ON THE USE OF THE GLOBE IN THE STUDY OF CRYSTALLOGRAPHY.[1]

IN modern treatises on crystallography, the crystal is imagined projected radially on the surface of a sphere, and the spherical triangles so obtained are dealt with by spherical trigonometry. Problems in astronomy and mathematical geography are also commonly dealt with by the methods of spherical trigonometry. But they can also be dealt with completely by the method of graphical construction on the surface of a sphere where the angles and arcs are directly measured with a divided circle; and the use of spherical trigonometry is dispensed with. Many years ago it occurred to the author that what eliminated the use of spherical trigonometry in the one case might eliminate it in the others: hence the idea of the use of the globe in the study of crystallography. Various arrangements of globe and circles were described and exhibited. The usual method of mounting globes on a polar axis, round which it can revolve inside a metal meridian, supported in its turn at right angles to a horizontal circle or equator, was found to be inconvenient. It is necessary to be able to reach every part of the globe, and to have it steady for drawing, and the fixed circle and axes stand greatly in the way of this. The instrument found most generally useful was a black globe, along with a system of brass circles, divided into degrees, which can be applied directly and exactly to any part of its surface. The system of brass circles is called the *métrosphère*, invented by Captain Aved de Magnac, of the French Navy, and published by E. Bertaux, of Paris. With this instrument every problem in the geometry of crystals can be solved with ease and accuracy by graphic construction alone.

The various manipulations occurring in the use of the globes were described and illustrated. In the practical determination of a crystal, the inclinations of its faces are observed with the goniometer. From these observations, treated usually by the methods of spherical trigonometry, the elements of the crystal, namely, the inclination of its axes and the proportion of its parameters, are deduced. The process is then reversed, and the elements found are assumed, and from them the inclinations of the faces are calculated. The usefulness of the globe was illustrated by demonstrating how these two processes can be carried out by simple graphical construction. On the globe, the face of a crystal is represented by its pole, or the point where the radius of the sphere, which is perpendicular to the face, pierces the surface of the sphere. The angle between two faces, measured by the goniometer, is the angle contained between their normals. It is therefore ready to be transferred directly to the globe on which it is entered as an arc. In doing so, any point on the globe is taken as the pole of the face from which a start is made. From this a great circle is drawn in any direction. When the first angle has been measured on the goniometer, it is laid off on the globe as an arc, of an equal number of degrees, along this great circle, and from the initial fixed point. The poles of the first pair of faces are situated at the extremities of this arc, which becomes the *base line* of the survey of the crystal. By triangulation from it, the angles being supplied by the goniometer, the positions of the poles of all the faces are placed as points on the globe.

The intersection of a face with the surface of the globe is a circle, which may be described on it with a pair of compasses, taking the pole of the face as centre. The circles in which any two faces, which are not parallel, meet the sphere, cut each other in two points. If these points be joined by the arc of a great circle, we obtain the projection of the edge which the two faces make on meeting. It is perpendicular to the great circle passing through the poles of the two faces. If it be carried parallel to itself to the centre of the sphere, it coincides with a diameter, and its poles are indicated by points on the globe. When the operation has been repeated with all the edges, we have a second group of points on the globe, which catalogues the edges occurring on the crystals.

If the circles of intersection, with the surface of the sphere, of any three faces, not in the same zone, be considered, the arcs connecting each pair of intersections meet in a point which is the projection of the *corner* formed by the three faces which meet there. A third group of points, representing corners, is thus obtained on the globe, and the characteristics of the crystal are exhausted.

If the corners be carried parallel to themselves to the centre, they find themselves already represented by the intersections of the diameters representing their edges. If the similar poles of any such group of diameters be connected by arcs of great circles, a spherical triangle or polygon is marked out, and its area compared with that of a hemisphere is a measure of the corner, just as the arc is the measure of the angle which it subtends. The secondary figures thus described on the surface of the sphere are always different from the primary ones. Thus the corners of the cube, when collected at and radiating from the centre of the sphere, delineate the regular octahedron, which in its turn, when similarly treated, delineates the cube. From this point of view they are reciprocal inversion forms.

Having got a complete projection of it on the globe, the crystal can be studied. It can be referred with equal ease to any system of coordinates and to any number of different systems; it is only necessary to shift the *métrosphère* over the surface of the globe. In fact, there is now no question touching the geometry of the crystal which cannot be directly answered after making one or more simple measurements; and the distinction between easy questions and difficult ones has almost disappeared.

The projection of the crystal has been constructed from supposed observed angles on the goniometer; but it is equally easy to construct it from its crystallographic specification—that is, the inclination of the axes and the proportion of the parameters.

The projections, of the normals to the faces, or the coordinate planes, are found by constructions on these planes. These positions are marked on the sphere by the points on the coordinate circles where they meet its surface. A great circle drawn through any one point, at right angles to the coordinate circle, contains the pole of the face. It is also contained in another great circle, found in the same way. It is fixed in their point of intersection.

In this way every possible face, permitted by the specification, can be easily and readily placed on the sphere by its representative pole; and the angles between every pair can be at once taken off with a pair of compasses or a tape. In a few minutes a complete catalogue can be made of the angles which each face makes with every other one. The advantage of this is particularly apparent in the oblique systems, which on the globe are dealt with as readily and as easily as those of the regular system.

In conclusion, the author alluded to other uses of the globe, where it does easily, and without fatigue, work which can be done in no other way without great labour; and he pointed out an important indirect advantage, gained by its use, in the education of the sense of direction, which is generally only sparingly developed in the mind.

[1] Abstract of a Paper read before the Chemical Society, December 6, 1894, by J. Y. Buchanan, F.R.S.

THE USE OF SAFETY EXPLOSIVES IN MINES.

A LARGE committee was appointed by the North of England Institute of Mechanical Engineers in 1888, to investigate and report upon the subject of flameless explosives in relation to their degree of safety in mines. Experiments with various explosives and appliances connected with shot-firing were commenced in 1892 at Hebburn-upon-Tyne, and a number of papers referring to them have been contributed to the Institute's *Transactions*. The first part of the Report of the Committee has just been published, and it clears away many of the doubts and uncertainties connected with the employment of safety explosives in underground workings. Into the details of the experiments we have not space to enter, but the following conclusions deduced from them show the kind of results obtained:—

(1) All the high explosives (ammonite, ardeer powder, bellite, carbonite, roburite, and securite) are less liable than blasting-powder to ignite inflammable mixtures of air and fire-damp. These explosives, however, cannot be relied upon as ensuring absolute safety when used at places where inflammable mixtures of air and fire-damp may be present.

(2) The variable results following upon the detonation of high explosives appear to be due in some measure to defective admixture of, or variation in the proportions of, the ingredients used in the manufacture of the explosive.

In view of the changes from time to time made in the pro-