Erth 16 Lecture 4: Grand Canyon - geologic history and canyon formation

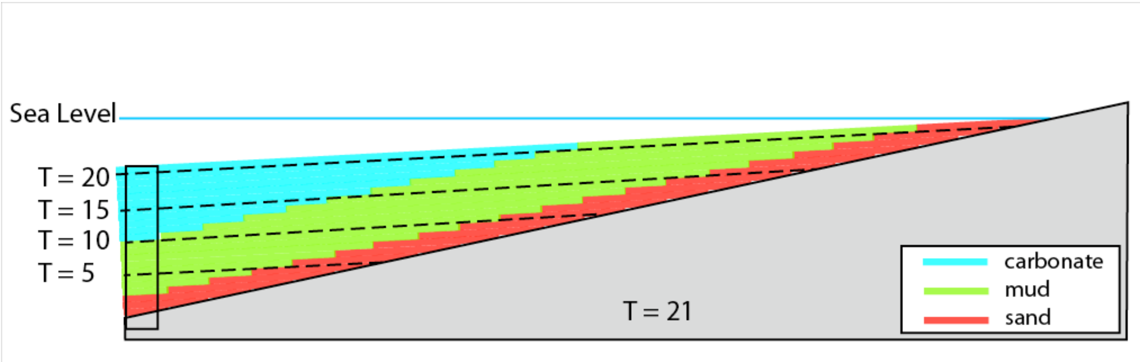
Questions from last time?

Quick review

- rock types (igneous and metamorphic)
- nonconformity
- mountain building and deformation (folds, faults)
- more techniques to establish relative time
- history of Grand Canyon through great unconformity

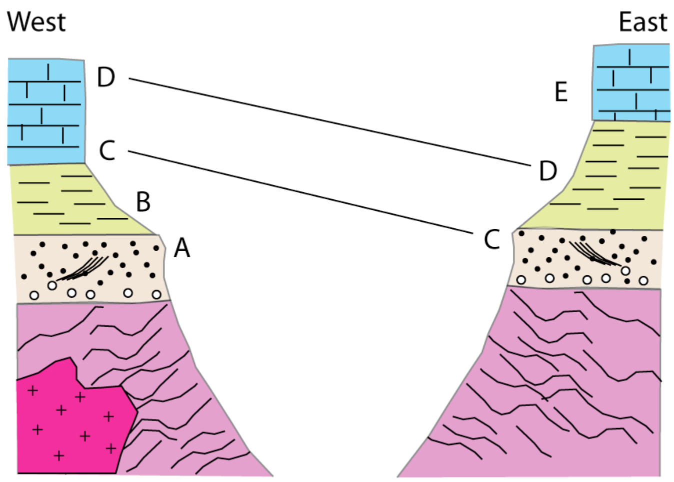
Transgressing and regressing seas

- Remaining rocks are flat lying sediments, some of which are marine deposits, others were deposited in terrestrial environment. The relative position of sealevel can be reconstructed from the rock record. First three units (Tapeats sandstone, Bright Angel shale, Muav limestone) are classic record of a rise in relative sealevel.
- Formations of the Tonto group
    - Tapeats sandstone
        - quartz, feldspar
        - medium-coarse sandstone; conglomeratic at base
        - trilobites, brachiopods
        - cross bedding, bimodal directions
        - beach environment (to few 10's meters)
    - Bright Angel shale
        - clay, mud
        - fine grained - lower energy
        - trilobites and other marine fossils
        - laminations
        - middle shelf below wavebase (~ few 10's meters)
    - Muav limestone
        - calcite, some terrigenous material decreasing to W
        - laminated
        - outer shelf (> few 10's meters to ~100m, far from land)
- Walther's law
    - energy and sediment supply in depositional environment can change laterally. For example, on broad continental shelf we may have sands being deposited near shore, muds farther off shore and carbonate muds with little terrigenous material still farther off shore.
    - *Sedimentary facies* = different sediment types that are accumulating at the same time in adjacent areas
    - *Walther's law* = facies adjacent to one another in a continous vertical series also accumulated adjacent to one another laterally
- movie of marine transgression
    - note time lines (dashed lines) indicate different sediments being deposited in different parts of the continental shelf



- *transgression* = relative sea level rise
- *regression* = relative sea level fall

- note that the resulting timelines are not parallel to the lithological boundaries



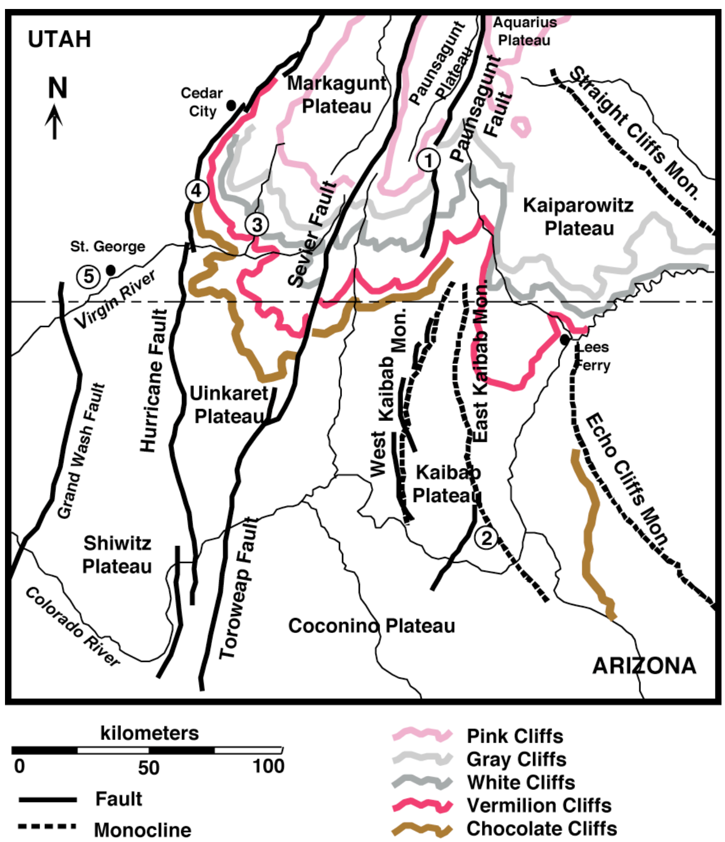
Paleozoic stratigraphy of Grand Canyon

- Overall transgression, regression, transgression
  - Tapeats, Bright Angel Shale, Muav limestone — Cambrian trans.
    - disconformity ~100 m.y (Ord,Sil,early Dev)
  - Temple Butte limestone — Devonian
    - bounded by disconformities
  - Redwall, Supai, Hermit, Coconino — Miss-Penn regress.
    - Redwall limestone — Miss.
    - Surprise Canyon — latest Miss.
      - logs, plant material at base
      - marine shells in sand and lime at top
    - disconformity
    - Supai, Hermit — Penn-early Permian
      - coastal plain
    - Coconino — Permian
  - Toroweap, Kaibab — late Perm. trans.
    - marine carbonates

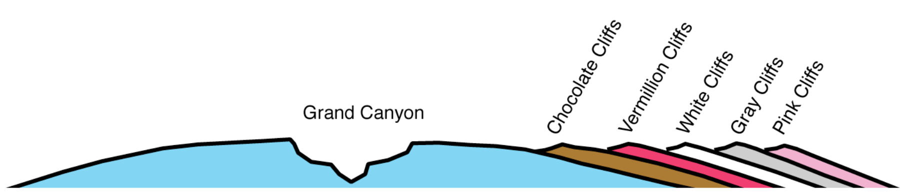
- for a more realistic movie of transgressions and regressions see
    - http://strata.geol.sc.edu/movies/CLASTICSYSTEMTRACTS.MOV
    - transgressive records more common in rock record, why?

Mesozoic and Cenozoic history of Grand Canyon

- Mesozoic sediments deposited on Colorado plateau
    - preserved in Zion, Bryce, Canyonlands, Arches elsewhere
    - dominantly terrestrial sediments
    - last marine incursion at end of Cretaceous
- Outcrop pattern of Mesozoic sediments. The broad upwarp of the Kaibab plateau resulted in erosion of these sediments in the immediate vicinity of the Grand Canyon. However, more than 10,000' of Mesozoic sediments are preserved in a series of outcrops (noted by the dominant color of the exposed rocks) to the north of the Grand Canyon. Thus, the Colorado Plateau represents a broad anticline (see second figure below) that has experienced considerable erosion in the area of the Grand Canyon.



http://www2.nature.nps.gov/geology/education/Foos/plateau.pdf



- Uplift of the plateau
  - some 2000m of uplift since the late Cretaceous (when the area still was near sea level as evidenced by marine sediments)
  - Several theories have been advanced for the uplift of the plateau; we'll focus on what is probably the dominant theory. The theory of plate tectonics will be covered in more detail later, but for now we'll simplify things
    - Laramide orogeny: compressional tectonics beginning in late Cretaceous (70-80 Ma) and ending in middle Tertiary (35-55 Ma) that resulted in formation of Rocky Mountains
    - widespread uplift from Montana to Mexico; Colorado Plateau is one of the largest blocks that experienced uplift.
    - Compression also resulted in slight folding and faulting.
- Canyon incision
  - As with the uplift of the plateau, there are a variety of ideas on the dissection of the canyon. The most prevalent theory involves stream piracy.
  - prior to 35 Ma, ancestral Colorado river (which drained the Rocky Mountains) crossed the western US on a track similar to the one it has today
  - starting at ~35 Ma, uplift of the Kaibab plateau forced the river to divert around these highlands.
    - western river (Hualapai) drained western portion
    - eastern river now drains to Gulf of Mexico
  - ~12 Ma, the passage of eastern river blocked, forming a large lake (Lake Bidahochi)
  - Headward erosion
    - Hualapai has steep drainage, headwaters in the Kaibab uplift and it drains to the Pacific ocean.
    - *base level* = the base level of erosion is the point at which the stream either enters the ocean, lake or pond, or enters a stretch in which it has much lower gradient.
    - headward erosion due to the high gradient and low base level results in rapid downcutting of the Hualapai river into the Kaibab uplands.
  - ~5.5 Ma the Hualapai headward erosion reaches the eastern (Colorado) river and captures the drainage = *stream capture*
  - Draining of Bidahochi lake (note that the direction of water flow reverses) and perhaps additional water from glacial melting lead to rapid downcutting of the Grand Canyon
  - The former (eastern drainage) is now the Little Colorado river course
- Most recent history of the Grand Canyon
  - 1.8-0.4 Ma volcanics
    - western portion of the Grand Canyon (and indeed the edges of the Colorado Plateau more generally) experienced volcanism.

        - flows extended into canyon and 13 times these flows are thought to have dammed the river, building lakes up to 2000' deep behind the dams
        - dams overtopped and then eroded. The remnants of flows on the canyon floor indicate that the canyon had eroded to essentially its present depth by 1.8 Ma.
        - since last flow (0.4 Ma) the river has downcut another 50'
    - human intervention
        - Glen Canyon and other dams upstream have substantially reduced sediment flow (and therefore erosive power) of the river

Useful links

- http://www2.nature.nps.gov/geology/education/Foos/plateau.pdf
    - General description of the sedimentary units, geomorphology and geologic history of the Colorado Plateau
- http://jan.ucc.nau.edu/~rcb7/paleogeogwus.html (Ron Blakely, Northern Arizona University)
    - This is a great site for information on the paleogeography of the southwestern US since the late Precambrian. Graphical representations of where coastlines were, what type of sediment was being deposited and where the highland source areas were located.