HOW EARTHQUAKES ROCK THE WORLD

BY EMORY HARRING DUNLAP

TO UNDERSTAND how an earthquake sends its quiverings and pulsations through the earth it will be helpful to review in a simple way our knowledge of waves and wave motion. All writers on earthquakes, both ancient and modern, beginning with Thales and ending with Milne, agree that there are waves of long periods and waves of short periods, a period being the time required for each complete vibration.

Everybody is familiar with what happens when a stone is dropped into a quiet pool of water. From the center of disturbance there radiates in every direction little crests and troughs in ever-widening circles. These circles gradually diminish in height as their distance from the center increases and finally die away. If they meet a reflecting surface they are sent back again until the whole surface of the pool is shivering with a delicate, tremulous motion, very complex in its character. In a water wave the particle of water moves up and down at right angles to the general direction in which the wave is moving. A piece of wood floating on the pond will be raised and lowered, but not moved to any extent from its position relative to the sides of the pond. In other words, there is no actual transfer or movement of any particle of water from where the stone disturbed the surface of the pool to the shore, although it looks that way to the ordinary observer, so deceptive is the motion. This kind of a wave, at right angles to the line of direction in which the wave is moving, is known as a transverse wave and is the kind of wave in which light travels from the sun to the earth.

Another kind of wave may be observed when a gentle wind passes over a field of grain in fruit. As the breeze progresses the heads of grain gracefully nod and sway, first in the direction in which the wind is moving and then in the opposite direction. This is done so regularly and harmonically that the disturbance may readily be seen traveling rhythmically across the field. It is very evident, even to the most careless observer, that no head of grain travels more than a few inches back and forward, but that the impulse travels successively from head to head. This is an excellent illustration of how a wave progresses. The wave itself is immaterial, a pulsation, although it travels by means of material substances. The amplitude, as it is termed, of a wave is the width of the swing of the swaying heads of grain forward or backward, or the vertical distance from the highest part of the water wave to the lowest depth of the trough. The form of wave observed in such a field as has been described is known as a longitudinal or normal wave and is the kind of wave in which sound travels.

In both kinds of waves, transverse and longitudinal, we observe that the motion of the particles is pendulum-like in its character. Let us consider what we may learn from the observation of an ordinary pendulum in vibration. Suppose we suspend a weight by means of a string and start it to swaying to and fro. The distance covered in a complete swing is termed, as given above, the amplitude of vibration; the time required for a complete swing back and forth is called the wave period. If we cause the pendulum to swing to and fro through a greater arc we observe that the time or period is just the same as before; in other words, the amplitude or width of swing may be increased or decreased, but the time or period required for each vibration is always the same for any given length. If we shorten the pendulum we find it will vibrate much faster. If we lengthen it it will vibrate much slower. Pendulums of different lengths, then, have different times of vibration.

Now suppose we combine two pendulums of different lengths into one. Each of the component pendulums will strive to do just what it was doing before and the resulting motion, as shown in figure 1, which represents a double pendulum, will be quite curious. Instead of swaying soberly back and forth, as every well-regulated pendulum is supposed to do, it takes on a curious, reeling motion. If we fill the funnel shown in the illustration with fine sand the sand will be deposited in a beautiful curve not unlike the figure 8 in general appearance, although the form of the curve depends upon the ratios existing between the lengths of the component pendulums. A similar effect is produced when two tuning forks of different rates of vibration are caused to reflect their wave forms by little mirrors attached to the ends of the forks into one image on a screen.

Now what has all this to do with earthquake waves? Very much. The same kind of waves as have been described as rippling the surface of a pond or scurrying across a field of grain are the waves that move through the earth when a shock, whatever be its origin, calls them into being.

Suppose we imagine a heavy charge of dynamite exploded somewhere down in the earth. The earth in the immediate neighborhood of the explosion will first be compressed, even as the water particles next to the stone thrown into the pool were pushed nearer together. Then the elasticity of the earth exerts itself and it immediately rebounds, just as the water particles did. A succession of waves of alternate compression and expansion then passes through the strata. These correspond exactly to the waves that pass over the field of grain and are longitudinal or normal waves, moving backward and forward in the direction of the wave motion, even as the spokes of a wheel radiate from the hub and the radii of a circle originate at the center.

But this explosion of dynamite would not only set these normal waves in motion, but would give rise to another set known as transverse waves, corresponding to the motion shown to exist in water waves. It is very easy to see how the normal waves originate, but it requires some little effort to understand how the other kind is started. When the dynamite explodes it imparts a peculiar, twisting motion to the entire rock face of the cavern in which the dynamite was exploded. This twisting motion is the parent of the transverse waves and they start on their way together with the normal waves.

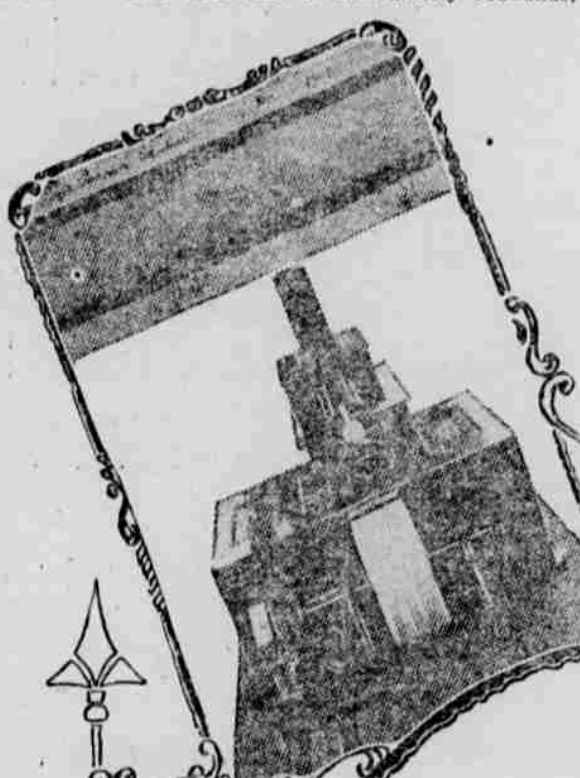
The two kinds of waves, normal and transverse, start out on their errands of destruction together and are generally present in earthquakes. Sometimes, however, they separate and travel in different directions, or one of them loses its energy through some variation in the nature of the strata, or from some unknown cause. When they travel together these waves correspond in their effect to that shown when two pendulums are acting as one, as in the sand pendulum referred to before. This explains the fact that usually there is a verticose or twisting motion present in most earthquakes; but sometimes, as when the waves separate, only an up-and-down motion, or a twisting motion alone. Normal waves travel faster than the transverse.

The speed of transmission varies from 200 or 300 feet per second in loose, soft earth to more than 10 times that velocity in solid rock. The crust of the earth varies much in different places as to the character of the strata. As the waves approach the surface they encounter areas of solid, highly elastic rock; then possibly they pass into regions of soft, incoherent sand and clay and weathered shales. The vibrations are consequently much changed as to their character and a new set of motions set up, differing considerably from the original waves.

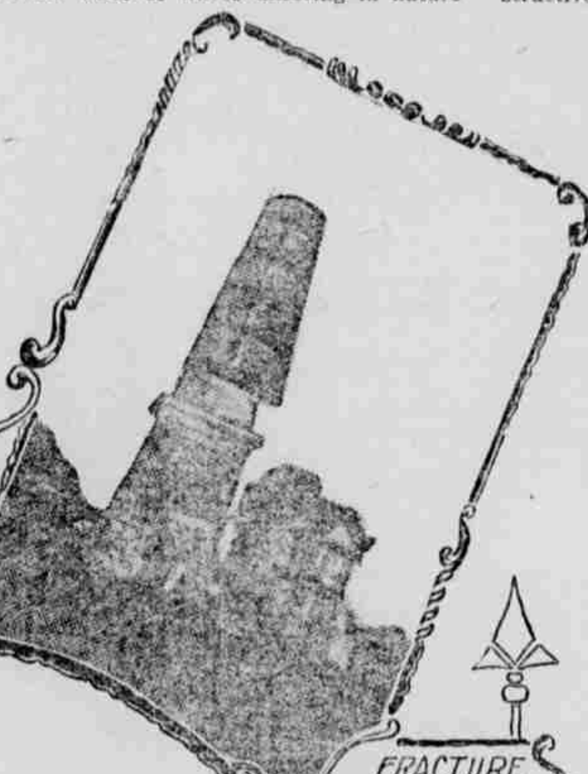
A third class of waves differing in nature from both the normal and transverse waves has been observed. They are known as surface waves, or, as Milne prefers to call them, earth pulsations. Their cause is obscure and earthquake specialists are divided as to whether they owe their origin to a tilting up and down of the strata of the earth's crust or whether they are due to a cause different from tilting and as yet unknown. These surface waves are quite different from the other waves that have been described in several respects. First, they are of extremely long periods, sometimes exceeding two minutes in length, while an ordinary wave is very much shorter. Second, they are long distance waves and are not the results of earthquakes three or four thousand miles away, as earthquakes violent enough to produce these effects at that distance must be, as Major Dutton points out, "necessarily of great power and could not escape notice and world-wide celebrity unless occurring in localities very far from human observation, or perhaps in the depths of mid-ocean."

In regard to earthquakes occurring under the sea little is known, especially as to the record of changes made in the topography of the sea bottom. In some cases, however, information has been obtained particularly with reference to some of the earthquakes off the coast of Greece. A number of cables had been broken in that vicinity and soundings taken when they were mended revealed some startling facts. In one case, according to Salisbury, where soundings were taken from the bow and stern of the ship which repaired the cable, there was a difference of more than 1,500 feet in the depth of water at the two ends of the ship. When the cable was laid a few years before the bottom was practically level.

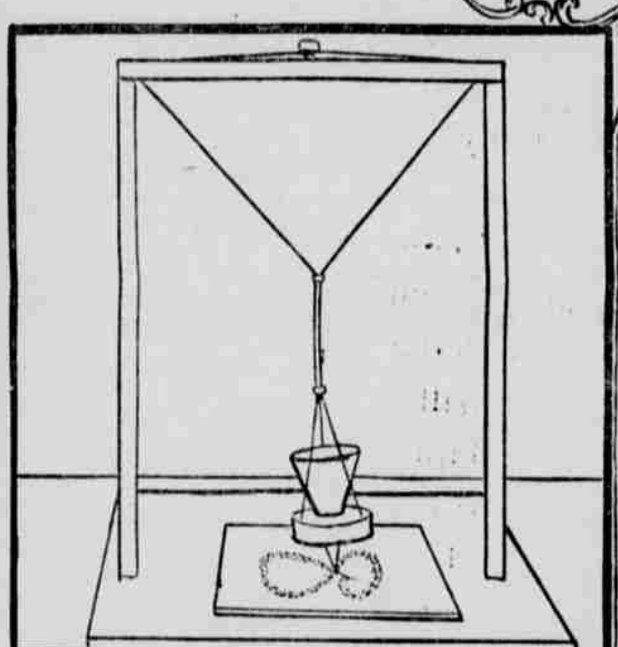
There is still a fourth class of waves, much more terrifying and spectacular in their effects. These waves seem to have no relation to the elasticity of the rocks and occur directly above the earthquake centrum, or epifocal district. Their lengths are small; they have very large amplitude of vibration and are too slow to be due to elasticity. In length they vary from 30 to 160 feet and in height from two inches to one foot. These waves are probably due to reflection or refraction from the deeper transverse waves when these latter waves pass from a highly elastic to a slightly elastic medium, and are the most destructive known. These are the waves which are responsible for the mischief in the great shocks. They tilt buildings, overthrow walls, upset chimneys, twist car tracks, swing and snap off immense trees and telegraph poles, make great cracks in the ground and are the prolific cause of great landslips where the conditions are favorable.



A MILNE SEISMOGRAPH SHOWING RECORD OF THE RECENT EARTHQUAKE IN ITALY

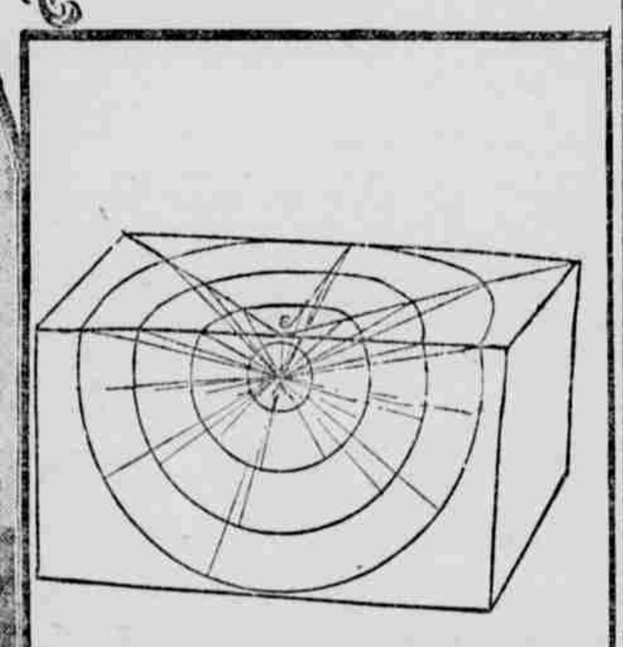


FRACTURE AND ROTATION OF A MONUMENT CAUSED BY EARTHQUAKE



SAND PENDULUM. NOTE THE 8-SHAPED DESIGN PRODUCED BY COMBINED ACTION OF DOUBLE PENDULUM

WHAT EARTHQUAKE MEANS



PROJECTION SHOWING CENTRUM THEORY OF EARTHQUAKE ORIGIN A-CENTRUM E-EPICENTER

THE OLD VIOLIN

Money talks just as loudly in the realm of music as anywhere else. The despised violin which merely is an incumbrance when it is thought to be worth not more than $10 becomes the chief ornament of the household when an expert says it is worth not less than $1,000. In Chicago there is a business man who owns a violin. He inherited it from his father, who was a musician. The business man does not play. One of his friends is a lover of violin music. That friend often had told the business man the violin was a good one and that he ought to treasure it. The business man regarded the advice as that of an enthusiast. One day the argument became so warm the friend insisted that the question be settled at once by carrying the instrument to a professor of music who is admittedly an authority on violins.

"Why, I wouldn't carry that violin through the street for anything," the business man said "My friends would think I had gone music mad in my old age."

"I'll carry it," his friend said quickly. "I'm not ashamed to carry a violin anywhere. Come along."

They went. The professor was at home. The back and belly, the neck and the bridge, the tailpiece and the sounding post all passed beneath his critical eye. "It looks all right," the professor said. From the case he drew the bow and ran the hair several times across the cake of rosin. Then, striking A on a nearby piano, he proceeded to tune the instrument which for so many years had been held in such light esteem by its owner.

"It is a genuine old Italian instrument, and I'll give you $1,000 for it," the professor said. The business man gasped.

"I'll tell you frankly it is worth more than that, but that is all I can afford to pay," the professor continued.

"I can't think of selling it," the business man replied, with a halt in his speech. "You see it came to me from my father. It is an heirloom. I thank you, however, for the test you have made and the good opinion you have expressed."

The two men started away from the home of the professor, the business man carrying the violin.

"Let me take it," his musical friend said. "You may meet some one you know."

"I'll carry it," the business man retorted. "I don't care how many friends I meet. And, besides, you might drop it."

Vain Sacrifice

Apropos of examinations and their terrors, A. E. Palmer, secretary of the department of education of New York, told at a recent dinner an odd story of a young African prince.

"This prince," said Mr. Palmer, "entered Yale or Harvard—I forget which—and amused himself with motor cars and bulldogs till examination time drew near.

"Examination time frightened the young prince horribly. He began to study and he cabled home to the king, his father:

"'Examinations next week. Most difficult. Implore aid of gods in my behalf.'

"A few days later this reply came back from the barbarous west coast monarch:

"'Rites performed. Fourteen picked youths, all sons of nobles, have been sacrificed. Omens propitious.'

"Yet, would you believe it?" Mr. Palmer concluded. "The young prince flunked."

To Memory Dear.

"Since I've come back I find I'm forgotten by all my friends."

"Why didn't you borrow money of them before you went away?"—Stray Stories.

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