GEOLOGY

Inside The Earth

Earthquake Waves Provide Primary Data From Which Scientists Infer Composition of Our Planet

THE only known abode of life in the universe is the green-garmented surface of a whirling blue ball, a speck of dust in the cosmos. This is the planet Earth. From it the brain of man looks forth into the immensities of the universe, surveys the galaxies, and weighs the stars.

But almost to the present generation one field of exploration has been closed. Man has not been able to look far under the surface of the oblate spheroid upon which his lot is cast. The interior of the earth has been a place of unsolved mysteries, and even now only a beginning has been made, almost entirely through logical deductions, toward some solutions.

Naturally the inside of the planet has intrigued man's imagination. A few generations ago he placed the abode of the damned there in a dark region of eternal fire and lakes of boiling pitch. Only 120 years ago bills actually were introduced in the Congress of the United States to authorize a Navy expedition into the interior through a supposed "hole" at the North Pole, for the purpose of appropriating for this nation rich virgin territories which an eccentric dreamer had calculated might be found there. This became an issue causing considerable political animosity at the time.

No Direct Observation

Any direct physical observations very far under the surface are, of course, impossible. Man has no way to get there. Two types of indirect observation are possible, and these have been explored so fully during the past 25 years by the Geophysical Laboratory of the Carnegie Institution of Washington and other research organizations that a fairly complete although still somewhat hypothetical picture of the planet's interior can be formed.

The primary data are furnished by earthquake waves. They move through the earth in all directions from their center of propagation, which can be precisely located. The impulses from a single shock of sufficient intensity can be detected everywhere in the world where sufficiently delicate instruments can be set up. It was observed early that the speed of these waves was not constant, that it varied for different segments of the path followed, presumably because of the varying nature of the material traversed. Through a complex mathematical procedure it was found possible to analyze these speeds and to determine the rate at which a wave was moving at the lowest point in the earth through which it passed.

Through what sort of materials would a wave travel at the observed speeds?

The determination of this basic problem was one task set for itself by the Geophysical Laboratory.

There could be set up in the laboratory experiments with matter under pressures and temperatures notably higher than those which obtain at the earth's surface—far less indeed than those at extreme depths, but tending in the same direction.

Speed Clue to Material

It had been observed, for example, that waves traveled through the uppermost ten miles of the earth's shell at a speed of approximately 3.3 miles a second. Geophysical Laboratory experiments showed that this would be precisely the speed to be expected through granite under the right pressures, and through nothing else. This same line of evidence has been extended to different levels. The work is slow and laborious, but it apparently is the most direct means of determining the internal construction of the planet upon which we live.

Geophysicists generally are agreed that the planet is wrapped in a thin crust of relatively light rocks averaging about 30 miles in thickness.

This crust is composed of several layers. First is the rough coat, about a mile thick, of loose earth, sedimentary rocks such as sandstone and limestone, and igneous rocks from volcanic eruptions. This covers a layer of granite from three to nine miles deep, the original skin of the earth.

Beneath the granite is a depth of about 25 miles of basalt. There must be enormous quantities of it, some solid, some molten into a thin liquid. The roots of a few volcanoes, notably a few in Hawaii and one in the Belgian Congo, appear to rest in this basalt liquid and occasionally pour it forth in great eruptions. Most volcanoes, however, shoot out molten granite, or rhyolite, from the more superficial layers.

There is another form of basaltic eruption which is on a far vaster scale: the so-called fissure eruption. The face of the earth splits open and the molten rock pours forth, covering thousands of square miles to depths of a mile or more. No such catastrophe has happened in the time of man. Two notable locations where something of the sort has happened in the distant past are the Columbia River basin and the Deccan area in India.

Crust Varies in Thickness

The crust varies greatly in thickness at various places. It is thickest under the Alps, very thin under the southwestern United States and most of western Europe, and of average thickness over western North America and nearly all of South America. Under large areas of the Pacific, it appears, there is none at all. This may be the result of the ancient catastrophe in which, it is believed, the moon was torn from this side of the earth.

Very slowly all over the globe the crust is increasing in thickness. It gains approximately 100,000 tons a year from the billions of invisibly minute specks of space dust which pelt upon its surface—an increase of about 5,000,000,000,000 tons, still hardly enough to be measured, in all the time of its existence.

Under this layered crust is a depth of approximately 2000 miles of an ultrabasic material of some sort, the nature of which can only be conjectured from the evidence of earthquake waves. It transmits them very rapidly, at a rate of about 4.8 miles a second as compared with 3.3 miles for granite. Whatever it is, it constitutes nearly seven-eighths of the total material of the planet. It might be said that the earth is made of it, any of the other constituents, except in the core mentioned below, being almost inconsequential in amount. Experiments at the Geophysical Laboratory show that two known forms of rock would fulfill the required conditions under the calculated pressures.

One—for various reasons the most likely—is a magnesia-iron-silica rock which is best represented by a lovely, scintillating greenish rock known as dunite, from Dun Mountain in New Zealand, where there is an outcrop of it. It comes to the surface in a few other parts of the world in a very similar form. Some of the finest specimens have come from the Appalachians in North Carolina. It is filled with crystals of olivine, a semi-precious stone. When weathered it forms one variety of the familiar soapstone.

The second possibility, which seems quite unlikely, is that seven-eighths of the earth is made of a mineral known as eclogite, of the same chemical composition as basalt but with its crystals formed in a different way and containing the semi-precious stones garnet and jade. On the surface it is extremely rare.

It is not contended that this dunite, or eclogite if one prefers that hypothesis, is homogeneous throughout its entire depth. There are at least two discontinuities recognized by the seismologists.

All this surrounds the enormous hot heart of the planet, its core. There have been many deductions about the nature and material of this core, but there is little question at present but that it is a ball of molten iron, about 4,000 miles in diameter, having a volume about an eighth of that of the earth.

Under Enormous Pressure

It is under the enormous pressure of approximately 44,000,000 pounds a square inch, a little more than 3,000,000 times the pressure of the atmosphere at the earth's surface. Under such pressures, it is calculated, a temperature of about 10,000 degrees centigrade is necessary to melt iron.

The state of matter under such a pressure can only be conjectured, since it is more than fifteen times the greatest pressure ever obtained by laboratory methods—a little more than 2,000,000 pounds a square inch, achieved last winter at the Geophysical Laboratory. Certainly a great deal of empty space must have been squeezed out of the iron. That is, all the molecules have been pressed close together. It still, however, is far from the stage where the outer electron shells of the atoms would be crushed; for this, it is estimated, a pressure of about 100,000,000 atmospheres would be necessary.

That the core is a ball of liquid iron is a matter of fairly probable conjecture, established by Geophysical Laboratory experiments.

Must Be Heavy Metal

First, the material must be a heavy metal to account for the weight of the earth, 5.22 times that of an equal mass of water. Tests by the Carnegie Institution geophysicists have shown conclusively that the necessary weight would not be reached by any ordinary rocks under pressure. Iron is the most likely heavy metal, abundant in the sun and stars and forming a large part of the meteorites, fragments of a disrupted planet, which strike the earth.

It must be in a liquid state because of the behavior of earthquake waves which pass through the core. As soon as they strike the central core they are immediately slowed down and their character changed in the manner to be expected if they enter a "stiff liquid."

Three outstanding problems in geophysics remain to be solved. As yet hardly a beginning has been made on them.

First, the source of the earth's magnetism. The earth acts as a gigantic magnet. It has an iron center. But Geophysical Laboratory experiments show that iron loses most of its magnetic properties at temperatures and under pressures far lower than those at the core of the planet.

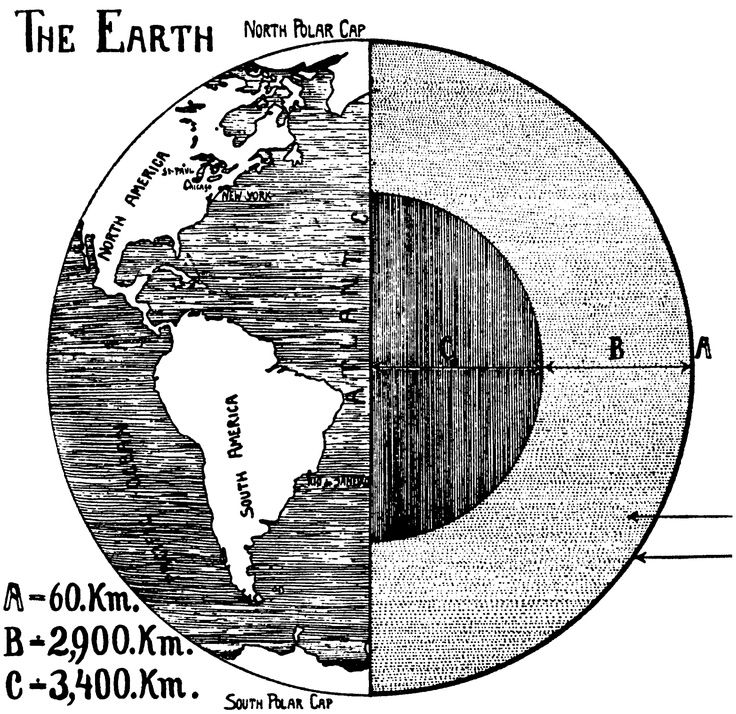
Second, the cause of deep-seated earthquakes. Those disturbances which originate in the crust can be explained easily enough as due to fractures and slippings of the relatively brittle rock. It is known, however, that some occur at depths of at least 500 miles. There is at present no simple theory of an instability at such great depths sufficient to produce such cataclysms.

Cause of Temporary Sinking

Third, the cause of the temporary depressions, apparently actual sinkings of the earth's crust, which result in shallow seas over the continents. For example, it is known that the present Appalachian mountain range has been sea bottom at least five times in the course of geologic history. This is perhaps the most difficult problem of all, and there is hardly a shred of evidence which throws any light on it.

Presumably the mountains came first, and were due—at least in part—to the wrinkling of the earth's granite "skin" because of contraction. Immediately erosion set in. Valleys were carved and summits cut down. The infinite variety of landscape was produced by this means. It continued for eons. The final result would be the leveling of the mountains almost, but never quite, to sea level. Yet they had to sink slightly below sea level for the ocean waters to rush in and cover the area. There is no known mechanism to account for this few feet of depression.

Is the process going on at present anywhere on earth? This is extremely difficult to determine, for, it may be assumed,



SECTION THROUGH THE EARTH

A is the crust, B the intermediate zone, and C the central core. (After Mohorovicic) the sinking would be at the rate of about an inch in a thousand years. There is some slight evidence that this is happening in the Rocky Mountain area and perhaps in some other disturbed regions of the world.

This does not apply to the major ocean basins, which presumably have changed very little in shape or position since the cooling of the planet.

A difficult problem is the distribution of the radioactive elements—uranium, actinium, thorium, and radium — throughout the earth. There are extremely minute amounts of radium in the crust, particularly in the granite rocks. But if the same amounts were distributed uniformly through the planet as a whole, so much heat would have been generated that, calculations show, it would have exploded millions of years ago.

Apparently, the most recent investigations at the Geophysical Laboratory have shown, these elements, together with all but four or five of the 92 known basic building stones of creation, are confined entirely to the crust. The most rigid analysis of the dunite from North Carolina shows it to be absolutely free of radium, and it is probably representative of at least 85 per cent of the planet.

How did this happen? A plausible explanation is that the earth "froze" from the bottom up, not from the top down like a pond. First the more abundant elements entered into the simplest possible chemical combinations and crystallized. Thus was formed the dunite. Then slightly more complex crystallization resulted in the basalt, leaving for the granite, last to be formed, all the leftovers.

Another serious problem, toward the solution of which little progress has been made, is that of the observed variation in the planet's rate of rotation—that is, the length of the day. This variation, amounting to a second or more, takes place about once in a century. The late Professor E. W. Brown of Yale sought to explain it by the hypothesis that just below the basalt layer is a thin shell of some material at or near a critical temperature, so that with a very slight temperature change it increases greatly in volume and causes the crust above it to bulge outward, giving the sphere a larger radius.

The origin of the ocean basins and the continents offers a fruitful field for speculation. Some authorities have held that the land areas, covering about a fourth of the earth's surface, once formed a single mass which was shattered into six or seven major fragments, and that these have been drifting apart ever since. Another hypothesis is that the granite formed like masses of scum on the underlying semi-liquid basalt. Perhaps it was one mass in the beginning, which broke up almost at once after the cooling of the planet.

None of these problems can be completely solved except by slow, patient observation and experimentation which may well require centuries.

Science News Letter, June 7, 1941

AGRICULTURE

Growing Seed for Defense Is Very Specialized Job

Amateurs Warned Not to Experiment Unless They Have Had Experience; War Has Increased Our Demands

THE Department of Agriculture is getting letters from all over the country from eager Americans who want to help defense and make some money by growing vegetable seed.

The answer is—Don't! Not unless you already have experience, and capital besides.

Raising the seed that produce the nice red tomatoes and all the other vitamin-filled fresh vegetables for a better nourished America is a very specialized business. So government scientists emphasize. Seed growing calls for some knowledge of plant genetics. Then too, the seed business requires a good deal of hand labor, and even employed laborers need to know which types of seed-producing plants to "rogue out," as sure to produce poor stock. Spinach plants, for instance, that go to seed too rapidly are undesirables. Farmers want spinach that will produce its green harvest to full perfection.

The United States is not going so far with amateur vegetable gardening and "all out" efforts to boost the food supply as it did in the first World War, it appears at present. The Department of Agriculture is encouraging those who live on the land to grow their own gardens, and farmers are especially asked to grow more tomatoes because of British needs and for our Army's vitamin C supplies. But back-yard gardeners are not being asked to plow up their small flower beds and plant cabbage as in World War I. And while war conditions have cut off our supplies of vegetable seed from many countries, the seed problem is being tackled by experienced growers and research scientists, with success on most fronts.

Spinach, for example: The United States used to import ten times as much seed for growing spinach as it produced at home. Almost all of our spinach seed came from the Netherlands. The forecast now is that we shall produce enough spinach seed this year for our needs and there may be a surplus. We could have produced it before, but it was more economical to import.

Cauliflower seed, on the other hand, is proving harder to raise in the United States. Growers here are having to fight harder against insects and diseases, which probably do not plague Dutch seed growers so seriously.

The weather has been unfavorable for producers of beet, carrot and onion seed this spring, so that crops may be somewhat smaller than early forecasts indicated. But in general more vegetable seed of nearly all kinds is expected to be harvested in the United States this year, compared to last year. Far from being dependent on other countries, as a rule, for all kinds of seed, the United States is the world's leading producer of carrot seed. It has been "running ahead," as government statisticians put it, in production of such seed as beans, peas, carrots, and squash, and a good deal of American seed is going to other countries, notably England.

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Fido may carry *ivy poison,* explains the Department of Agriculture—brushing against the plants, a dog may get the chemical irritant on his hair, and a person who pets the dog transfers the substance to himself.

In a study of 8,000 pupils in a typical American city, about 2% of the children in kindergarten wore *eyeglasses,* and the percentage steadily increased in successive grades, showing 23.7% wearing glasses in the twelfth grade.