ENGINEERING AND SCIENCE
April 1963, Volume XXVI, No. 7

MOUNTAIN-BUILDING

by Graham Berry

The processes of mountain-building and the mechanism by which ocean basins maintain their integrity are among the great interests and mysteries of geology. Now, C. Hewitt Dix, professor of geophysics at Caltech, has found some data which could offer an explanation of how the great ocean basins remain virtually unchanged for billions of years and how mountains and high plateaus may be formed by being "pumped up" hydraulically by the high-pressure intrusion of molten rock beneath them.

The theory is based on reflected wave patterns obtained by Dr. Dix with sensitive depth-sounding equipment on a Mojave Desert upland at the edge of the San Bernardino Mountains. The waves, generated by explosions, were reflections off deep subterranean layers.

Their patterns indicate the presence of groups of discontinuities in the earth's crust under the highland at various depths down to 22 miles and perhaps below. The most natural conclusion is that the discontinuities mark the presence of subterranean sills, horizontal layers of rock that were originally intruded as molten material into preexisting rock.

The mechanism of sill formation is at least partially understood. Molten rock rises from great depths under high pressure through a near-vertical fissure, which it forces open in seeking an outlet. The molten material will rise vertically to a level where the vertical pressure on the surrounding rocks is not great enough to prevent the fluid from cracking the rock. The fluid then spreads out in a horizontal or vertical crack, forming a fluid layer which will extend in some cases for great distances, depending upon the amount of fluid available. This material later will solidify to form a sill.

As mountains and plateaus are eroded away, their weight is lessened. According to Dr. Dix, this would result in a vertical pressure reduction to invite the intrusion of a sill. The higher the mountains, the more the wearing away, the more the unloading, and the more favorable the setting for sill formation and further mountain uplift. If such intrusions are several hundred feet thick, as indicated by the seismic data, they could have a hydraulic lifting action on the mountain or plateau above them.

The proposed mechanism for mountain-building can be turned around to suggest a major reason for the permanence of the great ocean basins. The growing load of sediments brought down by the rivers from the eroding continents maintains pressures that prevent sills from forming to lift the ocean floor.

Another weight factor could be the increase in the amount of water in the oceans over the geologic ages. There is good evidence that the amount of water in the oceans has increased in the past billion years.

During great glacial periods, the sea levels are lowered because the glacial ice is formed of ocean water and this water becomes locked up in ice on the land. This unloading of the oceans would permit the formation of sills even under the oceans for geologically short periods of time. These sills in their fluid form may be necessary to explain some of the large horizontal displacements of the ocean floor that appear to have occurred in the eastern Pacific. The evidence for these displacements comes from measuring the amounts of magnetism in the rocks of the ocean floor. This work is largely that of the Scripps Institution of Oceanography.

The areas involved in these shifts are large;

so is the amount of shifting. The crust under the ocean is known to be thin. It seems almost necessary that shifting of blocks of the ocean floor under these circumstances requires some sort of "lubrication." And a horizontal fluid sheet which later will form a solid sill seems to be the most likely setting for the shift.

The major evidence for Dr. Dix's theory is the groups of discontinuities he has found under the Mojave Desert upland. The main groups are at depths of 7, 12, 16, and 20 to 22 miles, with the reflecting signals being strongest from the group at 16 miles. The discontinuities at the greater depths must be nearly plane and nearly horizontal; otherwise it is difficult to account for the strength of the reflected signals from them.

Reflection records, like the one below, indicate that one sill is approximately 2,500 feet thick. One would expect that a sill of this thickness would extend for many miles under the Mojave region, according to Dr. Dix, and it could be expected to have a lifting action on any highlands and mountains above it.

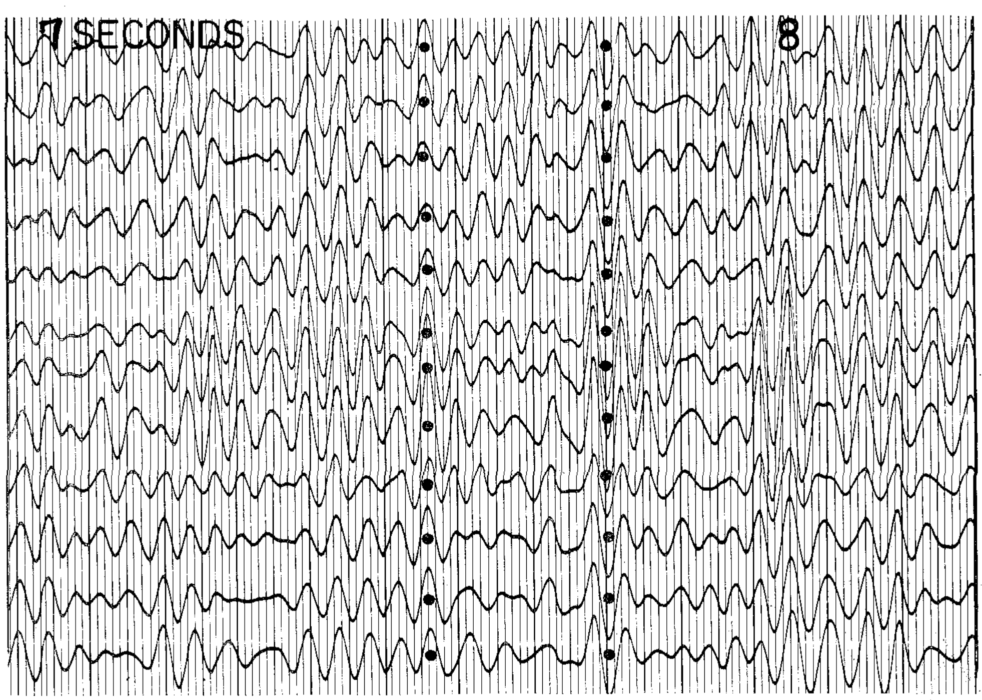
The records require careful interpretation, since the seismic waves will reflect off any discontinuity, such as shallower sills. Reflections which bounced back and forth several times between shallow discontinuities before being recorded may seem to come from deeper discontinuities because of the time intervals involved. The sounding technique is similar in principle to that used by seismic prospectors looking for oil.

The Mojave Desert soundings were taken some 40 miles east of Victorville and near Lucerne in dry lake country. Detecting equipment was located at various distances from each shot, most of the time within five to seven miles of it and occasionally as near as one mile and as far as 15 miles. The detectors were sensitive geophones that were buried a few inches deep to reduce surface noises such as wind. About a dozen pairs of geophones were set out for each shot and were spaced at intervals along a 2,000-foot path approximately in line with or across the line from each shot.

The geophones were linked by wires to recorders in a miniature bus outfitted as a laboratory. The electronic equipment included a radio transmitter and receiver for communicating with a radio system at the shot site. The shots were detonated and recorded individually. To time each shot with the necessary accuracy of five thousandths of a second, its dynamite cap was wired to release, at the instant of detonation, an electric surge that was radioed to recorders in the bus.

The recorders, one receiving data on photosensitive paper and the other on a magnetic drum, also picked up from the geophones the reflected shot waves, which traveled at about 20,000 feet a second through the ground, reflecting off discontinuities at different depths.

Dr. Dix plans other expeditions to record a series of shots in mountains in an attempt to learn more about the discontinuities and to obtain more evidence that they are sills which may have hydraulically "pumped up" the mountains.



Part of a reflection record. The shot is about 6 miles west of the line of detectors, and the line of receivers is about 2,000 feet long. The rows of dots are two reflection events. The earlier one on the left corresponds to the trough of the second, suggesting that they are reflections from the top and bottom of one sill about 2,500 feet thick.