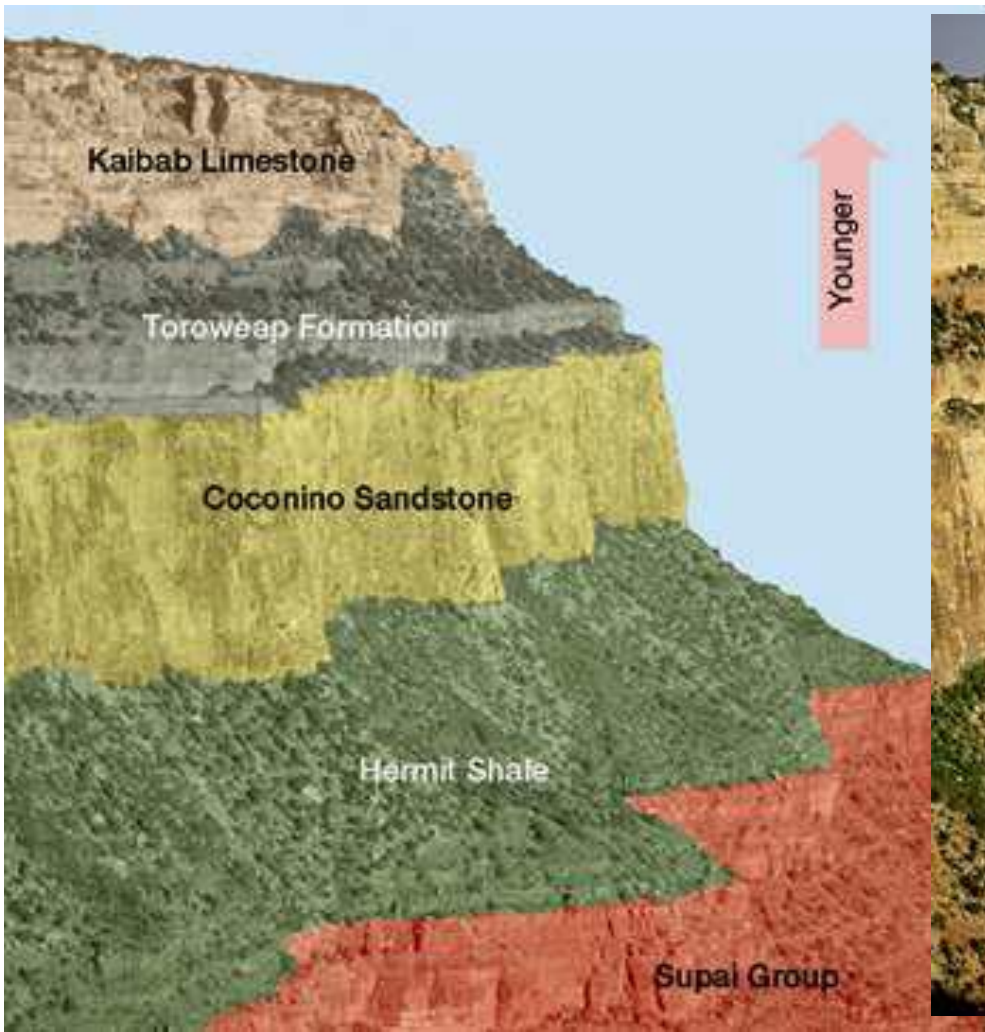
(3) An unconformity contact

(3) Law of original Horizontality

"Bedding planes within sediments or sedimentary rocks form in a horizontal to nearly horizontal orientation at the time of deposition"

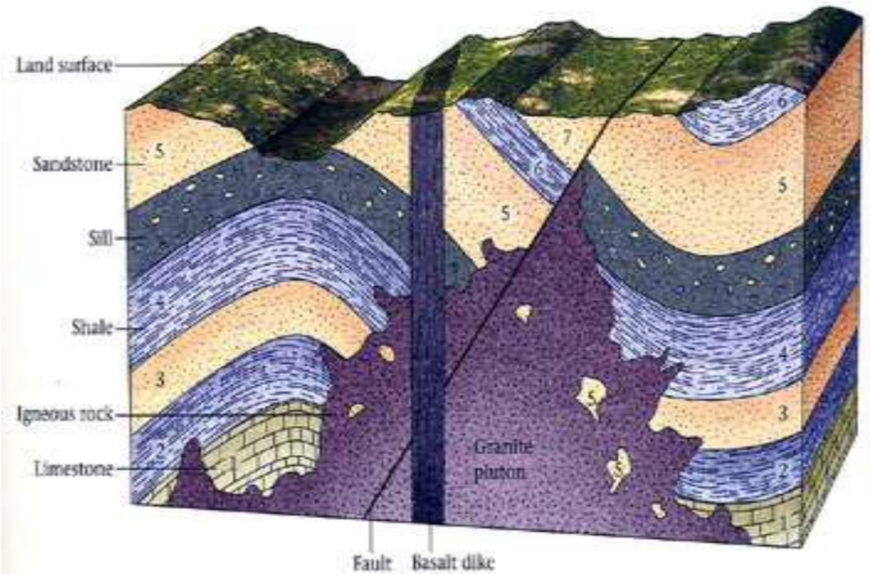
(4) Law of Superposition

“Within a layered sequence, commonly sedimentary rocks, the oldest rocks will occur at the base of the sequence and successively younger rocks will occur towards the top, unless the sequence has been inverted through tectonic activity”

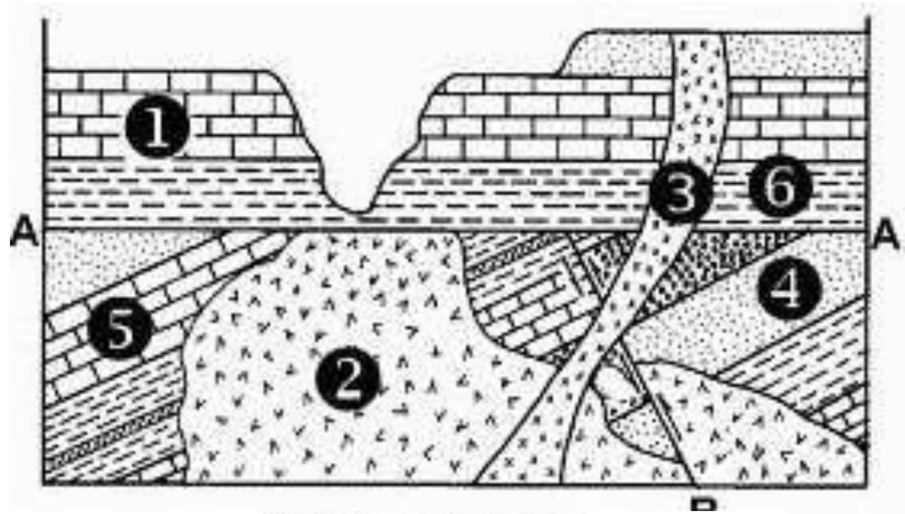


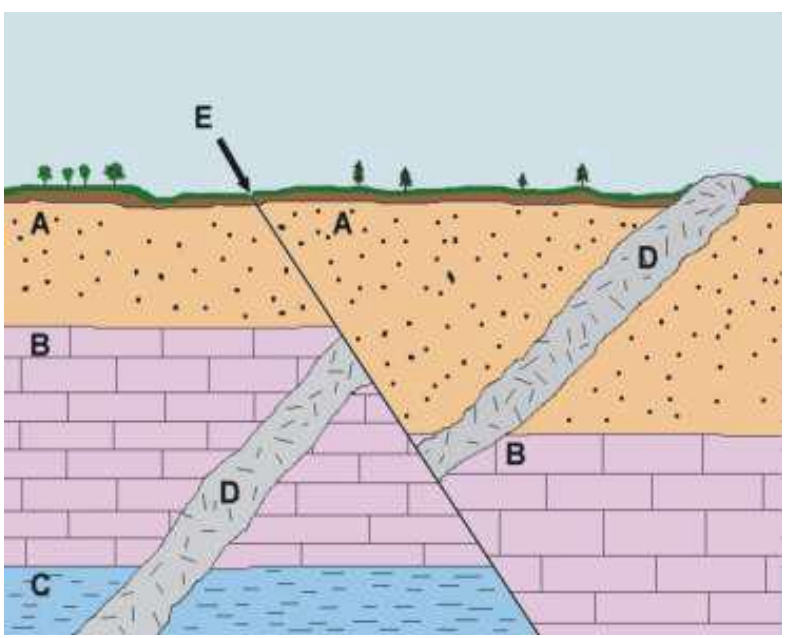
(5) Law of Cross-cutting relationship

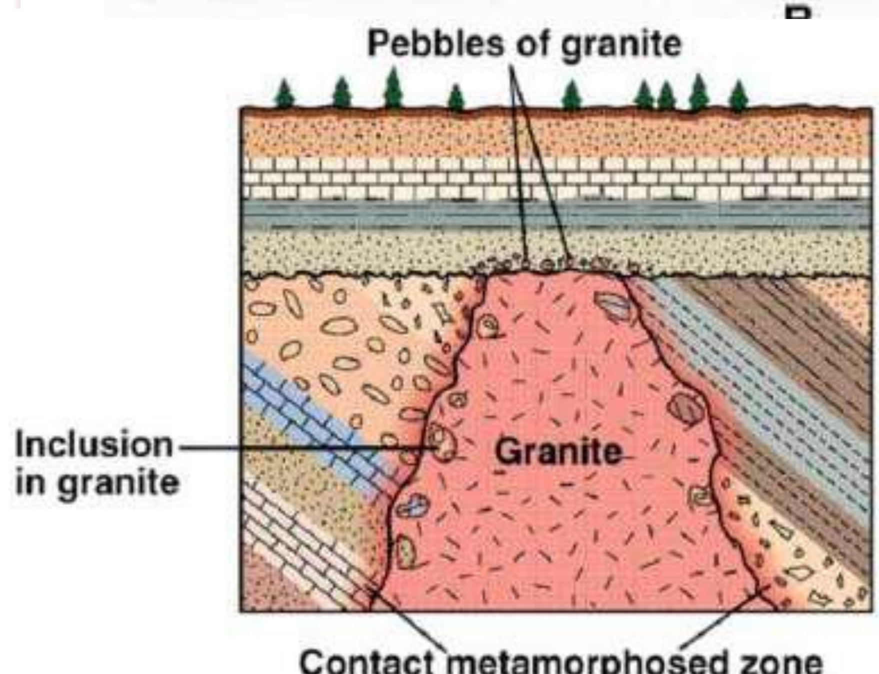
" An igneous body or a structure – that is, a fold or fault – must be younger than the rocks it cuts through"



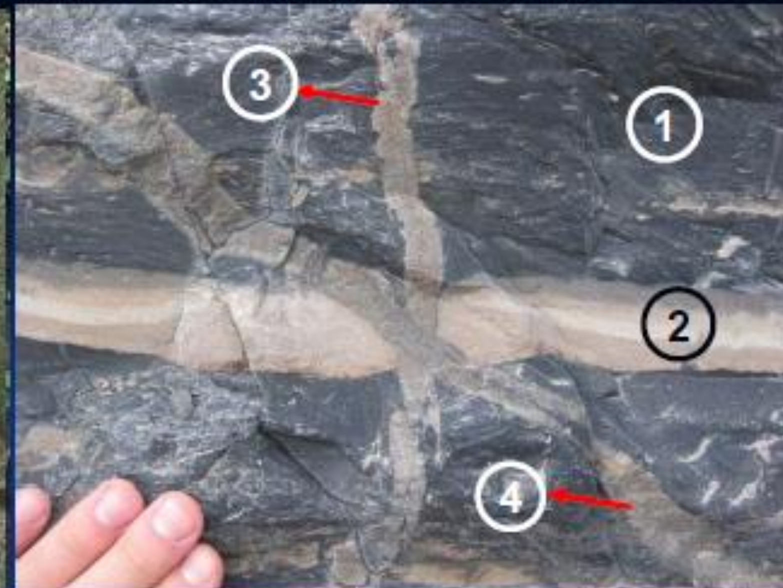
4 5 2 Faulting/ Unconf. **6 1 3**








2
3
1


3
1
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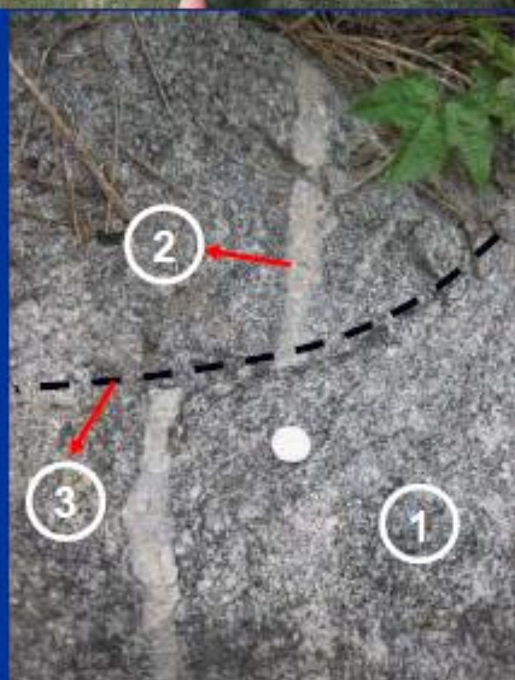
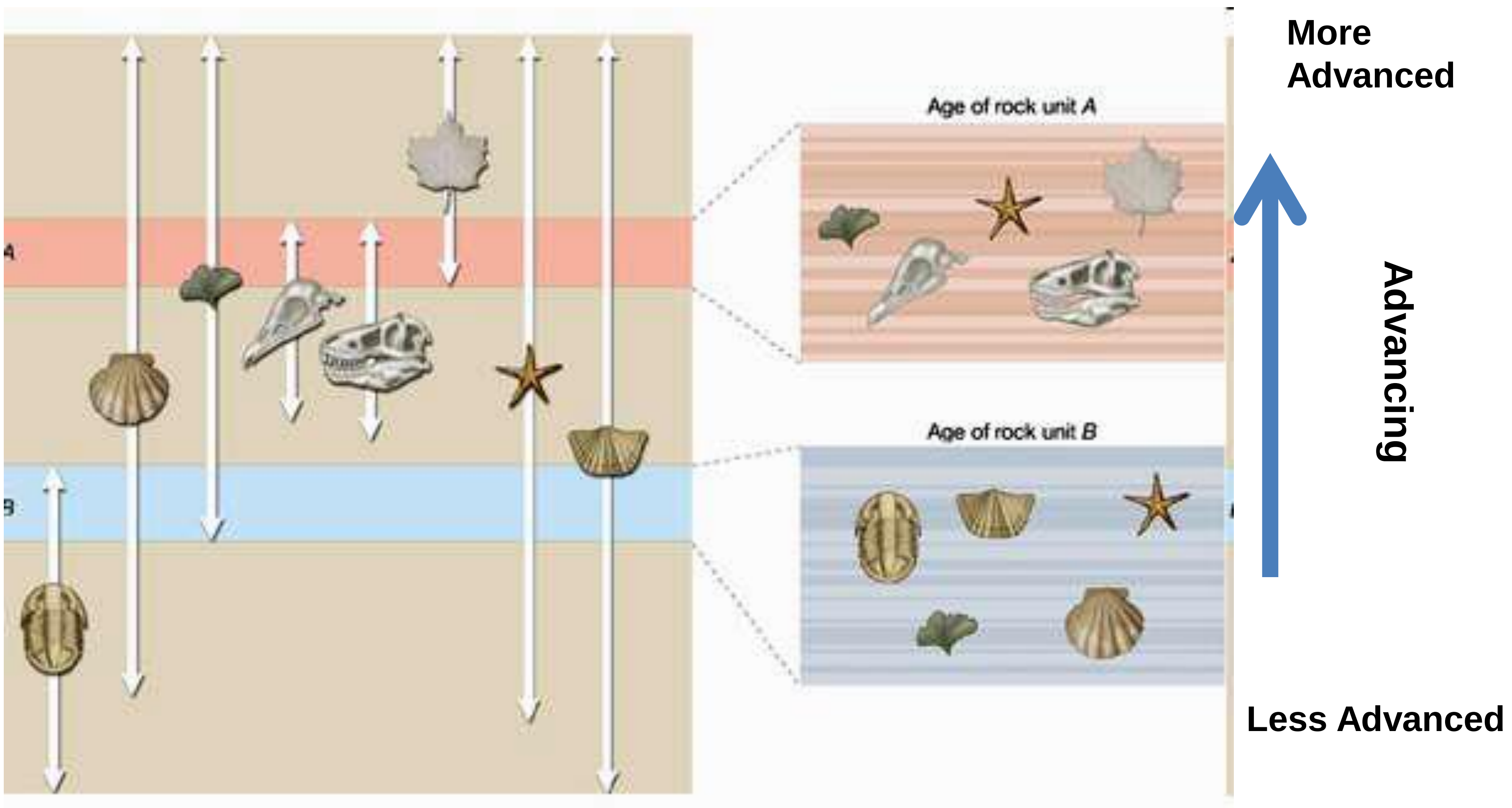
4


2
3
1


1
Granite
Basalt
2
Granite

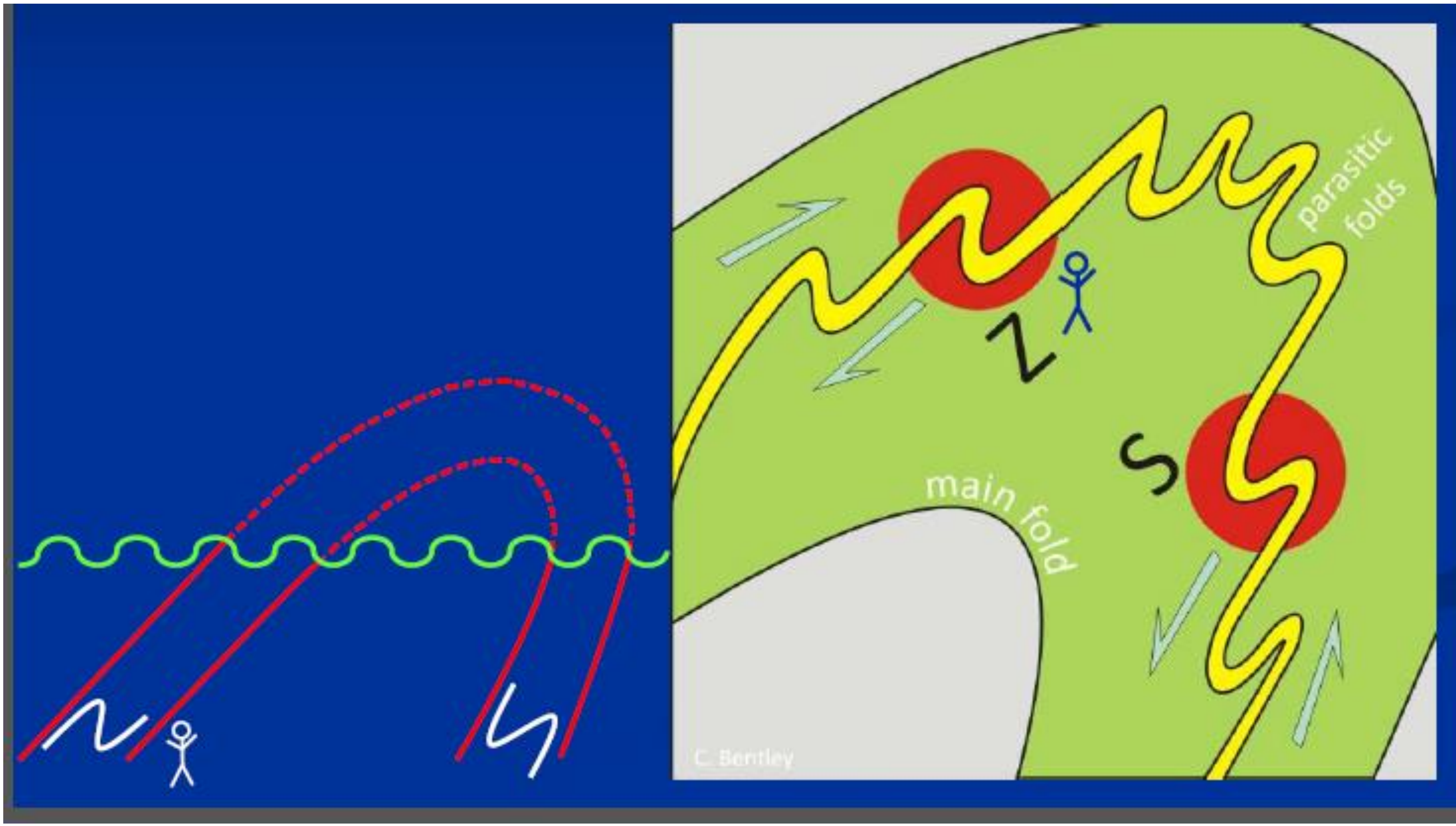
(6) Law of Faunal Succession

“The fossil organisms in a sequence should be more advanced toward the top of the sequence”



(7) Pumpelly's rule

"Small structures are a key to and mimic the styles and orientations of larger structures of the same generation within a particular area"



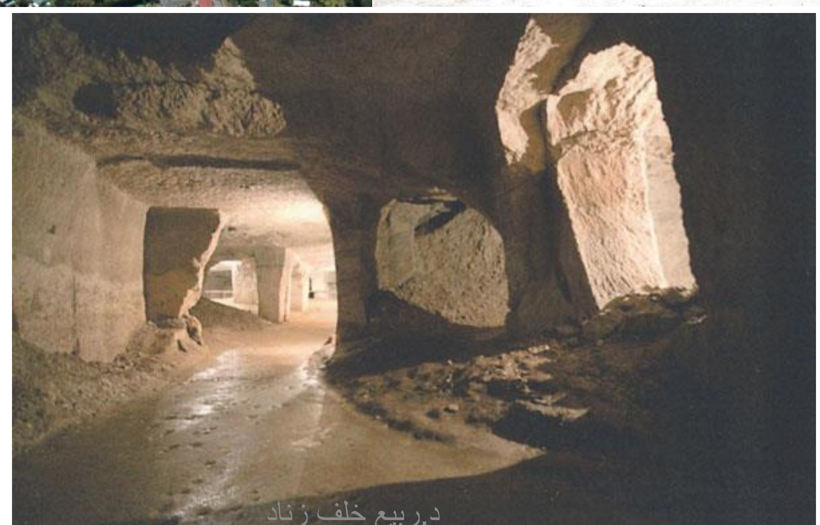
أهمية الجيولوجيا التركيبية:

تعد الجيولوجيا التركيبية مهمة في العديد من العلوم الجيولوجية والتي من أبرزها:

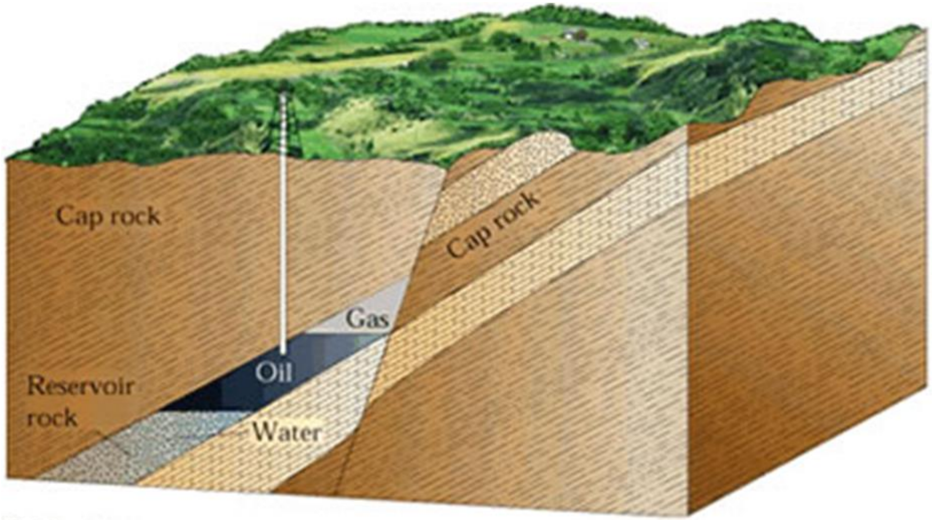
(1) الجيولوجيا الهندسية Engineering geology : لدى إقامة المنشآت الهندسية تأخذ دراسة بنية(Structure) صخر الأساس أهمية بالغة وبخاصة عند تشييد السدود والأنفاق، حيث يجب أخذ الكسور واتجاهاتها بالحسبان.

(2) الجيولوجيا المائية Hydrogeology : ترتبط الخزانات المائية بوجود التراكيب الجيولوجية كالتكسرات والطيات.

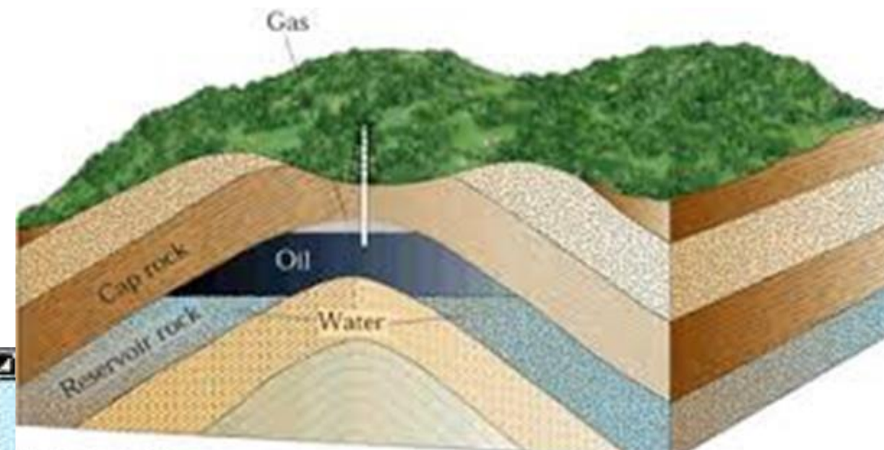
(3) جيولوجيا المناجم: إن تقويم الأهمية المنجمية لخام أو لجسم صخري كالفحم أو الحجر الكلسي يتم من خلال تحديد أبعاده ووضعه البنيوي.



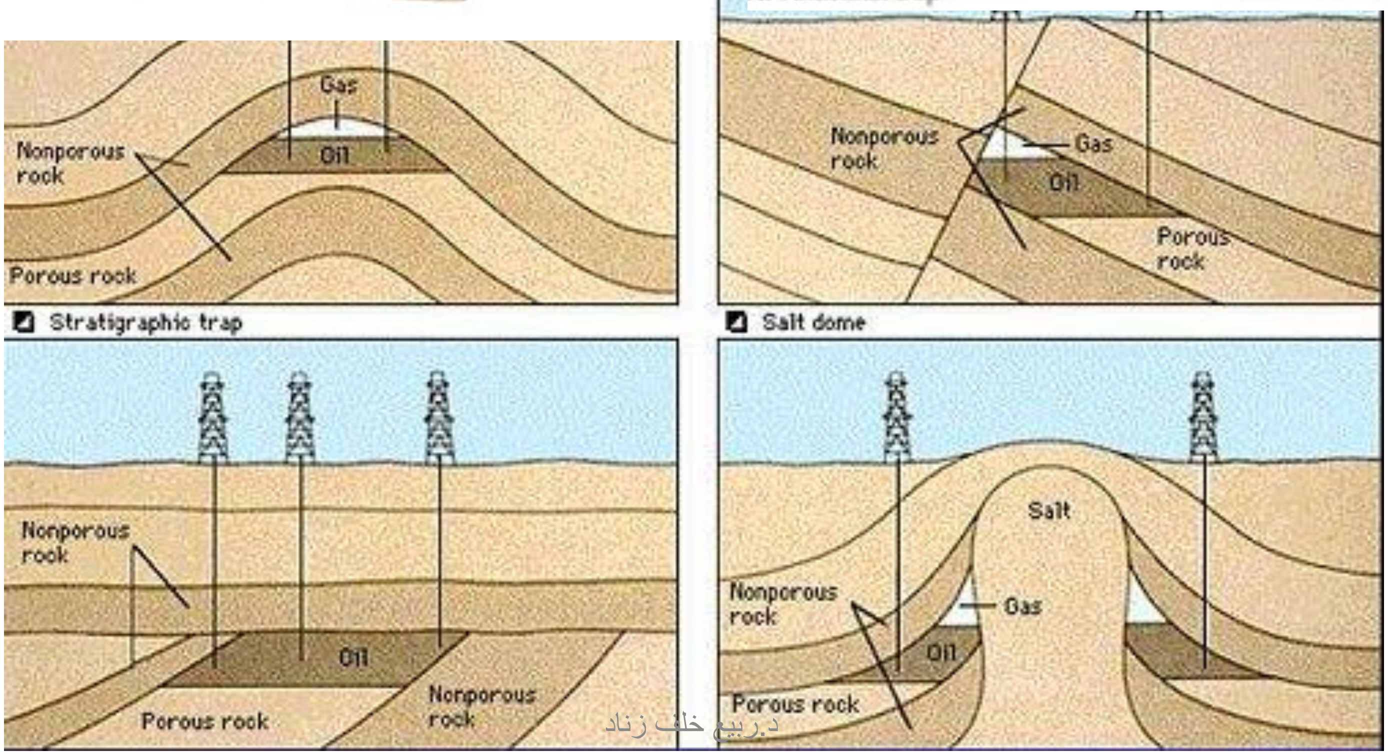
(3) جيولوجيا النفط: العديد من المصائد النفطية تمثل مظاهر تركيبية (طيات أو فوالق).



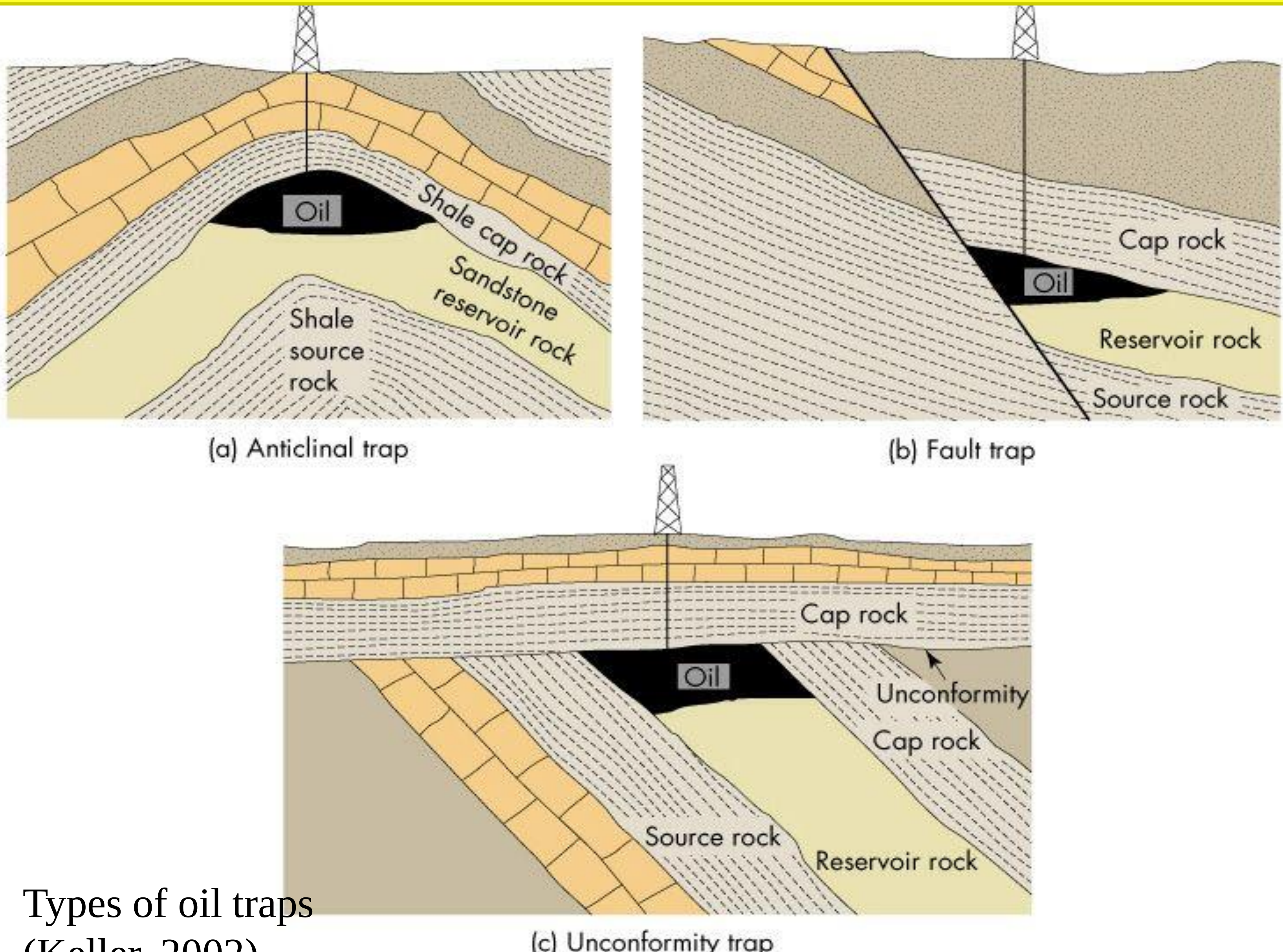
B. Fault trap



A. Anticlinal trap



Oil Traps



Types of oil traps (Keller, 2002)

Mineral resources

Crystallization in fluid-rich environment

Hot, metal-rich fluid migration as **vein deposits** or **disseminated deposits** (remobilized by faults)

(Quartz Veins)

(modified from slide by Ramon Arrowsmith)

Understand and anticipate توقع Natural Hazards

أهم العلوم الجيولوجية التي تستند إليها الجيولوجيا التركيبية:

يمكن القول أن جميع العلوم الجيولوجية مترابطة ومتداخلة مع بعضها، ويحتاج كل منها إلى الآخر، وفيما يتعلق بالجيولوجيا التركيبية، خصوصاً في فرع التحليل التركيبي، فأنها تعتمد على عدد من العلوم التي يعد بعضها مساعداً وبعضها الآخر أساسياً، من ابرز هذه العلوم ما يلي:

(1) الجيوفيزياء (Geophysics): وهو من العلوم المهمة جداً في دراسة التراكيب الثانوية التحت سطحية، إذ أن هذا النوع من التراكيب لا يمكن دراسته بالمشاهدة العينية، لذلك يدرس باستخدام الطرق الجيوفيزيائية فضلاً عن البيانات المستحصلة من حفر الآبار.

(2) الجيومورفولوجي (Geomorphology): ترتبط الكثير من مظاهر شكل الأرض بالتراكيب الجيولوجية، لذلك فان معرفة طبيعة العلاقة بين نوع التركيب والشكل الجيومورفولوجي الناتج عنه تعد وسيلة من وسائل دراسة التراكيب الأرضية الثانوية.

(3) علم الصخور (petrology): إن تحديد نوع الصخور المتعرضة للتشويه يساعد كثيراً في معرفة نوع التركيب وأسباب تكونه، فالصخور النارية لابد أن تشكل التراكيب النارية، والصخور الملحية تشكل تراكيباً ملحية، ولكل منهما أسباب وميكانيكيات خاصة به. فضلاً عن ذلك فان استجابة الصخور للتشويه تعتمد على نوع الصخور، فالصخور الفتاتية ذات استجابة مختلفة عن استجابة الصخور الكيميائية.

(4) ميكانيك الصخور (Rock Mechanics): تعد تجارب ميكانيك الصخور المصدر الرئيس لمعرفة كيفية استجابة الصخور للتشويهات، وطبيعة العلاقة بين نوع التركيب الناتج ونوعية الصخور، وكذلك علاقة اتجاهات القوى أو الإجهاد المسلط ونوعية أو شكل التركيب الناتج واتجاهه.

بالاضافة الى علم الرسوبيات(sedimentation) وعلم الطبقات(stratigraphy)

في المحاضرات القادمة ان شاء الله سنتناول الاسس الميكانيكيةMechanical principles والتي تتضمن القوة والاجهاد والانفعال الحاصل عند نشوء التراكيب الجيولوجية