SEISMOLOGY

Earthquakes

"A Classic of Science"

Confused Sounds and Rude Shaking Characterize Quakes Whose Spreading Waves Record on Distant Seismographs

EARTHQUAKES in the Light of the New Seismology, by Clarence Edward Dutton, New York, Putnam, 1904.

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WHEN the great earthquake comes, it comes quickly and is quickly gone. Its duration is generally a matter of seconds rather than of minutes, though instances have been in which it lasted from three to four minutes. Perhaps forty-five seconds would be a fair average. The first sensation is a confused murmuring sound of a strange and even weird character. Almost simultaneously loose objects begin to tremble and chatter. Sometimes, almost in an instant, sometimes more gradually, but always quickly, the sound becomes a roar, the chattering becomes a crashing. The rapid quiver grows into a rude, violent shaking of increasing amplitude. Everything beneath seems beaten with rapid blows of measureless power. Loose objects begin to fly about; those that are lightly hung break from their fastenings. The shaking increases in violence. The floor begins to heave and rock like a boat on the waves. The plastering falls, the walls crack, the chimneys go crashing down, everything moves, heaves, tosses. Huge waves seem to rush under the foundations with the swiftness of a gale. The swing now becomes longer and still more powerful. The walls crack open. A sudden lurch throws out the front wall into the street, or tears off or shakes down in rubble the whole corner of the building. Then comes a longer swaying motion, not like a ship at sea, but more rapid; not alone from side to side, but forward and backward as well, and both motions combined into a wriggle which it seems impossible for anything to withstand. It is this compound, figure-8 motion which is so destructive, rending asunder the strongest structures as if they were adobe. It is the culmination of the quake. It settles into a more regular swing of decreasing amplitude, then suddenly abates and the motions cease.

Or suppose we are out in the country and the earthquake comes suddenly upon us. The first sensation is the sound. It is wholly unlike anything we have ever heard before unless we have already had a similar experience. It is a strange murmur. Some liken it to the sighing of pine trees in the wind, or the falling rain; others to the distant roar of the surf; others to the far-off rumble of the railway train; others to distant thunder. It grows louder. The earth begins to quiver, then to shake rudely. Soon the ground begins to heave. Then it is actually seen to be traversed by visible waves somewhat like the waves at sea, but of less height and moving much more swiftly. The sound becomes a roar. It is difficult to stand, and at length it becomes impossible to do so. The victim flings himself to the ground to avoid being dashed to it, or he clings to a convenient sapling, or fence-post, to avoid being overthrown. The trees are seen to sway sometimes through large arcs, and are said, doubtless with exaggeration, to touch the ground with their branches, first on one side, then on the other. As the waves rush past, the ground on the crests opens in cracks which close again in the troughs. As they close, the squeezed-out air blows out sand and gravel, and sometimes sand and water are spurted high in air. The roar becomes appalling. Through its din are heard loud, deep, solemn booms that seem like the voice of the Eternal One, speaking out of the depths of the universe. Suddenly this storm subsides, the earth comes speedily to rest and all is over.

And yet this feeble description suggests but a single instance, or a few instances having a general similarity. There are many variations of detail in the incidents of great earthquakes. In some the full vigour of the shock comes without any *crescendo,* but as a *sforzando,* with an almost explosive suddenness. People find themselves suddenly thrown to the earth, the ground literally knocked from under their feet. Sometimes the rolling waves of soil are absent and the motion is a rude quiver, rapidly vibrating in every direction, twisting, contorting, wrenching the ground, as if in a determined effort to shake it into dust. Sometimes the most pronounced motion is vertical, as if the earth beneath were being hammered upward by a quick repetition of strokes. Sometimes the crescendo, climax, diminuendo are immediately repeated before the first cycle has come to complete rest, or it may be twice repeated. Or an interval of some minutes may elapse before the repetition, or even several hours. But a long-deferred repetition is very uncommon, though nearly all great earthquakes are followed by minor shocks for days, weeks, months, or even years afterward. Some of these are of considerable force though not of the devastating power of the principal shake. But they are alarming enough to keep people in a state of apprehension until they become inured to them. As time passes they diminish both in force and frequency and at length cease. . . .

Normal and Transverse Waves

Let us then conceive the interior of the earth as an indefinitely extended homogeneous solid. Imagine at the depth of a few miles below the surface a spherical cavity: that within this cavity a ball of dynamite is exploded. The suddenly expanding gases may be conceived as acting with equal force at all

points upon the spherical face of the cavity. The resultant direction of the forces at each point is radially outwards. Conceiving the surrounding mass as having a high degree of elasticity: every point of the surface will tend to move radially outward from the centre, imparting an outward thrust to points beyond, and propagating this thrust indefinitely. This purely ideal motion constitutes the method of movement in a *"normal"* wave. The vibration is to and from the centre of movement. It is the mode of vibration of sound-waves in air and water, as well as of *normal* waves in solids.

Elastic Resistance

Now let us change the conception. Imagine some force so applied as to tend to rotate the inner face of our cavity around a diameter as an axis. By the adhesion of the interior film to the surrounding mass this effect would be resisted in a solid, but not in a fluid. The resistance of the solid would be an elastic one. If the rotating or twisting force were withdrawn the elasticity of the material, after permitting a slight rotational displacement of the inner face of the cavity, would at once return to its original position. But in the meantime the rotating impulse would be imparted to more and more distant envelopes, indefinitely outwards, or as far as the medium might extend.

This ideal construction may give some notion of the kind of movement in a transverse wave. It is called transverse because the vibration of the particles is across a line extending outward from the origin. It can occur only in a solid, elastic medium, and is impossible in a liquid or gas. They are sometimes called waves of distortion, as they involve change of shape, or change in the relative positions of particles, without change of volume.

In the two foregoing suppositions the effort is to present in the first case the notion of a pure normal wave, and, in the second case, of the pure transverse wave. In nature the two, though they can be conceived of separately, can hardly be separately generated, and it may be said that an elastic wave in a solid is always compounded of normal and transverse vibrations at the origin, though they may separate afterwards. It is difficult and perhaps impossible to suggest any force actually occurring in nature and acting upon the rocks below the surface in such a way as to generate a pure normal wave or a pure transverse wave. Every force which can be suggested as at all liable to occur would create both normal and rotational displacements at the same time. A pure displacement of either kind can only be conceived of as a single or special case among an infinite number of possible ones.

That the normal and transverse waves should separate is due to the fact that their rates of propagation are different, that of the normal wave being the faster.* The speed of transmission of the normal wave is proportional to the square root of the ratio of volume-elasticity to density of the medium; that of the transverse wave is proportional to the square root of the ratio of the shape-elasticity (or rigidity) to the density. Volume-elasticity being greater than shape-elasticity, the speed of the normal wave is correspondingly greater.

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Third Class of Vibrations

Thus far we have spoken only of certain ideal waves in an elastic solid. They are of two kinds and the two simplest kinds, viz.: the normal and the transverse. They are contemplated as expanding radially outwards from a central point or origin and propagating themselves through a medium which has no other limit than the surface of the earth. Recent progress of seismologic investigation has brought to light a third class of vibrations called surface waves, which have awakened great interest among students of earth physics.

It may be questioned whether they are in reality a new discovery or anything else than a more definite and distinct recognition of a form of seismic motion which has always been imperfectly recognised as far back as the time of Thales and Aristotle, and only very recently brought into line with the most modern concepts of wave-motion. All writers ancient or modern seem to have been aware that seismic motion is vibratory and that there are vibrations of long periods and others of short periods. The ancient philosophers, Thales, Aristotle, Seneca, Pliny, Pausanias, seem to imply the idea that during an earthquake the ground moves in waves like the sea, while subject at the same time to sharp blows or shocks from beneath causing a "succussatory" or quick up-and-down motion superposed upon a slower undulatory movement. Thus Seneca says: "Duo genera sunt, ut Posidonio placet, quibus movetur terra. Utriusque nomen est proprium, altera succussio est, cum terra quatitur et sursum ac deorsum movetur, altera inclinatio, qua in latera, nutat navigii more." The notion that in an earthquake the ground undulates like the surface of the sea is surely very ancient and was deeply planted in the minds of the inhabitants of countries most subject to quakes, in Greece, the Ægean Archipelago, and southern Italy. It also became the foundation of the idea that the earth was composed of a crust floating upon a liquid.

WHAT AN EARTHQUAKE CAN DO

Since the earthquake disaster in Charleston, S. C., August 31, 1886, which Clarence Dutton investigated for the U. S. Geological Survey, many destructive tremors have been studied. The picture shows damage in one of the latest, Santa Barbara, 1925.

*This separation of the two kinds of waves is only an inference from the general theory of wave-motion in elastic solids. It has never been directly observed, though long-distance observations strongly support the presumption.

The more detailed accounts of earthquakes in the literature of the nineteenth century had often recited the occurrence of a swinging motion like that which is felt on the deck of a ship, though less in amplitude. It was an invisible motion, but it was distinctly felt and sometimes caused nausea. At considerable distances from the epicentrum people in the upper stories of buildings felt a swinging motion, and the chandeliers or other freely suspended objects would swing, while no movement would be felt by those out of doors or upon the ground floor. This slow, swinging motion would be perceived when no other form of vibration was sensible. It was observable not only at great distances from the epicentrum but at intermediate points.

When the seismograph came into use in Japan the first records obtained from it showed that vibrations of short period, from a tenth to a quarter of a second, were usually superposed upon and simultaneous with vibrations of one or two seconds. The short vibrations were usually a little before the longer ones, but quickly died away, leaving the longer ones predominant and at length the exclusive form of oscillation. Thus was given a partial confirmation of the ancient idea as expressed by Seneca. The seismograph showed the long, swinging movement like the rocking of a ship and at the same time the quick tremors which, though not strictly a *succussio,* were enough like it in their effects to be readily mistaken for it.

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ZOOLOGY

Bear with Bell Proud Although Ostracized

KNOWING that bears hate and fear noise, some packers on the trail in Glacier National Park this past season roped a black mother bear that had become too great a nuisance around their camp and hung a bell on a leather collar around her neck. She was then released.

The effect was amusing. Her cubs immediately ostracized her, squealing their displeasure. At first the mother bear resented the jingling neckpiece, then became accustomed to it, and finally actually displayed pride in it.

Her new cubs, if she retains the belled collar during the hibernating period, next summer probably will consider their mother a superior member of the bruin family because of her decoration.

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ENGINEERING

Research Hailed as Means To Save Railroad Lines

CONTINUED increase in efficiency of railroad operation as has been practiced during the past decade will be one of the chief methods by which the common carriers will extricate themselves from their present predicament. This thought is gathered from an address given by William C. Dickerman, president of the American Locomotive Company, before the Franklin Institute in Philadelphia.

Coming at a time when the railroads have been seeking higher freight rates, Mr. Dickerman's address emphasizes the great technical advances and economies the roads have made since 1920.

In spite of the fact that from 1920 to 1929 there was a reduction of 42 per cent. in the number of passenger-miles per year, this loss has been counteracted by savings and increased efficiencies, Mr. Dickerman pointed out. The loss of passenger-miles is not as serious as it at first seems because the bulk of the railroads' revenue is derived from freight, and freight revenue-ton-miles increased about ten per cent. during the decade.

Mr. Dickerman said that railroad operating costs in 1929 had been reduced to nearly three-fourths their 1920 value. The number of employees was reduced by 18 per cent., and 10 per cent. less coal was burned.

The concentration of trains into larger units and the expenditure of nearly $7,200,000,000 for capital improvements taking advantage of technical advances are held responsible for these savings. The number of freight cars decreased during the ten-year period, but their average size and their total carrying capacity increased. There are also fewer locomotives by 7,000, but as a group they have greater power and higher speed, and make longer engine runs with less fuel than they did in 1920.

"This technical experience with its background of research, invention and resourcefulness," Mr. Dickerman said, "may be expected to continue its unrelaxed efforts towards greater efficiency, whether to be secured through superpressures in steam practice or in refinement of internal combustion power far beyond anything that commercially has been developed to date."

Mr. Dickerman believes that the most immediate economies to be achieved by the railroads will come from replacing 25,000 locomotives more than 20 years old—nearly half the total number in the United States—with modern up-to-date efficient locomotives. Leaders in practically all fields have long recognized what obsolescence means to the progress of industry. They have not hesitated to replace their prime mover equipment as more efficient apparatus has been developed. Mr. Dickerman believes that the same economic analogy holds good in the field of railroad motive power.

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ZOOLOGY

Wild Boars of European Ancestry Roam in South

WILD BOARS, famous game animals of Europe in modern and mediæval times, exist today in certain mountainous regions of the South. Some thirty years ago their ancestors, believed to have been imported from Europe, were turned loose in the mountains immediately south of the Great Smokies.

The boars of today have the appearance and all the characteristics of the European boar, although it has been argued that they have crossed with the razor-back hog. In any case, however, the Tennessee boars are no less courageous or aggressive than their pure-blooded ancestors.

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MEDICINE

Adrenal Gland Operation Relieves Nervous Condition

AN OPERATION on the adrenal glands in which certain nerves are cut is successful in relieving the nervous condition known to scientists as neurocirculatory asthenia, Dr. George Crile, of the Cleveland Clinic, has announced. This condition acquired the name of soldier's heart during the World War, when a number of officers and men at