and indeed a marine or rather a brackish plant, closely related to the species of the present genus *Chorda*, Stack. This fragment seems to have been mixed in the tide pools with fresh water or land plants growing there. For another thick specimen of the same locality and compound bears a profusion of marine mollusks, and has only branches of this as yet undescribed marine species, *Calamophycus septus*.

Habitat lower heldeberg sandstone, Michigan, discovered and communicated by Dr. Carl Rominger (State Geologist).

On comparing my Manx specimen, which was found on the surface in a field at Laxey with that figured and described by Prof. Lesquereux, it agrees with the latter in every respect, except that striæ and scales are not observable on the stem. The stem is thick, dichotomous; divisions variable in distance, the terminal ones short, pointed nearly equal in size and length, surface nearly smooth. The branches in the lower part are thick comparatively to their length. The surface of the stem appears to be smooth and affords no evidence of striæ or scales.

The woodcut on the preceding page represents the specimen a little over the natural size.

The stone in which the plant is embedded is a fine-grained grit of a grey colour, and the specimen itself is of a yellow tint as if coloured by oxide of iron; it runs nearly at right angles to the bedding of the stone, and appears as if standing in the same position as it had grown. The stone is a rolled one but it is evidently from the Manx schists found in the vicinity. These, according to Profs. Harkness and Nicholson, are of the age of the Skiddaw slates, but the rock in which the fossil occurs may be of older date, as some of the lower portions of the series have not yet been clearly determined; so here we have evidence of a plant in the lowest part of the silurian formation, or even lower. By diligent search the rock in which the specimen occurs may probably be found *in situ* in the upper part of the Laxey valley. The great resemblance, if not the identity, of the Manx with the American specimen is very remarkable, and shows the similarity of conditions then prevailing in distant parts of the globe. The specimen might have been called *Psilophytum cornutum*, if any marking on the surface of the stem had been observed, but as these appear to be absent it is proposed to call it *Psilophytum monense*. As to the nature of the water in which it grew there is no evidence from organic remains, but its characters resemble those of a fucoid more than a land plant.

THE FIGURE AND SIZE OF THE EARTH[1]

THE portion of the earth's surface bounded by the horizon which one is able to take in at one view, is but seldom a regular plane; more generally heights and depressions, mountains and valleys, alternate with each other so irregularly, that at first nothing seems farther from reality than the idea of a regular form of the earth's surface. But the more our point of view overtops the mountains which lie within the horizon, the further obviously will our range of view extend, and all the mountains and valleys which give so irregular a form to the horizon of the plain will, under this condition, become imperceptible and unimportant. Indeed, one can easily conceive that if the eye were able to comprehend at one time a much greater portion of the surface, the irregularities of the plain caused by the mountains and valleys would appear exceedingly small in comparison with the extent of surface. But such considerations must also have occurred to the ancients; for the earliest conception among the Greeks of the form of the earth's surface was that of a flat disc surrounded by the river Okeanos, into which the sun plunged nightly. The first advance was made by Thales, who said the earth must have a point of support, and imagined it was borne by the water. Anaximenes supposed that a strong dense atmosphere supported the earth. Quite another idea prevailed in India, where the earth was believed to be borne on the back of an elephant. More correct views of the figure of the earth prevailed at an earlier period in other parts of the East, in Egypt and a part of Asia. The Egyptians and Chaldeans taught at the earliest period the spherical form of the earth, and Pythagoras appears to have adopted this idea from them.

This difference of conception need not, however, be wondered at when we remember that the Greeks seldom undertook long journeys, and knew of the lands outside Greece only from fabulous narratives. It was otherwise with the people of the East, who, through their frequent and extensive travels, learned at an early period to know the positions of the stars as guides, and attained to a more correct conception of the size and form of the earth. The Chaldæans already knew the circumference of the earth so nearly that they said a good walker would take three years to walk round it.

Eudoxus was the first in Greece to recognise a symmetrical curvature of the earth's surface. He had noticed on long journeys that stars which at their greatest height (culmination) stood near the horizon gradually diminished in altitude, and finally disappeared; but on his return to those regions they again gradually became visible and assumed their previous altitudes. The circumstance that these altitudes of the stars changed regularly in proportion to the length of way travelled, led him to the conclusion of a regular curvature of the earth's surface. This conclusion being accepted, a simple method was indicated for measuring the circumference of the terrestrial sphere. For suppose a star reaches at a place, A, at its maximum a height of seven degrees above the horizon, if the observer move to another place, B, lying to the north, but in the same geographical longitude as A, and measure again the highest altitude of the same star, say six degrees; then the distance of the place A from B is equal to the 360th part of the whole circumference of the earth. Let the distance between A and B be now measured, and it will be found to be sixty-nine English miles; thus the entire circumference of the earth would be $69 \times 360 =$ about 25,000 miles.

Aristotle inferred, from physical and especially hydrostatic considerations, that the earth was spherical, since, he said, the water, which formed the larger part of the upper stratum of the earth, sought, by virtue of its weight and the mobility of its molecules, to approach as near as possible to the centre of the earth, it sought to assume the lowest position, and could never be in equilibrium until all parts of its surface were equidistant from the centre of the earth, *i.e.*, formed a globular surface. This inference, near as it comes to the truth, was yet in Aristotle's time only an unproved hypothesis; the existence of a centre exerting attraction in all directions was first recognised as probable at a much later period, Newton being the first to publish the conception.

The theory according to which the earth is a spherical body, was more and more generally accepted, and was put beyond doubt when the first circumnavigation by the Portuguese Magellan (1519) became known, an example followed, at short intervals, by almost all European nations. Thus the idea so generally accepted at a very early period that the figure of the earth must be spherical, was again revived about the end of the seventeenth century. The desire to ascertain, according to the above-described methods the circumference of this circle was also cherished by the ancients, and we have accounts of measurements taken for this purpose in the earliest times, of the most important of which we give some account.

The first determination known to us of the size of the earth was made by Eratosthenes in Alexandria in the third century before Christ. He observed at the solstice (the time of its greatest northern declination) in Alexandria, the greatest altitude of the sun above the horizon, and it was known that at that time the sun stood when at its greatest altitude, in the zenith at Syene (from which we may conclude that it could be seen in a deep well). Now since the altitude of the sun above the horizon is always equal to 90° minus its distance from the zenith, he thus required only to subtract the measured height from 90°, and thus found the distance from the zenith to be the fiftieth part of the whole circumference, or 7° 12′. According to this process the distance of the two places was regarded as a fiftieth part of the earth's circumference; and as that distance, according to the accounts of travellers, was 5,000 stadia, the whole circumference of the earth was equal to 250,000 stadia. Eratosthenes altered the result to 252,000 stadia, taking for the length of a degree, 700 stadia. Without considering the great inaccuracy of his altitude measurements, there are yet too many other formidable sources of error in this estimate of the earth's circumference, to allow it any claim to much accuracy. First there was the taking for granted that both places lay on the same meridian, which was not the case, since Syene lay three degrees east from Alexandria; and second, the distance of the two places reckoned at 5,000 stadia was too great.

A second investigation was made by Posidonius in the first century before Christ, but his result was still more erroneous than that of Eratosthenes. He observed the height of one of the brightest stars (Canopus in Argo) above the horizon. It reaches, at the time of its culmination at Alexandria, an altitude equal to the forty-eighth part of the circumference, while in Rhodes it was

[1] From a series of papers in *Die Natur*, by Karl Maria Friederici.

visible just on the horizon. Hence it followed from a calculation similar to the above that Rhodes lay about $7\frac{1}{2}°$ farther north than Alexandria, and taking the distance of the two places to be 5,000 stadia, he reckoned the earth's circumference at 240,000 stadia. Here also we find the assumption that the two places lay on the same meridian, nearly $1\frac{1}{2}°$ wrong. But the chief source of error in this observation lay in ignoring the refraction of the atmosphere, which is subject to very great differences near the horizon, and makes the stars not only appear at greater altitudes than they actually have, but disturbs the places of the lower stars much more considerably than those of the upper. But we are not now in a position to be able to discover satisfactorily the extent of these sources of error in the results of Eratosthenes and Posidonius, since the stadium was of uncertain length, and we do not know in what relation it stood to our modern measures.

These are the only results worthy of notice that have reached us from these times, for then commenced the decay of science in the east, and it was only at a much later period that it flourished for a short time among the Arabs. The Kalif Al Maimon had obtained from the Greeks the writings of their philosophers, and turning his attention chiefly to mathematics and astronomy, he was incited to undertake an investigation into the mathematical figure of the earth. He formed the resolution of undertaking the measurement of a new degree, and collected for this purpose a great number of mathematicians. These selected an extensive and level tract of land, the Sinjar Desert, and made their measurements from one point, some going north, others south. The result was that the one party found a degree of the meridian to measure 56 Arabic miles, and the other $56\frac{2}{3}$. Al Maimon had the operation repeated in order to obtain a better result, but the figures obtained were the same. We have more certainty as to the unit of this measurement, the Arabic mile, than in the case of the stadium, but yet not sufficient for perfect accuracy, as appears from the following definition:—According to Alfraganus the Arabic mile contained 4,000 ells of twenty-four inches, the inch being the space covered by six barleycorns laid side by side. P. Snellius compared this measure of length with one of his own units of measure, and after numerous observations found that on an average eighty-nine barley-corns are equal to a Rhenish foot. By this proportion it is found that an Arabic mile is equal to 6472 Rhenish feet. It is usual to reckon the Rhenish foot as ·16103 of a toise, and thus the mean length of the measured degree would be 58710 toises, which is too great by 1700 toises according to recent measurements. The toise is equivalent to 6·3946 feet, or 1·949040 metre.

We have mentioned already that from the decline of science we had no other than this Arabic measurement to produce, and we may further add that the most boundless ignorance, particularly with reference to natural science, reigned supreme, especially among the European nations. But it was not enough that this inaccurate determination of the size of the earth should stand as the only one for centuries; very soon it, and with it the knowledge of the spherical form of the earth was forgotten. It was not until the sixteenth century that a French physician, Fernel, again undertook the measurement of a degree. He made use for this purpose of a peculiar apparatus, which would certainly not lead us to hope for an accurate result, but, nevertheless, through fortunate circumstances, he came very near to the truth. He had a waggon constructed which, by means of a piece of mechanism, registered the number of turns made by its wheel. With this he set out from Paris in the direction of Amiens until he had gone a degree of latitude northwards, calculated from the number of turns of the wheel the linear measure, and obtained for this distance, which, according to his observation, was equal to a degree, 57070 toises. This result, as we shall see further on, agrees very closely with later observations, which is all the more wonderful from his finding the geographical latitude of Paris too little by 12′. But since this resulted from a constant error of his instrument, he must also have observed the latitude of the other end of the arc as too little by the same amount, and thus since in the calculation only the difference of the two observations is used, these errors are without any influence in the result. The other sources of error, which arose from the unevenness of the measured distance, and evidently must have given too great a result, he eliminated by subtracting a certain quantity from his calculation, and he did this so successfully that, as we have said, his result very closely agrees with modern measurements.

Another investigation at this period into the circumference of the earth, without the help of the stars, but simply by terrestrial measurements, deserves mention. Starting from a point as high as practicable (a mountain top or high tower, whose height was known), the observer went as nearly as possible in a straight line until he reached a distance at which the top of the mountain or tower disappeared in the horizon. The distance of this point from the mountain or tower was then measured, and from simple trigonometrical considerations it will be seen that the square of this distance divided by the height of the mountain or tower would be equal to the earth's diameter. But in this method the irregular action of terrestrial refraction is so disturbing, that the point at which the mountain-top would seem to vanish must be very uncertain, and the result as to the diameter of the earth consequently very erroneous.

All the methods hitherto referred to as in use in ancient times and in the middle ages, for obtaining a knowledge of the size and figure of the earth, are deficient in trustworthiness, partly from their defective theory, but still more from the impossibility of then carrying out those practical geodetic operations which are necessary for the solution of the problem with anything like accuracy. We shall see in the sequel with what wonderful accuracy it became possible to solve this important question.

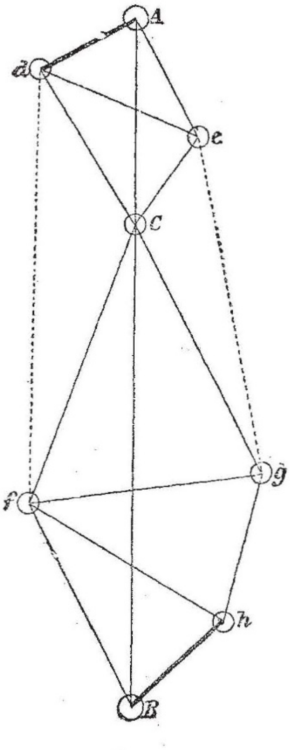

FIG. 1.

The method of measuring degrees underwent, in the beginning of the seventeenth century, a fundamental reformation. Hitherto, in all such measurements, only the simplest points in the geometry of the circle had been applied, but Snellius of Leyden, making use of the properties of triangles, founded a new method for the measurement of a meridian arc, and applied it first in the year 1615—viz. the method of triangulation. His method, which has been followed ever since, possessed the invaluable practical advantage over the earlier methods, that it considerably reduced the most difficult operation in the measurement of degrees, namely, the measurement of a base line on the earth's surface. How it is possible, even in regions of very uneven surface to measure a large extent of a meridian arc with great accuracy, will be seen from the following short explanation. Suppose two places, A and B, one or more degrees of latitude distant from each other, but in the same meridian; if the unevenness of the intervening surface, from mountains and valleys, allowed of no direct measurement, one would proceed in the following manner by the method of triangulation. First setting out from A (see Fig. 1) in whatever direction the character of the ground permits, a base-line A *d* is measured with the greatest possible accuracy. At the point A, the angle *d* A *e*, and at the point *d* the angle A *d e* are observed with a circular instrument. Thus in the triangle A *d e*, the adjacent side A *d* and the two other parts of the angles being known, the triangle can be computed. Place now in the straight line connecting A and B (in the same meridian) a point C, which can be seen from the points *d* and *e*; then we may, by means of the theodolite, measure at *d* and *e* the angles A *d* C and A *e* C.[1] Subtract now from these angles the previously observed angles A *d e* and A *e d*, and we have now found in the second triangle, C *d e*, the angles *d* and *e*. But then, also, the side *d e*, as belonging to the first triangle, is known, and thus also the second triangle, and consequently its sides C *d* and C *e* are known. But if the triangles A *c d* and A *e d* are known, so are also the triangles A *d* C and A *e* C; consequently, also, the common side A C; and thus a part of the distance is measured. To obtain the length of the other part B C, a base B *h* will be measured from B, and by operations similar to the above B C will easily be found. As a test of the accuracy of the measurements, we may connect the first operation, starting from C *e d* towards *f* and *d*, and going on to B, and obtain by means of the agreement of the measured length B *h* with the calculated length of B *h* as a side of the triangle B *h f*, a proof of the accuracy of the measurements of base and angles. Should the length A B be very great and the intervening ground mountainous, a very great number of small triangles may be required: in which case, though the principle is exactly the same, yet in practice, on account of the numerous measurements necessary under such circumstances, unavoidable errors and inaccuracies will certainly accumulate.

As we have already said, Snellius, in the year 1615, was the first to measure a degree by the method of triangulation. He measured a base line on the plain between Leyden and Sonterwonde (316 Rhenish rods and 4 feet long), and by means of connected triangles obtained an arc of the meridian (between Alkmaar and Bergen-op-zoom) of 1° 11′ 30″. Although Snellius was in possession of an improved instrument (Galileo had already taught the use of the recently-discovered telescope[2] for astronomical purposes), yet his measurements were so inaccurate that he obtained far too small a result (55011 toises for a degree). He soon became convinced of the erroneous nature of his result, and seven years after repeated the operation, measuring in the neighbourhood of Leyden a base-line in the ice. Probably deterred by the multifarious and difficult numerical operations which were at that time connected with the working out of the calculation of this new measurement by means of arithmetic, he did not carry this out, but his successor, Muschenbroek, devoting himself to the execution of this work after revising the triangulation, found 57033 toises as the length of a degree in the Netherlands.

Although the method of triangulation used by Snellius was a great step in advance, yet it was a long time before it became generally adopted; for even in the years 1633 to 1635 a degree-measurement was carried out by Norwood between London and York after the old method. He used an improved instrument (a five-foot sector) and obtained as the difference in latitude of the two places 2° 28′, and the length of a degree 57424 toises. Newton, who shortly after began the elaboration of his theory of universal gravitation, did not, at all events, know this result, since he took as the basis of his researches the earlier very inaccurate results as to the dimensions of the earth, and since he found his calculations did not correspond with them he abandoned for a time his theory.

Soon after, Picard, at the instance of the Paris Academy of Sciences, undertook anew a meridian measurement, and that not only after the improved method of Snellius (since he measured all three angles of each triangle, and computed the length of the arc by pieces), but he also gave to the measuring instruments a hitherto unattained accuracy by the addition of a micrometer apparatus.[3] He measured on the meridian of Paris an arc of 1° 22′ 55″, and finding for the latitude of that place 49° 13′, with the, as we now know, wonderfully accurate result of 57060 toises for the length of a degree. When Newton, in 1682, learned the result of Picard's measurement, he resumed his calculations in gravitation, and had the satisfaction, after thoroughly revising his work, of seeing his theory of gravitation established. A few years afterwards he gave to the world his immortal work on the mechanics of the universe. For a short time Picard's dimensions of the earth were accepted as correct and were universally made use of. But while hitherto the measurements had reference alone to the discovery of the size of the earth—for its spherical form was taken as proved—there now began a new epoch in the solution of the second part of the problem—the true figure of the earth. Influenced by the fact that the length of a degree measured at different places on the earth always gave a different result—which could not in all cases be ascribed to inaccurate measurement—Picard had already broached the idea that the earth could not be a true sphere. Soon after, Newton, in his great work, showed, on the supposition that the earth existed originally in a fluid state, that on account of the rotation round the polar axis, the supposed spherical form must be more truly that of an elliptical spheroid, the polar diameter being diminished and the equatorial diameter increased. Shortly after Huyghens was led to the same result; and while Newton by his calculations found the polar diameter to be to the equatorial as 229 to 230, Huyghens, on the basis of less general theories, found the proportion to be 577 to 578. Indeed, although differing somewhat in magnitude (Newton's proportion was then accepted as the more correct), yet, in principle, they both led to the same result, viz., that the earth is flattened at the poles, so that the length of a degree near the poles must be greater than in the neighbourhood of the equator. Moreover, Newton had shown experimentally the flattening at the pole, by rotating a soft clay sphere quickly round its axis, by which it became flattened at its poles.

To this was now added another valuable proof. The French astronomer Richer, in the prosecution of his observations at Cayenne, found to his astonishment that his pendulum, which beat seconds in Paris, vibrated too slowly in Cayenne; he had to shorten it by a line in order to make it again beat seconds accurately. On his return to Paris he had to lengthen the pendulum again by the same amount, since it now went too fast. Newton perceived that this apparently insignificant fact was really of the highest importance, for he recognised that these different rates of oscillation were due in Paris to the less, and in Cayenne to the greater, distance from the centre of the earth. Cassini's discovery of the notable flattening of the planet Jupiter was an additional proof of the truth of Newton's theory. Yet it was not until the middle of last century that Newton's theory was generally accepted as an irrefragable truth.

(*To be continued.*)

[1] There is no necessity for the point C being taken in a line between A and B, nor any advantage even if it could be done. The angles need not be measured in the way here laid down.

[2] This remark seems to imply that Snellius used a telescope in measuring angles. The application of the telescope to circular instruments was a step taken by Picard.

[3] Picard adapted to his measuring instrument a telescope with cross-wires in its focus; this appears to be the only "micrometer apparatus."

THE VARIOUS METHODS OF DETERMINING THE VELOCITY OF SOUND

THE propagation of sound is a question with many bearings in the province of physics, and the researches of physicists in relation to it, though numerous, have left some points still under discussion. It is useful in the view of further inquiry to be furnished with a historical survey of what has been already done, and this is the object of a recent memoir by Dr. H. Benno-Mecklenburg, published in Berlin (a *résumé* of which to the following effect appears in the May number of the *Journal de Physique*).

The author has adopted the following classification of the methods that have been employed for measuring the velocity of sound:—

I. Methods requiring the measurement of a time and a course traversed.

1. Direct measurement of the velocity; the most ancient measurements of this kind were executed by P. Mersenne in 1657, by the Academicians of Florence in 1660,[1] by Walker[2] (in England), in 1698; by Cassini and Huyghens (in France), &c.

2. Method of coincidences, indicated by Bosscha,[3] and employed by Koenig.[4]

[1] Newton, "Philosophia Naturalis Principia Mathematicæ," II., Prop. XLVIII.-L.

[2] Laplace, "Mécanique Céleste," t. v. livre xii. p. 115.

[3] Tentamina, "Exper. Academ. del Cimento," 1738, xi. p. 116.

[4] *Philosophical Transactions*, 1698.