Murnpeowie (South Australia), a granular type of meteoric iron.

(With Plates I–III.)

By L. J. SPENCER, M.A., Sc.D., F.R.S.
Keeper of Minerals in the British Museum of Natural History.

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A PRELIMINARY account of this fine mass, weighing 2520 lb., of meteoric iron was given in 1910 by L. Laybourne Smith,[1] who at that time was Registrar of the South Australian School of Mines and Industries in Adelaide; but the promised detailed description with chemical analysis never appeared. Except for a small piece cut off one corner (upper left-hand corner in fig. 1) the mass is preserved intact in the Museum of that Institution, and none of the material appears to have been distributed to other museums. Casts of the mass were, however, made for the South Australian Museum in Adelaide, and one of them was presented to the British Museum in 1917 (B.M. 1917,360), where in the meteorite collection it is a very striking object (fig. 1).

Recently, at the suggestion of Mr. R. Bedford of the Kyancutta Museum, the Council of the South Australian School of Mines has generously presented to the British Museum a piece of this meteoric iron, together with the milling cuttings, with the request that the description of it should be completed. This piece (B.M. 1934,52) weighed 875 grams (pl. I, fig. 2). Two slices were cut off the thinner end, leaving 773·5 grams with the larger cut surface of 10 × 5 cm., which was polished and etched (pl. I, figs. 3 and 4). A smaller slice (17·5 grams) was micro-polished (pl. III).

The mass was found in August 1909, and, as stated by L. L. Smith, ‘on the Beltana Pastoral Company's Murnpeowie run, at a

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[1] L. L. Smith, An Australian meteorite. Amer. Journ. Sci., 1910, ser. 4, vol. 30, pp. 264–266, 2 figs.

spot 29° 35′ latitude and 139° 54′ longitude, being about 16 miles N.E. by E. of Mt. Hopeless'.[1] This is north of Flinders Range and about 5 miles NW. of Lake Callabonna. There are several large areas in this region marked on the map 'Beltana Pastoral Co.' The Murnpeowie sheep run extends for a hundred miles or more, and the spot where the meteorite was found is 53 miles east of Murnpeowie head station on Twins Creek.

L. L. Smith suggested that the mass had fallen recently, and my examination of the material supports this view. It was found by some boundary-fence repairers, who used to stand on it as an 'isolated rock' when scanning the plain in search of their donkeys; and it had not been noticed when the vermin-proof fence, less than half a mile away, was erected some five years previously. Seventy yards to the west of the meteorite was a hole measuring 16½ × 12 feet and 4 feet deep, with its greatest dimension in an E.–W. direction. Between the meteorite and the hole were two smaller indentations. L. L. Smith suggested that the meteorite travelled from the west and ricochetted on the ground before coming to rest on the surface. If this were so the horizontal component of the velocity must have been much greater than is usually the case when meteorites reach the earth's surface; but here we have an unusually large mass of iron.

In shape the mass is a thin triangular slab or wedge. The height (in the position in fig. 1) is 87 cm. and the length 120 cm. The thickness at the left-hand bottom corner is 48 cm., at the right-hand bottom corner 23 cm., and at the top 20 cm. Fig. 1 is of what L. L. Smith described as the back of the meteorite. The two figures given in his paper show the front and an end view. The pits on the back surface are rather larger than those on the front surface. On the small specimen examined (fig. 2) the surfaces are smooth and rounded, with very much the same appearance as those seen on irons that have been observed to fall. The very thin black skin is rubbed off in places, and is in part covered with a film of brown limonite. Streaks suggestive of flow are faintly shown in two places in the black skin.

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[1] On the sketch-map (Min. Mag., 1932, vol. 23, p. 41) showing the distribution of South Australian meteorites this was plotted incorrectly. The spot is about 30 miles S. by W. of Carraweena. Accalana, which could not then be located, lies between the two, about 5 miles S. by W. of Carraweena. No particulars have yet been published about the Accalana and Carraweena meteorites. Casts of them were presented to the British Museum at the same time as the cast of Murnpeowie. That of Accalana (B.M. 1917,365) measures 13 × 12 × 10 cm., and that of Carraweena (B.M. 1917,366) 34 × 24 × 17 cm.

Drift markings due to surface fusion are stated to be visible on the front surface of the main original mass. Mr. Bedford tells me that the plaster cast does not do justice to the fresh appearance of the surface as shown by the original.

The internal structure shown on a polished and etched surface was described by Mr. L. L. Smith as brecciated. It is really granular and of a very unusual type (pls. I–III). The conspicuous grains, measuring up to 5 mm. across, are irregular in outline and orientation. They show well-marked Neumann lines. A very striking feature is shown when the slice is turned about in a strong light and reflections received at different angles. Three distinct areas (A, B, C in figs. 3 and 4) can then be distinguished. In certain positions for each area a ghost or palimpsest structure lights up uniformly over the whole of that area in the interspaces between the larger grains.

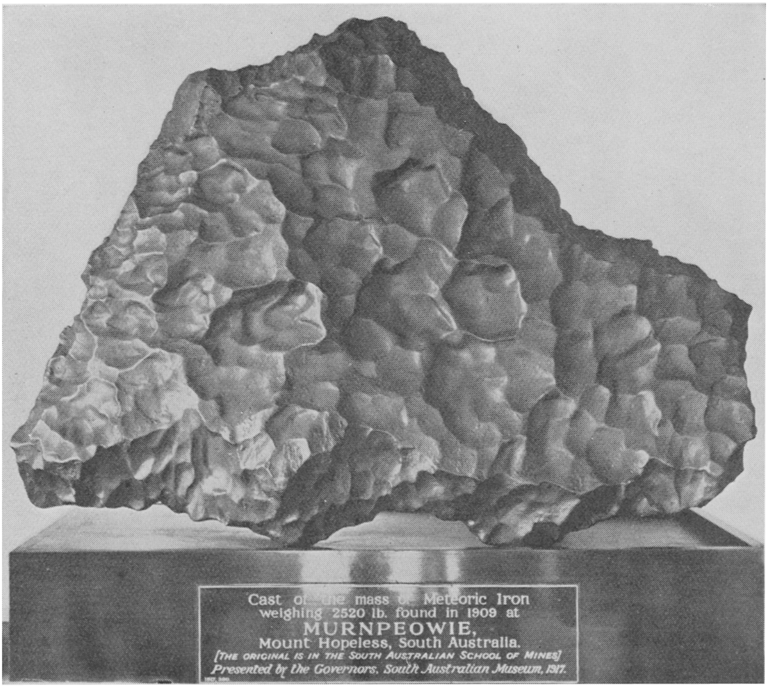

FIG. 1. Murnpeowie (South Australia) meteoric iron. Photograph of the coloured plaster cast in the British Museum. $\times \frac{1}{12}$.

This is shown by the minute white speckles for area A in fig. 3, and for area C in fig. 4. At another inclination of the light the same is seen in area B, whilst those in A and C are extinguished.

The reflecting specks are small ragged shreds or bars up to about 1 mm. in length, and in total amount they occupy only a small proportion of the whole area. They are not recognizable under the microscope in illumination normal to the surface, but with some manipulation they can be seen with outside oblique illumination (fig. 6). Further, the effect is only shown on a more deeply etched surface: it is not seen when the finely polished and lightly etched section used for the photomicrographs (pl. III) is held in the hand and turned about in the light. In area A (where they are most easily caught) the reflections can be seen in at least five different positions of the slice, the angles between which are 30°, 60°, and 90°, as near as could be roughly estimated. These reflections must therefore be from the surfaces of etching pits parallel to the faces of the rhombic-dodecahedron (110) and the icositetrahedron (211).[1]

This curious and unusual effect is due to the presence of remnants of a previous structure when the areas A, B, C were three individual crystals in the mass. As shown in fig. 6 (magnification 8) the shreds or bars are in three directions, strongly suggesting the remnants of an octahedral lamellar structure. The areas A, B, C of the original crystals are up to 5 cm. across in the slice examined (but would no doubt be larger in a larger slice); and it must be remarked that they are much smaller than is usually the case in meteoric irons of the octahedrite type. The mass must have been subjected to a prolonged heat treatment, above 850° C. but below the melting-point, when crystal grains of γ-iron grew to an appreciable size at the expense of the α-iron. It is useless to speculate how this may have happened. Perhaps this small asteroid had been careering too near the sun.

The effect of another, and later, heat treatment is excellently shown by the Murnpeowie meteorite. This is seen in the finely granular border at the outer edge of the slice (pls. I and II), and was produced on the surface by the heat developed during the brief flight of the meteorite through the earth's atmosphere. Here again there was a transformation of α-iron to γ-iron, but only very minute crystals

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[1] These faces in the etching pits of kamacite have been definitely determined by S. W. J. Smith, A. A. Dee, and J. Young, Proc. Roy. Soc. London, Ser. A, 1928, vol. 121, p. 489. [Min. Abstr., vol. 4, p. 121.]

grew in the short interval of time, followed by rapid chilling. This sharply defined heating zone follows the contours of the mass, but is thicker (3 mm.) on projecting corners and thinner (1 mm.) in hollows on the surface. During the flight this zone must have travelled inwards as molten material was swept from the surface.

With the permission of Prof. Sir Harold Carpenter, F.R.S., a microscopic examination of the iron was undertaken by Dr. J. M. Robertson at the Royal School of Mines, who has kindly supplied the photomicrographs reproduced on plate III, together with the following description. The identity of the reflecting portions mentioned above is here not evident, and at present there seems to be little that can be correlated between his and my descriptions.

Microscopic examination, by Dr. J. M. Robertson.

The general structure of the slice examined resembled that obtained under certain conditions in ferrite. Two different kinds of areas could be distinguished: (*a*) medium-sized crystals showing well-marked sub-boundaries and Neumann bands (figs. 7 and 8); and (*b*) large crystals in which the Neumann bands were very distinct and the sub-boundaries very vague (figs. 9 and 10). Crystals (*a*) occupied a greater proportion of the area than (*b*).

Neumann bands are readily produced in iron and iron-nickel alloys when they are subjected to impact. They have been shown to be narrow twin bands. Sub-boundaries are fairly common features of a number of metals and they have been the subject of several investigations. The ordinary or principal crystal boundaries in metals are due to differences in orientation between adjacent crystals, which are attacked at different rates by the etching reagent, and the surfaces of which are at different levels after etching. The principal crystal boundaries are therefore steeply sloping steps from one crystal to another. The cause of sub-boundaries is obscure, but they are not due to differences in orientation. In the present specimen the Neumann bands crossed sub-boundaries without change in direction (figs. 9 and 10), and in other work it has been shown that there is no change in the form of the etching pits on crossing a sub-boundary. It appears that the sub-boundaries are lines of impurities incorporated in the crystals during their formation. These boundaries are made evident under the microscope by the lines of etching pits that form along them. In fig. 11 sub-boundaries marked by lines of etching pits are shown.

The general conclusions that may be drawn from the structure of this meteoric iron is that it consists of one constituent similar to ferrite, and that it shows Neumann bands and sub-boundaries like those obtained in ferrite. It appears therefore that the nickel content is low.

The outer rim of the slice examined showed a different structure from the remainder (fig. 12). This difference in structure between the outer rim and the remainder is due to deformation of the former. The basic structure of the outer rim is the same as that of the remainder, but the structure has been drastically deformed. It appears from this that the outer rim was not melted, otherwise, if any nickel was present, it would show a martensitic structure. Apparently it was simply heated and deformed.

Chemical analysis, by M. H. Hey.

The following results were obtained in the Museum laboratory, using 16·4 grams of the millings.

Fe.	Ni.	Co.	Cu.	Ge.	Pt.	S.	Insol.	Total.
93·88	6·32	0·32	0·002	0·007	0·07	0·006	0·20	100·80

Traces of chromium and phosphorus are also definitely present, but less than 0·005 % in amount. Gold, palladium, iridium, osmium, ruthenium, manganese, and carbon could not be detected, and if present must be less than 0·002 %. The nickel percentage is the mean of four determinations, 6·25, 6·27, 6·38, and 6·39; and that for cobalt the mean of two, 0·26 and 0·38. The relatively high percentage (0·07) of platinum, corresponding to 700 grams (22·5 ounces troy) per metric ton, is considerably higher than any previously recorded.[1] No platinum vessels were used in the course of the present analysis. The direct quantitative estimation of germanium (0·007 %) gives a rather lower value than that (0·01–0·1) given by spectroscopic methods.[2]

The method of analysis was the chlorine distillation method previously described.[3] The amount used for the main analysis was 11·4 grams, and smaller amounts were used for repeated check determinations. Platinum metals were precipitated by H_2S, separated from copper by KCNS, and weighed as metal. Palladium was shown to be absent by the dimethylglyoxime test, while the colour of the Am_2PtCl_4 precipitate indicated the absence of iridium. Special tests for other platinum metals and for gold gave negative results. Germanium was separated by distillation as $GeCl_4$ and precipitation as GeS_2; its identity was confirmed by conversion into K_2GeF_6. Owing to an accident in the collection of the whole of the $GeCl_4$ the value given is possibly rather low, but it is correct in order of magnitude.

The specific gravity determined by hydrostatic weighing on the slice weighing 17·5 grams is D_4^{15} 7·78.

Mr. Hey's chemical analysis gives an atomic ratio Fe : (Ni + Co) = 14·86 : 1, corresponding closely with the composition of kamacite, which is usually given as $Fe_{14}Ni$. The ratio of the percentage weights of iron to nickel is also 14·9, corresponding with the hexahedrite class of meteoric irons.[4] No constituent other than kamacite was detected on the section of the meteorite. On the broken edge where the slice had been sawn nearly through there is no indication of the cubic cleavage said to be characteristic (but rarely seen) of hexahedrites.

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[1] Min. Abstr., vol. 1, pp. 97, 405; vol. 2, p. 34; vol. 3, p. 388; vol. 4, p. 425; vol. 5, pp. 6, 7, 13, 14, 157, 301.

[2] Ibid., vol. 5, pp. 7, 152, 402.

[3] M. H. Hey, Min. Mag., 1932, vol. 23, p. 13.

[4] G. T. Prior, Min. Mag., 1920, vol. 19, p. 57.

Hexahedrites and octahedrites are both cubic, and consist the first wholly and the second largely of kamacite. The essential difference between them is that in octahedrites a second alloy (taenite) richer in nickel has separated out parallel to the planes of the octahedron, giving rise to a lamellar structure, and interrupting and rendering still less conspicuous the cubic cleavage. In the coarsest octahedrites the proportion of kamacite is greater and that of taenite much less, and they contain correspondingly less nickel than medium and fine octahedrites. It is therefore probable that the original structure of the Murnpeowie iron was that of a coarsest octahedrite.

In Murnpeowie there are differently orientated grains of kamacite showing well-marked Neumann lines. The structure is not continuous throughout the whole mass, neither is it brecciated. This is rather a case of recrystallization of the material in the solid, due to heat treatment, whereby the structure of the original coarse octahedral lamellar structure has been changed.

As shown by F. Berwerth[1] such a change in structure can be produced artificially by heating, and meteorites so changed he called metabolites. This term has been extended by G. P. Merrill[2] to meteorites showing the same structure that had not been heated artificially. Metabolite and metabolism are not terms to be recommended in this connexion, especially as they have long been in use in biochemistry. Metamorphism is more appropriate; still more so paramorphism, since only a change from one modification of iron into another (polymorphic) modification is involved. It is probable that many ataxites and granular hexahedrites and octahedrites owe their structure to the effects of a later heat treatment.

The same change is shown on a smaller scale in the external heating zone of meteoric irons that have been observed to fall (e.g. Braunau, Charlotte, Rowton) and in some others that are evidently of recent fall (e.g. Bingera, Signal Mountain, San Francisco Mountains[3]); though strangely there are some such irons in which it is not evident (e.g. Boogaldi). It was first figured for Braunau by W. Haidinger[4] in 1855,

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[1] F. Berwerth, Künstlicher Metabolit. Sitzungsber. Akad. Wiss. Wien, Math.-naturwiss. Kl., Abt. 1, 1905, vol. 114, pp. 343–356.

[2] G. P. Merrill, A meteoric metabolite from Dungannon, Virginia. Proc. U.S. Nat. Mus., 1923, vol. 62, art. 18. [Min. Abstr., vol. 2, p. 161.]

[3] S. H. Perry, Amer. Journ. Sci., 1934, ser. 5, vol. 28, pp. 214–217. [Min. Abstr., vol. 6, p. 13.]

[4] W. Haidinger, Sitzungsber. Akad. Wiss. Wien, 1855, vol. 15, pl. 1, fig. 5.

and attention was specially drawn to it by Baron Reichenbach[1] in 1862. I have previously stated that it is not shown by any of the irons from the meteorite craters at Henbury in Central Australia.[2] Mr. R. Bedford has, however, since sent a slice in which this is shown very clearly, suggesting that Henbury also was a recent fall. Evidently the whole matter requires further study.

EXPLANATION OF PLATES I–III.

Meteoric iron of Murnpeowie, South Australia.

(Photographs, figs. 1–5, by H. G. Herring; fig. 6, by Dr. J. B. Knight; photomicrographs, figs. 7–12, by Dr. J. M. Robertson.)

FIG. 1 in the text (p. 15).

PLATE I, FIG. 2. External surface of the British Museum specimen (B.M. 1934,52). Actual size.

—— FIGS. 3 and 4. Polished and etched surface (B.M. 1934,52), photographed in different illuminations. Showing granular structure in three areas, A, B, C. Fig. 3 shows a ghost structure uniformly over the area A, and fig. 4 a similar structure in the area C. At a third inclination of the light a similar structure is shown in the area B. Actual size.

PLATE II, FIG. 5. Upper part of area A of figs. 3 and 4. Showing the granular structure with Neumann lines in the larger grains, and the outer heating zone. × 8.

—— FIG. 6. Same area as in fig. 5 in oblique illumination, showing remnants of the previous octahedral lamellar structure. × 8.

PLATE III, FIGS. 7 and 8. Area of smaller crystals showing well-marked sub-boundaries and Neumann lines. × 100.

—— FIGS. 9 and 10. Area of larger crystals, showing well-marked Neumann lines and less distinct sub-boundaries. In fig. 9 a single crystal occupies the whole area. × 100.

—— FIG. 11. Lines of etching pits marking the sub-boundaries. The dark line is an ordinary crystal boundary. × 840.

—— FIG. 12. The outer heating zone of the meteorite. × 840.

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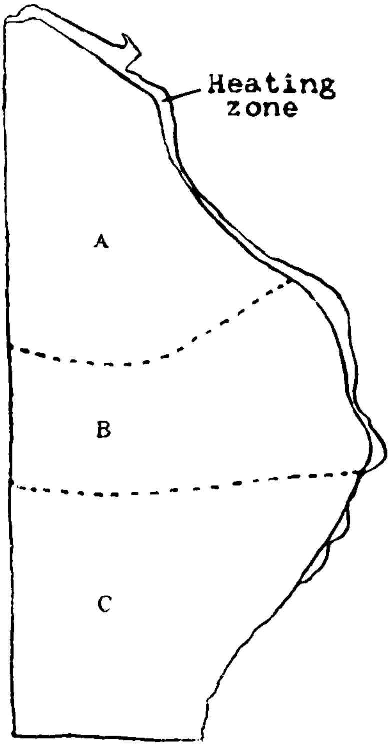
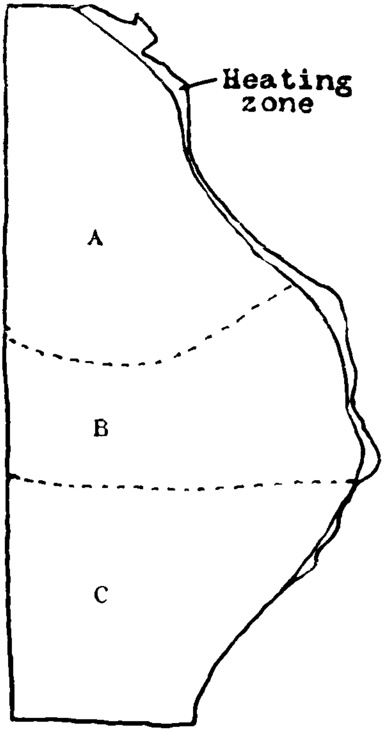
[1] K. L. von Reichenbach, Ann. Phys. Chem. (Poggendorff), 1862, vol. 115, pp. 155–156. Compare E. Cohen, Meteoritenkunde. Stuttgart, 1894, Heft 1, pp. 72–73.

[2] L. J. Spencer, Min. Mag., 1933, vol. 23, p. 389; Nature, London, 1934, vol. 133, p. 576.


Heating zone
A
B
C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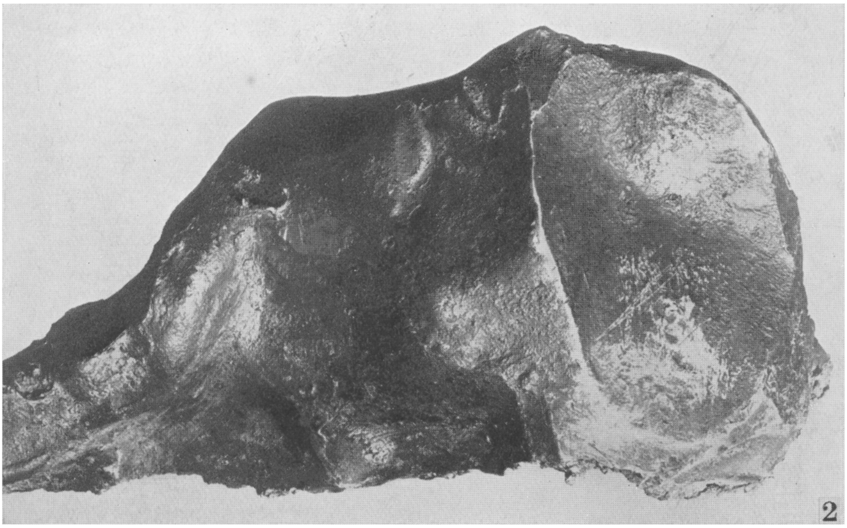
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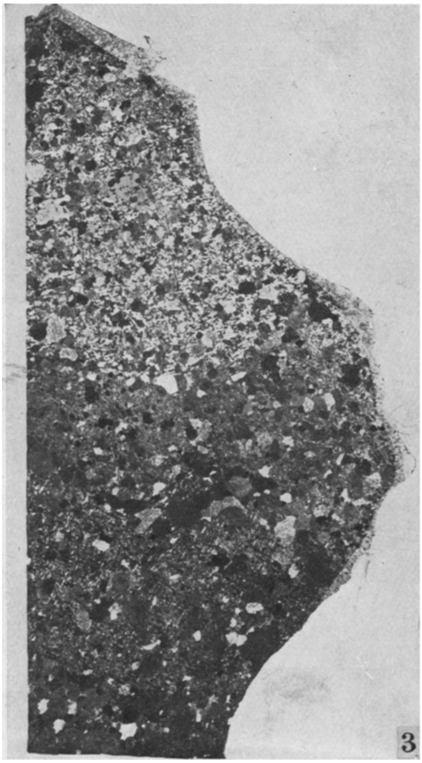
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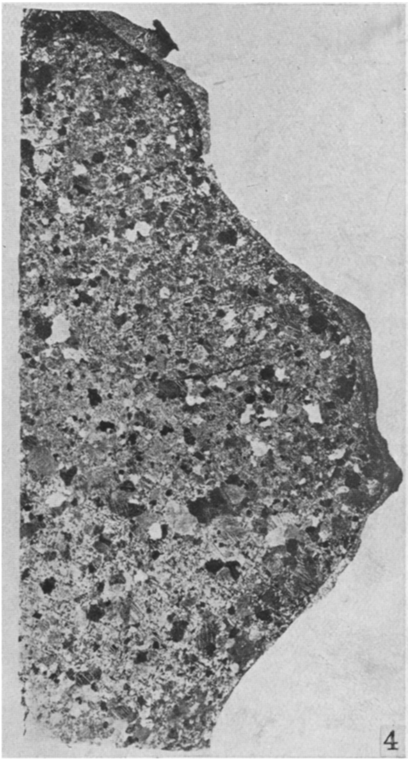
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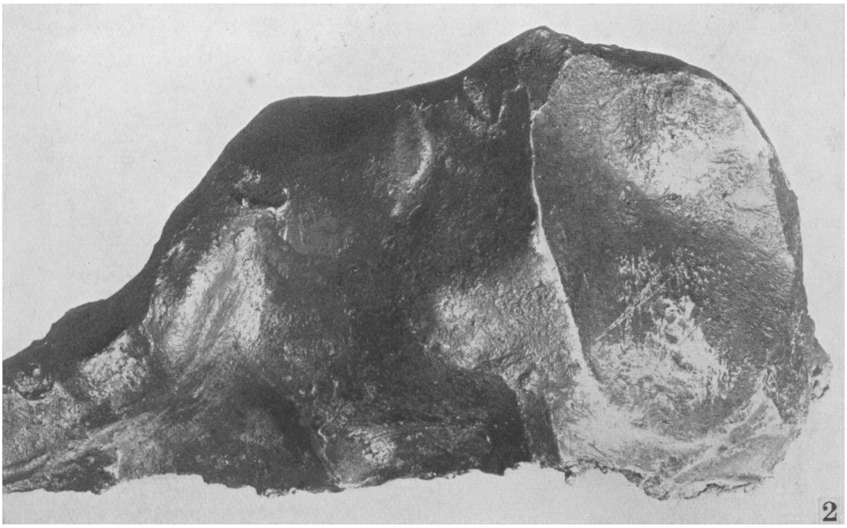
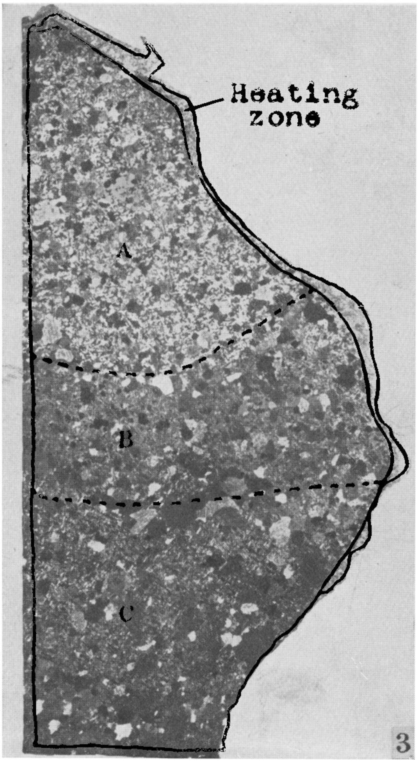
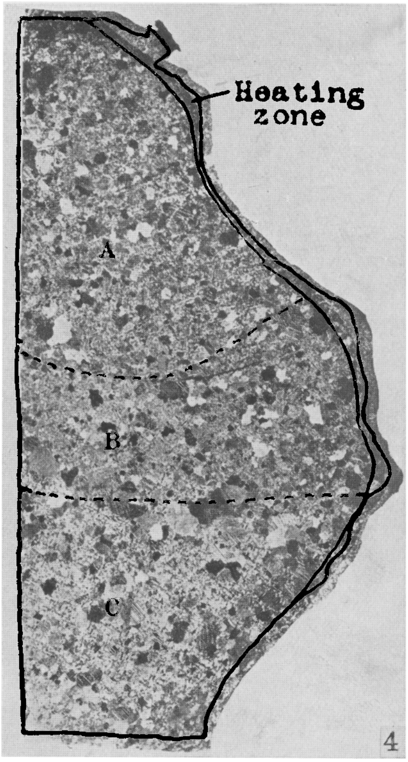
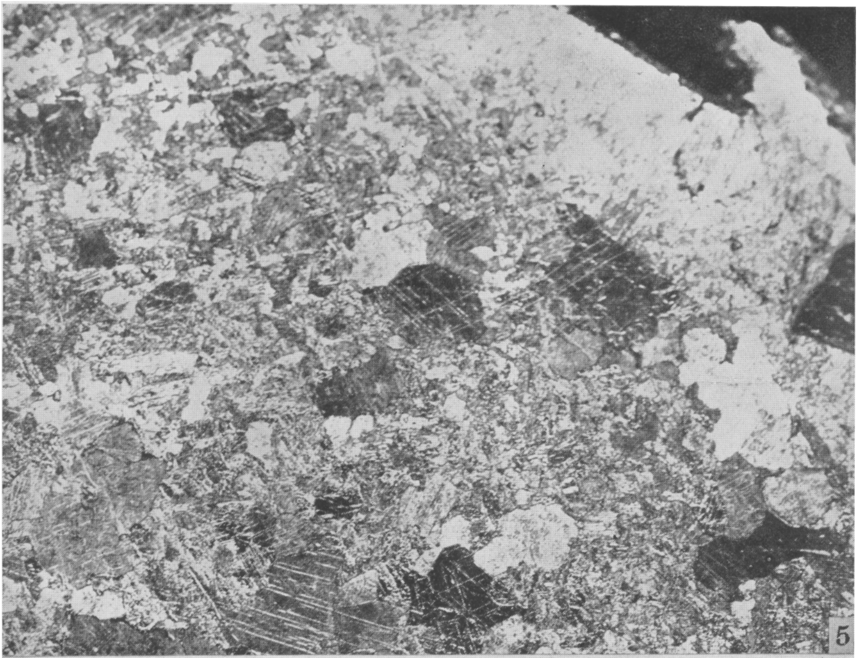
L. J. Spencer: Murnpeowie Meteoric Iron.



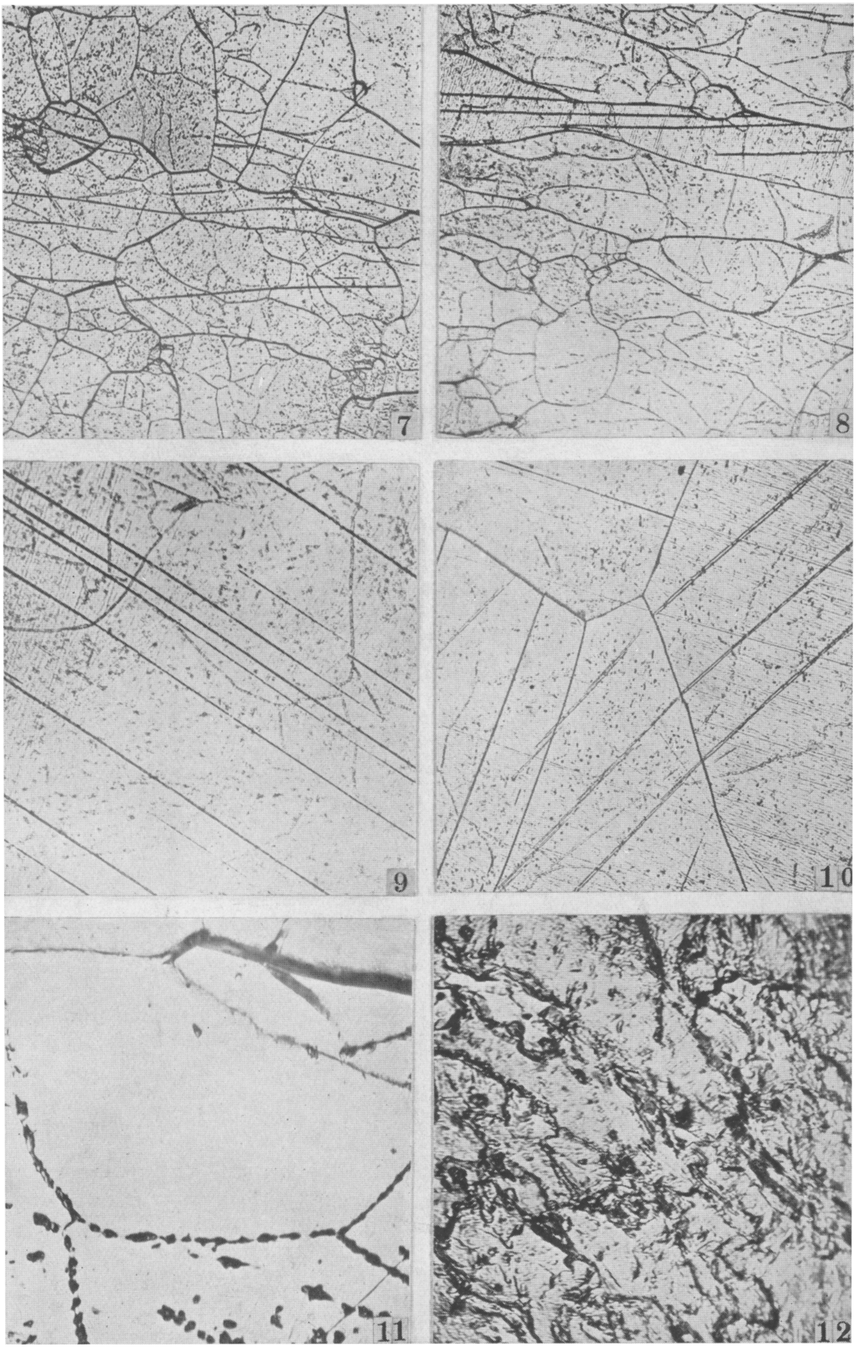




L. J. SPENCER: MURNPEOWIE METEORIC IRON.



L. J. Spencer: Murnpeowie Meteoric Iron.



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