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A metallographic and microprobe examination of a metallic nodule from the Bondoc Peninsula meteorite

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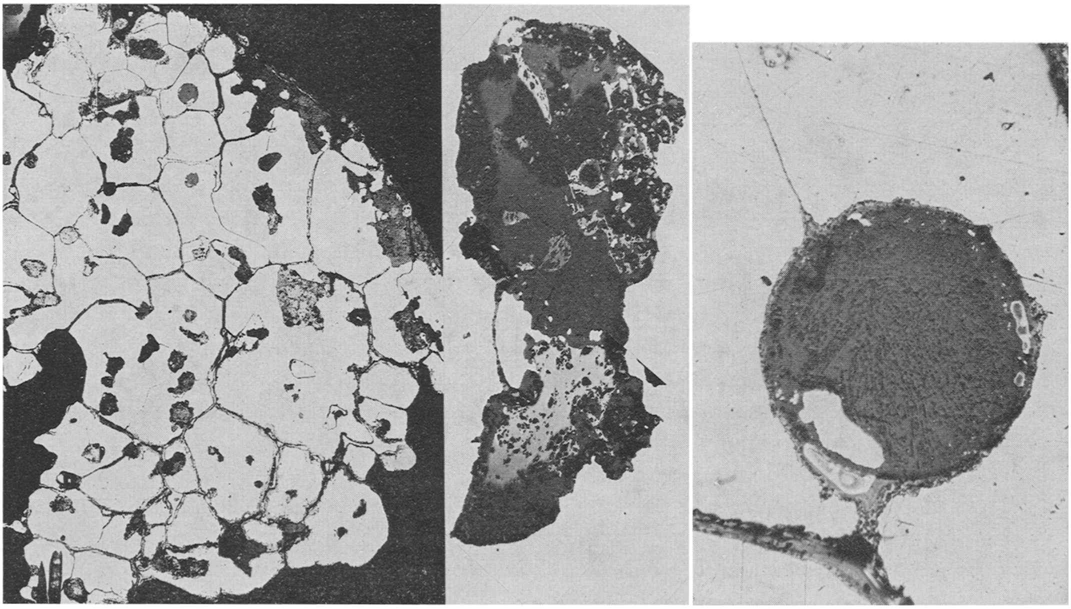
THE Bondoc Peninsula meteorite appears to be unstable and is disintegrating as the result of terrestrial corrosion. The meteorite is complex with occasional 1 to 3 cm dia. 'Nodules' of 'iron-class' material, fig. 1, within which are numerous non-metallic inclusions. These range in size from 0·5–1·5 mm and vary in shape from the extremes of angular to globular, shown in figs. 2 and 3. The metallic groundmass of fig. 1 is a polycrystalline array of kamacite grains that are equant in shape and about 3 to 4 mm dia. The boundaries between these kamacite grains are heavily invaded by corrosion product. The films of cracked schreibersite and strips of compositionally zoned taenite that are present at the kamacite boundaries each contribute about 2 % by volume and their average Ni contents are about 45 wt% and 40 wt% respectively. When these figures are combined with the average 6·2 wt% Ni, 0·75 wt% Co, and 0·02 wt% P of the kamacite the resulting bulk composition of the metal is $\sim$ 7·5 wt% Ni, $\sim$ 0·7 wt% Co, $\sim$ 0·3 wt % P. Nital etching reveals partially annealed Neumann bands in the kamacite, indicating a late stage reheating below about 500 °C. However, the M profile method of Wood (1967) when applied to the zoned taenite yields a cooling rate of 0·1–0·5 °C/Myr before this reheating event.

The angular inclusions are relatively coarsely crystalline and commonly have massive chromite and tridymite crystals, with pyroxene, anorthite, and whitlockite usually present. Most angular inclusions also contain small particles of metal (10–40 μm dia.) interstitial to the mineral phases in the depth of the inclusion. Small quantities of sulphide and phosphide are similarly located. The metal in the angular inclusions is not detectably zoned and both kamacite and taenite show a range of Ni contents that vary with particle size in the manner previously observed by Powell (1969) for a range of conventional mesosiderites. We have in addition measured the Co and P contents of this metal and find P $<$ 0·1 wt% and the Ni and Co analyses are consistent with equilibration in the ternary Fe–Ni–Co equilibrium diagram at $\sim$ 450 °C.

By contrast the globular inclusions are opalescent, microcrystalline with radiating feathery crystals of whitlockite in a background of devitrified glass, and are free of chromium. They also contain metal particles usually in the size range $<$ 10 μm, most of which are compositionally homogeneous but with variable P contents. If attention is restricted to metal particles with low P contents (0·2–0·4 wt% P) the Ni, Co analyses for metal within the globular inclusions follow the pattern described above for the angular inclusions but in addition a significant ($\frac{1}{3}$) proportion of particles are encountered with compositions about 10 wt% Ni, which is more appropriate to duplex plessitic structures. The metal-free regions of the globular inclusions are very similar at approximately 6 %MgO: 11 % Al_2O_3: 54 % SiO_2: 13 % CaO: 8 % P_2O_5: 3 % FeO: 1 % TiO_2, no detectable Cr_2O_3.

The distribution of kamacite, zoned taenite, schreibersite, and non-metallic inclusions in fig. 1 is consistent with the following thermal history: Above 750 °C the metallic nodules consisted of angular, globular, and intermediate types of inclusion randomly distributed within chemically homogeneous nodules of parent taenite of bulk composition 7·5 wt% Ni, 0·3 wt% P. The emplacement of these inclusions, ranging from the high-chromium unmelted condition of fig. 2 to the completely melted conditions of fig. 3, might be achieved by a shock that was not too severe acting upon material that was sufficiently hot before the shock event—perhaps in the region near 750 °C.



FIGS. 1 to 3: FIG. 1 (left). Unetched macrosection of the metallic nodule, showing angular and globular inclusions in polycrystalline kamacite. There is extensive penetration of terrestrial corrosion product along the kamacite grain boundaries. Taenite and schreibersite are present at kamacite boundaries. Field of view 1·6 cm × 2·2 cm. Angular inclusion fig. 2 is located in the upper-right quadrant and globular inclusion fig. 3 is located towards the top. FIG. 2 (middle). Polymineralic angular inclusion containing large areas of chromite (uneven, light grey) and tridymite (smooth, dark), with small metal particles (white) forming a belt near the major tridymite–chromite boundary. Unetched. The true length of the inclusion is 1·6 mm. FIG. 3 (right). Opalescent globular inclusion showing a radiating feathery structure of whitlockite in devitrified glass. The metal particles are concentrated in a rim around the edge of the globule. Light Nital etch. True diameter 0·7 mm.

Slow cooling from this temperature into the $\alpha+\gamma$ region of the equilibrium diagram allowed kamacite to nucleate at favourable locations on certain of the inclusions. On further cooling this kamacite developed by the usual process of diffusion-controlled growth, the final limits of growth being marked out in the macrostructure of fig. 1 by the fields of zoned taenite and grain-boundary schreibersite. At this stage of its development cooling rates of 0·1–0·5 °C/Myr appear to be indicated down to a temperature of about 350 °C as judged by the P content of 0·02 wt% in the bulk kamacite.

Two pieces of evidence indicate reheating after this initial slow cool. Firstly the annealed condition of Neumann lines suggests reheating below 500 °C; secondly the Ni, Co contents of the small, easily re-equilibrated, particles of metal within the non-metallic inclusions are consistent with a final reheating to $\sim$ 450 °C before terrestrial corrosion became important.

REFERENCES

Powell (B. J.), 1969. *Geochim. Cosmochim. Acta*, **33**, 789.
Wood (J. A.), 1967. *Icarus*, **6**, 1.

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The full text will appear in the 'miniprint' section of this volume.