

## ENCYCLOPEDIA ARTICLE

## Paleoseismology

The study of geological evidence for past earthquakes. This is a scientific discipline that has contributed greatly to modern understanding of the nature of earthquakes. The patterns of earthquakes, in both space and time, evolve over centuries and millennia and cannot be discovered by modern instruments. Knowledge of these patterns is important for understanding the physics of earthquakes and for forecasting future destructive earthquakes.

In certain natural environments, the features related to ancient earthquakes are preserved in the landforms and superficial layers of the Earth's surface. Geologists use this paleoseismological evidence to extend the short historical and instrumental record of earthquakes into ancient centuries and millennia.

Paleoseismological studies have been extended into the ancient past; they have clarified the earthquake record of many parts of the world, including the midcontinent and east coast of the United States, northern Africa, southern Europe, China, Japan, Indonesia, and New Zealand.

### Sedimentary record of ancient earthquakes

In certain geological settings, the disruptions produced during large earthquakes become preserved in geological strata. These sediments, therefore, provide a record of the earthquake. In this respect, the sediments are like seismograms. Geologists study the disruptions of these sediments to gain a better understanding of the earthquake. The San Andreas Fault in southern California provides one of the clearest examples.

Most Californians live within 100 km (60 mi) of the San Andreas Fault. Along the fault, coastal California, including Los Angeles, Monterey, and San Diego, has slipped northwestward over 300 km (180 mi), relative to the rest of North America. Despite this large horizontal translation over millions of years, no more than a few meters has occurred along the fault in the two centuries of historical record. These small movements occurred primarily during two great earthquakes—the 1906 San Francisco earthquake in northern California and the 1857 Fort Tejon earthquake in the southern part of the state. See also: Fault and fault structures

With no more than the short historical and instrumental records, scientists had no clear understanding of the frequency of large, destructive earthquakes produced by the fault. Fortunately, paleoseismological studies in southern California have extended the known record of earthquakes back nearly two millennia. Northeast of Los Angeles, a record of 10 large earthquakes is preserved in peaty and sandy stream and marsh deposits. Faulted sediments record evidence of the great earthquake that occurred around 1480. Overlying layers were deposited after this strand of the fault broke, and thus are undisturbed.

### Dating ancient earthquakes

In addition to determining the amount and type of motion along a fault in an ancient earthquake, it is necessary to determine the date. Radiocarbon dating is the most common of many methods. Precise dating of earthquakes along the San Andreas Fault has shown that earthquakes along one part of the fault have struck southern California about every 130 years on average. In the past, 10 large earthquakes occurred along the San Andreas Fault northeast of Los Angeles. The 1857 earthquake is known from historical records. The 1812 earthquake is a historical event, but was not known to have been generated by the San Andreas Fault until the completion of paleoseismologic studies of disturbed trees along the fault. The other quakes have been dated by the radiocarbon method. It is curious that the intervals between the earthquakes have

ranged between 44 and about 330 years. See also: Radiocarbon dating

The reason for the large variation in the dates of the earthquakes is the subject of much debate. Such large natural variations make forecasts of future earthquakes uncertain. Knowledge of the average period between large earthquakes, however, has given Californians a more informed basis for earthquake preparedness. Based upon paleoseismic data from several localities along the fault, the southern 200 km (120 mi) of the fault, near Palm Springs and San Bernardino, are considered the most likely to produce the next great earthquake in California. See also: Seismic risk

### **Geomorphic record**

The world's greatest earthquakes occur at subduction zones, where great slabs of oceanic lithosphere are sinking diagonally into the Earth's interior. One of the largest earthquakes of the twentieth century, of magnitude 9.2, was generated on the subduction zone of southern Alaska in 1964, when a huge slab of the Pacific Plate lurched suddenly downward about 30 m (100 ft) beneath Alaska. Southern coastal communities were devastated by the long and heavy shaking, by the seismic sea waves (tsunamis) that swept over them, and by permanent submergence of the land. No earthquake of this size had struck this portion of Alaska in the entire two centuries of recorded history. See also: Plate tectonics; Subduction zones; Tsunami

Studies of the effects of this devastating earthquake revealed paleoseismological evidence of previous great earthquakes in this region. There was clear evidence of earlier uplifts on a small island, far out to sea, that had risen 3.4 m (11 ft) in 1964. The flat-topped island exhibits a set of six concentric ancient shorelines, each a few meters higher than its seaward neighbor; these appear as small dark cliffs. Radiocarbon dating of the ancient shorelines revealed that the top of the island, now 50 m (165 ft) above sea level, first rose above the sea about 5000 years ago. In the past 5000 years, uplift occurred episodically, during six ancient earthquakes, 500 to 1500 years apart. The shoreline of early 1964, now also dry and 3.4 m (11 ft) high, forms a ring just inland from the modern shoreline.

Other than a few moderate earthquakes, the Cascadian subduction zone of the Pacific Northwest of the United States has been quiet during the period of historical record. Older building codes in Oregon reflect a historical lack of concern about earthquakes there. Along the coasts of Oregon and Washington, however, there are clear records of sudden and recurring submergence, a paleoseismic record that has been related to great earthquakes on the Cascadian subduction zone. In many coastal estuaries, geologists have found layers of peat intercalated with silt beds. The peats are composed of plants known to grow at certain elevations in the estuaries. The silts, carried to the sea by nearby rivers, are known to settle upon the floor of the estuary in deeper water. Yet, the paleoseismologists have found that the peats now reside well below the level at which they grew and were buried by the silts. Radiocarbon dating of the peats indicates that sudden submergence of the estuaries has occurred several times in the past few thousand years, most recently about 300 and about 1200 years ago. In some localities, geologists have found sand atop the peats, carried into the estuaries from the sea by tsunamis. Since the discovery of paleoseismic evidence for great earthquakes in the Pacific Northwest, much more civic attention has been focused upon seismic building codes and earthquake preparedness there.

The geological preservation of ancient earthquakes also has enabled scientists to compare modern earthquakes with those of the ancient past. In 1983, for example, a sparsely populated region of Idaho was struck by a magnitude-7.3 earthquake. Investigations after the earthquake revealed a fresh, 30-km-long (18-mi) fault scarp running along the western base of the lofty Lost River Range. During the earthquake, Borah Peak, which crowns the range, had jumped 2 m (7 ft) skyward. Inspection of the fresh escarpment produced during the earthquake revealed that it is surmounted by a more subdued, vegetated escarpment of

nearly identical length and height. Excavations across this ancient fault scarp showed that it had formed during an event very similar to the earthquake of 1983 but about 5000 years earlier. This is one of several examples of what paleoseismologists call a characteristic earthquake. It appears, from such examples, that some earthquakes are nearly identical repetitions of their predecessors. If nature were always as regimented as this, the prediction of earthquakes would be far simpler. Unfortunately, many examples of irregular behavior of faults also exist. See also: Earthquake; Seismology

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