which then pulls with more force, pulls with a smaller leverage, and it is easy to adjust the distance *v* so that the moment of the pull of the spring remains sensibly equal to the moment of the weight,—the condition necessary to make the bar astatic. This is secured when v=*h*2*/l*, *h* being the horizontal distance from the ful­crum to the point at which the spring acts, and *l* the length by which the spring is stretched when the bar is undeflected. Stability is given by making *v* somewhat less than this. A vertical-motion seismograph, constructed on the principle which fig. 8 illustrates diagrammatically, is arranged to trace its record on a revolving glass plate. This, along with a pair of horizontal pendulums recording on the same plate, completes a three-component seismograph.

An interesting mode of suspension, by which a mass is hung in neutral or nearly neutral equilibrium, with one degree of horizontal freedom, is shown in fig. 9. It is

based on the approximate straight line linkwork of Tchebicheff. When a bar is hung from fixed supports by crossed ties, at a distance below the supports equal to the distance between the supports, the length of the bar being equal to half that distance, its middle point moves in very nearly a straight line. By fix­ing a weight at the centre of the bar and adding a suitable recording apparatus, we have a very friction­less form of one-component hori­zontal seismometer. @@1 When a dis­placement of the ground occurs in the line of the bar, the bar is tilted through an angle which is proportional to the linear displace­ment, and the centre of the bar consequently shares, in a small and definite proportion, the motion of the ground,—a fact which is to be borne in mind in estimating the degree of multiplication given by the recording apparatus.

The instruments which have been described afford complete and satisfactory means of determining the motion which a point of the ground undergoes during any disturbance which would be recog­nized as an earthquake. For minute earth-tremors, however, a larger multiplication is necessary, and the absence of friction is of even more importance than in the measurement of earthquakes proper. Optical methods of magnifying the motion are accordingly resorted to. In the “ normal tromometer ” of Bertelli, used in Italy to detect earth-tremors, the bob of a pendulum, suspended by a fine wire from a fixed support, is viewed through a reflecting prism and its motion in any azimuth measured by a micrometer microscope. The great stability of the pendulum, which is only 11/2 metres long, prevents it from behaving as a steady-point seismometer ; and, if successive earth-movements were by chance to occur with a period equal or nearly equal to its own free period, its acquired swing would altogether mask the legitimate indications. This kind of action has, in fact, been turned to account as a means of detecting very minute earth - tremors

by Rossi, who has devised a micro-seismoscope, consist­ing of a number of pendu­lums of various lengths, one or other of which is likely to be set swinging when the ground shakes to and fro re­peatedly, through even the minutest range. To *measure* tremors, however, the instru­ments of Bertelli and Rossi are inappropriate ; for that purpose, just as for the pur­pose of measuring larger motions, the suspended mass must be in nearly neutral equilibrium. To find a mode of suspension which is at once astatic and extremely fric­tionless is a matter of some difficulty ; the crossed - link suspension, which has been already described, is probably the most satisfactory means hitherto suggested. It has been adopted in the micro­seismometer sketched in sec­tion in fig. 10. Two bobs are separately suspended, in the manner shown by fig. 9, at right angles to each other, one above the other, in a cast-iron case. A microscope, fixed to the top of the case and furnished with a micrometer eye-piece, is focused on a hair, which

is stretched transversely across a vertical tube in the upper bob *a.* This serves to measure horizontal motion in the plane of the drawing. Motion at right angles to this is shown by the lower bob *c* (drawn in section), which carries a similar transverse hair. A fixed lens *b* between the bobs gives an image of the lower hair in the plane of the upper hair, so that both appear crossed in the field of the microscope, thereby allowing both components of horizontal motion to be observed together.

*Equilibrium Method.—*In observing slow earth-tiltings an entirely different process is followed. The problem then is, not to measure displacements by aid of the inertia of a body which tends to pre­serve its original position, but to compare the direction of a line or plane fixed to the earth with the direction of the vertical. The earliest observations of earth-tiltings were made by the aid of spirit-levels. If a level be set on a table fixed to the rock, its bubble, watched through a microscope, will be seen to move slowly now to one side and now to another. The movements are so slow that the inertia of the fluid is unimportant. Observations with pairs of levels, set at right angles to each other, have been carried on systematically for some years by M. P. Plantamour. @@2 This is the simplest method of measuring earth-tiltings, but it is liable to errors which are not easily excluded. Another method of investigating changes in the direction of the vertical was initiated in 1868 by M. A. d'Abbadie, @@3 who had before that observed the movements of level-bubbles. Light from a fixed source is made to fall on a reflect­ing basin of mercury about 10 metres below it. Above the basin is a large lens of long focus, which brings the rays into parallelism dur­ing their passage to the mercury, and causes them to converge after reflexion, so that an image of the source is formed at a convenient distance from it, and in the same horizontal plane. The interval between the source and the image is measured (in amount and azimuth) at least twice a day by a micrometer microscope. The accuracy of the method depends on the fixity of the source of light relatively to the lens and to the surface of the ground, and to secure this M. d’Abbadie built a massive hollow cone of concrete for the support of his apparatus. His observations have shown that the earth’s surface undergoes almost incessant slow tilting through angles which, in the course of a year, have been found to range over four seconds. He has also noticed the occurrence of earth-tremors by the occasional blurring of the image through agitation of the mercury. An improvement on his apparatus sug­gested by M. Wolf4 is shown in fig. 11.

The light, instead of being all reflected from the free surface of mercury (*a*), is partly reflected from that and partly from a plane mirror (*b*) fixed to the rock. Two images are therefore formed, whose rela­tive position measures the tilting of the surface. The advantage of this is that the position of the source of light need no longer be fixed, and the accuracy of the method depends only on the fixity of the mirror *b* with respect to the rock.

Further, to avoid having the source and image at a great height above the surface,

M. Wolf allows the light to reach and leave the apparatus horizontally, in the manner indicated in the sketch, by using a plane mirror inclined at 45° to the horizon. Still another mode of investigating slow changes of the vertical was followed (at the suggestion of Sir William Thomson) by Messrs G. H. and H. Darwin, in observations made by them with the view of measuring the lunar disturbance of gravity. The *Reports* of the British Association for 1881 and 1882 contain a full account of their apparatus, as well as notices of the work of other observers and a discussion of the cause of earth-tiltings. Their in­strument was a short pendulum hung in a viscous fluid, from a fixed support, by two wires arranged V-wise to leave the pendulum only one degree of freedom. Below the bob was a small mirror hung by two threads, one of which was attached to the pendulum bob and the other to a fixed support. The pendulum was free to swing at right angles to the plane of the threads, and any movement of this kind caused the mirror to rotate through an angle which was measured in the usual way by a telescope and scale. The method is susceptible of very great delicacy, but Messrs Darwin found that when the instrument was adjusted to be specially sensitive its manipulation became extremely difficult. Wolfs modification of D’Abbadie’s method appears to furnish, on the whole, the most promising apparatus for measurements of this type. The ap­paratus represented in fig. 10 is also applicable. The method of measurement employed in the case of slow tiltings may be called the equilibrium method in contradistinction to the inertia method, which is used to measure comparatively sudden displacements. The

@@@1 Ewing, “ On certain Methods of Astatic Suspension,” in *Trans. Seis. Sοc. Jaρ.,* vol. vi. p. 25.

@@@2 Plantamour, *Comptes Rendus,* 24th June 1878, 1st December 1879, &c. ; and numerous papers in *Archives des Sciences,* Geneva, 1878-84.

@@@3 D’Abbadie, *Études sur la Verticale* (Association Française pour l’Avance­ment des Sciences), 1872, p. 159 ; also *Ann. de la Soc. Scient. de Bruxelles,* 1881.

@@@4 *Comptes Rendus,* xcvii. p. 228.