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## *The Gibeon shower of meteoritic irons in South-West Africa.*

(With Plates I and II.)


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[Read March 13, 1941.]


THE presence of much native iron in Great Namaqualand was heard of in 1836 by the traveller Sir James E. Alexander,[1] but he himself did not see any of the masses, and the material he acquired consisted only of small fragments that had been detached by the natives for pointing their weapons. An approximate chemical analysis of this material, made by Sir John Herschel,[2] proved it to be meteoritic. A fragment weighing 2 grams which Alexander presented to the Geological Society of London in 1838 was transferred to the British Museum collection of meteorites in 1911. This appears to be all of his material that has been preserved.

Various other vague reports and travellers' tales have mentioned the presence of large masses of iron beyond the old mission station of Bethany, between there and Beersheba, and on the east side of the Great Fish River. A critical summary of these accounts was given by Sir Lazarus Fletcher in this magazine.[3] Further historical details are

[1] J. E. Alexander, An expedition of discovery into the interior of Africa through the hitherto undescribed countries of the Great Namaquas, Boschmans, and Hill Damaras. London, 1838, vol. 1, p. 145, vol. 2, p. 272. Journ. Roy. Geogr. Soc., 1938, vol. 8, p. 24.

[2] J. F. W. Herschel, Notice of a chemical examination of a specimen of native iron, from the east bank of the Great Fish River, in South Africa. Phil. Mag. London, 1939, ser. 3, vol. 14, pp. 32–34. (Reprinted from the appendix of Alexander's book.)

[3] L. Fletcher, On various masses of meteoric iron reported to have been found

given in E. Cohen's 'Meteoritenkunde' (Stuttgart, 1905, Heft. 3, pp. 324–342), and in G. T. Prior's British Museum 'Catalogue of Meteorites' (1923 and appendices 1927, 1940).

The first large block actually recovered was one of 178 lb. (81 kg.), which was transported from the Lion River (map, fig. 1) via Cape Town and London to Amherst College, Massachusetts, where it was described by C. U. Shepard[1] in 1853. The collector, John Gibbs, stated that it was found on a clay plain near the Lion River in the close vicinity to one or more masses too heavy for transport. [But there appears to have been no later mention of these other masses.]

A second large mass of 511 lb. (232 kg.), referred to by Fletcher as 'the Wild mass', was sent to the South African Museum in Cape Town by John Wild in 1857. This was described in 1900 under the name 'Bethany' by E. Cohen,[2] who stated that it had long been known to the missionaries at Bethany, and after being brought as far south as the Orange river it was later transported to Cape Town. The label with the specimen in the Cape Town Museum (which I visited in 1929) states: 'Said to have been found at Bethany, Great Namaqualand, and to have been brought down to the Orange River by a trader. . . .'

The first record from the Gibeon region was a block of 178 kg. found at Mukerop (Mukorob, Mukorub) farm in 1899 and described by A. Brezina and E. Cohen[3] and independently by F. Berwerth[4] in 1902. This was followed by a mass of 404 kg. from Goamus farm described by F. Rinne[5] in 1910. Between these two dates several large meteoritic irons from the Gibeon district were exported to Germany and deposited

in Great Namaqualand and the adjacent region. Min. Mag., 1904, vol. 14, pp. 28–36.

[1] C. U. Shepard, Notice of meteoric iron near Lion river, Great Namaqualand, South Africa. Amer. Journ. Sci., 1853, ser. 2, vol. 15, pp. 1–4, 1 fig.

[2] E. Cohen, The meteoric iron from Bethany, Great Namaqualand. Ann. South African Museum, 1900, vol. 2, pp. 21–29, 4 pls. Das Meteoreisen von Bethanien, Gross-Namaland, West-Südafrika. Mitt. Naturwiss. Ver. Neu-Vorpommern und Rügen, Berlin, 1901, vol. 32 (for 1900), pp. 12–25, 3 pls.

[3] A. Brezina and E. Cohen, Ueber ein Meteoreisen von Mukerop, Bezirk Gibeon, Grossnamaland. Jahresh. Ver. Naturk. Württemberg, 1902, vol. 58, pp. 292–302, 1 pl.

[4] F. Berwerth, Über das neue Meteoreisen von Mukerop. Anzeiger Akad. Wiss. Wien, Math.-naturwiss. Cl., 1902, vol. 39, pp. 46–49. Der Meteoreisenzwilling von Mukerop, Bezirk Gibeon, Deutsch-Südwest-Afrika. Sitzungsber. Akad. Wiss. Wien, Math.-naturwiss. Cl., 1902, Abt. I, vol. 111, pp. 646–666, 1 pl., 2 text-figs.

[5] F. Rinne, Ein Meteoreisen mit Oktaeder- und Würfelbau (Tessera-Oktaedrit). Neues Jahrb. Min., 1910, vol. 1, pp. 115–117, 2 pls.

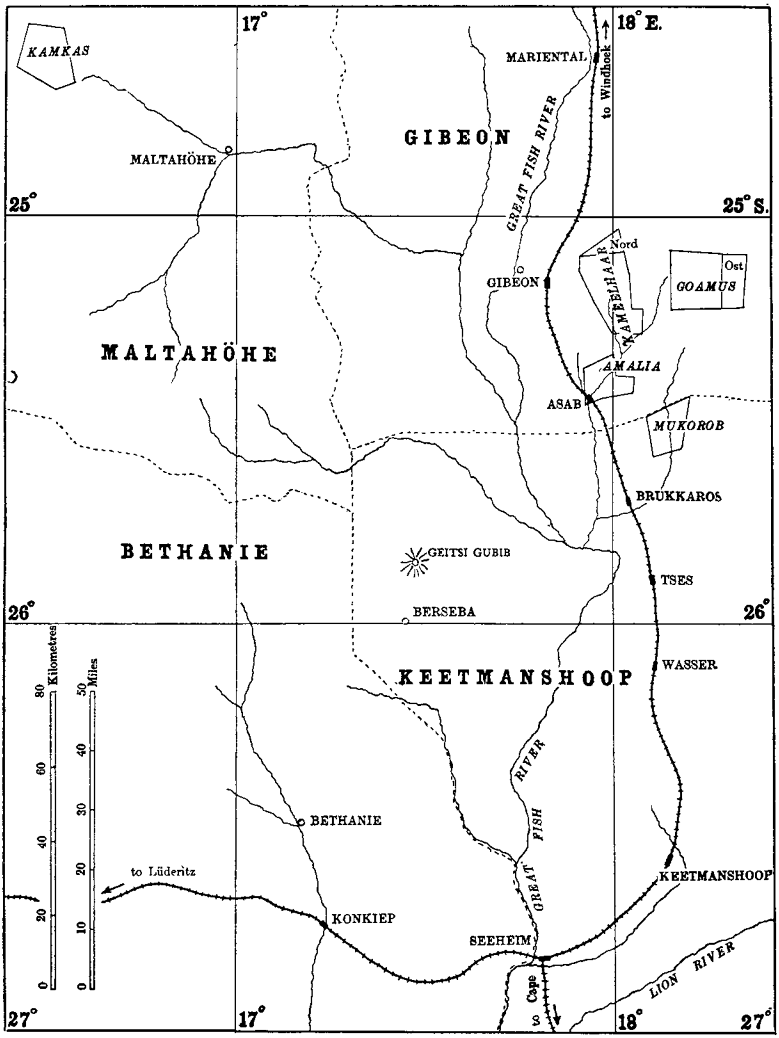


FIG. 1. Sketch-map of meteorite localities in Great Namaqualand, South-West Africa. Adapted from the Farm Area maps 1896 and 1930 (scale of originals 1 : 800,000).

The Lion (= Xamob = Kamob = Chamob = Kamop = Löwen) River joins the Great Fish (= Fish = Oup = Boradaile Aub = Grosser Fisch) River at 27° 10′ S., and the latter joins the Orange River at 28° 10′ S.

in German museums. W. Schrauf[1] in 1912 estimated the total amount at 2312 kg.

P. Range,[2] the former Government Geologist of South-West Africa, tells that in 1907 he saw seven large blocks, with a total weight of 28 cwt., set up outside the farm-house of Goamus. These had been collected from the neighbouring farms Amalia and Kameelhaar. They were sold by the farmer and were no doubt the ones shipped to Germany. Several other masses were mentioned by Range, and in 1911 he was instructed by the Government to collect together such masses as were still available. Further masses were found over an area of 200 sq. km. on the Amalia and Kameelhaar farms to the south-east and east of Gibeon. The result was that during 1911–12 thirty-seven masses weighing from 134 to 600 kg. and totalling 12,613 kg. were taken to Windhoek. He estimated that by that time (1912) fifty-one masses with a total weight of over 15 tons had been removed from the Gibeon district.

In 1930 W. Edlinger, a German mining engineer, obtained from Kameelhaar farm three masses weighing 195·2, 188·9, and 132·17 kg., although the property in meteorites was vested in the State and their export prohibited. Two of these were sold to America and cut into slices, and the third was described and figured by V. Zsivny,[3] it having been offered to but declined by the Hungarian National Museum.

During my visit to South-West Africa with the excursion of the International Geological Congress in 1929 I saw the pile of meteorites collected by Dr. Range in the Public Garden at Windhoek.[4] The specimen to which I am pointing with the walking-stick in fig. 2 was generously presented by the Administration of South-West Africa, through Mr. L. G. Ray, then Chief Inspector of Mines, to the British Museum,

[1] W. Schrauf, Die grossen Eisenmeteoriten aus Deutsch-Südwestafrika. Ber. Senckenberg. Naturfor. Gesell. Frankfurt am Main, 1912, vol. 43, pp. 214–221, 2 figs.

[2] P. Range, Geologie des deutschen Namalandes. Beitr. Geol. Erforsch. Deut. Schutzgeb. Berlin, 1912, Heft 2, pp. 67–70. Meteoriten aus Deutsch-Südwestafrika. Mitt. Deut. Schutzgeb. Berlin, 1913, vol. 26, pp. 341–343, 2 figs. (sketch-map).

[3] V. Zsivny, Egy délnyugatafrikai meteorvasról. [A South-West African iron meteorite.] Pótfüzetek a Természettudományi Közlönyhöz, Budapest, 1932, vol. 64, pp. 84–87, 2 figs. [M.A. **5**–155.]

[4] L. J. Spencer, Meteoric irons from South-West Africa. Nat. Hist. Mag. British Museum, 1930, vol. 2, pp. 240–246, 5 figs. [M.A. **4**–422.] This popular article was rewritten by Mary Proctor in Everyman's Astronomy, London, 1939, chap. XIII, pp. 189–197, 2 pls. [M.A. **8**–55.]

in which collection none of the larger masses from this fall was previously represented. It weighs 299 lb. (136 kg.) and was selected as an example

FIG. 2. Pile of meteoritic irons (some thirty, weighing about 10 tons) in the Public Garden at Windhoek. (Photo. by Prof. W. T. Gordon, September 1929.)

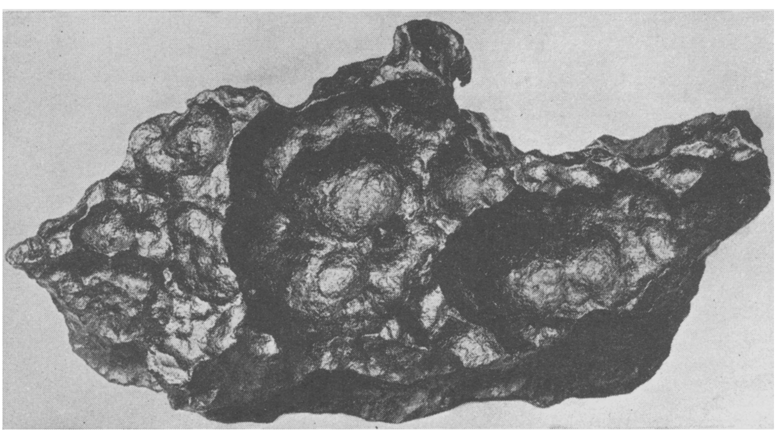

FIG. 3. Meteoritic iron from near Gibeon. 299 lb. (136 kg.), 26 × 13 inches. (British Museum no. 1930,422.) × $\frac{1}{7}$.

of prominent surface pitting (fig. 3). During my visit I was also able to obtain from Dr. Range some further information about these meteorites. Unfortunately I was not able to break my journey at Gibeon, but was told by the station-master there and by the sergeant of police that several large masses were still lying on the Kameelhaar farm 12 miles east of Gibeon. A small meteorite weighing 195 grams (fig. 4) was given to me for the British Museum collection by the station-master, Mr. P. James.

This is the smallest individual mass of the Gibeon irons that has been recorded. No doubt other small masses have been found and

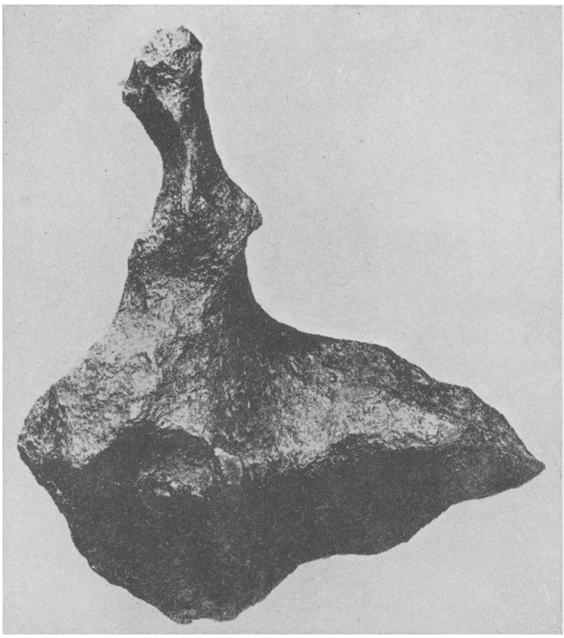

FIG. 4. Meteoritic iron from near Gibeon. 195 grams. (British Museum no. 1929,1563.) Actual size.

remain to be found. Dr. Range remarked that they are difficult to find, being embedded in the surface limestone (Kalahari Kalk). The largest mass of this fall is one of 1431 lb. (650 kg.) which was presented by the Administration of South-West Africa to the South African Museum at Cape Town. (This was presumably from the collection of 37 masses at Windhoek, but amongst these the largest weight mentioned by Dr. Range was 600 kg.)

It is therefore evident that the centre of this large shower of iron meteorites was in the Gibeon district. The iron had been used by the natives, and it is also evident that some of the large masses had been transported. Curiously, Sir L. Fletcher (1904, loc. cit., p. 34) suggested that the first Mukerop mass found in 1899 had been transported, while the Lion River mass, having been said to be associated with other masses, he considered to have been found in place. But transportation towards centres of civilization is more probable than in the reverse direction. The 'Bethany' mass described by E. Cohen had evidently been transported, first to Bethany and then to the Orange River before being finally taken to Cape Town; and there is no evidence that any large mass has been found in place in the Bethany district.

The name 'Bethany' for this meteoritic fall was suggested by E. Cohen in 1900 to replace the indefinite designations 'Great Namaqualand' and 'Great Fish River'. This change was favoured by Sir L. Fletcher and has since been followed in meteorite catalogues. 'Gibeon' would seem to be a better term. The several masses concerned have in common a fine octahedral structure and a nickel content of about 8 % (p. 34).

The farm names Amalia, Goamus, Kameelhaar, and Mukerop are without significance as applied to the separate meteorites. The masses from the different areas have been mixed up: as mentioned above, they have been transported from one farm area to another, and at Windhoek they were all placed together in one huge pile (fig. 2). From this pile a few specimens have from time to time been distributed to various museums. The country is divided into a network of farm areas, and some of the meteorites quite likely came from farms lying between those named above; e.g. Noronaub, Korra Korrabes, Grundorner, Gaus, &c. These farm areas are of considerable size: Kameelhaar is almost twenty miles long and Goamus more than a hundred square miles. In this stony and semi-desert region grazing is very sparse, but after rain the result is surprising and a fairyland of flowers springs up as if by magic. The average rainfall at Gibeon is 6·36 inches, but in different years (1921–26) it varied from 1·99 to 16·39 inches. The rivers on the map (fig. 1) are dry rivers showing as sandy tracks, except when in flood.

The distribution of these masses over an area of several hundred square miles and the fact that they are all of considerable size suggest that the shower was a swarm of meteorites, rather than a single mass broken up in the earth's atmosphere as is the case with showers of stones. Again, the distribution and relative sizes of the masses is here quite different from that of meteoritic iron found around a meteorite crater, where a single large mass of iron was shattered by the gaseous explosion, yielding a preponderance of smaller distorted fragments.

There is in this region a remarkable topographical feature which may possibly have some connexion with these meteorites. This is the large crater of the Geitsi Gubib or Groot Bukaros mountain, which has been described in some detail by A. W. Rogers.[1] The mountain has a height of 5200 feet above sea-level and 1800 feet above the plateau, and it is a prominent feature seen from the railway to Gibeon. (Unfortunately this is all that I saw of it.) The crater is $1\frac{1}{3}$ miles across and the flat bottom is 1500 feet below the highest point of the rim. This is considerably larger than the Arizona meteorite crater ($\frac{3}{4}$ mile in diameter and 570 feet deep). The material of the mountain is a fine breccia (fragments usually less than an inch across) of sedimentary rocks—hard shales, jaspery rocks, sandstones, &c.—with some quartz-gabbro and fragments of felspar, but no volcanic material. There are no volcanic rocks in the neighbourhood, but between here and Gibeon there are many kimberlite pipes (without diamonds). Rogers describes it as an explosion-pipe penetrating shales and sandstones of the Fish River series; and he accounts for the crater by the weathering of softer material inside a ring of silicified rocks, or by a ring fault. He remarks on the close similarity to the Arizona crater as described by G. K. Gilbert (1896), who favoured the explosion volcanic theory and rejected the meteoritic theory of its origin (now amply proven). There is, however, one important difference between these two craters. The thick beds of breccia at Geitsi Gubib dip inwards, while at the Arizona crater the beds dip outwards.

Another remarkable feature is presented in the situation of Geitsi Gubib. Ignoring for the moment the probability that the meteorites of Lion River, Bethany, and Kamkas (p. 32) were transported masses from the Gibeon district, it will be seen from the map (fig. 1) that this large crater lies near the centre of a ring of meteorite finds. But this cannot be put forward seriously in support of a meteoritic origin of the crater. Still another coincidence is the presence of kimberlite pipes between Geitsi Gubib and Gibeon, with a cluster close to where meteorites have been found, as shown on Range's maps (1912 and 1913, loc. cit.). But the idea that there can be any connexion between meteorites, kimberlite pipes, and diamonds is really too fantastic.[2]

Two specimens of meteoritic iron from this region were presented through Mr. L. G. Ray to the British Museum collection in 1940 by

[1] A. W. Rogers, Geitsi Gubib, an old volcano. Trans. Roy. Soc. South Africa, 1915, vol. 5, pp. 247–258, with sketch-map and section. A. L. du Toit, The geology of South Africa, 1939, p. 392.

[2] H. Helberger, Kann der Diamant kosmogenetischen Ursprungs sein? Zeits. Prakt. Geol., 1934, vol. 42, pp. 124–125. [M.A. 6–8.]

Mr. E. Zelle, meteorologist to the Administration of South-West Africa. These came from the Kameelhaar and Kamkas farms, but unfortunately details of the finding and weights of the masses from which they were cut are not yet available.

### Kameelhaar Farm, Gibeon.

As received, this piece weighed 1453 grams. After levelling and polishing two of the cut surfaces and cutting off a fragment for chemical analysis the weight is now 1439 grams (B.M. 1941,1). A portion of the larger (14 × 6 cm.) polished and etched surface is shown, actual size, in pl. I, fig. 8. The natural surface at the back of the specimen shows a series of shallow pits. The section shows one large (3 × 2 cm.) and several smaller troilite nodules. This specimen is of special interest in consisting of two crystal individuals, as shown by the different orientation of the Widmanstetter figures on two portions of the section. This is well shown by the enlarged (× 3) photograph reproduced in pl. II, fig. 11. The junction is marked by a kamacite band which, along its course, is approximately parallel to kamacite bands in one or other of the two crystals. The kamacite bands are about ⅓ mm. in width, corresponding to a fine octahedrite; but in some parts of the section they are much finer and more closely packed together. Narrow bands of taenite bordering the kamacite shine up brightly at certain inclinations of the specimen in the light. Plessite areas are rather smaller in one crystal than in the other. In the crystal on the right (larger portion in pl. II) the kamacite bands are somewhat irregular and confused, and they show more than the four directions required by the Widmanstetter structure parallel to the faces of the octahedron. Prominent amongst the extra bands are a few longer bands (vertical in the picture, pl. II). At an angle of 85° to these is a series of less distinct bands, seen to the left near the contact of the two crystals. A third extra direction is represented by a short band forming a hook at 10° at the top of the long vertical band. These three sets of bands are similar to the subordinate system of longer (up to 3 cm.) bands parallel to the faces of the cube which were described by F. Rinne[1] in the 404 kg. Goamus mass. For this new type of structure he suggested the term 'tessera-octahedrite'. O. C. Farrington[2] modified this to 'tesselated octahedrite'.

[1] F. Rinne, 1910, loc. cit. In this case, as the section plane was parallel to a cube face, there are actually only four directions of the lines: one set at right angles for the octahedron and another set also at right angles for the cube, the two sets being at 45° to one another.

[2] O. C. Farrington, Meteorites. Chicago, 1915, p. 95.

Still better would be cubo-octahedrite. Of the seven directions shown by these Widmanstetter figures four belong to the octahedron and three to the cube.

The crystal on the left (pl. II) shows only the four directions as required by the octahedral structure. The essential angles between these four directions are given in fig. 5A. But in addition to these angles there are several others at which the different directions may intersect.[1] Some of the several polygons that may so result are represented in the upper part of fig. 5. Similar shapes will be seen in the crystal on the left in pl. II. The essential angles of the seven directions in the other crystal (right-hand side of pl. II) are shown in fig. 5B.

The determination of the orientation of the section plane from the directions of the lines of the Widmanstetter figures involves complex formulae with tedious calculations[2] or a tangled graphical method.[3] These I have not attempted, but have obtained an approximate result by trial and error with the Hutchinson stereographic net.[4]

On the stereographic projection (fig. 6) are drawn the great circles at 90° from the poles of the octahedron and cube faces. They represent the intersections on the sphere of planes through its centre parallel to these faces. The section plane is also represented by a great circle; and the arc distances between its points of intersection with the several zone circles give the plane angles between the intersection of crystal faces on the section plane. This is made clearer by models. Disks of cardboard parallel to the faces of the octahedron and passing through

[1] 73° = 36°+37°, 77° = 36°+41°, 103° = 37°+66°, 107° = 41°+66°, 114° = 180°−66°, 139° = 180°−41°, 143° = 180°−37°, 144° = 180°−36°.

[2] A. Brezina, Meteoreisenstudien II. Über die Orientirung der Schnittflächen an Eisenmeteoriten mittelst der Widmannstädten'schen Figuren. Denkschr. Math.-naturwiss. Cl. Akad. Wiss. Wien, 1881, vol. 44, pp. 121–158, 5 pls., 11 text-figs.

N. T. Belaiew, The inner structure of the crystal grain as revealed by meteorites and Widmanstätten figures. Journ. Inst. Metals, London, 1923, vol. 29, pp. 379–403, 1 pl., 18 text-figs. Crystallisation of metals. London, 1923, pp. 72–78. [M.A. 2–87, 5–483.]

J. Leonhardt, Die morphologischen und strukturellen Verhältnisse der Meteoreisen im Zusammenhang mit ihrem Entwicklungsgang. Fortschr. Min. Krist. Petr., 1927, vol. 12, pp. 52–55; Neues Jahrb. Min., Abt. A, 1928, vol. 58, pp. 153–212, 2 pls., 9 text-figs. (pp. 179–201: Orientierungsmethoden und ihre Anwendung zur Untersuchung geometrischer und kristallographischer Zusammenhänge). [M.A. 3–533, 4–122.]

[3] A. Himmelbauer, Orientierung von Schnittflächen an Meteoreisen. Min. Petr. Mitt. (Tschermak), 1909, vol. 28, pp. 153–166, 8 figs.

[4] A. Hutchinson, Min. Mag., 1908, vol. 15, p. 100, pls. IV, IVa.

a common centre are built up of 60° sectors, the disks being of different colours for the two individuals and for the section plane.

The very few known examples of slices of meteorites showing two large crystal individuals in contact have been described as spinel-twins; and it was at first assumed that here we also have a spinel-twin.

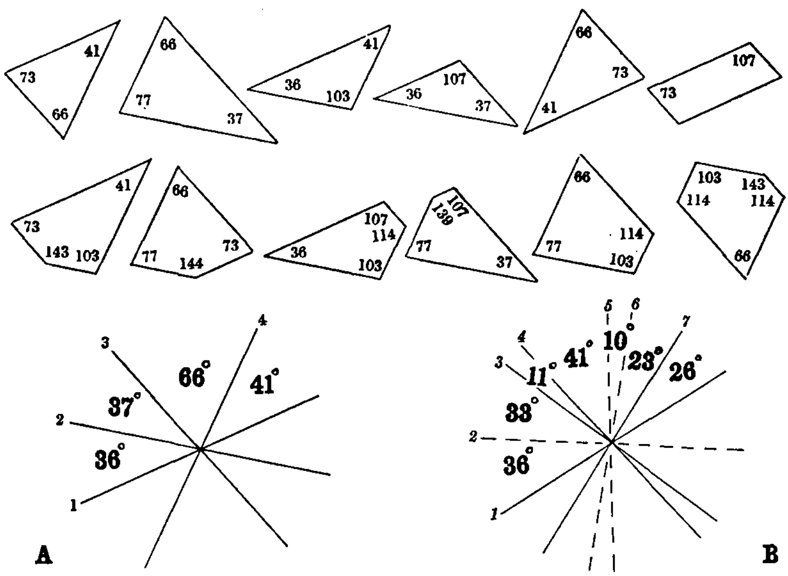


FIG. 5A. Direction of the lines of the Widmanstetter figures in one crystal individual (left-hand side of pl. II).

FIG. 5B. Same for the other crystal individual (right-hand side of pl. II). Barred lines for the direction of cube faces.

The polygons in the upper part of the figure show the various shapes given by the angles in fig. 5A and seen on the left in *pl. II*.

The section plane as drawn in fig. 6 shows a good agreement in the angles for the portion *A* and a tolerable agreement for the portion *B*. The following angles were measured: I, on the photograph[1] (pl. II) and given in fig. 5; II, on the stereographic projection (fig. 6); *A* for the crystal individual on the left and *B* for that on the right; *o* for octahedral faces and *a* for cube faces; $\bar{o}$ as twin-plane.

| | | 1–2($\bar{o}o$). | 2–3($oo$). | 3–4($oo$). | 4–1($o\bar{o}$). | |
|---|---|---|---|---|---|---|
| *A* | I ... ... ... ... | 36° | 37° | 66° | 41° | = 180° |
| | II ... ... ... ... | 32 | 39 | 68 | 41 | = 180 |

[1] The photographic plate was inclined at about 5° to the surface of the section, but this makes no appreciable difference in the angles.

| | | 1–2(ōa). | 2–3(ao). | 3–4(oo). | 4–5(oa). | 5–6(aa). | 6–7(ao). | 7–1(oō). | |
|---|---|---|---|---|---|---|---|---|---|
| B | I | 36° | 33° | 11° | 41° | 10° | 23° | 26° | = 180° |
| | II | 38 | 28 | 20 | 34 | 14 | 26 | 20 | = 180 |

This is, however, a false solution of the problem, and proves that the two individuals are not in twinned position. Although there is an apparent agreement in the angles, they are in reversed order in the

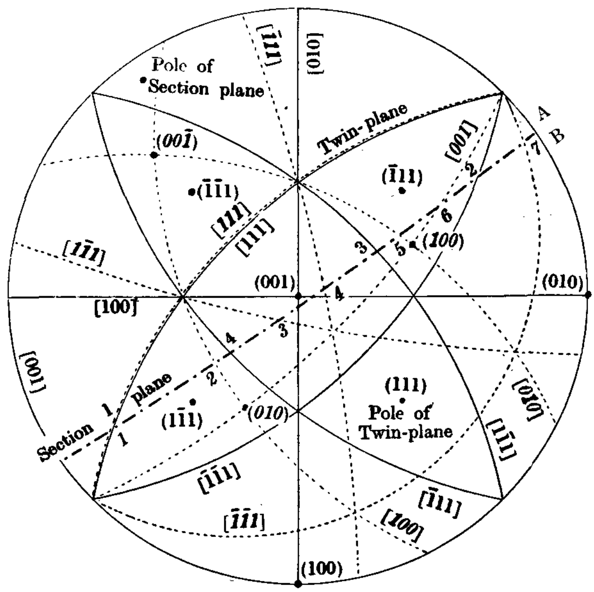


FIG. 6. Stereographic projection of the zones perpendicular to the crystal faces of a spinel-twin and of the section plane. (A false solution!)

two individuals in fig. 6 (one set clockwise and the other set counter-clockwise), whereas in fig. 5 both sets are numbered clockwise. Further, the directions no. 1 taken as the trace of the twin-plane are not quite parallel in the two individuals (a difference of 7°); while *A*3 and *B4*, which are strictly parallel, do not fall on the same point in the projection. Taking *A*3 and *B4* as the twin-plane there is no agreement in the angles.

Dr. M. H. Hey has interested himself in the problem. For the simpler case of individual *A* his results agree completely with mine; but for the more complex individual *B* he obtains two solutions, neither of which agrees with twinning with respect to *A*. The method he has devised will be detailed in a later paper.

Large-scale spinel-twinning in meteoritic iron was first described in the Mukerop mass of 178 kg. by A. Brezina and E. Cohen and independently by F. Berwerth in 1902. Berwerth (loc. cit., 1902, p. 663) also mentioned and figured a spinel-twin in a small slice from the 'Bethany' mass of 232 kg. The twin-law in these two examples was confirmed by a graphical method by A. Himmelbauer in 1909, and he added (loc. cit., p. 157) a third example in the siderite (also a fine octahedrite) of Laurens County (South Carolina, found 1857). Spinel-twins of this gigantic size are surely unique in any material.

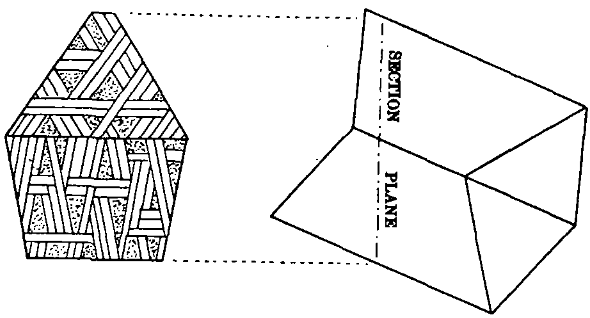


FIG. 7. Widmanstetter figures on a section of a spinel-twin.

Small-scale twinning on (111) had been previously described by G. Linck.[1] On a specimen of the Toluca siderite two small cleavages at 38° 58′ were interpreted as cube planes each twinned on different octahedral planes of a third crystal. This multiple twinning he believed to account for the oriented sheen sometimes seen on kamacite; and he further suggested that the Widmanstetter structure itself was due to polysynthetic twinning on four octahedral planes. Slip-band lamellar twinning on (211), as shown by Neumann lines in kamacite, is of frequent occurrence in siderites.[2]

A diagrammatic representation of Widmanstetter figures on a section of a spinel-twin is given in fig. 7. Here, as the section plane and the twin-plane are both perpendicular to the same dodecahedral plane of symmetry (for convenience in drawing), there are only three directions of the lines in each portion of the twin. The section plane is inclined at 5° to an octahedral plane of one individual of the twin and at 11°

[1] G. Linck, Ueber das Krystallgefüge des Meteoreisens. Ann. Naturhist. Hofmus. Wien, 1893, vol. 8, pp. 113–117, 1 fig.

[2] L. J. Spencer, Min. Mag., 1930, vol. 22, p. 276; 1931, vol. 22, p. 493; 1932, vol. 23, p. 39; 1933, vol. 23, pp. 331, 388; 1935, vol. 24, p. 15.

to a cube face of the other individual. I give this figure because the much-copied figures of Tschermak,[1] showing section planes in four directions on octahedra, represent the sections completely filled by kamacite bars without any intervening plessite areas.

Meteorite specimens of the octahedrite and hexahedrite types usually seem to consist of a single crystal, there being a continuity of the structure throughout the whole mass whatever may be its size. The only examples that I know of where the mass consists of more than one large crystal are the few mentioned above. In other cases the mass may consist of an aggregate of small crystals, sometimes still showing remnants of a previous octahedral structure, as in Murnpeowie and Kamkas. It seems probable that the granular structure of ataxites may be due to the same heat-treatment with complete obliteration of the original structure.

### Kamkas Farm, Maltahöhe.

The only available information about the finding of this mass of meteoritic iron is given in Mr. E. Zelle's letter of July 17, 1940: 'It was found on the farm Kamkas on the hard ledge of a small flat river in the Fish River series [Nama System = Cambrian?], about 3 miles from the farm-house. At my request it was taken to a shop in Maltahöhe, where it was loaded on to a farmer's motor-car and brought to Windhoek.' It is thus evidently a large mass, but no mention is made of its weight.

The slice as received weighed 819 grams; after polishing and sawing off a fragment for chemical analysis the weight is now 810 grams (B.M. 1941,2). The polished and etched surface measures $10 \times 5\frac{1}{2}$ cm. This surface is dull and granulated, but at certain inclinations of the light it shows indistinctly a fine octahedral structure (pl. I, fig. 9). The enlarged ($\times 3$) photograph (fig. 10) brings out this structure much more clearly than was expected. Under the microscope the octahedral structure is less obvious, owing to the granulation of the kamacite and the breaking up of the lines of taenite, which shows as bright specks. A few small nodules of troilite are present.

The faint circular line shown in the photograph (fig. 9) had not been previously noticed on the specimen, and it was at first thought to be due to a fault in the photograph (suggesting that a bottle had been placed on the wet film). But at a certain inclination of the light it is plainly seen on the etched surface of the meteorite. The parallel surface

[1] G. Tschermak, Lehrbuch der Mineralogie. 4th edit., Wien, 1894, p. 585.

of the slice and the surface at the edge were then smoothed and etched to see if the ring extended through the mass, but no indication of it could be detected. No explanation can be offered for this peculiar structure.

During this second etching, which proceeded slowly with very dilute acid, it was noticed that the faint Widmanstetter figures at first produced showed none of the granulation. They were sharper and more distinct, but the kamacite bars showed crenulated edges. As the etching proceeded the granular structure became evident and then more and more pronounced, while the octahedral structure became less and less distinct.

In its fine octahedral structure and percentage of nickel (p. 34) this Kamkas mass agrees with the various Gibeon masses; and a similar granulation is seen in one portion of the Mukerop mass. It is therefore probably a mass of the Gibeon shower that had been transported. The transportation by ox wagon of the 'Bethany' and Lion River masses evidently became too irksome, and they were abandoned north of the Orange River, to be found again and later continue their journey to Cape Town. The Kamkas mass was found a hundred miles north-west of the Gibeon farm area on a direct line to the seaport of Walfish Bay, with 170 miles still to go, and was then no doubt abandoned.

The granulation was no doubt effected by a moderate heat-treatment during a period previous to the entry of the mass into the earth's atmosphere. This was not intense enough to obliterate the octahahedral structure; nor was it prolonged enough for the crystallization of coarser grains, as in the case of the Murnpeowie siderite.[1] The heat-treatment was also less intense than in a portion of the Mukerop mass, described by Brezina and Cohen and by Berwerth (loc. cit.). In the etched slices of the Mukerop mass one of the twinned portions shows a fine granulation, having at first sight the appearance of an ataxite, but in an oblique strong illumination some traces of a Widmanstetter structure are seen with a magnifying glass. Across the straight sharp line of contact the Widmanstetter structure in the adjacent portion of the twin is perfectly clear and not affected. How one portion of the twin could undergo a heat-treatment and the other escape is difficult to understand.

Chemical analyses of these two specimens have been made by Miss Hilda Bennett in the Mineral Department of the British Museum. Her results given under I and II are in agreement with each other and with

[1] L. J. Spencer, Murnpeowie (South Australia), a granular type of meteoric iron. Min. Mag., 1935, vol. 24, pp. 13–20, 3 pls., 1 text-fig.

previously published analyses (III–VII) of the Gibeon irons. The early determination by Sir John Herschel in 1838 of Ni 4·61 %, stated to be a hasty preliminary examination, is obviously too low; and C. U. Shepard's determination of Ni 6·70 % is also rather too low for a fine octahedrite.

TABLE I. Chemical analyses of meteoritic irons of the Gibeon shower.

| | Fe. | Ni. | Co. | Cu. | Cr. | C. | S. | P. | Cl. | Insol. | Total. | Sp. gr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. | 92·38 | 7·68 | 0·30 | 0·006 | — | — | nil | 0·05 | — | 0·03 | 100·45 | — |
| II. | 91·63 | 7·93 | 0·55 | 0·008 | — | — | nil | 0·04 | — | 0·01 | 100·17 | — |
| III. | (93·30) | 6·70 | nil | — | — | — | trace | trace | — | — | 100·00 | 7·45 |
| IV. | 92·06 | 7·79 | 0·69 | 0·03 | 0·01 | — | 0·10 | 0·05 | — | — | 100·73 | — |
| V. | 91·07 | 8·18 | 0·63 | 0·03 | 0·02 | 0·01 | 0·04 | 0·06 | trace | — | 100·04 | 7·841 |
| VI. | 90·96 | 8·19 | 0·46 | 0·04 | 0·02 | 0·02 | trace | 0·18 | 0·01 | 0·01 | 99·89 | — |
| VII. | (91·37) | 7·97 | 0·50 | 0·02 | 0·04 | 0·05 | 0·02 | 0·03 | n.d. | — | 100·00 | 7·783 |

I. Kameelhaar farm. Analyst, Miss Hilda Bennett, 1941, on 1·87 grams.
II. Kamkas farm. Analyst, Miss Hilda Bennett, 1941, on 2·35 grams.
III. Lion River. Analyst, C. U. Shepard, loc. cit., 1853. Also Sn, K ?, traces.
IV. Lion River. Analyst, O. Sjöström in E. Cohen, Meteoreisen-Studien. V. Ann. Naturhist. Hofmus. Wien, 1897, vol. 12, p. 43. Later addition of figures for Cu and S by J. Fahrenhorst in E. Cohen, Mitt. Naturwiss. Ver. Neu-Vorpommern und Rügen, Berlin, 1901, vol. 32 (for 1900), p. 23; E. Cohen, Meteoritenkunde, 1905, Heft 3, p. 330.
V. Bethany. Analyst, J. Fahrenhorst in E. Cohen, loc. cit., 1900; Meteoritenkunde. Stuttgart, 1905, Heft 3, p. 335.
VI. Mukerop farm. Analyst, O. Hildebrand in A. Brezina and E. Cohen, loc. cit., 1902; E. Cohen, Meteoritenkunde, 1905, Heft 3, p. 338.
VII. Mukerop farm. Analyst, Krupp's chemical laboratory in A. Brezina and E. Cohen, 1902; E. Cohen, Meteoritenkunde, 1905, Heft 3, p. 338.

South-West Africa is noted for its meteorites. Besides the remarkable Gibeon shower, it has the largest of all known meteorites. This is the 60-ton Hoba[1] mass in Damaraland, about 400 miles north of Gibeon in Great Namaqualand. It is, however, of quite a different type, being a nickel-rich ataxite containing about 17 % of nickel.

[1] L. J. Spencer, Hoba (South-West Africa), the largest known meteorite. Min. Mag., 1932, vol. 23, pp. 1–18, 1 pl., 5 text-figs.

EXPLANATION OF PLATES I AND II.

Polished and etched sections of meteoritic irons from the Gibeon shower, South-West Africa.

(Photographs by M. G. Sawyers, British Museum of Natural History.)

FIGS. 1–7 in the text.

PLATE I, FIG. 8. Kameelhaar farm, Gibeon. Portion of British Museum no. 1941,1, showing two crystal individuals with different orientation of the Widmanstetter figures. One large and several smaller nodules of troilite. Natural size.

FIG. 9. Kamkas farm, Maltahöhe. Portion of B.M. 1941,2, showing indistinctly the fine octahedral structure obscured by granulation. Patches covering small nodules of troilite. Natural size.

FIG. 10. Kamkas farm, Maltahöhe. Portion of fig. 9. Fine octahedral structure with granulation. The photograph, taken at a particular inclination of the light, comes out much better than was expected. $\times 3$.

PLATE II, FIG. 11. Kameelhaar farm, Gibeon. Portion of pl. I, fig. 8. $\times 3$.

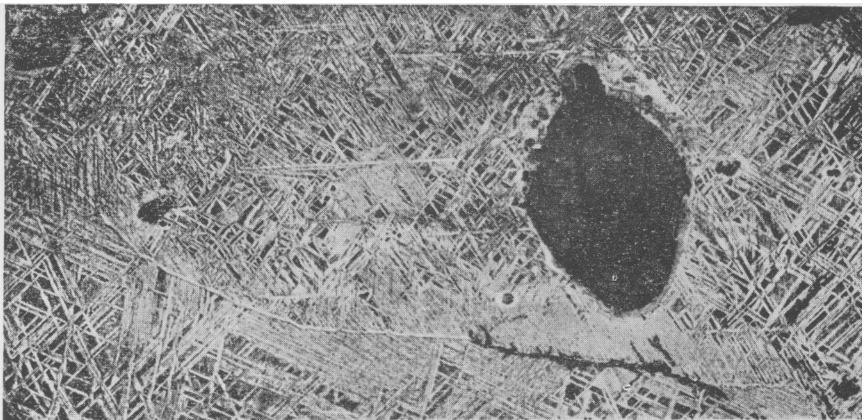

Fig. 8.

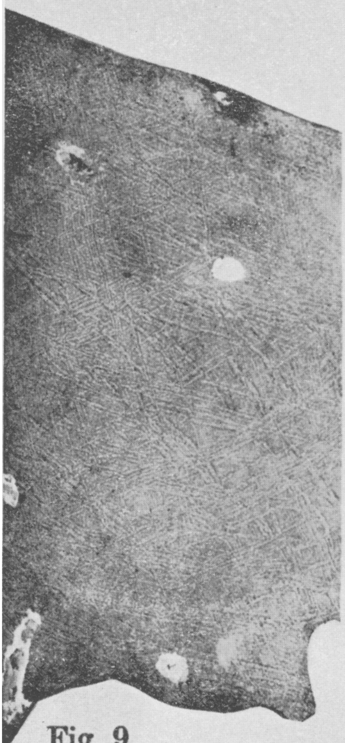

Fig. 9.

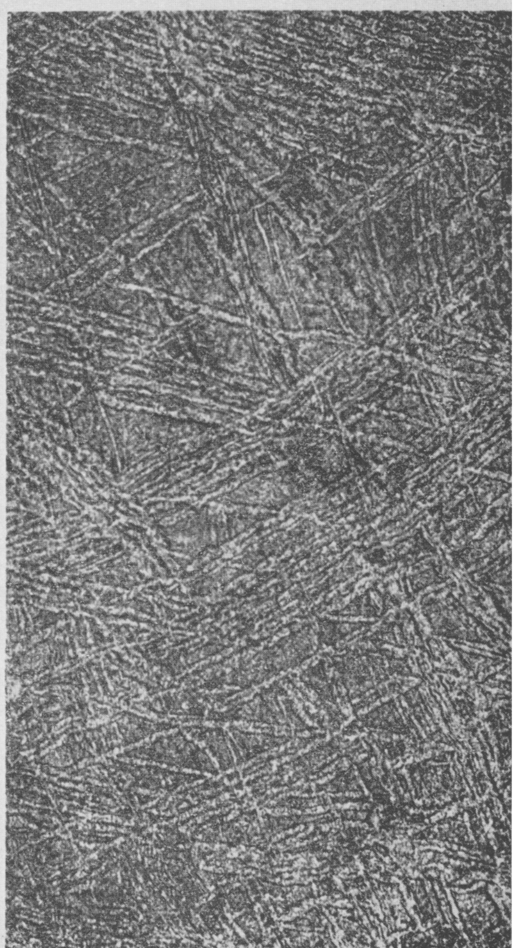

Fig. 10.

L. J. SPENCER: METEORITIC IRONS OF THE GIBEON SHOWER.

FIG. II

L. J. SPENCER: METEORITIC IRONS OF THE GIBEON SHOWER.