THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

VOL. 5 MAY, 1920 No. 5

PRACTICAL CRYSTAL DRAWING

MARY W. PORTER[1]

Oxford University

The ordinary method of crystal drawing involves the previous preparation of an "axial-cross" upon which the intercepts of the crystal faces may be laid off, yielding the directions of the edges; the perspective drawing is then obtained by a process of truncating and bevelling a "primitive figure." It presents the following disadvantages:

1. The derivation of the axial-cross alone is somewhat laborious in the case of a monoclinic crystal, and is decidedly irksome in the case of a triclinic crystal.
2. Much judgment and practice are needed in making successive truncations; otherwise the final result is not a faithful representation of the crystal.
3. The orthodox position for the axial-cross is not suitable for all crystals. The preparation of a suitable axial-cross for any but the normal position is a difficult matter for which no general directions can be given.

In the year 1891 Professor Victor Goldschmidt[2] introduced an entirely new method of drawing, based on the gnomonic projection, and this method would appear to be preferable, for the following reasons:

1. No axial-cross is required and the only construction lines needed, the guide-line (Leitlinie) and angle-point (Winkelpunkt) may be drawn in a few minutes.
2. All truncations are effected at the outset in an orthogonal projection of the top of the crystal. This drawing is made as a free-hand sketch before measurement, and afterwards accurately from the gnomonic projection.
3. As will be seen below, a preliminary examination of the gnomonic projection will show whether the orthodox drawing position is suitable or not. The alteration of this standard position is a matter involving no extra labor whatever.

[1] Lady Carlisle Research Fellow, Somerville College, Oxford.
[3] *Z. Kryst. Min.*, 19, 352, 1891.

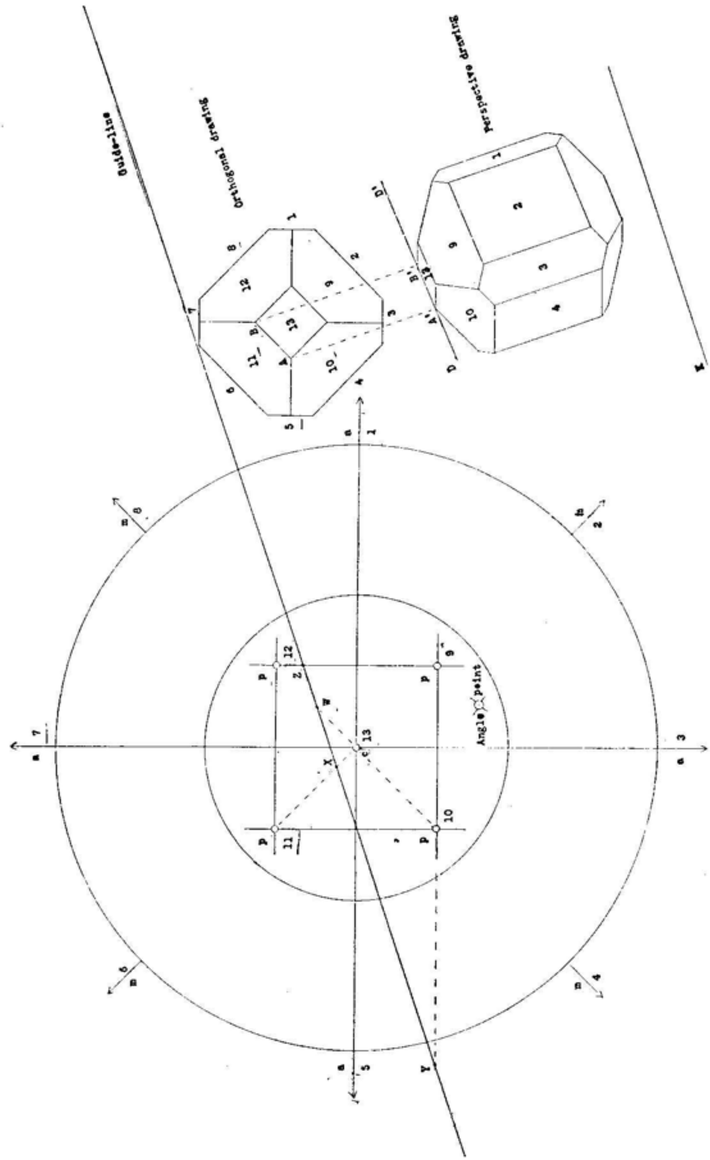
Guide-line
Orthogonal drawing
Perspective drawing
Angle point

FIG. 18.

The most satisfactory way of illustrating Professor Goldschmidt's method is to give a concrete example of the drawing of a simple crystal. A crystal of vesuvianite (idocrase) was chosen for this purpose; the gnomonic projection and drawing are given in Fig. 18, on page 90.

The orthogonal projection is made normal to the basal plane. Since in the gnomonic projection all zones become straight lines, the direction of the edge between any two crystal faces in orthogonal projection is perpendicular to the zone line in which they lie. In the orthogonal drawing, then, to find the direction of the edge between the two faces 9 and 10, place a ruler[1] on the zone 9–10 in the gnomonic projection and with a right-angled triangle or set-square obtain the perpendicular direction. In the case of an edge between a prism and a terminating face, such as that formed by the faces 2 and 9, the required direction will be perpendicular to that of the direction-line (arrow) representing the prism.

In preparing the orthogonal drawing it is convenient to draw the prism outline first. In the example given the faces were drawn in the following order: the prisms 2–4–6–8; the pinacoids 1–3–5–7; the basal pinacoid 13, and finally the pyramids 9–10–11–12.[2]

It need scarcely be stated that in the preparation of the orthogonal drawing of an idealized crystal every care must be taken to preserve every equality of dimensions demanded by the symmetry; for example, in drawing the prism outline, the edges 2–4–6–8 must be of equal length. If the drawing is to be a "portrait," reproducing the actual proportions of the crystal, this important aid to correct work will not be available and the best judgment of the worker must be employed to secure the correct balance of the various parts of the figure. It is also important that the scale of the drawing should be large; with a complicated figure it is impossible to secure accurate results in a small, crowded plan. Lines should be drawn with a wedge-sharpened hard pencil so that the ruler may be placed accurately upon the point thru which the line is to be drawn. If the crossing points of lines are marked by pricking with a needle point and circling the hole with a soft pencil it will be much easier to find them again and to draw accurately thru them should occasion arise.

[1] A heavy steel straight-edge will be found convenient, tho not necessary.

[2] Before starting the orthogonal drawing, the ρ values of the inclined faces should be carefully considered. Faces with high ρ values will appear very much wider in the perspective drawing than in the plan, and faces with low ρ values very much narrower. Allowance must be made for this when deciding the width of the faces in the orthogonal drawing. In practice the width can be estimated by the eye but the mathematical relation may be used as follows: In a right-angled triangle ABC in which C is 90° and A is ρ, let AB be the width of a face in perspective drawing; then AC will be the apparent width in the plan.—$\frac{AC}{AB} = \cos \rho$ or $AC = AB \cos \rho$.

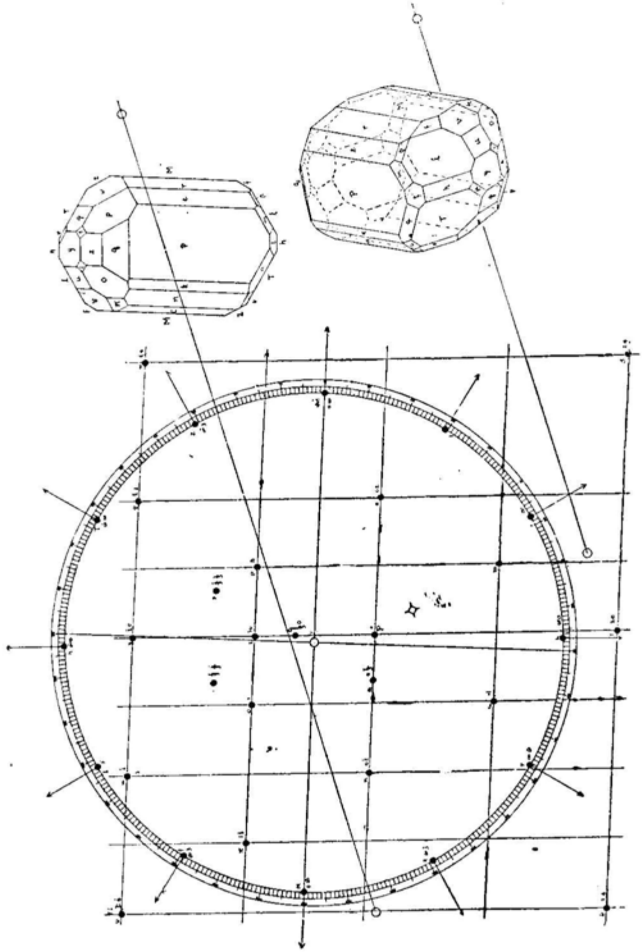

FIG. 19.

The parallel-perspective drawing is made from the orthogonal drawing with the help of the gnomonic projection, guide-line and angle-point. To obtain such a drawing in the generally accepted position the guide-line and angle-point are to be constructed according to the following directions (taken from Prof. Goldschmidt's paper above cited):

Draw a vertical diameter of the 5 cm. unit circle, AB. From B lay off to the right a chord BF = $\frac{1}{3}$ OB. Draw the diameter FOE and on OE lay off OD = $\frac{1}{6}$ OB. Thru D draw a line all the way across the projection perpendicular to FOE. This is the *guide-line*. Draw the radius OJ parallel to the guide-line. The point at which OF is cut by a circle with center D and radius DJ is the *angle-point*, GP. Geometrical proof of the correctness of the methods to be used will be found in a supplementary note following this paper.

The position of the first crystal edge to be drawn,[1] say that between faces 11 and 13, is arbitrarily selected on the drawing paper at a convenient distance under the plan. To find the direction of this edge in the perspective drawing note where the zone 11–13 (dotted line) cuts the guide-line (the point X) and join this point to the angle-point.[2] The direction of the required edge will be perpendicular to the line so obtained; it is lettered DD′ in the figure.

The direction of the edge having been obtained, its length is determined from the plan as follows: In a convenient position such as K draw a line parallel to the guide-line and with the help of a ruler and triangle draw lines (dotted in the figure) perpendicular to the guide-line from points A and B until they intersect line DD′. The length A′B′ between the points of intersection is the length of the required edge between faces 11 and 13. In practice it is unnecessary to draw in the dotted lines. In the same way, to find the edge between 10 and 13, note where the zone containing them cuts the guide-line at W; and take the direction perpendicular to the line joining W to the angle-point. Next draw the edges between 9 and 13, and 12 and 13, thus completing face 13. The edge between 9 and 10 might next be drawn. In this case the zone intersects the guide-line at Y. Then draw the edge between 12 and 9. Now to find the edge between a terminating face and a prism, for example that between faces 9 and 3: Lay one side of the triangle along the direction line (arrow) of the prism face 3; shift it parallel to itself until it passes thru the pole of face 9; note the point Z where this line cuts the guide-line; and take the perpendicular to the

[1] This edge should be a front edge of the crystal. Front and back edges can be easily distinguished, for an edge is never at the back of the drawing except when both the face-poles concerned are behind the guide-line in the gnomonic projection.

[2] It is not necessary to draw the line connecting X with the angle-point. Lay one leg of a right-angled triangle on the two points; slide the triangle along a straight-edge to the desired position; and draw *DD′* on the other leg.

line connecting Z and the angle-point. The edge between 9 and 2 is next drawn, the point on the guide-line being X again. Finally the edge between 9 and 1 is drawn, thus completing face 9. In the same way the directions and lengths of all the edges in the perspective drawing are obtained.

A perspective drawing obtained by Goldschmidt's method is indistinguishable from one derived by the axial-cross method; and the time required to draw an average crystal is about one third (or even less) of that needed with the older methods.

As an example of the simplicity of the Goldschmidt method, a drawing is given of an anorthite crystal (Fig. 19, p. 92) showing thirty forms, together with its gnomonic projection. In this particular case instead of plotting the φ and ρ values from chord and tangent tables, a new gnomonic chart (based on a 5 cm. unit circle) has been used, designed by the author in order to save even more time.[1] It must be noted that the printed graduated circle does not represent the circle of projection. It is drawn with a 10 cm. radius so as to insure greater accuracy in marking off the φ values. The linear distance (5 times nat. tan ρ) corresponding to the angular ρ reading of each face is found with a pair of dividers from a horizontal scale printed at the top of the chart, on the lines recommended for the stereographic projection by Penfield. The angle-point is printed, as also dots which when joined give the guide-line. The latter is not printed in, as occasionally the standard position[2] for drawing the crystal is not suitable because one or more faces disappear if their poles fall on the guide-line, or become too narrow if their poles are too close to the guide-line. In such cases a new and more appropriate position of the guide-line may be found by trial, which need not differ widely from the usual position.[3]

The preparation of a gnomonic projection from single-circle measurements is not so direct as in the case of two-circle measurements. In the former case, as is well known, it is an easy matter to prepare a stereographic projection, especially when a stereographic net is available. From this the gnomonic projection may be derived by a method previously described in this series (page 76). It may be noted here that Professor Goldschmidt's method was adapted by Stöber to the stereographic projection.

[1] See advertising page ii.

[2] The standard position accepted by most crystallographers for the perspective drawing is the one in which the crystal appears as if rotated 18°26′ to the left and inclined 9°28′ forward. In the chart the rotation is 20° and forward inclination about 10°.

[3] See Figs. 20 and 21 on page 95. In Fig. 20 we have a projection of a crystal whose poles 1 and 2 are nearly intersected by the guide-line, which faces accordingly practically disappear in the perspective drawing. In figure 21 we have the same projection with the guide-line so shifted that the poles 1 and 2 are no longer so close to it. Having drawn the guide-line the angle-point is found as before but in reverse order. Draw OJ parallel to the guide line and FOE perpendicular to it. With radius DJ draw the arc intersecting OF at the angle-point, G.P.

This adaptation[1], simplified by Viola[2] and fully worked out by Penfield,[3] altho not so accurate as the original method based on the gnomonic projection, can be confidently recommended to users of the one-circle goniometer as being much superior to the axial-cross method generally described in the text-books. It should also be noted here that in the paper by Penfield just referred to there is a presentation of Goldschmidt's method of crystal drawing in a rather different form from that of the present paper. Any student who intends to master the art of crystal drawing would do well to read with great care both this

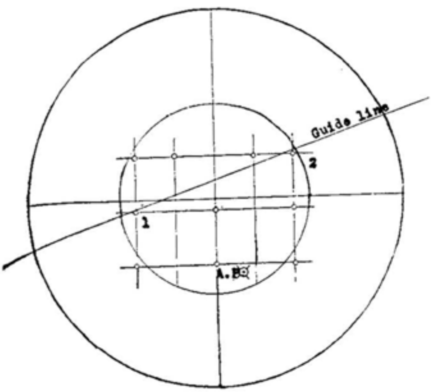

Fig. 20.

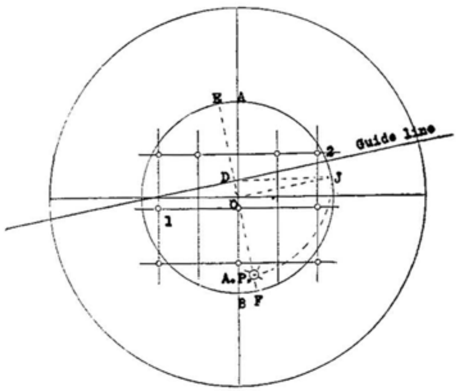

Fig. 21.

and other articles on that subject by this master of crystallography.

Enough has been said to illustrate the great simplicity of construction and the rapidity of execution of crystal drawings resulting from the ingenious application of the gnomonic projection by Professor Goldschmidt.

When one takes into account the enormous number of drawings made annually by crystallographers the world over, the conclusion is irresistible that the new method of drawing is one of the most valuable aids to practical crystallography that has yet been devised.

In conclusion, it gives me pleasure to have an opportunity to thank Mr. T. Vipond Barker, lecturer in chemical crystallography, for most valuable suggestions and criticisms in connection with preparation of the above account.

[1] Stöber, F., *Bull. soc. franc. min.* **22**, 42, 1899.
[2] Viola, C., Grundzüge der Kristallographie, 29, 1904.
[3] Penfield, S. L., *Am. Jour. Sci.*, **21**, 206, 1906.