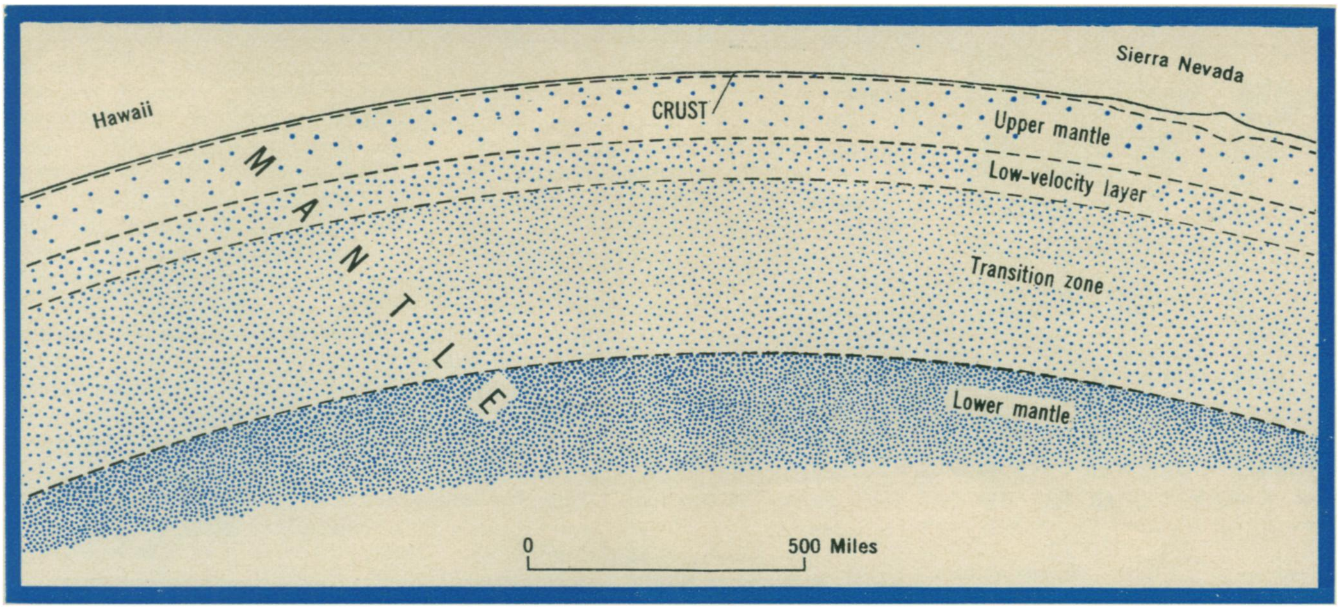


Geological Survey

Upper mantle and crust between Hawaii and California, indicating the nonhomogeneity of the mantle.

GEOPHYSICS

A more complex view

Computer models of the earth's interior may bring changes in some long-held ideas

by Ann Ewing

Scientists have long agreed that the earth has three main divisions—a central core, an intervening mantle and a very thin crust; some 300 years ago Isaac Newton showed that the interior had to be much heavier than the crust we live on.

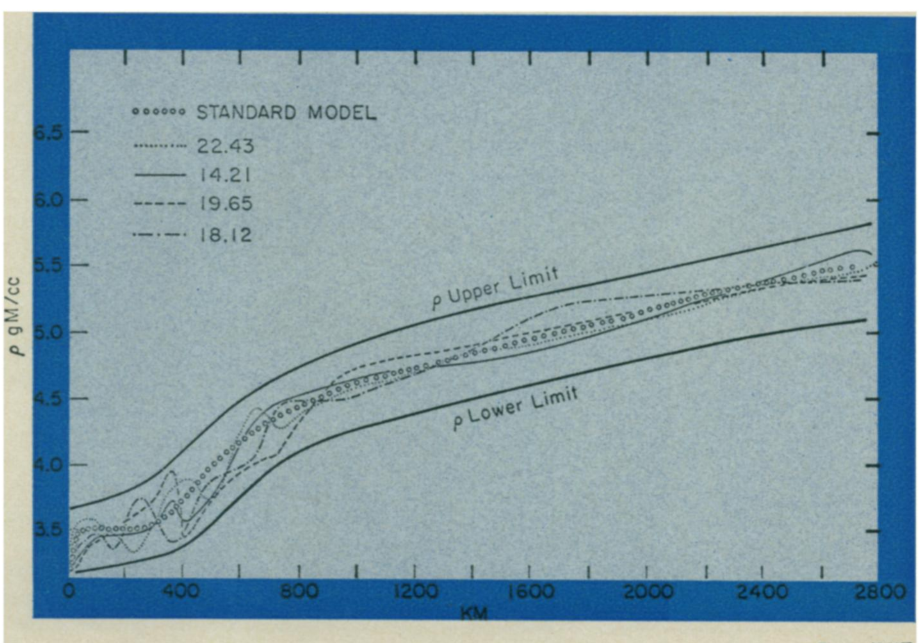
During the last 60 years, scientists have not only found layers within these divisions but have also learned to estimate the depths of these internal layers with increasing confidence.

But models now being computed show that the planet's structure is very likely to be even more complex than most geophysicists thought. These models also indicate that the previously assumed dimensions for the earth's core and mantle could well be off by miles.

This latest attempt to delineate the earth's structure has been made by Dr. Frank Press of Massachusetts Institute of Technology, who programmed a computer to generate five million models of the earth. Of this number, only six were found that fit the known facts, and only three were found plausible. (Another experimental group, in the U.S.S.R., is doing similar work.)

The five million models were generated using what is known as the Monte Carlo method; that is, the known measurements were fed into the computer on a completely random basis, as when dice are thrown, and the resulting figures then tested to see how closely their mathematical structure resembled the real earth.

Of the six that passed this examination, all had a larger core than is usually assumed for the earth. The outer fluid core is shown to be consistent with an alloy of iron and 15 to 25 percent silicon, and the inner solid core with



Press/MIT

Dr. Frank Press (above) developed these computer models of earth's mantle.

. . . Computer describes a more complex earth

an alloy of iron and 20 to 50 percent nickel.

The mantle is well known to have internal chemical inhomogeneous differences, with a transition zone between the deep and upper mantle. The upper mantle also shows large density fluctuations—one of the most surprising results of the new models.

That a drastic change in composition occurs between the crust and the mantle has long been known. But most earlier earth models have assumed a smooth transition of structure in the mantle and most suggestions concerning earth's internal structure are based on one or more of the following assumptions:

- Large segments of the mantle, except for the transition zone at depths of 400 to 1,000 kilometers, are homogeneous, and lose neither heat nor water.
- An initial density distribution corresponding to specific chemical compounds is presumed for the upper mantle, based primarily on analysis of rocks.
- The density is related to seismic velocities using an equation derived from laboratory measurements of minerals and rocks.

"These assumptions have varying degrees of plausibility," says Dr. Press, "but the possibility is a real one that the earth behaves differently." He has, therefore, derived his models of earth's structure independently of these assumptions.

To compute his five million models, Dr. Press picked a plausible range of values for a number of characteristics of the earth. He then let the computer pick random values for these characteristics, within the ranges he set, and compute what the earth would look like with those values.

Among the variables chosen were the compressional velocity and shear velocity of waves within the earth, density distribution in the mantle and density of the core.

Since the models are for the entire earth, Dr. Press made the pseudocrust spherically symmetrical, based on the weighted average of oceanic and continental crustal data.

Each of the five million models generated was tested against the mass of the earth, the moment of inertia, the travel times of seismic waves and oscillation resonances.

Monte Carlo models, Dr. Press notes, are without bias based on preconceived notions of the earth's structures.

Of the five million models, six met all constraints, but three of these were rejected on the grounds that they gave implausible temperatures for the core-mantle interface.

Every successful model required an increase in the radius of the earth's core of between 18 to 22 kilometers over the normally assumed value of 1,280 kilometers. Each also showed inner core densities significantly higher than the standard model, the central densities varying between 13.3 and 13.7 grams per cubic centimeter, rather than about 12 grams.

Dr. Press found that the initial densities at the top of the fluid core range between 9.4 and 10.0 grams per cubic centimeter, the upper value being close to that used in the previous standard model. In the mantle below 1,000 kilometers, the results are consistent with its composition being a mixture of high pressure oxides with iron content constant.

The transition zone has long been recognized as a region of high density and velocity changes in which materials vary between liquid and solid. Dr. Press found that it has even higher density changes than in the standard model.

The successful models for the upper mantle show surprisingly large density fluctuations. Dr. Press says this suggests the "possibility that the upper mantle may be zoned vertically and horizontally to an extent not heretofore appreciated."

This implies unstable conditions, "not unwarranted in view of the abundance of evidence for dynamic processes in the upper mantle, such as spreading sea floor, volcanism, seismic activity, heat flow variations and pole wandering," reports Dr. Press.

He stresses that his conclusions "must be tempered by the possibility that had more than five million models been generated, successful solutions might have been found which differ significantly from those reported."

Dr. Press' pioneering work is complemented by studies in the U.S.S.R. However, the results reached in the Soviet calculations cannot be compared with those of Dr. Press for two reasons:

- The Russian work is based not on the earth as a whole but only on limited sections, such as Europe, the Canadian shield and the earth's upper mantle.
- The mathematical basis for generating the Russian models, of which about a million have been made, is somewhat different from the method used by Dr. Press, though both use the Monte Carlo method of randomly selecting figures for the computer.

Dr. Vladimir I. Keilis-Borok of the U.S.S.R. Academy of Sciences in Moscow, now visiting at the University of California at Los Angeles, says the Russian models also involve different approximations concerning earth's structure than those used by Dr. Press.