Western Cordillera NA
Cretaceous to present

When last we left off…
• Wild and weird things happened in the murky past of the Archean and preCambrian
• Cambrian through Devonian development of deep water sediments to carbonate shelf deposits.
• Antler orogeny provided a ready source for clastic deposits (Late Devonian – Carboniferous)
• Permian through Jurassic transition from marine to dominantly non-marine setting.

Cretaceous
• Central Cordillera dominated by Western Cretaceous Interior Seaway
  – Extends from Alberta to Arizona
  – Sedimentary depositional environments range from deep water to non-marine
  – Structural basins, arches and faults strongly influence depositional patterns.
  – Dominant locale for sedimentary models for the past 25 years.

Cretaceous, continued
• Western Interior Seaway formed as a foreland basin that resulted from:
  – Nevadan Orogeny (late Jurassic)
  – Sevier Orogeny (late Jurassic – late Cretaceous)
  – Laramide Orogeny (late Cretaceous)
• The name is a big problem: Western Interior Seaway, Cretaceous Interior Seaway, Western Cretaceous Interior Seaway, Western Cretaceous Seaway…

What’s So Great About the Western Cretaceous Interior Seaway, Anyway?
• Exposure
  – big outcrops
  – no (relatively) vegetation
• Easy Access
  – road cuts
  – few (relatively) landowners, mostly government lands
• Active exploration
  – thousands of well-logs
  – thousands of miles of seismic
• Very good chronostratigraphic control
  – ammonites
  – forams and other nannofossils
  – lots of ash layers
• Not too old (<150 My)
Key word is Western

- Eastern and center of the Cretaceous Interior Seaway are boring deep water carbonates.
- The western edge is well exposed and contains continental to marine transition enabling models to be tested in a variety of environments.
- Oh, and not much oil and gas (comparatively) in the eastern part – coincidence?

Although the Western Interior Seaway covers the entire Midwest, ~95% of all published papers focus on the dark band (marine coarse clastics/shoreface) area.

Western outcrops with pretty impressive views
Northeast face of the Kaiparowits Plateau, Utah. Cliffs are formed by the Straight Cliffs Formation, not very original in naming.

Now compare the standard figure from a study of the eastern part.

Except for a slight rotation of the continent, the location of the continent was pretty close to the present position – unlike the Paleozoic where most of the existing parts were located in near the equator and southern hemisphere.

Montana - Dakotas
Prior to the Cretaceous, deposition in the North was dominated by the Williston Basin, which continued to be a controlling factor through the Tertiary.

Southern US Example #1 – Book Cliffs of Utah
(excellent exposure of marine – non marine depositional facies transition)
The Book Cliffs not only have very good outcrop exposure, but also most of the entire exposed outcrop has been cored and well-logged in a series of wells close to the cliff face allowing cores, well logs to be tied directly to the outcrop.

Expansive, relatively structure free, exposures provided excellent examples for illustrating the basic concepts of sequence stratigraphy.

Stratigraphic relationships within the Book Cliffs outcrops form type sections for many of the standard models.
THE DOWNSIDE OF FAME:
While the exposures and resource
provide the stimulus for research, the
overabundance of studies and
geologist (as well as corporate data
hoarding) leads to many different
conclusions, models, and
interpretations.
An example we will look at is the
Gallup Ss.

While relatively far from the presumed shoreline, the eastern ed ge of the Gallup Sandstone falls close to the bathymetric high of the foreset and which may or may not affected the deposition.
Fine-grained sandstone in the Gallup Fm.

Gallup Formation in outcrop

Sedimentary data and mid-80's interpretation of the depositional environment of the Gallup Formation

Comparison of depositional model with actual data – of course the data is for a different formation in Wyoming.

Well data from the San Juan basin showing a different view. Note the presentation of the cross-section (particularly the choice of the datum influences the interpretation – aligning the wells on the base of the Gallup SS would make the sandstone appear more like the beach model.)

Gallup Fm.: Comparison between outcrop and well-log
Interpretation of the Gallup SS as a shelf sand ridge
Cretaceous Summary

- Tectonic uplift along the western edge of the North America forms a large foreland basin (Western Interior Seaway)
- Strong clastic influx from the west, generally carbonate shelf deposits in the east.
- Probably more sed-research has focused on this area for the past 25 years.

Cenozoic

- Uplift of present day Rockies and Sierras
  - Alluvial – Fluvial Complexes (non-marine depositional fans) from both east and west.
  - Comprised of red bed units
  - generally the arid environment allows oxidation of the iron in the clay matrix and preserves plagioclases.
  - clastic sediments are derived from felsic plutons which will produce arkosic sandstones and conglomerates.
- Isolation and evaporation of the Western Interior Seaway
- Influx of volcanics throughout the NW.
- Climate fluctuations (glaciation) Oligocene – Present

Structure contour map of the Denver Basin

Fans of the Ancestral Rockies

Fans of the New and Improved Rockies
From the cross-sections we see that most of the sediment comprising the Denver Basin is Cretaceous in age. Pennsylvanian – Jurassic age sediments thicken slightly to the south. Cambrian – Mississippian age sediments form a thin covering over the basement.

Pleistocene excavation roughly coincides with big time glaciation. Bigger ice sheets, lower sea level; lower sea level requires a readjustment to stream equilibrium.

Subaerial (non-marine) response to sea-level changes

**Alluvial Fans**

- Typically arid climate – temperate or tropical would most likely remove sediments at a constant rate preventing fan build up
- Close to the source – coarse grain deposits breccias grading to conglomerates
- Debris flows common
Fluvial Environment

- River and streams
  - Type depends on energy, gradient and climate
  - Typical mature, meandering river (Mississippi River) has low gradient, temperate climate, and low energy
  - Typical immature, braided stream (Platte River, sort of) has higher gradient, arid climate, higher energy – but not all the time

Braided River

- Typically gravel and coarse sand deposits
- Because the channel changes often, the coarse-grained fluvial deposits cover a broad area with channels cutting and cross-cutting the underlying deposits
  - In contrast the more mature meandering deposits the sand/coarse material is confined to the location of the channel, and most the fluvial deposit is overbank mud from floods
Lacustrine Facies

- Form at low points in the topography and collect the water from fluvial sources
- Many drain to other fluvial networks and continual on to the marine basin – but sometimes the lake is the lowest point and cannot drain to the sea (Salt Lake, Dead Sea)

Many fluvial systems ended in closed lacustrine basins

Ephemeral Basins – not too much rain – reflux (periodic addition of fresh or marine [non-brine]) is low, just enough to carry more brine to the playa

Deposits are mostly evaporites and mixed mud/salt at the center grading to the normal alluvial deposits towards the highlands.

Perennial Lakes – the rain is seasonal – such that the streams flow regularly during one period of the year then turn ephemeral flowing only if the rainfall is unusually high.

Deposits are alternating evaporite with mud and high organic influx (kerogen-rich shales) towards the center, and carbonate algal mats or clastic sands and muds form the shoreline (both will show signs of desiccation structures – finally grading to the alluvial fans.)
Open Freshwater Lake – continually fed by streams year round, do not usually dry out. The center contains organic rich muds (kerogen shales again) shoreline will either be carbonate or clastic depending on the clastic influx. Lake level will decide some of the sedimentary structures observed (some desiccation, possibly small deltas where streams enter the lake; possibly small turbidites if the sed supply can manage it.)

Example of Alluvial to Lacustrine depositional system
Green River Basin of Utah-Colorado-Wyoming

Eocene = 55-35 Ma
Paleocene = 65-55 Ma
Fig. 61—Great River Formation, Winter Creek Canyon, Utah. Chertaceous sandstone with well-developed, large-scale, low-angle cross-bedding associated with mineral bedding and thin, discontinuous, parallel, and cross-laminated parts. The upper part of the section consists of a thin section with red-bed-like structures and thin lenses of cross-laminated sandstone. The lower part of the section is characterized by well-developed, low-angle cross-bedding and thin lenses of cross-laminated sandstone.

Fig. 62—Douglas Creek Member of the Great River Formation, Utah. Exposed on the bank of the river, the section consists of red-bed-like structures and thin lenses of cross-laminated sandstone. The lower part of the section is characterized by well-developed, low-angle cross-bedding and thin lenses of cross-laminated sandstone.
Generally, the Green River Basin resembles the model for a perennial basin. It is important to remember that each model is essentially a temporal snap-shot and that a fresh water basin can change into an ephemeral basin slowly over time, or with a faulting – instantaneously (geologically speaking).

Structurally Controlled Basins

- Extensional basins in California formed by dextral (left-lateral) slip

Forearc basin as a variation of the tectonically formed sedimentary basin

More common is the half-graben basin formed by uplift on one side of the basin
On the regional scale – this is the general model for the Green River Basin could be described as a half-graben basin.

For the West Coast – many smaller basins are the result of strike-slip faults that generate small, but deep basins.
With periodic strike-slip motion along the San Gabriel Fault the basin is “exposed” to “new” highlands generating an influx of coarse sediments.

**Cenozoic Summary**

- Continued tectonic uplift east, west and central; plus increased volcanic activity in the NW leads to an influx of sediments without to basins without direct access to the ocean – continental/non-marine deposition.
- Later global climate change in the Oligocene lowers sea-level and accelerates stream erosion.
- Smaller deep basins along the west coast are formed from strike-slip faults.