GLG310--Structural Geology, Fall 2013

Professor Ramón Arrowsmith
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Tuesdays and Thursdays, 10:30-11:45 AM LSE-B04 (Lecture)
Mondays OR Thursdays 1:30-4:30 pm, PSH 460 or in the field (Lab)

Announcements Syllabus Schedule Weekly lecture notes GLG310 Labs Links

Rotating porphyroblast in amphibolite (Alps)

Folding at Barnhardt Canyon

Left-lateral offsets along the Altyn Tagh Fault

Mohr Circle and equations for stress

$$\sigma = \frac{1}{2}(\sigma_1 + \sigma_3) + \frac{1}{2}(\sigma_1 - \sigma_3) \cos 2\theta,$$

$$\tau = \frac{1}{2}(\sigma_1 - \sigma_3) \sin 2\theta.$$
Cordilleran (W. North America) Tectonic overview

cordillera (n.) --1704, from Spanish, "mountain chain," from cordilla, in Old Spanish "string, rope," dim. of cuerda, from L. chorda "cord, rope"
Cordilleran (W. North America) Tectonic overview

Well studied; Dominantly a convergent margin (starts at 800 Ma)

- 1 continental plate interacting with numerous oceanic plates (Pacific and Farallon) + continental and oceanic (mostly island arc) fragments

- Terrane accretion is important (terranes are tectonic fragments with their own history distinct from surrounding rocks (island arcs, aseismic ridges, oceanic plateaus, small fragments of probable oceanic crust). Accretion means to add to margin during subduction

- *Mostly from Moores and Twiss, Tectonics*
Figure 12.1 Worldwide pattern of orogenic belts differentiated according to the time period during which the deformation occurred. Belts are grouped according to their ages in ocean basin time (1–200 Ma), plate tectonic time (200–1000 Ma), Meso-Paleoproterozoic (1000–2500 Ma), and Archean (2500–3800 Ma). (After B. C. Burchfiel, 1983)
Noteworthy as an orogen for

- Suspect terranes (far travelled allochthons; more as you go oceanward)
- Strike-slip faulting (San Andreas System)
- Voluminous magmatism
- Plateau uplift
- Normal faulting (Basin and Range)
Serial cross sections through the modern system

Figure 12.4  Cross sections of the North American Cordillera. Locations indicated in Figure 12.3.  A.  Cross section A–A’ across Alaska.  B.  Cross section B–B’ approximately along the 49th parallel.  C.  Cross section C–C’ of the Cordillera through the Basin and Range province. (A. after Csejtey et al., 1982; Roeder and Mull, 1978; B. after Potter et al., 1986; C. after Maxwell, 1974; Allmendinger et al., 1986)
FIGURE 22.1.5 Summary of events leading up to the formation of the Basin and Range Province of the western United States.
Grand Canyon:  Proterozoic, Paleozoic, and Mesozoic history of AZ
A SUMMARY:

Proterozoic to early Mesozoic convergent margin

Sierra Nevadas

Mesozoic convergent margin ("classic")

Shallow subduction in the Laramide (early Cenozoic)

Grand Canyon Geology
Northern Pacific and North American Plates

0 Ma

Many cool animations: http://emvc.geol.ucsb.edu/

Fate of the Farallon Plate and western North America
Fate of the Cenozoic Farallion slab

FAR = Farallon; NAM = North America

Magmatism in the western United States over the past 65 million years

http://www.navdat.org/animations/index.cfm
Figure 20. Temporal relationships between tectonics, sedimentation, and erosion in the Grand Canyon region, Arizona, during Laramide and post-Laramide time.
Laramide + Monoclines + Reactivation in late Cenozoic as normal faults

Figure 3. Locations of the Laramide monoclines in the Grand Canyon region, Arizona. From west to east: M - Meriwhtica; LM - Lone Mountain; H - Hurricane; T - Toroweap; A - Aubrey; S - Supai; FME - Fossil-Monument-Emita; WK - West Kaibab; PG - Phantom-Grandview; EK - East Kaibab; EC - Echo Cliffs

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Figure 4. Stages in the development of a typical north-trending monocline-fault zone, Grand Canyon region, Arizona.
J. Tertiary-Quaternary
Monoclines

South Mountains
Catalinas, etc.

Central AZ basins

Colorado Plateau

Superstitions

N. AZ Volcanics

Central AZ basins

Colorado Plateau

Figure 20. Temporal relationships between tectonics, sedimentation, and erosion in the Grand Canyon region, Arizona, during Laramide and post-Laramide time.
Salt River and Goldfield Mountains (volcanic)
Superstition Volcanic rocks at Saguaro Lake
Figure 20. Temporal relationships between tectonics, sedimentation, and erosion in the Grand Canyon region, Arizona, during Laramide and post-Laramide time.
Tectonic reconstruction of the North America-Pacific plate Boundary 36 Ma to present
http://www.pitt.edu/~nmcq/animations.htm

Mid Cenozoic extension around the Colorado Plateau
Figure 14. Cartoon illustrating tectonic erosion and subsidence along the southwestern edge of the Colorado Plateau over extending shear-bounded lenses in Late Oligocene-Early Miocene time. Lense concept from Hamilton (1982). Heavy arrows show absolute motions within the Basin-Range and Colorado Plateau provinces. Fine arrows show relative motions between shear surfaces. Notice that the relative motion between the lenses causes the crust to both thin and lengthen. Vertical scale greatly exaggerated, particularly at top.
3D view from south of Tucson (1990)
3D view of Paradise Valley area (1990)
Monoclines
South Mountains, Catalinas, etc.
Central AZ basins
Colorado Plateau
Superstitions
N. AZ Volcanics
Central AZ basins
Colorado Plateau

Figure 20. Temporal relationships between tectonics, sedimentation, and erosion in the Grand Canyon region, Arizona, during Laramide and post-Laramide time.
Figure 4: An idealized sequence of landforms developed during evolutionary stages of the Basin-Range disturbance in Arizona (from Menges and Pearethree 1989). Many of the ranges in the area developed as a fault bounded range during the extension of the Basin and Range disturbance and owe their current form to the culmination of such a sequence of events. The throughgoing drainage depicted in the termination phase would be the Salt River and other large rivers of the greater Phoenix area.
Depth to Bedrock  http://geology.asu.edu/%7Esreynolds/azgeophys/azdepth3d_map.htm
AZ and New Mexico topography
Grand Canyon to Phoenix tour
Grand Canyon to Phoenix tour
Rock types are shown in normal text, and well-known places where the rock type is present are shown in italics beneath the rock type. A "/" between two rock types (for example 'Tan ss/ red shale') indicates that the first rock type overlies the second one.

Major unconformity, where rocks of the upper age were deposited on top of an erosion surface cut across rocks of the lower age; unconformities within an Era (for example between two units of Mz age) are not labeled.

**Explanation**

- **Cz** = Cenozoic (0 to 66 m.y. ago);
- **Mz** = Mesozoic (66 to 245 m.y. ago);
- **Pz** = Paleozoic (245 to 560 m.y. ago);
- **PC** = Precambrian (mostly 1.0 to 1.8 billion years ago; Precambrian rocks older or younger than this age range are not common in Arizona)
Eastern Arizona to Tucson tour
Schematic stratigraphic sections for various parts of Arizona.

S. J. Reynolds
Essay 2: Draw a present-day E-W tectonic cross section across the Cordillera from coastal California to Denver. Identify each of the major tectonic belts and write a short paragraph or bullet list summarizing the most important features of each (maybe turn this page sideways).