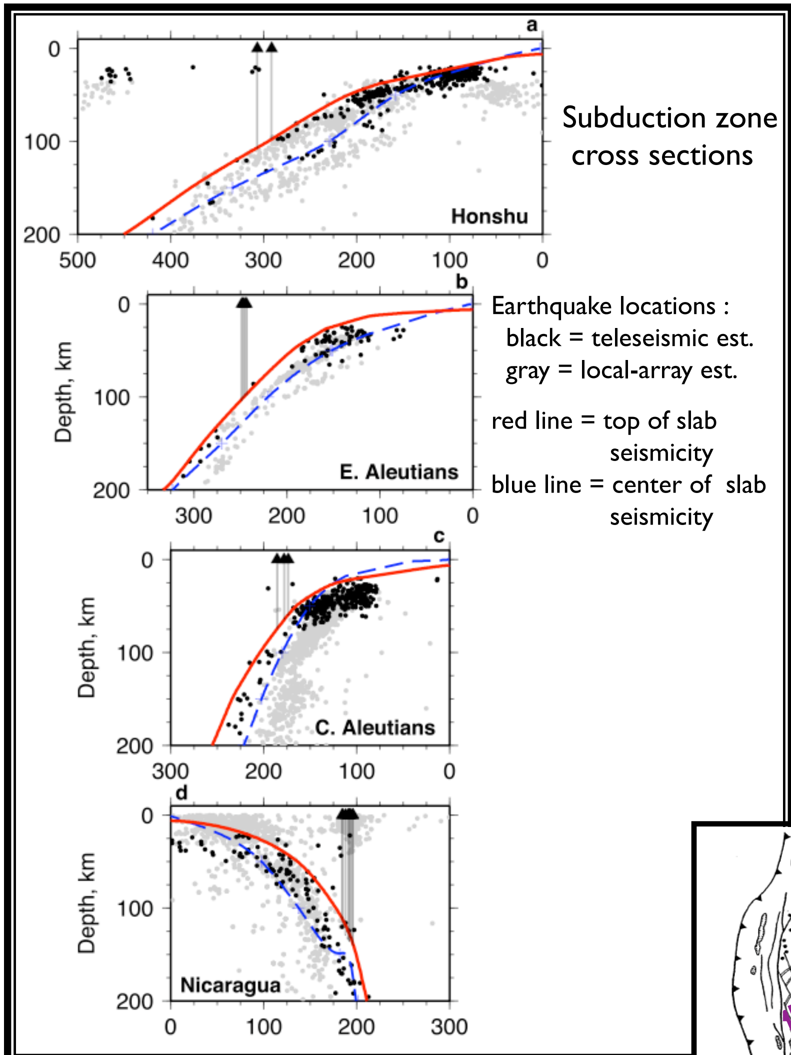
Non-ideal Subduction

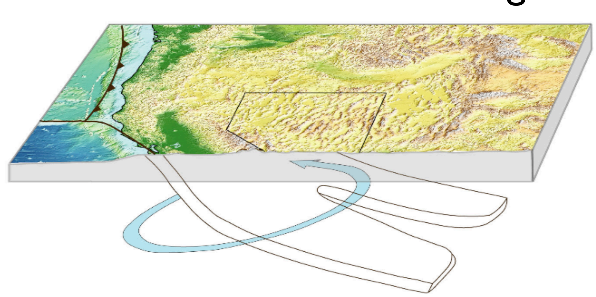


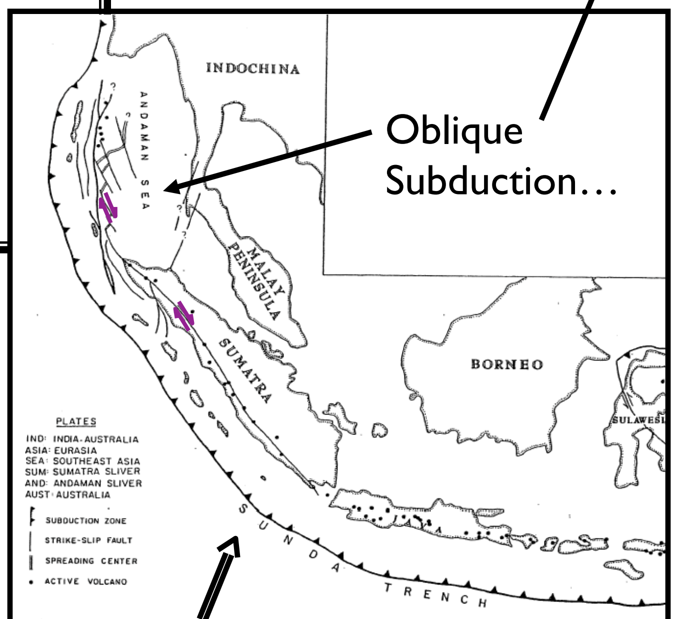
Oblique subduction causes strike-slip faulting in upper pate. Typically, about half of the transform component is partitioned onto the strike-slip system

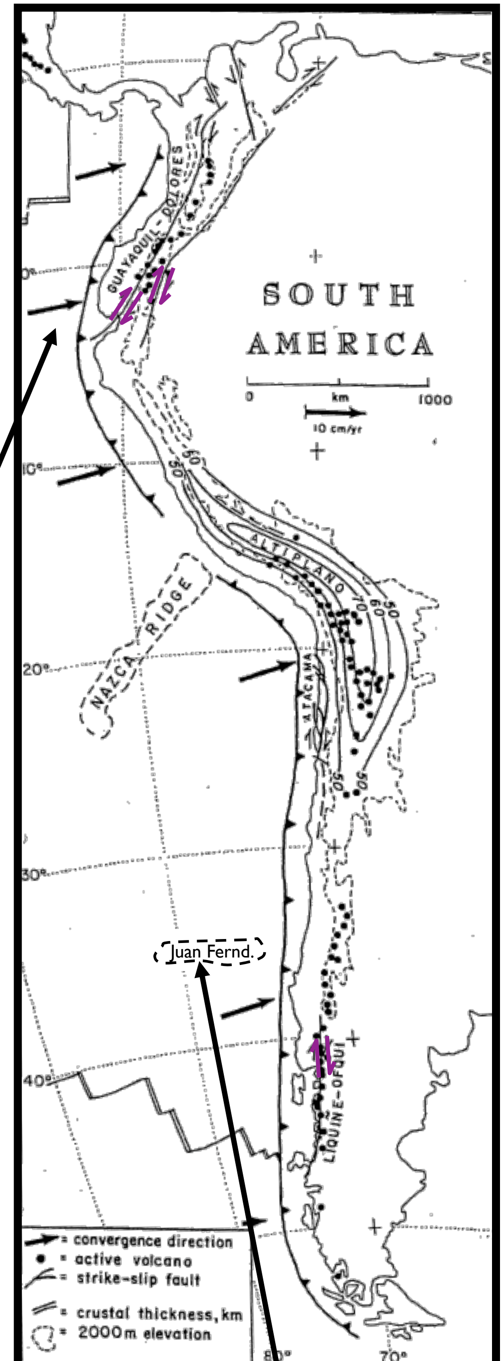
Plateau subduction (i.e., subduction of thick ocean crust) causes subducted slab to flatten, oftentimes right against the overriding plate, which causes increased coupling and continental thrusting. (slab flattening happens because slab weight is reduced by inclusion of low-density crust.)

Subduction near slab edge allows flow around the slab edge, which results in slab rollback.

Subduction Near Slab Edge



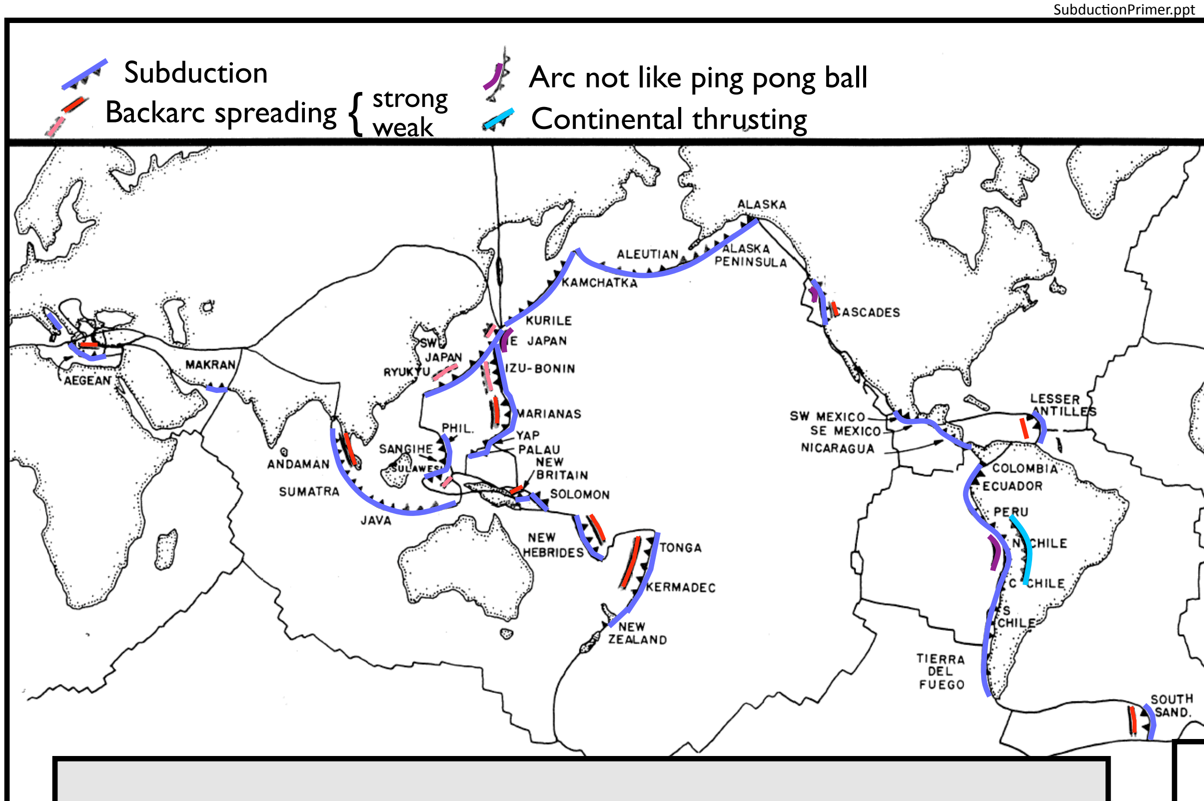


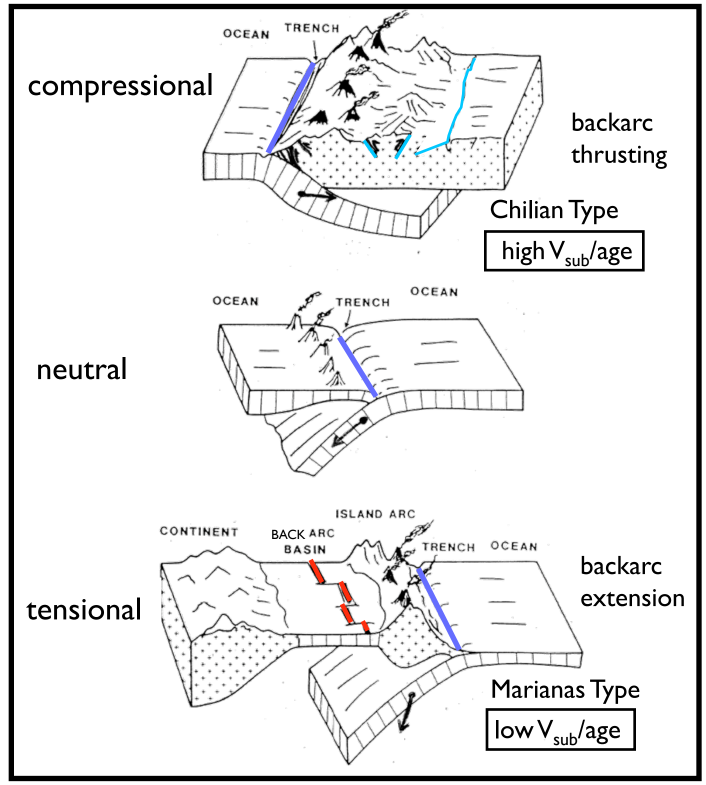


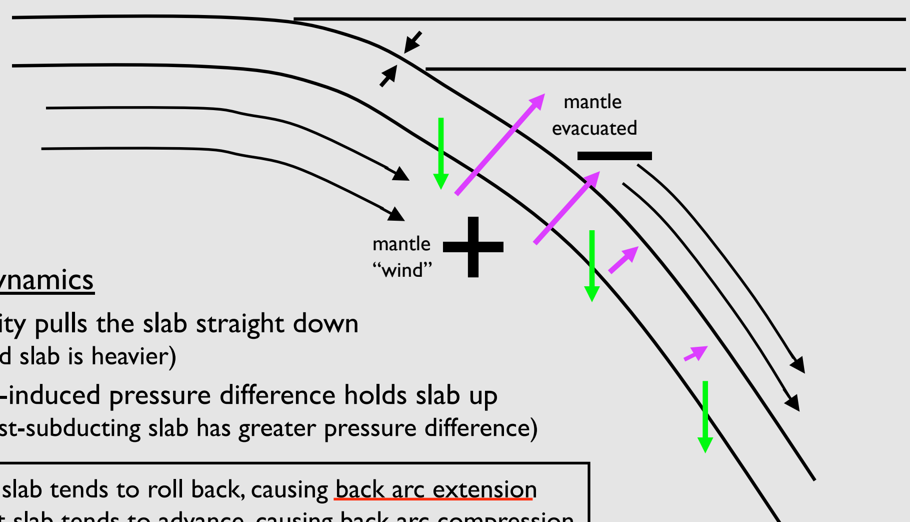
…and Plateau Subduction

Subduction Primer

SubductionPrimer.ppt



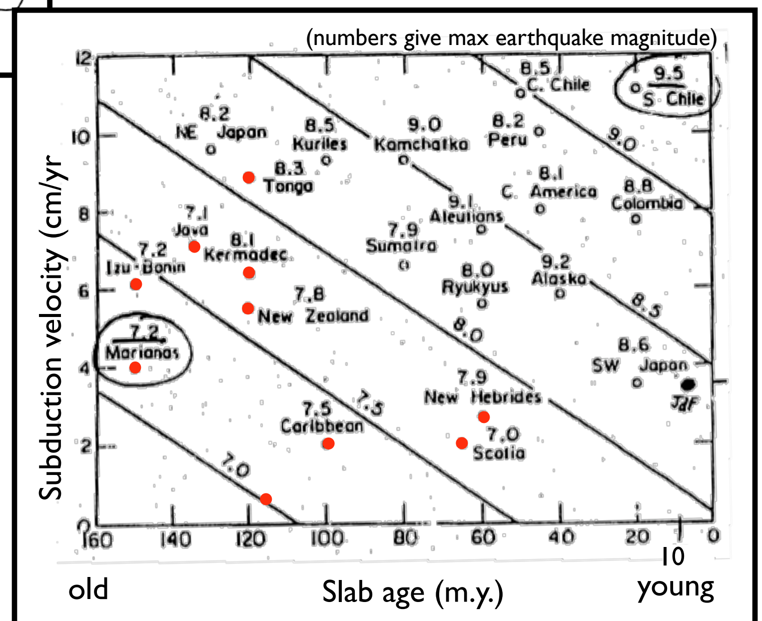




Slab Dynamics

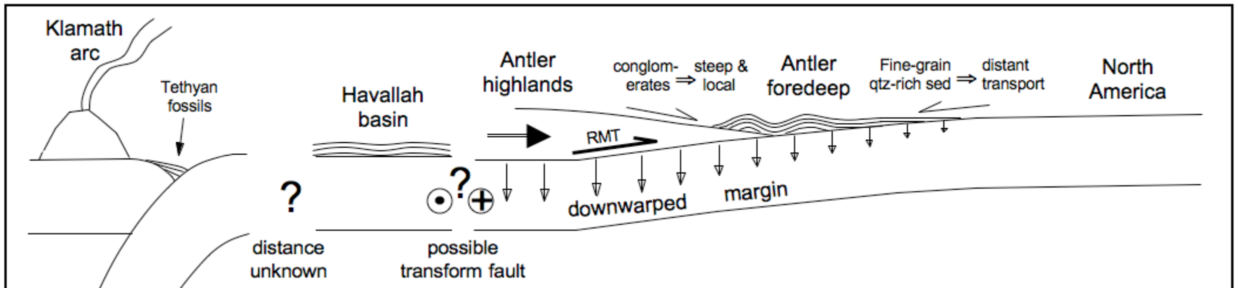
- Gravity pulls the slab straight down
  (old slab is heavier)
- Flow-induced pressure difference holds slab up
  (fast-subducting slab has greater pressure difference)

Old, slow slab tends to roll back, causing back arc extension
Young, fast slab tends to advance, causing back arc compression

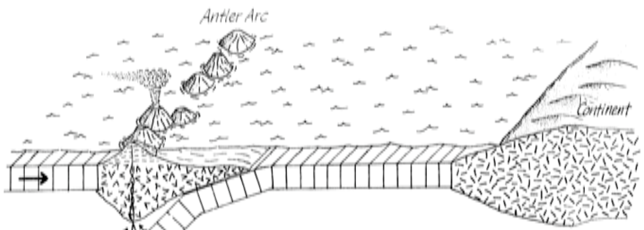


Paleozoic thrusting

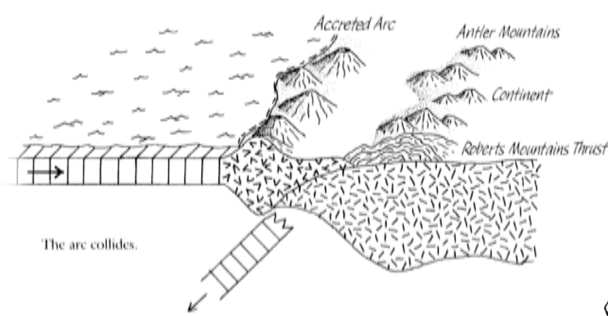
The **Antler** orogeny (370 m.y. ago) ended the passive times of of the Atlantic-type margin, when the deep water sediments of the miogeocline were thrust over the shallow water sediments (on the Roberts Mountain thrust fault), and a volcanic arc arrived (fragments of which are found within the Klamath and Sierra Nevada Mountains). The main elements are shown to the right; the details beyond this are a matter debate. Below is the classic story, which has a volcanic arc approaching from the west, which both closes the seaway between the arc and North America and causes volcanism in the arc. The docking of the arc



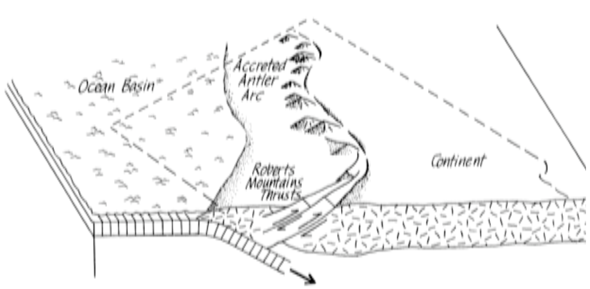
Antler orogeny. A ~370 Ma thrusting event (duration≈10 m.y.) that shoved deep-ocean sediment onto the North American margin.
The Antler foredeep filled with sediment derived from both the west and the east… the first time any sediment came from the west.
The Klamath arc is the same age, and the Antler orogeny probably represents its convergence onto North America.
However, volcanic sediment is absent from the Havallah and Antler basins, suggesting that the Klamath arc was far away.
Unlike the fossils in the Havallah and Antler basins (which indicate their proximity to North America) sediments in the Klamath arc accretionary prism have Tethyan fossils (suggesting a distant origin for the Kalamath arc). So, some mysteries.



The approach of the Antler arc.



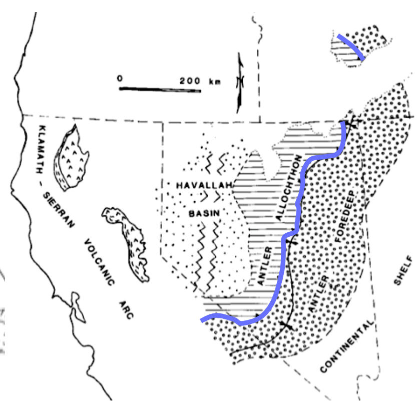
The arc collides.

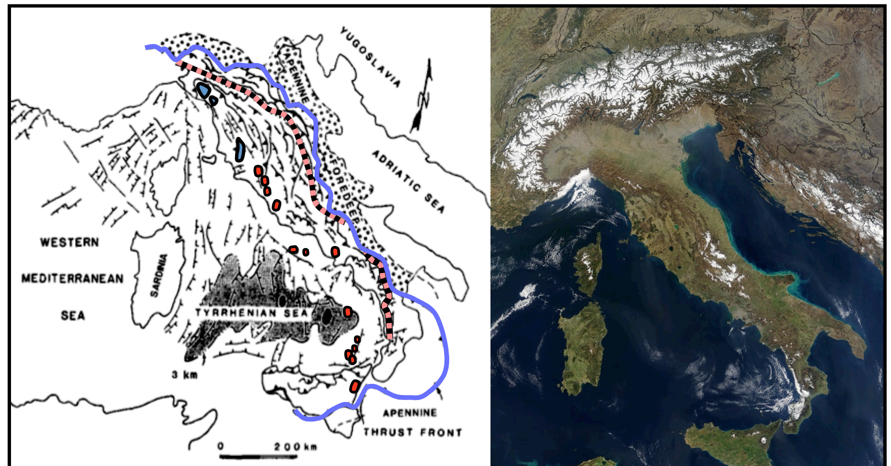


drives thrusting. The Antler thrust sheet rides over the downwarped margin (foredeep) on the Roberts Mountain thrust (RMT above, shown in blue below).

A problem with this model is the presence of the Havallah Basin between the thrust zone and the volcanic arc (that is supposed to be causing the thrusting).

Two suggested solutions are:
1) A transform fault





APENNINE OROGENY, ITALY

juxtaposed unrelated elements at a later time (see above figure), and
2) The Antler orogeny was more like the Apennine orogeny currently active in Italy. This is the subject of the 3/31 in-class exercise.

The **Sonoma** orogeny (250 m.y. ago) followed the Antler orogeny, and if most notable for being so similar to the Antler.

The **Ancestral Rocky Mountains** were created by a mysterious orogeny that occurred in between, at about 300 m.y. ago.

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Late Devonian / Early Mississippian Antler Orogeny.

Above: the sheared and folded deep water sediments of the distal (far west, deep sea) Antler marine basin thrust over and placed on top of the shallow water deposits of the continental margin.

It is uncertain what process caused these deep water sediments to thrust up and over the continental edge, extending from southern California to Alaska.

We have a good idea that they were not transported much more than a few hundred kilometers as the sediments contain fossils of North American affinity but, they lack volcanic and Arc materials.

To understand the story of what happened when, we rely on the sediments deposited during the orogeny. The Antler foredeep (between the thrust front and the miogeocline) records the sediments derived from the mountain building event that occurred as the deep-water sediment overrode the shallow sediments.

In the foredeep, we see both sediments derived locally off the topographically high Antler thrust sheet and those from the long traveling continental rivers. The Antler sediments, transported from the west are composed of conglomeratic deposits composed of cherts, shales and other low-grade metamorphic rocks. This is the first time we see sediments derived from the west-- a feature that indicates the first tectonic activity and mountain building in the west.

Transported from the east, we find finer-grained, quartz-rich sediments that have traveled great distances (during transport, other minerals are eroded away, weathered or deposited, leaving quartz grains preferentially carried over large distances).

This is a view of the Robert's Mountain thrust contact up close. Above the contact we see the Early Missisppian conglomerates and below we see a thick band of sheared rocks.

To constrain the age of a thrust fault like this, you need to know the age of the youngest rocks in the footwall and the oldest age of the sediments produced by the deformation (the oldest age of the foredeep sediments). For the Roberts Mountain thrust, we know that the fault was active over roughly 10 million years.

If we move west from the previous slide we see the continental margin sediments sourced from the east inter -finger with the conglomerates sourced from the Antler Orogeny in the foredeep. In the central part of the foredeep, the sediments are 5-6 km thick, but if you go east, out of the foredeep, toward the continentally derived sediments, you find for the same time period sediments that are 300-400m thick.

This is a thick section on the eastern edge of the foredeep where continental sediments and carbonates continued to do be deposited.

Here there is no record of the Antler foredeep or orogeny.

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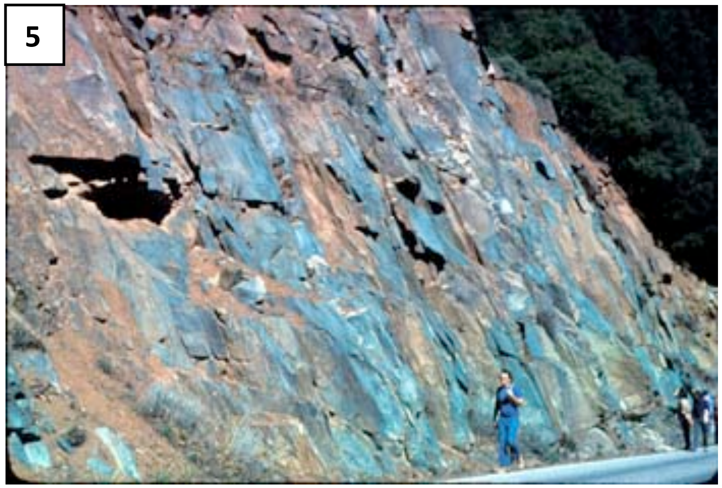
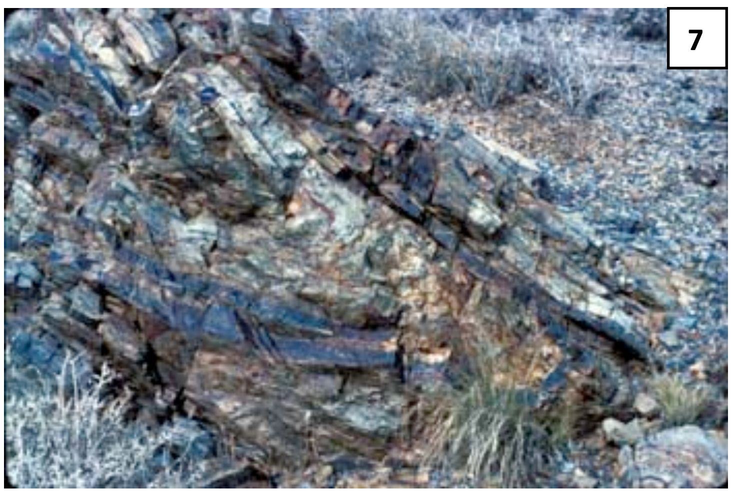
This section stolen from: http://ocw.mit.edu/ans7870/12/12.114/f05/gallery/lec3final/pages/lec3photo1.html



An arc of the same age as the Antler orogeny, now found in the Klamath Mountains, was active somewhere west of North America. This image shows ashes and sediments associated with this arc.

Although these volcanically derived deposits were created at the same time as the Antler, there are no evidence of ashes or volcanic fragments in the Antler-related sediments, suggesting that the Arcs were still far away from the edge of North America during Antler time.

Student contemplating the rocks further west of the Klamath arc. This is the ocean floor upon which the Arc was deposited. The structurally lowest rocks we find are tectonically layered dunite (olivine-rich) and peridotite (olivine -pyroxene) mantle rocks from below the ocean crust.



Folded carbonates that were deposited in the Havallah basin west of the Antler Orogeny at the time that deformation was occurring. This suggests that there was no major continental or island arc collision that created the Antler Orogeny.

A view of early Pennsylvanian sediments deposited over the eroded mountains of the Antler Orogeny. This suggests that the topography created by the Antler was eroded to low relief, and that the Antler Orogeny was complete by the early Pennsylvanian.

Timing of depositional events around the time of the Antler Orogeny (dates are approximate).
Arc Volcanism continued throughout the time oft the Antler.
Sediment found in the Antler Allochthon experienced active deposition until ~360 Ma.
The filling of the foredeep then starts ~355 Ma, suggesting that the material had been thrust over the sinking continental margin.
By ~350 Ma, we find sediments overlapping the Antler Orogeny, suggesting that it had been significantly eroded.
Note that deposition continues in the Havallah basin east of the arc and west of the developing Antler Mountain belt, suggesting there was no arc collision during Antler time.