CALIFORNIA QUAKE DUE TO EARTH CRACKS

Breaking of Rock-Masses, Along Fault Lines, Made Concussion That Shook Down San Francisco.

WHEN a heavily laden wagon rolls along a street, it sets up a miniature earthquake, that rattles windows of near-by houses.

When a solid rock mass within the earth breaks under dislocations of the earth's crust, the snap and jar make an earthquake that shakes down cities.

In the case of the wagon the crust of the earth merely trembles within a small area, because the jar is feeble. But in the case of the other the crust is shaken with a violence that wrecks buildings and sends a quiver throughout the world, as recorded by scientific instruments in far-off lands.

Breaking of Rock Masses.

The earth is wrinkling continuously into mountains and valleys. This movement puts an enormous strain on the rock masses beneath the surface. Sometimes they bend and stretch without breaking, but often they split and tear apart. The slip and grind produce a concussion called earthquake. Though the slip may be only a few inches, it is often disastrous to the surrounding country and the undulations may extent hundreds of miles.

This is the kind of jolt that shook San Francisco. It is the kind that makes the frequent shocks in Japan. To it are traced the most destructive earthquakes that have occurred—not to volcanoes, for some of the severest quakes have taken place distant from volcanes and the worst of them have had no connection with lava explosions. However, quakes are commonest in mountain regions.

What Makes Earth-Wrinkles?

What causes the earth to wrinkle? This question is one of dispute among scientists. Some attribute it to shrinkage of the earth's cooling mass, just as a drying apple shrinks and its skin wrinkles. The crust of the earth is but as a thin skin—only about 30 miles thick, while the globe inside is almost 8000 miles through.

Another explanation is that the heating and expansion of rocks cause the pressure that makes the fracture.

Still another is that the erosion of the earth's surface by water and air, and the carrying away of enormous quantities of finely powdered rock-masses by rivers, shift the weight of the crust on the globe, removing a load from one region, which therefore may tend to rise, and, taking it to another, which may be caused to sink. This causes pressures at weak spots and a collapse or yielding to relieve the strain. According to this theory the breaks occur almost always near the ocean, due to vastly increased pressure of sand and silt on the ocean's floor.

The first and the third explanations are advanced by prominent geologists for the San Francisco, or rather the California quake, for the disturbance was felt in many large areas of the state, and that city suffered most on account of its vulnerability.

Earth-Cracks Are Weak Spots.

Where a break has once occurred thereafter is a weak spot, and at that place strains on the region round about are likely to be relieved by new shiftings.

The breaks in the earth's strata are called "faults." They are gaps, or lines of cleavage in the layers of rock, that make up the world's surface.

Are there faults in California? Yes, many of them. California has had many earthquakes in the century that white men have studied the region. The mountain wrinkling of the Coast Range is proved by geologists to be recent and still in progress. The mountain uplift makes many fractures, and most of them follow weak fault lines. The underground jars are transmitted to the soil of the adjacent country, becoming less violent, the further away from the break.

Big Fault Near San Francisco.

One of these breaks is south of San Francisco, five miles west of Stanford University, called the Portola fault. The great shock of April 18, 1906, was due to a new fracture along this old fault, which can be traced 40 miles, more or less, says Dr. David Starr Jordan, by disturbances in the surface soil. The known length of this fault is nearly 200 miles, reaching more than 100 miles north of San Francisco.

Other faults may have been involved also. The long parallel valleys of the state are believed to have been caused in part by old-time faults. "One great fault that seems to have been involved in the San Francisco earthquake," says Professor J. C. Branner, head of the department of geology, Stanford University, in the Pacific Monthly for June, "follows down the entire length of the Santa Clara Valley, from about the headwaters of the San Benito, south of Hollister, past San Jose, through the Bay of San Francisco, up the valley past Santa Rosa, Ukiah, Willets and down the Eel River to Eureka, in Humboldt County, 350 miles. Since the earthquake, this fault line has not been examined thoroughly, but many cracks have opened along its axis, near the south end of the Bay of San Francisco, between Milpitas and Alviso. At this place, not only were large cracks opened in the soil, but for a couple of days water ran out through the cracks, bringing up sand and forming small cones about them."

Crack 150 Miles Long.

Another fault—the one believed to have been most involved in the break of April 18, and in the many successive shocks since—is the one first mentioned. Along the California Coast, extending from Garcia River, 100 miles north of San Francisco, to Santa Cruz Mountains, 50 miles south of that city, making a break line over 150 miles in length. Where this line dips into the ocean, muddy water has been observed by navigators. Passing San Francisco, this line is under the ocean, and running south, it enters the shore again at Mussel Rock, seven and one-half miles south of the Cliff House. It appears that the land on the oceanside of the break shifted northward, or that on the inlandside, where San Francisco stands, the land moved southward, or that both these movements took place on the two sides of the break.

The conclusion to be drawn from geological and seismical observations is that earthquakes in California have been of frequent occurrence and that they will continue. The many faults visible in the surface of the earth are evidences of the many jars to which California has been subjected.

"The fact, however," says Professor Branner, "that there are so many and such recent faults in this region, leads us to expect that there can be no very destructive shocks, simply because great strains cannot accumulate in rocks so much broken. There will be small shocks but it is improbable that there will ever be any more violent than that of April 18, 1906."

Coast Range a New Ridge.

The process of mountain formation is going on continuously. New crests are rising out of the sea and other portions of the earth are sinking. The Coast Range, in California, Oregon and Washington, is one of the young mountain chains that have been "squeezed" up out of the sea by pressure on the earth's crust, resulting in "folding" or "rumpling" of that crust into mountain ridges.

The earth's crust is composed of layers or strata of rock, that were deposited, mostly by the sea—more than one-half the surface of the earth being of rocks that were laid down by the sea, as is pointed out by Ralph S. Tarr, professor of geology, Cornell University. These layers are displaced from their even, level form, and often tilted and folded by the "wrinkling" already described, and while some of them, under the enormous pressures to which they are subjected, yield without fracture, oftentimes they break with a concussion that makes an earthquake.

Mountains are of slow, not sudden growth. This is the rule, though there are exceptions. While they are growing, plants and animals and men dwell upon them, scarcely aware of their rise. The Japanese Islands and the East Indies are examples of mountains still in this moving process, and in those regions earthquakes are common. The breaks that occur in the strata open fissures in the earth's crust, which release the molten masses beneath, resulting in volcanoes.

Volcanoes Due to Faults.

Such lava spouts are common in mountains, for the reason that mountain growth produces fault breaks or fissures. These fissures, if near the ocean, often admit sea water into the hot interior of the earth. Then follows a battle between the expansive energy of the pent-up steam and the retentive resistance of the surrounding strata, ending in an explosion like those of Vesuvius and Pelee. This is the most violent kind of volcanic eruption.

The most notable eruption on record was that of Krakatoa, in 1883, in the Straits of Sunda, between the Islands of Java and Sumatia, when half the island was blown into the air. A prodigious mass of ash and dust was hurled upward apparently reaching elevations as high as 15 miles above the sea, where the finer portions floated about in the upper air currents, passing entirely around the earth and causing brilliant sunsets in both Europe and America. To a distance of 150 miles from the eruption the day was darkened. Some of the ash falling back on the island buried the surface to such a depth that a new vegetation has been obliged to develop. Vast quantities of ash fell also on the sea and floated about in such masses that for weeks navigation near the volcano was difficult. The eruption also produced a great earthquake wave, that rushed on the neighboring coast, flooding it to a height 100 feet above the ordinary sea level, causing an appalling loss of life. The wave extended as far as the coasts of America, Africa and Australia, having passed over a distance of more than 5000 miles.

Volcanoes Not Quake-Makers.

Mighty as was this eruption, earthshaking was not felt even close to the island, though thunderings were heard across two oceans. In 1888, when Bandaisan, a mountain in Central Japan, suddenly blew off its head and shoulders, the earth tremors hardly extended 50 miles. Drawing conclusions from these facts, John Milne, a celebrated English scientist, says:

"As earthquake producers volcanoes do not add one per cent to the seismic history of our globe. From time to time they produce crops of tiny tremors, and that is all. To a certain extent both may be regarded as having a common parentage, but beyond the fact that an earthquake occasionally shakes a volcano into activity, their direct relationship is slight."

Thus it is not to be supposed that volcanoes and earthquakes stand in the relation to each other, of cause and effect, but that they represent different expressions of the same subterranean force. This force is usually believed to be contraction of the earth, whose pressure either causes the rising of liquid rock near enough the surface to be expelled by steam through the fissures made by the breaking of the strata, or melts the rocks in the roots of mountains, through the liquefying force of the pressure, and the molten lava coming in contact with water, is forced to the surface and blown out by steam.

One Cause Produces Both.

Therefore we see that one agency produces volcanic eruptions—heat—while another produces earthquakes—faults—and that while the origin of the two may be the same there is no likely connection between the activity of a volcano, say of Vesuvius, and a quake of the earth in another part of the world, say in California, though a quake might stir a volcano to action. What causes the rise of mountains and the sinking of other areas and what produces the lava and the steam? These are unanswerable questions.

But we are digressing from the real subject of earthquakes.

The Pacific Coast of America is the latest addition to the continent, and the Coast Range, whose growth is believed to be the cause of the faulting about San Francisco, is the youngest of mountain ridges. Time was when that portion of America west of the Allegheny Mountains was beneath the ocean. At that time the Appalachians of the Atlantic coast were as great a chain, perhaps, as the Rockies, today. This was "long before the flood," as pointed out by H. S. Lyman, in his History of Oregon and long before the ages of ice and indeed far back toward the Archaean times.

Growth of American Continent.

Slowly this part of the present continent rose from the ocean, forming mountain chains, between which extended gulfs from the sea or inland seas. The Rockies lifted themselves up, then the Sierra Nevadas and the Cascades. The Willamette Valley in Oregon was a sound, whose waters surrounded the hills that are now seen to rise like islands from the plain. The basin of the Columbia River was an inland sea, whose remnant is Great Salt Lake and the Blue Mountains were an island, overlooking an expanse which has now been raised to a continental plateau. The pressure of the earth's shrinkage, throwing up the Cascade Mountains higher and higher, opened fissures through the fault breaks, up which welled molten lava, seeking relief from the inside pressure, and building up the cones of Mount Hood, Mount Jefferson and Three Sisters in Oregon; Mount Adams, Mount Rainier, Mount St. Helens and Mount Baker, in Washington, and Mount Shasta and other numerous peaks in California.

But there was an earlier time, when even the Appalachian range was an ocean bed; the strata of that ancient range, though worn down by the denuding agencies of air and water, show that they were deposited by the ocean and were uplifted by the buckling of the earth's crust.

Strata Deposited by the Sea.

For a long time before the Appalachian and the Rockies and the Cascades and the Coast Ranges began to rise there was a preliminary settling of the sea bottom, during which thick deposits of sediment were accumulated on the ocean floor. These mountains therefore were made out of thick beds of sediment, which were deposited mostly if not entirely near the shore lines during a period of long-continued subsidence. Such was the condition preliminary to the rise of the Appalachians, these mountains being formed out of sediments which in some places became 30,000 or 40,000 feet thick. As these beds were folded up by the earth's pressure, there was a crushing of the materials, faulting and outpourings of molten masses.

In California the Sierra Nevada, and in Oregon and Washington the Cascades once formed the western boundary of the North American Continent. The Pacific Ocean washed against the foot of that range, just as it now washes against the foot of the Coast Range. Where California now is, marine sediments accumulated to a thickness of 20,000 feet. Just before the arrival of existing forms of life on the world, these sediments, yielding to lateral pressure, were crushed upward. The Coast Range slowly rose from the ocean and California came into existence. Such is the explanation made by the English scientist, John Milne, who says further:

California a New Land.

"Geologically, it is an extremely new country; its faulted rocks show that it has experienced many severe shakings, whilst its history tells us that it is in a state of seismic unrest, particularly in its central region. Like Japan, the Alps and the Himalayas, the Coast Range is still growing, and as it increases, fracturing of rocky strata must take place. As an evidence of its growth, it may be mentioned that the precise levels made from San Francisco toward Los Angeles a few years ago differ from eight inches to a foot with those made last season. Not only is there a bending upward, but from San Francisco northward the strike of the Range changes, and horizontal deformation may also play its part in the production of seismic stress.

"If the water of the Pacific could be removed, we should see a coast range not merely 1200 feet in height, but a steeply sloping ridge of 13,000 feet. The basal frontiers of slopes, with the steepness these figures indicate, are recognized districts of seismic activity. Soundings also indicate that along this suboceanic frontier submerged valleys of considerable depth are to be found. Such a valley exists near Monterey, off the mouth of the Salinas River, extending westward toward the bed of the Pacific.

"From Salinas on April 27 we hear that shocks were felt every day since the shock of April 18. The Salinas River had sunk 10 or 12 feet along its course for miles. Nearly all the bridges have been condemned and will have to be rebuilt. From this and other records, it may be inferred that the Salinas Valley, visible and invisible, was as much a center of disturbance as was San Francisco."

Many Quakes in California.

Many quakes have been felt in California in the century that white men have been closely familiar with. This is not the case with the Oregon and Washington portions of the Pacific Coast, which have the Cascade and Coast ranges to match the Sierra Nevada and Coast ranges of California. In Oregon and Washington it cannot be said that a slight tremor has never been felt in the earth's crust, but there have been no earthquakes here in the 75 years that white men have been living in these states.

The first earthquake recorded in California was in October 11, 1800, followed in 1803 by a second shock, and again in 1806 by a third one. The years 1818, 1830 and 1857 each were marked by severe seismic disturbances. In 1868 there was a very heavy shock around San Francisco Bay. Others followed in 1871, 1898, 1899, and finally the disastrous one of last April.

Evidences of the rise and depression of regions of the earth's surface are many. The Middle Western portion of the United States has been sinking for many years. On the New England shore there are many places where forest trees and peat-bogs are under the ocean tide. The coast of Maine carries evidence of land submergence; so do the Hudson River, the St. Lawrence, Delaware and Chesapeake Bays and San Francisco harbor. The coast of New Jersey is known to be sinking at the average rate of two feet a century. Two years ago Chicago was startled with the announcement that the site of the city is subsiding.

Signs of Increasing Elevation.

In many parts of the world there are abundant evidences also of growing elevations along shore lines. The great earthquake in Japan in 1891 caused the ground to rise on one side of a fault which was traceable over a distance of many miles. The shore of Peru was raised three or four feet by an earthquake in 1822, and a part of the shore of Chile was raised four or five feet in 1835. Along the western coast of South America there is evidence of a much greater elevation in recent times. An example of this movement is cited by Professor Tarr, in his work on geology, as follows:

"The evidence of the movement of the land that has been most frequently described, is that of the Temple of Jupiter Serapis, near Naples, in Italy. This was built near sea level, and three of its columns are now standing, while the floor of the temple is beneath the water. At a height of 12 feet above their base these columns begin to show the borings of a shell, the lithodomus, which bores in the stones on the shores of the Mediterranean. The borings on these columns continue through a distance of nine feet. They could have been made only while the columns were standing in water, and the reason for their absence in the lower 12 feet is that the lower 12 feet were cased in mud. So built on dry land, these columns sank 21 feet or more and then were raised again to nearly this height. Even while the Romans used the temple the land was sinking and a new floor had to be laid above the water level."

To return again to the California earthquake.

Dr. Jordan on California Quake.

As has been said, San Francisco stands on the inland side of the great fault that runs along the coast. On the ocean side of that city the fault dips under the sea. On the authority of Dr. Jordan, we learn that the Sierra Morena, which forms the backbone of the peninsula of San Francisco, has suffered a displacement. The fault on the ocean side of the range has slipped northward, he says, three to six feet, with change of level on either side. It is from readjustments along this line that San Francisco earthquakes usually originate, and the frequent lesser shock since April 18 come from further settlings along the line of this fault.

Evidence of displacement is seen in the shearing off of water mains. Unfortunately for the city, the mains were laid out so as to cross the fault near the northern end of the structural valley at an angle of about 45 degrees. When the earthquake came nothing could save them. No matter what their construction might have been, the very great shifting which occurred would have produced the same result. They were cut as though by a huge knife.

The maximum slide was approximately six feet. All pipes and pipe lines were shaved off. Where fences crossed the fault the sections on either side are displaced many feet. The whole of the western fragment seems to have been moved forward toward the north-northwest.

Ruins Near the Fault.

Everything on or near the line of this fault suffered severely. Stanford University was near it and is almost a ruin. Salinas City, nearly in its path, is laid waste. The large sugar plant below Salinas, built by Mr. Spreckles, has buckled up, and the huge steel beams shortened up a foot or two. San Francisco lay somewhat to the north and east of the fault and suffered very severely in places. Here, in some localities, the jelly-like shaking was most marked, and wherever in the city was soft soil, or filled-in land, there great damage resulted.

On the other hand, the experience has demonstrated that even very large buildings may be built upon such soil, if the foundations are constructed with the nature of the soil and the liability to earthquakes ever in mind. For example, the ferry building is built on piles sunk in the mud of the bay, yet the floor of the building is perfectly level, and the building itself in all essentials is undamaged. But the foundations of the ferry building were put in to stay. There are 72 groups of 60 piles 80 feet long, driven down into the hard blue clay. On top of these groups of piles concrete arches were built, and on these arches rests the Ferry building, a structure of steel and cement. When the earthquake came this building, practically a solid mass from foundation to top, vibrated as a unit, and, except for the splitting off of some of the stone casing, is undamaged.

Many changes and land shifts have been noted in addition to those observed along the fault, but the general opinion of those who have studied the problem seems to be that all such lesser movements, as for instance, the sliding of secondary faults which branch from the San Bruno, are resultants and not causes. In places such secondary faults, which meet the main at an acute angle, give the appearance of having been thrust wedgelike north into the land above. Here the knowledge gained by Professor Branner in years past will be of the greatest value, as the measurements and surveys now being carried on by him will tend to clear up many of these now obscure points, particularly when taken in conjunction with the work of the Coast Survey in re-establishing the exact location of what are called points.

Displacement at Big Break.

Professor Branner describes the fault as follows, in the Pacific Monthly:

The northern end of this line of fracture has not yet been gone over by the writer, but from Mussel Rock toward the southeast it has been examined in detail to near Loma Prieta, in the Santa Cruz Mountains. Everywhere along the southern part of this line the rocks have been broken, shifted and squeezed past each other. Being an ancient fracture, the rocks upon and everywhere near the break are so ground up that it is seldom that large blocks are to be seen near the fault. In most places the soil is deep and yielding, so that any movement along the fault is partly taken up by the drag or yielding of the soil and loose materials that conceal the fault. These details are important, because they suggest that the total displacement along a fault plane is not likely to be clearly and fully shown by the displacement in the soil or elsewhere on the surface of the ground, and they also account for the fact that the displacement visible at

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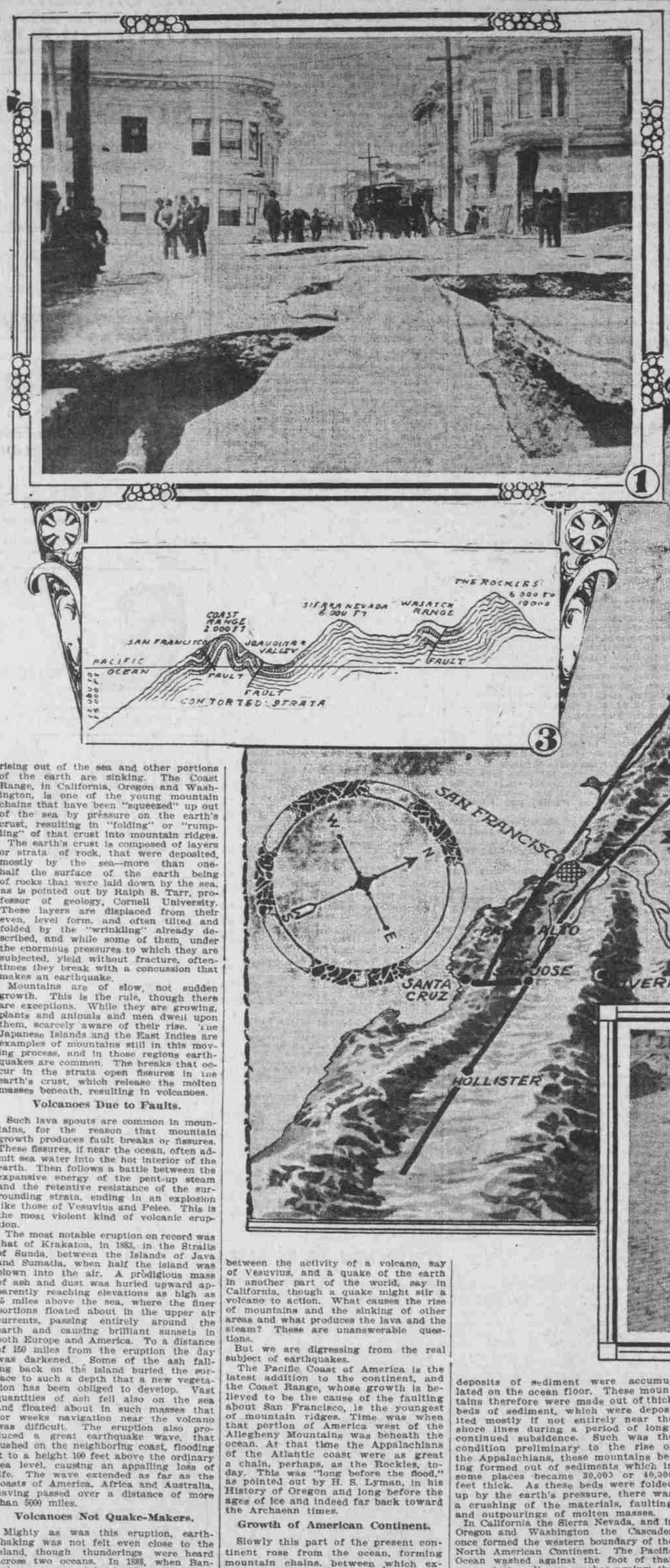

1. Breaks in street pavement and ruined water mains on Valencia street. The building on the left has sunk to the second floor.

2. Cracks and displacement on a fault line near Stanford University.

3. The Coast Range, at the foot of which San Francisco is situated, consists of closely compressed and contracted strata, which have broken under excessive strain with a shock that caused the recent great earthquake. The places of the breaks are known to geologists as faults and are cracks in the earth's crust. The strata represent sediments which collected on the sea floor until they were 30,000 feet, more or less, in thickness. Eventually they yielded to horizontal pressure, supposedly from weight of the sea floor or from contraction of the earth, and were buckled up in their present position to make one of the last additions to the American Continent, the Coast Range. This range, like most mountain ridges, represents a line of weakness in the earth's crust, and the recent great earthquake indicates that the process of mountain formation on the western side of North America has not ended. It was still buckling up, when it suddenly yielded, April 18, 1906, and the crash which followed gave rise to the earthquake.

4. Cracked pavement at Eighteenth and Howard streets. (The foregoing pictures are from the Pacific Monthly.)

The large map, accompanying the above pictures, is marked by black lines along the "faults" where the earthquake started from fracture of internal rock masses.

At least three main cracks or "faults" in the earth's crust are believed to have been involved in the California earthquake, being places where the breaking of subterranean rock masses, under the "wrinkling" of the earth and the buckling up of the Coast Range, made jars which were transmitted to San Francisco and other places.

One of these, believed to be the largest and the cause of previous quakes in San Francisco, is that which has been traced along the Coast from Garcia River, 100 miles north of San Francisco, past that city on the ocean side to the Santa Cruz Mountains, 50 miles south of the Bay City.

Another is that running through the Santa Cruz Mountains, between San Jose, inland, and Santa Cruz, on the ocean.

The third runs the entire length of Santa Clara Valley, from San Benito River, south of Hollingsworth, past San Francisco, through the Bay of San Francisco, northward past Santa Rosa, Ukiah Willets and down Eel River to Eureka, on the ocean, a distance of 350 miles.