Lecture Goals:  
A) The Triassic  
B) The Jurassic  
C) The Cretaceous


A) The Triassic  
Before we start discussing Mesozoic tectonics in western North America, it’s necessary to remind you of world paleogeography in the Paleozoic. In that era, the big event was the assembly of Pangaea. If you recall, Laurentia (proto-North America) was drifting toward Baltica (proto-Europe) and Gondwanna (proto-Africa/South America/Antarctica/Australia/India). Laurentia’s motion was toward the west-southwest. The net result (and this is what we spent a bunch of time on) was that the eastern coastline of the continent was an active continental margin (officially a convergent plate boundary). We kind of omitted the western side of Laurentia because all of the tectonic “action” was in the east. The western coastline during the Paleozoic was mostly passive. Thick blankets of mature siliciclastic sediment was deposited all along the coast from what is today Alaska to what is today California. Quartz arenite sandstones were deposited in beach deposits whereas siltstones and shales were deposited in deeper marine environments. There were also reef deposits and some oolites. Sound familiar? It should. This was the same type of sediment that was deposited in the east before convergence began. As in the east, much of the sediment deposited along western Laurentia was tropical during the Paleozoic – remember that the equator passed through the continent during much of the Paleozoic. The stratigraphic names of the rock formations in the west are as you might expect completely different that those in the east. The one formation that I remember from my undergraduate days is the Gog Quartzite (pictured to right from http://www.terragalleria.com). It is a thick, slightly metamorphosed quartz arenite sandstone that was deposited in the early Cambrian in what is today southern British Columbia. The name is kind of unfortunate. Quartzite is a term better left for highly metamorphosed quartz arenite sandstones. I prefer the term Gog Formation for this rock unit. Whatever you call it, it’s a pretty impressive rock. It is thick and was highly resistant to deformational events. It shaped the way the Cordilleran Mountains formed in western Canada during a series of Mesozoic orogenies. The Gog Formation provides a friendly reminder about the importance of sedimentary rock units during mountain building. Mountains form during deformational events from pre-existing rock units. The
Cordilleran Mountains formed through deformation of rocks that were initially deposited along a passive continental margin.

The majority of deformation occurred during the Mesozoic, but there was a bit of mountain building in the west as early as the Devonian. The Paleozoic event is known as the Antler Orogeny and it affected western Laurentia from what is today the Canadian-US border to what is today southern Nevada. It was a pretty long-lived event as it lasted until the Pennsylvanian. The Orogeny was caused by a collision of an island arc. This might strike you as a bit surprising considering that I just stated that western Laurentia during the Paleozoic was a passive continental margin. If you look back, you will see that I actually said mostly passive continental margin. The reason for the ambiguity and the orogeny is shown in the cartoon at the top of this page. The Pacific Plate and the Laurentian Plate were both moving in the same direction during much of the Paleozoic (picture 2 conveyor belts aligned end to end). Laurentia started to slow down once the east coast began to experience orogenic events and this seems to have allowed the Pacific Plate to overtake it. This induced subduction along the western coastline.
The Antler Orogeny was very much like the Taconic Orogeny in terms of deformation. It was mostly thrust faulting and metamorphism was minor to absent (see cartoon cross section at the bottom of the previous page from http://jan.ucc.nau.edu). The Mesozoic orogenies were more intense because larger land masses started hitting us. Each of these land masses is called a terrane and as you will see, most of the large ones were named.

The Triassic Earth is pictured in the next cartoon. The most obvious thing to note is that Pangaea is still in one piece but “cracks” are starting to open up between North America, Europe and Gondwanna. These rift valleys (a rift valley from Iceland is pictured above from http://www.waste.org/~chelsea/images/Iceland/rift.jpg) were the initial stages of divergence and by the Jurassic, they had widened and deepened enough to be flooded by sea water (more on this in the next lecture). During the Late Permian and early Triassic a series of island arcs lay to the west of Laurentia. The Brook Range was the most northern terrane. The Stikina and Sonoma Terranes lay to the south. Sonoma hit first and produced a
series of thrust mountains primarily in the area that is today Nevada and Utah. The **Sonoma Orogeny** was the first of the Mesozoic events that would ultimately produce the **Cordilleran Mountains**. The impact of the Sonoma Terrane (and the Stikinia and Brook Range terranes that followed it later in the Triassic) are officially called **docking events** and each docking added more territory to the continental margin. This process is termed **accretionary tectonics** and it is very different from the continent-continent collisions that shaped the Appalachian Mountains. From the time the Cordilleran Mountains began to form 150 million years ago, there has never been a continent-continent collision in the west. All of the tectonics have been drive by small-scale (relatively speaking) docking events of island arcs and other terranes. However, the cumulative effects of numerous terrane dockings was enough to produce a mighty impressive mountain belt stretching from Alaska to Mexico.

**B) The Jurassic**

In the Jurassic, rift valleys between North America and Europe and between North America and Gondwanna began to be flooded by sea water. This was driven by the continued subsidence of the rift valley floor, and augmented by a world-wide transgression. The overall sea-level rise flooded large portions of the continents including North America.
Western tectonics continued to be driven by docking events. Several large terranes impacted the western continental margin in the Jurassic. Some, like the Klamath Terrane were mixed lithologies. They consisted of some volcanic rocks (e.g., island arc sequences) and some older (e.g., Paleozoic) sedimentary rocks (deep marine siliciclastic rocks, chalks etc). For the first time, igneous intrusions and associated volcanism also started to occur in western North America. The intrusions were largely felsic (granite) in composition as were the volcanic eruptions (rhyolite and tuff). Many of the granite intrusions were large (actually the intrusions themselves were small — perhaps a few km or 10s of km wide — but, they overlapped forming large composite structures called batholiths), and in some cases, whole mountain ranges were formed from them (e.g., the Sierra Nevada Mountains). Metamorphism also occurred during the Jurassic in part because of the high heat flow from the intrusions.

The numerous docking events that characterize the Jurassic comprise the Nevadan Orogeny. This phase of mountain building lasted until the early Cretaceous. A second tectonic event known as the Sevier Orogeny began in the middle part of the Jurassic and lasted well into the Cenozoic Era. This mountain building episode was mostly thrust fault-induced and involved newly deposited (e.g., Jurassic-Cretaceous-aged) sedimentary rocks. In some cases, the sedimentary rocks were detached from the basement and pushed for dozens of km along the thrust faults. This horizontal shortening translated into vertical uplift of many thousands of meters. Something else was starting to occur that would really take off in the Cenozoic. The first major strike slip faults were starting to develop in the southern portion of the United States. Strike slip faults are caused by shear and involve large portions of lithosphere sliding past other portions (see the Jurassic cartoon). The San Andreas Fault in California (see image to right from http://geography.sierra.cc.ca.us/booth/California/1_lithosphere/san_andreas_fault.jpg) is a Recent example of this type of faulting.

C) The Cretaceous
In the Cretaceous, things pretty much kept going the way they has during the Triassic and Jurassic. The rift valleys in the east had separated wide enough that a full blown ocean now occupied them. Between North America, Europe and Africa, this ocean was called the Atlantic. Between North America and South America, it was called the Gulf of Mexico. Are you surprised to see me using North America instead of Laurentia and Africa/South America instead of Gondwanna? The Atlantic Ocean instead of the Iapetus Ocean? By the end of the Cretaceous, Pangaea was mostly broken up. Africa, South America and India were all separate continents (only Australia and Antarctica remained stuck together). North America and South America were moving in the same direction.
away from Africa and Europe. The ocean between them, although still relatively young and narrow, was the Atlantic Ocean we know and love today.

Sea-level was really high and the climate was very warm. This gave rise to significant marine sedimentation in epeiric seaways across most of the continents on the planet, including North America (see diagram to right from http://en.wikipedia.org). This will be the subject of the next lecture or two in GY 112.

Western North American tectonics was still accretionary and once again, there were docking events, plutonic intrusions and metamorphism (Nevadan Orogeny), as well as thrust fault mountain formation (Sevier Orogeny). One of the most impressive (and biggest) terranes to dock with North America in the Cretaceous was
Wrangellia. It probably hit us near California, but strike slip movement since the time of docking has moved it north of the Canadian border. Today, it comprises Vancouver Island and the Queen Charlotte Islands along the western coastline of British Columbia. I recommend both islands for a holiday and not just because of the geology. The scenery is second to none (see image to left from http://images.britishcolumbia.com/photogallery/3/310.0.2.jpg).

Another interesting thing about Wrangellia is the composition of the rocks. They are highly varied and detailed geologically work has demonstrated that the terrane was originally located near South America. The Wragellian Terrane has traveled well over 1000 km from its place of formation.

Names and terms to be familiar with from today's lecture

(Google any that you aren't familiar with)

Convergent plate boundary
Passive continental margin
Gog Quartzite 'Gog Formation
Cordilleran Mountains
Terrane (Brook Range, Stikina, Sonoma, Wrangellia Klamath)
Antler Orogeny
Sonoma Orogeny
Nevadan Orogeny
Sevier Orogeny
Laramide Orogeny
Accretionary tectonics
Docking events
Rift valley
normal fault
intrusions
granite
batholith
horizontal shortening
strike slip faults
shear