larger, better equipped laboratories and offices in the new George H. Brimhall Building, now nearing completion on University Hill. The late Dr. Brimhall was president of the university from 1903 to 1921, when he became president emeritus and professor of religious education.

THE *St. Louis Post-Dispatch* reports that seven Russian geologists, exploring for the first time the crater of Kliutcheff volcano in the Kamchatka Peninsula, barely escaped with their lives when the crater suddenly filled with smoke and sulfur gas. The expedition, which was sent out by the Academy of Sciences, is said to have pulled to the top with most of its members in a semi-asphixiated condition. Kliutcheff is 15,750 feet high.

A PWA appropriation to scientific and medical institutions in New York City includes: To supplement the staff in the Department of Health's clinics, baby health stations, school hygiene and tuberculosis registration—$321,732. To enable the twenty-six city hospitals to cope with demands, including additional hospital help, social, medical and nursing service, clerical and research work—$4,112,148. For the New York Botanical Garden to carry on labeling and preparing descriptions of various plants and for genetic studies —$149,340. For laboratory and curatorial assistance in the Brooklyn Botanic Garden—$55,654. For study involving tabulation and analysis of meteorological data to provide a basis for the rendition of accurate visibility forecasts in the Port of New York—$13,740.

# DISCUSSION

## EARTHQUAKE PREDICTION

EVERY once in a while, as recently, the claim that earthquakes can be predicted is brought to public attention in the press or in other ways. Some of the claimants are obviously not competent; others proceed along rational lines but without due regard to the difficulties involved. Some may be publicity seekers; others are undoubtedly sincere.

In a recent number of SCIENCE, July 12, 1935, Dr. H. Landsberg stated quite correctly that in the present state of knowledge reliable earthquake prediction is impossible; and he went on to mention briefly some of the lines of research which have been suggested as prerequisite to any competent prediction, neglecting to mention others equally or more important, for example, study of foreshocks and measurement of strain by geodetic means.

To have any useful meaning the prediction of an earthquake must indicate accurately, *within narrow limits,* the region or district where and the time when it will occur—and, unless otherwise specified, it must refer to a shock of important size and strength, since small shocks are very frequent in all seismic regions.

On the other hand, generalized forecasting of the occurrence of shocks in regions known to be seismically active is entirely possible, but this is not earthquake prediction in the proper sense. The exact, or even approximate, time, place and magnitude can not be stated; only that shocks will occur and that some will be strong, so that proper safeguards should be set up to minimize the risk incurred from them.

Earthquake prediction has two aspects, one relating to the development of seismologic science and one relating to public welfare. With respect to the latter, unless and until such prediction can be reduced to a very precise procedure, giving place, time and magnitude reliably and almost infallibly, the public announcement of a prediction is likely to be harmful and mischievous, causing unwarranted worry and apprehension among large numbers of the population. On the other hand, even only approximately successful forecasting of earthquake occurrence on a rational basis, or even only empirically, would be an important forward step in seismology, for it would mean the attainment of a better understanding of the action of the forces which produce earthquakes, or at least a better grasp of their occurrence statistically. Such prediction or forecasting should not be made public in the press, however, but simply notified to proper scientific groups who would subject it to test as to its realization and rational method, to determine its value.

Most of the earthquake prophets who are sincere do not realize the obstacles which confront successful prediction—the limitations as to place of occurrence and the high frequency of occurrence of shocks.

In the very strictest sense we do not know what causes earthquakes, but the evidence is well-nigh overwhelming that nearly all are caused by the sudden release of elastic strain when rock strained beyond its strength breaks and slips in geologic faulting, with attendant friction and vibration and the radiation of elastic waves. (A few other earthquakes are, or may be, due to underground collapse or rock-fall or explosion or sudden magma movement in volcanoes.) Again in a very strict sense we do not know whether the rock strain is developed suddenly or slowly, but once more the evidence is very strong that in most cases it is of slow growth, due to forces active in the

bending and warping of rock in the process of mountain building. However, it is possible that such strain could be of rapid growth due to sudden changes in bulk, or relatively rapid movement in magma, beneath the surface. Such a possibility must be kept in mind. The cause of deep-focus shocks presents a problem as yet unsolved. At any rate it is in regions of recent and present-day mountain development that all but a negligible fraction of earthquakes occur, both great and small. And the rocks strain whose sudden release is the proximate cause of them is not *built* by gravitational or tidal forces, variations in barometric pressure, wandering of the pole (variation of latitude), or other similar cyclical or sporadic forces of small magnitude, though such stresses may on occasion add their mite at the critical epoch and act as "trigger" forces to *release* the strain. The rock will break and slip, however, when it can no longer withstand the strain, whether or not the action of such a trigger coincides with the time of rupture.

Of the "trigger" forces probably the tidal stresses are the most important—though earthquakes have occurred at times when a steep barometric gradient crossed the originating fault at a large angle, and there is apparent correlation with abrupt changes in the variation of latitude. The gravitational attraction due to the moon is known to produce tides in the solid crust of the earth with an up-and-down movement twice in one day which in many regions frequently exceeds one foot in amplitude. Similar effects produced by the attraction of the sun are about two fifths of those of the moon, while effects due to the planets are only an exceedingly small fraction of those due to the sun. If these gravitational forces really act effectively in precipitating the occurrence of shocks there should be a clear and unequivocal parallelism between the frequency of shock occurrence and the changes in amount and direction of gravitational attraction. Statistics, however, show that in many earthquake regions such a parallelism definitely does not exist, while in other seismic districts such a correspondence is found to a slight extent but by far too small to afford a satisfactory basis for earthquake prediction. This is to be expected, since such forces can not set off shocks except in regions already greatly strained by other causes, and as long as we do not know what regions are already highly strained, the degree of strain nor the amount or direction of the geologic forces responsible, we can not judge when or where trigger forces can be effective.

Unless the region or district, not too great in area, and the exact or closely approximate time, and the shock magnitude are stated—any earthquake prediction stands a good chance of apparent verification because of the great number of shocks which occur in all seismic regions in a given period. If a vague prediction is made and news of a shock is sought to check it, a vague verification is more than likely to be obtained. Notwithstanding this, a majority of such predictions have failed. In 1930, the latest year for which the International Seismological Summary is completely available, many more than 7,000 earthquakes were reported to the central bureau at Oxford University by seismological stations in many parts of the earth. These are very far from being all the shocks which occurred in that year, for not all seismological stations made report to Oxford, and, more important, there are wide regions in which small and moderate shocks are numerous where there are no instruments to record them. Finally, in general only a few of the thousands of aftershocks following a strong earthquake are reported. However, probably all or nearly all large and very large shocks in 1930 are included in the summary. In that year 653 shocks were recorded well enough and widely enough for their epicenters to be determined closely or approximately. A few of these were small shocks, and a small number were aftershocks of important earthquakes. More than 400, however, were large enough to be registered over an area 40° or more (say 3,000 miles) in diameter, and of these some 178 were large enough to be registered over an area of one half of the earth's surface or more. There were but few days on which a large or moderately large shock did not occur, and there was no day on which fewer than 7 shocks were reported to Oxford. In nearly all seismic regions shocks occurred at frequent intervals. The ease of obtaining apparent verification of a prediction vague as to time, place and size, and the difficulty of making a very precise prediction are obvious from the above considerations.

Prediction on the basis of astronomical or tidal hypothesis is not new. It has always failed in the past, and recent predictions on such a basis have in part failed completely and in part obtained vague verification which has no meaning as indicated above.

Any moderately successful method of prediction for scientific testing will be welcomed by all seismologists, but public prediction in the present state of knowledge is nothing short of a menace. Generalized forecasting, on the other hand, is not a menace but is a duty which informed men of science owe to the population of seismically active lands.

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