

Excerpt from

Geologic Trips
San Francisco and the Bay Area

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ISBN 0-9661316-4-9
GeoPress

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PREFACE

San Francisco is built on a thick suite of unusual red, green, gray, black, blue, yellow, and brown rocks called the *Franciscan*. These rocks were formed in the *Franciscan subduction zone* as a result of a slow-motion collision between two of the large plates that covered the surface of the earth during Cretaceous time. During the collision, the Farallon plate, which was made up of dark, heavy, oceanic crust, dove eastward under the lighter rocks of the North American plate and continued to sink into the earth's mantle to depths of several hundred miles. While the collision was in progress, there was no San Francisco Bay and no California Coast Range. Instead, there was a deep trench on the ocean floor above the subduction zone. The west coast of North America was tens of miles to the east of the trench and the Pacific Ocean extended far to the west.

After the subduction ended, the rocks in the subduction zone were uplifted to form the California Coast Ranges. The Coast Ranges became the new western margin of North America. As uplift continued, erosion stripped away thousands of feet of Franciscan rocks. Eventually, rocks that had once been at buried at depths of several miles in the subduction zone were exposed at the surface. These rocks now form the well-known hills of San Francisco, the islands in San Francisco Bay, and the sea cliffs and hills of the Marin Headlands and Golden Gate.

San Francisco is probably the best place in the world to observe the innards of a subduction zone. The fraternity of rocks once housed in the subduction zone are well exposed and have been investigated by geologists and other scientists for over a hundred years. As a result of these studies we know where the rocks came from, how and when they got into the subduction zone, and what happened to them during the subduction process. It's a fascinating story. And the story is written in the hills and sea cliffs of San Francisco and the Marin Headlands.

Many geologists have contributed to our understanding of the geology of the Coast Ranges, the San Andreas fault, the Franciscan rocks, and to the geology of the San Francisco area. I have drawn freely on their work in preparing this book. Without their work this book would not have been possible. For brevity and simplicity, I have not referenced these sources in the text, but a number of excellent publications are listed in the section on Further Reading. These references are highly recommended for anyone who wants more detail on the geology of the San Francisco area and the Coast Ranges.

ROCK TYPES, SAN FRANCISCO AREA		
Igneous	Rocks crystallized from magma.	
Basalt	Black or dark green if fresh; most grains too small to see, but may have small white crystals of feldspar. Pillow basalt is basalt shaped like a stack of pillows.	Trip 2. Marin Headlands (Pt. Bonita Lighthouse)
Granite	Light gray, coarse grained, with large crystals of feldspar and quartz; weathers into blocks.	Trip 7. Pt. Reyes Peninsula (Sea Lion Overlook)
Serpentine	Green; slippery; heavy; waxy luster; breaks along curved surfaces, often with grooves.	Trip 1. San Francisco (Fort Point)
Ultramafic	Dark green or black; coarse grained; very heavy; composed of iron and magnesium silicate; mainly pyroxene and olivine.	Trip 4. Ring Mountain (Crest)
Sedimentary	Rocks deposited in water, usually as grains of other rocks.	
Sandstone	Sand grains cemented into a hard rock by deep burial; feels sandy.	Trip 5. Fort Funston (Bluff)
Graywacke	Similar to sandstone, but darker and has and fine-grained matrix of mud and silt.	Trip 1. San Francisco (Alcatraz, Cliff House)
Siltstone	Silt grains (too small too see); cemented into rock; feels gritty.	Trip 7. Pt. Reyes P. (Drakes Beach)
Shale	Mud or clay cemented into rock by deep burial; usually dark gray; soft; feels smooth; breaks into thin tablets.	Trip 7. Pt. Reyes P. (Agate Beach)
Chert	Smooth; very fine-grained; very hard; breaks into sharp fragments; occurs in red layers a few inches thick; silica-rich.	Trip 2. Marin Headlands (Battery 129)
Meta-morphic	Sedimentary and igneous rocks altered by heat and/ or pressure.	
Schistose sandstone	Sandstone altered at moderate temperature and pressure; still has original sandstone texture; also has metamorphic minerals.	Trip 3. Angel Island (lone Point)
Schist	Forms hard plates with shiny surfaces; original rock not obvious, may have been graywacke, basalt or other igneous rock. Blueschist has blue color from blue minerals that form at great depth and at abnormally low temperature.	Trip 3. Angel Island (Perle's Beach) (Camp Reynolds)
Exotic blocks	Large blocks in soft clay melange; blocks are strikingly different from the melange and other blocks in the melange.	Ring Mountain (Taylor Road)

ROCKS OF THE SAN FRANCISCO AREA

Rock Types

The table on the opposite page briefly describes the various rocks that you will see on the geologic trips in the San Francisco area. There are three main types of rocks, *igneous, sedimentary and metamorphic*. Igneous rocks consist of minerals that have solidified or crystallized from molten rock, called magma. The crystals form as the magma cools, just as ice crystals form in a glass of water that is frozen. The type of igneous rock that is formed depends on the composition of the magma and the rate of cooling. If the magma cools slowly, large crystals are formed and the rock is coarse-grained, like the granite that you will see on the Point Reyes Peninsula. If the magma cools rapidly, the crystals are very small, usually too small to see without magnification, and the rock is fine-grained, like the basalt in the Marin Headlands.

When igneous rocks are subjected to erosion and weathering, they break into smaller fragments - pebbles, sand, silt, and clay. These *sediments* are carried by rivers to the ocean and deposited on the sea floor as sedimentary rocks. The most common sedimentary rocks are sandstone, graywacke, siltstone, and shale. You will see examples of these rocks on the trips to San Francisco, Fort Funston and the Marin Headlands. Some sedimentary rocks are also formed by precipitation of chemicals from supersaturated water. Chert forms from water supersaturated with silica. The red chert in the Marin Headlands was formed in this manner.

When igneous or sedimentary rocks are buried deeply in the earth by geologic processes, they are subjected to high heat and pressure and the rocks are altered, or *metamorphosed*. At very high temperatures and/or pressures new minerals are formed by alteration of the previous minerals, and the rock may take on a banded or platy appearance. Some rocks may be altered to the extent that they look quite different from the original rocks. You will see good examples of metamorphic rocks on the trips to Angel Island and Ring Mountain.

Franciscan Rocks

During the first four geologic trips in the San Francisco area you will see examples of many different types of Franciscan rocks - graywacke, shale, red chert, pillow basalt, serpentine, many types of metamorphic rocks, and thick units of melange. This unusual group of rocks was formed in the Franciscan subduction zone, mainly during Jurassic and Cretaceous time. The Franciscan rocks, although named for their excellent exposures in the San Francisco area, are widespread in the Coast Ranges of northern California. Patches of these rocks can be found in the Coast Ranges of Central California and as far south as Catalina Island offshore from Los Angeles.

The most common rock in the Franciscan is *graywacke*, a variety of sandstone that has a relatively small amount of quartz and a relatively high proportion of feldspar, rock fragments, and fine-grained matrix. The typical Franciscan graywacke is about 30% quartz, 30% feldspar, 25% grains of chert, volcanic rocks, metamorphic rocks, and/or shale, and 15% very fine-grained matrix. Graywacke usually occurs in beds that are a few inches to a few feet thick and is commonly interbedded with minor amounts of shale. The shale is similar in composition to the graywacke, but differs mainly in having smaller grain size.

Most Franciscan graywacke, like the graywacke in the Alcatraz terrane, contains *plagioclase* feldspar. This feldspar is rich in sodium and calcium, and was derived from rapid weathering of the volcanic-rich source areas that were prevalent during the early and middle phases of subduction. In contrast, the younger Franciscan graywackes, like the San Bruno Mountain terrane, often contain *K-feldspar*, which is rich in potassium. The K-feldspar was derived from weathering of granitic rocks in the ancient Sierras. This granite was not present during the early stages of subduction.

Melanges are quite common in the Franciscan of the Coast Ranges. The typical melange consists of soft blue-gray clay peppered with hard exotic blocks. Most Franciscan melanges are similar to the Tiburon, Hunters Point and City College melanges of the San Francisco area. The most extensive Franciscan melange is called the *Central Belt*, and lies north of San Francisco.

Volcanic rocks and greenstones make up about 10% of the Franciscan. These volcanic rocks include basalt flows, pillow basalts, agglomerates, tuffs, and diabase dikes, and are similar to the volcanic rocks of the Marin Headlands terrane. Chert is not common, but is fairly widespread, and is almost always associated with pillow basalt.

Most Franciscan rocks are not highly metamorphosed. The rocks that are metamorphosed generally fall into one of three distinct categories: extensive terranes, like the Angel Island terrane; small isolated patches of dense metamorphosed graywacke or greenstone; and metamorphosed exotic blocks that occur in the melanges, like the exotic blocks at Ring Mountain.

Serpentine is also widespread in the Franciscan. It can occur in thick sheets, like those at the top of Ring Mountain; as isolated blocks that have forced their way into other Franciscan rocks; or as blocks within melanges, like the serpentine blocks found in the Hunters Point melange at Fort Point.

