Arispe, Sonora, Mexico

30°31′30″N, 110°22′W

Coarse octahedrite, Og. Bandwidth 2.9±0.5 mm. Neumann bands. HV 175±10.

Anomalous. 6.70% Ni, 0.47% Co, 0.3% P, 51 ppm Ga, 260 ppm Ge, 9 ppm Ir.

HISTORY

A specimen of 124 kg (272 lbs) was found in 1898 in the rugged mountains 15 miles northwest of Arispe. It was later brought to Denver and described by Wuensch (1903) and by Ward (1902b), who cut most of it in parallel slices 1-2 cm thick. An endpiece of 32.7 kg is now in Chicago, a large slice of 11.4 kg is in the Colorado Museum of Natural History at Denver, and another full slice of 9.6 kg is in the U.S. National Museum. Two masses found in 1896, 25 miles northwest of Arispe (Farrington 1914) weighing 116 lbs (B) and 20 lbs (C), respectively, are now in the U.S. National Museum (no. 325, undivided) and Chicago (no. 781, 1 kg cut from it).

Six masses were acquired by Nininger between 1927 and 1953. They weighed 30.9 kg (D), 9 kg (E), 22.6 kg (F), 51.8 kg (G), 19.5 kg (H) and 60.3 kg (I). A field survey disclosed no craters but located at least three areas where specimens had been recovered through the years. One of these was about 3 km north of the Santa Rosalia mine, and two others were 11 and 16 km northwest of the site of the first find in 1898 (Nininger, personal communication).

Two further masses of 18.6 kg (J) and 31.2 kg (K) were recovered through the Hawley Brothers, assayers of Douglas, Arizona, and the last mentioned was analyzed by F.G. Hawley (Buddhue 1950). A 122 kg mass (L) that had been used as an anvil in Hermosillo, Sonora, was taken from Arispe on muleback sometime between 1910 and 1912. This is now undivided in the Tempe collection and has been figured by Nininger & Nininger (1950: plate 19).

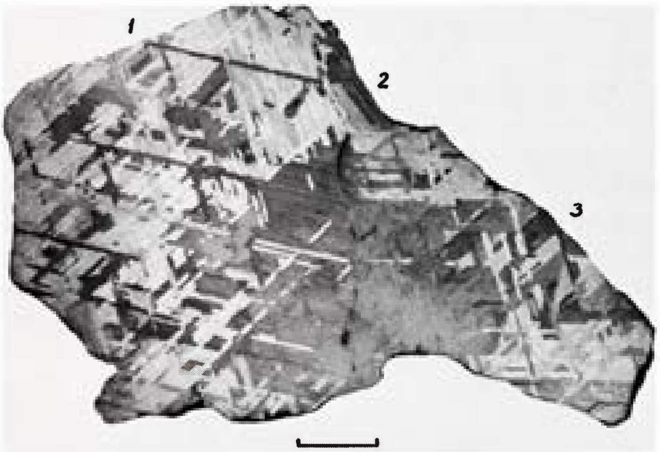

Figure 262. Arispe (U.S.N.M. no. 299). Section through the 124 kg mass, A. The meteorite is composed of several large precursor austenite grains of which three are seen in the photo. Etched. Scale bar 50 mm. S.I. neg. 1353C.

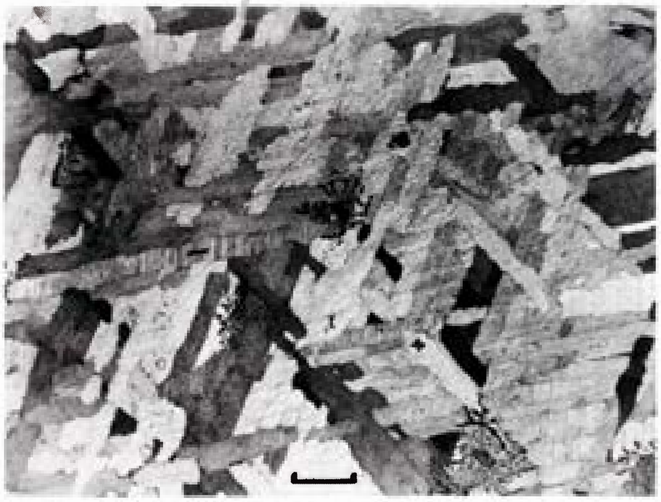

Figure 263. Arispe (U.S.N.M. no. 299). Detail of foregoing, showing coarse octahedrite structure and several cohenite nests. Etched. Scale bar 10 mm.

ARISPE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Hawley in Buddhue 1950	6.80	0.45	0.31	140	200		200				15.8*	
Goldberg et al. 1951	6.97	0.49							55.6			
Lovering et al. 1957		0.48				46	110		51	233		
Nichiporuk & Brown 1965											7.6	17.2
Smales et al. 1967						14	112	7.3	51	229		
Moore 1968, pers. comm.	6.69	0.46	0.31									
Wasson 1968, pers. comm.	6.54								50.8	260	9	

*The value is from Hawley (1939) and includes all platinum metals.

Three masses of 17.9 kg (M), 69.8 kg (N) and 22.0 kg (O) were acquired by the U.S. National Museum in 1938 and 1939. As late as 1954 a mass of 22.6 kg (P) was reportedly found in the same general area.

It thus appears that Arispe was an important shower of iron meteorites, comprised of at least 16 individuals ranging from 123 kg downwards, and scattered over a 20 km "line" extending from Mount San Antonio southeasterly toward Arispe. The coordinates for the midpoint of this line are those given above. The accumulated weight of specimens A-P is 683 kg, which appears to be a conservative minimum estimate of the Arispe shower.

Short descriptions with photomacrographs have appeared on several occasions: Ward (1902b), Wuensch (1903), Merrill (1916a: plates 12, 33), Perry 1944: plate 1), Nininger & Nininger (1950: plates 2, 19), Nininger (1952a: plate 5) and Mason (1962a: figure 52). Short & Andersen (1965) measured in detail the composition of the kamacite and taenite phases, and Frost (1965a) used Arispe as an example for calculating the bandwidth of octahedrites. Stoenner & Zähringer (1958) found by the K/A method the very high age of 6.8 x 10^9 years; the method is, however, unreliable (Rancitelli & Fisher 1968). Schaeffer & Fisher (1960) estimated the cosmic ray exposure age to be 340 million years, using the data of Schaeffer & Zähringer (1960). Vilcsek & Wänke (1963) found a ^{36}Ar/^{36}Cl cosmic ray exposure age of 440±30 million years, a value revised by Chang & Wänke (1969) to 270±40 million years, based upon ^{36}Ar/^{10}Be. The ^{21}Ne/^{26}Al method, as developed by Lipschutz et al. (1965) gave, however, only 120±20 million years, while the ^{40}K/^{41}K method (Voshage 1967) gave 905±90 million years. At the present time it is difficult to decide which method is most reliable. Hintenberger & Wänke (1964) measured the concentration of various noble gas isotopes.

COLLECTIONS

Washington (178.7 kg), Tempe (122.3 kg anvil, L; 13.4 kg endpiece of D; 1.66 kg slice of I); London (39.9 kg and 1.89 kg), Chicago (32.7 kg endpiece of A; 8.0 kg of C; 1.46 kg slices), Denver (11.4 kg slice of A; 4.6 kg; 8.4 kg), Vienna (13.8 kg), Utah (11.0 kg), Tucson (5.19 kg endpiece; 1.40 kg slice), New York (6.1 kg), Albuquerque (2.8 kg), Mainz (2.3 kg slice of I), Ann Arbor (1.8 kg), Mexico City (1.20 kg part slice of A), Helsinki (0.63 kg part slice of A), Harvard (0.57 kg), Budapest (0.50 kg), Canberra (0.45 kg), Tübingen (0.2 kg), St. Louis (0.05 kg), Copenhagen (54 g).

DESCRIPTION

The single fragments range in size from 50 x 35 x 25 cm (A) to 20 x 15 x 10 cm (C). They are irregular and rounded with poorly developed regmaglypts. Small-scale corrosion has been active, but apparently has not removed more than a few millimeters as the heat-affected rim zone is preserved on parts of many specimens. The 69.8 kg uncut specimen (N) displays a 25 mm wide and 25 mm deep cavity where troilite was burned out in the atmosphere. The wall of the cavity is still covered with a corroded fusion crust.

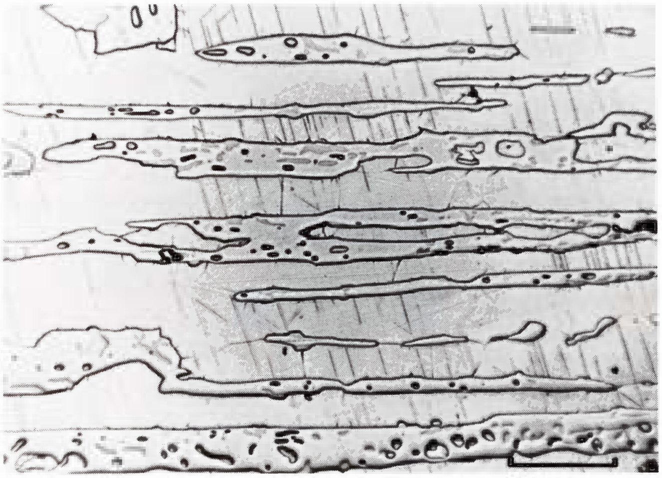

Figure 265. Arispe (Tempe no. 9.47). Elongated cohenite crystals, which stand in high relief due to their hardness. HV 1075±25. Etched. Scale bar 400 μ.

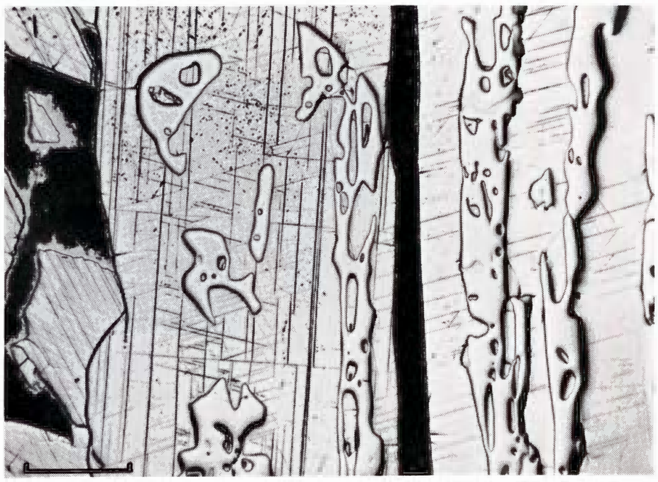

Figure 264. Arispe (Tempe no. 9.47). Elongated cohenite crystals, kamacite with Neumann bands, and pearlitic plessite (black). Etched. Scale bar 400 μ.

Figure 266. Arispe (Tempe no. 9.47). Branching cohenite crystal with inclusions of kamacite, taenite and schreibersite. Etched. Scale bar 400 μ.

The large specimen (A), which was extensively cut by Ward (1902b), shows a polycrystalline nature, with original austenite individuals up to 25 cm in diameter. The grain boundaries are clearly indicated by elongated troilite bodies 2-5 mm wide. On both sides of the grain boundary the α-lamellae are narrowly bundled, only one direction of the Widmanstätten pattern dominating at a time. This is probably because the α-lamellae nucleated heterogeneously at the grain boundary and grew inwards in parallel bundles until they came in contact with homogeneously nucleated lamellae in the interior of the grains. Quite similar development around the grain and twin boundaries may be observed in many other polycrystalline irons, e.g., Gibeon and Savannah.

The width of the α-lamellae is 2.9±0.5 mm. Neumann bands are common; they are somewhat indistinct and appear to be decorated along both sides with submicroscopic precipitates. This observation is supported by the fact that Neumann bands are sometimes selectively corroded near the surface, a phenomenon which I believe only occurs when microsegregation has created a chemical potential. The kamacite has a microhardness of 175±10; this decreases to a minimum of 145±10 at the transition to the heat-affected rim zone, which is 185±10 hard. Where cohenite has provided carbon for local martensite-bainite formation, it is still much harder.

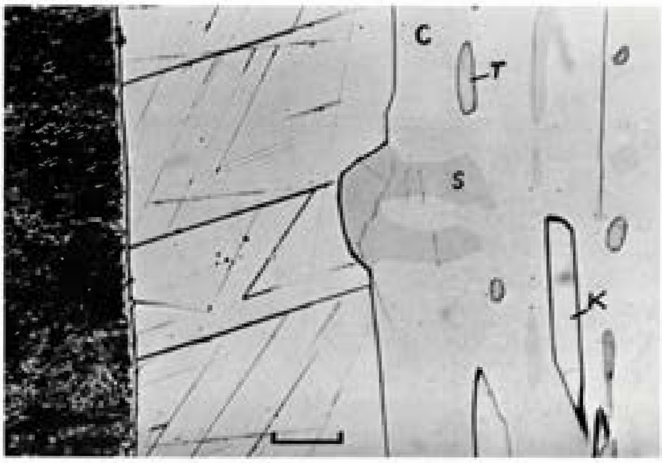

Figure 267. Arispe (Tempe no. 9.47). Detail of cohenite (C) with schreibersite (S), kamacite (K) and taenite (T) inclusions. To the left, dark pearlitic plessite. Etched. Scale bar 50 μ.

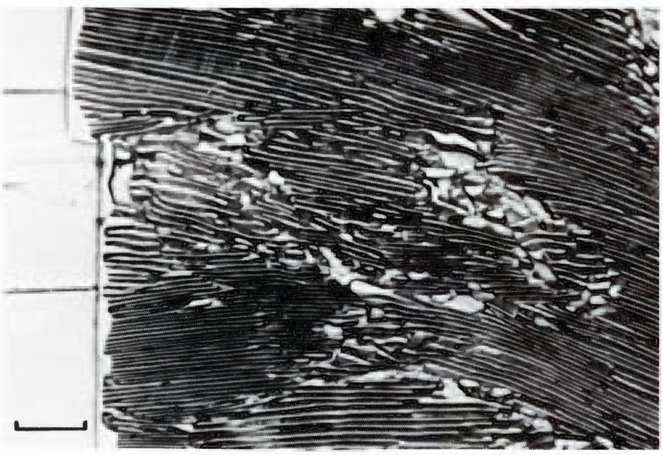
Figure 268. Arispe (Tempe no. 9.47). Pearlitic plessite. The kamacite of the lamellar structure is partially etched away, so that the taenite lamellae stand in distinct high relief. Scale bar 20 μ.

Troilite inclusions 1-3 mm in diameter are irregularly distributed. On 10 sections totaling 3,115 cm^2, 59 nodules were encountered with a total area of 15.9 cm^2, corresponding to an average content of 0.11% S in the meteorite. Troilite in the interior of the grains is in the form of well-rounded nodules while in the grain boundaries it occurs as elongated, rounded bodies. In one troilite nodule, a hard, black, angular mineral 3 x 2 mm was included; by visual inspection it was determined to be either chromite or a phosphate, like the sarcopside described from Bella Roca (Olsen & Fredriksson 1966). The smaller troilite nodules (0.1-0.5 mm) have been shock melted and now display a polycrystalline array of intergrown troilite, daubreelite and metal with 5-10 μ grain size.

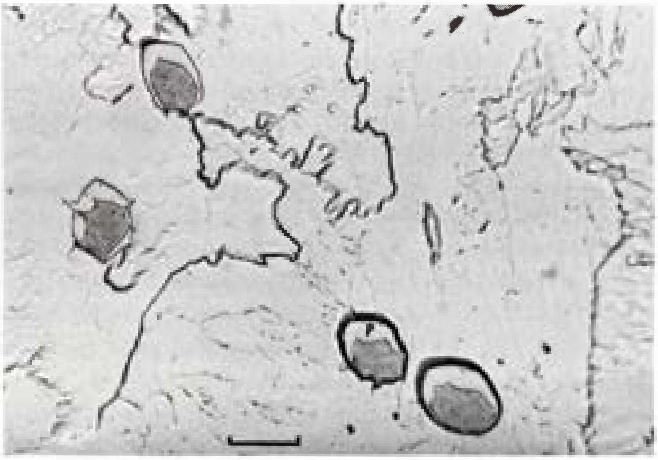
Figure 269. Arispe (Tempe no. 9.47). Detail of the heat-affected α_2 zone with melted rhabdites. These solidified by heat conduction from the interior (above), so that the primary solidification products (P) grew from the interior sides of the walls. Etched. Scale bar 20 μ.

Schreibersite with a microhardness of 960±30 is present as laths and hieroglyphs, typically 5 x 1 mm in size, positioned centrally in the α-lamellae. It also occurs as 20-50 μ wide grain boundary precipitates, and envelops the troilite with 100-300 μ thick rims. Rhabdites are abundant as 5-20 μ thick prisms. A most unique characteristic of Arispe is the distribution of the cohenite nests. They occur as 1-2 cm^2 arborescent, palmate or feathery aggregates which are spaced with approximately one per 50 cm^2. Each branch may be 100 μ thick and may itself include tiny schreibersite, ferrite and taenite bodies. These cohenite complexes never are located near the original austenite grain boundaries, but apparently occur where carbon-saturated residual austenite became concentrated. Cohenite is also present as a 100-200 μ thick envelope around the larger schreibersite bodies. The microhardness is 1075±25.

As is always the case when iron meteorites are rich in carbon, the plessite is frequently pearlitic with single lamellas being about 1 μ thick. Plessite and taenite, however, are not abundant in Arispe, covering only about 2%, in harmony with the low overall nickel content of 6.7% Ni.

Carbon and sulfur determinations by Buddhue (1950) apparently represent inclusion-free material. A modest quantity of carlsbergite in the form of 5 x 1 μ hard, oriented particles occurs in the kamacite phase.

On several specimens the rim zone from atmospheric heating was observed. Due to lack of cutting data, however, it is not known if both primary and secondary surfaces developed a heated transformation zone. Heating was intense enough to create a 4 mm thick α_2 zone, with melted phosphides in the exterior 50%. The cohenite melted to form ledeburite eutectics where the temperature was briefly above 1100° C. Farther in, carbon diffused out from the cohenite to create 20-50 μ thick, black-etching borders of bainitic-martensitic structures. Even a 100-500 μ thick, laminated fusion crust of dendritic iron may be found locally.

Occasionally, plastic deformation is observed over some square centimeters near the surface. The Widmanstätten structure with Neumann bands is elongated and/or curved as if a tensile test had been carried out. The included rhabdites are broken and arranged en-echelon because of their nonconformity with the plastic metal. The structure is best interpreted as caused by the breakup in the atmosphere of the main mass. Although part of the fracture would follow brittle inclusions and grain boundaries, the fracture zone occasionally would have to pass metallic areas, thus giving rise to a tensile fracture with local elongation and necking. Individuals from other showers show similar plastic features which in my opinion may be caused by the same series of events. Particularly illustrative specimens are found among Gibeon fragments.

Chang & Wänke (1969) found the terrestrial age of Arispe to be 240,000±50,000 years by measuring the decay rates of ^{36}Cl and ^{10}Be. This is a surprisingly high age for an iron that still retains considerable parts of its heated rim zone, and it is hard to explain even considering the (present) aridness of the place of find, the Sonoran Desert zone, where only ocotillo, catclaw and cacti thrive.

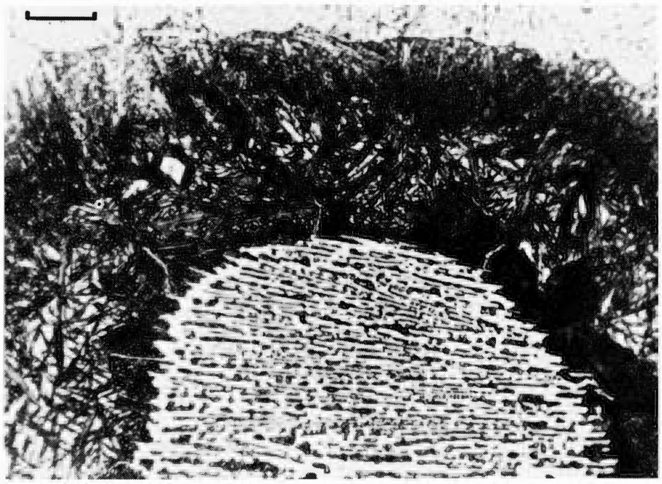

Figure 270. Arispe (Tempe no. 9.47). Cohenite crystals in the exterior part of the heat-affected α_2 zone melted rapidly and solidified to ledeburitic structures. Acicular carbon-nickel martensite surrounds the melted material. Etched. Scale bar 20 μ.

In summary, Arispe is an unusual meteorite, with the same Ga-Ge content as group I meteorites like Toluca and Bischtübe, but with considerably less nickel and more iridium. The bandwidth is 2.9 mm, double that of Toluca and Bischtübe, and the cohenite nests are a unique feature. The polycrystallinity is rare, but far from extraordinary. Bendego may be a related iron.

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

9.6 kg slice (no. 299, 44 x 30 x 1.5 cm, part of A)
52.5 kg individual (no. 325, 35 x 20 x 13 cm, B)
17.9 kg individual (no. 1313, 19 x 16 x 11 cm, M)
69.8 kg individual (no. 1327a, 35 x 20 x 20 cm, N)
22.0 kg individual (no. 1327b, 25 x 19 x 18 cm, O)
4.63 kg endpiece (no. 826, 22 x 13 x 4.5 cm, part of D)
1.63 kg slice (no. 826, 25 x 15 x 1 cm, part of D)
0.7 kg smaller cuts and slices (nos. 1573, 2637, 2638, 3280)

Arlington, Minnesota, U.S.A.

44°37'N, 94°3'W

Medium octahedrite, Om. Bandwidth 0.80±0.20 mm. Neumann bands. HV 160±10.

Anomalous. 8.52% Ni, 0.43% Co, 0.02% P, 21.3 ppm Ga, 64.9 ppm Ge, 6.1 ppm Ir.

HISTORY

A mass of 8.95 kg was found by a boy, Joe Barry Jr., in 1894 on his father's farm 2.5 miles northeast of Arlington, in Sibley County. Because of the unusual flat shape of the meteorite it was easily broken in two with a sledge hammer, but both fragments eventually were procured for the University of Minnesota, where it was described by Winchell (1896) with several photographs. About 1 kg in 25-100 g slices was distributed through Ward's Establishment about 1900. Bauer (1963) estimated the cosmic ray exposure age to be 220 million years.

COLLECTIONS

Washington (6.14 kg main mass), New York (996 g), Chicago (164 g), London (157 g), Vienna (112 g), Tempe (62 g), Berlin (55 g), Vatican (35 g), Bonn (34 g), Budapest (27 g), Harvard (24 g), Paris (16 g), Yale (10 g).

DESCRIPTION

Arlington and Tawallah Valley are perhaps the flattest meteorites known. Arlington is bounded by two almost plane-parallel surfaces and its greatest dimensions are 39 x 39 x 2.5 cm, but the average thickness is only 2 cm. On superficial inspection, it resembles a furnace product or a cast iron slab. It is covered by 0.1-0.5 mm limonitic corrosion products, but the original flight markings may still be seen in many places as delicate striae, furrows and warts. One face, evidently the front side during flight, is largely smooth, but pockmarked all over with shallow