Introduction to Structural Geology

Geology 3063 - Course Notes

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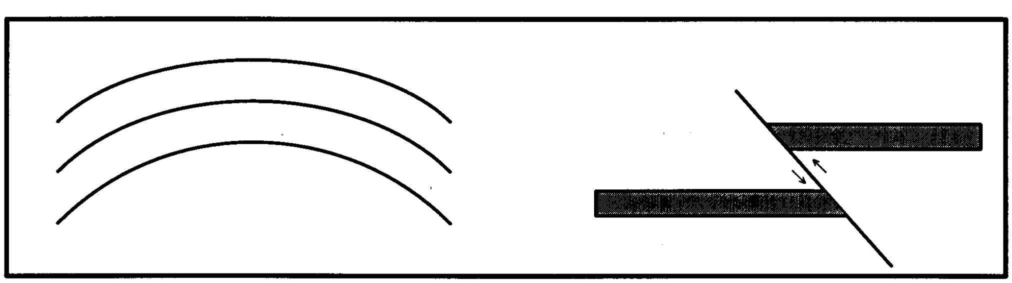
Introduction

Structural geology is the study of deformed rocks, and rock deformation. In structural geology, we are faced with a series of natural features that we try to interpret and explain. Each of these features formed through the interplay of external forces on rock materials, and the "local" conditions at the time of deformation. To interpret structures in the natural setting we need to understand their mechanical basis, how the forces that formed them came about, and how the materials in the structure behaved through time. In structural geology, as in all geology, we are presented with the end result of several processes that we must infer based on our observations of the structure. In this course we will investigate several classes of structures from a mechanical viewpoint.

> In the first segment of the course we will look at specific categories of structures and investigate their geometry and occurrence.
>
> In the second segment of the course we will work to develop the necessary understanding of basic mechanics, and deformation mechanisms, and describe structures mechanically.
>
> In the final segment of the course we will examine plate tectonics, and place the classes of structures into a larger global tectonic scheme.

The description and interpretation of structures involve several steps. Typically the first step involves pattern identification, where a pattern is a recognizable (recurrent) arrangement of material points in space. The second and third steps involve a mechanical analysis to first measure the displacement of particles comprising the structure relative to each other and relative to some reference frame. The final step is the inference of the forces that lead to the formation of the structure. Structures can be found in all rock types. It is quite common; however, to use structures found in sedimentary rocks, or low grade metamorphic rocks as type examples.



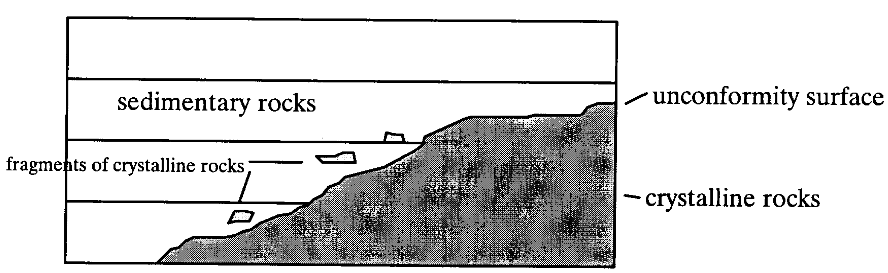
Basic Principles for Determining Sequence of Events.

- Law of superposition: In a sequence of sedimentary rocks that have not been disturbed, the oldest rocks will be on the bottom while the oungest will be on top.
- Law of crosscutting relationships: That which is cut is older than that which cuts.
- Law of inclusions: An inclusion is older than the rock that contains the inclusion.
- Law of initial horizontality: Sedimentary rocks are deposited in basins. The lower surface of any sequence of rock will conform to the shape of the basin, while the upper surface will tend toward horizontality.
- Law of initial continuity: Any deposit of rocks will initially be continuous, without any sharp breaks or changes in the rocks.
- Law of faunal succession: Ancient life forms are unique for the period of that they exist. Life forms do not replicate themselves through time. Therefore, an individual fossil* or fossil group will be unique to a certain time. These fossils or fossil groups can be used to determine relative time.

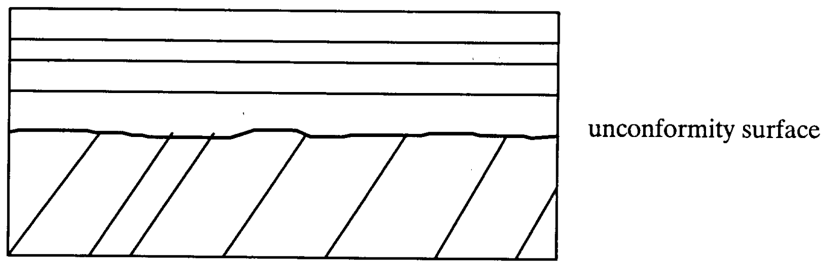
Unconformities.

An unconformity is a break in the rock record representing a loss of rock record or a time hiatus; erosion or non-deposition. The rocks above an unconformity surface are younger than the rocks below the unconformity surface.

- Nonconformity: Sediments deposited on crystalline rocks. The unconformity surface preserves a history of intrusion or metamorphism, uplift and erosion followed by subsidence and deposition.



- Angular unconformity: The unconformity surface preserves a history of deposition followed by, deformation, uplift and erosion followed by subsidence and deposition.



- Disconformity: The unconformity surface may preserve nondeposition or erosion. In a disconformity the layers above and below the unconformity surface are parallel.

Primary depositional features.

In the field it is often difficult to see enough of a rock sequence to establish that the principal of superposition holds, and it becomes necessary to determine the direction of younging in the outcrop. Determination of younging direction is essential in highly deformed rocks. Most often this determination relies on primary sedimentary structures. Primary structures are features preserved in sedimentary rocks that display some aspect of the environment of deposition, or features that formed very early in the diagenetic sequence.

Ripple marks:

Ripple marks are formed by current or wave action during transport and deposition of sediments.

- Oscillation ripple marks: (symmetric) Wave induced, show bimodal current. Sharp crests, smooth troughs. Younging clearly shown.

- Current ripple marks: (asymmetric) Current induced; show unimodal current direction. Usually have smooth crests and troughs.

  Current ripple marks cannot be used as reliable younging indicator unless:

  - heavy minerals preserved in troughs, or
  - coarse particles preserved in troughs. *Wind ripple dposits in eolian systems can preserve coarse particles in the crest of the ripple.*

- Crossbedding: These features show internal layering inclined to the accumulation surface. There are several types of crossbeds in overall geometry. Symmetry of the crossbeds is the significant factor in the determination of younging direction.

  - Symmetric
  - Asymmetric:

- Graded bedding: A systematic variation in grain size in a layer from the bottom to the top of the layer. Graded beds are generally formed when a swiftly flowing current carrying a range of particle sizes enters a calm depositional site. The largest particles settle faster (why?), forming a fining upward sequence.

- Turbidite (Bouma sequence): Turbidity currents are density driven currents. Most turbidity currents represent flows of sediment from the upper potion of a depositional basin into the lower parts of the basin. The currents flow as suspensions of particles more dense than the surrounding water. Turbidity currents have several distinct layers that demonstrate different flow rates (flow regimes) of the current. The most pronounced feature of a turbidity current is graded bedding in each layer as well as within the turbidite as a whole. The diagram below shows a classical Bouma sequence, in field settings the complete sequence is typically not present.

Bed bottom markers.

Form on the top of beds. Molds mark the top of a layer, casts mark the bottom of a layer (sometimes called sole marks).

- Flute casts: Scour and fill features formed by flow over weak materials. Typically found in, but not limited to, turbidites.

- Groove casts: Trace of debris drug along bottom by current.

- Prod casts: Trace of debris carried in saltation by a current.

Inorganic top markers.

Show the top of a layer if preserved as a mold. Show the bottom of a layer if preserved as a cast.

- Mud cracks: Polygonal desiccation features. These may be preserved as molds or casts.

- Rain pits: Show rain impact on a surface. (rare).

Organic markers.

Markers that show younging direction due to the activity of organic life.

- Fossil tracks: Footprints or feeding tracks. Molds show the top of the layer, casts show the bottom of a layer.

- Algal mounds: Colonies of algae, usually blue-green. Successive layers of sediment are bound by the algae, and are domed upward.

- Burrows: Formed by burrowing organisms. Useful only when the top of the burrow can be found.

- Geopetal structures: Show two phases of diagenesis. Infill of shell with silt or lime mud, preserving horizontal, followed by infill of remaining space by calcite spar. These can easily be misinterpreted.