The Seismological Laboratory and Earthquake Study

By C. F. RICHTER

THE Seismological Laboratory, which recently completed its twentieth year, is situated off-campus in Pasadena. While its iron gates are open most of the time, its location back of the Annandale golf course on the north side of Colorado Boulevard not far west of the Arroyo Seco is probably seldom noticed by the passer-by.

In 1921, the Carnegie Institution of Washington, on the initiative of Harry O. Wood, set up a program of seismological investigation in his charge. This was to provide a central station in Pasadena and a group of auxiliary stations in Southern California for a study of local earthquakes. Later, with the participation of the California Institute, a site was chosen, the present building was constructed and occupied, and in 1927 the recording of seismological observations commenced. Important features determining the selection of the site were the granitic bedrock and the remoteness from traffic disturbances.

By 1929 six auxiliary stations had been established, and each of these is now operated with the help of an agency other than the California Institute. At Mount Wilson this is the Carnegie Institution of Washington. The remaining stations with the local sponsors are at Riverside (City of Riverside), Santa Barbara (Museum of Natural History), La Jolla (Scripps Institution of Oceanography), and Tinemaha and Haiwee in Owens Valley (Department of Water and Power, City of Los Angeles). In 1939 another station was added, on Palomar Mountain. The auxiliary stations with their instruments are used only for the recording of earthquake data on photographic sheets. The records are sent weekly to the Pasadena office, where they are developed and studied.

In 1937 the entire program and the staff in charge were continued under the auspices of the California Institute. The Laboratory investigations do not include engineering problems that result from motion. The elements of motion resulting from an earthquake, as for example amplitude, velocity, and acceleration, as they affect physical structures are being studied by the Department of Civil Engineering of the Institute.

To lay a ghost, it is worth mentioning that the Laboratory does not predict earthquakes. On the other hand, the average probability of an earthquake in a given period of years can be stated approximately. There is at present no prospect of prediction, in the sense that it can be stated that a strong earthquake will occur at a certain time and place.

The principal research activities of the Laboratory are:

1. The location of earthquakes the world over, including a determination of their depth of origin
2. the accurate location of earthquakes in the Southern California area
3. a study of the seismograms of distant earthquakes recorded at this and other stations over the world, to determine what can be learned as to the interior structure of the earth
4. a similar use of records from the local stations to determine the structure of the upper layers of the earth's crust in the California area.

All these investigations bear on important problems of geology and geophysics. Moreover, the individual characteristics of seismograms give to the specialist limited information about the mechanism of rock fracturing which causes earthquakes. Finally, the earthquake magnitude scale, devised at Pasadena, has led to a completely new interpretation of earthquake statistics.

International seismology rests upon a world-wide exchange of data among the recording stations. Pasadena, having one of the best equipped laboratories, plays a significant part in this exchange. Its published bulletin circulates all over the world, and similar bulletins are received from Bolivia, New Zealand, India, Czechoslovakia, the Soviet Union, and many other countries. The principal center of exchange is the international office at Strasbourg; here data for all stations are collected. These are finally published in the International Seismological Summary, formerly issued from Oxford, but now from Kew Observatory (near London).

The Pasadena bulletin each year gives data for about 1000 teleseisms—earthquakes distant more than 1000 km. In addition, a report on local shocks is issued in which epicenter, time of occurrence, and magnitude are given for about 300 shocks annually in the area of southern California. For only these local shocks can sufficient data be gathered to permit a location of origin. Hundreds of smaller unlocated disturbances are recorded, some of them undoubtedly artificial, being due to blasting or explosions.

For the study of local shocks data are exchanged with two regional groups of stations. One of these groups centers at the University of California, Berkeley, and deals primarily with earthquakes in central and northern California. The other has headquarters at Boulder City, Nevada, maintaining stations in the Lake

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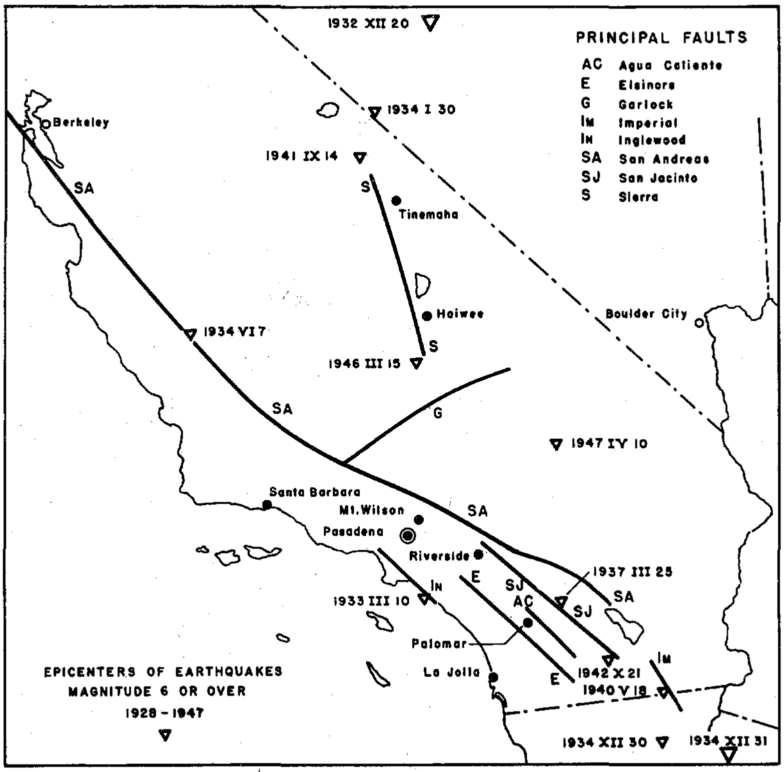
Dr. Richter supervises the measuring and cataloging routine at the Laboratory. Data for local and distant earthquakes are preserved in a large and detailed card file. From this file Dr. Richter compiles and edits the Laboratory bulletins.

The Pasadena magnitude scale was set up by Dr. Richter, originally for use in studying local earthquakes. Many of his publications deal wholly or in part with this scale and its applications. Most of them are released in collaboration with Dr. Gutenberg, among them the series on seismic waves and on the seismicity of the earth. Some are studies of particular earthquakes, others are theoretical.



Outline map of the California area, showing stations, principal faults, larger shocks 1932-1947.

Mead area, as well as at Shasta and Grand Coulee Dams. This latter group of stations, fully equipped with sensitive Benioff seismometers, is operated by the U. S. Coast and Geodetic Survey.

The destructive Long Beach earthquake of March 10, 1933, occurred almost in the center of the Pasadena station network. Location and timing for this shock are consequently more accurate than for almost any other earthquake of comparable magnitude. Since the shock was recorded at many distant stations, it provided data for revision of the standard time-distance tables.

An extremely valuable check was provided by the Baker Day atomic bomb test at Bikini on July 24, 1946. The first waves from the resulting shock were recorded at Mount Wilson, Riverside, Palomar, and Tinemaha. Since the explosion was accurately timed, the zero of the time-distance curve is now well established. Similar work has been done on the smaller local scale by timing large quarry blasts at the shot point.

It was at first anticipated that the location of small earthquakes would outline the major active faults and help supplement the geologic data as to the local seismicity. This expectation was disappointed, but in an interesting way. Except for the swarms of small aftershocks which always follow larger disturbances, it is found that small local earthquakes are irregularly peppered over the area. Closer examination shows that they are associated with various small faults that make a mosaic of the regional structure. The occurrence of large shocks appears to be nearly independent of this continuous smaller activity; the time-honored notion, according to which small shocks may serve as a "safety valve" to delay or inhibit the occurrence of larger ones, has had to be abandoned.

Precise seismometrical survey of the desert and mountain portions of Southern California has revealed the occurrence of earthquakes in unexpected areas. Even in settled districts important results of this kind have been reached. Thus, the records establish the activity of the Norwalk fault, which is an important feature bounding the Los Angeles Basin on the north, corresponding to the Inglewood fault on the south (on which the Long Beach shock of 1933 originated). The Norwalk fault is a potential source of serious risk to the metropolitan area.

On April 10, 1947, a large shock took place in the central part of the Mohave Desert, nór far from Manix and Field on the Union Pacific Railroad. Small fault displacements amounting to a few inches were found on a known fault passing near the epicenter located by instrument. The distribution of the small aftershocks, now under investigation, suggests another active line, and indicates unusual complexity in the fracturing which produced this shock.

Study of the direction of first motion as indicated by the seismograms of hundreds of local shocks has confirmed the conclusion of geologists that the parallel northwest-southeast faults of Southern California represent a series of shear fractures, probably conditioned by a north-south compression, along all of which displacement is occurring in the same direction; that is, the southwest side of each fault is being relatively displaced to the northwest. Such displacements, amounting to 15 feet or more, occurred on the San Andreas fault during the earthquake of 1906 and in the Imperial Valley in 1940.

The magnitude scale, previously mentioned, has introduced new precision into the statistical handling of earthquake data. The smallest recorded shocks are of magnitude between 0 and 1; the greatest erthquakes are of magnitude about 8½. This corresponds to a range of about 10^{17} in the energy radiated in the form of elastic waves. The scale, originally devised for California shocks, has been extended to earthquakes over the world and at all depths, using the data of all reporting stations. Among the results is a carefully compiled list of 94 great earthquakes (magnitude 7¾ and over) from 1904 to date. The list of major earthquakes (magnitude 7 to 7.7) is more extensive, there being about 10 such shocks each year. Finally, a critical list of the larger shocks (magnitude 6 and over) in the California area since 1932 has been prepared.