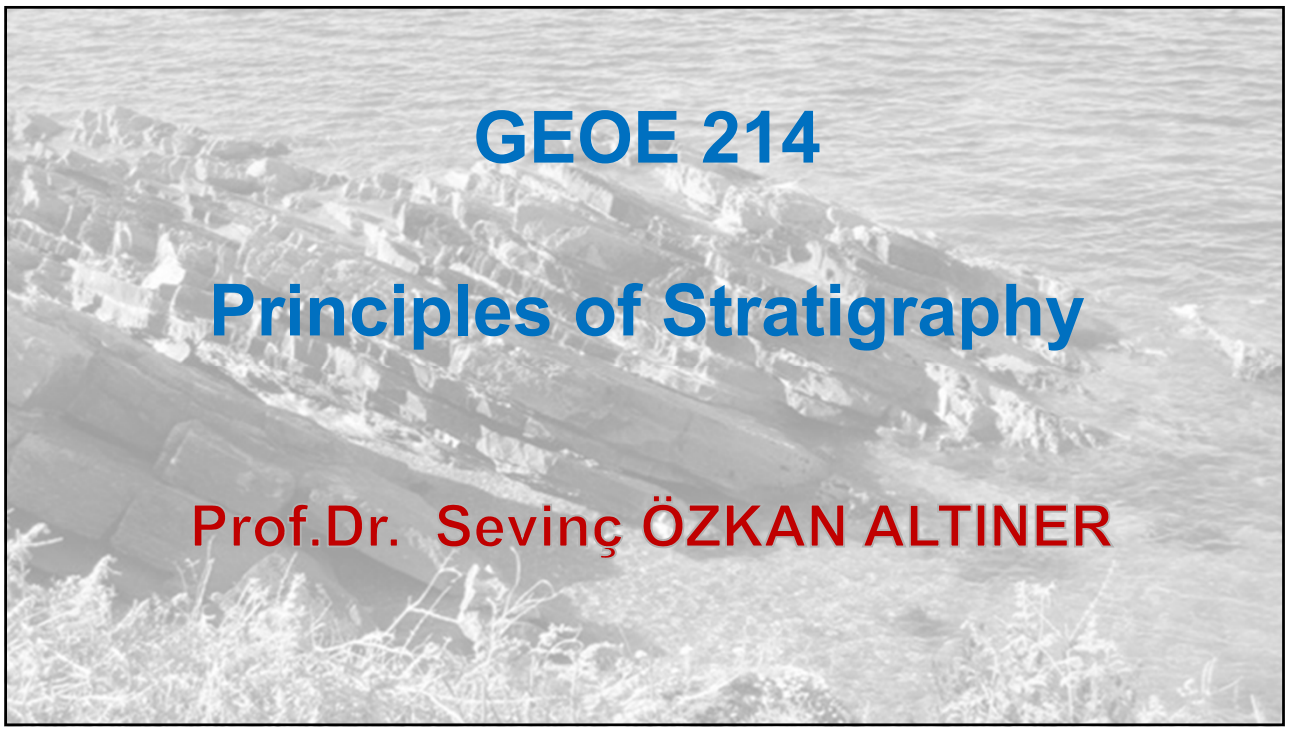


GEOE 214

Principles of Stratigraphy

Prof.Dr. Sevinç ÖZKAN ALTINER

STRATIGRAPHY, SEDIMENTOLOGY AND MICROPALEONTOLOGY RESEARCH GROUP

http.//www.ssm.geoe.metu.edu.tr

Research Assistants

Serdar Görkem Atasoy

Gamze Tanık

MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF GEOLOGICAL ENGINEERING

GEOE 214 Principles of Stratigraphy (2-2) 3

Catalog description:

Depositional processes and classification of depositional environments. Stratification, unconformities, and facies concept. Fundamentals of stratigraphic nomenclature. Lithostratigraphic, biostratigraphic, chronostratigraphic and geochronologic units.

Textbook:

Boggs, S. Jr., 2010 - Principles of Sedimentology and Stratigraphy, 4th Edition, Pearson Education International, Prentice Hall, 662p.

Reference books:

- Nichols, G., 2009 - Sedimentology and Stratigraphy, 2nd Edition, Wiley and Blackwell, 419p.
- Thurman, H.V., and Trujillo, A.P., 2002 - Essentials of Oceanography, Prentice-Hall Inc., New Jersey, 524p.
- Doyle, P., Bennett, M.R. And Baxter, A.N., 1994 – The Key to Earth History: An Introduction to Stratigraphy: John Wiley and Sons, Inc., New York, 231p.
- Schoch, R.M., 1989 – Stratigraphy: Principles and Methods: Van Nostrand Reinhold, New York, 375p.
- Fritz, W.J. and Moore, J.N., 1988 – Basic of Physical Stratigraphy and Sedimentology: John Wiley and Sons, Inc., New York, 371p.
- Ager, D.V., 1984 – The Nature of the Stratigraphical Record: Mac Millan Publishers Ltd., Hong Kong, 122p.
- Reineck, H.E. and Singh, I.B., 1980. Depositional Sedimentary Environments: with reference to terrigenous clastics. Springer-Verlag, New York, 549p.

Lecture Notes

http://www.ssm.geoe.metu.edu.tr

https://odtuclass.metu.edu.tr/

Several photographs and figures used in the lecture notes were taken from books whose references are given above and downloaded from the various websites whose references are given below.

http://www.sepmstrata.org
http://www.stratigraphy.org
http://en.wikipedia.org

Course objectives:

1) Provide students with the basic knowledge of formation of sedimentary rock packages, their relations and nomenclature.

2) Teach students how to seek information about stratigraphic data and their classification into meaningful categories.

3) Teach students recognition of fundamental sedimentary rock packages and their lateral and vertical relations in the field.

4) Teach students how to combine stratigraphic data to see and interpret the natural processes as a whole.

5) Create opportunity for students to work on a stratigraphic problem by himself/herself in order to increase his/her confidence in approaching geological problems.

Topics covered on a weekly basis:

Week 1: Introduction to Sedimentology and Stratigraphy
Week 2: Surface Processes - Origin of Sediments
Week 3: Transportation and Deposition of Sediments
Week 4: Stratification
Week 5: Breaks in the record - Unconformities
Week 6: Depositional Environments – Interpretations and Classification
Week 7: Continental Environments
Week 8: Continental Environments
Week 9: Marine Environments
Week 10: Marginal Marine (Mixed) Environments
Week 11: Marginal Marine (Mixed) Environments
Week 12: Sedimentary Facies - Recognition and Interpretation of Facies Change
Week 13: Vertical and Lateral Successions of Strata
Week 14: Stratigraphic nomenclature - Lithostratigraphy

Evaluation/Grading:

Students must attend the classes.

Exam and quiz grades will be done on a 100 point scale.
Final grades will be determined based upon the following distribution of effort:

1st Midterm Exam → 15 %
2nd Midterm Exam → 20 %
Final Examination → 50 %
Average of Quiz, Field Report, Homework, Term-Project → 15 %

1st Midterm → **23rd November 2018 Friday – 16.00**
2nd Midterm → **28th December 2018 Firiday – 16.00**

Field work:

an compulsory daily field trip(s) around Ankara at a weekend. Students will conduct field work and data manipulation in groups, but each student will be responsible for their own field report.

Field-Work → ??? November 2018 Sunday

Term-Project:
The subject will be announced later.

Field Report

Students will conduct field work and data manipulation in groups, but each student will be responsible for their own field report.

Field Report Outline and Grading:

- Introduction (5 points)
- Geographic and Geological setting of the studied area (5 points)
- Methods (10 points)
- Observations and Data (40 points)
- Conclusions (10 points)
- References (5 points)

Figures:

- Location map (5 points)
- Geological map (5 points)
- Stratigraphic sections: Columnar and Cross-sections (15 points)

Remarks on assignments

- Written-essay type homeworks and field reports will be submitted in two steps:
  - Upload on ODTUClass-Turnitin System (without cover page and figures: only the text)
  - Submitted to research assistants in printed and full form

Any announcements should be followed on:

https://ssm.geoe.metu.edu.tr/

https://odtuclass.metu.edu.tr/

Remarks on assignments

- Copy-Paste of any kind will not be accepted! Reports with Turnitin similarity percentage equal or higher than 25% will get a "0" (zero) directly.
- In essay homeworks and field reports, figures, tables and etc. should be labeled and mentioned (referred to) in the text. Language should be to the point and clear. Format should be coherent, presentable and clean.
- References should be written in APA stlye.

ATTENTION

Please DO NOT use your cell phone or any other mobile device during class hours:

Class participation also means that you are fully present in class, NOT surfing the web, gaming, or looking at your cell phone or any other mobile device.

Doing this during class is disrespectful to the instructor and to the students around you.

Cell phones or any other mobile device must therefore be turned off and put aside during all classes.

ATTENTION

If you do something with your mobile phone

during an exam

it will be considered a cheating / a copy.

If I see someone violating this policy, I will stop class and ask that person to leave.

TURN-OFF or SILENT MODE and PUT ASIDE your CELL PHONE

during the class & exams....

INTRODUCTION

Geology is the science of the Earth.

Its aim is to understand the composition, structure and history of the Earth throughout the 4.6 billion years of its existence.

Earth as a System

Earth is a giant multi-dimensional system.

It is an assemblage or combination of things/parts forming a complex system.

It consists of many separate but interacting parts.

A change in one affects the other.

A change one part can produce changes in any or all of the other parts – often in ways that are neither obvious nor immediately apparent.

There are many different disciplines in geology such as mineralogy, petrology, geochemistry, sedimentology, paleontology, geomorphology, geophysics, hydrogeology, petroleum geology, engineering geology, mining geology, etc.

These subjects have parallelisms/resemblances with other physical sciences, such as physics, chemistry, biology

BUT

geology has the unique component of **TIME:**

The development of the Earth in time and space

Within geology

the study of time

is

the study of stratigraphy.

What is stratigraphy?

Stratigraphy = Stratum (Latin) + graphia (Greek)

by d'Orbigny, 1852

It literally means the study of stratified rocks.

What are the most common and typical stratified rocks ?

Sedimentary Rocks

What is the fundamental characteristic of the sedimentary rocks?

How could you recognize sedimentary rocks in the field?

BEDDING

Beds/strata are tabular/planar or lenticular layers of sedimentary rock.

BEDDING

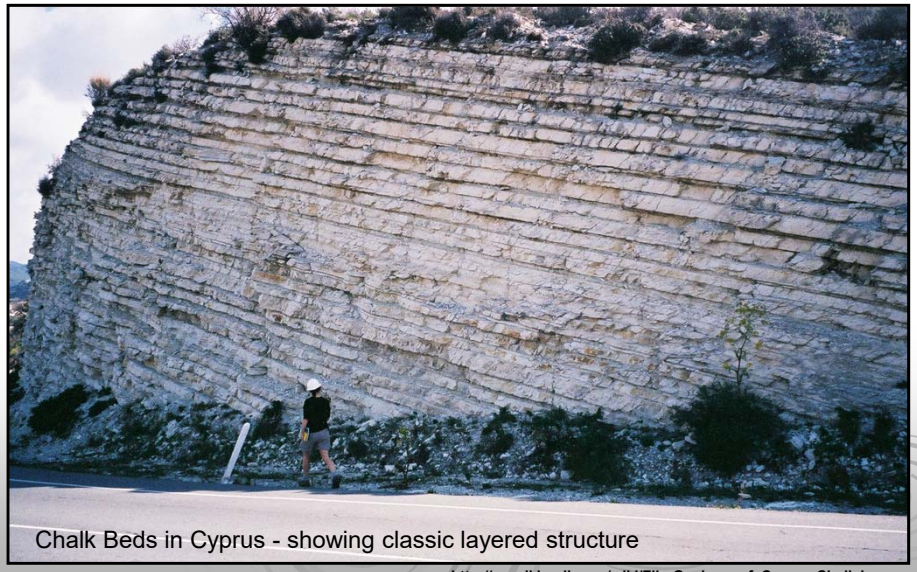
Bedding is perhaps the most important feature of a sedimentary rock, and is the most widely used term in describing a sedimentary sequence.

Beds/strata are tabular/planar or lenticular layers of sedimentary rock.

A planar unit of rocks was originally spread as sheets over a surface of accumulation.

Bed (beds) / stratum (strata)

A planar unit of rocks was originally spread as sheets over a surface of accumulation.



Chalk Beds in Cyprus - showing classic layered structure

http://en.wikipedia.org/wiki/File:Geology_of_Cyprus-Chalk.jpg

THE SCOPE OF STRATIGRAPHY

The main target is the sedimentary rocks.

The study of sedimentary rocks has two aspects:

Sedimentology: is the study of the processes of formation, transportation and deposition of material that accumulates as sediment in continental and marine environments and eventually forms sedimentary rocks.

Stratigraphy: is the study of rocks to determine the order and timing of events in Earth history: it provides the time frame that allows us to interpret sedimentary rocks in terms of dynamic evolving environments.

The stratigraphic record of sedimentary rocks is the fundamental database for understanding the evolution of life, plate tectonics through time and global climate change.

Interpreting Earth history is one of the prime goals of the geology in particular, stratigraphy.

Stratigraphy is the art of detection

Like a dedective,

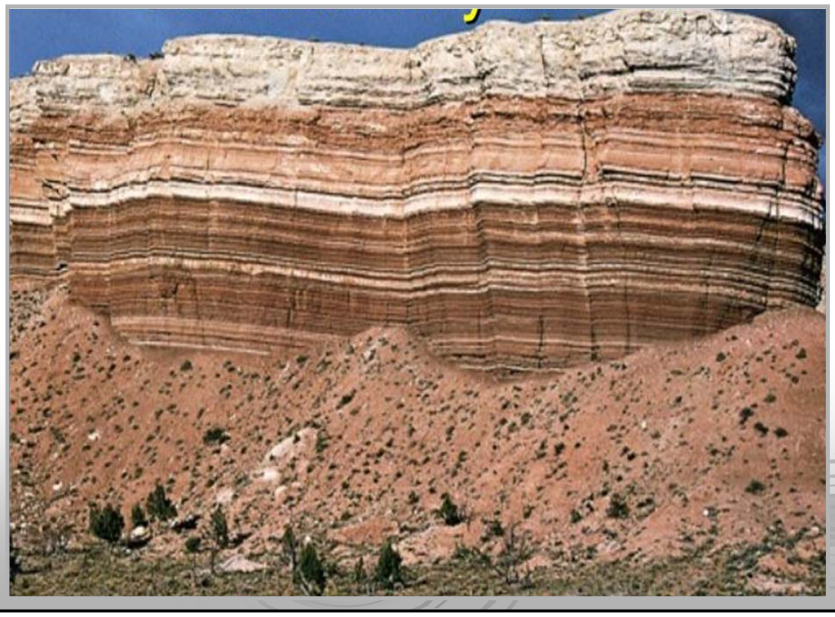
the geologist must collect and interpret clues

found /preserved in the rocks.

Stratigraphy is the art of detection

- The rocks on the Earth's surface are the clues from which the Earth's history and the processes which have shaped it can be deduced.
- Each layer or **stratum** of rock contains a **clue** to the Earth's geography, climate and ecology at a specific time.
- The job of the stratigrapher is to **observe, describe** and **interpret** a sequence of such layers and the rock bodies in terms of events and processes in the history of the Earth.

Sedimentary Rocks —
The Archives of Earth History



What can sediments / sedimentary rocks tell us?

Why are they important?

Sedimentary rocks are types of rock that are formed by the deposition of material at the Earth's surface and within bodies of water.

Sedimentation is the collective name for processes that cause mineral and/or organic particles (detritus) to settle and accumulate or minerals to precipitate from a solution.

Particles that form a sedimentary rock by accumulating are called **sediment**.

Sedimentary Depositional Environments → Sedimentary Rocks

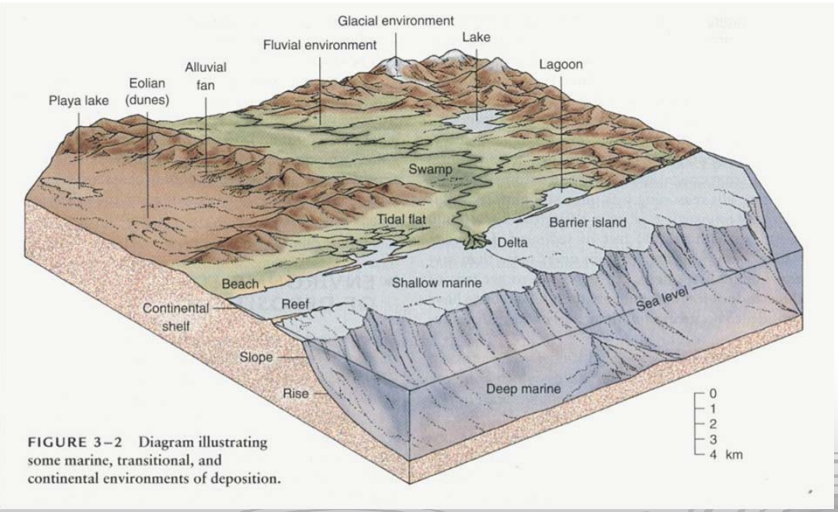
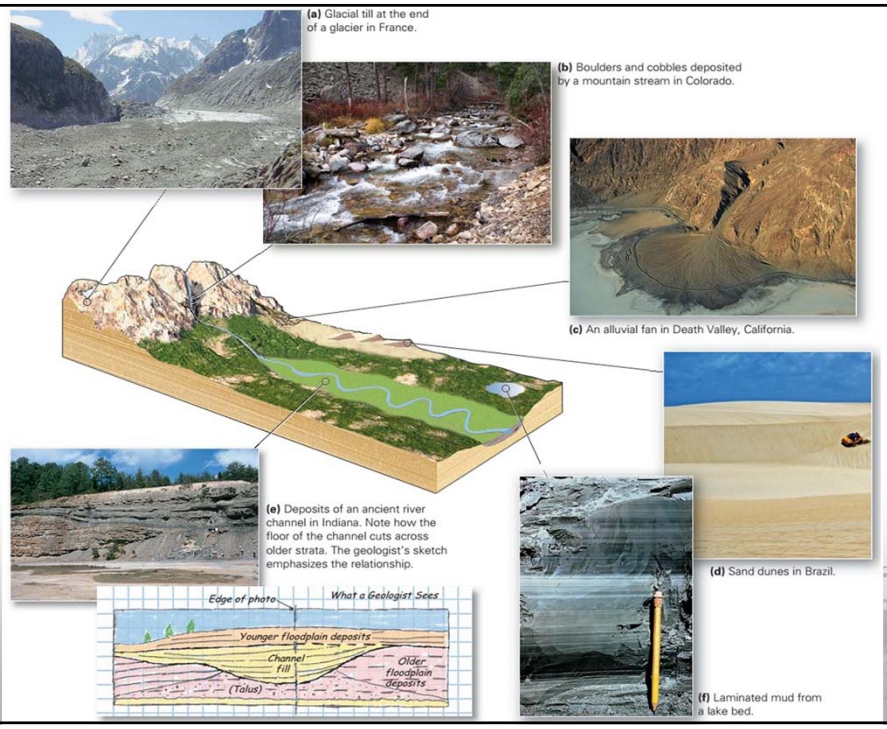


FIGURE 3–2 Diagram illustrating some marine, transitional, and continental environments of deposition.

Using sedimentary rocks to interpret Earth history



Reading Sedimentary Rocks

The characteristics of sedimentary rocks provide information about transport and environment.

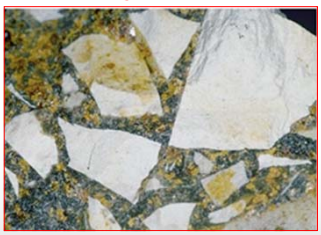
These are:

- Texture (clues about depositional environment and transport)
  - Grain size
  - Grain shape
  - Sorting
  - Maturity
- Components (clues about origin and depositional environment)
  - Minerals and rock fragments
  - Fossils
- Fabric /structures

The size, shape and distribution of particles all provide clues to the way in which the material was carried and deposited.

Well-rounded

Poorly-rounded



Sedimentary Rocks Clastic/Detrital Rocks

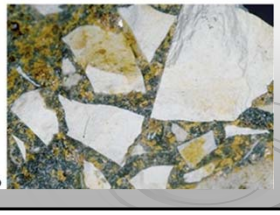
Conglomerate-Pebbles/cobbles

Well-rounded →

- Long transportation
- High-energy environments
  - Beach, River

Sedimentary Rocks Clastic/Detrital Rocks

Breccia



Breccia- Pebbles/cobbles

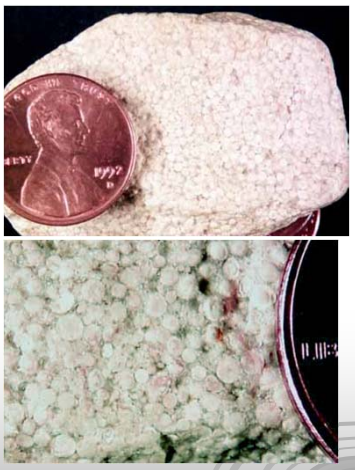
Poorly-rounded

- Short transportation
- High-energy environments
- Beach, River, Fault zone

Sedimentary Rocks Chemical Rocks

Some Limestone is precipitated directly from water

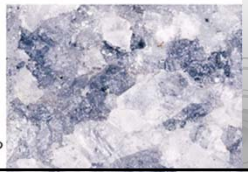
Travertine is typically precipitated from groundwater and is seen in caves



Oolitic limestone contains small spherical ooids

Sedimentary Rocks Chemical Rocks

Evaporites are precipitated directly from seawater when a large quantity evaporates



Rock salt
Halite

Rock
Gypsum

Sedimentary Rocks Biochemical Rocks

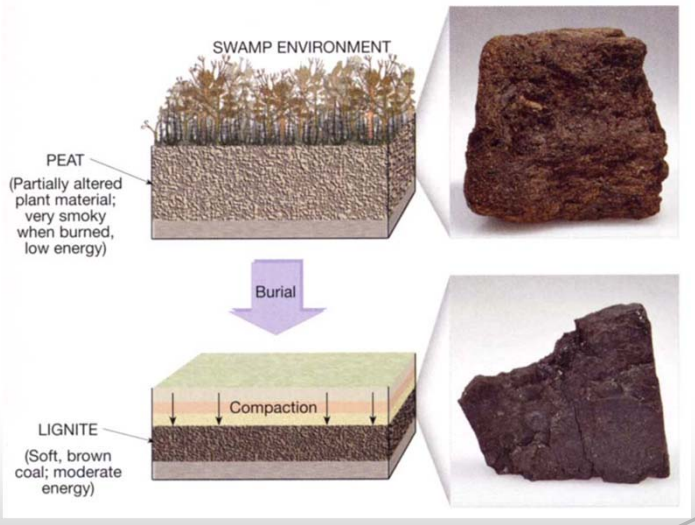
Fossiliferous Limestones

Marine Environments

Sedimentary Rocks Biochemical Rocks

Chert, like chalk, is composed of tiny shells from planktonic life, but the organisms involved secrete SiO_2 shells.

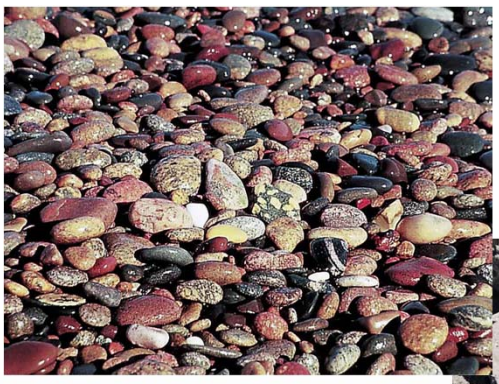
Sedimentary Rocks Biochemical Rocks



Coal is organic: buried and un-oxidized plant remains

Non-Marine environments - Swamp

Rounding and Sorting



Well rounded, well sorted gravel

Angular, poorly sorted gravel

Sedimentary Rocks

Sedimentary Structures

Large-scale cross-beds:
wind-blown sands in an arid environment

Ripple-marks:
running water- beach or river

Uniformitarianism

"Present is the key to the past"

Uniformitarianism is 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.

Sedimentary structures such as ripples can be seen in sedimentary rocks and can be compared to ripples forming today, either in natural environments or in a laboratory tank.

Uniformitarianism

(a) Modern ripples exposed at low tide along a sandy beach on the shore of Cape Cod, Massachusetts.

(b) These 145-million-year-old ripples are preserved on a tilted bed of solid sandstone at Dinosaur Ridge, Colorado.

Modern ripples exposed at low tide along a sandy beach on the shore

These 145 million-year-old ripples are preserved on a tilted bed of sandstone

Present is the key to the past

Stratigraphy is subdivided into three phases:

- Description of the strata in local area.
- Correlation of local sections.
  - *Outcrops and well logs*
  - *Seismic*
  - *Paleontology*
  - *Magnetostratigraphy and geochemistry*
  - *Radiometric dating*
- Interpretation of the stratigraphic record.
  - *Time and Space*
  - *Reconstruct History – Exploration*
  - *Predictions*

1st step: Description of the strata in local area

Dip in stratified rocks below Rosemullion Head, England

www.geograph.org.uk - 835837.jpg

Observation and Data Gathering

Visit rock exposures (outcrops)

You take note of objectively observable features in the rocks.

Here's a seemingly obvious but important point:

You take note of objectively observable things in the rocks, and

⇩

then you use your knowledge, your experience, and your intuition

⇩

to make interpretations, specific or general.

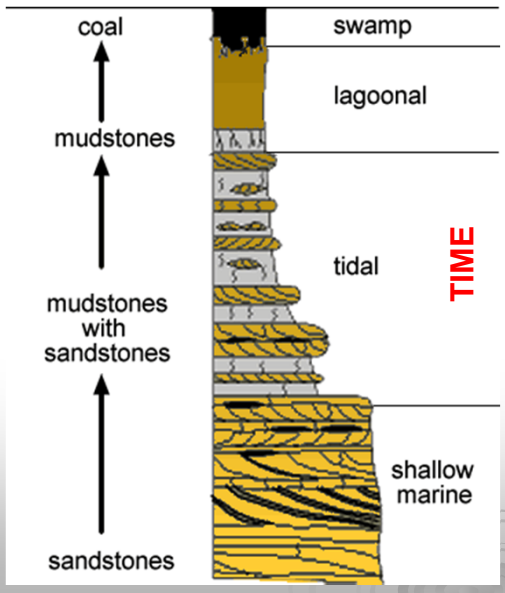
You can be right in your observations and wrong in your interpretations,

and you're not doing any great damage.

But *if you are wrong in your observations,*

you are not going to be right in your interpretations.

sequence of rock layers



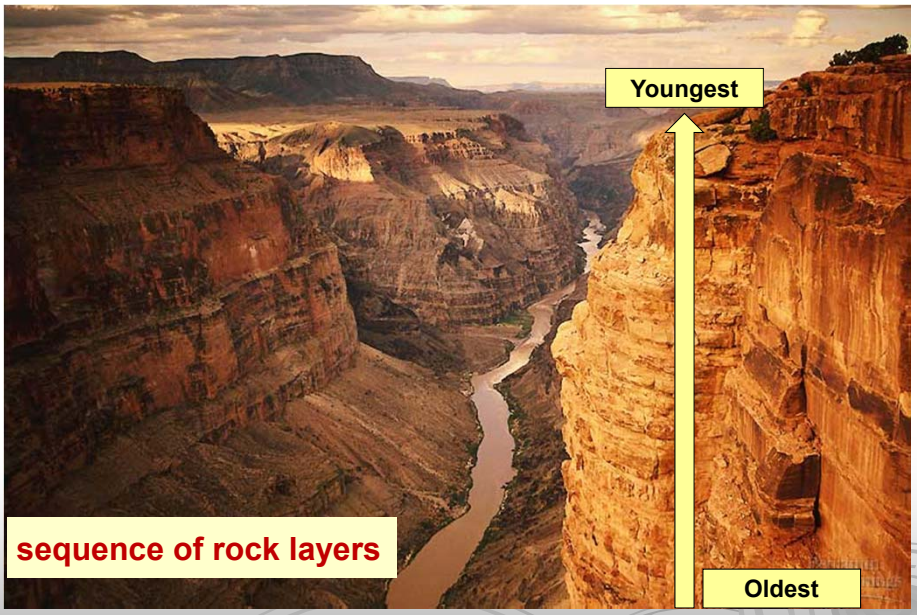
The oldest rocks are on the bottom (sandstones).
The sandstones represent rocks deposited in a shallow marine environment.

The younger rocks reveal an environment change into a tidal area.

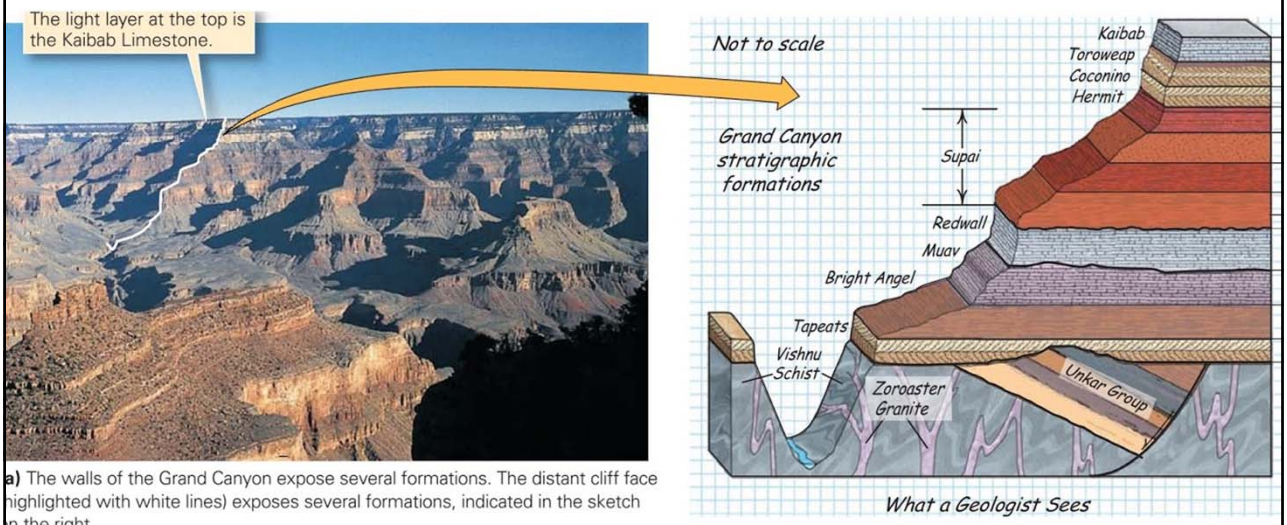
Through time the tidal area evolves into a lagoon and then a swamp.

The sequence provides information on changing environments through time.

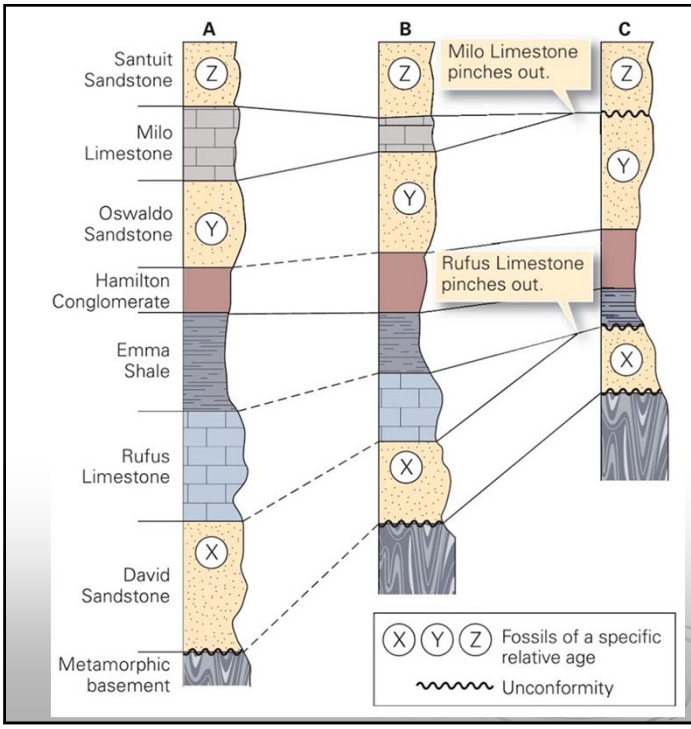
Then you can determine the sequences in other places and then correlate one rock type with another.



Grand Canyon National Park, USA



a) The walls of the Grand Canyon expose several formations. The distant cliff face highlighted with white lines) exposes several formations, indicated in the sketch on the right.



2nd step

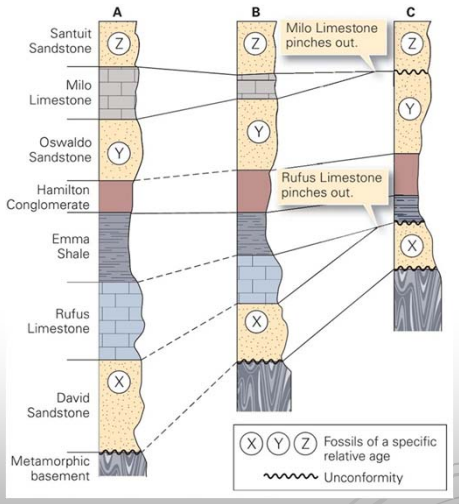
Correlation of local sections

Correlation of

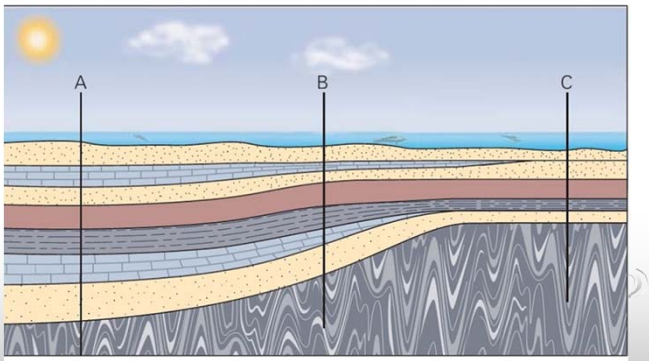
sequence of rock layers

Stratigraphic columns can be correlated by matching rock types (lithologic correlation)

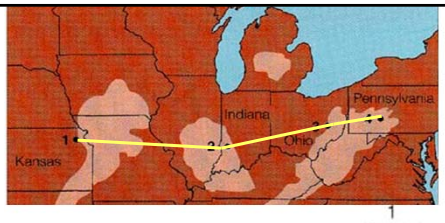
3rd step
Interpretation of the stratigraphic record



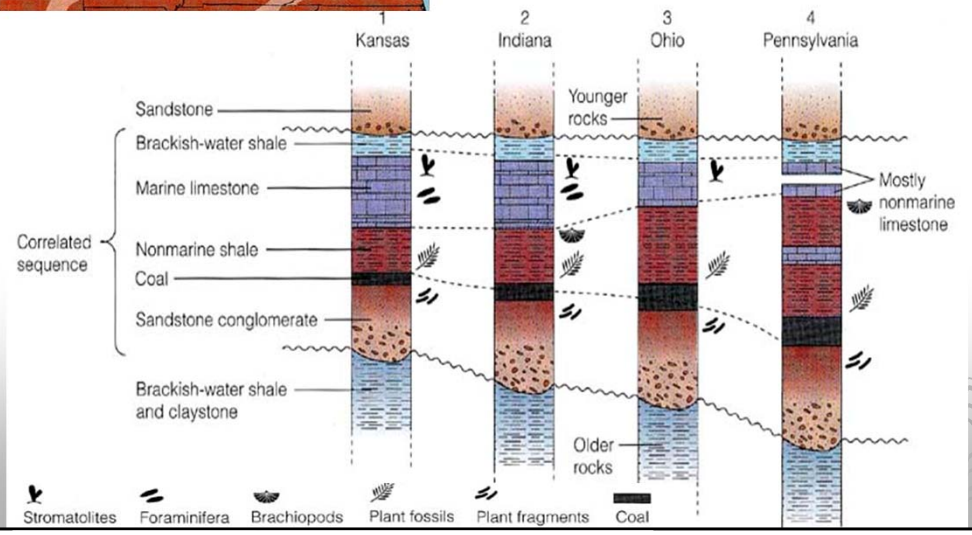
(a) Stratigraphic columns can be correlated by matching rock types (lithologic correlation). The Hamilton Conglomerate is a marker horizon. Because some strata pinch out, Column C contains unconformities. Fossil correlation indicates that the youngest beds in C are Santuit Sandstone.



(b) At the time of deposition, locations A, B, and C were in different parts of a basin. The basin floor was subsiding fastest at A.



Correlation of local sections
&
Interpretation of the stratigraphic record



3rd step:
Interpretation
of
the stratigraphic
record

Reconstruct History

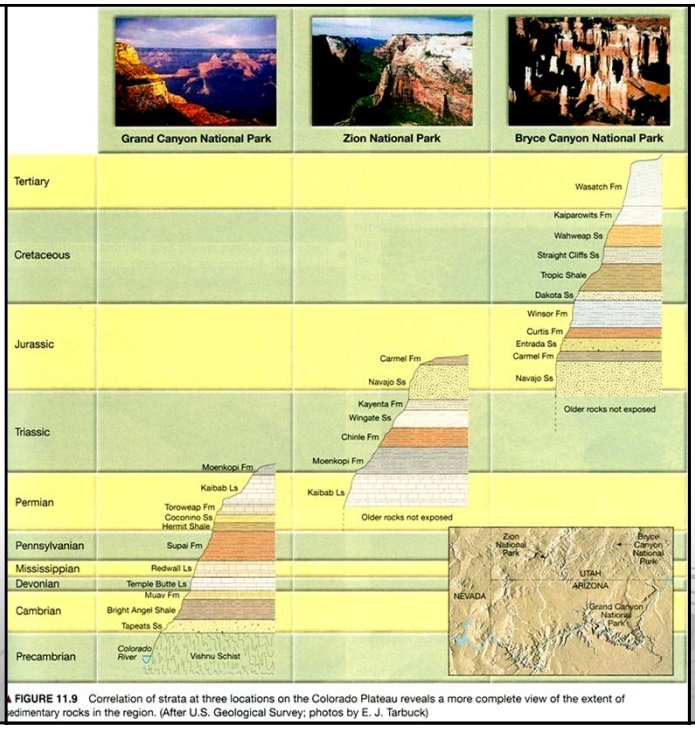


FIGURE 11.9 Correlation of strata at three locations on the Colorado Plateau reveals a more complete view of the extent of sedimentary rocks in the region. (After U.S. Geological Survey; photos by E. J. Tarbuck)

Value of Stratigraphy

Sedimentary Rocks are Important and have a Wide Variety of uses

Sedimentary rocks have a wide variety of uses, making them extremely important.

Types of sedimentary rocks have surprising physical, everyday uses and uses in construction.

They are also useful to geologists and other scientists with interest in studying the earth.

Organic sedimentary rocks, like coal, are energy resources.

Sedimentary Rocks are Important and have a Wide Variety of uses

Coal and limestone which are sedimentary rocks are widely used in industry.

Sedimentary rocks also possess other critical resources needed in them such as oil, salt, natural gas, and iron ore.

Salt has long been used to season and preserve foods.

Oil is used in many things from gas to plastics, medicine, make-up, heat, lubricants and a host of other uses.

Fertilizers used to help maximize yield and feed the modern world are derived from phosphates found in sedimentary rocks.

Sedimentary rocks are also home to the vast majority of the world's **iron ore** deposits, making them indirectly useful as well.

Sedimentary rocks have been used throughout history for **construction**.

Sandstone has been used in building construction for thousands of years.

Limestone, another important building stone, has long been used by cutting them into building stones for walls due to their durability.

Today it is widely used in **cement** providing the foundation for the modern world.

Quartz is used to create glass providing protection from elements and windows for buildings and cars.

Plastering relies on **gypsum** and this material is widely used in construction.

Value of Stratigraphy

- **From the philosophical point of view, stratigraphy provides the basis for understanding the past history of the earth.**

  (Stratigraphy = the key to the Earth's History)

  - Reconstruct phyical/chemical/biological attributes of ancient environments
  - Reconstruct paleogeography and paleoclimatology
  - Detailed earth's history as a predictive environmental tool
  - Sea level as links to climate, oceanography, evolution, tectonics

- **From the practical / economical points of view, stratigraphy permits an understanding of formation and exploration of ;**

  - Fossil fuels; coal, petroluem...
  - Mineral resources; trona, borax, stratified iron ore, phosphates...
  - Groundwater
  - Building materials; clay, sand, man-made material such as cement