minerals prove unambiguously that the object that caused the Monturaqui crater was an iron meteorite. However, the long, probably more than 100,000 years of exposure to a terrestrial climate — which previously may have been slightly more wet, judging from the prominent erosion in the area — has almost entirely devoured the little material that survived the crater-forming impact.

Figure 2109. Monturaqui (Copenhagen). Other fragments are of the breadcrust type. When the octahedral and breadcrust-shaped fragments disintegrate, smaller laminated fragments are produced. Weight 49.6 g, specific gravity 3.60. Scale bar 10 mm.

In an attempt to classify the weathered remnants of what seems to have been slugs and distorted specimens similar to those described from, e.g., Henbury and Canyon Diablo, we will have to rely on the few discernible, but important details: the cohenite, the high-nickel, high-carbon morphology of the martensite inside some plessite fields, and the bandwidth of about 2 mm. These structural elements all point to a coarse octahedrite of the resolved chemical group I, possibly with about 7% Ni and 0.25% P, and closely related to the Canyon Diablo object that formed Meteor Crater, Arizona. Being familiar with Canyon Diablo specimens, one might perhaps expect that graphite, troilitie and silicate should also be present in the Monturaqui samples. It should, however, be remembered that these components are very rarely seen in the small Canyon Diablo slugs, probably because the fracturing followed the minerals, so that they were preferentially lost during the breakup.

In conclusion, it can be stated that (i) the Monturaqui crater is definitely proven to be of meteoritic origin, with the present dimensions 360 x 380 x 34 m; (ii) the impact probably occurred more than 100,000 years ago; (iii) the impacting object probably was a coarse octahedrite of group I related to Canyon Diablo; and (iv) the high terrestrial age and a previously more wet climate, combined with the nitrates and chlorides of the region, sufficed to transform virtually all metallic material to limonite.

In Table 18, Chapter Four, several meteorite craters were discussed. We may now add more precise data on Monturaqui, the most important piece being that of the classification as a coarse octahedrite of group I. Out of ten established craters with surviving meteoritic debris, four thus belong to group III (Wabar, Henbury, Boxhole and Wolf Creek) and four to group I (Canyon Diablo, Odesa, Monturaqui and Kaalijärvi), confirming the previous conclusion that these two iron meteorite classes are by far the most important types.

Mount Sir Charles, Australia

Preliminary information indicates that this new meteorite belongs to group I and has the following composition: 6.8% Ni, 90 ppm Ga and 394 ppm Ge (Wasson 1974).

Nutwood Downs, Australia

In the 1970s several small twisted and ear-shaped slugs, of 25 to 100 g weight, have been offered for sale by various dealers, e.g., David New, under the name Nutwood Downs. Analytical data were presented by Scott et al. (1973) who found 7.66% Ni, 18.5 ppm Ga, 35.2 ppm Ge and 11 ppm Ir. The morphology, structure and composition clearly indicate that the Nutwood Downs material must be transported fragments from the central Australian crater fields, most probably Henbury.

The same is equally true of the older Nuleri material, briefly treated in the handbook, which in a new analysis (Wasson 1974) shows: 7.44% Ni, 18.0 ppm Ga, 36.7 ppm Ge and 9.3 ppm Ir.

Otasawian, Alberta, Canada

Coarse octahedrite, Og. Bandwidth 2.0±0.3 mm. Neumann bands. HV 180±10.

Group I. About 7.0% Ni, 0.25% P.

It is concluded below that Otasawian is a transported Canyon Diablo mass.

HISTORY

Meteorite fragments totaling 8.7 kg were briefly mentioned by Baldanza et al. (1969) and by Baldanza & Pialli (1969). The authors, who presented photomacrographs and photomicrographs and discussed the mechanical deformation, assumed that Otasawian was an independent fall, discovered near Otasawian in Alberta, Canada.

When I had had the opportunity to examine significant parts of the material, it occurred to me that the macro- and microstructure, see below, is remarkably similar to Canyon Diablo masses of shock-transformation stage I. In August 1973, Dr. Baldanza kindly gave me the following details which had not been included in the above mentioned papers.

On a visit to Arizona in the sixties, Dr. Baldanza had stopped at a curio shop near Meteor Crater. The proprietor was the proud owner of a meteorite which he maintained had been found by his father near Otasawian in 1907. When the family moved to Arizona
they also brought the meteorite. Baldanza estimated the entire mass to weigh 18-20 kg; he and the owner had it cut in a nearby garage and Baldanza purchased about half of it and brought it to Italy, where it was further divided and examined.

With this new piece of information and with the structural results below, there is only one conclusion possible. Otasawian is a 20 kg transported Canyon Diablo mass which by a deliberate fraud was sold as an independent meteorite and was given a fictitious place of discovery.

COLLECTIONS
Perugia (about 7 kg), Copenhagen (600 g).

ANALYSIS
Unanalyzed but no doubt the same composition as typical Canyon Diablo masses.

DESCRIPTION
The 20 kg mass is undescribed. The fragments cut from it show that it is weathered and provided with the sculptural details that are common to Canyon Diablo masses that have been slightly buried. The fusion crust and the heat-affected α₂ zone are lost, and it is estimated that on the average more than 3 mm has been lost to corrosion. Fine fissures penetrate the samples. The fissures usually follow schreibersite precipitates in grain boundaries; the schreibersite is brecciated and individual fragments have been free to rotate before they again were recemented by terrestrial corrosion.

Etched sections reveal a coarse Widmanstätten structure of straight, bulky (La 10) kamacite lamellae with a width of 2.0±0.3 mm. The kamacite has subboundaries decorated with 1-2 μ rhabdites, and it is rich in well defined Neumann bands. The hardness is 180±10.

Taenite and plessite cover less than 2% by area; comb and acicular plessite are common, but spheroidized fields with 2-10 μ taenite globules and pearlitic fields with 1 μ wide taenite lamellae are also abundant.

Schreibersite and cohenite occur as millimeter-sized bodies and also as irregular rims around the troilite-graphite nodules. These are 15-25 mm across and display intricate intergrowths of fan-shaped graphite lamellae and (mainly) monocristalline troilite. No shock melting has occurred. The graphite shows cliftonitic development in many places; particularly good crystals, 0.2-0.3 mm in size, are to be found in the complex transition zones between troilite, cohenite and schreibersite. The cohenite itself has not started decomposition to graphite.

The structural elements discussed above are locally sheared and displaced 30-100 μ relative to each other. The larger schreibersite and troilite crystals are brecciated, and chips often break free during cutting and polishing operations in the laboratory. This development is common to shocked Canyon Diablo masses. The black dots, called nodules or graphite nodules, in the photomicrographs presented by Baldanza & Pialli (1969:Figures 1, 2 and 6), are not structural components but mainly grooves and defects caused by imperfect polishing.

Otasawian corresponds in all details to the masses that have been collected on the plain around Meteor Crater. It may be assumed to be a fragment that separated from the huge Canyon Diablo mass in the high atmosphere and thus had an independent long flight before it hit the ground. It did not participate in the cratering impact.

Paneth’s Iron
Unknown Coordinates

Coarse octahedrite, Oq. Bandwidth 1.5±0.3 mm. Neumann bands. HV 160±15.
Group IIIE. About 8.9% Ni and 0.3% P. 17 ppm Ga, 34 ppm Ge, 0.37 ppm Ir.
Originally listed as a Toluca sample, it is here shown to be an independent iron, possibly of over 100 kg, and related to Burlington and Staunton.

Figure 2110, Paneth’s Iron. To the left, the 26.1 kg slice in British Museum (No. 47192), to the right, the 15.2 kg endpiece in the Institute of Geological Survey, London. Ruler in cm.
HISTORY

During work on the present handbook the author was puzzled by two large, polished and etched samples, labeled Toluca. From previous examination of a number of Toluca samples, it appeared to me that these two were drastically different in structure; nevertheless, one had long been considered a prize specimen of Toluca (British Museum 47192, of 26.1 kg), and had been used a number of times for analytical purposes, e.g., by Paneth and his co-workers (Chackett et al. 1953). The other was an endpiece of 13.18 kg in the Max-Planck-Institut für Chemie, Mainz (No. Pa 103/13), which judging from the many cut and hack-sawed irregularities had lost about 800 g; it had evidently also been used for analytical purposes, the results having been presented as Toluca analyses, e.g., in the paper by Chackett et al. (1953).

Thorough microscopic study of small samples, put at my disposal by Dr. R. Hutchison and Dr. H. Wänke, confirmed that the material was different from Toluca. The samples were those of a coarse octahedrite of group IIIE related to Burlington, Rhine Villa and Staunton, and entirely different from genuine Toluca samples, which belong to group I. However, the kamacite bandwidths of Toluca and the new material were approximately the same, which may partly explain the mislabeling.

The material and the complex history has been described elsewhere by Buchwald et al. (1975). Because the provenance of this iron is unknown, it is here proposed that it be named “Paneth’s Iron” to honor one of its investigators.

In the following we shall try and follow the few leads that can be found in the archives and the literature.

A. The 13.18 kg endpiece in Mainz (No. Pa 103/13), measuring 29.5 x 24 x 4.5 cm. This piece was originally in the Calvert Collection in England. John Frederick Calvert (1811-1897) was a mineral collector and dealer, who, judging from various remarks in contemporary letters, was held in little esteem by his colleagues. He must have been quite an eccentric autodidact since he claimed that he “discovered in combination with other substances, one after the other, Purilium, Aozone, and Zoine” and also found “a new gold, whose specific gravity is greater than any of our at present known golds, and whose salts are totally different, and which I have called colidium.” In the preface to “Meteoric Papers” (London 1895) he mentions two iron meteorites, “a rather large metallic iron . . . . from Africa, which showed a crack nearly across the middle” and “a meteoric iron I discovered through the grove (sic!) it had cut before burying itself, and which I dug out of a peat bog on Dartmoor [Southwest England], weighing 320 lbs. [146 kg], on being cut also exhibited a crack.” In the same publication is a full page lithograph of a deep-etched slice of a coarse octahedrite with a crack extending from the surface across the center of the slice. The figure caption reads “Fell in Apla Forest, Brazil, in the year 1873. Weight, 632 lbs [285 kg].”

In “Particulars of the Calvert Museum” (London, 1905) we read on page 44, “The slab of iron, about a foot in diameter, placed on a very solid table, is a fourth section of a meteorite or ‘thunderbolt’ which fell on Dartmoor, and of which the School of Mines and British Museum also possess parts.” An accompanying small figure of a full,
etched surface clearly shows that this slab is identical to the one discussed here as A and presently in Mainz.

After Calvert's death the slab remained for an unknown period in his collection, but some time after 1928 (possibly in the 1930s) it was purchased, with other minerals from the collection, by the dealer Martin Ehrmann, who took it to New York and later to Los Angeles. In December 1948, the slab was purchased through Dr. E.P. Henderson, by Professor F.A. Paneth, then at the University of Durham, England, and Paneth immediately started gas analytical work on it, and published several results (Chackett et al. 1953). Helped by a correspondence with Dr. Max Hey, British Museum, Paneth established that "Calvert's Iron"—which evidently by this time had no better label—was a parallel slice to No. 47192 in the British Museum, and since this was labeled Toluca, it was decided that "Calvert's Iron" was also a Toluca specimen. In the said publication there are two photomacrophographs of the entire sections.

When Paneth returned to Germany in 1953 and became director of the Max-Planck-Institut in Mainz, his meteorite collection followed him; it is now under the custody of Dr. H. Wänke. For an obituary of Paneth, see Wänke (1959).

B. British Museum No. 47192: an almost entire slice (see figure in Chackett et al. 1953) weighing 26.1 kg and measuring 30 x 29 x 4 cm. According to the records of the British Museum, this slab labeled Toluca was bought from the mineral dealer Houseus of Basle in 1873. However, the original records and labels no longer exist. This is an intriguing error or omission, for Dr. Lazarus Fletcher, then the keeper of minerals, was of a standard rarely met with and his notes and entries were very dependable. All that can be found, relating to the said specimen is the following entry, made fifty years later: "No. 47192. Weight about 80 lbs. [80 lbs. entered in pencil]. Entry omitted at time of purchase." It appears that during the 1920s an effort was made to register all the specimens that had been in the department for a considerable time and had not at that time been registered.

It appears that only little has been removed from this beautiful slice, until on the present occasion small samples were taken for microstructural and analytical purposes. Wasson (1974, personal communication) reported: 8.98% Ni, 16.9 ppm Ga, 34.1 ppm Ge and 0.37 ppm Ir. This analysis has also been published by Wasson (1974:305) under the name "pseudo Toluca." It is possible that the controversial "Toluca" analysis by Smales et al. (1967) was also performed on a small (8.9 g) sample of this material; it was, unfortunately, at the time of analysis without a number of identification, but the trace element results suggest that Smales' analysis relates to Paneth's Iron.

C. The 15.2 kg endpiece in the Institute of Geological Science, London (no number; measuring 29 x 25 x 4 cm). This piece was identified by Dr. Hutchison during the present investigation. It is cut parallel to the other two specimens, as indicated by the orientation of the Widmanstätten structure on the etched section. Common to all three specimens are the traces of rough circular marks, which show that the pieces were machined on the same lathe; the distance from the center of these circles to a straight cut—which is also common to all sections—is in all cases 14 cm. In the most recent time renewed finishing and polishing have removed part of the old rough grooves; however, the central conical holes that secured the samples on the lathe are still visible.

The Institute of Geological Survey obtained its endpiece in the 1870s as a donation from a Mrs. Warne, who was probably related to a J.P. Warne who is said to have had an extensive collection of gems from Brazil and which Calvert acquired.

D. The three samples A, B and C are parallel sections through one and the same mass. When one tries to reconstruct the original mass, however, it becomes evident that much material is missing. From each slab a part has been cut off in a plane perpendicular to the large surfaces. It appears further that at least one central slice of perhaps 25-35 kg must be fitted in in order to complete the mass. Further, that one endpiece, capping the others across their parallel cut sides, is missing (5-10 kg?). Or, perhaps that this "hat" has been removed as shavings or in another way in order for the rather large meteorite to fit into the lathe. Many kilograms have certainly been wasted in the cutting operations; compare also the sketch of reconstruction in Buchwald et al. (1975).

DISCUSSION

If we take Calvert's notes (A, above) at face value, he was once in possession of three large iron meteorites, one from Africa, one from Brazil, and one which he himself discovered on Dartmoor. However, as suggested above, Calvert was not known for his integrity. It rather appears that Calvert some time about 1870 acquired one entire or
almost entire mass, possibly weighing between 100 and 150 kg. It may of course have come from one of the postulated locations, but it appears unlikely. Its exterior corroded and artificially worked surface rather suggests an origin in the United States or Mexico.

Calvert let the mass be cut in or about 1872 and later published three different stories. Common to the brief accounts are the figures given and the presence of deep cracks. By comparison of figures with existing slices, it is clear that the figures are of adjacent slices, in each of which is the same prominent crack.

In “Particulars of the Calvert Museum” (London, 1905:44) it was noted that the present Mainz specimen was the “fourth section of a meteorite.” This may be interpreted to mean that this endpiece was number four out of four sections, and that this last piece was retained for the Calvert collection. If this is the case, we may still look for specimen No. 3, D above, or perhaps 30 kg. This may, of course, have been subdivided on a later occasion.

Specimen C was rapidly acquired by the Institute of Geology, but not directly from Calvert. Specimen B may also have come rather rapidly to its final destination. In the absence of a record to the contrary, it may have been obtained for the British Museum directly from Calvert. Specimen A had a long and crooked way before it reached Mainz; on the other hand, virtually all intermediate locations can be reasonably well established as shown above.

Since the archivalia will not yield any information as to the origin of Paneth’s Iron, one may cautiously compare the structural and analytical data with other irons, in order to reveal whether Paneth’s Iron might be a part of another already well established mass.

Fortunately, there is a very limited selection of irons with similar structures and compositions and these are all coarse octahedrites of group IIIE: Rhine Villa, Willow Creek, Kokstad/Matatiele, Tanakami Mountains, Coopertown, Staunton and Burlington. The first four can easily be ruled out for geographical, historical and structural reasons. The last three are all from the United States and were found in the nineteenth century prior to the first appearance of Paneth’s Iron in 1873. Paneth’s Iron is too large to be a part of either Coopertown or Staunton; it could, however, be a paired fall with either one of them.

There remains Burlington of which we know very little. A comparison with the main section of the handbook will show that Burlington was found about 1819, in the state of New York. Burlington presumably weighed between 50 and 100 kg when plowed up, but we do not know for certain, since the bulk of the material disappeared before its description in 1844, and less than 5 kg is presently in collections. The surviving Burlington material has been severely thermally altered and part has been forged. Is Paneth’s Iron in fact the missing material which, because of an eccentric collector, was saved from destruction? The macro- and microstructures, the bulk composition and the degree of corrosion and subsequent thermal alteration seem to be compatible within analytical and observational error.

COLLECTIONS

British Museum (No. 47192, 26.1 kg, Sample B above), Institute of Geology, London (15.2 kg, sample C above), Max-Planck-Institut für Chemie, Mainz (Pa 103/13, 12.2 kg, sample A above), Copenhagen (800 g, from Mainz).

DESCRIPTION

In addition to the notes above, it may be remarked that the masses are corroded. There is no fusion crust and no heat-affected $\alpha_2$ zone. The often mentioned crack is up to 17 cm long and penetrates from the surface along schreibersite-filled Widmanstätten boundaries. The schreibersite fragments in the crack are slightly rotated and the whole is then recemented by terrestrial corrosion products. Minor cracks are also present. The cracks are hardly inflicted upon the mass by artificial handling.

However, in several places, and particularly well on the British Museum specimen, the marks of hammers and chisels may be seen. One face of 10 cm$^2$ is roughly battered and flattened, suggesting some hot-working of the meteorite.

Etched sections reveal a coarse Widmanstätten structure of swollen, short ($\lambda \sim 15$) kamacite spindles with a width of 1.5±0.3 mm. The kamacite is rich in grain boundaries with 1-2 $\mu$ phosphide precipitates, and undecorated Neumann bands are common. The sections available were — about 1872 — cut almost parallel to a (111) Widmanstätten plane; therefore, the fourth set of lamellae appear as irregular plumes that occasionally reach dimensions of 60 x 5 mm, but more usually are 20 x 4 mm.

Taenite and plessite cover 20-25% by area, mainly as dense fields or fields with acicular or spheroidized interiors. Comb, net and cell plessite are virtually absent. In one out of four plessite fields carbide roses, 100-400 $\mu$ across, occur. High magnification reveals intricate intergrowths of haxonite, taenite, kamacite and schreibersite.

Schreibersite is common as 20-100 $\mu$ wide precipitates in grain boundaries, and as an occasional 1-2 mm angular bleb. Rhabdites, 2-10 $\mu$ across, are very common. The bulk phosphorus content is estimated to be 0.39±0.05%.

Troilité occurs as a few 9-12 mm nodules and as more numerous small blebs, ranging from 2 mm to microscopic dimensions. Almost all of them have served as nuclei for schreibersite crystals and are now almost entirely wrapped by these. Daubreeelite occurs as parallel, 0.1 mm wide bars in some of the troilité nodules.

While the above description relates to the meteorite before it was handled by man, the following structural details clearly indicate a subsequent thermal alteration.

(i) The Neumann bands have in places disappeared, and recrystallization of the kamacite has started at Neumann band intersections.
(ii) The kamacite shows polygonization; locally, adjacent to schreibersite, it is recrystallized to 10-30 μ new grains, without Neumann bands.

(iii) The microhardness of the kamacite is erratic, but very low, 145-175. This is in harmony with (i) and (ii) and suggests that the meteorite was artificially reheated to 500-700° C for a short time, on the order of one or two hours, insufficient for equilibrated structures to form.

(iv) The rhabdites have started to decompose by diffusion.

(v) The haxonite has started to decompose to 1-3 μ wide graphite lamellae.

(vi) The troilite crystals have decomposed to extremely fine aggregates of alternating, <1 μ thick daubreelite and troilite lamellae.

(vii) The corroded veins have reacted with kamacite and formed weird lace-like textures, 10-50 μ wide.

(viii) The limonite-schreibersite interfaces have reacted and formed yellowish diffuse reaction zones, only 1-5 μ wide. Alterations (vii) and (viii) clearly suggest that the reheating took place after corrosion had worked for centuries on the meteorite, i.e., the reheating was artificial, although never mentioned in the sources.

The reheating was heterogeneous; perhaps one end of the mass reached temperatures above 800° C, while the opposite end never was above 500° C. Certain structural elements indicate that this was the case, but the entire reheating probably lasted only a few hours. Individual small samples, chiseled from the mass, may have been exposed to even higher temperatures.

Paneth’s Iron belongs to the rare group IIIE and is, in its genuine unaltered structure, closely related to Rhine Villa, Staunton and Tanakami Mountains. It is also related to Burlington, the main mass of which disappeared long ago. Paneth’s Iron, but particularly Burlington, has been hammered and annealed. This has unfortunately made the structural comparison uncertain. The question whether Paneth’s Iron is a paired fall with Staunton or is the missing part of Burlington is left open until more structural, chemical and/or archival information, becomes available. For the time being Paneth’s Iron is best treated as an independent meteorite.

I wish to thank Mrs. Joyce Hall, British Museum, for excellent assistance during my study of the records, and Dr. R. Hutchison and Dr. H. Wänke for samples and advice.

Rateldraai, Cape Province, South Africa

Appended are two photographs showing the fascinating sculpture of this large medium octahedrite.

Figure 2114. Rateldraai (South African Museum, Cape Town). The 550 kg mass has an extremely rugged shape with a length of 144 cm and a maximum width of 52 cm. The thickness ranges from 10 to 45 cm. What resembles regmaglypts is mainly pitting from terrestrial corrosion. Scale bar 20 cm.

Figure 2115. Rateldraai (Cape Town). A view from another direction, see the arrow on Figure 2114. To the left and to the right, in the background, two raised portions occur. These small portions have escaped severe corrosion, probably because they projected above the ground, while the buried bulk of the mass deteriorated. Scale bar on the cut section in the left part of the picture, divided in cm.

Redfields, Western Australia

30°43’S, 116°30’E


Anomalous. 6.78% Ni, about 0.35% P, 0.5% C, 40 ppm Ga, 94 ppm Ge, 0.83 ppm Ir.
Redfields

**HISTORY**

This meteorite was found some years before 1969; it was briefly mentioned by De Laeter (1972a), Reed (1972b) and Rosman (1972), then more fully described by De Laeter et al. (1973). According to the latter authors, who also presented a map sketch and several photographs of the structure, the meteorite was discovered during stone picking in fields on the Redfields Farm, about 11 km east of Gabalong. The location is about 150 km north-northeast of Perth. The meteorite, which weighed 8.47 kg, was acquired by Mrs. M. Bennett of Wongan Hills and donated to the Western Australian Museum, Perth, in 1969. One corner had evidently, at an early date, been cut by a blowtorch, but the samples examined by De Laeter et al. (1973) and myself have not been exposed to artificial thermal alterations.

**COLLECTIONS**

Perth (main mass), Mrs. Bennett (668 g), Western Australian Institute of Technology, Bentley (580 g), Canberra (120 g), London (x g), Copenhagen (35 g).

**DESCRIPTION**

According to De Laeter et al. (1973) the mass was an elongated wedge with a brown oxidized surface; the original weight was 8.74 kg, but the dimensions were not given. The regmaglypts were rather poorly defined.

Polished and etched sections through the mass reveal a polycrystalline structure. The parent taenite grains are 3-8 cm in diameter and separated by poorly-defined grain boundaries.

**REDFIELDS - SELECTED CHEMICAL ANALYSES**

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1 Bulk analyses.
boundaries. The polycrystalline nature is mainly visible because each grain, on cooling, developed the Widmanstätten structure independently. Locally, however, there are bulky phosphide precipitates in the grain boundaries, even in one place reaching a size of 15 x 4 mm. Corrosion has penetrated along the boundaries, so that they now appear partly recemented by limonitic corrosion products. The fusion crust and the heat-affected α2 zone have been lost to corrosion, so it is estimated that the meteorite is terrestrially old, having lost on the average more than 2 mm of the exterior.

The Widmanstätten structure within each parent taenite grain is unusual and not easily defined. Very irregular kamacite bands range in width from 0.2 to 0.8 mm and are rarely longer than 5 mm. Interrupting them, and intercalated between them, occur almost equiaxial kamacite grains, 0.2-0.5 mm across. Local grain growth has created kamacite grains up to 5 mm across; on the other hand, many grain boundaries are pinned by 1 μm phosphide particles. The complex array of lamellar and equiaxial kamacite grains is best revealed on an etched section at low magnification under polarized light. Many kamacite units are subdivided by intricate subboundaries and cell walls. Taenite and plessite were not observed, although these constituents are normally present in iron meteorites on the 6.8% nickel level.

Neumann bands are ubiquitous in the kamacite; they are undecorated and late, probably caused by the cosmic event that reduced the meteorite to its present size. In places the Neumann bands are severely bent, and lenticular deformation bands occur in some strained grains adjacent to minor cracks. The kamacite hardness ranges from 235 to 305, clearly representing the variety of cold-working of individual grains. Apparently, no annealing has taken place whatsoever.

Schreibersite occurs as scattered millimeter-sized grains that occasionally show sharp facets. According to De Laeter et al. (1973), such early schreibersite can have the anomalously low nickel content of 7%, significantly lower than that reported for Bellsbank, La Primitiva and several others (10-12%). Schreibersite is further common as slightly spheroidized particles, 2-5 μm across, both inside kamacite and on kamacite grain boundaries. Very often, the fine particles form straight lines up to 5 mm in length and parallel to the residual Widmanstätten structure. Occasionally, the schreibersite appears as irregular to vermicular bodies, e.g., 100 x 5 μm in size. Normal rhabdites are absent. The bulk phosphorus content is estimated to be 0.35±0.05%.

Troilite, cohenite and silicates were not observed.

Graphite, however, is characteristic of Redfields. It occurs as rather evenly scattered cakes, that typically measure 2 x 1 mm across. From the few available sections it appears that the graphite cakes are indistinctly flattened and mutually parallel. Most cakes are composed of a massive graphitic center (10-25% by volume), surrounded by an intimate intergrowth of graphite and irregular kamacite particles, 5-50 μm across. These are sometimes arranged in imperfect cell walls. The graphite is a polycrystalline aggregate of 1-5 μm crystallites with little texture. All graphite cakes are enveloped in swathing kamacite. This forms almost equiaxial grains, 0.8-1.2 mm across, which are

**Figure 2118.** Redfields (Copenhagen). The irregular mixture of massive and polygonized kamacite is clearly revealed by exposing an etched section to slightly polarized light. Diagonally, a string of fine phosphide particles of uncertain origin. Scale bar 0.5 mm.

**Figure 2119.** Redfields (Copenhagen). The complex array of large and small kamacite units is clearly seen in this picture. Neumann bands are everywhere but more conspicuous in the massive grains than in the fibrous-cellular textures. To the left, a graphite cake. Etched. Scale bar 0.5 mm.
independently nucleated and oriented, and have coalesced at high temperature (~650°C) before the bulk of the meteoritic taenite decomposed.

Carlsbergite is a very minor constituent, ocuring in the kamacite grains as rose-colored, spheroidized particles, 1-5 μ across.

Redfields has on the whole a rather unique structure, which suggests that its formation and cooling story deviate from those of the main stream of octahedrites. The small size of the parent taenite grains is comparable to that in, e.g., N’Goureyma and Ysleta, and indicates that Redfields was not exposed to extended grain growth at elevated temperatures (1200-1300°C). The low nickel content of the massive schreibersite crystals and the large amount of phosphorus in solid solution in the kamacite suggest that Redfields thereafter was exposed to a rather rapid primary cooling, so that nickel and phosphorus had insufficient time to create equilibrated phases by diffusion. Only carbon had a sufficiently high diffusion coefficient and managed to form aggregates, spaced with a distance of 5-10 mm. Around these a significant amount of swathing kamacite developed.

The kamacite development away from the graphite cakes points to a rather rapid primary cooling that prevented the normal Widmanstätten development of large α-lamellae and distinct residual plessite fields, as in, e.g., Youndegin and Smithville, which show the same bulk nickel content. Apparently Redfields existed as a supercooled polycrystalline taenite aggregate with scattered schreibersite rosettes and graphite cakes (with swathing kamacite), when it was exposed to shock and slight reheating, perhaps at 500-550°C. This event started decomposition to the complex aggregate of kamacite grains which is now present and which in some respects resembles the plessitic fields of Maria Elena. When, finally, the macrostructure was fully developed, another cosmic shock workhardened the kamacite and formed the Neumann bands.

Redfields has no immediate relatives. It does, however, in several chemical and structural respects resemble Santa Rosa and Chihuahua City, but it lacks the prominent troilite cylinders of these.

**Vaalbult, Cape Province, South Africa**

The very coarse sculpture of this iron is seen in the two appended photographs of the main mass in the South African Museum of Cape Town. In the Geological Survey Museum, Pretoria, there is a cast purported to be of Vaalbult. However, the size and shape are entirely different, so we either have here an error, or else two masses exist.
This new fine octahedrite, Of, was briefly mentioned by Scott et al. (1973) who presented the following analysis: 10.07% Ni, 14.0 ppm Ga, 25.0 ppm Ge and 0.18 ppm Ir, and gave a bandwidth of approximately 0.4 mm.

Victoria West, Cape Province, South Africa

A photograph of this maltreated and broken mass is appended.

Figure 2124. Victoria West (South African Museum, Cape Town). There is presently in Cape Town an endpiece of about 1 kg. It is shown here in its damaged state, artificially reheated and broken with heavy chisels. It was not observed to fall although so stated on the museum label. Ruler above 10 cm long.

<table>
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<th>Meteorite</th>
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<th>Ge ppm</th>
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¹The new analysis supports the idea that Las Vegas is a transported Canyon Diablo mass.
²The new analysis supports the conclusion that Maldyak and Susuman are independent falls.
³The analysis suggests that Nuleri is a transported fragment from the Boxhole or Henbury crater fields.
⁴This is a considerably improved analysis compared to the old one by Wasson.
⁵The new analysis indicates that Summit is related to Santa Luzia and Ainsworth, and not to Tombigbee.

For further information the reader is kindly requested to study the detailed descriptions in the handbook section.