Determination of Octahedron Orientation from Widmanstätten Figure by the Template Method

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Abstract. An easily constructed device is described for ascertaining the angles of orientation of the octahedron of Widmanstätten figures.

It is well known that in iron meteorites containing appropriate amounts of nickel much of the nickel is concentrated in thin, evenly spaced lamellae running in four directions. Consistent with the isometric lattice structure of the iron, these lamellae (taenite) parallel the faces of an octahedron. Thicker layers of nickel-poor material (kamacite) lie between them. On an etched section, the kamacite appears to be divided into four sets of bands running in different directions. This pattern has long been referred to as the "Widmanstätten figure."

Angles between the four sets of bands obviously depend on the orientation of the octahedron relative to the plane of sectioning. For certain purposes it may be desirable to know this orientation. Its mathematical determination, though possible, is a rather imposing task. If errors of two or three degrees are tolerable, an experimental procedure may suffice.

One such procedure involves the construction of quadrilateral templates from the Widmanstätten figure. These are tried in various positions against a four-sided pyramid whose faces are equilateral triangles. When a satisfactory fit is obtained, the orientation of the template relative to the pyramid duplicates the orientation of the plane of sectioning relative to the octahedron in the meteorite.

The pyramid (or rather, its edges, which are all that are needed) may be constructed from eight straight, slender rods of equal length (for example double-pointed knitting needles.) For the templates, some type of cardboard—thin, but as stiff as possible—is needed.

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The four sets of kamacite bands in the Widmanstätten figure may be represented by four lines intersecting at a point (Fig. 1A). If the four lines are shifted outward from this point, it will be found that four, and only four, quadrilaterals with different angles can be constructed (Fig. 1B-E), assuming that re-entrant angles are excluded. The four quadrilaterals are to be used as templates. In order to obtain suitable sizes, they should be constructed inside circles with diameters about four-fifths as long as one edge of the pyramid. All sides should be of reasonable length. The outside edge of each template may be marked by a second circle (diameter about equal the length of one edge of the pyramid) circumscribed about the first. The template is then cut out, using the point of a knife for the quadrilateral and a pair of scissors for the outside edge.

If one of the templates is slipped over the apex of the pyramid, its position may be adjusted so that three sides of the quadrilateral are in contact with three of the pyramid faces. The fourth side either will

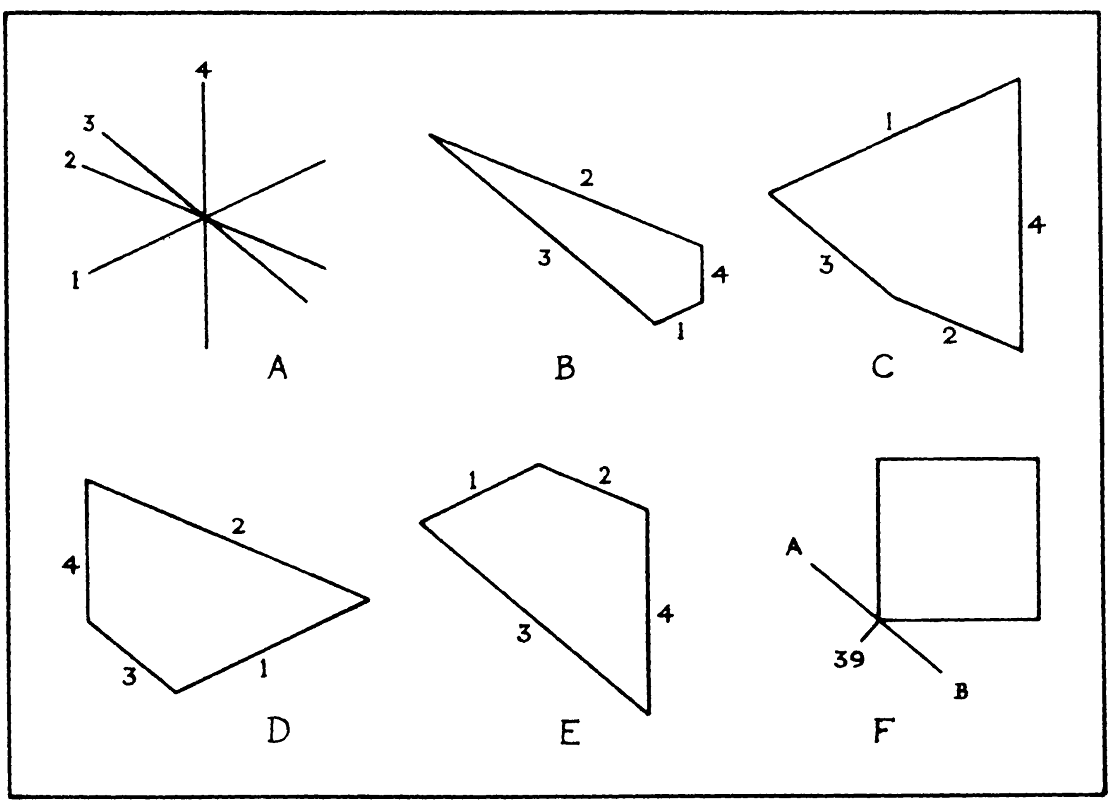

Fig. 1. Steps in determining octahedron orientation in one part of the Zenda meteorite (Read, 1963) relative to a plane of sectioning. A: directions of kamacite bands. B-E: quadrilateral templates derived from A. F: orientation diagram based on template B.

or will not be parallel to the fourth face. If it is not, this template is discarded. The procedure is repeated with successive templates until the one that "fits" is found. As noted above, when the fit is obtained, the position of the template relative to the pyramid will be the same as the position of the plane of sectioning in the meteorite relative to the octahedron. Templates must be kept "right side up."

It now remains to define the position of the template quantitatively. The simplest way of doing this is to determine (1) the horizontal angle between the plane of the template and one of the basal edges of the pyramid, and (2) the template's vertical angle of inclination.

To accomplish (1), place the pyramid on a large sheet of paper and apply short strips of drafting tape to keep it from shifting. Then direct a beam of light down the slope of the template. Adjust the position of the light source until the shadow of the template is, as nearly as possible, a straight line. Mark this line (A--B) on the paper. Also draw the square formed by the base of the pyramid. The angle between A--B and one side of the square is the horizontal angle sought.

For (2), measure the height of any point along the upper edge of the template. This can easily be done with a centimeter scale attached to an elongated wooden block of square cross-section. The edge of the scale should coincide with one edge of the block. Mark the point (P) where the bottom of the scale touches the paper, and record the height at which the scale and template are in contact. Now drop a perpendicular from P to A--B and measure its length. The vertical inclination of the template is the angle whose tangent equals the height at P divided by the length of the perpendicular.

Some symbol for representing the orientation on paper might be useful. A convenient one is indicated in Fig. 1F. The line A--B is shifted to meet one corner of the square representing the base of the pyramid. The vertical angle is marked at the end of a short perpendicular extending down-slope from A--B.

A brief method for verbal description is also desirable. It is suggested that the smallest angle clockwise from A--B to the nearest basal edge of the pyramid be referred to as the "basal clockwise angle," and that the vertical angle be referred to as the "dip." From the method of construction it follows that the dip direction must always be away from the pyramid.

REFERENCE

Read, W. F. 1963, The Zenda meteorite, Trans. Wis. Acad. Sci., Arts, and Letters, 52, 153.