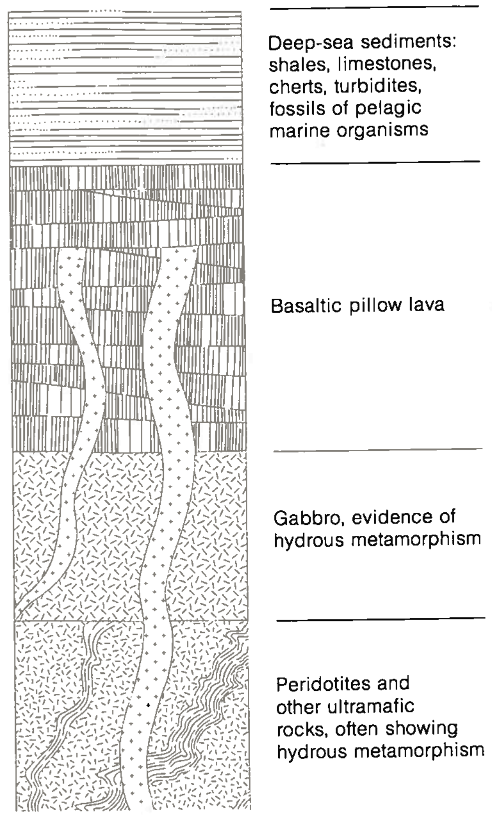


**Figure 19-12**
Idealized section of an ophiolite suite. The combination of deep-sea sediments, submarine lavas, and mafic igneous intrusions indicates a deep-sea origin. Many geologists now believe ophiolites to be fragments of oceanic lithosphere emplaced on a continent as a result of plate collisions.

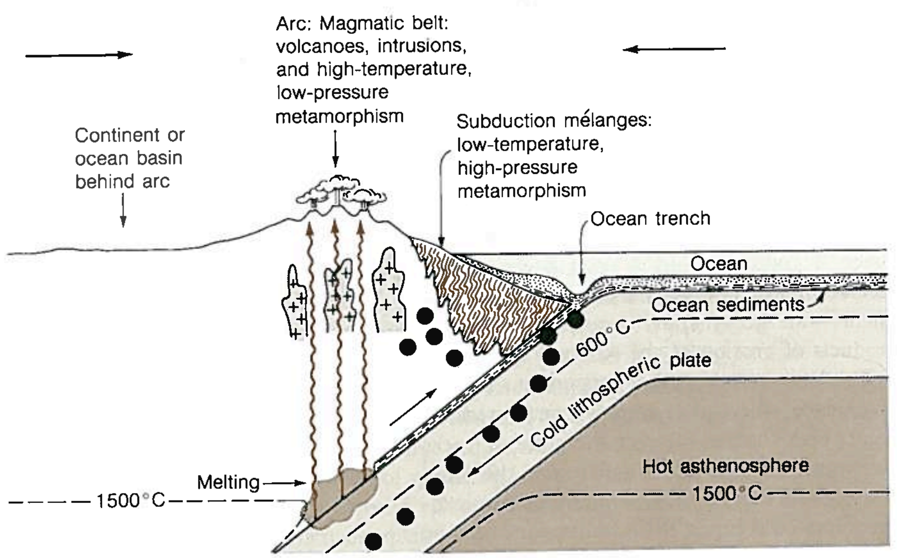


**Figure 19-13**
Geologic features and activities associated with plate collisions and subduction: ocean trenches, mélange deposits, magmatic belts, metamorphism, volcanism, earthquakes (dots). Not to scale. Thickness of lithosphere is about 70 km, depth of ocean trench 10 km, distance from trench to arc is 300–400 km.

mafic rocks, such as gabbro and peridotite, often showing evidence of alteration in a water environment (hydrous metamorphism). A carpet of deep-sea sediments would cover all of this. From Chapters 10 and 11 we remember that these deposits are recognized by thin layers of shale, limestone, and chert,* often intercalated with thin, discontinuous turbidites† and containing the fossil remains of pelagic (open ocean) marine organisms. A combination of deep-sea sediments, submarine basaltic lavas, and mafic igneous intrusions like that shown in idealized section in Figure 19-12, is called an **ophiolite suite.** The presence of narrow ophiolite zones in convergence features like the Alpine-Himalayan belt and the Ural and Appalachian belts may indicate that slices of oceanic crust and mantle originally produced at accreting plate margins were thrust onto land when an ancient ocean finally disappeared as two continents converged. Some geologists believe that the Appalachians, for example, mark the site at which the ancestral Atlantic Ocean closed when North America and Africa converged about 375 million years ago. They also propose that the Atlantic reopened a few hundred kilometers east of this old suture, about 200 million years ago, in a spreading episode that is still underway.

Just as the events that take place in a convergence zone are different from divergence-zone phenomena, so do the rock assemblages have different characteristics. The main features of ocean-ocean or ocean-continent collision are shown in transverse section in Figure 19-13. Thick marine sediments, mostly turbidites, eroded from the continent or the island arc, rapidly fill the adjacent, elongate, marginal depressions. In descending, the cold oceanic slab stuffs the region below the inner wall of the trench with these sediments as well as with deep-sea materials brought in with the incoming plate. Regions of this sort are enormously complex and highly variable, as they include turbidites and ophiolitic shreds scraped off the downgoing slab by the edge of the overriding plate—all highly folded, intricately sliced and metamorphosed. They are difficult to map in detail but recognizable by their distinctive mix of materials and structural features; such a chaotic mess has been called a **mélange.** The metamorphism is characteristically the kind that takes place under high pressure and low temperature, because the material may be carried relatively rapidly to depths as great as 30 kilometers, where recrystallization occurs in the environment of the cold slab. Somehow, perhaps by buoyancy and mountain-building, the material rises back to the surface much later. Find a mélange and you can't be too far from the place of downturn of an ancient plate, long since consumed, but leaving this relic of its former existence.

*A reminder: Chert is a siliceous rock; cherts derived from the siliceous ooze of the sea floor are made up largely of radiolarian (marine protozoans) or diatom (algae) skeletons.

†A turbidite is a turbidity-current deposit—the result of a sudden underwater flow of a mix of sediments and fluids, plunging downslope under gravity, settling finally on the deep-sea floor.



all you must do is look for certain pelagic organisms in magmatic belts.

Refer again to Figure 19-13. Parallel to the mélange is a magmatic belt, coincident with the island arc or a mountain chain near the continental margin as the case may be. Here the conditions are dominated by the rise of magma from the descending plate. At the interface, where the descending plate slides past the overriding one, perhaps friction is great enough to melt the upper part of the downturned slab, including the subducted wet sediments and ocean crust. The liquids rise buoyantly from depths of 100–200 kilometers to erupt and build the volcanic chains on the leading edges of plates. The characteristic igneous rocks produced are andesitic lavas and granitic intrusives. Island arcs, built up from the sea floor, may contain larger amounts of basalt; continental margins typically erupt rhyolitic ignimbrite and are intruded by granitic batholiths below. These differences were discussed in Chapter 15 on volcanism. In contrast to that in a mélange, the metamorphism in the magmatic belts is typically the result of recrystallization under conditions of high temperatures and low pressures. This is because the hot fluids rise close to the surface, delivering much heat to a low-pressure environment.

Paired belts of mélange and magmatism shown in Figure 19-13 are the signature of subduction. The details may differ from place to place, but the essential elements of these features of collision have been found in many places in the geologic record. One can see mélange in the Franciscan Formation of the California Coast Ranges and magmatism in the parallel belt of the Sierra Nevada to the east (Fig. 19-14). This paired belt marks the Mesozoic boundary between the colliding Pacific and American plates, and even shows the polarity of the convergence by the spatial order of mélange on the west and magmatism on the east: the Pacific plate was the subducted one. Other paired belts—for example, in Japan—can be found along the continen-

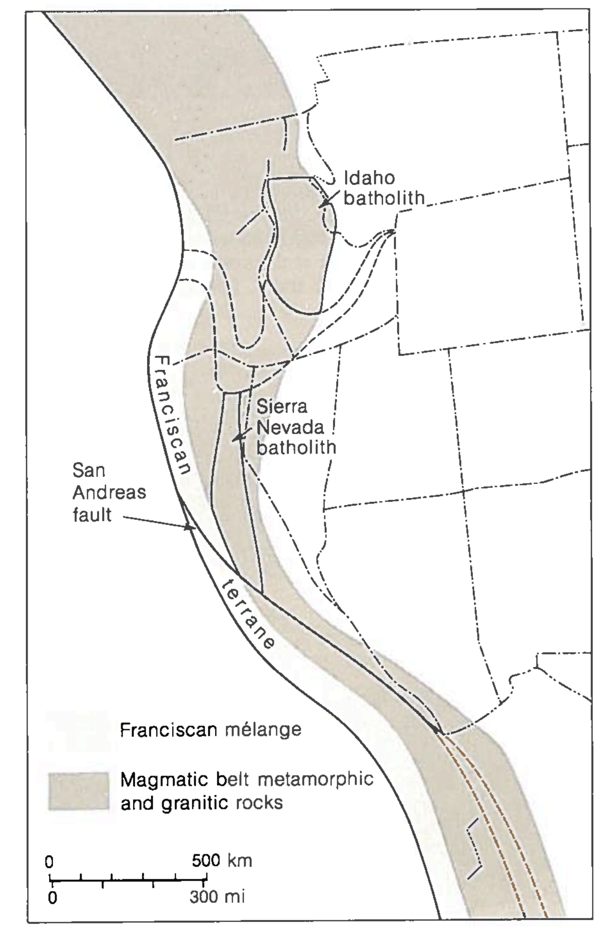


**Figure 19-14**
Paleogeologic map of the western United States shows the geology of the region as it was at the beginning of Tertiary time. The paired mélange and magmatic belts indicate a collision of the Pacific and American plates in Mesozoic time, the Pacific plate being the subducted one. [After W. Hamilton and W. B. Myers, "Cenozoic Tectonics," *Reviews of Geophysics,* v. 4, p. 541, 1966.]