

numerous places it is completely worn off, probably due to human handling. A little metallic fusion crust is seen here and there, up to 300  $\mu$  thick and layered. The metal is solidified to dendritic aggregates with an armspacing of 6-10  $\mu$ ; the hardness is 290 $\pm$ 20.

Under the fusion crusts is a heat-affected  $\alpha_2$  zone ranging from 1.5 to 5 mm in thickness. The  $\alpha_2$  is composed of fine-grained, frayed units, 5-25  $\mu$  in size — fine-grained as is usually the case when the  $\alpha_2$  forms from shock-hardened  $\epsilon$ -structures. The  $\alpha_2$  has a hardness of 180 $\pm$ 10, except immediately under the fusion crust where it increases to 335 $\pm$ 25. This is partly due to the almost complete solution of phosphides in the outer region and partly due to carburization from the melt; the zone extends 10-50  $\mu$  inwards. Hard zones (HV 275 $\pm$ 25) are also found as 20-50  $\mu$  wide borders around taenite and plessite, where the structure is visibly altered to bainitic-martensitic structures. This must be due to carbon enrichment, the carbon having diffused away from the adjacent taenite in the very brief time available.

The schreibersite crystals and the rhabdites are micro-melted in the exterior 50% of the heat-affected  $\alpha_2$  zone. It is common to see intercrystalline, zigzagging veinlets of melted phosphides in this zone. They are 1-2  $\mu$  wide and mark the grain boundaries of the short-lived austenite, formed by the atmospheric reheating. The austenite grains may thus be estimated to have been 15-25  $\mu$  in diameter. The phenomenon is perfectly common in the iron meteorites but often obscured by terrestrial corrosion.

Etched sections reveal a medium Widmanstätten structure of straight, long ( $l/w \sim 25$ ) kamacite lamellae with a width of 1.15 $\pm$ 0.15 mm. The kamacite has subboundaries decorated with 0.5-2  $\mu$  phosphides, but this structure is superimposed by a hatched shock-hardened  $\epsilon$ -structure. The hardness increases from a minimum of 175 at the inner  $\alpha_2$  boundary to 215 $\pm$ 10 10 mm below the surface. This is low for a hatched structure and suggests that some cosmic annealing (300-400 $^\circ$  C) has occurred.

Taenite and plessite cover about 40% by area. Comb and net plessite fields are common, and the wider taenite wedges (HV 270 $\pm$ 15) have acicular kamacite needles only 1-5  $\mu$  thick. Numerous fields have marked martensite, developed parallel to the bulk Widmanstätten structure (HV 290 $\pm$ 20). The yellowish taenite rims and ribbons have hardnesses of 235 $\pm$ 20. All hardness values are low — probably due to some cosmic annealing.

Schreibersite occurs as 20-80  $\mu$  wide grain boundary veinlets and as 2-50  $\mu$  wide blebs in the plessite. Rhabdites are common but mostly as small, 1-3  $\mu$  thick prisms. They occasionally reach a size of 10  $\mu$  in cross sections. The bulk phosphorus content is estimated to be 0.15 $\pm$ 0.02%.

Troilite occurs as scattered nodules, 0.5-8 mm across, but was not present in any of the microsections prepared. The troilite nodules will probably turn out to be polycrystalline, shock-melted aggregates like those present in, e.g., Uwet. Daubreelite is disseminated as bluish blebs in the

kamacite, generally 10-50  $\mu$  in diameter. Schreibersite sometimes has nucleated and grown upon them.

Rowton is a medium octahedrite which is related to Kayakent, Puente del Zacate, Kyancutta, Bagdad and Merceditas. Chemically, it is a normal group IIIA.

#### Specimens in the U.S. National Museum in Washington:

19 g part slice (no. 86, 4 x 2 x 0.5 cm)

13 g part slice (no. 2395, 2 x 1.5 x 0.9 cm)

### Ruff's Mountain, South Carolina, U.S.A.

34 $^\circ$  10'N, 81 $^\circ$  21'W; 125 m

Medium octahedrite, Om. Bandwidth 1.25 $\pm$ 0.15 mm. Recrystallized. HV 150-225.

Group IIIA. 8.59% Ni, 0.53% Co, 0.26% P, 21.5 ppm Ga, 46.5 ppm Ge, 0.47 ppm Ir.

The meteorite appears to have been reheated twice, both preterrestrially and artificially.

#### HISTORY

A mass of 53.1 kg (117 pounds) was found in 1844 on the surface of Ruff's Mountain, Lexington County. It went through several hands and was forgotten for a while until it was acquired by Shepard who published several brief accounts of it, with sketches of the exterior appearance (1850; 1851; 1853). He believed it to be a recent fall and presented an alleged eyewitness report; all later investigators agree, however, that it is a weathered find. Brezina (1880b) gave two prints of etched sections showing poorly developed Reichenbach lamellae, and he later (1885: 213; 1896: 277) briefly discussed the metallic matrix and gave a photomicrograph. References to numerous other, older papers and comments will be found in Wülfing (1897: 298) and Farrington (1915: 387). Wherry (1917) determined the angles of the schreibersite inclusions with a two-circle goniometer and found the phosphide to be tetragonal.



Figure 1469. Ruff's Mountain (Tempe no. 99b). A recrystallized medium octahedrite transitional between group IIIA and IIIB. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

Merrill (1919) discussed a new analysis by Whitfield which proved far superior to previous analyses. Nininger & Nininger (1950: plate 4) reproduced a photomicrograph, and Reed (1965a, b) presented microprobe data on the kamacite and schreibersite. Buchwald (1966: 33; 1971d) gave several photomicrographs and discussed the cosmically recrystallized structure. In addition he saw evidence that the mass had been artificially reheated (Hey 1966: 414). Schultz (1967) found that this evidence could explain the  $^3\text{He}$  deficiency of Ruff's Mountain, since much of the parent tritium nuclide would be expected to diffuse out of the mass during recrystallization in cosmos.

The location of Ruff's Mountain is not indicated on modern maps. It may, however, be identified as a well-marked locality on Colton's General Atlas (1866: plate 44), where it appears about midway between Newberry and Columbia, just inside Lexington County. It is near present-day Chapin. The corresponding coordinates are given above.

### COLLECTIONS

Amherst (21.4 kg endpiece), Washington (4.55 kg), Tempe (2.42 kg), Geological Museum University of South Carolina (1.2 kg), Vienna (597 g), London (577 g), Yale (510 g), Harvard (448 g), Budapest (289 g), Calcutta (287 g), Berlin (275 g), Leningrad (242 g), Chicago (234 g), Paris (191 g), Bonn (155 g), Göttingen (152 g), Stockholm (144 g), New York (125 g), Los Angeles (116 g), Uppsala (102 g), Copenhagen (84 g), Tübingen (79 g), Dresden (62 g), Prague (58 g), Strasbourg (42 g) and in several other collections.

### DESCRIPTION

According to Shepard (1850), the mass was irregular, truncated at both ends and measured  $31\frac{1}{2}'' \times 29\frac{3}{4}''$  in two, perpendicular directions. The third dimension was not given, and the two measures given are almost certainly wrong, since they would lead to a much larger weight than 53 kg, unless the mass had had the shape of a thin plate which we know it had not. The endpiece of 21.4 kg preserved in Amherst measures  $22 \times 18 \times 17$  cm and has a polished and etched face,  $22 \times 17$  cm in size. It appears that Shepard's original figures may be correct if they read

$31\frac{1}{2} \times 29\frac{3}{4}$  cm, or if it is assumed that he only quotes some very bad figures obtained from a third source. Shepard had evidently not seen the main mass when he wrote. I would estimate the original dimensions to have been  $35 \times 23 \times 20$  cm, judging from the many specimens I have seen and from the total known weight of 53.1 kg before cutting.

The mass is corroded and covered with 0.1-1 mm thick crusts of terrestrial oxides; no fusion crust and no heat-affected  $\alpha_2$  rim zone are preserved. The corrosion penetrates several centimeters below the surface, following the grain boundaries of the recrystallized grains and particularly attacking the nickel-poor kamacite adjacent to the schreibersite inclusions. The corrosion pattern clearly indicates that the recrystallization was preterrestrial. It also suggests that the mass already had several intercrystalline fissures when it landed on the ground.

Etched sections display a medium Widmanstätten pattern of straight, long ( $l \sim 20$ ) kamacite lamellae with a width of  $1.25 \pm 0.15$  mm. Taenite and plessite, mostly as comb plessite fields, cover about 40% by area. Schreibersite is common as 0.2-0.8 mm wide and 1-5 mm long crystals, situated centrally in the kamacite lamellae, and further as  $50-100 \mu$  wide grain boundary veinlets. Rhabdites, 1-5  $\mu$  across, are present in the kamacite interior. Cohenite was

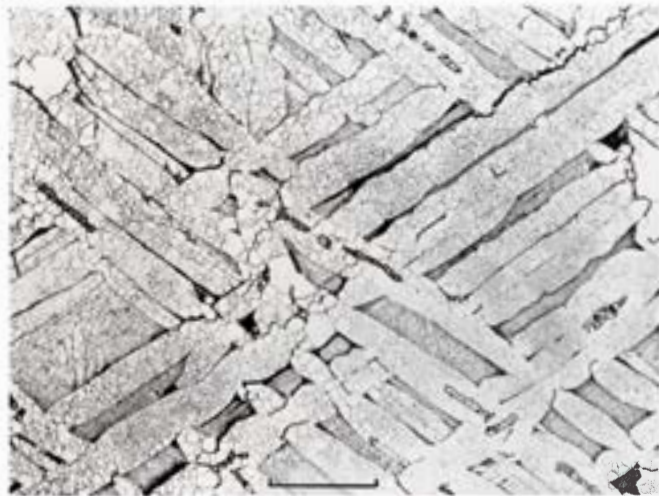
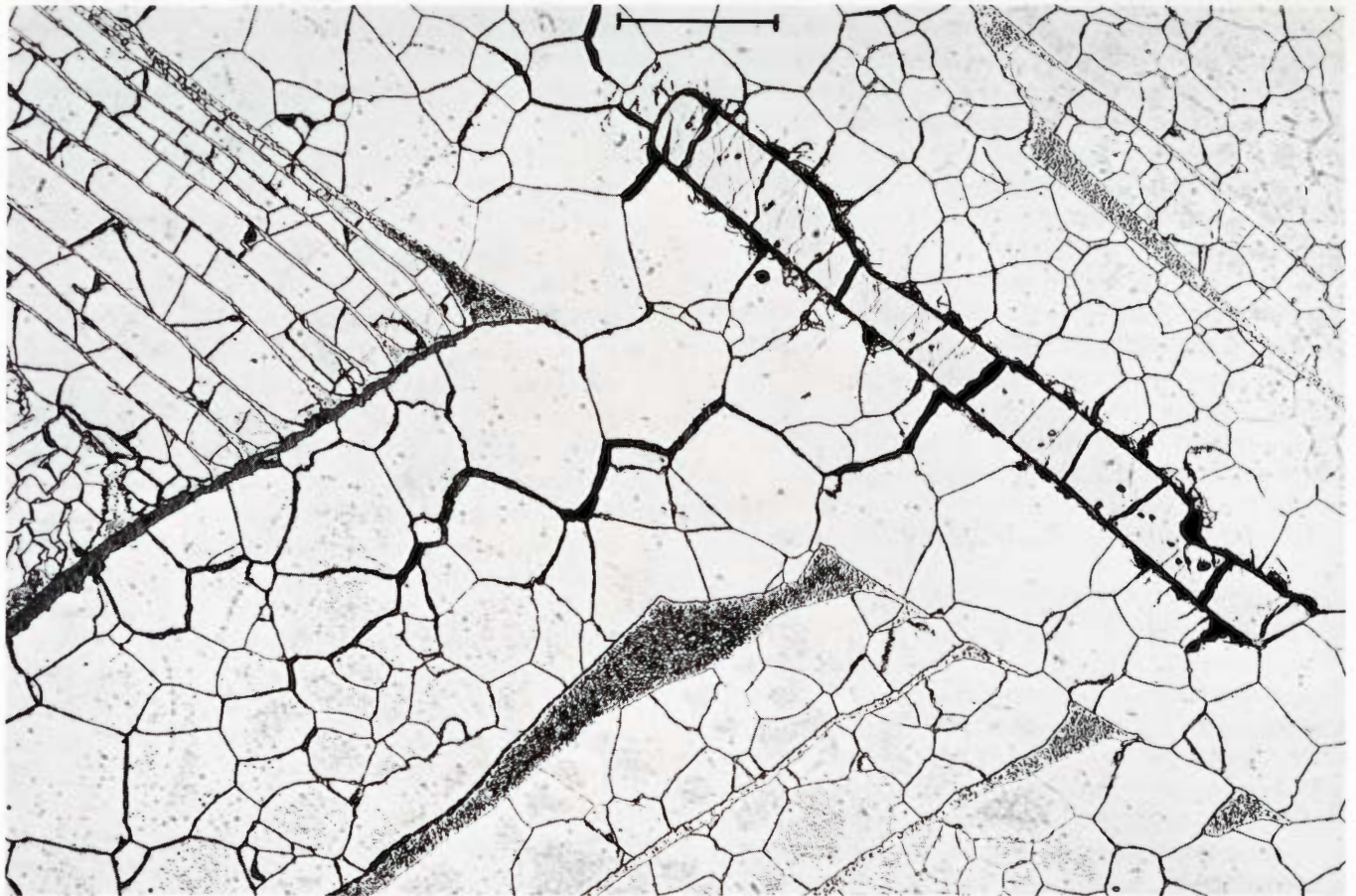


Figure 1470. Ruff's Mountain (Copenhagen no. 37). The kamacite is fully recrystallized to equiaxial grains. Etched. Scale bar 3 mm.

### RUFF'S MOUNTAIN - SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Whitfield in Merrill 1919	8.55	0.50	0.23	250	200		180					
Buchwald 1966, unpubl.	8.69	0.56	0.30		50		180			44		
Wasson & Kimberlin 1967	8.55								21.5	46.5	0.47	
Lewis & Moore 1971	8.56	0.53	0.26	50								

Reed (1965b) found 7.26% Ni in the kamacite phase.

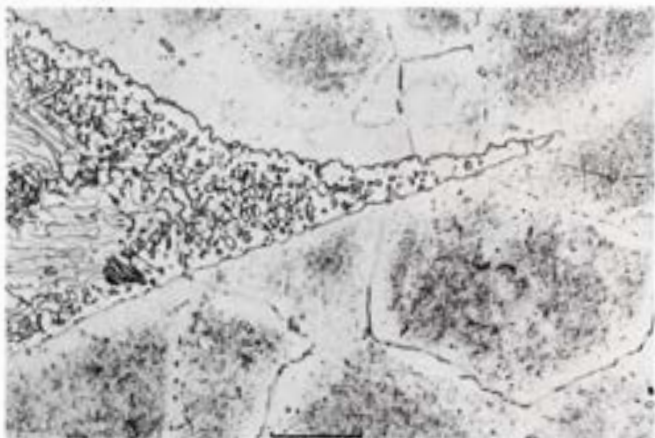


**Figure 1471.** Ruff's Mountain. Detail of Figure 1470. Schreibersite crystals are common centrally in the kamacite lamellae. Spheroidized plessite fields. Terrestrial limonite along the grain boundaries. Etched. Scale bar 400  $\mu$ .

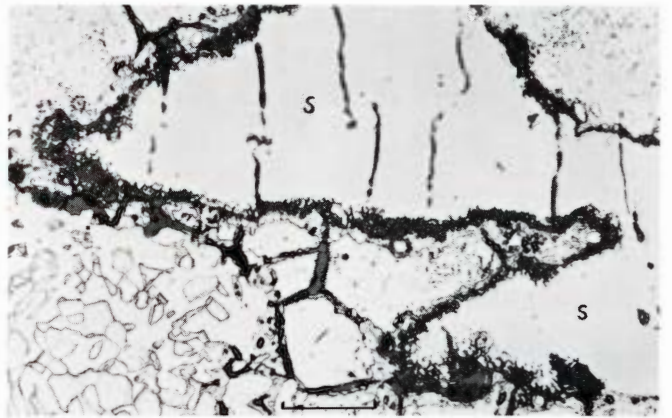
reported by Brezina (1896), but this could not be confirmed in the present study and appears to be a misinterpretation of schreibersite.

The primary structure corresponds very well to the structure of, e.g., Aggie Creek, Campbellville, and Tamarugal. It is, however, superimposed by a secondary structure caused by cosmic annealing. All kamacite lamellae are

recrystallized to equiaxial units, 0.1-0.5 mm in diameter, while the kamacite of the plessite fields forms smaller, recrystallized grains 0.02-0.05 mm in diameter. The taenite is partly spheroidized and homogenized; the martensitic transition zones have disappeared, and most plessite fields display easily resolvable, duplex  $\alpha + \gamma$  structures. A few of the recrystallized kamacite grains contain Neumann bands, decorated with small phosphide particles. In the near-



**Figure 1472.** Ruff's Mountain (Copenhagen no. 37). Spheroidized plessite and recrystallized kamacite with numerous fine precipitates. Etched. Scale bar 100  $\mu$ .



**Figure 1473.** Ruff's Mountain (Copenhagen no. 37). A large schreibersite crystal (S) with limonite from terrestrial corrosion. Artificial reheating caused schreibersite to react with limonite and form serrated laceworks along the interfaces. Etched. Scale bar 40  $\mu$ .

surface corroded parts these Neumann bands have been selectively transformed to limonite.

Troilite occurs as irregular nodules, ranging from 1 to 10 mm in diameter. They are shock-melted and converted to fine eutectics of sulfide and metal. Rounded fragments of schreibersite, which originally was precipitated upon the nodules, are now dispersed through the eutectic and themselves partly melted.

The secondary structure suggests a violent shock followed by a significant annealing in cosmos, sufficient to recrystallize the kamacite and spheroidize the taenite. The secondary structure appears to have required more energy than Roebourne and corresponds perhaps to what is seen in Casimiro de Abreu, Maria Elena, and Willamette.

Unfortunately, Ruff's Mountain must have been artificially reheated by the early possessors, although not mentioned in any of the original reports. Evidence for this is (i) the 2-5  $\mu$  wide, creamcolored reaction zones intercalated between the schreibersite and the terrestrial corrosion products, (ii) the 20-100  $\mu$  wide laceworks of oxides and metal developed along all corroded grain boundaries, (iii) the finely dispersed 0.5  $\mu$  metal grains in the limonite, and (iv) the partial dissolution of the rhabdites in the matrix. The microhardness of the kamacite ranges from 150 to 225 which also reflects a late, inhomogeneous, artificial reheating. A number of double kamacite grain boundaries suggests a late readjustment of the grain sizes. The maximum temperature reached appears to have been 600-650° C.

Ruff's Mountain is thus a normal medium octahedrite of group IIIA which, on two occasions, was reheated – first, preterrestrially by a thorough recrystallization-annealing that probably followed a shock and, then, artificially for a considerably shorter time which gave rise to the many peculiar reaction products between the limonite and the meteorite matrix.

The artificially reheated structures were observed to be present on the Washington, Tempe and Copenhagen specimens which strongly indicates that the reheating took place before the mass was cut, probably while in the possession of the unknown finders between 1844 and 1850.

#### Specimens in the U.S. National Museum in Washington:

- 4,040 g box-shaped section (no. 1127, 9.5 x 8.5 x 8 cm)
- 305 g triangular prism, cut therefrom (no. 1127, 5.5 x 5 x 3 cm)
- 50 g various, small specimens (no. 1127)
- 105 g part slice (no. 1670, 5.5 x 3 x 0.8 cm)
- 49 g part slice (no. 3020, 5 x 3 x 0.5 cm)

## Russel Gulch, Colorado, U.S.A.

39° 47'N, 105° 31'W; 2,700 m

Medium octahedrite, Om. Bandwidth 0.90±0.10 mm. Cold-worked kamacite. HV 240-340.

Group IIIA. 7.48% Ni, 0.13% P, 19.1 ppm Ga, 35.6 ppm Ge, 7.2 ppm Ir.

### HISTORY

A mass of 13.1 kg (29 pounds) was found in 1863 by Otho Curtice in Russel Gulch near Central City, Gilpin County. The corresponding coordinates are given above. The meteorite was acquired by J.L. Smith, who described it briefly and gave an analysis (1866). Brezina (1885: 208) classified Russel Gulch as a fine octahedrite with a bandwidth similar to Charlotte and Gibeon; this classification stuck and is, e.g., still found in Hey (1966: 415), Mason (1964: 27) and Horback & Olsen (1965: 287). Cohen (1905: 361) gave a description, and Brezina & Cohen (Atlas 1886-1906: plate 21) presented two photographs of etched sections. Nininger & Nininger (1950: plate 9) gave another photomicrograph. Berwerth (1914: 1081) interpreted the structure as a result of artificial reheating, and Buchwald (quoted in Hey 1966: 416) believed for a while that this observation was correct. The following reexamination shows, however, (i) that Russel Gulch is a *medium* octahedrite related to Sacramento Mountains, Henbury and San Angelo, and (ii) that the mass – as determined by specimens in New York, Washington, Tempe and Copenhagen – has *not* been artificially reheated.

### COLLECTIONS

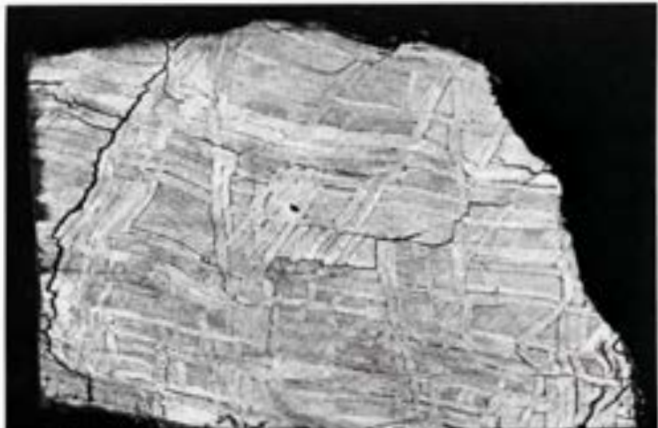
New York (5,046 g endpiece), Harvard (1,519 g), Berlin (502 g), Göttingen (425 g), London (292 g), Chicago (273 g), Denver (no. 5910), Paris (183 g), Calcutta (133 g), Yale (121 g), Copenhagen (118 g), Vienna (105 g), Dorpat (85 g), Ottawa (85 g), Tempe (78 g), Washington (72 g), Philadelphia (71 g), Vatican (71 g), Amherst (61 g), Dresden (28 g).

### DESCRIPTION

The extreme dimensions were, according to Smith (1866), 21 x 18 x 14 cm, and the weight was 13.1 kg. The 5 kg endpiece in New York measures 20 x 10 x 7 cm and has a 20 x 10 cm polished surface. It is weathered and covered by 0.1-1 mm thick, limonitic crusts. The original regmaglypts, 2-3 cm in diameter, have almost lost their

### RUSSEL GULCH – SELECTED CHEMICAL ANALYSES

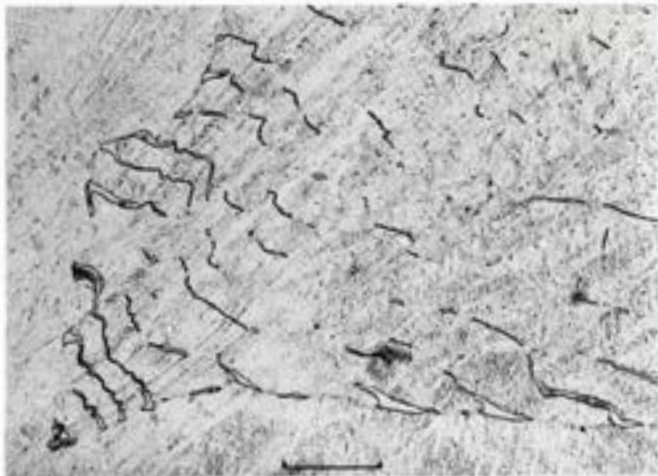
References	percentage			C	S	Cr	Cu	ppm			Ir	Pt
	Ni	Co	P					Ni	Ge	Ir		
Bürger in Cohen 1905	7.43	0.66	0.13		+	100	400					
Scott et al. 1973	7.52							19.1	35.6	7.2		



**Figure 1474.** Russel Gulch (Tempe no. 307.1). Medium octahedrite of group IIIA. Cold-worked by cosmic events so that the Widmanstätten pattern is distorted. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

identity and are smoothed out. Locally, corroded patches of fusion crust are nevertheless preserved, and heat-affected  $\alpha_2$  zones are present on several sections, e.g., U.S.N.M. No. 747. The fusion crust on it is composed of 100  $\mu$  magnetite and wüstite, underlain by laminated, dendritic-cellular metal. The thickness is up to 300  $\mu$  and the microhardness is  $350 \pm 20$ . The  $\alpha_2$  zone ranges from 1 to 2 mm in thickness and has micromelted phosphides in the exterior half. The  $\alpha_2$  is extremely fine-grained, from 50  $\mu$  across in the 1500° C zone to 3  $\mu$  across in the 800° C zone. The microhardness is  $180 \pm 10$  for both grain sizes. Inwards, the hardness rapidly rises to the high level of about 300 for the interior, cold-worked material (hardness curve type I).

Corrosion penetrates deep into the mass along octahedral cleavage planes. The corroded fissures are 0.03-1 mm wide, and a close examination reveals that these fissures are preatmospheric and frequently filled with a breccia of

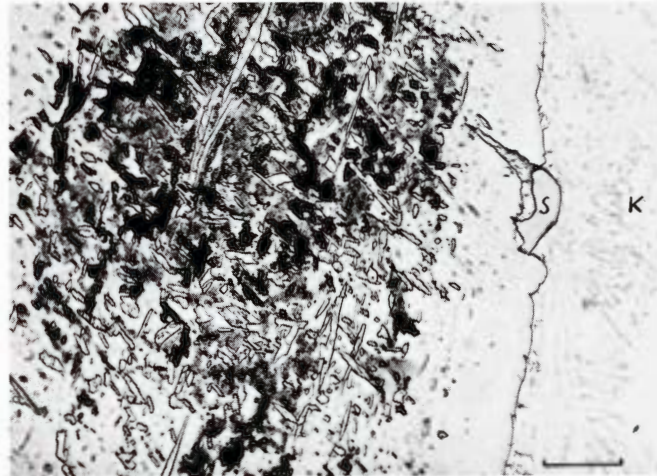


**Figure 1475.** Russel Gulch (Copenhagen no. 1876, 48). Open-meshed comb plessite field with almost resorbed taenite lamellae. The kamacite is work-hardened and the plessite is violently distorted. See also Figure 148. Etched. Scale bar 200  $\mu$ .

troilite and daubreelite. The sulfide grains are sharp angular fragments, 10-100  $\mu$  across, apparently formed by the crushing of larger monocrystalline sulfide bodies; they have not been remelted in the process of filling the fissures. The breccias are now cemented together by limonitic corrosion products, but it appears that the fissures were loosely packed open cracks, when the meteorite circled in Cosmos. Independent evidence for this conclusion is found in the  $\alpha_2$  zone. While the inner boundary of the zone is generally smooth, reflecting a uniform heat penetration during atmospheric flight, the boundary locally jumps 0.5-1 mm where it passes a crack that runs subparallel to the surface. This suggests that the crack was already open and insulating when the mass struck the atmosphere. Similar cracks have been observed in numerous other irons in this study, but Russel Gulch is a prominent example.

Etched sections display a medium Widmanstätten structure with violently distorted kamacite lamellae ( $\frac{L}{W} \sim 20$ ) with a width of  $0.90 \pm 0.10$  mm. Few other irons are so cosmically deformed as Russel Gulch. All structurally linear elements are bent and kneaded, and locally show repeated folding on a microscale. Few large-scale displacements occur, however; most of the deformation is an equally distributed, deeply penetrating plastic kneading as if the mass had been subjected to rather slow and repeated displacements of the overburden. The kamacite is subdivided into rhombic-lenticular cells by densely spaced shear planes; the largest undeformed islands appear to be 20-30  $\mu$  across. The microhardness ranges from 240 to 340, reflecting the local variation in cold-working intensity. At low magnification the structure somewhat resembles a shock-produced structure, but I think that it is a significant difference that the overall texture of Russel Gulch indicates plastic working and that the hardness shows a considerable difference from spot to spot.

Taenite and plessite cover about 30% by area. The taenite has brown-etching rims; the larger taenite wedges display martensitic transition zones to a duplex, poorly



**Figure 1476.** Russel Gulch (Copenhagen no. 1876, 48). Plessite field with acicular kamacite and unresolvable martensite (black). Schreibersite (S) and cold-worked kamacite (K). Etched. Scale bar 20  $\mu$ . See also Figure 148.

resolvable  $\alpha + \gamma$  interior. The taenite is cold-worked with a hardness of  $425 \pm 25$ , the interior,  $400 \pm 25$ . Comb and net plessite fields are common; the framing taenite is discontinuous in accordance with the 7.5% Ni level. Since the kamacite of the plessite fields is intensely kneaded in exactly the same way as the kamacite of the lamellae, there is very little contrast on the surface of etched specimens. There is only an undulatory, silky sheen.

Schreibersite is only present as  $2\text{--}50 \mu$  thick grain boundary precipitates and as  $2\text{--}20 \mu$  thick, irregular blebs inside the plessite fields. Locally, a host of well defined rhabdites,  $2\text{--}3 \mu$  across occurs, and minute phosphides,  $0.5\text{--}1 \mu$  across, decorate the kamacite subboundaries. All phosphides are broken and displaced by shear, often in successive  $10 \mu$  steps.

Troilite is common as lenticular or rounded nodules,  $0.1\text{--}10$  mm across. It is monocrystalline, but brecciated, and shows lenticular deformation twins. Daubreelite covers about 15% by area in the form of  $10\text{--}150 \mu$  wide parallel bars that are also sheared. From the troilite nodules, several fissures extend for many centimeters, filled with a breccia of troilite and daubreelite, as noted above.

The hard platy precipitate of carlsbergite, noted in Costilla Peak, Cape York and others, also occurs here in the form of  $20 \times 1 \mu$  lamellae that are bent and sheared in the same way as all the other minerals.

Russel Gulch is a medium octahedrite which is intensely cold-worked, presenting a range of deformation that may be expressed as a kamacite hardness range from 240 to 340. No late annealing seems to have taken place except in the heat-affected rim zone. Russel Gulch is structurally related to Sacramento Mountains and Davis Mountains; and, chemically, it is a typical group IIIA of the phosphorus-poor variety.

#### Specimens in the U.S. National Museum in Washington:

47 g part slice (no. 747,  $4.5 \times 2.7 \times 0.6$  cm)  
25 g polished section

## Sacramento Mountains, New Mexico, U.S.A.

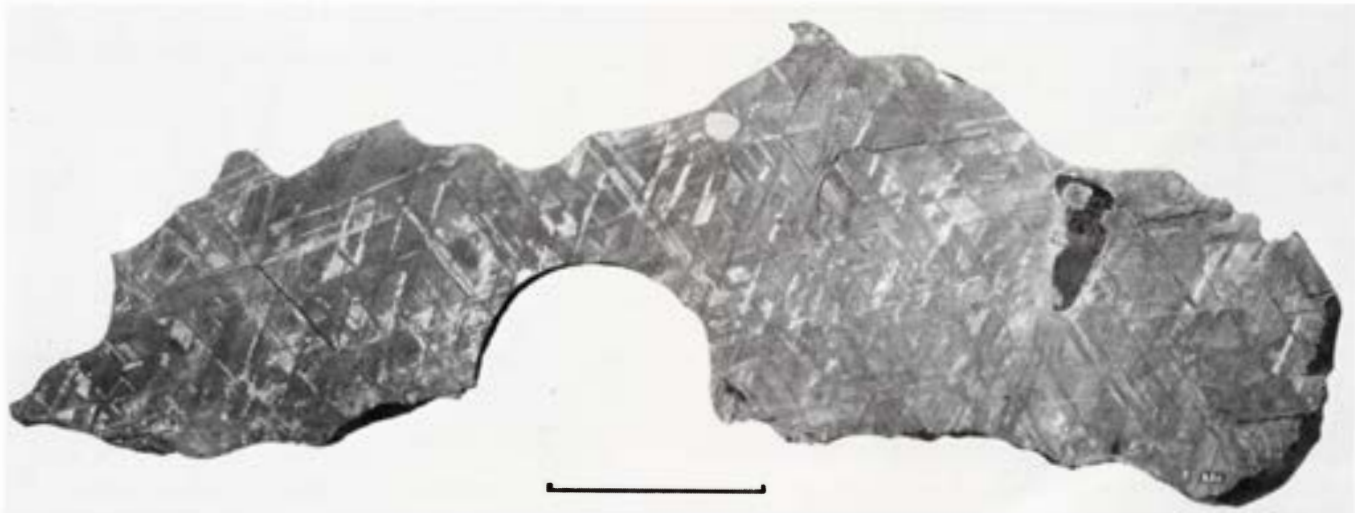
Unknown coordinates

Medium octahedrite, Om. Bandwidth  $1.00 \pm 0.15$  mm. Deformed Neumann bands. HV  $195 \pm 15$ .

Group IIIA. 7.93% Ni, 0.49% Co, 0.12% P, 19 ppm Ga, 36 ppm Ge, 6.7 ppm Ir.

### HISTORY

A mass of 237 kg was found by a shepherd, named Beckett, about 1890 in the lower foothills of the Sacramento Mountains, Eddy County. It lay partly buried on top of a limestone hill about 23 miles southwest of Badger, and the discoverer and his associates believed it had fallen in 1876. Somehow, Foote (1897) who acquired and described the iron believed this story, although the corroded surface clearly indicated that the mass had a considerable terrestrial age. The locality of find is impossible to reconstruct today on the basis of the data given. These are partly conflicting, partly insufficient, since the Sacramento Mountains do not extend into Eddy County, even with a very liberal interpretation, and since the place called Badger could not be identified on any available map, old or new. Foote gave a figure of the exterior and of an etched slice, and these figures were reprinted later (Foote 1912) with indications of exactly how the cuts were taken through the deep impressions on the mass. Other photomicrographs have appeared in Ward's Catalog (1904a: plate 3), Mauroy (1913: figure 21), Merrill (1916a: plate 33) and Chackett et al. (1953). Kase (1925) examined the microstructure of small specimens after various heat treatments, involving, e.g., recrystallization at  $550^\circ\text{C}$ , partially and full homogenization at  $1050\text{--}1300^\circ\text{C}$ , and full melting. Kase reported, surprisingly, that Neumann bands were still present in the kamacite after a heat treatment at  $1000^\circ\text{C}$  for 20 minutes. In the discussion below the explanation will be



**Figure 1477.** Sacramento Mountains (U.S.N.M. no. 230). A full slice through the mass showing a troilite nodule to the right and the large hemispherical cavity below. Deep-etched. Scale bar 10 cm. S.I. neg. 28938.

given for this unusual deceit. Other of Kase's explanations are now abandoned, but his experiments are interesting.

Chackett et al. (1953) found hardly any variation in the helium content in seven different places of the London slice. Reed (1965a,b; 1969) reported on the composition of kamacite, taenite and schreibersite. The kamacite was found to be homogeneous with 7.3-7.4% Ni and 0.14% P. Short & Andersen (1965) determined the compositional variations across plessite and also noted that the Laue photographs of the kamacite lamellae were too diffuse for an orientation to be deduced. Jaeger & Lipschutz (1967b) estimated that the lattice damage was due to shock pressures of the order 130-400 k bar. Hintenberger et al. (1967) determined the amount of occluded, noble gases, while Voshage (1967) by the  $^{40}\text{K}/^{41}\text{K}$  method estimated a minimum cosmic ray exposure age of  $185 \pm 85$  million years.

#### COLLECTIONS

New York (19.5 kg and 4.73 kg), London (14.0 kg), Vatican (9.96 kg), Bryn Mawr College, Pennsylvania (9.50 kg), Stockholm (8.95 kg), Chicago (8.43 kg), Washington (6.48 kg), Yale (4.69 kg), Vienna (4.30 kg), Rome (2.78 kg), Berlin (2.76 kg), Ottawa (2.71 kg), Bally (1.84 kg), Parris (1.62 kg), Sydney (1.36 kg), Tokyo (1.36 kg), Harvard (1.23 kg), Ann Arbor (1.11 kg), Philadelphia (992 g), Hamburg (985 g), Copenhagen (760 g),

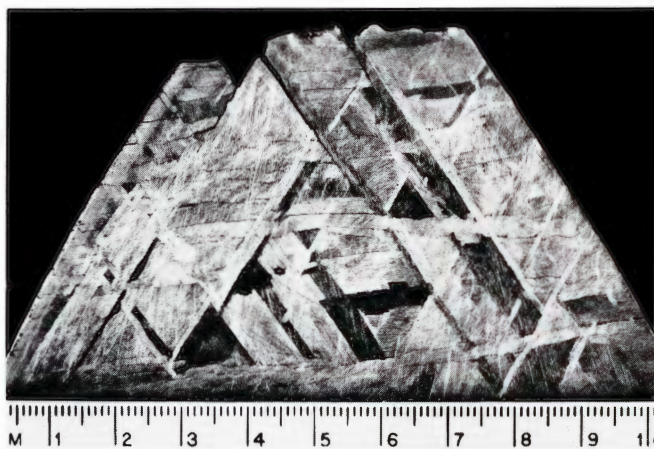


Figure 1478. Sacramento Mountains (Tempe no. 372.1). A deformed medium octahedrite of group IIIA. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

Bonn (590 g), Buffalo (about 500 g), Prague (385 g), Tempe (109 g), Amherst (83 g).

#### DESCRIPTION

The meteorite was an irregular, discoid mass with the average dimensions of 80 x 60 x 20 cm. It appears to have been a mass which was differentially sculptured on the two opposite sides. On the flat or slightly concave, rear side there are several cup-shaped pits, the two largest being 10 and 12 cm in diameter and 5 and 6 cm deep, respectively. The slightly domed front side, on the other hand, is covered with normal regmaglypts, 4-7 cm across and 1-2 cm deep. There are 0.1-1 mm thick crusts of warty fused oxides which are preserved in many depressions, so the bold sculpture is, in all major respects, due to ablation in the atmosphere and not to corrosion. The surface is locally corroded, and the deep preatmospheric fissures, in particular, are corroded. Selective corrosion follows the Neumann bands for some distance from the surface, because the bands are sensitized by precipitation. At an early date several fragments, easily recognizable because of the jagged edges, were chiseled free along these fissures (Foote 1897). See e.g., U.S.N.M. Nos. 3022 and 3024.

Etched sections display a medium Widmanstätten structure of straight or distorted, long ( $l/w \sim 30$ ) kamacite lamellae with a width of  $1.00 \pm 0.15$  mm. The kamacite has

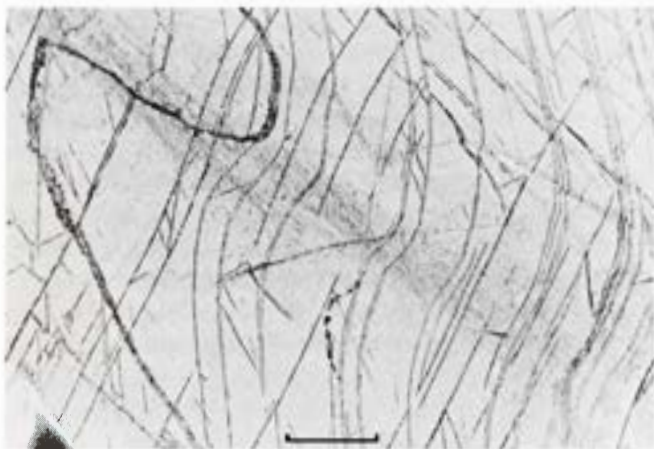


Figure 1479. Sacramento Mountains (Copenhagen no. 1905, 1741). Severely deformed kamacite with sheared and bent Neumann bands. Etched. Scale bar 300  $\mu$ .

#### SACRAMENTO MOUNTAINS – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Whitfield in Foote 1897	7.86	0.52										
Goldberg et al. 1951	8.10	0.55							20.4			
Lovering et al. 1957		0.48				22	165		19	29		
Wasson & Kimberlin 1967	7.75								19.2	36.6	6.7	
Moore & Lewis 1968	8.01	0.41	0.10	45	35							

In a partial analysis, for phosphorus, I found 0.13% on a selected sample, typical for the bulk composition.

subboundaries with 0.5-2  $\mu$  phosphide precipitates, but rhabdites in the matrix proper are absent. Neumann bands are common; they are often severely bent and kneaded, and they are always decorated along both sides with tiny beads, 0.2-0.5  $\mu$  across. These precipitates are taenite grains and also some phosphides; this is best seen in the heat-affected  $\alpha_2$  zone where most of the grains behave as taenite, while a minority micromelt as phosphides do. The kamacite lamellae are duplex. They are decomposed on an almost submicroscopic scale to kamacite, taenite and phosphide — the phosphides forming a multitude of less than 0.4  $\mu$  wide grains which particularly decorate slip bands and other lattice imperfections. Reed (1969) found 0.14% P in solid solution in the kamacite. It appears now that the phosphorus is not really in solid solution but precipitated as ultrafine particles — too fine to be resolved with the electron microprobe. The hardness of the lamellae is 195 $\pm$ 15 but increases locally in the shear zones to 250.

Taenite and plessite cover about 35% by area, mostly as degenerated comb and net plessite fields with discontinuous taenite rims. The larger wedges and ribbons of the fields are decomposed to martensitic and dark-etching duplex structures, while the taenite rims are tarnished and show tiny precipitates in an oriented grid; compare Anoka's taenite. A typical field will have a tarnished taenite rim (HV 310 $\pm$ 15) followed by martensitic transition zones (HV 345 $\pm$ 20). The poorly resolvable, duplex interiors are softer (HV 280 $\pm$ 30), and the easily resolvable plessitic cores are as soft as the surrounding kamacite lamellae.

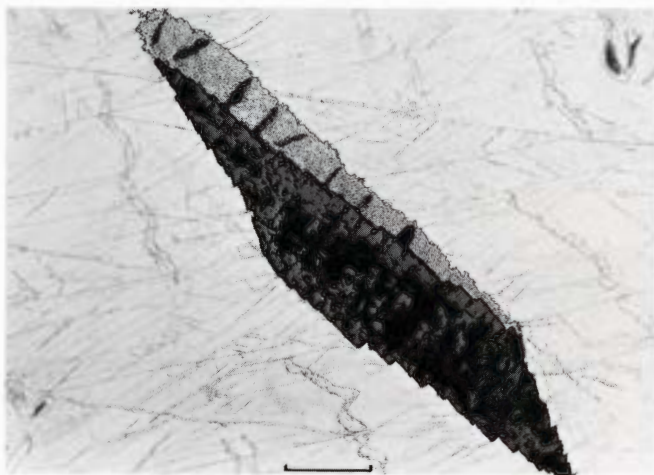
Schreibersite occurs as 10-50  $\mu$  wide grain boundary precipitates and as 5-50  $\mu$  irregular blebs inside the plessite fields. They are often heavily brecciated and displaced their own thickness in successive steps. In many cases the adjacent metal has been able to flow plastically around the sheared phosphides and completely fill in the cavities; in other cases gaping fissures are left.

Troilite is common as large and small nodules, ranging from 55 x 32 mm in size and downwards. On a 700 cm<sup>2</sup>

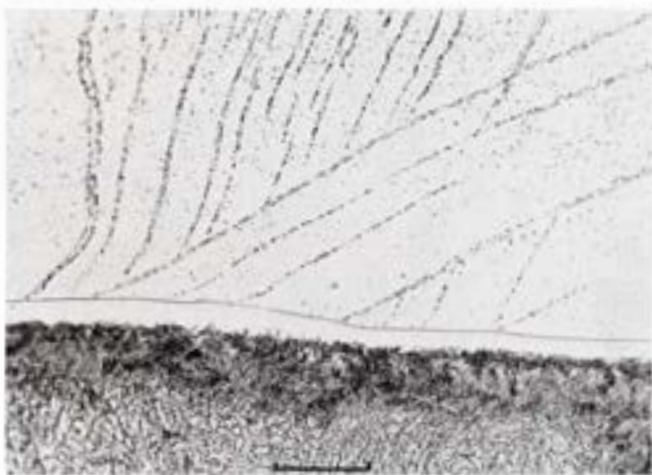
section e.g., there were two nodules 15 x 12 and 10 x 6 mm, one lens 9 x 1 mm, and 22 small blebs 0.5-2 mm in size. The troilite is shock-melted and the included, about 10% daubreelite is likewise melted and redistributed in 1-3  $\mu$  drops. The troilite has dissolved part of the adjacent kamacite and solidified to fine-grained metal-sulfide eutectics. Discontinuous schreibersite bodies, 5-50  $\mu$  thick, that previously rimmed the troilite are now brecciated and dispersed as fragments in the melt. The hardness of the complex is 265 $\pm$ 20. Terrestrial corrosion has converted the metal phase of the near-surface nodules to terrestrial oxides.

Chromite is present in many sections as euhedral crystals, 0.1-1 mm across. They may be situated in the  $\alpha$ -phase or may be associated with the troilite. An unusually large chromite occurs in U.S.N.M. No. 230 which is a full slice. The chromite is at least 5 x 2 x 1.5 cm in size and is associated with a 10 x 6 mm shock-melted troilite nodule. The chromite is brecciated and sheared, some of the distortion apparently having taken place when the surrounding metal was very ductile — perhaps while being in the  $\gamma$ -phase. It is interesting to note that even with the common appearance of chromite and daubreelite, the chromium content of the metallic phases remains low, about 20 ppm (Lovering et al. 1957).

Sacramento is an unusually deformed meteorite. Well polished and etched sections readily show to the naked eye dense slipband systems following the Widmanstätten structure irregularly as 50-200  $\mu$  wide zones of a high hardness. In numerous cases the shear is of the order of 1.5-3 mm with the distinct drag of the taenite and plessite on either side. The deformation is so thorough that it must be due to "geologic" forces on the parent body. The shear forces which deformed the meteorite plastically also introduced a significant number of long fissures in the schreibersite-rich grain boundaries. These fissures crisscross the mass irregularly and are only 10-50  $\mu$  wide. During the violent deceleration in our atmosphere, some fragments may have become dislodged by rupturing along the fissure planes.

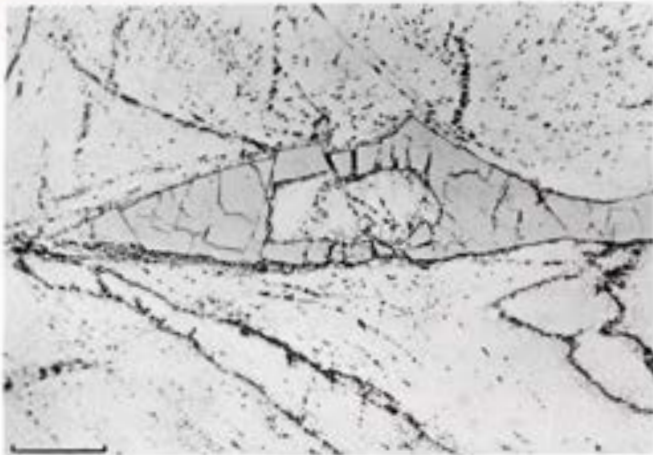


**Figure 1480.** Sacramento Mountains (Copenhagen no. 1905, 1741). A chromite crystal (black) which has been sheared and displaced along successive cleavage planes. The associated troilite (gray) was shock-melted. Kneaded Neumann bands. Etched. Scale bar 300  $\mu$ .

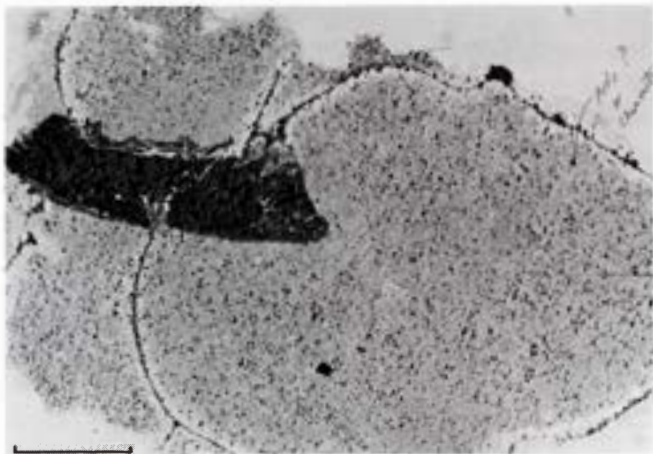


**Figure 1481.** Sacramento Mountains (Copenhagen no. 1905, 1741). The distorted Neumann bands are slightly annealed and decorated with minute precipitates. A plessite field below. Etched. Scale bar 30  $\mu$ .





**Figure 1482.** Sacramento Mountains (Copenhagen no. 1905, 1741). Brecciated schreibersite and incipient recrystallization in the adjacent kamacite. Distorted and decorated Neumann bands. Etched. Scale bar 30  $\mu$ .

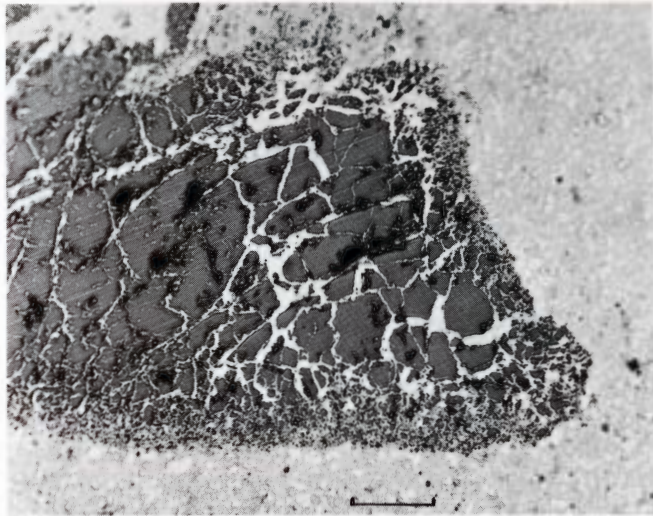


**Figure 1483.** Sacramento Mountains (Copenhagen no. 1905, 1741). Shock-melted troilite nodule with the characteristically curved interior walls and with serrated interfaces against kamacite. The chromite crystal is bent and brecciated. Polished. Scale bar 200  $\mu$ .

Presumably, the two deep cups on the rear face, noted above, were formed by the loss of fragments and subsequent ablational rounding of the cavities.

The heat-affected  $\alpha_2$  zone is 0.5-2 mm thick on the front side but 3-5 mm thick on the rear side. The hardness is  $215 \pm 10$ , and the hardness drops to a minimum of 180 in the transition zone before the unaffected interior (HV  $195 \pm 15$ ) is reached at a depth of 6-10 mm (hardness curve type II). The  $\alpha_2$  zone may be difficult to etch out by routine preparation because the kamacite is so rich in fine precipitates. At low magnification it appears that Neumann bands extend to the very edge of the polished and etched sections. A close examination discloses, however, that the Neumann bands are deleted as usual, but the numerous, tiny gamma beads which lined the bands are unaltered and thus still reveal their original location.

Sacramento is in many respects an interesting meteorite, illustrating a number of important characteristics. It is a



**Figure 1484.** Sacramento Mountains. Detail of Figure 1483. The troilite shock melt was mobile enough to become injected between the fragments of the brecciated chromite crystal. Polished. Scale bar 30  $\mu$ .

normal member of group IIIA, related to, e.g., Chilkoot, Cumpas and Dalton. It is severely deformed, apparently both as a result of relatively slow rate deformation processes and as a result of shocks whereby the troilite inclusions melted. After these two events, a gentle annealing decomposed the Ni- and P-supersaturated kamacite and precipitated fine taenite beads on the Neumann bands; simultaneously fine precipitates were formed in a grid in the taenite. Finally, in passing our atmosphere, the plate-shaped mass developed an oriented flight pattern with normal regmaglypts and shallow  $\alpha_2$  zones on the convex front side and wide  $\alpha_2$  zones on the flat rear side where the ablation rate was lowest. It is proposed that the deep cups are due to the release of fragments along preexisting cracks.

#### Specimens in the U.S. National Museum in Washington:

- 4,400 g slice (no. 230, 61 x 17 x 0.9 cm)
- 346 g part slice (no. 1495, 6.5 x 5 x 1.7 cm)
- 123 g part slice (no. 3021, 8 x 4 x 0.7 cm)
- 195 g part slice (no. 3022, 7 x 5 x 0.8 cm)
- 134 g part slice (no. 3023, 6 x 3.5 x 0.6 cm)
- 255 g part slice (no. 3024, 9 x 4.5 x 0.9 cm)
- 30 g part slice (no. 3365, 3 x 2 x 0.6 cm)
- 992 g slice (no. 3397, 20 x 13 x 1/2 cm)

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### Saint Francois County, Missouri, U.S.A.

Approximately 37° 50'N, 90° 30'W

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Coarse octahedrite, Og. Bandwidth  $2.7 \pm 0.5$  mm. Annealed. HV  $164 \pm 9$ .

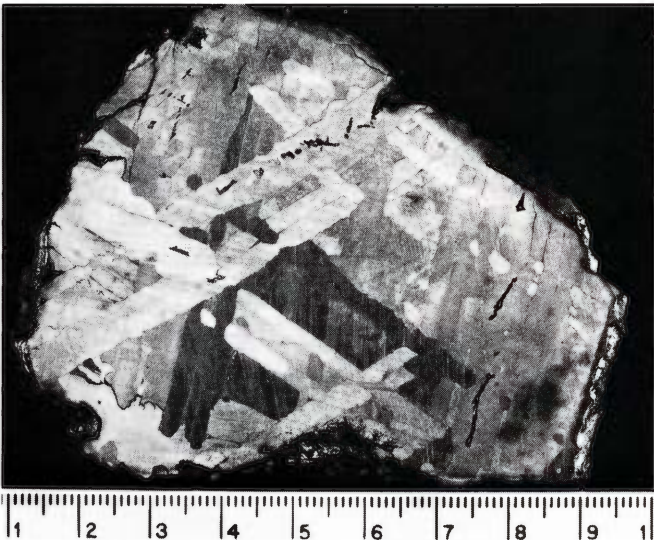
Anomalous. 6.54% Ni, 0.52% Co, 0.34% P, 48.1 ppm Ga, 246 ppm Ge, 0.11 ppm Ir.

Two different coarse octahedrites are in collections under this name; one is a mislabeled Wichita County, and the other is the genuine Saint Francois County.

**HISTORY**

Shepard (1869) reported that in 1863 Professor Shumard had discovered a meteoritic iron, weighing about 12 ounces (340 g) in a mineral collection in St. Louis. Nothing was known of its origin. It was cut and distributed, but apart from brief descriptions by Shepard (1869) and Brezina (1885), apparently no results have been published. During the present study, it was discovered that the material was different from other material called Saint Francois County. Therefore, the examination is treated separately below, under the entry *pseudo Saint Francois County*.

A second specimen was introduced as "Saint Francois County" without further notice as to size, date of find or exact locality. The name appears almost simultaneously in various catalogs (Bement 1894: 14; 750 g; Cohen 1895: No. 119; 34 g; Brezina 1896: 286; 300 g; Tassin 1902a: 693; 275 g). Cohen (1900b: 369) assumed that this material had been made available through the gemmologist, Dr. Kunz. Cohen described and analyzed a 300 g (288 g) specimen from Vienna and a 34 g (30 g) specimen from Greifswald. These were found to be identical and to contain no cohenite, although this mineral had previously been reported by Brezina (1896: 286). Ward (1904a: plate 2) gave a photomicrograph, and Farrington (1915: 391) reviewed the literature. Brett (1967) again reported cohenite to be present, but this could not be confirmed in the present study.



**Figure 1485.** Saint Francois County (Tempe no. 173b). An anomalous coarse octahedrite with numerous schreibersite crystals (black) in the larger kamacite lamellae. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

**COLLECTIONS**

The following specimens came from the second mass: Chicago (no. 866, 749 g), Vienna (300 and 274 g), Tübingen (322 g), New York (no. 65, 312 g), Tempe (no. 173 of 192 and 117 g), Amherst (260 g), Washington (236 g), Budapest (103 g), London (no. 1920, 353 of 4 g). These add up to about 2.1 kg. As shown below, the original specimen must have weighed at least 3.6 kg, so the difference must be due to loss in cutting and the existence of probably several unknown, unrecorded specimens.

**DESCRIPTION**

The following description is based upon the authentic material preserved in Tempe, Amherst, Washington and Chicago.

The largest section I know of is the one to be found in Chicago, measuring 12 x 9.5 cm; other sections measure 12 x 9 cm, 9 x 8 cm or 8 x 7 cm, and an endpiece in Arizona measures 7 x 5 cm and is 1 cm thick. A tentative reconstruction shows the mass to have been a well rounded specimen, averaging 12 x 9.5 x 8 cm and with an approximate weight of 3.6 kg. The fusion crust and the heat-affected  $\alpha_2$  zone are lost due to terrestrial weathering, and corrosion penetrates a few millimeters in along some grain boundaries. Locally, exfoliation along the Widmanstätten boundaries is taking place. The Neumann bands, which have been sensitized by phosphide precipitation, are selectively corroded, and the acicular phase of the near-surface plessite is also corroded.

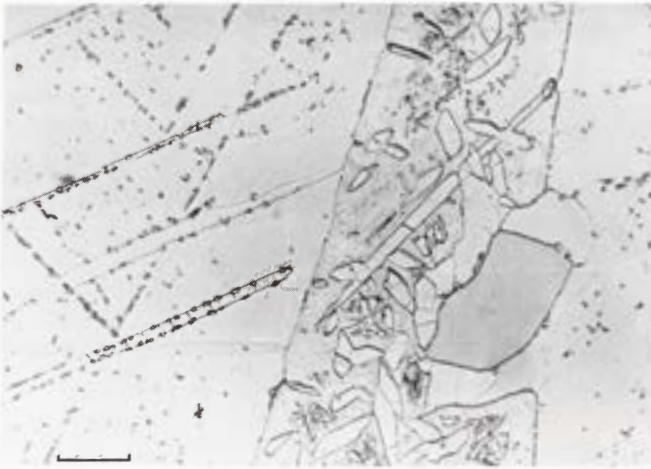
Etched sections display a coarse Widmanstätten structure of straight, long ( $l/w \sim 15$ ) kamacite lamellae with a width of  $2.7 \pm 0.5$  mm. The lamellae are unusually long for



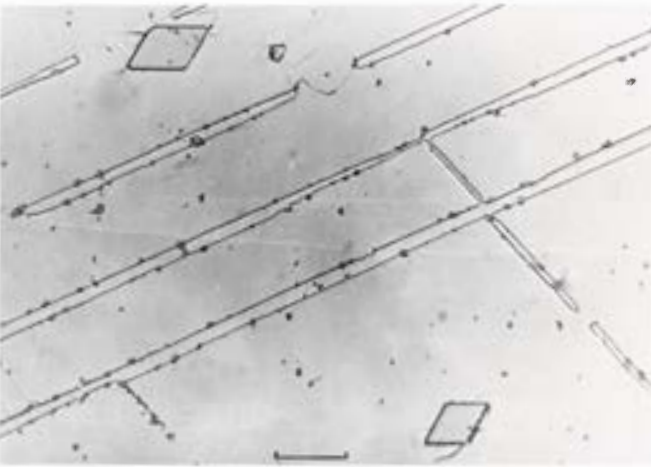
**Figure 1486.** Saint Francois County (Tempe no. 173a). Annealed acicular plessite field with scattered phosphide inclusions (S). The kamacite is subdivided in cells. Etched. Scale bar 100  $\mu$ .

**SAINT FRANCOIS COUNTY – SELECTED CHEMICAL ANALYSES**

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Fahrenheit in Cohen 1900b	6.97	0.52	0.34		100		200					
Wasson 1970a	6.12								48.1	246	0.11	



**Figure 1487.** Saint Francois County (Tempe no. 173a). Annealed acicular plessite and schreibersite with detached  $\gamma$ -particles. Degenerated and decorated Neumann bands. Etched. Scale bar 20  $\mu$ .



**Figure 1488.** Saint Francois County (Tempe no. 173a). Annealed and decorated Neumann bands. Softly rounded rhabdites. Etched. Scale bar 20  $\mu$ .

their width. The kamacite appears to have Neumann bands, but high magnification reveals that they are under decomposition to dense tangles of subboundaries or, in other places, have been fixed in position by the precipitation of 0.5-2  $\mu$  thick phosphides. Subboundaries are extremely common, frequently forming cells in the kamacite lamellae as small as 2-5  $\mu$  across. The hardness is 164 $\pm$ 9, indicating that a significant cosmic annealing has taken place.

Taenite and plessite cover about 35% by area, often as very large and very degenerated fields (e.g., 12 x 6 mm) in which little taenite is left at all. The smaller fields show an acicular plessite type in which 2-10  $\mu$  wide  $\alpha$ -needles form a Widmanstätten felt in a martensitic background. The hardness of these duplex fields is low, 200 $\pm$ 10.

Schreibersite occurs in a rather unusual way, which has led many observers to identify it as cohenite. It forms elongated bodies, typically 6 x 0.3 mm or 10 x 0.5 mm, located centrally in the widest kamacite lamellae. It is monocrystalline and somewhat brecciated and has a hard-

ness of 900 $\pm$ 40. Schreibersite also forms 10-100  $\mu$  wide grain boundary precipitates and 1-40  $\mu$  inclusions in the plessite fields. Rhabdites are very common as 5-20  $\mu$  tetragonal prisms; an occasional plate 1.5 x 1 x 0.01 mm in size is also present. The rhabdites display rounded edges to a varying extent, due to annealing.

Troilite is rare, but in a few places there are indications that 0.1-0.2 mm nodules with daubreelite inclusions were previously present. The troilite is finely disseminated in the iron phase around the original location, while the daubreelite has remained in place. The morphology suggests a shock melting and dissipation of the troilite. Similar structures are present in Willamette.

Saint Francois County is structurally anomalous by its bandwidth and high volume percentage of fields for this 6.5% Ni level. Late cosmic events – possibly a shock followed by cosmic reheating – have annealed and partly recrystallized the meteorite, resulting in various interesting structures. Wasson's trace-element data support the interpretation of the mass as an anomalous one, standing apart from the bulk of group I, and perhaps resembling Arispe and Bendego a little.

#### Specimens in the U.S. National Museum in Washington:

236 g slice, now divided (no. 130, 9 x 8 x 0.5 cm)  
34 g fragment (no. 1616, 3 x 2.5 x 1.2 cm)

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### pseudo Saint Francois County, or Southeast Missouri, U.S.A.

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Coarse octahedrite, Og. Bandwidth 2.0 $\pm$ 0.4 mm. Neumann bands. HV 175 $\pm$ 6.

Group I, judging from the structure. About 7.0% Ni, 0.2% P.

It is concluded here that the small mass is a fragment of Wichita County.

#### HISTORY

A mass of about 12 ounces (340 g) was found in a mineral collection in 1863 and was identified as a meteorite by Professor Shumard. Sections which were sent to Shepard were described by him (1869) but nothing could be learned of the origin except that the label in the St. Louis mineral collection had stated the specimen originated in southeast Missouri. It was cut and distributed by Shumard and possibly subdivided and further distributed by some of the recipients. In due time, the following places received small specimens which, however, were very insufficiently described: London (no. 35414), Vienna (Brezina 1885: 215 and 216, 239), Yale (Dana 1886: no. 135), Harvard (Huntington 1888: 82), Washington (Clarke 1889: 262) and Paris (Meunier 1893a: 248). In Shepard's handwritten notebook from 1884 (in the Smithsonian Archives) his 5.4 g specimen is entered as "Bates County, Southeast Missouri, 1864." Apparently because Bates County lies in midwestern Missouri, a later handwritten list of Shepard's

Collection only says “South East Missouri, 1863.” The origin remains obscure.

About 1890, when a complete sample of about 3.6 kg turned up, both kinds of material were united under the entry Saint Francois County (Brezina 1896: 286; Wülfing 1897: 301; Farrington 1915: 391), evidently without any good reason at all. All the specimens in collections are now relabeled Saint Francois County, but it should be possible to segregate the two kinds of material again on the basis of the description below and with the help of old labels and acquisition numbers.

#### COLLECTIONS

The following is a tentative reconstruction which should be checked by the individual curators: London (no. 35414 of 102 g), Yale (no. P47 of 68 g), Harvard (no. 275 of 27 and 17 g), Vienna (23 and 4 g), Paris (about 10 g), Washington (5.4 g). Today, there is nothing in the St. Louis collection.

#### ANALYSIS

No analysis is available. From the structure, I would estimate about 7% Ni, 0.2% P, 0.5% C, and trace elements corresponding to a typical group I, such as Wichita County or Bohumilitz.

#### DESCRIPTION

The following is based on the small fragment of 5.4 g in the U.S. National Museum. It is authentic material since it has been acquired with Shepard's Collection, under the old number 64 (Clarke 1889: 262) and the revised number 72 (Merrill 1916a: 93). Unfortunately, the name was changed about 1900 from Southeast Missouri to Saint Francois County.

The specimen is a fragment which has not been damaged by artificial reheating. The fusion crust and the heat-affected  $\alpha_2$  zone have apparently been removed by terrestrial corrosion. Corrosion also penetrates along grain boundaries and has, e.g., converted ferrite around graphite to limonite. Shumard (quoted by Shepard, 1869) noted that the material had been hammered.

The etched section corresponds structurally to Wichita County in every respect. The specimen is a coarse octahedrite with a bandwidth of  $2.0 \pm 0.4$  mm. There are numerous subboundaries in the kamacite decorated with  $0.5\text{--}5\ \mu$  rhabdites. There are undecorated Neumann bands in profusion, and the microhardness is  $175 \pm 6$ .

Taenite and plessite cover 2-4% by area; comb plessite is present, but pearlitic plessite ( $0.5\text{--}2\ \mu$  wide  $\gamma$ -lamellae) and spheroidized plessite ( $5\text{--}20\ \mu$  spherulitic  $\gamma$ ) are more common. The tarnished taenite rims have hardnesses of  $200 \pm 15$ , while the bainitic-martensitic interiors have hardnesses of  $310 \pm 15$ .

Schreibersite occurs as  $10\text{--}60\ \mu$  wide grain boundary folia. Large schreibersite crystals and typical rhabdites are absent in the section which is cohenite-rich.

Cohenite occurs as  $6 \times 0.8$  and  $4 \times 0.7$  mm rounded crystals, elongated according to the Widmanstätten pattern. They contain the normal “windows” of  $\alpha$ ,  $\gamma$  and schreibersite,  $10\text{--}50\ \mu$  across. The cohenite has a hardness of  $1120 \pm 50$ . It is partially decomposed to graphite and ferrite – both along cracks and along schreibersite-cohenite interfaces which perhaps also contained some fissures. The graphite forms plumose aggregates,  $600 \times 10\ \mu$  in size, enveloped in a  $20\text{--}40\ \mu$  wide layer of serrated ferrite crystals.

As mentioned before, all the details are in agreement with the structure of Wichita County. Since this is a rather unusual coincidence, I examined the little we know of the origin more closely. It turns out that the Wichita County meteorite was first brought to public attention by Shumard (1860) who had acquired material for examination in the late 1850s. In the mid 1860s, Shumard was again active in meteoritics – this time distributing small specimens of a fragment which had been “discovered in the museum of the Academy of St. Louis.” Shumard was a professor of the St. Louis Academy of Sciences and had found the fragment labeled “Southeast Missouri” among minerals that belonged to the old Western Academy of Sciences. It appears that somehow – perhaps during rearrangement of the collections – an original Wichita County specimen, acquired by Shumard, was later rediscovered by him and presented with a new locality name.

#### Specimen in the U.S. National Museum in Washington:

5.4 g fragment (no. 1128,  $20 \times 19 \times 2$  mm)

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#### Saint Genevieve County, Missouri, U.S.A.

$37^\circ 58'N, 90^\circ 19'W; 225$  m

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Fine octahedrite, Of. Bandwidth  $0.49 \pm 0.07$  mm. Neumann bands. HV  $208 \pm 10$ .

Anomalous. 7.94% Ni, 0.37% Co, 0.22% P, 6.7 ppm Ga, 0.79 ppm Ge, 1.8 ppm Ir.

The Abancay meteorite is, no doubt, a mislaid slice of Saint Genevieve County.

#### HISTORY

A mass of 244 kg (539 pounds) was found in 1888 by Z. Murphy about one mile west of Punjaub in the extreme western portion of Saint Genevieve County. Murphy, a surveyor, retained the meteorite for several years, showing it at county fairs, etc. It was eventually purchased by Ward who described it (1901b) and gave photographs of the exterior and of an etched section. Cohen (1905: 372) examined the specimens in Vienna and Greifswald, and Brezina & Cohen (Atlas 1886-1906: plate 33) presented a photomicrograph. Further photomicrographs were published by Mauroy (1913: plate 2) and by Nininger & Nininger (1950: plate 3). Voshage (1967) found the concentration of  $^{40}K$  and  $^{41}K$  too low for a cosmic ray age determination.



come from atmospheric ablation heat, from rough cutting of small slices and probably, in particular, from some genuine cosmic reheating. At the moment it is not quite clear whether the phenomenon is restricted to zones up to 30 mm below the surface where I have noted it, or whether it extends right through the mass and thus would be an indication of thorough cosmic annealing.

Schreibersite occurs as an occasional 0.2 mm crystal but is much more common as 10-60  $\mu$  wide grain boundary veinlets and as 2-40  $\mu$  blebs inside the plessite fields. Rhabdites were not observed. Troilite is present as nodules and rhomboidal bodies, ranging from 1-9 mm in diameter. They have discontinuous, 10-50  $\mu$  wide schreibersite rims and swathing kamacite rims, 0.5-1.0 mm wide. Numerous, parallel daubreelite lamellae, ranging from 1-100  $\mu$  in thickness are precipitated in the troilite; they cover about 15% by area. The troilite is monocrystalline, without deformation twins, and has a hardness of 250 $\pm$ 15. In addition to the lamellae, daubreelite is present in troilite as 10-150  $\mu$  euhedric crystals in the kamacite lamellae.

Saint Genevieve County is a fine to medium octahedrite with a very unusual bandwidth of 0.5 mm. Only Moonby displays a similar bandwidth and chemistry. Moonby was, unfortunately, artificially reheated so a detailed structural comparison is not possible. The two irons are, however, closely related. As discussed below, Abancay is a mislaid and mislabeled Saint Genevieve specimen.

#### Specimens in the U.S. National Museum in Washington:

109 g part slice (no. 454, 5 x 3 x 1.4 cm)  
413 g part slice (no. 3026, 9 x 7.2 x 0.8 cm)  
839 g part slice (no. 3366, 12.5 x 10 x 0.8 cm)

### Saint Genevieve (Abancay)

Fine octahedrite, Of. Bandwidth 0.49 $\pm$ 0.07 mm. Neumann bands. HV 210 $\pm$ 15.

Anomalous. 7.85% Ni, 0.37% Co, 0.18% P, 6.59 ppm Ga, 0.78 ppm Ge, 1.8 ppm Ir.

A mislaid and mislabeled Saint Genevieve specimen.

#### HISTORY

This iron was first mentioned by Nininger & Nininger (1950: 26) who had acquired a 156 g slice. The date of find and the total weight were not given, but the locality was reported as Abancay, which is near Cuzco in the High Andes Mountains. The meteorite is undescribed but well analyzed under the name Abancay.

#### COLLECTIONS

London (Brit. Mus. no. 1959, 968 of 79 g), Tempe (no. 209ax of 75 g). When about half of Dr. Nininger's collection was purchased by the British Museum in 1959, the 156 g slice was divided into two equal slices, as was the case with a large number of other specimens. Specimens originally in the Nininger Collection now in the British Museum may be recognized by their acquisition numbers which range from 1959, 754 to 1959, 1056 (Dr. Hutchison, personal communication 1972).

#### DESCRIPTION

The specimen in Tempe is a slice 5 x 4 x 0.5 cm in size, which now weighs 64 g, after material has been removed for the recent analyses. The original surface is present along two of the four sides; it is weathered and covered with a thick (0.1-0.2 mm), loosely adhering crust of terrestrial oxides. No fusion crust and no heat-affected  $\alpha_2$  rim zones are preserved. From the shape of the section it may be estimated that the unknown main specimen was larger than 2 kg, but an upper limit is, of course, impossible to derive.

The etched section displays a fine to medium Widmanstätten structure of straight, long ( $\bar{w} \sim 25$ ) kamacite lamellae with a bandwidth of 0.49 $\pm$ 0.07 mm. The kamacite has numerous, marked subboundaries upon which are precipitated many rod-shaped phosphides, 0.5-3  $\mu$  in thickness. Neumann bands are common, and the microhardness (100 g) of the kamacite is 210 $\pm$ 15.

Taenite and plessite cover about 40% by area – mainly in the form of open-meshed fields of comb and net plessite. The taenite of the plessite fields is frequently spheroidized to 2-10  $\mu$  blebs, and the rims around the fields may be discontinuous. The taenite has a hardness of 250-300; and the duplex interiors of  $\alpha + \gamma$  ("black taenite"), a hardness of 225-275. Around several of the dark-etching taenite-plessite fields the kamacite lamellae display slipbands and dislocations that are decorated with submicroscopic precipitates of carbides and/or phosphides. The phenomenon is discussed under Saint Genevieve County above.

Schreibersite occurs as a few, scattered 0.2 mm wide crystals centrally in the kamacite, but it is particularly common as 10-50  $\mu$  wide grain boundary precipitates and as 5-30  $\mu$  blebs inside the plessite fields. Rhabdites are absent. Troilite was not observed, but daubreelite is present in the kamacite as scattered, 10-100  $\mu$  thick euhedric, bluish crystals.

Abancay is a fine to medium octahedrite with a very unusual bandwidth of 0.5 mm. Only a few other meteorites

#### SAINT GENEVIEVE (ABANCAY) – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				Pt
	Ni	Co	P					Zn	Ga	Ge	Ir	
Moore & Lewis 1968	7.94	0.37	0.18	75	10		180					
Wasson 1969, pers. comm.	7.78								6.59	0.78	1.8	

display this bandwidth, notably Moonbi and Saint Genevieve County. Of these two, Saint Genevieve is structurally so closely related to Abancay that it is impossible to find any differences at all. The analytical data for the two irons, for both major and trace elements, agree surprisingly well. The hardnesses of all phases are identical. The state of corrosion is identical. The Abancay specimen I studied, Tempe No. 209.ax, is even cut through the parent taenite crystal in exactly the same direction as several Saint Genevieve specimens also examined by the author, a fact which is a surprising coincidence.

Having noted these facts, I asked for Dr. Nininger's advice. In a letter of February 20, 1970, he answered:

"The specimen, so labelled, lay in the Ward Natural History Establishment on occasion of several of my visits, but no one could give any further information. Finally in one of our exchanges I received it hoping to be able to find some information, but never did. If your surmise is correct then somebody must have made a wild mistake somewhere. After their big fire some problems of labeling plagued them . . ."

It appears to me that the evidence for Abancay being an individual, separate meteorite is very meager indeed. The fragmentary nature and the fact that the specimen originally came from Ward's, who at various occasions cut Saint Genevieve material, indicate strongly that Abancay is a mislaid Saint Genevieve specimen. Perhaps the name Abancay was originally attached to some mineral specimen, which after the fire (September 30, 1930) was interchanged with the meteorite slice. Tambo Quemado is the only other recorded meteorite from Peru and this is definitely different from Saint Genevieve (Abancay).

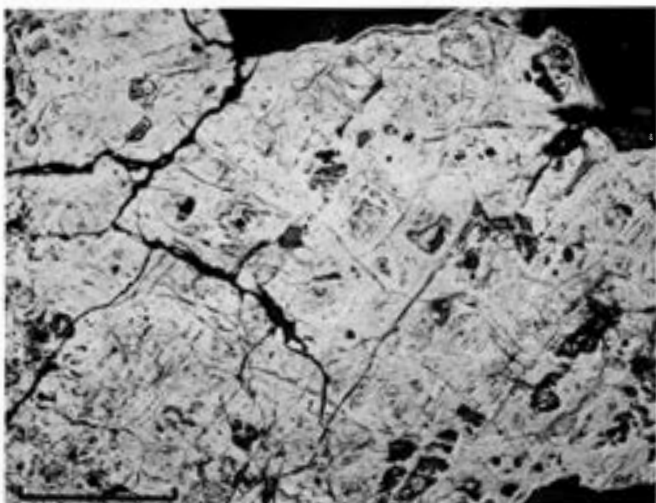
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### Salina, Utah, U.S.A.

38°59'N, 111°51'W

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A number of shale-balls, up to 2 kg in weight, were found about 1908 around a small depression in the Pahvant Mountains, 15 miles



**Figure 1490.** Salina (U.S.N.M. no. 1272). This meteorite is converted to limonite, except for some minute patches, only visible under the microscope. Scale bar 10 mm. (Perry 1944: plate 77.)

from Salina, Sevier County. Only one completely weathered fragment of 235 g has been preserved. It was described by Perry (1939c; 1944: plate 77), who cautiously concluded that the material was originally a medium octahedrite. Buddhue (1957: 121) briefly discussed the material.

#### Specimen in the U.S. National Museum in Washington:

221 g fragment (no. 1272, 6 x 4 x 4 cm). The only known sample.

### Salta. See Imilac (in the Supplement)

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### Salt River, Kentucky, U.S.A.

Approximately 38°0'N, 85°45'W; 150 m

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Plessitic octahedrite, Opl. Spindle-width  $70 \pm 20 \mu$ . Artificial  $\alpha_2$ . HV 178±8.

Group IIC. 9.80% Ni, 0.57% Co, 0.43% P, 39 ppm Ga, 99 ppm Ge, 6.6 ppm Ir.

As discussed in the following entry, Tocavita also belongs here. All specimens have been artificially reheated to about 1000 or 1050° C.

#### HISTORY

A mass of unknown weight was found by J. Watters near Salt River, a tributary of the Ohio, about 20 miles south of Louisville. The mass was "heated in a forge by its original proprietor, to remove a portion, and, in this process, the original form was somewhat defaced" (Silliman 1850). When the main mass reached Silliman, it weighed 3.6 kg, but material from the same mass was still said to be in private possession. The total weight may have been about 4 kg, estimating from the early descriptions and from what is preserved in collections. Silliman described and analyzed the material, and Rose (1864a: 70) examined the specimen in Berlin. Reichenbach (1859: 175; 1862b: 578) discussed the iron at several occasions. Cohen (1900a: 74; 1905: 275) presented a new analysis and, in his description, compared Salt River to Tocavita and Ballinoo. Brezina & Cohen (1886-1906: plate 30) gave three photomicrographs and again emphasized the remarkable resemblance to Tocavita. Also Buchwald & Wasson (1968: 23) noted this similarity and expressed the opinion that Tocavita might be mislabeled Salt River material. They presented two photomicrographs (Figures 15 and 16) to show how the artificial reheating had altered the material.

#### COLLECTIONS

Yale (751 g), London (492 g), Harvard (272 g), Amherst (148 g), Washington (111 g), Chicago (79 g), Tübingen (61 g), New York (60 g), Calcutta (48 g), Vienna (45 g), Paris (34 g), Tempe (34 g), Stockholm (27 g), Dresden (20 g), Berlin (19 g), Ottawa (17 g), Göttingen (13 g), Vatican (11 g), Strasbourg (7 g). Of "Tocavita:" Tübingen (No. 2220 of about 300 g; No. 2294 of 22 g), Chicago (No. 1155 of 15 g).