the movement of the boom over a second slit perpendicular to the first and made in the lid of a box containing clockwork driving a band of bromide paper. With this arrangement of crossed slits a spot of light impinges on the photographic surface and, when the boom is steady, gives a sharp fine line. The passage of the long hand of a watch across the end of the slit every hour cuts off the light, and gives hour marks enabling the observer to learn the time at which a disturbance has taken place. The chief function of the instrument is to measure slow displacements due to distant earthquakes. For local earthquakes it will move relatively to the pivoted balance weight like·an ordinary bracket seismograph, and for very rapid motion it gives seismoscopic indications of slight tremors due to the switching of the outer end of the boom, which is necessarily somewhat flexible. If we wish to obtain mechanical registration from a horizontal pendulum of the above type, we may minimize the effect of the friction of the writing index—say a glass fibre touching the smoked surface of moderately smooth paper—by using a considerable weight and placing it near to the outer end of the boom. In the Isle of Wight there is a pair of pendulums arranged as in fig. 5. The stand is 3 ft. in height. Weights of 10 lb each are carried at a distance of 10 in. from the pivots of booms which have a total length of 34 in. With these, or even with booms half the above length, actuating indices arranged as shown in fig. 2, but multiplying the motion six or seven times, good results may be obtained. At Rocca di Papa near Rome there is a pair of horizontal pendulums with booms 8 ft. 9 in. in length, 17 ft. in vertical height, which carry near their outer ends weights exceeding half a hundred- weight. Although such apparatus is far too cumbersome to be used by ordinary observers, it yields valuable results.

An apparatus of great value in measuring slight changes in the vertical which have a bearing upon seismometrical observation is the Darwin bifilar pendulum. This consists of a mirror about half an inch in diameter, which, when it is suspended as shown in fig. 9, rotates by tilting at right angles to the paper. By this rotation a beam of light reflected from the surface suffers displacement. It is possible to adjust the apparatus so that a tilt of 1/1000 sec. of arc, or a change of slope of 1 in. in 1000 miles, can be detected. (See Sir G. H. Darwin,

Scientific Papers, vol. i. (1907).)

The principle of the Vicentini instrument described

above has been adopted by G. Agamennone, director of the observatory at Rocca di Papa, near Rome, and also by E. Wiechert of Göttingen. In the Agamennone seismometrograph the pendulum is cheese-shaped, and weighs 500 kilos in one form and 2000 kilos, or over two tons, in the largest. This cylinder, which is suspended from a stand rigidly attached to the earth, has a vertical hole in its centre extending from its upper surface to its centre of gravity, and to the bottom of this well a light rod is fixed. The motion of the frame is communicated to this rod by an extension of the frame which makes contact with it just above its point of attachment to the well. The motion is first magnified by the lever, and, on its communication to a complex lever system above the stationary mass, is still further magnified before registration, which is effected by a pen supplied with ink writing on white paper. Mechanism is provided whereby the speed of the paper is doubled on receipt of a shock, an electric bell ringing at the same time to summon an attendant. In the Wiechert astatic pendulum seismometer the stationary mass is also cheese-shaped, but it is supported by a conical extension from its base, which balances it on the floor of its case. There is also an extension from the upper surface of the pendulum, in contact with a system of levers and rods attached to the case; an air-damping cylinder is fitted to annul the free vibrations of the pendulum. The motion of the rod consequent to a motion of the case is modified by the projecting axle of the stationary mass, and after much magnification is recorded on a sheet of smoked paper. This instrument was made with a pendulum weight of 1100 kilos or over a ton; and with a modified construction the weight was increased to 17,000 kilos or nearly 19 tons, porta­bility being obtained by replacing the solid pendulum of the smaller instrument by a shell which can be filled with barytes, a heavy mineral readily obtainable in most places. This instrument, which has a magnification of 2200, detects the slightest tremors, and is consequently most useful in recording earthquakes of distant origin; its high sensitiveness and complications, however, militate against its common use. Wiechert has also constructed a seismometer on the same principle, but in which the stationary mass is smaller, being

adjustable between 80 and 200 kilos (180 and 440 lb).

The Strassburg or Bosch seismograph differs from those just de-

scribed in resembling the Milne instrument, *i.e.* it is a horizontal and not a vertical pendulum. The steady mass, however, is much larger, being 100 kilos (or 220 lb); the magnification is from 80 to 100; and the registration is effected on a roll of smoked paper. An air-damping apparatus is attached in order to annul the natural oscillations of the pendulum. Two of these instruments are set up, one in the N.-S. direction and the other in the E.-W. so as to record the two horizontal components. A more popular Strassburg instrument has a stationary mass of 25 kilos. The Galitzin seismograph, devised by Prince

Galitzin, is of the same type, but it essentially differs from the Milne instrument in having its pendulum dead-beat ; this is brought about by an electromagnetic device. Magnification and registration of the motion is effected in the following way. Attached to the pendulum is a coil of fine wire which moves in the field of a pair of magnets. The currents induced in the coil are led to a dead-beat D’Årsonval galvanometer having the same natural period of vibration as the pendulum. It is found that the motion of the galvano­meter mirror faithfully records, except in a few special cases, the motion of the pendulum; the actual record is made on sensitized paper. Two instruments are set up, and the two components are recorded on one strip.

Authorities.—For older forms see R. Mallet’s *Report of the British Association* (1858). For modern forms see J. Milne, *Seismology* (London, 1898); *Transactions of the Seismological Society of Japan,* vols. i.-xvi., *Seismological Journal,* vols. i.-v. (Yokohama, 1880- 1895); *Bollettino della Società Sismologica Italiana,* νols. i.-v. (Rome, 1895); J. A. Ewing, *Memoir on Earthquake Measurement* (Tokyo, 1883); *Reports of the British Association* (1887-1902); E. von Rebeur-Paschwitz, *Das Horizontalpendel* (Halle, 1892); A. Sieberg, *Handbuch der Erdbebenkunde* (Braunschweig, 1904).

SEISTAN, or Sistan (Sejistan), the ancient *Sacastane* (“land of the Sacae ”) and the *Nimruz* or “ Meridies ” of the *Vendidad,* a district of Persia and Afghanistan, situated generally between 30° 0' and 31° 35' N.,and between 61° 0' and (including Rudbar) 62° 40' E. Its extreme length is about 100 and its breadth varies from 70 to over 100 m., but the exact limits are vague, and the modern signification of the name practically comprehends the peninsula formed by the lower Helmund and its embouchure on the one side and the Hamun (lake) on the other. Its area is 7006 sq. m.; 2847 sq. m. are Persian territory, while 4159 sq.m. belong to Afghanistan. When British arbitration was brought to bear upon the disputed claims of Persia over this country in 1872, it was found necessary to suppose two territories—one compact and concentrated, which was called “ Seistan Proper,” the other detached and irregular, called “ Outer Seistan.”

I. Seistan Proper is bounded on the north by the Naizar, or reed-bed which fringes the Hamun; west by the Hamun itself, of which the hill called Kuh-i-Khwajah marks the central point; south by a fine shutting in Sikuha and all villages and lands watered by the main Seistan canal; and east by the old bed of the Helmund, from 1 m. above the dam at Kohak to the mouth. Kal'ah-i-nau and Rindan are among the more northerly inhabited villages. The Kuh-i-Khwajah is a sufficient indication of the western side. Burj-i-'Alam Khan should be included within the southern boundary as well as Sikuha. Khwajah Ahmad and Jahanabad, villages on the left bank, or west of the true bed of the Helmund, denote the eastern line. The whole area is esti­mated at 947 sq. m. The fixed population may be roughly stated at 35,000−some 20,000 Seistanis and 15,000 settlers—the greater part of whom are Parsiwans, or rather, perhaps, a Persian- speaking people. To the above numbers may be added 10,000 Baluch nomads. Taking the aggregate at 45,∞o, we find nearly 48 persons to the square mile. These figures are eight times in excess of the proportional result found for the whole of Persia. It should be explained that the designation Seistan Proper is not arbitrarily given. The territory comprehended in it is spoken of as Seistan by the dwellers on the right bank of the Helmund, in contradistinction to their own lands. At the same time it could only be but a fractional part—as indeed the whole country under consideration could only be—of the Seistan of Persian history.

Seistan Proper is an extensive tract of sand and clay alluvium, generally flat, but irregular in detail. It has heaps, but no hills; bushes, but no trees, unless indeed three or four tamarisks of aspiring height deserve the name; many old ruins and vestiges of civilization, but few monuments or relics of antiquity. It is well watered by rivers and canals, and its soil is of proved fertility. Wheat or barley is perhaps the staple cultivation; but pease, beans, oil-seeds and cotton are also grown. Among fruits, grapes and mulberries are rare, but melons and water­melons, especially the latter, are abundant. Grazing and fodder are not wanting, and besides the reeds peculiar to Seistan there are two grasses which merit notice—that called *bannu,* with which the bed of the Hamun abounds on the south and the taller and less salt *kirta* on the higher ground.