EARTHQUAKES

—RECORDED ON TAPE

Caltech's Seismological Laboratory is making continuous sound recordings of the movements of the earth—and starting operation of the world's best earthquake recording station on Palomar Mountain.

LAST YEAR was a big earthquake year. Caltech's Seismological Laboratory recorded a total of 1400 distant quakes. Encouraged by this activity, the Lab set up a number of new seismographs and other apparatus to test this year. To date, however, 1951 has been almost spectacularly quiet. In fact the Laboratory staff is now entertaining the suspicion that it can keep down the number of quakes by setting up new equipment.

One of the most interesting of the new instruments under test at the Lab is a seismic tape recorder which enables Lab workers to actually listen in on the movements of the earth. When a local earthquake occurs, it comes through on the tape with a sharp report like a pistol shot. A distant quake sounds like a ten-strike in a mammoth bowling alley.

The machine records continuously. The vibratory movement of the earth, acting on a pendulum seismograph, generates a small amount of electric power. When this is amplified it serves to actuate the tape recorder. The recorder operates at a speed of ½ millimeter per second, in order to cover a band of seismic frequencies from approximately ten cycles per second to one cycle in several minutes.

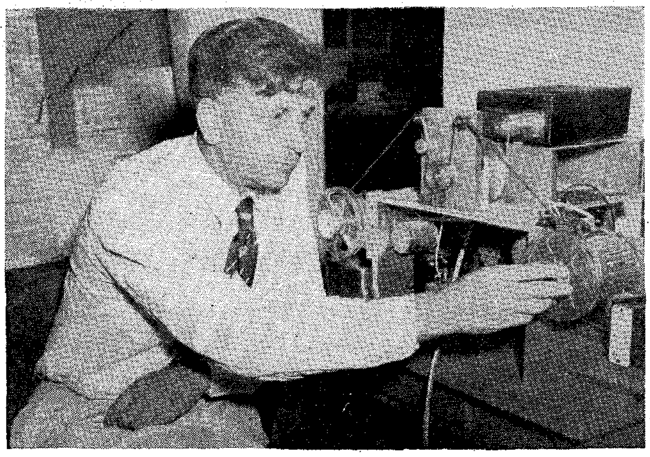
When the tape is run through a playback mechanism at 15 inches per second, the frequencies of the recorded seismic waves are multiplied by a factor of 600. Thus, although the waves—as recorded—have frequencies which are too low to be audible, they are raised into the audio range when played back.

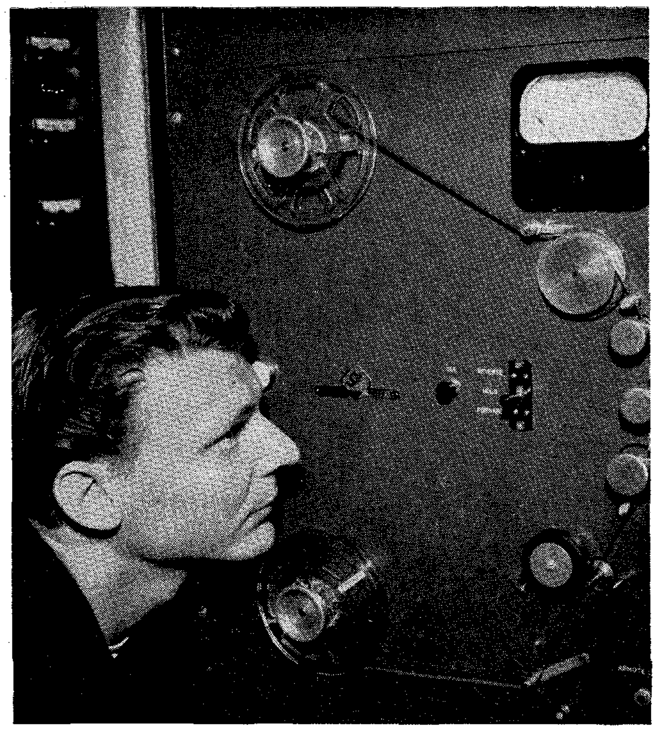
Though it is undeniably exciting to hear the sound a quake makes deep in the bowels of the earth, the primary purpose of the new tape recorder is not to listen to the earth waves, but to provide a means for measuring the energy of earthquakes as well as for measuring seismic spectra. Measurement of such spectra, a fundamental problem in seismology, indicates how the energy is distributed in the different frequencies.

The machine will also be valuable in studies of the microseismic movement of the crust of the earth. The surface of the earth moves, just as the sea does, and with approximately the same frequencies. This movement varies from day to day, like the sea. Though seismologists still don't know what causes the movement, they are certain that it is related in some way to the waves of the ocean, and that it is in fact generated at sea. The evidence to be heard on the seismic tape recorder does nothing to refute this theory; the sounds of the earth at rest are exactly like the steady, regular rise and fall of the ocean waves.

In their search for the causes of these microseisms, workers at the Laboratory have already learned to differentiate between the actual sounds made by the earth and assorted man-made disturbances which make their way onto the tape. A recent playback of the tape, for instance, revealed two very pronounced sounds which had nevertheless been too minor to show up on any of the Laboratory's regular photographic records.

One of the sounds was traced to the heavy contracting machinery which was being used on the new Colorado Street Bridge construction job, less than a mile from the Lab. The other noise, a continuous single-pitch disturbance, which disappeared on Saturdays and Sundays, sounded suspiciously like a large reciprocating engine somewhere in the vicinity. It turned out to be the compressors in an ice plant on the other side of town.





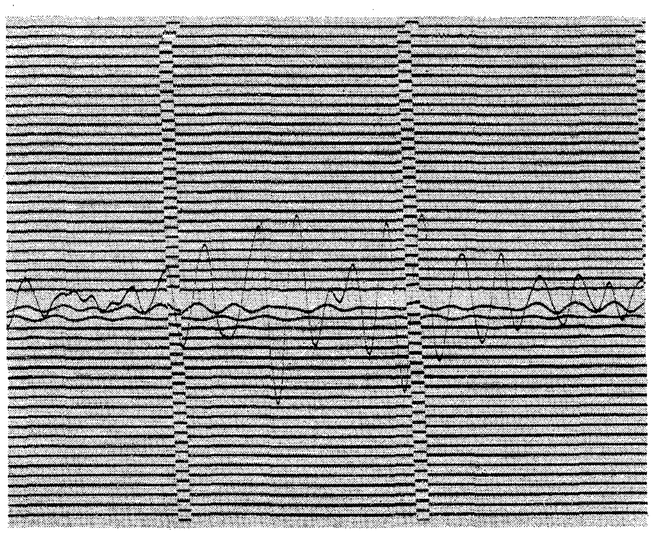
The Seismological Laboratory's new seismic tape recorder enables Lab workers to actually listen in on the movements of the earth. Above, the recorder is being operated by Dr. Hugo Benioff. It records at a speed of one-half millimeter per second. When the tape is run through the playback mechanism (at the right) it's speeded up 600 times, bringing low frequency seismic waves into the audio range. The recorder is useful for measuring the energy of earthquakes.

This indication of the sensitivity of the tape recorder explains why the Lab is already planning to build equipment which will translate its tape recordings into ordinary ink and photographic records. The resulting records will include details that can now be obtained only from a combination of several of the standard instruments.

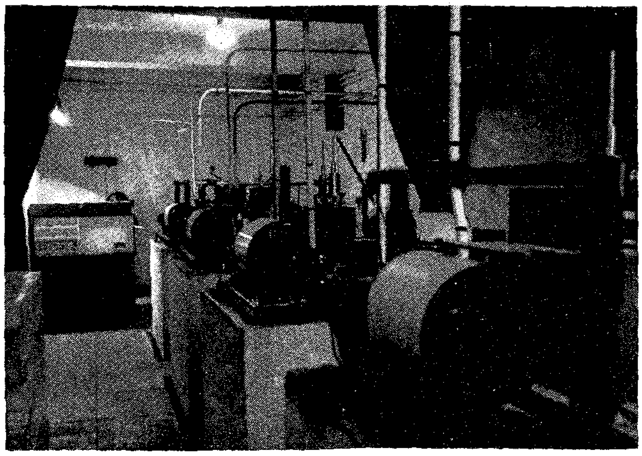
Permanent tape recorder

This translating equipment will probably not be built for a year or more. The tape recorder now in use at the Lab is only a pilot model. A permanent recording machine is just about completed, and as soon as this job is done, construction will get under way on analyzing equipment, which will take about a year to build.

The most spectacular equipment that the Lab is putting into operation this year is not at its headquarters in Pasadena, however, but at its auxiliary station on Palomar Mountain. The Lab has 13 auxiliary stations scattered throughout the southern California area. This earthquake-recording network makes possible the location of quakes not only in southern California but throughout the world. Stations are located in Riverside, Santa Barbara, La Jolla, Mount Wilson, Tinemaha, Haiwee, Palomar Observatory, China Lake, Perris, Big Dalton, Desert Hot Springs, El Cajon and Big Bear. Each of these is operated with the aid of some outside



This is the record of an earthquake—specifically, of one at Baffin Bay in 1930. Recorded on a linear-strain seismograph like the one across the page, it shows the strains produced in the rock underneath the Seismo Lab by the passage of long-period surface waves. Since the horizontal lines on the record are 15 minutes apart, it is evident that the activity shown here continued for about two hours. The short, faint jiggles in the horizontal lines, which can be seen in the upper portion of this record, have nothing to do with the earthquake; but they do give some indication of the sensitivity of the strain seismograph, because they are caused by people walking in the building in which the instrument is located.



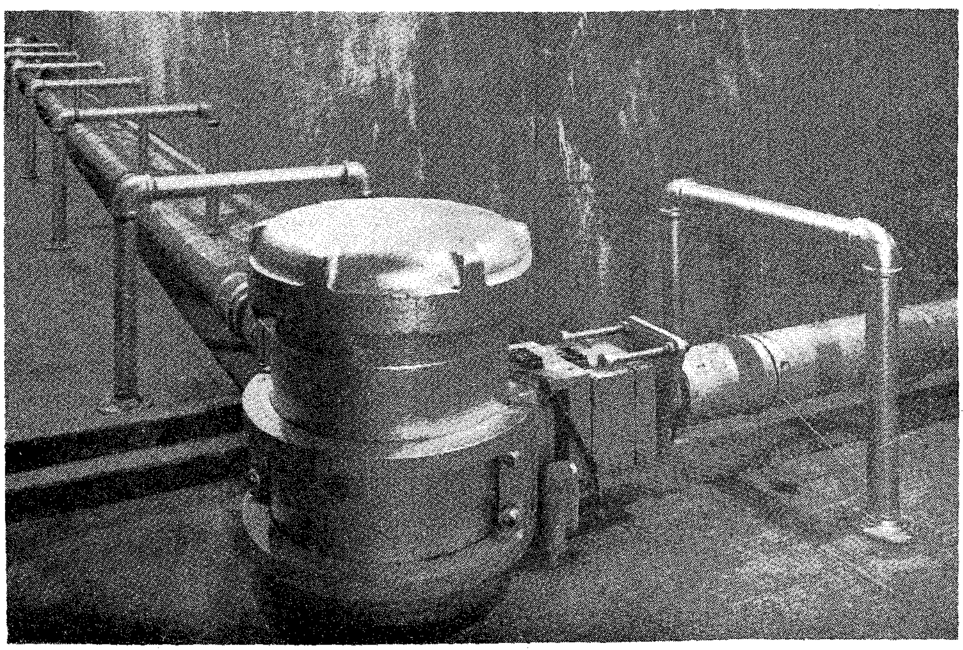
Principal recording room in the Seismo Lab has 18 photographic recorders in continuous operation. Most of these recorders are actuated by seismometers located in the tunnels bored into the hillside under the lab. They operate in complete darkness. The photo above was taken in red light. At left, girl is working on some of the 40 records which are processed at the lab every day, washing paper records. Some recorders use photographic paper, others use 35-mm. film.

agency. In Riverside, for example, this agency is the City Light Department; at Santa Barbara it is the Museum of Natural History; at La Jolla, the Scripps Institution of Oceanography; at China Lake, the Naval Ordnance Test Station. Earthquake data, automatically recorded on photographic sheets at each of the auxiliary stations, are sent to the Lab in Pasadena once a week.

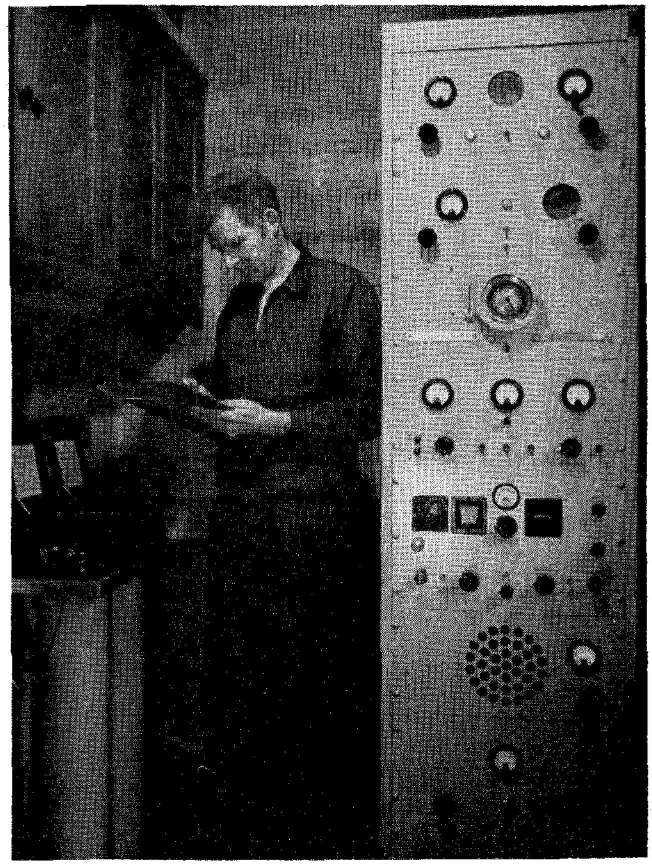
The new equipment, which is exepected to go into preliminary operation at Palomar this month, will make this station the best earthquake recording unit in the world. The Palomar station will be equipped to record more characteristics of earthquakes than any existing station can, and to record waves which are not received by any other station.

One of the most valuable recording instruments in the Seismological Laboratory in Pasadena is the electromagnetic linear-strain seismograph. The response of this instrument is derived from strains produced in the ground by seismic waves rather than displacements of the ground, as is the case with all the pendulum-types of seismographs. The linear-strain seismograph records as little as six millionths of an inch of ground-squeezing produced by a distant quake, and if the Atlantic Coast should be squeezed a foot closer to the Pacific Coast it

The linear-strain seismograph responds to strains produced in the earth by seismic waves rather than displacements of the ground. It will record as little as six-millionths of an inch of ground-squeezing produced by a distant quake. Two of these instruments—each 150 feet long—are now being installed at the Seismo Lab's auxiliary station on Palomar Mountain.



Marine-type chronometers and synchronous motors are used to make seismographs operate with extreme uniformity. In the Lab's time room, shown here, marine chronometers (left) serve as clocks. They have electrical contacts operating once a minute, which serve to put minute marks on all seismographic records. At the right, in this picture, is a radio receiver with an automatic time switch which turns the receiver on seven times a day in order to record the time signals broadcast from Mare Island, California—which, in turn, are rebroadcast from Washington. Chronometers at the Lab are therefore corrected seven times daily. In determining the time of arrival of earthquake waves, the Lab tries to maintain an accuracy approaching a tenth of a second.



would record that. Observations made with this instrument, taken by themselves or in combination with those of the pendulum instruments, provide information concerning seismic waves which cannot possibly be had from the records of the pendulum instruments alone.

The Palomar station will have two of these linear-strain seismographs in operation. The main Lab at Pasadena has two now—one of which is 20 feet long, the other 60 feet long. The Palomar instruments are 150 feet long. Each seismograph consists of two piers set 150 feet apart, with a two-inch quartz tube rigidly fastened to one pier and mounted by a series of flexible supports so that the free end comes close to the second pier. The passage of a seismic wave in the rock in which the piers are set produces changes in the separation between the two piers, and this is recorded by means of an electromagnetic device attached between the free end of the quartz tube and the fixed pier.

Linear-strain seismographs are so sensitive that, even though they are installed deep in the tunnels under the Seismological Laboratory in Pasadena, the presence of people in the building is enough to hamper their effectiveness. The footsteps of a man walking down a hall in the Lab will be clearly recorded on the instruments. As a result, the Pasadena instruments are completely effective only at night, when the building is unoccupied.

At Palomar, the strain seismographs, at the southern end of the mountain top, well removed from the Observatory, will get no human interference at all—except for the man who comes to change the records once a week. And if the instruments behave as expected, they will record earth waves of a longer period than have hitherto been recorded anywhere in the world.

This isn't the only new instrument being installed in the Palomar station, though. In addition there's to be one which photographs an enlarged pattern of the actual movement of the earth in two dimensions—a picture of what you'd see if you could look down into the earth—with the ground motion magnified approximately 5,000 times. With these records seismologists can determine, by inspection, the kind of movement occurring in a seismic wave. With older instruments this had to be computed from point to point by comparing records; and it was such a laborious process that it was rarely done at all. But the photographs at Palomar will furnish this information at a glance.

Finally, there is to be a new installation which will provide accurate information as to the direction of arrival of earthquakes and microseismic waves.

Estimating the distance of a quake is difficult enough. But the determination of its direction is even harder. A seismograph writes a very complicated record, showing two kinds of shock waves coming through the earth at different speeds, plus various echoes from the surface of the earth and from the central core. Except for very deep shocks, all this is followed by a long train of waves traveling over the surface of the earth. The whole process may take hours to record—not because the original earthquake lasted that long, but because it sets up a commotion that takes a long time to die down. From such a record, a seismologist can usually estimate the distance of a quake.

Every earthquake sends out two kinds of shock waves, called P and S waves. P waves vibrate longitudinally, while the vibratory motion of S waves is at right angles to the direction of propagation. P waves travel faster than S waves, and the time interval between them varies from a few seconds at short distances, up to more than 11 minutes at 7,000 miles. By multiplying this time interval by 5, a seismologist can get a rough idea of the distance from the earthquake in miles. At best, he gets a distance within 50 miles or so.

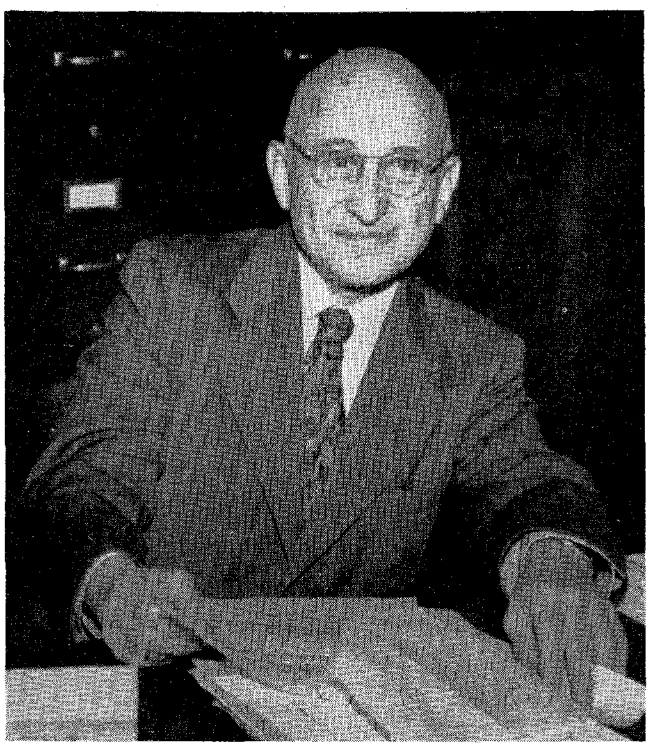
Direction is not so easy to determine. When times are reported from other stations, and the seismologist has two distances and a rough indication of direction—or three distances—he can locate the earthquake epicenter on the globe.

The new instrument at the Palomar station will provide information on three distances simultaneously—thus making it possible to determine direction accurately. This will be a tripartite installation, consisting of three vertical seismometers—so arranged at the vertices of a triangle of about 3,500 feet on a side, that they will record three traces side by side.

Aside from these new instruments, the Palomar station will, of course, have the normal complement of all auxiliary station equipment, including marine chronometers, automatic radio time-signal records and a recording microbarograph (used to study the possible relation between microseisms and atmospheric pressure variations).

Most of this equipment is housed in an insignificant-looking, box-like cement structure within hailing distance of the Palomar Observatory. Despite the disparity in the structures, the research programs being conducted in these two locations are remarkably complementary. Just as the big 200-inch telescope is pushing further out into the dark and unknown regions of the sky, so will the new earthquake recording station probe deeper into the core of the earth than man has ever been before.

THE MEN WHO RUN THE SEISMO LAB



Dr. Beno Gutenberg, Director of the Lab, came to Caltech in 1930 from the University of Frankfurt. He is probably the world's greatest living earthquake expert. Now president of the International Association of Seismology and Physics of the Earth's Interior, he recently returned from a UNESCO mission to Turkey and Israel to advise the two nations on establishing and improving seismological studies.

Dr. Hugo Benioff, in charge of all instrumentation for the Lab, is shown at the lower left with his newest variable reluctance seismograph for measuring horizontal motions of the ground. The instrument will drive two recorders simultaneously—one for slow vibrations of the ground and one for rapid vibrations. Benioff has developed almost all of the Lab's instruments, and his seismometers are now used throughout the world.

Dr. Charles Richter, shown below reading the Lab's ink-writing recorder, which reports quakes as soon as they occur, is in charge of the measurement of all records at the Lab and of the preparation of all reports and bulletins. During the '30s Dr. Richter developed for the first time an accurate yardstick for the measurement of the size of an earthquake. This magnitude scale has led to a completely new interpretation of earthquake statistics.