nels and basins which hold the coal, composed of the Waverley shales, or the carboniferous conglomerate.

From these facts I translate the following history, which I am sure will be accepted as true by every geologist who has had sufficient experience in field-work to make his judgment of such phenomena trustworthy.

I. At the beginning of the formation of the coal-measures, north-eastern Ohio was a land surface, underlain by the Waverley shales, or beds of gravel, now the conglomerate. This surface was furrowed by the valleys of streams, and pitted by local basins, similar to those which mark the present surface.

II. With a slow subsidence, which continued with interruptions throughout the coal-measure epoch, the drainage was checked, and lakes and marshes were formed in the depressions of the surface. In these basins a fine sediment was deposited, — the 'fire-clay,' — like the clay now found under some of our peat-beds. When overgrown with vegetation the roots of plants penetrating this silt drew out of it iron, potash, soda, etc., leaving it nearly pure silicate of alumina, and specially refractory; whence its uses and name.

III. The marshes and lakes were ultimately filled with peat, which rose to a general level near the water-line, and was sometimes thirty or forty feet deep in the deepest parts of the basins.

IV. In places, water-basins remained such through a considerable portion of the time occupied in the accumulation of the peat; and sluggish streams flowed through the marshes, connecting these basins, and transporting to them fine sand, clay, lime, iron, etc., which, mingling with the completely macerated vegetable tissue, formed cannel coal, black-band iron-ore, and bituminous shale. After a time these basins also were filled with peat growing from the margins, just as our lakelets are now filled, and converted into peat-marshes.

V. After ages had passed with the physical conditions described, a subsidence caused a submergence of the peat-marshes, which first resulted in the destruction of the generation of growing plants that covered them. These dropped, in succession, leaves, twigs, and branches; and, finally, most of the standing trees fell. Some, however, continued longer to maintain an upright position, while the fine argillaceous sediment suspended in the water was slowly deposited around them, to form the roof shale, — of which the lower layers are charged with the *débris* of the plants growing on the marsh; the upper layers, deposited when these were all buried, nearly barren of fossils.

VI. The weight of the superincumbent mass pressed down the bed of peat; which, consolidated by that process, and undergoing internal chemical changes, ultimately became a bed of coal, thickest in the deepest part of each basin, thinning and rising on each side up to its edge, which remains to mark the original level of the surface of the peat-marsh.

Thus, and in no other conceivable way, was the resulting coal-bed made six feet thick in the bottom of the basin, and running out to nothing on the sides, thirty or forty feet higher.

The whole anatomy of the coal-seam shows that it was formed where it is found; the erect trees and plant-bearing shale above, the root-penetrated fire-clay below, the small amount of ash (only the inorganic matter of the plants), with many other features it presents, making the theory that it has been transported untenable. J. S. NEWBERRY.

THE YALE OBSERVATORY HELIOMETER.

FOR the benefit of the non-astronomical reader whose heliometric ideas are vague, the instrument may be defined as a measuring-machine in which the images of two stars, or other celestial objects to be measured, are superposed in the telescopic field by the following method: a telescope object-glass is cut across one of its diameters, and the two halves thus formed can be moved in opposite directions along the line of section by the observer while looking through the eye-piece. If he were examining the sun, for instance, with the two halves of the object-glass together, then he would have an ordinary telescopic view of the sun; but let him separate them, and he has the effect produced in the sextant when the two sun's images are separated by moving the arm. Now, if he brings the two images tangent first on one side and then on the opposite side by passing one over the other, the distance the object-glass halves are moved can evidently be expressed in arc, when the focal length is known, and is a measure of the sun's angular diameter. The advantages of such a method of measurement are only to be fully appreciated from certain considerations in physiological optics, from which it seems to be established that the most accurate measurements by direct vision are to be expected when the measuring-scale and the object measured are precisely similar in appearance and can be symmetrically placed. In the case given, the sun's limbs are of the same color and form, and the two positions are symmetrical with reference to each other. In measuring stars, the apparent magnitudes being made approximately equal, their images may be made to pass over each other with the greatest nicety; and in both these cases the observer's eye is steadily directed to a definite point in the telescopic field. In practice this seems to give more precise results than when the observer's attention is directed to two points at some distance from each other, and both bisected by the webs of the ordinary micrometer. In the telescope, with such a micrometer, the most exact measurements are not often extended over a minute of arc. And this limit is fixed by the field of view, which decreases as the magnifying power increases. With the heliometer, however, the limit of the distance which can be measured is independent of the magnifying power and the field of view, but is limited by the amount of motion given to the two halves of the object-glass. In the Yale heliometer this motion is about two degrees. Another advantage is the absence of either the bright webs or the bright field of the ordinary micrometer; but this is counterbalanced to some extent by the necessity of making the heliometer object-glass smaller than is usual in equatorials.

The difficulties and expense of construction of the modern heliometer, the fact that it is a special instrument to be devoted to measuring rather than to viewing, and the less difficulty of manipulation of meridian instruments and equatorials, led to the comparative neglect of the heliometer by English-speaking people until the erection of the Oxford heliometer of 190 mm. aperture. Lord Lindsay's admirable volume (*Dun Echt obs. publ.*, vol. ii.), describing his heliometer of 107 mm. aperture, presented in a very forcible manner the precision attained in measurements with comparatively small instruments. An inspection of the measurements executed with the instruments at Breslau (76 mm. aperture), Königsberg (158 mm.), Bonn (162 mm.), and Strasburg (76 mm.) shows a precision for distances over 1 minute not equalled by any other measurements made at the same period by instruments of another class.

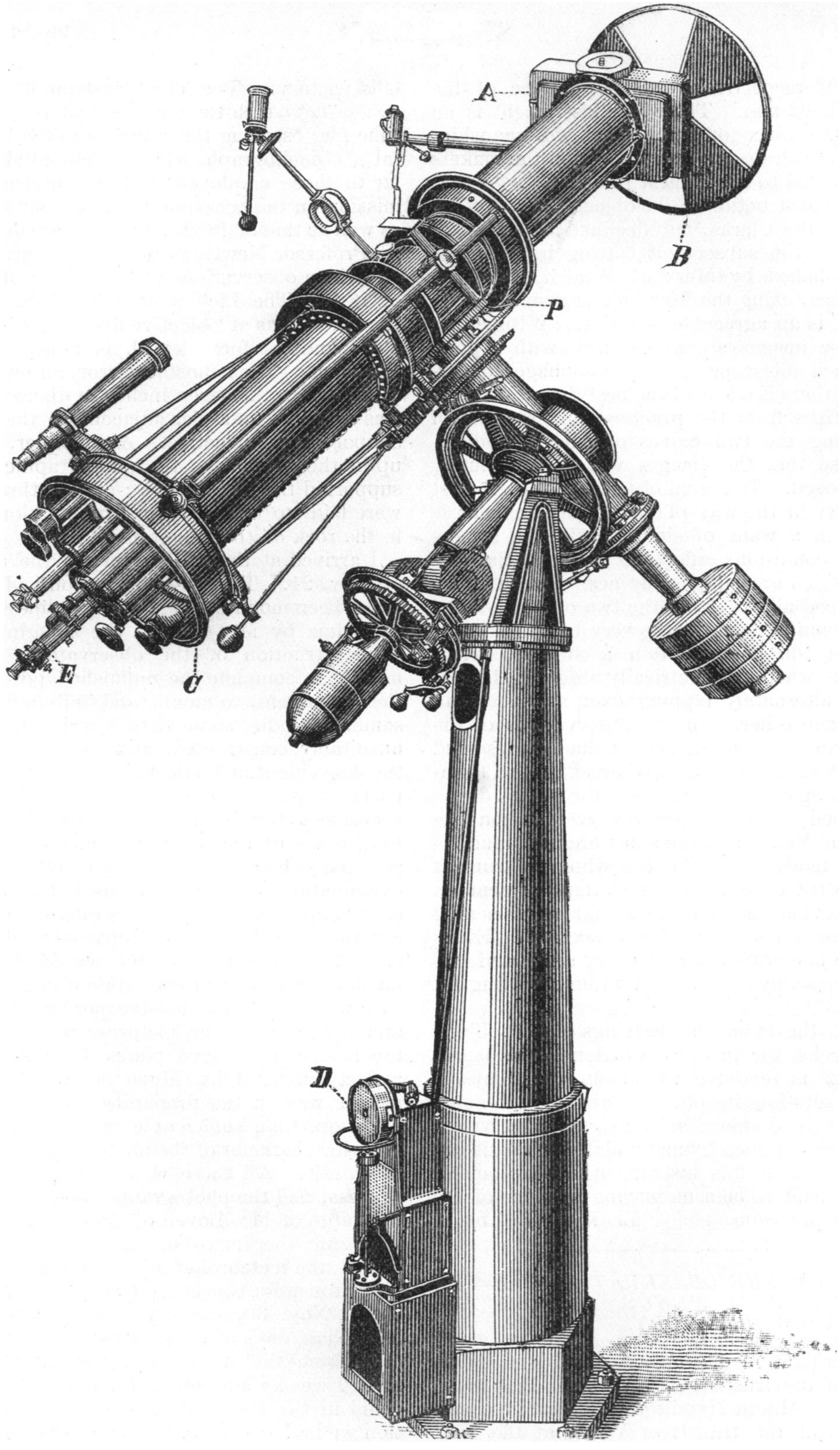
The belief that a heliometer of the largest size, and built according to the most recent theories as to material, form, and symmetrical arrangement of parts, would be an important adjunct to the instrumental resources of American astronomy, led to the writer's recommending to the Yale observatory board the acquisition of such an instrument.

The contract with the Messrs. Repsold bears the date of June 11, 1880. The heliometer was erected in Repsold's shops in January, 1882, for inspection, and arrived in New York the following May. About the beginning of September it was in place in the west tower of the observatory.

The figure shows it as erected in Repsold's shop at Hamburg, and without its tripod foot. The object-glass is mounted in the rectangular metal frame A, which contains the two sliding-pieces holding the object-glass halves, which rest on four cylindrical surfaces each 107 × 13 mm., and having a radius 125 mm. less than the focal length of the object-glass. The large rotating disc B contains three sectors of different thicknesses of wire gauze, which can be swung over either object-glass half, to diminish the apparent brightness of either image. This whole head can be rotated in position angle by means of the shallow sheet-iron cylinder, which has a rack with its appropriate gearing attached to it. By this device the motion in position angle is as expeditious as in the common form of position micrometer. The position circle is at P. The slow motions and clamps for all the circles are brought within easy reach of the eye-piece E, by a number of ingenious mechanical devices.

The two small brass oil-lamps, which are carried at the extremities of long arms to avoid their heating effects on the instrument, by a careful economy of the light, and a beautiful arrangement of lenses and mirrors, illuminate the object-glass platinum scales, the scale metallic thermometer, and both the position and declination circle indices, which are all read by their appropriate microscope micrometers projecting from within the cylinder C. The telescope tube is of steel, the circle graduations are on silver; the column axes and counterpoises are of iron, and rest upon a massive tripod foot of 0.85 m. radius. The distance from the surface of the granite capstone on which the tripod foot rests, to the intersection of the polar and declination axis, is 2.9 m. The clockwork, with its connecting rod, is shown at D.

The more important instrumental constants are as follows: aperture, 155 mm.; focal length, 2,495 mm.; maximum arc to be measured, 2°; magnifying power of the eye-pieces, 90, 126, 159, 245. The scale micrometer has a value of 0″.25 for one division of its head; while the hour circle, declination circle, and position circle micrometer divisions have values of 1^s, 10″



THE YALE OBSERVATORY HELIOMETER.

and 10″ respectively. The aperture of the finder is 62 mm. The whole instrument is an exquisite piece of mechanical workmanship, and for both design and execution the makers are entitled to the highest praise.

The construction of the object-glass, first offered to the Clarks, but declined by them because of the subsequent cutting in two, was accomplished by Merz of Munich. Its performance, using the Steinheil achromatic eyepieces, is an agreeable surprise. With either half the images are as sharp as with a good four-inch telescope. With the images superposed, there is a loss of the best definition; and this arises from the practical impossibility of adjusting the two halves of such an object-glass so that the images will be absolutely superposed. In actual observing, the greatest difficulty in the way of exact measurement is found in a want of similarity in the atmospheric conditions affecting two celestial objects which are supposably near enough to be influenced alike. Thus the two opposite limbs of the sun, except in the very best observing weather, do not maintain a steady contact together when heliometrically observed, but vibrate, alternately lapping over and receding from each other. In the observations of the last transit of Venus, this peculiarity presented the curious effect of a rapid breaking and forming of a ligament analogous to the 'black drop' described by the older observers when the limbs of Venus and the sun were in contact.

The model on which the whole instrument is constructed is a very great improvement on any previous heliometer, so far as lessening the observer's fatigue is concerned. Every motion is controlled, and every scale and circle is read, by the observer without leaving his seat.

With the cylindical bearings of the object-glass cells, the image distortion for measures up to 2° is rendered extremely small; by the rapid rotation in position angle, and equal rapidity in distance settings, the observer is no longer fatigued by manipulation; and it can be said that in this instrument the heliometer shows itself to be a measuring-machine of the highest precision. LEONARD WALDO.

NOTE ON THE OBSERVATIONS OF THE TRANSIT OF VENUS, 1882, AT THE LICK OBSERVATORY.

BY invitation of Capt. R. S. Floyd, president of the trustees of the James Lick trust, I went to Mount Hamilton to direct the observations of the transit of Venus at the Lick Observatory. The chief instrument of the equipment which the trustees had provided in time for observing the transit was the horizontal photoheliograph, which is essentially similar to those employed by the American commission on the occasion of the transit of 1874, as well as that of 1882, and which are described by Professor Newcomb in the first part of the American observations of the transit of Venus of 1874. The Lick photoheliograph, like all the others, has an objective five inches in diameter; and its focal length is almost exactly forty feet. The heliostat mirror, an unsilvered disk of glass, is seven inches in diameter, and was mounted on a pier adjacent to that which supported the objective. A third pier, coming up in the interior of the photographic house, supported the plate-holder; and all three piers were laid up of brick, their foundation being in the rock of the mountain summit.

I arrived at the observatory in the evening of Nov. 21. The photoheliograph had, in the main, been mounted and got in readiness before that time by Mr. Fraser, the superintendent of construction of the observatory. It remained to complete the unfinished portions of the instrument, to mount and fully adjust the same, to modify some details which had been unsuitably constructed, and to make sure of the convenient and effective working of every part. Especial attention was given to the accurate determination of the position of the focal plane of the objective; and the method adopted — being nothing short of a critical examination, by many persons independently, of several sets of trial-plates exposed at varying distances from the objective — finally indicated the true setting of the plate-holder with much more than the required precision. Great care was taken to insure the perfect definition and figure of all the pictures, and to prevent the mishap of fogged plates from scattering and extraneous light. Much time was consumed in this way in the preparatory work, but we had more than sufficient compensation in the superior character of the photographs of Venus in transit. All these were taken by the wet process, and the photographic operations were in charge of Mr. Lovell of Amherst.

During the important days of the transit-period, the meteorological conditions on Mount Hamilton were especially favorable. At midnight, Nov. 30, the sky cleared, after three and a half days of continuously cloudy weather. From that time until the afternoon of Dec. 7 we saw no cloud, day nor night, which could in the least interfere with any observation we had to make. Thin cirrus was float-