

The following Supplement treats in considerable detail, eleven meteorites which were examined after January 1, 1973. In addition, there are brief references to a few new meteorites, and paired falls and supplementary notes and photographs relating to meteorites which were previously treated in full. On page 1418 there is a table with the most recent analytical data by Dr. J. T. Wasson and his co-workers.

## Albuquerque, New Mexico, U.S.A.

The meteorite was described by Beck & La Paz (1950) and was again mentioned by La Paz (1965:19) and Hey (1966:14). It was briefly treated in the handbook section but further conclusions pended my detailed microscopic examinations.

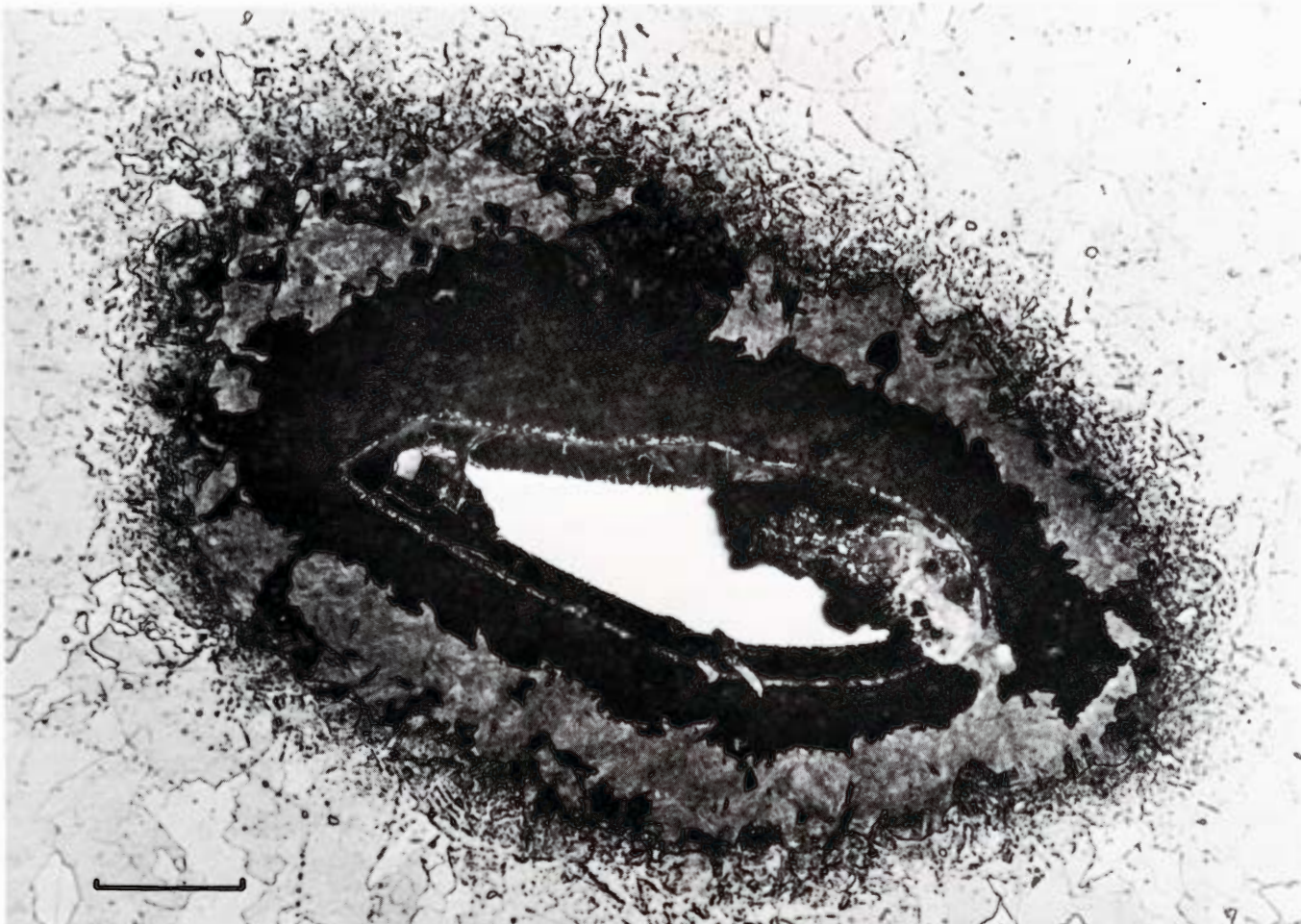
For this purpose the only existing material was kindly put at my disposition by Professor Klaus Keil, Institute of Meteoritics, Albuquerque, New Mexico. The meteorite, of 22.4 grams and measuring about 41 x 15 x 4.5 mm, is a full section through a small slug. Before sectioning, the entire mass must have measured perhaps 5 x 3 x 2 cm and may have weighed 100-300 g, certainly not more. This is in harmony with the statement by Beck & La Paz (1950) that it originally weighed 157 g. It is not clear where the remaining material is.

It is a medium to coarse octahedrite with a bandwidth of 1.3-2.0 mm. However, because of secondary reheating the original Widmanstätten structure is blurred, and because of the small size of the section the bandwidth is not well defined.

All kamacite is transformed by shock-reheating to serrated  $\alpha_2$  units. Around massive schreibersite crystals the new  $\alpha$ -grains are better equilibrated and form equiaxial units 5-25  $\mu$  across. The Neumann bands have disappeared



**Figure 2050.** Canyon Diablo (Albuquerque) (Institute of Meteoritics, Albuquerque). A coarse octahedrite of group I. Cohenite (white) has been thermally altered and is enveloped in black bainitic rims. Etched. Scale bar 0.5 mm.



**Figure 2051.** Canyon Diablo (Albuquerque). Thermally decomposed cohenite (white), enveloped in concentric rims of bainitic-martensitic transformation products. Before reheating the cohenite crystal boundaries were along the thin white line, now early-nucleated ferrite. The extreme variation in appearance is caused by two opposing composition gradients: Nickel increases from 1.5 to 6.5%, while carbon decreases from 6.7 to 0%, when passing from cohenite out into the matrix. Etched. Scale bar 100  $\mu$ .



or are locally to be seen as ghost-lines with modest precipitates. The taenite etches yellow or displays irregular mosaics of yellow and brown patches, suggesting brief reheating above 900° C.

Cohenite occurs as palmate or finger-shaped crystals, typically 3 x 0.5 mm in size. They correspond to the normal massive cohenite crystals in group I octahedrites, such as Canyon Diablo, but they are severely altered by the same shock-reheating that altered the kamacite. Some cohenite crystals are surrounded by 0.1-0.2 mm wide black-etching zones of bainite, other crystals are entirely decomposed by melting to ledeburite. Where cohenite was associated with schreibersite the melts solidified to fine-grained steadite eutectics. Fine graphite lamellae have precipitated in these melts and the retained carbon- and nickel-rich austenite has at low temperature (about 0° C) transformed to rather coarse martensitic structures.

In many places the section is crossed by heavy shear zones that have cut and displaced the various minerals several hundred microns.

The extreme modifications discussed above are known to occur in the small slugs of stage VI-VII, collected around Meteor Crater, Arizona, and in these only. A full treatment

of these is given in the handbook section under Canyon Diablo.

There exists a preliminary analysis of Albuquerque (La Paz 1965:20): 7.41% Ni, 90.5 ppm Ga, 4.46 ppm Pd and 1.9 ppm Au. Although La Paz considered this as a proof that Albuquerque was an independent fall, I am inclined to see the analysis as a proof that Albuquerque is, in fact, a transported Canyon Diablo slug.

The conclusion is that Albuquerque should be deleted as an independent meteorite and be included under Canyon Diablo as another of those small slugs which were exposed to violent shock-alterations during the cratering impact. The specimen examined is a beautiful example of a small slug with a steep shock and temperature gradient: within the same section melted and unmelted cohenite and schreibersite occur side by side.

### Aswan, Egypt

23°59'N, 32°37'E

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. Decorated Neumann bands. HV 220±15.

Group IIIA. 8.2% Ni, about 0.25% P, 20 ppm Ga, 42 ppm Ge, 0.22 ppm Ir.

### HISTORY

The history and a preliminary examination of this 12 kg octahedrite have been given previously in the handbook section. In the following are presented a new analysis and a detailed description based on a study of a 41 g sample, kindly put at my disposition by Dr. Agrell, Cambridge University.

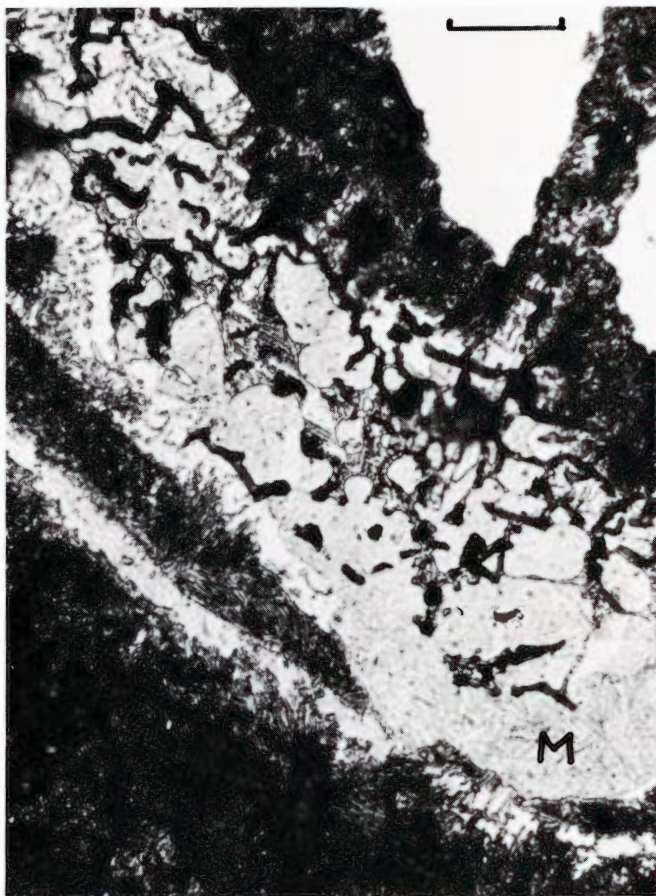
### ANALYSIS

Scott et al. (1973) reported 8.21% Ni, 20.0 ppm Ga, 41.8 ppm Ge and 0.22 ppm Ir.

### DESCRIPTION

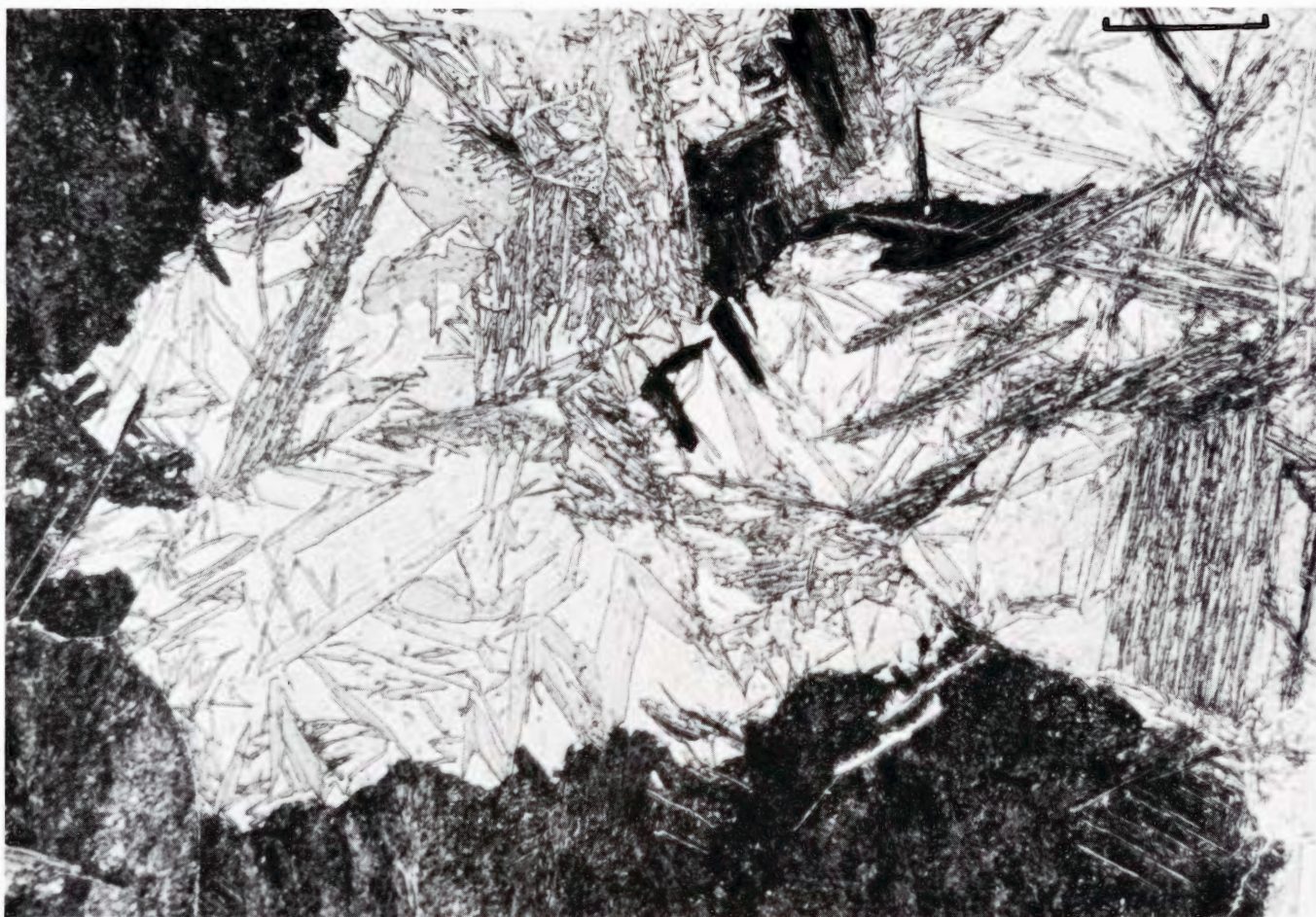
The Cambridge sample (No. 672) is a small corner, measuring 35 x 32 x 16 mm, which has not been exposed to artificial reheating. It is, however, marred by heavy hammer and chisel blows, and straight grooves indicate where hacksawing has been attempted. The surface is weathered. There are no traces of fusion crust and, on sections, there is no heat-affected  $\alpha_2$  zone. Corrosion penetrates several centimeters below the surface and forms 10-100  $\mu$  wide limonitic veins, especially along the schreibersite-kamacite interfaces. It is estimated that at least 2 mm has been lost to terrestrial corrosion, so the Aswan octahedrite must have been exposed to the arid Egyptian climate for countless generations. The supposition, advanced in the handbook section, that the sample in the Smithsonian Institution was thermally altered by artificial reheating, can thus be confirmed.

The polished and etched section shows a medium Widmanstätten structure of straight, slightly swollen ( $\downarrow$ W~



**Figure 2052.** Canyon Diablo (Albuquerque). Another case of extreme decomposition of cohenite (white). Because of a schreibersite inclusion, the reheating led to the formation of a Fe-Ni-P-C melt, which on rapid solidification formed a very fine-grained steadite eutectic with a few graphite lamellae. The austenite dendrites are now martensitic (M). Etched, Oil immersion. Scale bar 15  $\mu$ .





**Figure 2053.** Canyon Diablo (Albuquerque). Various transformation products from austenite in the zone around a previous cohenite crystal. Nickel is relatively high ( $\sim 5\%$ ) and carbon low ( $\sim 1\%$ ) in the martensitic region (gray), while the nickel is relatively low ( $\sim 2\%$ ) and carbon high ( $\sim 2\%$ ) in the black bainitic region that shows proeutectoid cementite needles. Etched. Oil immersion. Scale bar  $20\ \mu$ .

20) kamacite lamellae with a width of  $1.10 \pm 0.15\ \text{mm}$ . The kamacite displays numerous subboundaries decorated with  $2.5\ \mu$  phosphide particles. Each subgrain is divided into a large number of cells, often aligned in fibre-like textures, comparable to those discussed under Uwet and Plymouth. Neumann bands are ubiquitous, but on a close examination two generations may be distinguished. The primary Neumann bands are now degenerated, discontinuous and partly erased; they are bounded by very straight sides decorated by  $0.5\ \mu$  phosphide particles. The secondary bands are unaltered and have ragged sides without precipitates. The hardness of the kamacite is  $220 \pm 15$ , increasing to above 250 in near-surface places where bent structural elements suggest artificial cold-working.

Taenite and plessite cover about 25% by area. The comb and net fields are somewhat annealed, and the taenite is not very hard ( $275 \pm 25$ ). Original martensitic enclaves are now tempered to distinct duplex  $\alpha + \gamma$  aggregates with hardnesses of  $210 \pm 30$ . The kamacite component disappears from these aggregates by prolonged etching with dilute alcoholic nitric acid (2% Nital).

Schreibersite occurs as massive crystals up to  $12 \times 3\ \text{mm}$  in size. It is surrounded by swathing kamacite that

has grown to widths of  $1.5\text{--}2.0\ \text{mm}$ . Schreibersite is further present as  $5 \times 0.2\ \text{mm}$  bodies along the center of kamacite lamellae, as  $20\text{--}50\ \mu$  wide grain boundary precipitates and as irregular vermicular bodies inside the open-meshed plessite fields. Rhabdites were not observed. The bulk phosphorus content is estimated to be  $0.25 \pm 0.05\%$ .

Troilite is present in a few places as  $0.1\text{--}0.2\ \text{mm}$  blebs. These troilite bodies originally had parallel  $5\text{--}25\ \mu$  wide daubreelite lamellae. However, caused by a cosmic shock, they are now entirely melted, and the daubreelite lamellae and any adjacent schreibersite have been shattered and dispersed throughout the melts.

Aswan is a normal medium octahedrite transitional between group IIIA and IIIB, related to, e.g., Thule, Gundaring, Staunton and Aggie Creek.

It must have had a rather complex history. After the initial very slow cooling that developed the Widmanstätten structure, it was exposed to shock and reheating. Thereby the primary Neumann bands formed and were again partly erased and decorated. Simultaneously the plessite fields were tempered, the troilite shock-melted and the kamacite polygonized to the fine cellular textures. The hardness of all metallic phases dropped to annealed equilibrium values,



perhaps. 150-160. Then followed another cosmic shock, that work-hardened the phases to the present values and introduced a new generation of Neumann bands. Finally some samples were exposed to artificial reheating.

In its thermally altered structure Aswan may be compared to, e.g., Owen’s Valley, Sandtown, Uwharrie, Thule and Plymouth, all members of the resolved chemical groups IIIA and IIIB.

De Hoek, Cape Province, South Africa

29°23’S, 23°6’E; 950 m

Polycrystalline, troilite-rich ataxite. A few kamacite spindles 8±4 μ wide. HV 220±5.

Anomalous. 9.97% Ni, 0.42% Co, 0.06% P, about 1.2% S, 0.09% C, 0.12% Cu, 0.24 ppm Ga, 0.079 ppm Ge, 0.27 ppm Ir.

HISTORY

A mass of 17.2 kg was discovered in 1960 on the De Hoek portion of the farm Lanyon Vale 376 in the Hay district. The location is about 46 km northeast of Prieska and only 1 km west of the Orange River. In 1967 another mass of 3.8 kg was found 750 m east-southeast of the first one. According to Schumann (1967), who reported the discoveries and gave a very precise description of the circumstances of finding, the 17.2 kg mass was found within 20 meters of a commonly used farm road across the river terrace. It was found between boulders of roughly its own size and color, consisting of andesitic lava and cherty dolomite. The 3.8 kg mass was found by the farm owner, G.F. Strauss, himself; it lay almost entirely buried somewhat lower on the river terrace. Schumann (1967) and Frick & Hammerbeck (1973:15) speculated that the meteorites were seen to fall on January 2, 1959, and thus could be associated with the Quadrantid meteor shower, but as shown below this seems to be impossible. Frick & Hammerbeck (1973:15) presented a preliminary description of the structure, a photograph of the exterior and a macrograph of a polished section, clearly showing the anomalous structure.

COLLECTIONS

Geological Survey, Pretoria (the main mass of the 17.2 kg meteorite). The 3.8 kg mass appears to be in private possession. The following examination is based upon the



Figure 2054. Aswan (Cambridge No. 672). A large composite comb and net plesite field with numerous irregular schreibersite precipitates. The kamacite shows subboundaries and degenerate Neumann bands, compare Figure 2057. At T, a shock-melted schreibersite-troilite-daubreelite aggregate. Etched. Scale bar 0.5 mm.

examination of samples from the 17.2 kg mass, which Dr. Frick, Pretoria, kindly put at my disposition.

DESCRIPTION

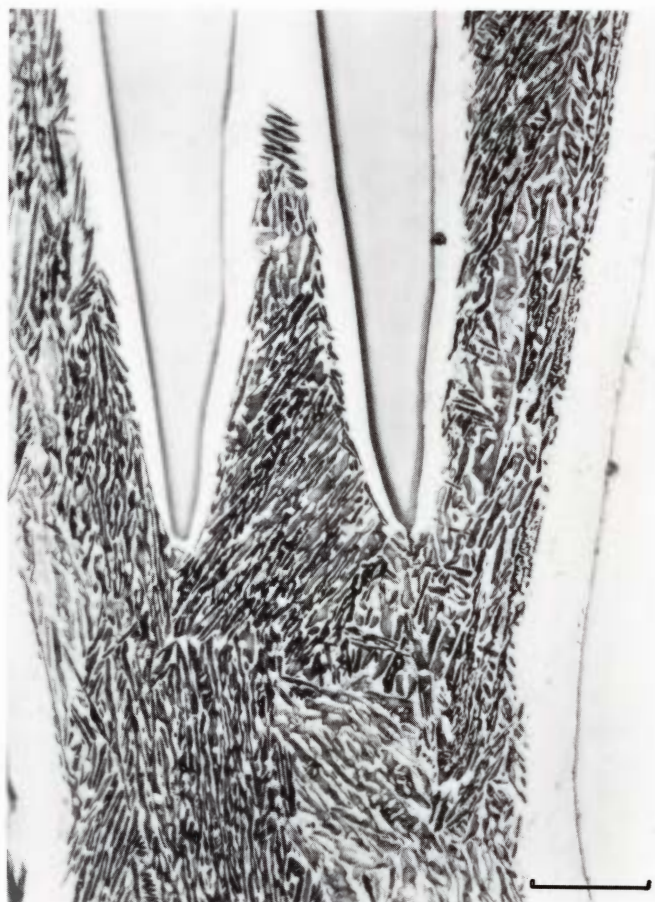
The 17.2 kg mass is a flat iron with a triangular shape and the maximum dimensions 33 x 23 x 10 cm, while the 3.8 kg mass is somewhat more irregular and has the approximate maximum dimensions 18 x 10 x 8 cm (Schumann 1967). The 17.2 kg mass which I examined in Pretoria is weathered; the fusion crust has disappeared except in regmaglypt depressions and at the bottom of the

DE HOEK – SELECTED CHEMICAL ANALYSES

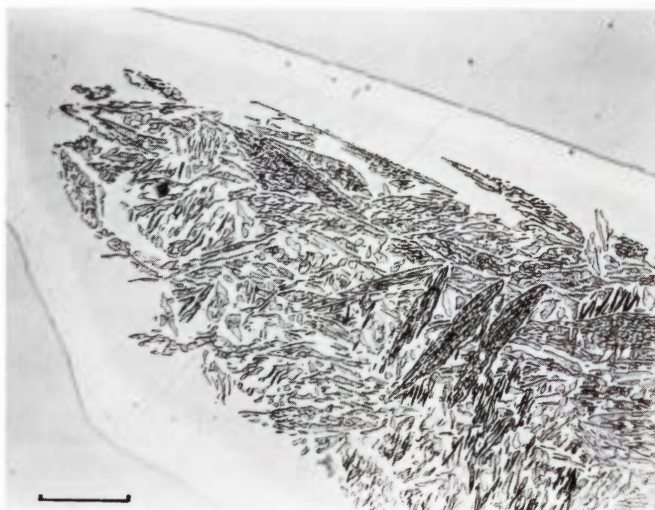
References	percentage			ppm					
	Ni	Co	P	C	S	Cu	Ga	Ge	Ir
Frick & Hammerbeck 1973	9.99	0.42	0.06	900	100	1200			
Wasson & Scott 1974 (pers. comm.)	9.95						0.24	0.079	0.27

The copper content is among the highest reported for iron meteorites and serves to further stress De Hoek’s anomalous position.





**Figure 2055.** Aswan. High magnification reveals that the taenite interiors are thoroughly decomposed. The textures suggest tempered high nickel-martensite with a significant carbon content ( $\sim 0.5\%$ ). Deep-etched, so that the ferritic phase is partially dissolved. Oil immersion. Scale bar  $20\ \mu$ .



**Figure 2056.** Aswan. Another tempered taenite field. The wide homogeneous taenite rims and the two-phase tempered martensite are conspicuous. Etched. Oil immersion. Scale bar  $20\ \mu$ .

troilite grooves. The regmaglypts are 10-15 mm across on one side but 20-30 mm across on the opposite side, suggesting an oriented flight. The two fragments may

perhaps be reconstructed to one plate-shaped body, about  $45 \times 25$  cm in width and 10 cm thick, that burst late during flight.

The surface is rich in pinpoint holes and elongated grooves from ablation-melted troilite. On sections the fused troilite may be seen to be composed of fine eutectics of iron, sulfur and oxygen, often with well developed primary ferrite dendrites; these are, however, usually altered by terrestrial corrosion, and also most of the normal fusion crust is either lost or severely altered. The terrestrial attack must have required at least several generations so it may be safely ruled out that De Hoek can be associated with the Quadrantids in 1959.

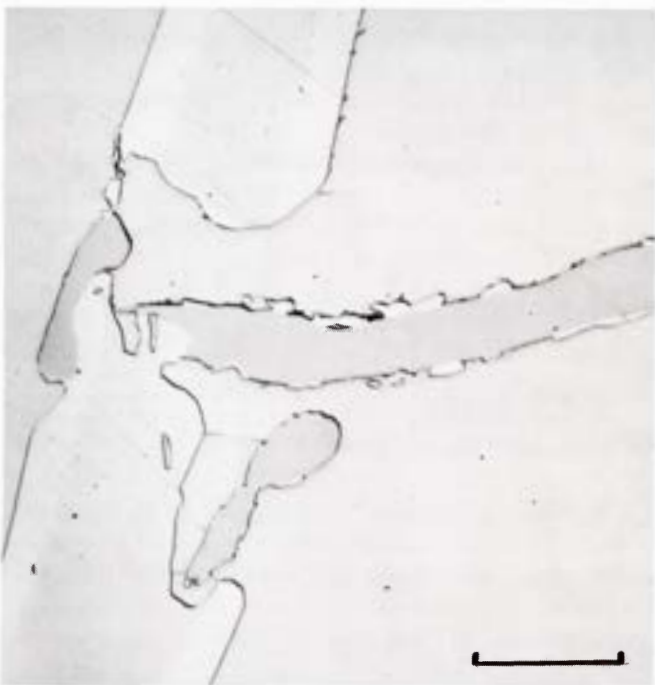
Sections through the mass reveal a very unusual macrostructure which may be compared to that of N'Goureyima, Tucson and Mundrabilla. The matrix is a polycrystalline aggregate of parent taenite grains which are separated by almost continuous films and veins of troilite. Troilite also occurs as spherules and drop-shaped particles, 2-5 mm in size, inside the parent taenite crystals. The troilite constitutes approximately 6% by volume, corresponding to a bulk sulfur percentage of about 1.2, and thus much more than indicated by the analysis quoted above.

The parent taenite grains are elongated and roughly parallel to the exterior boundaries of the mass. The grain



**Figure 2057.** Aswan. Tempered kamacite. A grain boundary (G) with phosphide precipitates is slightly out of focus. Decorated Neumann bands (D) run obliquely across, and late Neumann bands (N) are also seen. A subboundary (S) is mainly visible because of its micron-sized phosphide precipitates. Etched. Scale bar  $50\ \mu$ .





**Figure 2058.** Aswan. Tempered schreibersite (gray) adjacent to two taenite ribbons. The nickel-rich schreibersite has on reheating segregated fine taenite particles (white). See also, e.g., Figure 1020. Etched. Scale bar 20  $\mu$ .

size is from about 3 x 1 to 4 x 1.5 cm, but larger grains occasionally occur. The grain boundaries consist of very thin ribbons of kamacite wherever the troilite films are discontinuous. These 10-30  $\mu$  thick kamacite ribbons are very early precipitates that nucleated heterogeneously on the grain boundaries before the bulk taenite decomposed. Very often the kamacite has grown in saw-toothed shape or as allotriomorphs into one of the adjacent grains, but the growth has stopped at widths of 40-100  $\mu$ .

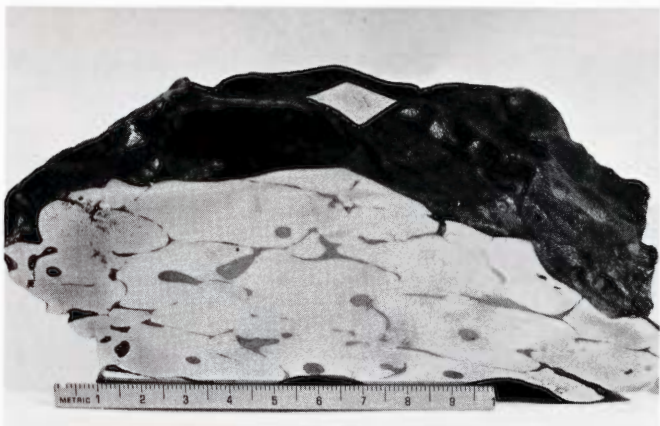
The bulk of the grains show, at low magnification, a martensitic texture, which at high magnification, is revealed to be an  $\alpha + \gamma$  structure that may well be termed a tempered martensite. The kamacite forms oriented 1-5  $\mu$  cellular structures, separated by vermicular taenite, 1  $\mu$  thick. Whenever the taenite increases above 3  $\mu$  in width, the interior is decomposed into submicroscopic aggregates. The hardness of the  $\alpha + \gamma$  mixtures, integrating over many units, is  $220 \pm 10$ . The individual phases were too fine-grained for a measurement. Neumann bands are absent; the rather high microhardness nevertheless indicates that the metal is cold-worked, probably because of a shock event.

Scattered through the grains a few, narrow kamacite spindles occur. They are oriented in a Widmanstätten pattern and are  $8 \pm 4 \mu$  thick and about 5-10 times as long. They occur with a frequency of one spindle per 2 mm<sup>2</sup> and are apparently the very first traces of a homogeneous taenite decomposition that never went far because of a high cooling rate.

The troilite nodules and films were originally composed of millimeter- to centimeter-sized crystals in which occurred scattered 0.1-1 mm phosphate crystals and smaller



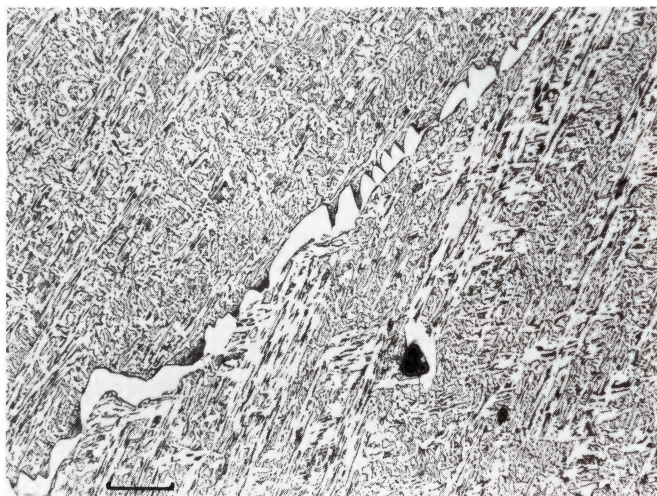
**Figure 2059.** De Hoek (Pretoria). Full-size model of the 17.2 kg mass. Grooves and marked holes indicate where troilite ablated away during flight. Ruler divided in centimeters.



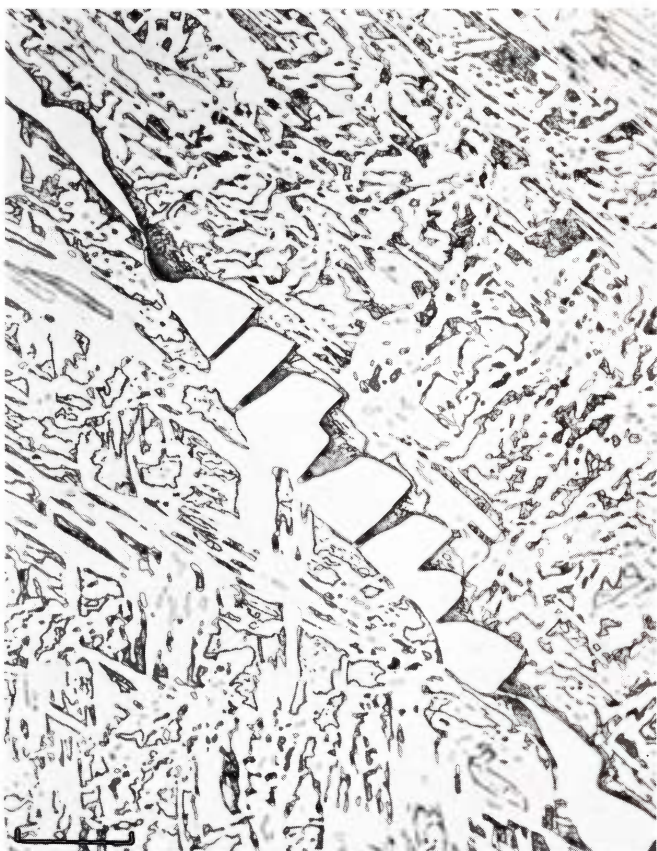
**Figure 2060.** De Hoek (Pretoria). Polished section through the 17.2 kg mass (section K). Elongated taenite grains separated by films of troilite. Also spheroidal troilite nodules inside many taenite grains. Ruler in centimeters.

chromite crystals. While the cooling rate was almost sufficiently rapid to prevent Widmanstätten formation, it did not entirely prevent heterogeneous nucleation and growth around the troilite inclusions, which are therefore in several places rimmed by 20-150  $\mu$  wide zones of swathing kamacite. A late shock-reheating has entirely altered the





**Figure 2061.** De Hoek (Copenhagen 1975.xx). The taenite boundaries are either marked by troilite, or, as here, more discreetly indicated by imperfect precipitates of kamacite. Note the different orientation of the Widmanstätten structure in adjacent grains. The black angular body is a phosphate crystal. Etched. Scale bar 100  $\mu$ .



**Figure 2062.** De Hoek (Copenhagen). A grain boundary between two taenite (i.e., austenite) crystals. The kamacite (i.e., ferrite) grows preferentially into one grain; the rejected nickel becomes concentrated between the individual ferrite blocks and delays or prevents this austenite from decomposing. Etched. Scale bar 50  $\mu$ .

troilite nodules so that they now appear as microcrystalline eutectics mainly of iron and sulfur with dispersed phosphate and chromite fragments. The rapidly melted material has intruded upon the swathing kamacite rims and partly

devoured them; the edges are extremely serrated and unequilibrated.

The phosphates are rather evenly distributed throughout the taenite grains, with one or two particles per  $\text{mm}^2$ . They are usually rectangular in cross section and 50-200  $\mu$  across, but they were not further identified. They have usually served as nuclei for the formation of rims of swathing kamacite 20-50  $\mu$  wide.

Schreibersite and rhabdites were not observed in any section. The analytically determined phosphorus content of 0.06% is probably equally divided between the phosphates and phosphorus in solid solution in the metallic phases.

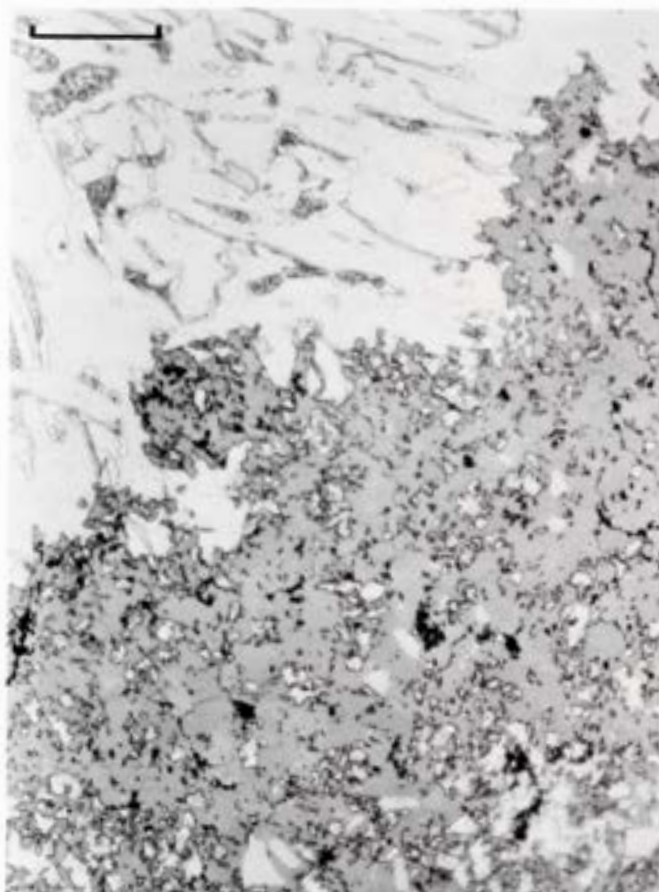
Under the fusion crust is a 1-2 mm thick heat-affected  $\alpha_2$  zone, but it is difficult to perceive, as is usually the case with ataxites. However, on a good section it can be seen that the kamacite is transformed to 5-20  $\mu$  serrated units, while the taenite is homogenized slightly and has lost its tarnished-cloudy appearance. The hardness drops in the  $\alpha_2$  zone to  $200 \pm 10$ , reflecting the structural transformations. Part of the  $\alpha_2$  zone has been lost to corrosion, confirming the conclusion that De Hoek did not fall in this century.

De Hoek is perhaps the result of sintering promoted by the presence of a liquid sulfide phase. This reaction may



**Figure 2063.** De Hoek (Copenhagen). Occasional kamacite spindles occur in a Widmanstätten arrangement inside the grains. Sometimes they have been nucleated by phosphate crystals, as in this case above. The spindles shown are unusually wide for De Hoek, probably because they have been cut almost parallel to  $(111)_\gamma$ . Etched. Scale bar 100  $\mu$ .





**Figure 2064.** De Hoek (Copenhagen). The edge of a shock-melted troilite nodule. The troilite has remelted part of the adjacent metallic matrix, and a previous schreibersite rim has become shattered and is now dispersed in the melt (angular white fragments). Etched, Oil immersion. Scale bar 20  $\mu$ .

have occurred at 1000-1200° C; if so, the bulk of the material has never existed as an equilibrated melt.

The small grain size, averaging a few centimeters, indicates that the high temperature was not maintained for the long periods that were required to form Cape York and similar meter-sized crystals. The flattened grains suggest that De Hoek on the parent body was exposed to a rather uniform strain that slightly deformed and squeezed the material. The cooling rate was high, estimating from the narrow rims of kamacite around inclusions and in grain boundaries, and from the rarity of homogeneously nucleated kamacite. The supercooled taenite of the grain interiors probably decomposed by a martensitic mechanism and finally some tempering occurred. Much later a cosmic

shock event cold-worked the matrix and melted the troilite inclusions. Virtually no changes took place during the atmospheric flight except in a thin ablated and heat-affected surface layer.

De Hoek is anomalous; it has, however, several structural and chemical characteristics in common with N'Goureyima. Further away stands such an important iron as Tucson. Some of De Hoek's structural features can be recognized in irons of an entirely different composition, e.g. Mundrabilla, Waterville, Elga and Ysleta.

#### REFERENCES

F.W. Schumann (1967): *Meteoriete Gevind op De Hoek*, Distrik Hay, Kaapprovinsie. *Annals of the Geological Survey, Pretoria*, 6:99-101, 2 maps.

Frick & Hammerbeck (1973), see main list of references.

### Etosha, Southwest Africa

Approximately 19°S, 17°E

Anomalous octahedrite.

Anomalous. 6.78% Ni, 0.44% Co, 0.33% P, 49 ppm Ga, 217 ppm Ge, 0.10 ppm Ir.

#### HISTORY

A mass of 110.7 kg was found near the Etosha Game Reserve and about 1970 was presented to the University of Potchefstroom, South Africa, by the Rev. Van Reysen (Frick & Hammerbeck 1973:16). Apparently nothing is known about either the precise location or the circumstances of recovery of the Etosha meteorite.

#### COLLECTIONS

Department of Geology, University of Potchefstroom (main mass), Geological Survey Museum, Pretoria (200 g).

#### DESCRIPTION

The main mass is undescribed. A preliminary examination of hand specimens in Pretoria indicates that Etosha is a weathered find, which has lost the fusion crust. Polished and etched sections show a somewhat anomalous Widmanstätten structure in which unusual intergrowths of schreibersite and cohenite are quite common. By the time of writing no material was available for a thorough study, but it appears that Etosha is an anomalous meteorite which as its nearest relatives may have such irons as Chihuahua City, Santa Rosa, Arispe and Nocolche. It is certainly unrelated to Gibeon.

#### ETOSHA – SELECTED CHEMICAL ANALYSES

References	percentage			ppm					
	Ni	Co	P	C	S	Cr	Ga	Ge	Ir
Frick & Hammerbeck 1973	6.70	0.44	0.33	300	100	100			
Wasson & Scott 1974 (pers. comm.)	6.85						48.9	217	0.10

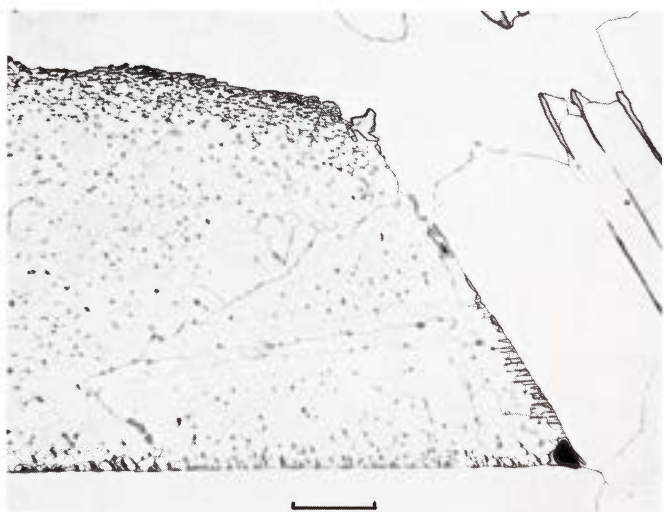


## Gallipoli Station

Examination of a few hundred grams of material, entered into the Tempe Collection in 1973 under the name Gallipoli Station, Australia, led to the conclusion that the material was, in fact, a transported Henbury specimen. The micrographs show typical structures; a chemical analysis by C.B. Moore (personal communication) supported the conclusion.



**Figure 2065.** Henbury (Gallipoli) (Tempe). A degenerate comb plessite field. This type is characteristic of medium octahedrites with less than about 7.5% nickel. Lightly etched. Scale bar 500  $\mu$ .



**Figure 2066.** Henbury (Gallipoli) (Tempe). Another degenerate plessite field with a few schreibersite grains in the grain boundaries. Lightly etched. Scale bar 500  $\mu$ .

## Gibeon, Southwest Africa

Approximately 25°20'S, 18°E; 1000 m

Polycrystalline, twinned, fine octahedrite, Of. Bandwidth 0.30±0.05 mm. Neumann bands. Some samples with annealed, some with cold-worked structures, some with a shock-hardened  $\epsilon$ -structure. HV 170±10, increasing to 300 in shock-hardened parts.

### NEW OBSERVATIONS

Supported by the Carlsberg Foundation and the Technical University, Lyngby, Denmark, the author had in July and August 1974 the opportunity to perform some field work in Southwest Africa. It is my pleasure to acknowledge the support of Mr. Flemming Heilmann, managing director of Metal Box Company Ltd., Johannesburg, and Mr. C.G. Coetzee, director of the Museum at Windhoek, as well as the authorities who were helpful in permitting me to work within the Gibeon, Tses and Berseba Reserves. In the following, some results of the field work and preliminary laboratory investigations are reported. The numbers of the masses refer to the table in the handbook section, page 592.

### NO. 3, BETHANY (WILD)

The mass, of 232 kg, is exhibited in the South African Museum, Cape Town (No. 45), see Figure 2067. Although not mentioned on the museum label, the weight and the dimensions clearly indicate that No. 45 is the Bethany (Wild) mass, already found before 1857. It measures 48 x



**Figure 2067.** Gibeon (Cape Town No. 45). The Wild or Bethany mass. Regmaglypts on the right side and a large bowl-shaped depression in front. Overfolded crests are seen along the bowl. Ruler divided in centimeters.



38 x 30 cm and is well rounded. On one side is a hemispherical cavity, 9 cm deep and 25 x 21 cm across, around which the metal is cold-worked and overfolded, probably from the violent breakup. The regmaglypts are somewhat altered by corrosion, but the overall state of preservation is good. In one place a large sample has been removed, leaving an exposed cut of 18 x 12 cm. In a few other places insignificant slices have been removed. The numerous large specimens in various collections, labeled Bethany, cannot come from this mass but must derive from one or more of the masses No. 4, 7, 9, 10, 14 and 15.

#### NO. 11, BURGSDORF

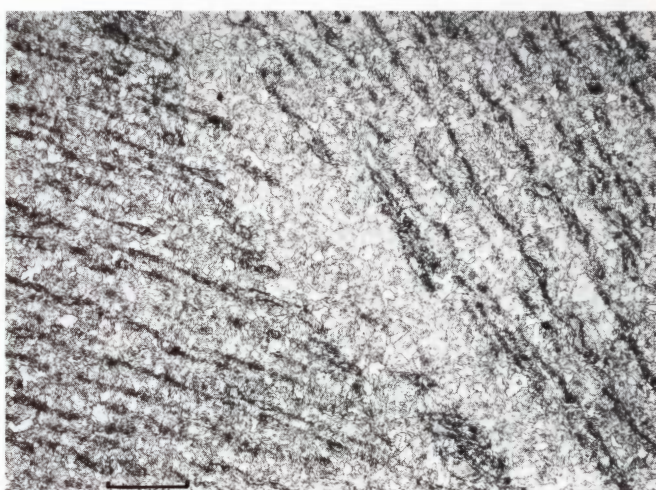
Range (1913) reported a 200 kg mass from Burgsdorf which had been deposited in the Office of the Mining Commissioner, Windhoek. However, on a visit to the Office, I found that the meteorite was lost, or at least unknown to any of the present officers.



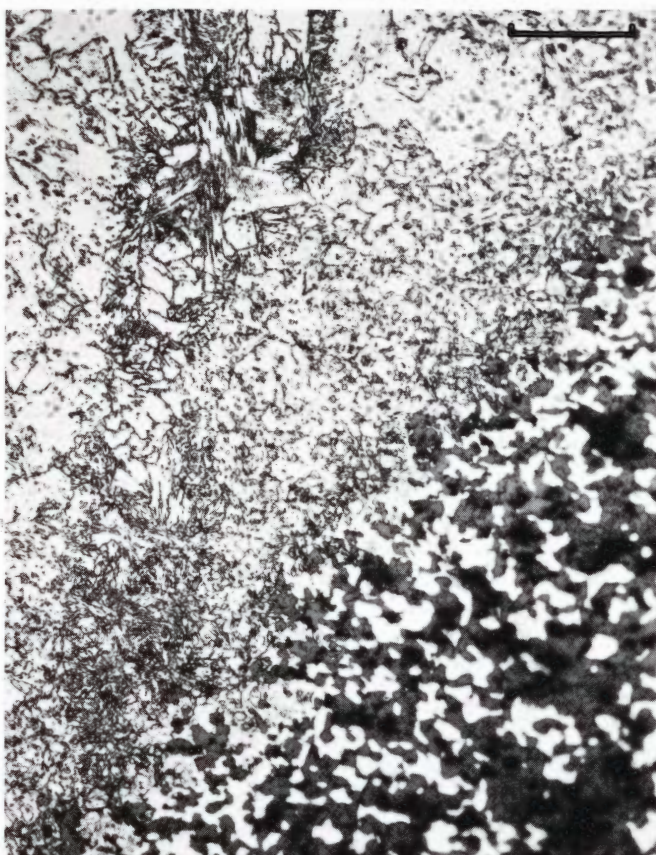
**Figure 2068.** The Windhoek pile in the Verwoerd Public Garden, Southwest Africa. The lower layer of meteorites is partially anchored in concrete. Because of the intricate shape of some specimens and the almost entire lack of records, the number of masses can only be estimated to  $33 \pm 1$ . The author's son, Niels, provides a convenient scale for the size of the pile. Photo August 1974.

#### NOS. 26-58, THE WINDHOEK PILE

In the Verwoerd Public Garden, Windhoek, about 33 iron meteorites are exhibited, without label, but well protected by a grid of iron profiles that little adorn the meteorites. Opinions differ as to how many masses are in the pile. Range (1940) stated that there were 37, while Citron (1967:31) reported 36. From my observations I would say: certainly 32, perhaps 33 and possibly 34, with an average weight of 300-400 kg. In numbering the Gibeon meteorites, I have assumed that the pile presently contains



**Figure 2069.** Gibeon (Kamkas) (Copenhagen 1975.xx). A grain boundary separates two differently oriented parent taenite grains. Both kamacite and taenite are severely thermally altered. Etched. Scale bar 500  $\mu$ .



**Figure 2070.** Gibeon (Kamkas). Edge of a remelted troilite nodule which shows coarse eutectic solidification. Above, a diffuse taenite ribbon between altered kamacite lamellae. Etched. Scale bar 50  $\mu$ .

33 specimens (Nos. 26-58), while I have listed four specimens, initially in the pile (Nos. 59-62), separately, since they have been donated to foreign institutions. Since there are no modern records, and the material has never been examined, I suggested to Mr. Coetzee that the pile be split, weighed, photographed, individuals clearly marked



(with chiseled numbers) and samples removed for examination and verification. The proposal is pending hearings in the magistrate of Windhoek, since by tradition the meteorites apparently belong to the town and not to the museum authorities (Southwest African Nature Conservation, Windhoek; National Monument Council, Cape Town). The city's claim to the meteorites goes back to the confused period of World War I when German Southwest Africa was occupied by British forces and the newly established pile in the Public Garden was secured from private robbery on the initiative of the magistrate.

The meteorites are of widely varying shapes. At least 20 of them exhibit severe surface deformations (faulting, necking and plucking) from the atmospheric breakup. Hemispherical cavities, up to 10 cm across, occur on many masses, and regmaglypts are well developed upon a significant number. The deformations must be rather late, since they usually overlap the regmaglypts; the deformations are generally so severe that it is out of the question that they were caused by human activity. The pile was closely scrutinized for indications of polycrystallinity and silicate inclusions but with negative result.

#### NO. 59, GIBEON

Reed (1969) studied material from this 136 kg mass in the British Museum and found the kamacite homogeneous with 7.2% Ni and 380 ppm P in solid solution.

#### NOS. 60 and 61, GIBEON

These two masses, of 410 and 320 kg, are exhibited in the large hall of the Museum of the Geological Survey (Transvaal Museum) Pretoria.

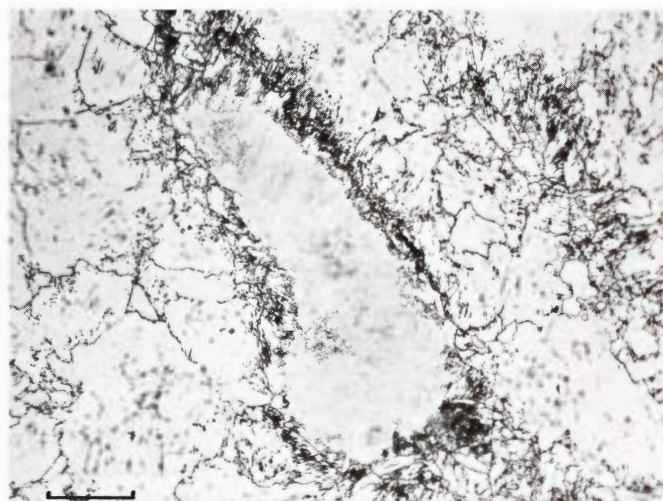
#### NO. 62, GIBEON

This, the largest of all Gibeon masses, weighs 650 kg and is exhibited in the South African Museum, Cape Town (No. 80). It is in the shape of a huge ham, measuring 85 x

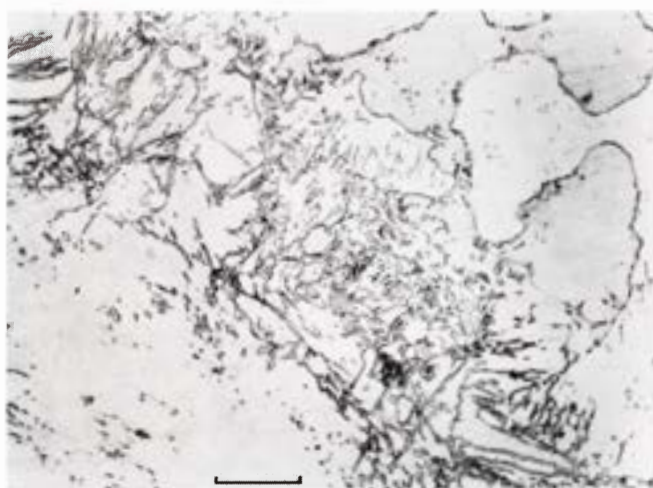
85 x 38 cm in the extreme dimensions. The regmaglypts are 3-4.5 cm across; at one end is a cavity, 8 cm deep and 18 x 11 cm in aperture, around which the metal is overturned and cold-worked. There are no obvious fracture surfaces which might indicate where adjacent masses broke free.

#### NO. 67, KAMKAS

Material from the Kamkas mass was first described by Spencer (1941), who assumed that the mass had been transported from the Gibeon area towards the seaport of Walvis Bay. A detailed description of the microstructure was recently given by Axon & Smith (1970b) who in a noteworthy paper discussed a number of Gibeon specimens in the British Museum. However, with respect to Kamkas, they were unable to reach a conclusion. During the present study I have examined the British Museum material (British Museum 1941.2) and the 1.09 kg fragment in the Geological Survey, Pretoria (No. 2651/23). A polished section that included a boundary between two parent taenite crystals, a troilite aggregate and some corroded surface was prepared; see Figures 2069-2076. At low magnification the Widmanstätten structure is reasonably well defined, but on high magnification all boundaries appear diffuse. The grain boundary itself, originally a normal 0.5 mm wide strip of kamacite, has decomposed to serrated unequilibrium  $\alpha_2$  grains with scattered  $1\mu$  taenite beads. This is the kind of structure – a tempered martensite with 7% nickel – that develops when kamacite is briefly reheated above  $800^\circ\text{C}$  and again cooled. The microhardness is  $175\pm 15$ . On either side of the boundary the previous kamacite and taenite lamellae are thermally altered in a similar way. The taenite and plessite fields have been imperfectly resorbed by diffusion of nickel, but cooling commenced before equilibrium conditions were reached. The fields now have the acicular martensitic morphology characteristic of austenite with 10-20% nickel cooled from temperatures above  $800^\circ\text{C}$ . The microhardness varies from 200 to 370, reflecting the steep nickel gradients in these regions. The troilite has been shock-melted and, in part, squeezed out to

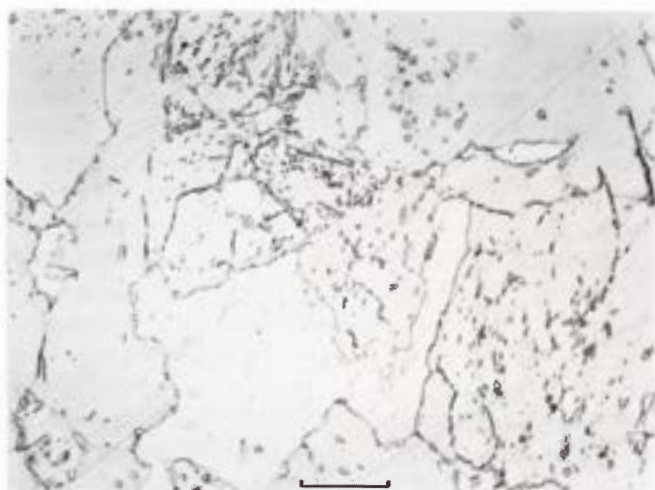


**Figure 2071.** Gibeon (Kamkas). A diffuse taenite body that may have had slightly more carbon in solid solution than the average taenite. It is now martensitic and enveloped in tempered bainitic products. Etched. Scale bar 50  $\mu$ .



**Figure 2072.** Gibeon (Kamkas). The unequilibrium transformation structure of Kamkas is reminiscent of commercial ferritic stainless steels. Etched. Oil immersion. Scale bar 20  $\mu$ .





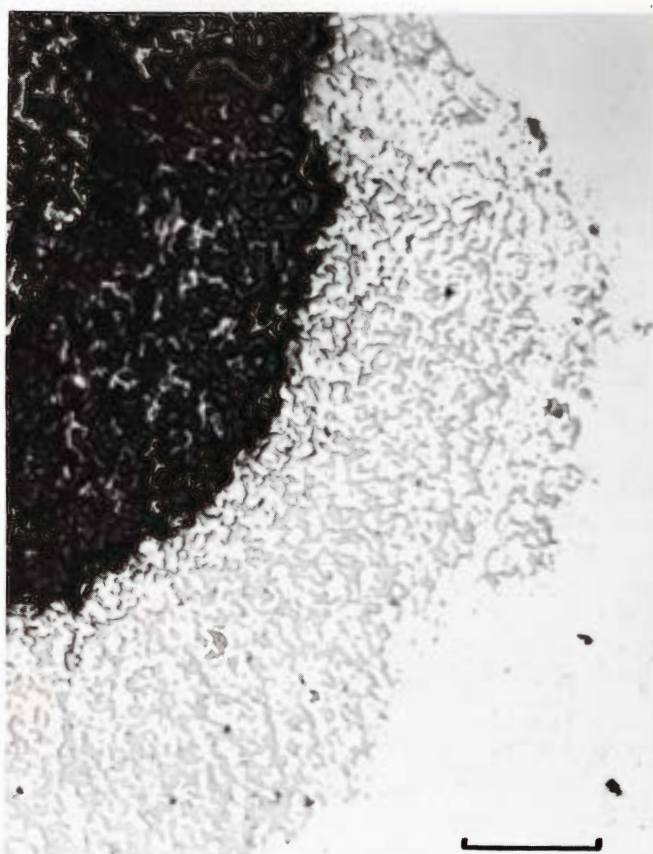
**Figure 2073.** Gibeon (Kamkas). Unequilibrated transformed kamacite with numerous angular to spheroidized taenite precipitates of micron size. Etched. Oil immersion. Scale bar 20  $\mu$ .

laminated mixtures of metal and sulfide in bizarre intergrowths. The metallic component has often been selectively transformed by corrosion, and the troilite has been partially converted to pentlandite. The corrosion products have *not* been thermally altered which serves to prove that the thermal alterations occurred before the mass was exposed to terrestrial corrosion.

The weight of Kamkas is presumably about 150 kg, but its present location is still controversial. However, the London and Pretoria specimens have with certainty been cut from the main mass about 1940. The thermal alterations of this museum material are, as shown above, severe and not caused by human activity. They were probably inflicted upon the material when the kinetic energy of the incoming mass was rapidly and inhomogeneously transformed to heat energy during breakup in the atmosphere. Perhaps the unusual large energy that fell to Kamkas' share also can explain the unusual long deflection from the main strewnfield which made the mass land on the Kamkas farm (No. 20), 150 km west northwest of Gibeon.

#### NO. 68, ENOS

On a visit to the Enos farm (No. 279) I was informed by Mr. Brits, Junior, that the Enos meteorite had been excavated from a dry river bed in 1957 by his father, A.J. Brits, assisted by two others. Only a small portion had protruded above the gravel; it had probably been known before 1957, but it was certainly not removed before, and the Britses maintained that it was found on its primary location, showing no signs of having been transported. In 1957, the meteorite was sold for 10 Rand (about \$12) — the check was, however, a fraud! Brits assumed that the meteorite changed owners a few times and was now in Johannesburg apparently under the name Kinas Putts and in the private possession of a certain A.H.L. Smit. Kinas Putts is the name of a parcel of the Enos farm. The important conclusion is that the mass was in fact found on



**Figure 2074.** Gibeon (Kamkas). Edge of a remelted troilite nodule. The sulfide portion of the coarse eutectic is gray. Corrosion has transformed a part to limonitic products (black). Polished. Scale bar 300  $\mu$ .

this farm which is 225 km southeast of the district where most of the specimens were found. The weight is assumed to have been 193 kg. I have studied a small section, allegedly cut from Enos before it disappeared. It has an unusual altered structure which strongly resembles that of Kamkas as discussed above.

#### NO. 69, KEETMANSHOOP

This meteorite was stolen in 1964 from the Keetmanshoop High School. On my visit to the school, the inspector, Mr. D.P. Coetsee, stated that the police some years later had traced the meteorite to Eastern Transvaal where it had been dumped in a river by four white men who had tried to sell it for, reportedly, 20,000 Rand. The meteorite which is again in the school is a shapeless mass with maximum dimensions of 57 x 35 x 35 cm and a weight of 204 kg. The regmaglypts are 3-5 cm across, and fusion crust can be seen in numerous places, albeit in a slightly weathered form. Locally a cylindrical cavity, 35 mm across and with flat bottom, indicates the location of a troilite nodule lost by ablation during atmospheric flight. There is also severe overfolding and necking from the breakup. In one place a wedge-shaped section has been removed with the aid of a blowtorch. The scar measures 9 x 8 cm, and the section 6 x 5 x 3 cm; this section is now in



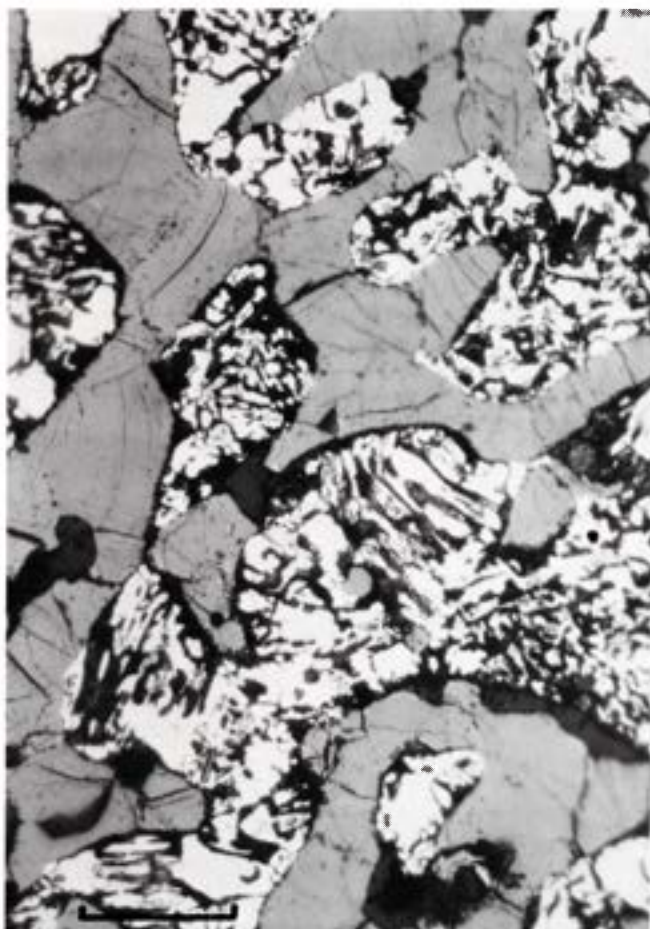


**Figure 2075.** Gibeon (Kamkas). Enlarged part of the eutectic in Figure 2074. White is unequilibrated kamacite, gray in shadings is polycrystalline troilite. Polished. Partly crossed Nicols. Scale bar 50  $\mu$ .

the Smithsonian Institution (No. 2505 of 550 g; cut by Robert Citron 1964). There has not been removed other material from the mass, but there are many heavy chisel marks near the oxy-acetylene cut. A study of the section reveals a structure which, although somewhat influenced by the blowtorch, may be readily compared to that of Kamkas, described above. The hardness (100 g Vickers) is  $185 \pm 10$ , dropping to 140 near the oxy-acetylene cut which annealed the kamacite. The meteorite was not found in Keetmanshoop, but allegedly somewhere along the railway in the Gibeon Reserve; it had been purchased as scrap iron by the garage owner, Mr. Hulmes, for 10¢ (!?) and donated to the high school.

#### NO. 70, DONAS

On a visit to the farm Donas, now Pompie no. 70, the owner, Mr. R.M. de Scande, related the sad story of this mass. It had been known to lie in the bush some 5 km southeast of the farmhouse when, in 1961, de Scande with his father and an older brother excavated it and hauled it to the porch. He was certain that it had been found on its primary location; it was far from any road or path and it was partly buried. Through a lawyer in Keetmanshoop, de Villiers, the family tried to sell the mass, that reportedly weighed 263 kg. However, before it could be sold, in or about 1964, the meteorite was stolen and never again heard of. Mr. de Scande assumed that it had been smuggled out of



**Figure 2076.** Gibeon (Kamkas). Enlarged part of the eutectic in Figure 2074. This view is from a region which is somewhat attacked by terrestrial corrosion. Thereby the structure of the unequilibrated kamacite has been developed by natural etching. No artificial reheating has occurred. Polished. Oil immersion. Scale bar 20  $\mu$ .

Southwest Africa, possibly through Angola, and was now overseas. An examination of a small ear, allegedly cut from the mass in 1964 by R. Citron and now in the Smithsonian Institution (No. 2511 of about 56 g), reveals a normal Gibeon macrostructure with severe cold-working and overfolding. In addition, all structural elements are thermally altered: the kamacite matrix is transformed to serrated  $\alpha_2$  units, 25-50  $\mu$  across, and tiny taenite beads, 0.3-1  $\mu$  in diameter, appear on the subboundaries. The troilite is shock-melted and smeared out along shear zones through the metal. Donas is shock-altered although not to the same degree as, e.g., Kamkas, Enos and Keetmanshoop. The location of discovery is 210 km south southeast of the district where most specimens were found.

#### NO. 71, HUNSRÜCK

This mass, of about 73 kg, was allegedly for a while in the possession of Mr. Byleveld, Keetmanshoop. There are no details available as to discovery, etc., and I could not trace the present location of the meteorite. A 34 g sample was in 1964 hacksawed from the mass by Robert Citron and donated to the Smithsonian Institution (No. 2512,



3.5 x 2 x 1.5 cm). It has a normal Gibeon structure and shows a well-preserved heat-affected  $\alpha_2$  zone. Severe necking and distortions overlap the primary structures, but the thermal alterations are small.

#### NO. 72, LICHTENFELS

This beautiful meteorite of 350 kg is shown in Figure 781A. It was allegedly discovered in 1963 in a dry river bed by a search party that applied an electronic mine detector. Another mass, of several hundred kilograms, is still said to be on the farm. The 350 kg mass was in 1970 purchased by the Max-Planck-Institut, Heidelberg, where it is presently exhibited. It has the most perfect regmaglypts of any Gibeon specimen, and the fusion crust is well-preserved, albeit slightly tarnished in brownish colors. There is at least one hemispherical cavity, 9 cm deep and 15 x 13 cm in aperture, and there is a 2 cm deep cylindrical hole, 3 cm across, from a burned out troilite nodule. The maximum dimensions of the mass are 89 x 44 x 36 cm and there seems to be only one cut surface of 7 x 7 cm. Part of the cut material is in the Smithsonian Institution (No. 2508, 3.3 x 1 x 1 cm). The polished section shows a normal Gibeon structure with a 1-2.5 mm thick heat-affected  $\alpha_2$  zone. The primary structure is almost unaffected by thermal annealing and the microhardness is  $169 \pm 9$ , increasing to the normal values of  $196 \pm 8$  in the  $\alpha_2$  zone (hardness curve type II). The black taenite is  $215 \pm 15$  in hardness.

#### NO. 73, HARUCHAS

This 38 kg mass was reportedly found by C. Berger about 1900 on the farm Haruchas (No. 156). The son and present owner, C.E. Berger, is a mineral collector and presumably still owns the mass. Unfortunately, I could not meet him, since he was away on business; it appears, however, that the location of discovery is not well founded. The family Berger lived for a long period about the time of World War I in the Berseba district, much closer to the Gibeon specimens, and it is possible that the Haruchas mass was found there and only acquired its name later when the family moved to the Haruchas farm. A 6 g sample in the Smithsonian Institution (No. 2510, 2 x 1 x 1 cm) shows a normal Gibeon structure with a 0.5-1.2 mm wide heat-affected  $\alpha_2$  zone. Severe cold-working and necking characterize the cut section, and there is little evidence of annealed structures. The hardness is correspondingly high,  $210 \pm 10$ ; it increases to above 300 in the most cold-worked areas. All deformations are genuine and can be referred to the breakup in the atmosphere.

#### NO. 74, GIBEON

According to Mr. C.G. Coetzee, the Windhoek Museum, this meteorite, of about 35 kg, was reported to the museum in 1959 when a certain garage owner in Windhoek died and left his estate. The meteorite had been in the family for many years and had served as an anvil. There were no particulars as to location or date of discovery, and,



**Figure 2077.** Gibeon (Railway A) (Pretoria). A violently deformed fragment of the Gibeon shower. Twisted, necked and over-folded structures. Ruler in centimeters.

unfortunately, in 1974 the mass could not be located in the museum.

#### NO. 77, RAILWAY (A)

According to the accession papers of the South African Railway Museum, Johannesburg, this — and possibly the following mass No. 78 — was found near the main railway line Keetmanshoop-Mariental, i.e., in the Gibeon or Berseba district. It was allegedly seen to fall by railway personnel on the train, so on the return journey they stopped, searched near the line and excavated the meteorite from a hole almost two feet deep. It weighed 47 kg and was in 1943 donated to the S. A. Railway Museum by Mr. G.H. Dawson, then the system manager of Windhoek. About 1965 (?) it was donated to the Geological Survey Museum, Pretoria, where it has now been divided for research purposes. The sections go through some of the hemispherical cavities which are so typical of Gibeon specimens, and also display the severely twisted, bent and overfolded textures very well; compare, e.g. Figures 781B and 2077. The report that the 47 kg mass was seen to fall can not be accepted. The railway personnel may have seen a fireball and by coincidence on their searching stumbled over the meteorite — or else, the entire story may be invented, as has repeatedly been met with in meteoritics.

#### NO. 78, RAILWAY (B)

In the South African Railway Museum, Johannesburg, there is presently (1974) displayed another Gibeon meteorite, originally of 71 kg, and recovered from near the railway line under similar circumstances as Railway (A), No. 77. The mass is roughly ellipsoidal, with dimensions of 32 x 26 x 24 cm and has the museum number 2042. At the slightly pointed end two portions have been removed by a blowtorch and one with a hacksaw, so that the mass now weighs about 66 kg. Apparently no portions have been made accessible for analysis or metallographic examination.



**NO. 79, GARIN AIS**

According to the accession papers in the East London Museum, in 1934 a mass of 31.75 kg was dug out from a depth of 1.5 m during repair work to a dam on the farm Garin AIS (No. 30). The owner of farm Karris, Mr. E. Luchtenstein, donated the meteorite to the East London Museum in 1943. The farms Garin AIS and Karris are "small" farms, parcelled out from the big Lochkolk farm, with the coordinates 26°30'S, 19°30'E. The location is 50 km north of the farms Donas and Enos, so if a scientific examination can confirm the Gibeon nature, we have another good fixpoint in the southeastern end of the strewnfield. The mass is shaped as a small human head covered by a beret. It measures 20 x 18 x 18 cm, and the somewhat weathered regmaglypts are 15-25 mm across. In 1969, Siegfried Haag had 5 kg sawed from the mass and transferred to the Max-Planck-Institut in Heidelberg. No results of the investigations are available.

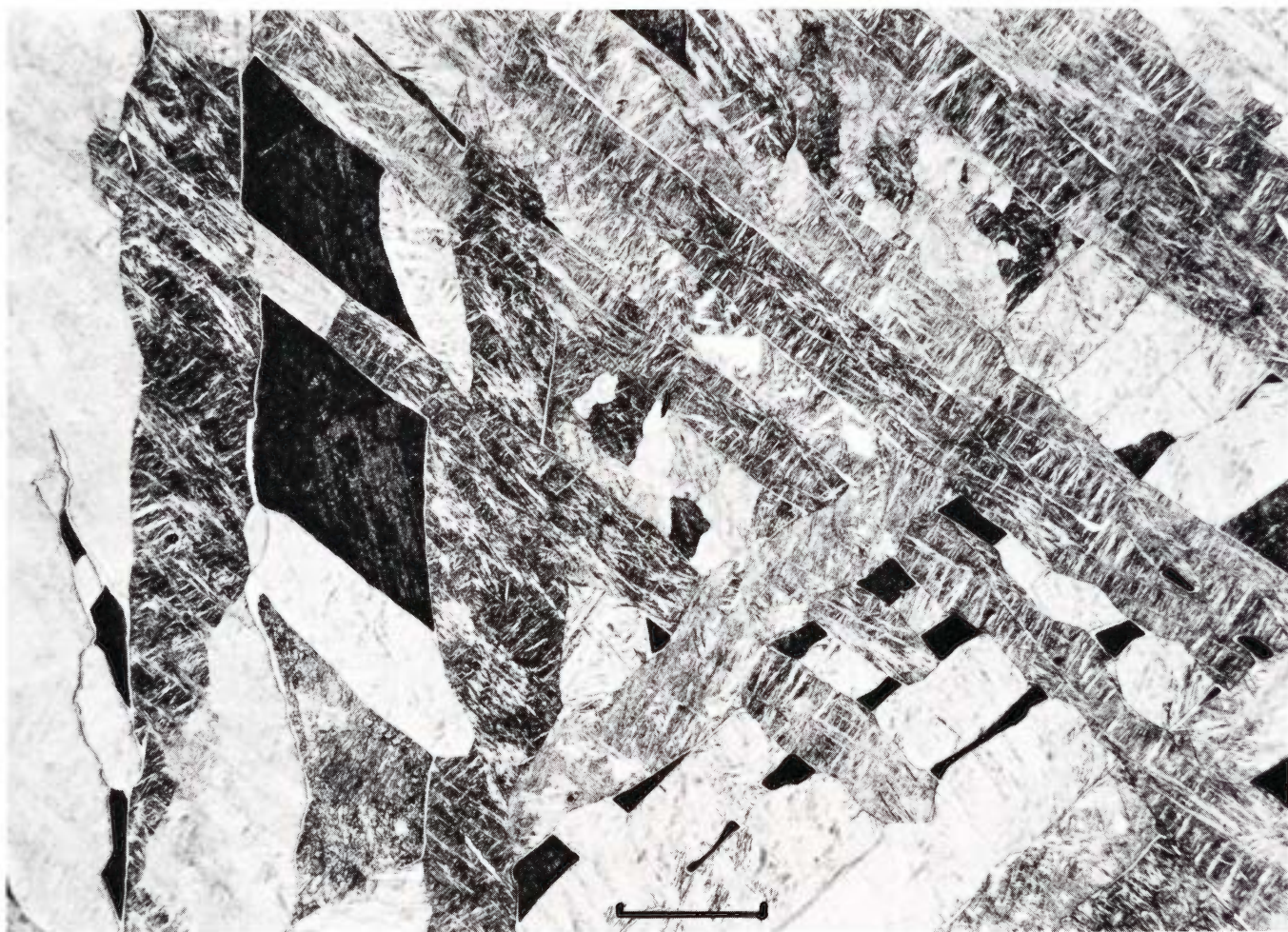
**NO. 80, PUBLIC LIBRARY**

There is in the Geological Museum, Public Library, Johannesburg, an 11.5 kg meteorite from the Gibeon district entered as No. 63/1337. According to the curator, Mr. R. Townsend, the meteorite was acquired by the

previous curator, Mrs. Blignaut, probably at the same time as the Karasburg meteorite, i.e., about 1960. No further information was available, except that Robert Citron allegedly sent a 9 x 8 cm section to the Smithsonian Institution for investigation about 1967. No report has, however, been published. The meteorite measures 19 x 14 x 11 cm and the regmaglypts are 2-4 cm across. There is no conspicuous cold-working or overfolding, but the macrostructure (as visible on the exposed deep-etched section) is clearly that of a Gibeon specimen, with 0.3 mm bandwidth and scattered millimeter-sized troilite inclusions. The heat-affected  $\alpha_2$  zone is partly preserved, partly lost to corrosion. While all specimens, Nos. 73-80, weigh less than 100 kg, the Public Library mass with 11.5 kg, is the smallest mass reported, except for No. 66 of 0.2 kg. The histogram in Figure 780 will have to be redrawn.

**NO. 81, GANIGOBIS**

Encouraged by Mr. C.G. Coetzee, Windhoek, the author went to the west to visit Commissioner F.R. Balt, in the Otjimbingwe Reserve; he turned out to have had a long experience with the Gibeon meteorites from his life in Berseba. He had himself, in 1964, excavated a 654-pound (296 kg) mass in the dry bed of the Fish River. The



**Figure 2078.** Gibeon (Ganigobis) (Copenhagen 1975.xx). Shock hatched  $\epsilon$ -structure with marked contrasts between adjacent grains. The Ganigobis is so far the only Gibeon fragment in which shock-hardened  $\epsilon$  occurs. Etched.



location was near the spring Ganigobis, i.e., 15 km northwest of the railway station Tses. Assisted by some colored men and a 3-ton truck, he hauled the mass to Berseba, and later it followed him to Otjimbingwe. Several parties from the United States and Germany had offered him 10,000 to 15,000 Rand and had counted upon illicit transport out of Southwest Africa through either Walvis Bay or Angola. The mass is roughly pyramidal with dimensions of 56 x 41 x 38 cm, corresponding well to the weight above, obtained on a farmer's scales. The regmaglypts, not very conspicuous, measure 3-5 cm across, and there are two hemispherical cavities, 14 x 14 and 10 x 9 cm across, respectively. From one end several parallel cuts have removed a total of about 5 kg. A portion has been assayed by the Standard Bank (7.80% Ni, 5.6 ppm Pt, according to the certificate), other portions have been given away as curios. I was presented a slice of 250 g, representing the exterior as well as the interior of the mass. Microscopic examinations reveal a normal bandwidth of 0.3 mm, but instead of Neumann bands or soft, annealed structures, Ganigobis is extremely shock-hardened. The kamacite is of the shock-hatched  $\epsilon$ -variety with a hardness of  $280 \pm 20$ .



**Figure 2079.** Gibeon (Ganigobis). The hatched  $\epsilon$ -structure is shock-hardened to a Vickers hardness of  $280 \pm 20$  (100 g load). The high hardness is the combined effect of a high dislocation density and an extreme subdivision of the originally homogeneous kamacite crystal. Etched, Oil immersion. Scale bar 20  $\mu$ .

#### SOME REMARKS

The number of recovered Gibeon meteorites has by now increased to 81, totaling about 21,400 kg, and the author is convinced that many more masses are still waiting to be discovered or have already been found but are being

withheld from the public eye in the hope of economic profit. The district has, unfortunately for the research worker, recently changed its status. By Government decree, effective 1967, the Gibeon, Tses and Berseba Reserves have been extended and all white property has been expropriated. Instead, colored people, particularly from the Karasburg area, have been encouraged to move in as a part of the government's apartheid policy. This means that continuity is broken, and all records of previous finds and locations have disappeared, since the white farmers have moved in all directions, sometimes as far away as South Africa. The new inhabitants have for the time being no understanding or interest in the meteorites, as witnessed by the numerous colored farmers whom I interviewed in July and August of 1974. However, encouraged by rewards from Museum people at Windhoek, it might be possible to have new finds reported.

The Brukkaros Crater which from time to time has been associated with the Gibeon meteorites has now been definitely proven to be of terrestrial origin. Ferguson et al. (1974) have minutely described the Brukkaros crater and samples from here and the vicinity. They conclude that it is an ancient kimberlite-carbonatite volcano.

#### CONCLUSION

The present study has extended our knowledge as to number, size, locations and structure of the Gibeon masses. The locations of Donas, Enos and probably Garinai, show unambiguously that the shower covered a huge and broad ellipse with the 275 km long main axis trending N 35° W and the broad axis being on the order of 100 km. The severely faulted, overfolded and necked textures suggest a violent breakup in the high atmosphere, and the well-preserved regmaglypts on many specimens show that the individual fragments thereafter had a long flight with part of the cosmic velocity preserved. The extremely long axis of the dispersion ellipse suggests that the angle of approach, Figure 13, was small, on the order of 10-20°. It may also cautiously be concluded that the mass came from southeast and that the bulk of the material landed in the north-western end, just south of Gibeon, while fragments scattered all over the dispersion ellipse. The Kamkas individual apparently landed 150 km west northwest of the dispersion ellipse, and the Burgsdorf mass possibly 100 km west of it. The thermally altered structures of Keetmanshoop, Donas, Enos, Kamkas and others, indicate that the breakup was of a very violent character, with kinetic energy being transformed into heat energy inside the masses. Some masses escaped reheating but were extremely hardened by cold-working; one, Ganigobis, even acquired a shock-hardened  $\epsilon$ -structure.

Perhaps the parent mass, before it was decelerated by our atmosphere, was an irregular chunky plate with dimensions of the order of 4 x 4 x 1.5 meters. Such a thing would probably be able to coast somewhat in the atmosphere and would then break up along troilite-filled grain boundaries and along any preexisting cracks from previous



collisions in space. The end result would be a number of fragments, mainly comprising entire parent taenite grains, but occasionally showing smaller fragments, or masses composed of a number of grains. Although searched for, no conspicuous silicate minerals were disclosed.

#### FURTHER WORK

It is recommended that the pile in Windhoek be thoroughly examined so that we may fully learn the variety of thermal and shock-induced alterations in the material. The verification that all members of the pile *are* in fact Gibeon specimens is also required.

In the author's opinion, it would be very interesting to examine and possibly calculate how and when the breakup occurred. Nothing like the Gibeon strewnfield or the Gibeon variation in microstructure has been reported from any stone or iron meteorite — except from the crater-forming Canyon Diablo iron — so the mechanism of breakup must have been rather peculiar to Gibeon. It would further be of interest to solve the problem of the hemispherical cavities, which are almost a hallmark of Gibeon but are known to occur on other iron meteorites, too.

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#### Guadalupe County, Texas, U.S.A.

Approximately 29°30'N, 98°W

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A small specimen of 20½ g was listed by Nininger & Nininger (1950) as being in their collection. They assumed that it was a transported Canyon Diablo sample, and Hey (1966:185) supported this and listed the material *doubtful*.

However, a cursory examination of the specimen, an endpiece now in the Tempe Collection (No. 521.1, 27 x 19 x 8 mm), reveals that this can hardly be the case. It is a medium octahedrite with a bandwidth of 1.2±0.3 mm, and the kamacite is of the shock-hardened hatched  $\epsilon$ -variety with marked contrasts between adjacent grains. There is 5-10% taenite and plessite, and the schreibersite crystals are in many places arranged in garlands of tiny grains just outside the taenite and plessite fields.

The material is corroded, but no more than the heat-affected  $\alpha_2$  zone is preserved along a significant part of the periphery.

Guadalupe County is apparently an endpiece of a larger mass of which we have no record. A thorough examination is evidently needed. The remote possibility that it has been cut from the 6.8 kg Sanderson mass, also from Texas, should be considered.

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#### Imilac, Antofagasta, Chile

24°12.2'S, 68°48.4'W

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Pallasite. About 50 vol.% subangular olivine crystals in metal. Neumann bands. HV 160-295.

Pallasite. 9.8% Ni, 0.7% Co, 0.3% P, 22 ppm Ga, 47 ppm Ge, 0.07 ppm Ir.

An unusually large number of fragments from this shower have circulated under separate names. Many are still mislabeled in numerous collections: particularly as Ilimaes (pallasite), Gran Chaco, Del Parque, Calderilla, Potosi and Atacama. Further: Antofagasta, Campo del Pucará, Caracoles, Catamarca, La Encantada, La Rioja, Peine, San Pedro, Toconao, and, possibly, Salta and Ollague.

#### HISTORY

In 1828 a mass of 9.265 g (B.M. 90239) was presented to the British Museum and another of 1.8 kg was given to the Royal Scottish Museum in Edinburgh (Allan 1828; Hey 1966). The masses had been acquired for the museums by the British Consul-General at Buenos Aires from an Indian who had traveled from the Atacama Desert across the Andes Mountains to sell the specimens in the capital of Argentina. The precise locality was only given in very loose terms, but it was stated that there existed numerous other fragments in the place and that several had been collected into a heap, estimated to weigh about three quintals (i.e., about 140 kg).

In the second quarter of the nineteenth century many of these fragments were carried in small portions by Indians to Peruvian, Bolivian, Chilean and Argentinean coast towns from where they were slowly spread to a surprisingly large number of public museums and private collectors. See, for instance, the list in Buchner (1863: 127). Therefore, many examinations and descriptions appeared in these years, most valuable probably being those by Turner (1828), Partsch (1843) and Bunsen & Bronn (1857).

Bollaert (1851) in traveling through the Atacama Desert tried to pinpoint the finding place but in vain. Philippi (1855; 1856), at that time a professor in Santiago, was commissioned by the Chilean government to explore the Atacama Desert and make extensive reports on his geographical, botanical and geological observations. He happened to meet the original finder of the meteoric iron, José Maria Chaile, who guided him to the place in January 1854. Chaile had found the first samples about 1820 while hunting guanacos. Since he supposed them to be silver or silver ore, he removed two pieces, estimated to weigh 60-75 kg each, and buried them safely in the vicinity of the watering place Pajonal, 20 km southeast of the finding place. Later these specimens could not be found by Chaile, and it is uncertain whether they have ever been recovered.

Philippi found 673 small fragments, ranging in weight from less than 0.1 g to 60 g, and totaling slightly less than 1.5 kg. He estimated that his two companions collected a similar amount. A total of 4.5 kg was thus collected by three persons within a few hours. Philippi found no large masses and also stated that the field was now, after his visit, entirely deprived of meteoritic fragments. Many fragments had evidently already been collected by the natives who used the site as a veritable iron mine and had forged various items from the metal.

Philippi noted at one end of the small strewnfield a hole, about 6 m deep. According to Chaile and others (e.g.,