these are found to be coincident with geologic change.

The lecture might well have been called "The Philosophy of Paleontology," though the evidences are drawn chiefly from the vertebrates, the discussion being illumined by a very interesting diagram of the pulse of life, showing the influences of climate, continental elevation, and extinctions on the pulsations of vertebrate life. The discussion follows such interesting topics as "Emergence of Terrestrial Vertebrates," "Evolution of Terrestrial Foot," "Origin of Reptiles" and closes with the interesting comparison of the graph produced by a sphygmograph, recording the movements of the human pulse, with the graph deduced from the study of geologic and paleontologic evidences, recording the pulsations of life through many millions of years.

In the closing lecture of the series Professor Huntington discusses "Climate and the Evolution of Civilization." This is a proper closing for such a series, thus bringing out the influence of physical factors in the highest form of evolution. The lecture discusses the influence of climatic influence on certain primitive tribes and nations of America and is illustrated by a number of climographs.

The volume is thus a discussion, in brief form, of the chief factors bearing on the evolution of the earth and its inhabitants from the cosmical origin to the culmination of the highest phylum in the production of a high type of civilization.

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SPECIAL ARTICLES

A PRACTICAL LONG-PERIOD SEISMOGRAPH

A SEISMOGRAPH which is to record earth-motion with fidelity must have a "steady point" which shall be uninfluenced, as nearly as may be, by that motion. In existing instruments this steady point is the center of oscillation of a mass so suspended that when disturbed it vibrates slowly about an equilibrium position. The relative motion of the ground with reference to this steady point is then recorded with magnification on a sensitive surface by means of a suitable optical or mechanical system.

With suitable damping, and with a faultless recording system, the resulting record has considerable accuracy for rapid seismic motion whose period is not greater than the free period of the instrument; for slower motion the accuracy declines rapidly; and the instrument is wholly insensitive to motion whose period is several times greater. It is therefore of prime importance that the period of the instrument shall be as great as possible.

When this period is made large, however, a difficulty arises in that the equilibrium position of the heavy mass changes slowly, due to tilts of the support in case of the horizontal pendulum, to temperature changes in the vertical-motion instrument, and in both due to other less important causes. With the ordinary method of recording, these slow wanderings are magnified in the record, increasing the technical difficulty of obtaining the record, and excessively increasing the size of sensitive surface required. For these reasons practical seismometry has limited itself to periods rarely exceeding twenty seconds.[1]

Galitzin was the first to employ a method which permitted the recording of seismic motion without registering the wanderings. He employed an electromagnetic system which depended upon the velocity of the earth-motion rather than upon the displacement, thus avoiding the slow changes. In doing this, however, he sacrificed the flatness of the magnification curve of his instrument, so that his record not only did not represent the seismic motion directly, but did not permit its computation except in the case where such motion was simply harmonic—a case which does not occur in practise.

The writer has devised a method of record-

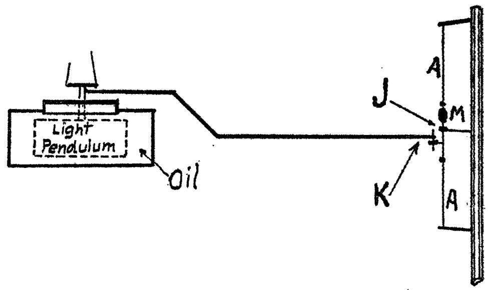
[1] From the literature one might infer that in practise, there is a low upper limit to the period of the horizontal pendulum. Walker sets this limit for laboratory purposes at forty seconds. But Omori has achieved much longer periods. The first pendulum constructed by the writer in the College of Hawaii laboratory had a period of three minutes.

ing which ignores the objectionable slow wanderings of the heavy mass, and yet records displacements directly, retaining the flat magnification curve of the best seismographs, and permitting the use of very long-period instruments. The essential feature of this recording system is that the (apparent) motion of the heavy mass is transmitted through a viscous medium to a light system having a shorter period of its own: the viscous coupling amounting to direct connection for the seismic motion of a period up to that of the pendulum, but permitting the light system to avoid the very slow changes.

This method of recording may be explained by describing the system as applied to a certain horizontal pendulum at the College of Hawaii. The adaptation to vertical-motion instruments will suggest itself.

Attached to the seventy-pound mass of a suitably damped horizontal pendulum is a horizontal cylindrical vessel of heavy oil, the axis of the cylinder being in the direction of motion of the pendulum. The cylinder is two inches in diameter, and has an opening in the form of a longitudinal slit one half inch wide at the top, around which there is a rim, to allow the surface of the oil to be somewhat higher than the top of the cylinder. In the cylinder, immersed in the oil, is the mass (about one pound) of a second horizontal pendulum. This mass is itself cylindrical and forms a piston within the larger vessel, though not touching it. The axis of rotation of this light pendulum coincides approximately with that of the heavy pendulum, but is sufficiently inclined to give a free period short enough to allow of registration, and it is the motion of this light pendulum which is recorded. It will be seen that for ordinary seismic motion the two pendulums form a single mass, but that the oil can flow so as to allow the light pendulum to retain approximately its own equilibrium position.

Registration is accomplished photographically as follows: A piece of no. 36 nickel wire two inches long is soldered at its ends to pieces of galvanometer suspension ribbon *AA* (see figure) each three inches long, and stretched between spring supports in a vertical position. At its middle this nickel wire passes through the hole of a watch jewel *J* of suitable size held by an arm fastened to the support, preventing transverse vibration. Fixed to the nickel wire just below the jewel is an arm of wire, one fourth inch long, holding at its other end a similar jewel. Through the hole of this jewel passes a short piece of no. 36



wire *K* attached to the end of an aluminum wire which is itself attached to the light pendulum by a flexible connection. The motion of the pendulum is thus transmitted to the mirror *M* which is cemented to the nickel wire at another point. The rocking of the mirror is recorded in the usual way on bromide paper.

This system succeeds with a magnification of 75 on a pendulum moving sometimes half an inch in the course of the twenty-four hours, with a lateral drum-motion of an eighth inch per (hourly) revolution.

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