of this university, carved on the granite gateway presented by him to Cornell:

So enter that daily thou mayest become more learned and thoughtful,
So depart that daily thou mayest become more useful to thy country and to mankind.

ERNST COHEN

CORNELL UNIVERSITY

SO-CALLED VOLCANIC EARTHQUAKES[1]

IN considering the crustal mechanism that shakes the surface of the earth geologists seem to have adopted a convention or fashion, backed by honored names like Dana, Geikie and Suess, that relegates volcanic causes to the background. Volcanism to many teachers does not connote magma and substratum, but rather volcanoes and explosions. On the other hand, geanticlines and geosynclines, quite apart from anticlinoria and synclinoria in stratigraphic series, are drawn around the earth in long belts through every possible geologic structure and topographic obstruction under the magic of the word "tectonic." I have not found a single text defining the word "tectonic." Frankly, I do not know what it means. We are told that it is derived from a word meaning "roof." A roof is a structure protecting a void within. Tectonics involves "folding" into "forelands" whole strips of the earth's surface containing everything from gneiss to till and from granite to flowing lava, and from mountain ranges to a quarter of a continent. I am not mathematician enough to appreciate the geometry of folding a surface. If I might venture appositely to coin an equivalent word "volcanics," current texts would give the student to understand that volcanics involves explosion of steam mostly along ocean shorelines. Tambora and Krakatoa are the types; the earthquakes there are tiny and due to underground gases, and they are shallow and diminish a short distance away.

Modern volcanology is not in sympathy with these ideas. "Volcanic earthquakes" have no more meaning than "tectonic" ones. The volcano is not the seat of volcanism. The volcano is the least part of the process the volcanologist is interested in. The explosion is the part least volcanic of the very small part of volcanism that the volcano represents. I am speaking volumetrically.

What modern volcanology is interested in primarily is the under heat and the juvenile gas of the earth crust, the identity of that crust, thermal phenomena of geophysics wherever found and wherever measurable, kinetic phenomena of all sorts which can be considered fundamentally thermal, and measurable gradations athwart the land and vertically downward (and also athwart that seventy-two per cent. of the surface called sea-bottom), which will lead by quantitative measurement to sound and reasonable theory concerning magmatic intrusion in progress to-day. This and this only is the reason for studying active volcanoes, in order to find gradations away from them in measurable process. The processes measurable are primarily heat evolution, juvenile chemistry, seismicity, visible magmatic emission, gravity and terrestrial electric fields. All sorts of devices are possible by way of method. The science is essentially experimental because untouched. Seismology and geodesy have provided solid ground for belief in a crust and in a more mobile substratum. The geology of igneous rocks undeniably exhibits them everywhere in depth.

The earth's crust and the under stratum of magma are necessary for the concept of isostasy. Bowie, Sandberg and others have come to the conception of thermal isostasy. The crust is in balance. The disturbance of balance may arrive below by intrusion or cooling, or above by erosion and accumulation of sediment. The balance is a fact. Volcanology must measure the disturbances, assisted by all the other branches of geophysics. If the balance is a fact, and magma is a fact, and crust is a fact, and magma moves at volcanoes, and the crust moves as proved geodetically within decades and seismometrically within hours, there seems no possible doubt of the fact that magma moves at places where volcanoes have long since been buried and replaced by intrusion, or even where volcanoes of modern type have never existed. These motions just as much concern volcanology as volcano movements.

Gradations of volcanicity across country are exactly what are found and cited by the authorities as being non-volcanic. In Montessus de Ballore's "Geologie Sismologique" of 1924, page 225, the diminution of seismicity from north to south in Chile with increase of volcanic eruption in that direction is cited as proving that the earthquakes are "non volcanic." And in time the increase of earthquakes when volcanoes become quiet proves that earthquakes are "non-volcanic." No reasoning could possibly seem more fallacious to one who thinks of volcanism as dominantly intrusive.

If one examines the facts of these gradations in the world, the more one is impressed by both time and place evidence, that as crust thickens over magma and outflow of lava disappears, the seismic centers become

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deeper, the thermal manifestations change from boiling springs to warm springs, the seisms become fewer but perhaps stronger, the area over which these are perceived becomes larger, probably geodetic level and creep change becomes smaller and more widespread, and in large-scale sequences across continents the geologic formations and deformations become older.

Examples of such gradation are the change cited from seismic north to volcanic south in western South America; from seismic south to volcanic north in California; from volcanic Aleutian Islands to seismic Mount McKinley; from volcanic Java to seismic Sumatra; from volcanic Tertiary to seismic modern in most of the volcano districts of the world; and across the United States from east to west from deep volcanic and deep seismic at the east to shallow or active volcanic and seismic at the Pacific coast, with much higher thermal gradients. Across the United States also we pass in general from older to younger deformations.

It is precisely because of such gradations and because of isostatic adjustment as conditioning process that it seems reasonable to consider heat and magma as conditioning the causes of big earthquakes. This would be through intrusive flow, gas expansion, change of volume by water acquisition or crystallization, deep-seated engulfment accompanying "stoping," thermal effects on the environing rocks and every other possible magmatic motion conditioning pressure, *except* volcanic eruption, subterranean explosion or "collapsing steam." No volcanologist would seriously consider any of these last as having any bearing on the earthquake problem whatever.

T. A. JAGGAR

HAWAIIAN VOLCANO OBSERVATORY

NEW YORK CITY AS A FIELD FOR EARTHQUAKE STUDY[1]

THE modern seismograph has been developed during the last thirty-five years. Within this period, the study of earthquakes has passed from a more or less speculative phase to a quantitative study of the phenomenon. In 1912, two 450 kilogram components of a Mainka seismograph were installed in the American Museum of Natural History, New York. Numerous earthquakes have been recorded on these instruments during the past thirteen years, but the greater number of the disturbances have been distant quakes which originated thousands of miles from New York. Nearby quakes have also been recorded, but most of them have been so faint that they were not felt by citizens of the city. Those of February 10, 1914, and February 28, 1925, which originated in eastern Canada, were felt, however, by a large number of the inhabitants of New York City and the northeastern United States. Although the metropolis is considered to be immune from earthquakes by a large number of scientists and laymen, the above brief résumé indicates that it is advantageous to have seismograph stations in New York City. There are two stations at present, one at Fordham University, and the other at the American Museum of Natural History.

In an earthquake record, or seismogram, we are concerned with the mechanical effects propagated from the region in which the earthquake occurred. Astronomical and seismological theory demand a solid earth with more or less uniform physical properties for the propagation of the earth waves. The wave effects on a seismogram of a distant earthquake may persist for several hours, although at the point of origin they may last for only a few seconds. On such a record three principal phases of types of waves, corresponding to the longitudinal, transverse and long waves, may be noted. The first two types travel by the shorter way, through the earth, and the third type around the earth's surface. The initial portion of the record will be recognized as the longitudinal waves or first preliminary tremors. These waves are of short period, small amplitude and tend to die down preceding the arrival of the transverse waves of second preliminary tremors, which are of longer period, quite irregular and of greater amplitude. The relative duration of these first two types of waves on the record is dependent upon the distance, the greater the distance the longer the time involved. The third type, or long waves, have a much greater amplitude and assume a strongly periodic and sinusoidal character. For distances greater than two thousand kilometers the first phase is indicated by a few waves with a period of about twenty seconds which gradually increase in amplitude. This phase is followed by a rapid development of extremely smooth waves of rather shorter period which reach a maximum amplitude, subside and pass through a succession of maxima before merging into the tail portion of the earthquake.

In nearby earthquakes where the distance is less than one thousand kilometers the preliminary waves are very much abbreviated and not well resolved into the two distinct phases.

The curved surface of the earth introduces many diffraction effects into the seismogram. These features start immediately after the P and S waves or first preliminary and second preliminary tremors begin, and are referred to as PR_1, SR_1, etc. With a whole series of diffraction effects in addition to the P and S features the earthquake record becomes com-

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