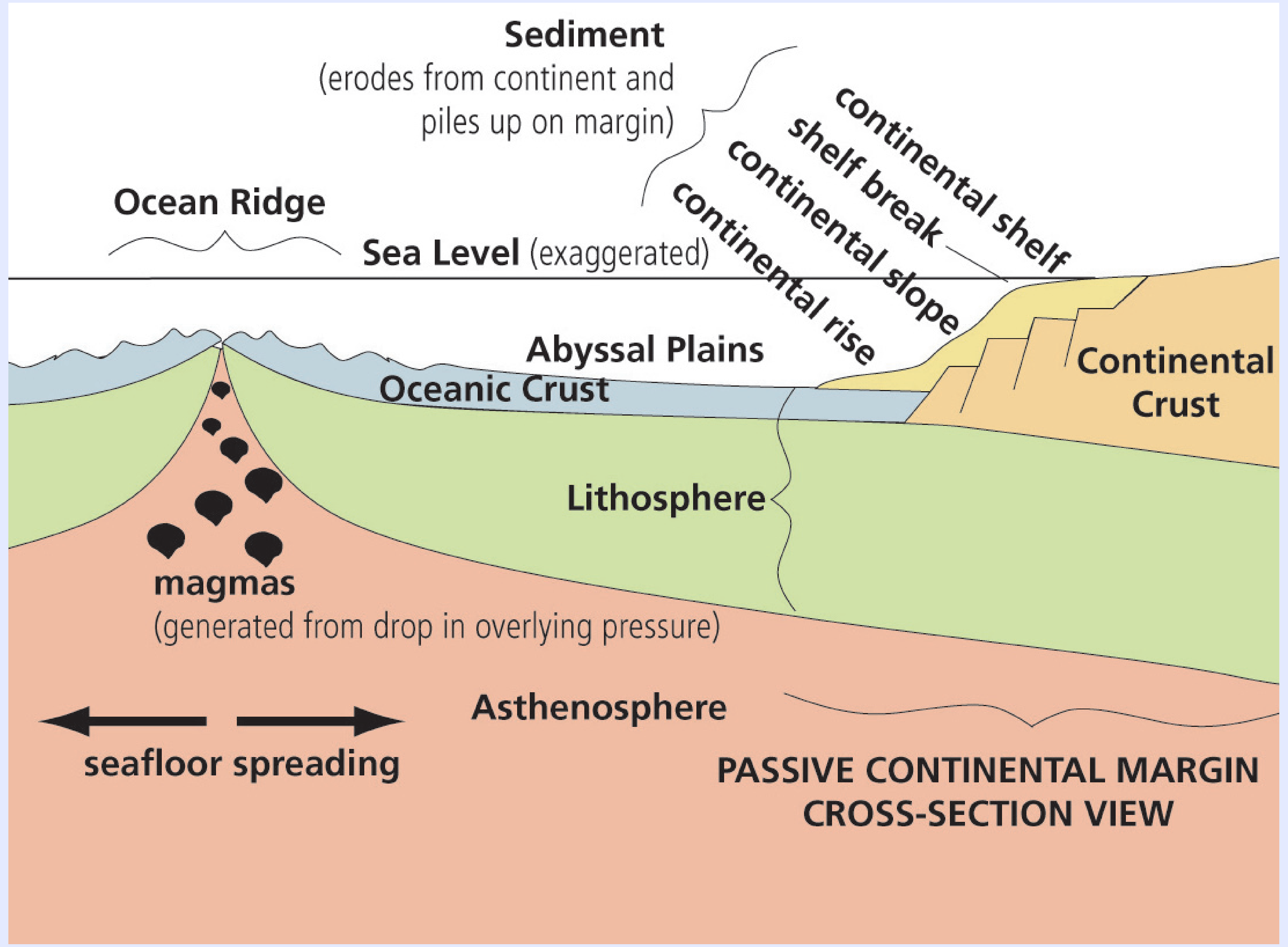
PACIFIC PLATE DIVES UNDER NORTH AMERICA — 475 MILLION YEARS AGO

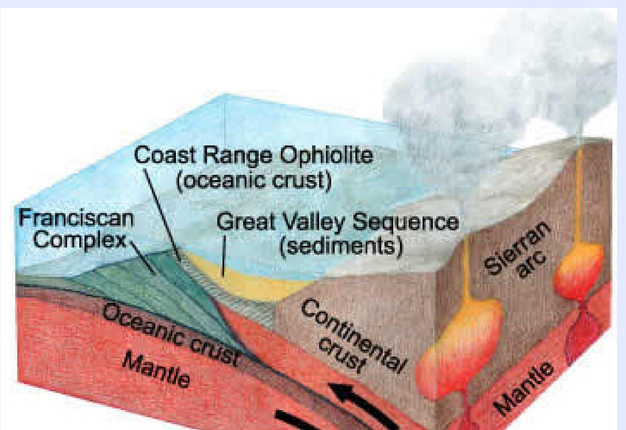
Passive and active margins—a review

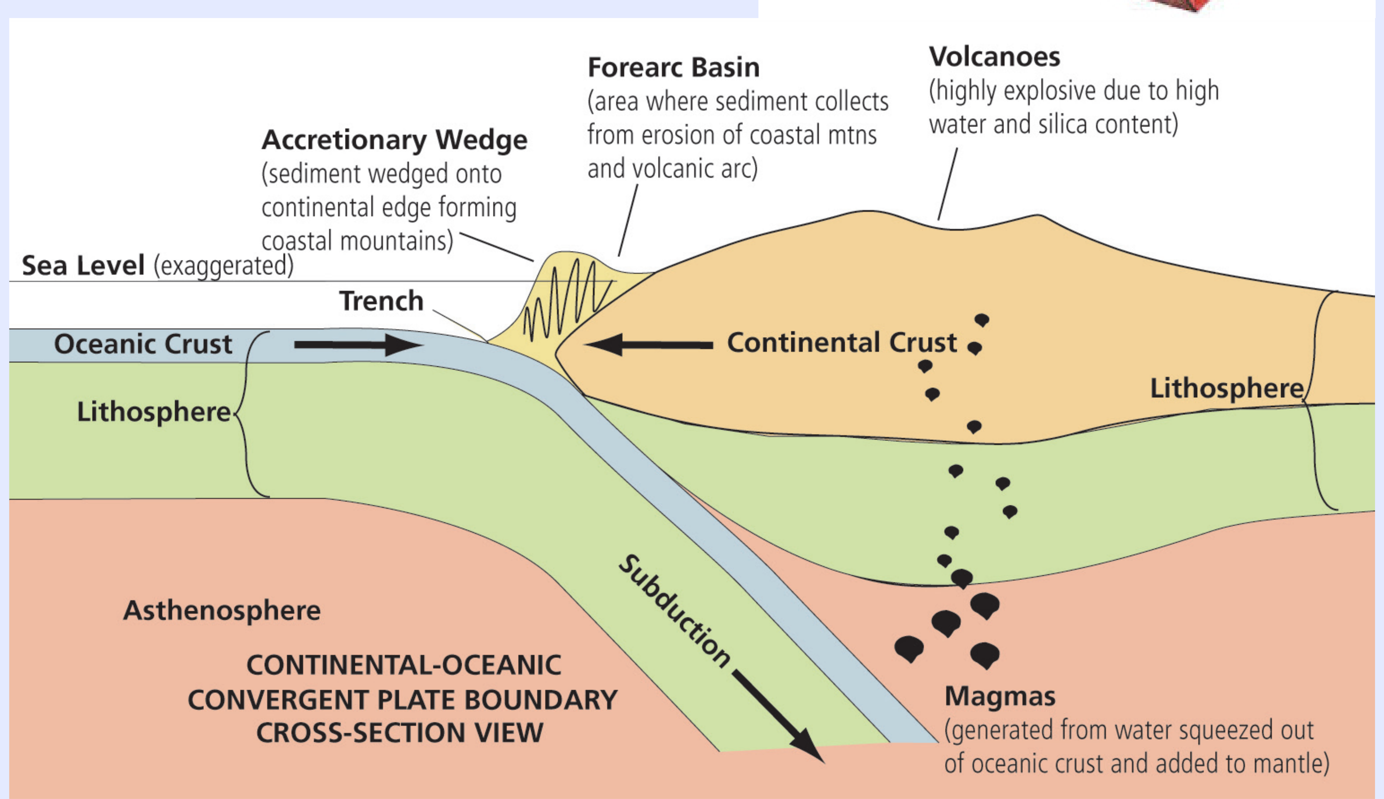
Today, North America's east coast is primarily a **passive continental margin**, a coastline where continental crust and oceanic crust are fused together, embedded in one large plate that is slowly being pushed away from an offshore seafloor spreading center. The North American continent is embedded in a plate that also contains the western half of the Atlantic Ocean. The entire plate is being pushed away from active seafloor spreading centers in the middle of the Atlantic Ocean. When continent and ocean are embedded in the same plate, there is no tectonic activity at their boundary—no volcanoes, no major earthquakes, no mountain building. All that happens is the slow, steady piling up of sediment from the erosion of the backcountry. Thus passive margines usually have wide continental shelves.



A passive margin. Notice that ocean and continental crust are fused together and embedded in a larger plate that moves as one unit away from a nearby seafloor spreading center. Sediment is carried by rivers out of the eroding backcountry and collects at the coastline, where it creates a huge pile of sediment that overlaps the ocean crust. The flat offshore extension of the continent is called the SHELF; the edge of it, the BREAK; the steep face where it falls downward to the seafloor is called the SLOPE; and the apron of sediment that collects at the base of the slope in fans and cones, the RISE.

When new oceans form, the passive margins along their edges are young and buoyant. But as time passes, they get colder, older, and denser. They sink down under the weight of sediment piling atop them. Eventually, after about 200 million years at the most, this ocean crust and the **plate**, or **lithosphere**, in which it is embedded will sink down into the mantle (**subduction**) to eventually be recycled. Now the continental margin is called **active** or a **convergent** plate boundary. Its features include major earthquakes, a deep trench on the seafloor, mountain building in the wedge of sediment and islands that are caught between the plates and accreted to the edge of the continent, and inland volcanism associated with the melting of mantle under the continent when water is squeezed out of and rises upwards from the sinking oceanic plate.

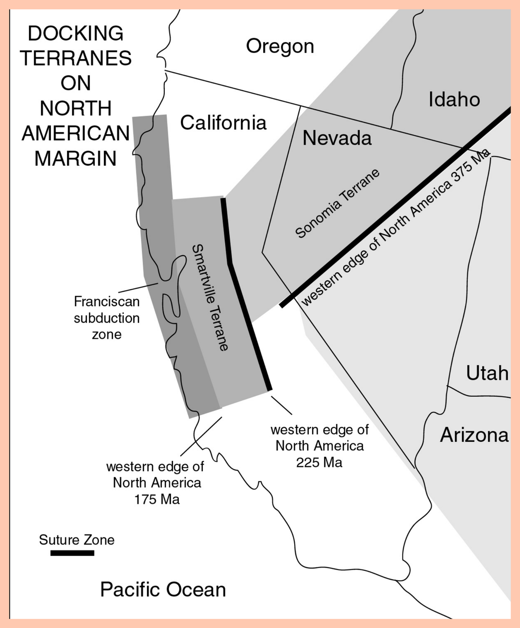




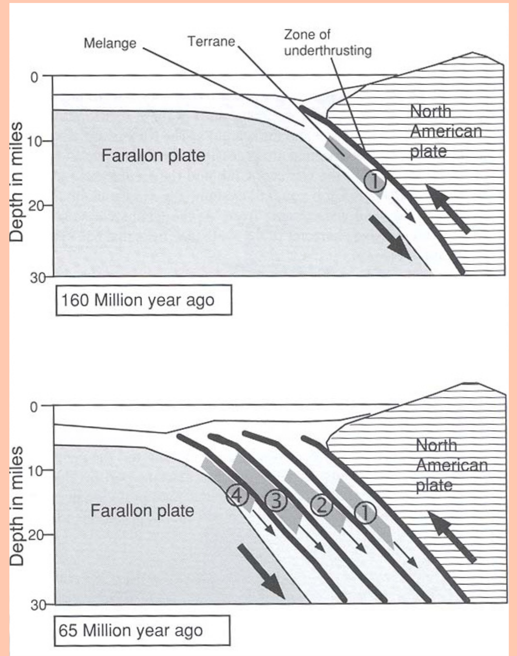
A subduction zone (or ocean-continent convergent plate boundary), otherwise known as an active continental margin. Notice the inland active chain of volcanoes, the offshore trench, and the wedge of material that creates coastal mountains between the trench and the continent. The inset block diagram shows what this margin looked like in California 165 million years ago. The accreted rocks that formed from the scraping and wedging of sediment and islands in the subduction zone are referred to today as the Franciscan Complex. Most of the granite we see today in the Sierra Nevada was formed as magma chambers cooled and solidified under the active arc of subduction volcanoes. The sediment that fills the San Joaquin Valley (and makes for one of the most fertile valleys in the world) was carried off these active volcanoes and the coastal mountains. GGNRA ©

The story of North America's western continental margin

While the former supercontinent Rodinia was rifting apart, the North American continent's western margin was passive. 475 million years ago, the oceanic edge broke off and began to subduct. A chain of volcanoes formed inland. Sediment, islands, and ocean crust were scraped off and accreted (attached) to the western edge of North America to form rocks called **terranes**. The western edge of North America grew larger through inland volcanism and coastal accretion of terrane—a process that also created large coastal mountains due to the collision of accreted material. Since 475 million years ago, there have been three different major episodes of subduction on our margin. Each episode ended by a temporary plugging up of the subduction zone with a large terrane. Subduction eventually restarted in a new position. The most recent episode of subduction began about 200 million years ago. Hundreds of terranes were added, collectively referred to as the **Franciscan Assemblage**. These terranes dominate the current coastal mountains north and south of San Francisco, including the hills of San Francisco itself.



Names, ages, and locations of the three main terrane assemblages accreted to the North American western margin over the past 475 million years in subduction zones. Image modified from T. Konigsmark ©.

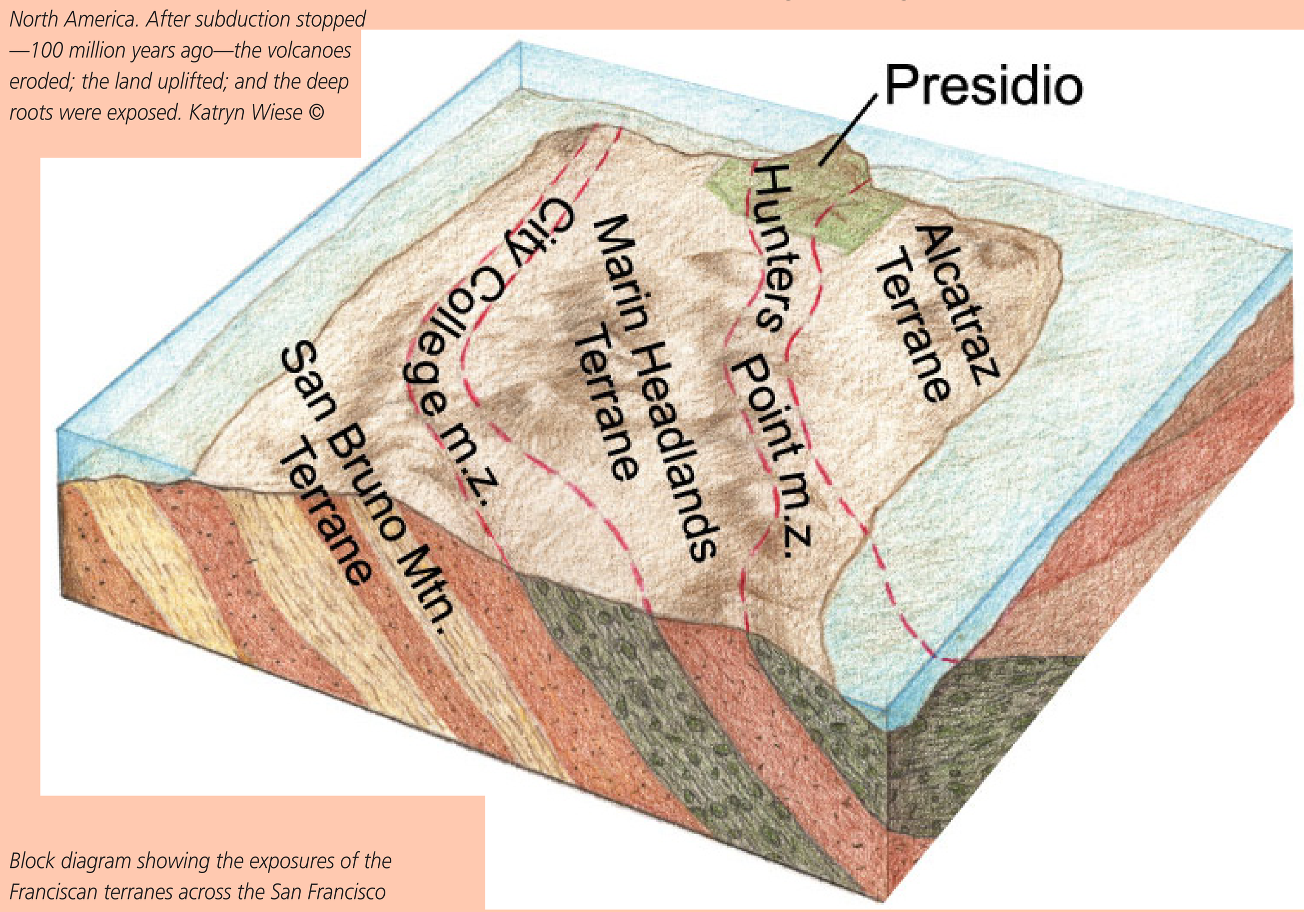


As ocean crust subducts, bits of it are scaped off and attached to the edge of North America. New material is accreted behind the old terranes, and so on, until you get strips (or walls) of older terrane behind newer terrane. In the picture above, 1 is the oldest terrane. Image modified from T. Konigsmark ©.

About 65 million years ago, an offshore spreading center with its associated high relief entered the subduction zone along the California coastline and plugged up the zone. Although subduction still continued north, in all but the northern-most parts of California, subduction ceased, inland volcanism stopped, and the **San Andreas Fault** began forming. The volcanoes of that old arc have long since eroded, as have the coastal accretionary mountains. Now the deeply eroded terranes are exposed along the coastline and the granitic roots of the volcanoes are exposed in the Sierra Nevada. Although these rocks are exposed now at the surface, they formed between 65 and 500 million years ago!

Header image: High Sierra—Yosemite National Park—Gallison Lake. These granite formations are the eroded roots of volcanoes (the crystallized magma chambers that cooled and solidified slowly underground). They formed during active subduction of the western coast of North America. After subduction stopped —100 million years ago—the volcanoes eroded; the land uplifted; and the deep roots were exposed. Katryn Wiese ©

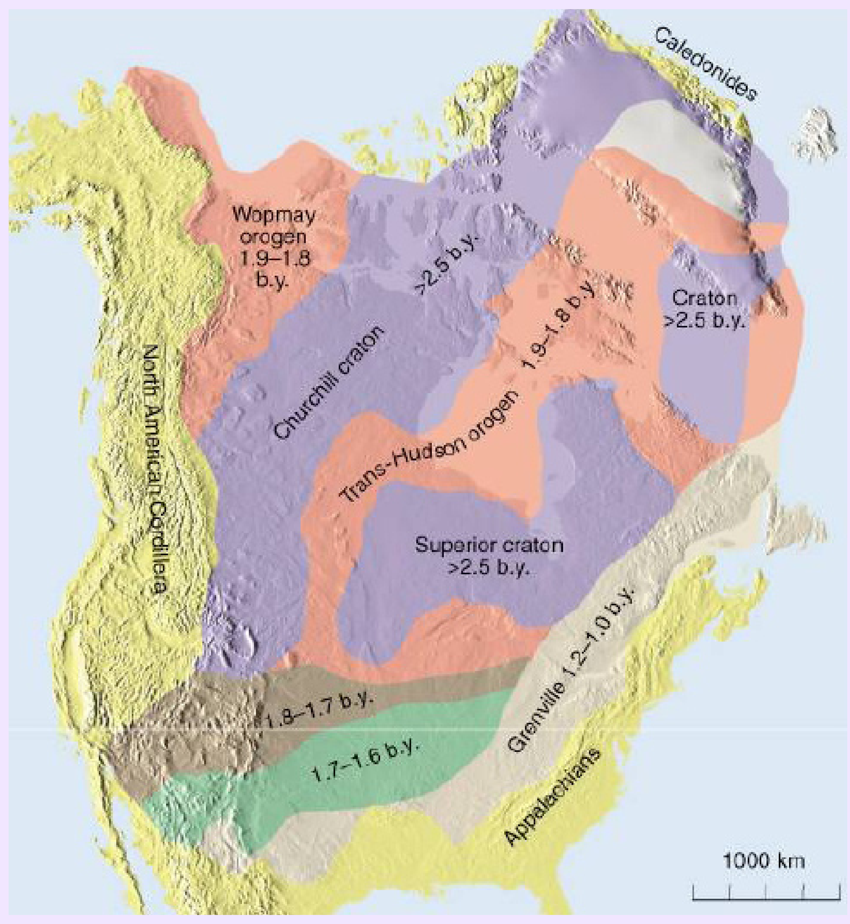
Terrane map of North America's western margin with tectonic plate boundaries that we have today. Although most of the rocks of western North America were accreted to its edge in a subduction zone, that subduction ceased about 100 million years ago in California. We now have a transform plate boundary (the San Andreas Fault) that actually separates continent from continent. There is still active subduction, however, in Washington and Oregon and Northern California. Prentice Hall Publishing ©



Block diagram showing the exposures of the Franciscan terranes across the San Francisco Peninsula. GGRNA ©

The future of North America's eastern continental margin

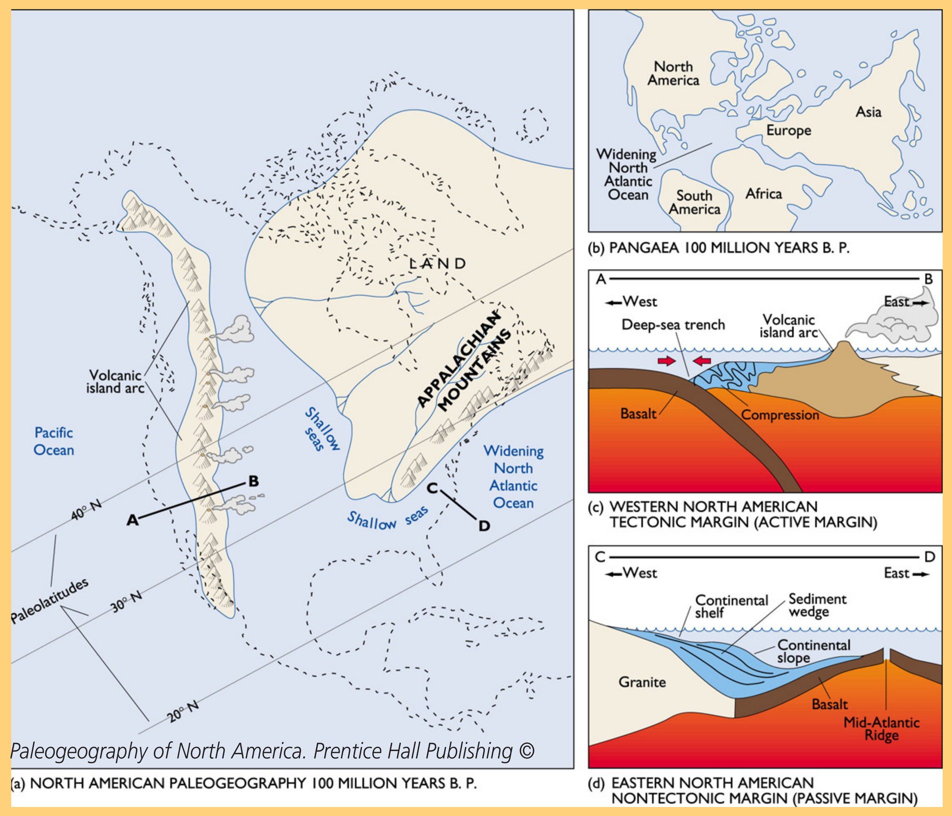
Continental margins typically change from passive to active and vice versa as continents come together and collide and then break apart and separate. The North American continent records a number of these episdoes in the rocks (and displayed in the terrane map of North America below). The center of the continent, known as the **Canadian Shield** or **Craton**, is the old core of our continent, which has grown through accretionary mountain-building episodes along its margins. Each colored strip in the map represents the location of a subduction zone (active margin) during Earth's past. During these subduction episodes, a number of rocks were brought in by the ocean plate, scraped off, and accreted to the edge of the continent, growing North America over time. Notice the yellow edges on the east and west. The west is the area of active subduction (Washington, Oregon, primarily). The east was an area of active accretion when supercontinent **Pangaea** formed (225 million years ago). Since then, it has been a passive margin, simply collecting sediment as the no-longer-active Appalachians erode. Eventually, the ocean crust off the east coast will also begin to suduct (in the next 10-20 million years), and the eastern seaboard will become an active subduction zone with massive earthquakes, volcanoes, and mountain building!



Terrane map of North America. Prentice Hall Publishing ©

A story of oil

The image below shows what North America looked like 100 million years ago. Notice the active margin (subduction) all along the west coast (no longer present today in most of California) and the passive margin along the east coast. Also notice that the interior is an inland sea. Continental crust here is flat, and a shallow ocean is covering it. It was during this time in our geologic past that most of the oil and gas and salt deposits of the midwestern and Gulf of Mexico states were forming. As microscopic sea creatures rained down to the seafloor, their remains were buried. Over time these remains have been cooked and turned into oil and gas.



Paleogeography of North America. Prentice Hall Publishing ©

A continent of contrasts

The high relief we see along the western margin of North America indicates its youthful age. This region is the most active area of continent building in North America and has formed from the last 500 million years of mountain building, volcanism, and accretion. Meanwhile, for the past 200 million years, the eastern margin has been passive, collecting the eroded sands of the old Appalachian Mountains, which stand out as the highest relief in the east. 225 million years ago, the Appalachians were as large as the Himalayas and forming in an active collision zone. Today, they are a slowly eroding remnant of the past.