On the orientation of kamacite in meteoric iron.

By JAMES YOUNG, B.Sc., F.R.A.S.
Lecturer in Physics, University of Birmingham.

[Received July 26, 1930.]

THE present note arises out of a paper by O. B. Bøggild,[1] to which my attention was drawn recently, concerning the peculiar segregation of kamacite which gives rise to the Widmannstätten figures produced by etching plane sections of the octahedrite meteoric irons. As the figures which occur in these meteorites are met with on a much smaller scale in many alloys, the structure to which they owe their origin must be of special interest to those engaged in the study of metals.

Some results of an X-ray examination of the structure and orientation of kamacite in meteoric iron have been described elsewhere,[2] but for convenience the conditions which control the orientation of the kamacite may be repeated here. They are as follows:

(1) The body-centred cubic crystals of kamacite grow from a face-centred cubic solid solution of nickel-iron in such a way that a {110}-plane of the kamacite is parallel to a {111}-plane of the solid solution. (It is this condition together with the plate-like nature of the kamacite which gives rise to the Widmannstätten figures.)

(2) The mean positions of the kamacite {110}-planes which are perpendicular to a Widmannstätten plane, and therefore parallel to a [111]-axis of the solid solution, are parallel to the three {211}-planes of the solid solution intersecting in that axis.

There are, therefore, three systems of kamacite associated with each of the four [111]-axes of the octahedrite, giving rise altogether to twelve systems of kamacite.

This arrangement of the kamacite is shown in the gnomonic projection of the octahedrite in fig. 1. The plane of projection is (001)

[1] O. B. Bøggild, Meddelelser om Grønland, 1927, vol. 74, p. 11 [Min. Abstr., vol. 3, p. 535].

[2] J. Young, Proc. Roy. Soc. London, Ser. A, 1926, vol. 112, pp. 630–641 [Min. Abstr., vol. 3, p. 259].

and planes of types {110}, {111}, and {112} are indicated. The small circles represent the mean positions of the cube axes of the twelve systems of kamacite. Each axis has been labelled with two letters. The letters A, B, C, and D indicate the kamacite as originating in the Widmannstätten planes (111), ($\bar{1}11$), ($\bar{1}\bar{1}1$), and ($1\bar{1}1$) respectively, while the suffixes p, q, and r have been applied to differentiate between the kamacites belonging to the same Widmannstätten plane. The dotted lines in the figure represent the loci of the cube-axes when condition (1) only is fulfilled. Thus the cube-axes of crystals belonging to the A-plane must lie on the straight line A_pA_q or on the hyperbola one of the branches of which is $A_pA_rA_q$

The following characteristics of the orientations are easily seen by inspection:

(*a*) Every [100]-axis of the octahedrite can be associated with four adjacent kamacite cube-axes (originating from different Widmannstätten planes), all inclined to it at 9° 44′ in such a manner as to form a system of fourfold symmetry.

(*b*) Every [110]-axis of the octahedrite can be associated with four adjacent kamacite cube-axes (originating from different Widmannstätten planes), two of which are parallel, and two of which are inclined to it at 9° 44′, in such a manner as to form a system of twofold symmetry.

Thus of the 36 cube-axes belonging to the twelve systems of kamacite, 12 are associated with cubic, and 24 with dodecahedral, axes of the octahedrite. Further, every crystal of kamacite has one and only one cube-axis associated with a cube-axis of the octahedrite, the other two cube-axes of the kamacite being necessarily associated with a particular pair of dodecahedral-axes of the octahedrite. Therefore, since there are only three octahedrite cube-axes, there are only three directions in which the twelve systems of kamacite are approximately orientated as a result of conditions (1) and (2).

This remarkable arrangement of the kamacite in three orientations seems to have been observed for the first time by Bøggild (loc. cit., p. 28), who examined the orientations of kamacite crystals in the Toluca and Coopertown meteorites by means of the small rhabdite rods which they contained. His results are incorporated in a gnomonic projection on what is nearly a (521)-plane of the octahedrite. The positions of the kamacite cube-axes in this projection have been inserted in fig. 1, where they appear as small crosses. Thus it becomes possible to test how far conditions (1) and (2) are fulfilled in the particular meteorites which he examined.

Condition (1).—The small crosses are found to lie on or near the dotted lines. Out of 27 crystals, only three lie with the dodecahedral plane as much as 5° from the octahedral plane of the octahedrite,

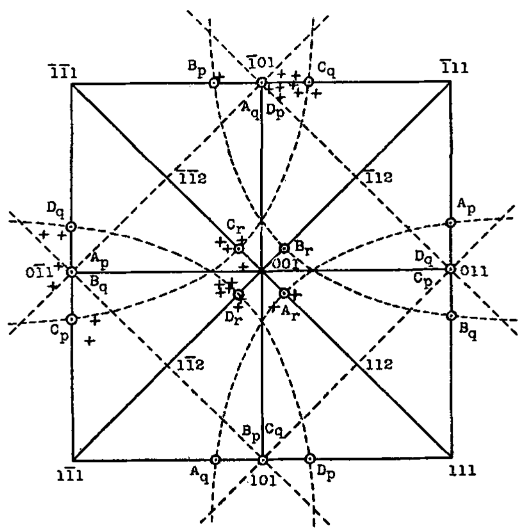

FIG. 1. Orientation of kamacite in meteoric iron.

while in the majority of cases this angle is less than 3°. Thus condition (1) is only approximately fulfilled in these meteorites.

Condition (2).—In my examination of the Cañon Diablo meteorite by the X-ray method (loc. cit., p. 634), deviations amounting to over 7° from the mean position given by condition (2) were found. In particular, two orientations presented themselves, and it was thought that these might represent positions of equilibrium of the kamacite. In fig. 1, however, the crosses are scattered in a direction parallel to the dotted lines as well as perpendicular to them. There is thus no standard deviation from the mean position in the meteorites examined by Bøggild. Further, the observed positions of the kamacite are not inconsistent with condition (2).

The chief interest which attaches to Bøggild's observations is the placing of the kamacite crystals in three orientated groups. These groups are somewhat accentuated observationally by the scattering effect produced when condition (1) is only approximately fulfilled. It must be remembered, however, that these groups are only observationally distinct and that a classification of the kamacite crystals by such grouping rather loses sight of the origin of the orientations in conditions (1) and (2), the physical basis of which has been discussed in my earlier paper.

It is a pleasure to thank Professor S. W. J. Smith, F.R.S., to whom I am specially indebted for suggesting a note on this subject.