SURVEYING FOR ARCHÆOLOGISTS.[1]

II.

Horizons—Earthly and Heavenly.

So long as we are dealing with measurements of azimuth on the horizon, and altitude above the horizon, we are considering only our position on the earth—on that part of it which is bounded by our horizon. We are not dealing with the true position in the heavens of any body, whether sun or star, which may rise or set in the directions defined by our measures.

We are only dealing, in fact, with what is termed the *sphere of observation.*

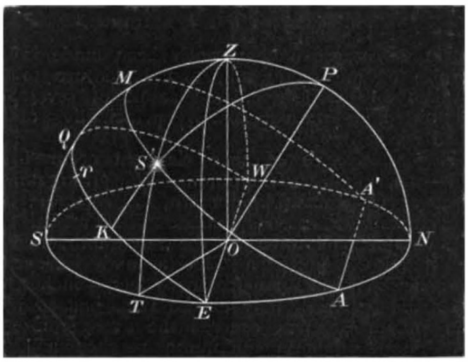

FIG. 4.—The sphere of observation. O, the position of an observer at the centre of the sphere, surrounded by the horizon; N. E. S. W. (the true cardinal points), with Z, the zenith, the point over the observer's head. The line N. S. is the true meridian line. The plane bounded by the line N. E. S. W. is the plane of the horizon, or the horizontal plane. The line O Z, a *vertical* line, is at right angles to the plane of the horizon.

The figure will illustrate what has already been said about azimuth, and will enable us to define some new technical terms which will be used later on. For *true* azimuths the zero is at N., which represents the N. point of the horizon, so that the azimuth of the E. point is 90°, of the S. point 180°, of the W. point 270°. Next let us take some intermediate points, A and T. The arc NA is the azimuth of A, the arc NT the azimuth of T. Sometimes it is convenient to define the position of a point on the horizon, not from the N. point (*azimuth*), but from the E. or W. point; we speak of this measure as *amplitude.* In any quadrant the one is the complement of the other, that is, added together, they make 90°.

The points A, T, like the points N. E. S. W., are represented as being on the horizon, so the distances of all these points from Z, called the *zenith distance,* are the same. If we represented these points not *on*, but *above* or *below* the horizontal plane, it is obvious that the zenith distances would not be the same. The higher the point is above the true horizon, as would happen if there were a hill there, the less the zenith distance.

The circle which we actually observe all round us when the heavens seem to rest on the surface which we see is termed the *visible horizon.* We imagine a plane parallel to the plane of the visible horizon, but passing through the centre of the earth; this is called the *rational* or *true* plane of the horizon.

So much for the horizon as a part of the earth's surface.

In the astronomical survey of ancient monuments, the determination of the azimuth of the various sight-lines, and the altitude of that part of the horizon which bounds them, is for the purpose of studying the sight-lines in relation to the rising or setting places of sun or star.

What we have to do, therefore, is to study the relation of the sphere of observation to what is called *the celestial sphere,* the sphere on which in old time the stars were supposed to be fixed by golden nails.

To do this we must pass from the consideration of the sphere of observation at any place to a study of the earth as a whole, and its movements, or at all events of some of them.

We have the earth in space with the universe of stars, almost infinitely removed, all round it, and we now know that the apparent movements of the stars from east to west, their daily risings, passing over the meridian and setting, in the sphere of observation at any place, are only the reflections of the earth's daily movement, or spin, on its axis from west to east.

The points at which this axis cuts the earth's surface are called the N. and S. poles, and half-way between these the earth is bounded by a circle called the *equator.* Now, as the daily motion of the earth is reflected in the apparent daily motion of the stars, so is the system of defining positions on the earth reflected in the system employed by astronomers in defining positions in the heavens.

As the earth is belted by *parallels of latitude* and *meridians of longitude,* so are the heavens belted to the astronomer with *parallels of declination* and *meridians of right ascension.* If we suppose the plane in which our equator lies extended to the stars, it will pass through all those which have no declination (0°). Above and below we have north and south declination, as on the earth's surface we have north and south latitude, until we reach the poles of the equator (90°). As on the earth we start from the *meridian of Greenwich* in the measure of *longitude,* so do we start from a certain point in the celestial equator occupied by the sun at the vernal equinox, called the *first point of Aries,* in the measure of what is termed *right ascension.*

So that we have terrestrial *latitude,* reckoned from the terrestrial equator, corresponding with celestial *declination*, reckoned from the celestial equator, and longitude corresponding with right ascension.

It is the *declination,* that is, the distance from the celestial equator, with which archæologists chiefly have to deal, for the reason that the rising and setting places of celestial bodies depend upon their declination; *bodies with the same declination rise and set in the same azimuths.*

Now the presentation of the plane of the horizon of a place to the surrounding stars which together constitute the celestial sphere varies vastly with its position on the earth's surface. Whether stars rise and set at all, or if they do whether they rise and set vertically or obliquely, depends upon this position, or, to be more precise, upon the latitude of the position. It is a pity that "calisthenics and the use of the globes" no longer form part of a liberal education, for a study of a terrestrial globe, which is a model of the earth in relation to the celestial sphere, gives us help in the matters we are now considering.

Such a globe is furnished with a wooden horizon, which represents the true or rational horizon passing through the centre of the earth as before defined. The axis of the globe prolonged is fixed into a brass ring representing the meridian, and the axis can be inclined at any angle in regard to the wooden horizon.

Now, wherever the archæologist is working, his

[1] Continued from p. 393.

©1908 Nature Publishing Group

observing place, bounded by his horizon, appears to lie at the top of the earth, and therefore parallel to

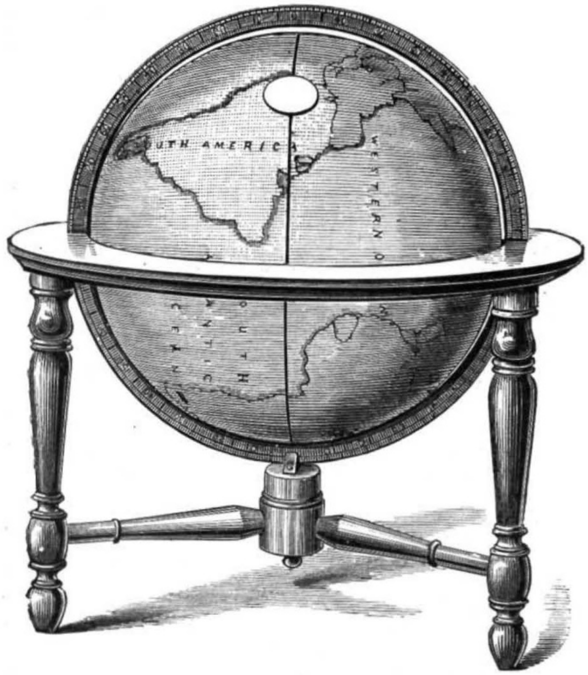

FIG. 5.—A model of the earth, showing that when the poles lie in the plane of the true horizon, and therefore of the wooden horizon which represents it, the horizon, represented by a wafer, of an observer situated on the equator, is carried vertically up and down by the earth's rotation ; this motion reflected causes the apparent up-and-down motion of the stars as observed at the equator.

FIG. 6.—In this case the axis is inclined to the wooden horizon, which is parallel to the horizon of Britain when at the top of the globe. The wafer representing the horizon of Stonehenge is carried obliquely up and down in a direction parallel to the equator, so that the sun and stars rise obliquely to the horizon.

the wooden horizon; let us therefore use two wafers to represent local horizons, and place one on the equator and the second on Britain.

When we bring the equatorial wafer to the top of the globe, where it lies parallel to the wooden horizon, we find that on rotating the globe it sweeps down in a vertical plane. The wafer over Britain, parallel to the wooden horizon when it is brought to the top of the globe, when the globe is rotated takes an *inclined* path to the horizon. This happens because the axis, instead of lying in the plane of the wooden horizon, is inclined to it. This inclination of the axis varies with the latitude of the place, and so the angle of inclination of the path of the wafer to the wooden horizon varies with the latitude. If we so arrange our model earth that the inclination of the axis is the greatest possible and the earth's equatorial plane lies in the plane of the wooden horizon, it is obvious that the earth's movement will only cause a wafer at the pole to rotate; with this exception it will remain at rest, and as there is no vertical motion to reflect, the stars will neither rise nor set.

Now the value of these little experiments depends upon the already stated fact that the *apparent* movements of the heavenly bodies are brought about by the real movements of the earth, and the experiments show us that in regard to the horizon at any place the *true* movement of the underlying earth, and therefore the *apparent* movement of the overlying heavens, is vastly different.

At the equator an observer's horizon is being whirled round in a vertical plane at the rate of 1000 miles an hour; at the poles the horizon remains parallel to itself. In Britain we have a midway condition. Correspondingly with these differences, at the equator we have stars rising and setting vertically and rapidly; in Britain stars rising and setting obliquely and more slowly; at the poles the stars neither rise nor set.

We may now return for a moment to Fig. 4, which we have so far considered in relation to the sphere of observation. It really enables us to study as well the conditions of the celestial sphere for the horizon N. E. S. W. of, let us say, Stonehenge in lat. 51° N. P represents the position of the celestial pole, and EQW the inclination to the horizon of the celestial equator for that latitude. The lines EQ and ASM give the angle of slant as the sun or a star on the equator or in a northern declination rises above the horizon.

Two or three technical terms which will be often used afterwards may here again be referred to. PN gives the height of the celestial pole, which is the same as the latitude of the place, ZP its *zenith distance*; it will be seen that these are complementary to each other, that is, together they make up 90°. S representing a star or the sun, PS is its *polar distance*, as KS is its *declination* or distance from the equator; it is seen that these again are complementary to each other. The line SZ represents its zenith distance.

NORMAN LOCKYER.

INTERNATIONAL CONGRESS ON TUBERCULOSIS AT WASHINGTON.

THE International Congress on Tuberculosis to be held in Washington between September 21 and October 12 promises to be one of the most interesting and important in the history of these meetings. Presided over by the President of the United States, assisted by Dr. Edward L. Trudeau, acting as honorary president, Dr. John S. Fulton, secretary-general, Mr. Henry Phipps, of New York, as treasurer, an exceedingly strong national committee has been brought together, and very complete arrange-

©1908 Nature Publishing Group