0.1-0.4 mm across, which, on high magnification, turn out to be oriented intergrowths of carbide with minor amounts of kamacite, taenite and schreibersite. The inclusions are generally 2-10 μ across; depending upon the exact morphology and quantity of carbide, the hardness ranges from 1025 to 650. The carbide is isotropic and identical to the new mineral haxonite, (Fe,Ni)₂₅C₆ described by Scott (1971).

Schreibersite occurs as scattered lamellae, typically 3 x 0.5 mm in size, as 20-100 μ grain boundary veinlets, and as 2-20 μ thick blebs in the plessite fields. Rhabdites are common on the α-subboundaries, and are locally abundant as 0.5-2 μ precipitates in the α-lamellae.

In the examined specimen, troilite occurs as 0.1-0.6 mm monocristalline nodules, associated with and often completely embedded in the large schreibersite crystals. Daubreelite forms 1-100 μ wide, parallel lamellae in the troilite. Rhythmic intergrowths of alternating, 1-5 μ wide troilite and daubreelite lamellae are common. The smaller the nodule the higher the percentage of daubreelite, up to about 50%. The troilite is severely altered to pentlandite due to terrestrial corrosion.

Chromite occurs as 0.1-0.2 mm euhedric crystals, either alone in the kamacite or associated and in direct contact with daubreelite and troilite.

Although small, the examined specimen clearly indicates that Tanakami is a somewhat unusual coarse octahedrite, with its anomalous kamacite morphology and the significant amount of carbide roses. It appears to be very closely related to the small 3.3 kg iron, Rhine Villa, and to Staunton. It is less closely related to Kokstad and Willow Creek.

Specimens in the U.S. National Museum in Washington:
78 g three weathered fragments (no. 1431, about 4 x 2 x 1 cm each)
12 g weathered fragment (no. 1456, 3 x 2 x 0.5 cm)

Tandil, Buenos Aires, Argentina
Approximately 37°22'S, 59°20'W

Previously known as a hexahedrite fall in 1916; here shown to be a pseudometeorite.

HISTORY
A mass of 1.1 kg was discovered by a farmer before 1916 in the vicinity of Tandil. It was in use as a gate stop at his house 15 km (three Argentinean leagues) west of Tandil when it was acquired by a Dr. Ronco between 1916 and 1919. He, in turn, donated the mass to the Museum in La Plata in 1929. A preliminary description by Fossa-Mancini appeared in 1948; Radice (1959: 126) gave curatorial information.

COLLECTIONS
Musaeo de La Plata (977 g), Harvard (65 g).

ANALYSES
No analytical work has been reported.

DESCRIPTION
According to Fossa-Mancini (1948), the fist-sized mass was observed to fall between 1916 and 1919. A deep-etched section made it possible for him to classify Tandil as a normal hexahedrite. In spite of the fall date, the meteorite allegedly had a limonitic crust and weathered inclusions.

During a brief visit to the La Plata Museum in March 1973, I critically reexamined the mass. It measures about 9 x 7 x 6 cm and weighs 977 g. Its specific gravity may be estimated to be 5-6, far below that expected for an iron meteorite (7.5-8.0). There are no meteoritic sculpture, no regmaglypts and no meteoritic minerals. The mass is nonmagnetic. One face, of 6 x 5 cm, is covered by substantial ochre-laminae which, to the uninitiated, may suggest weathered meteoritic elements. In my opinion, the ochre is rather part of the mass itself. The only section made, of 2 x 1 cm, reinforces this impression.

Conclusion: the Tandil mass is a terrestrial rock, probably an ochre-limonite concretion.

Tarapaca. See Tamarugal (Tarapaca), and La Primitiva

Tawallah Valley, Northern Territory, Australia
15°42'S, 135°40'E

Group IVB, 17.6% Ni, 0.69% Co, about 0.10% P, 0.25 ppm Ga, 0.07 ppm Ge, 16 ppm Ir.
HISTORY
A mass of 75.8 kg was found in 1937 by Mr. Condon in Tawallah Valley, which is 48 miles northwest of Borroloola, in the Northern Territory. It was described by Hodge-Smith & Edwards (1941) who presented several figures of the unique shape and of etched sections. They failed to identify schreibersite, and their description is now also obsolete in several other respects. Lovering et al. (1960) studied the atmospheric ablation process and used Tawallah Valley as an example, concluding that this particular meteorite had lost about 27% of its preatmospheric mass in the atmosphere. They also provided a better structural description than previously available, and they gave a few photomicrographs. Lovering & Parry (1962) included the meteorite in their thermomagnetic studies. Voshage (1967) found by the \(^{40}\text{K}/^{40}\text{K}\) method a cosmic ray exposure age of 245±85 million years.

COLLECTIONS
Canberra, Geological Survey (39.3 kg), Sydney (about 30 kg), Washington (1.22 kg), Melbourne University (453 g), New York (217 g), Moscow (158 g), Tempe (14 g).

DESCRIPTION
The mass is unique by its shape, being a large trapezoid slab, 65 cm in its longest direction and 38 cm wide. The thickness ranges from 5 mm at one end, which is slightly upturned, to 65 mm at the opposite end. Locally, near the middle of one long side it attains a thickness of 90 mm. Excellent macrophotographs have been published by Hodge-Smith & Edwards (1941). The flat shape is not structurally conditioned and is hardly the result of atmospheric sculpturing alone. It rather suggests the flakes which spall off heavy targets when shocked. If so, Tawallah Valley is — together with Arlington — a unique example upon “spallation products” from cosmic collisions. Inconspicuous shallow regmaglypts, 2-4 mm across, are present in some places, but otherwise the surface is smooth. Remnants of a corroded fusion crust 0.05-0.15 mm thick are present locally, and it is clear that on the average only 0.1 mm of the surface has been lost by terrestrial exposure. The mass is preserved as well as, e.g., Keen Mountain, Bushman Land and Tamentit.

Under the fusion crust is an unusually wide, heat-affected zone. Lovering et al. (1960) estimated the 650° C isotherm to lie at a depth of 2.5 mm and used this as a basis for calculating the ablation loss. On the several sections I have seen I have found melted phosphides to be present to a depth of 2.9-3.2 mm, indicating the position of the 1000° C isotherm. I found the 650° C isotherm at a depth of 6-7 mm, and at about the same depth upon both sides of the flat slab. The values calculated by Lovering can, therefore, only be regarded as guiding. The only other large slab-shaped iron, Arlington, displays significant differences in morphology and thermal gradients between its two faces. Evidently Tawallah Valley and Arlington penetrated the atmosphere under different conditions of flight. The hardness of Tawallah decreases from a maximum of 290±10 immediately below the surface to a rather uniform level of 205±10, in the inner part of the heat-affected zone. Further inwards the hardness decreases to a minimum of 20±10, which appears to be the preatmospheric hardness level (taken at a depth of 25-30 mm). These hardness measurements were taken in the bainitic matrix, since the α-component was too small for consistent readings. The values are therefore not directly comparable to most other values in this book, since the latter were taken in the austenitic matrix, and they help to map the thermal gradient set up by the ablational process in the atmosphere.

Etched sections are of an ataxitic nature with a subdued, oriented sheen, broken only by a few, minute troilite inclusions. At high magnification the structure is clearly duplex. The kamacite phase occurs in two forms: a principal form, which appears to be the preatmospheric hardness level and which serves, however, to show that there is a significant hardness gradient from the ablated surface to the unaffected interior, and they help to map the thermal gradient set up by the ablational process in the atmosphere.

Figure 1714. Tawallah Valley (U.S.N.M. no. 1458). Nickel-rich ataxite of group IVB. Spindles of kamacite, often developed around a nucleus of schreibersite. Etched. Scale bar 40 \(\mu\). (Perry 1950: volume 9.)

### TAWALLAH VALLEY - SELECTED CHEMICAL ANALYSES

<table>
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<th>References</th>
<th>Ni</th>
<th>Co</th>
<th>P</th>
<th>C</th>
<th>S</th>
<th>Cr</th>
<th>Cu</th>
<th>Zn</th>
<th>Ga</th>
<th>Ge</th>
<th>Ir</th>
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<td>Schaudy et al. 1972</td>
<td>17.06</td>
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<td></td>
<td>0.25</td>
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α-blebs, 10-50 μ across, which have been nucleated by the large amount of tiny phosphides. The two forms together occur with a frequency of about 500 per mm², creating a salt-and-pepper felt against a continuous, plessitic matrix, resembling particularly Weaver Mountains and Shingle Springs.

The matrix is decomposed to a bainitic structure, which requires electron microscopy for any details to be observed. The immediate surroundings of the kamacite blebs are, as usual, yellowish, nickel-rich, undecomposed taenite. The hardness of the matrix near the central midsection of the mass is 205±10.

Phosphides are evenly distributed throughout the mass, but they are small, generally only 1-15 μ across. A few blebs attain sizes of 100 x 30 μ. Wherever there is a phosphide bleb there is also a rim of "swathing kamacite," ranging from 5-30 μ in thickness. The bulk phosphorus content is estimated to be 0.10±0.02%. As mentioned above, the phosphides are melted to a depth of 3 mm and have solidified to globules with 2-10 μ wide gasholes or shrinkage holes. Already at low magnification this same surface zone will be seen to be rich in small, zigzagging fissures which generally run perpendicular to the surface and appear to jump from phosphide to phosphide. They probably represent cracks created by the tensions set up by the abrupt heating and cooling in the atmosphere, but it is interesting to note that they are restricted to the 3 mm wide zone in which the phosphides were melted. I have observed similar hot-cracks in numerous other irons, always restricted to the region of phosphide melts. However, Tawallah Valley shows the phenomenon in a pure form because the phosphides are well distributed, and the meteorite is little corroded.

Troilite occurs as scattered nodules, 0.5-2 mm across. Eighteen inclusions were noted on a total of 450 cm² or one per 25 cm². The troilite is monocrystalline but shows beautiful twins as a result of plastic deformation. It has only very few schreibersite precipitates, but a 10-20 μ wide rim of swathing kamacite is present locally. Otherwise, the taenite is in direct contact with the troilite.

Tawallah Valley is a well-preserved nickel-rich ataxite, closely resembling Warburton Range and Weaver Mountains. The α-precipitates are somewhat larger in Tawallah Valley than in Weaver Mountains. Tawallah Valley also resembles Skookum Gulch, but this mass has unfortunately been altered by artificial reheating. Tawallah Valley’s shape is unique, and it is therefore perhaps not the best for estimating average ablation losses and flight histories in the atmosphere.

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

120 g part slice (no. 1458, 6 x 4.5 x 0.6 cm)
1.10 kg full slice through the middle (no. 4855, 38 x 7 x 0.7 cm)

Tawell, Tennessee, U.S.A.

36°26'N, 83°45'W; 450 m

Group IIIID. 16.9% Ni, 0.65% Co, about 0.3% P, 4.7 ppm Ga, 4.0 ppm Ge, 0.063 ppm Ir.

HISTORY

A mass of 60 pounds (27.2 kg) was plowed up in 1853 on the land of William Rogers, about ten miles west of Tazewell, in Claiborne County. The irregular lump lay in clayey soil on a hillside where much of the soil had been washed away by rains. The mass was easily broken into three fragments, of 4 pounds, 55 pounds and six ounces, respectively, and it was assumed that the meteorite was much weathered. While the small fragment was retained by Professor Mitchell, Knoxville, the 4-pound fragment was described by Shepard (1854) and the 55-pound fragment by Smith (1855). Smith gave a figure of the complex, exterior shape that showed three regular holes through the

Figure 1716. Tazewell (Amherst). The 8.65 kg endpiece constitutes one-third of the original mass. The irregular sculpture is mainly a result of ablation during flight. Ruler in centimeters.

Figure 1715. Tawallah Valley (U.S.N.M. no. 1458). A group of schreibersite particles (S) surrounded by a common kamacite envelope. The ataxite matrix is decomposed on a submicroscopic scale. Etched. Scale bar 20 μ. (Perry 1950: volume 9.)
mass. He also discussed the presence of important amounts of schreibersite and presented analytical data on isolated components which were well ahead of his time. He believed lawrencite to be present, but the evidence is not convincing. What he observed appears rather to have been deliquescent chlorides located in a crevice and introduced by circulating ground water.

Huntington (1888: plate 2) gave a sketch of the structure. Cohen (1905: 254) gave a description and used the meteorite as a type member for his Tazewell-group. The meteorites included with this group, e.g., Narraburra, Carlton, Mitz and Laurens County, are, however, different from Tazewell as seen with modern eyes. Brezina & Cohen (1886-1906: plates 10 and 11) presented five photomicrographs, and further macrographs were given by Mauroy (1913: plate 2), Belaiew (1923) and Nininger & Nininger (1950: plate 1). Perry (1944: plate 14) and Buchwald (1967a: figures 26 and 27; 1967b) gave several photomicrographs. The older literature has been compiled and partly reviewed by Wulfing (1897: 351), Cohen (1905: 253) and Farrington (1915: 431).

Agrell et al. (1963), working with the microprobe, observed that kamacite less than about 80 μ wide did not reach the maximum nickel content attained in the wider lamellae of other octahedrites. Goldstein (1963) extended this observation and presented curves showing average bandwidth versus average nickel content, Figure 95A. Buchwald (1967a: figures 26 and 27) noted that ablation crusts and heated rim zones were present on several specimens. He further showed Tazewell and Föllinge to be closely related. Jaeger & Lipschutz (1967b) deduced from data of Leonhardt (1928) that a shock-altered kamacite was present. This is, however, incorrect; Leonhardt's asterism appears to have been caused by poor preparation techniques, or, perhaps, by examination of heat-affected rim zones. Reed (1965a, b; 1969) presented detailed data on the composition of the kamacite, taenite, plessite and schreibersite. He found the kamacite to average 6.5% Ni and 0.03% P.

**COLLECTIONS**

Amherst (8.65 kg endpiece and 200 g slice), Washington (1,635 g), Berlin (722 g), Harvard (716 g), Yale (443 g), New York (368 g), Paris (324 g), London (308 g), Philadelphia (308 g), Tübingen (292 g), Chicago (279 g), Cutta (267 g), Leningrad (198 g), Budapest (176 g), Vienna (165 g), Tempe (164 g), Los Angeles (161 g), Göttingen (84 g), Vatican (79 g), Uppsala (77 g), Prague (75 g), Hamburg (70 g), Oslo (61 g), Strasbourg (58 g), Copenhagen (56 g), Dorpat (56 g), Dresden (55 g), Bonn (47 g), Rome (42 g), Stockholm (39 g), Ann Arbor (33 g), Helsinki (30 g), Ottawa (16 g).

**DESCRIPTION**

According to Smith (1855), "the dimensions are such that it will just lie in a box 13 inches long, 11 inches broad and 5 1/2 inches deep." The flattened mass is very irregular, having deep, hemispherical pits, three penetrating holes (the "beaks," 2 cm thick and extending 5 cm from the mass. Regmaglypts, 1-4 cm across, are present on several parts of the surfaces, and small amounts of fusion crusts may be observed in protected depressions. In several places there are 0.5-1 mm wide, straight grooves, resembling chisel marks. They indicate where schreibersite was partly removed by ablation-melting in the atmosphere. Some terrestrial corrosion has occurred, resulting in a roughened surface where the taenite and schreibersite peep out in bronze-colored flakes. On polished sections the near-surface fusion crusts and heated rim zones were present on several specimens. They indicate where schreibersite was partly removed by ablation-melting in the atmosphere. Some terrestrial corrosion has occurred, resulting in a roughened surface where the taenite and schreibersite peep out in bronze-colored flakes.

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The magnetite fusion crust is corroded away, but the metallic fusion crust occurs as a laminated, 10-150 μ thick crust in numerous places. It is composed of dendritic, fine-grained material with a little interdendritic phosphides. The hardness is 330±15. As usual, the lower melting, nickel-rich taenite and plessite fields below the fusion crust are somewhat stronger attacked than the higher melting, nickel-poor kamacite lamellae, the difference in level being 2-10 μ. Micromelted phosphides are present to a depth of 0.5-1.5 mm below the fusion crust. The kamacite lamellae are transformed to serrated α₃ units to twice these depths. Their hardness is 170±15. This is rather low for an α₃ zone of an octahedrite but may be explained by the relatively low nickel content. The magnetite fusion crust is corroded away, but the metallic fusion crust occurs as a laminated, 10-150 μ thick crust in numerous places. 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Figure 17.17. Tazewell (Copenhagen no. 1863, 756). The fusion crust to the left is composed of an exterior oxidic part (almost black) and an interior laminated metallic part (gray). Where schreibersite particles (high relief) occur in the kamacite lamellae these are swollen. Etched. Scale bar 300 μ.

low average nickel content of the kamacite. The lower the nickel content, the softer the α₂ phases (Buchwald 1966: figure 13).

Etched sections disclose a finest Widmanstätten structure of straight, long (χ ~ 50) kamacite lamellae with a width of 45±15 μ. The kamacite has subboundaries and, in the wider parts, normal Neumann bands. No shock-hardened structures are present. The hardness is 165±20, exhibiting a rather wide variation, possibly due to a corresponding variation in the nickel content (Reed 1965b: table 2).

Taenite and plessite cover 70-90% by area, mostly as dense, martensitic or bainitic fields in which the taenite is rather uniformly transformed to platelets parallel to the bulk Widmanstätten structure. The hardness is 290±15. Comb and net plessite proper are not present. The untransformed, yellowish taenite rims have a hardness of 265±15, which drops to 215±15 in the heat-affected surface zone.

Schreibersite occurs as conspicuous plates, e.g., 50 x 20 x 0.5 mm in size, that cut through the Widmanstätten structure following the {110} planes (Cohen 1905: 258). They have a hardness of 850±30 and are enveloped by 0.2-0.4 mm wide zones of swathing kamacite which is rich in Neumann bands. Schreibersite also occurs evenly distributed as 10-50 μ wide blebs, always enveloped in kamacite and usually located within the kamacite lamellae. A small number of the hard blebs, 5-100 μ thick, are not enveloped

Figure 17.18. Tazewell (Copenhagen no. 1863, 756). A schreibersite skeleton crystal with a rim of swathing kamacite. The finely developed Widmanstätten pattern is similar to that of Föllinge. Etched. Scale bar 3 mm.
by alpha phase, are of a somewhat more rose hue and are isotropic. They are haxonite, intergrown with, and attached to, the taenite, and with fine inclusions of schreibersite. They have a hardness of 950±50. The haxonite crystals often completely fill in the kamacite lamellae at a junction, enclosing whatever schreibersite crystals may have been present there originally. A typical haxonite crystal may thus have a central part, 100 µ across, with fingers as wide as the kamacite lamellae extending in several directions.

Trollite occurs as 1-20 mm nodules with 0.1-2 mm wide schreibersite rims. The trollite is monocristalline but displays numerous well-defined twins from slight plastic deformation. Its hardness is 240±15. Smith (1855) reported small amounts of olivine.

Tazewell is a well-preserved iron of a rare type. Structurally and chemically the closest relatives are Follinge which, being so small, does not show the same variation width as Tazewell, and Dayton which shows much more variation. Somewhat more distant relatives are Wedderburn and Freda.

Specimens in the U.S. National Museum in Washington:
1,423 g endpiece (no. 1155, 11 x 6 x 6 cm; Shepard's 4-pound fragment)
81 g irregular segment (no. 1622, 3 x 3 x 1.5 cm)
131 g part slice (no. 3089, 6 x 4 x 0.8 cm, divided in two sections)

Teocaltiche, Jalisco, Mexico
21°26’N, 102°34’W

An octahedrite of 10 kg was found in 1903 near Teocaltiche, according to a note by Ward (1904a: 25). Ward acquired a 40 g sample for his collection, but it has apparently since been lost or perhaps relabeled. It is not in Chicago, where the bulk of Ward’s collection ended. Ward (ibid.) stated that the 10 kg main mass was in the Institute of Geology, Mexico City, but it is not listed by Haro (1931), and I was not able to trace it during two visits to the museum in 1968.

Tepla, Bohemia, Czechoslovakia
49°57’N, 12°52’E

Medium octahedrite, Om, Bandwidth 0.90±0.15 mm, e-structure. HV 280±10.
Transitional between group IIIA and IIIB. About 9.0% Ni, 0.3% P.

HISTORY
Two masses of 14.42 and 2.63 kg were plowed up in 1909 on Finsterholzel-Ries near Tepla, east-northeast of Marianske Lazne (Marienbad) in the Karlovy Vary region. The meteorites were briefly described by Ježek (1923) who also presented a photomacrograph of an etched section. Two additional photomacographs were presented by Tuček (1966: plate 12; not plate 6 as erroneously stated in the text; plate 6 shows Bohumilitz). Further references may be found in Hey (1966: 477); some of these draw attention to the probable existence of more masses in the area.

COLLECTIONS
- Prague (10.7 kg main mass and 1.86 kg sections), Vienna (409 g), Budapest (173 g, lost in 1956), London (57 g), Chicago (42 g), Paris (36 g).

Tepla - Tepla 1185

Figure 1719B. Tepla (Vienna no. J3456). The Reichenbach lamellae are conspicuous on this deep-etched and slightly corroded (lower right) slice. Consisting of a very thin chromite backbone, each Reichenbach lamella has served as a substrate for massive, but irregular precipitates of trollite and schreibersite. Scale bar in millimeters.
ANALYSIS

Only an inappropriate analysis (7.47% Ni etc.) reported by Ježek (1923), is known. The following examination indicates an analysis of 9.0±0.5% Ni, 0.5±0.1% Co, 0.3±0.05% P and trace elements corresponding to group IIIAB.

DESCRIPTION

The dimensions of the two masses are unreported. The almost complete main mass (Prague No. 352) now weighs 10.7 kg and measures 25 x 16 x 16 cm in its extreme dimensions. The following is based on a cursory examination of the specimens in Prague, London and Chicago, and a thorough study of a Vienna specimen (No. J3456 of 409 g) which was kindly loaned to me by Dr. Kurat.

The masses are weathered and covered by limonitic oxidation crusts, 0.1-1 mm thick. Locally, exfoliation along the Widmanstätten lamellae has taken place, and the octahedral pattern may be distinctly seen on most of the natural surfaces. The fusion crust and the heat-affected zones have been lost, and no hardness gradient towards the surface could be detected. It thus appears that, on the average, more than 5 mm has been lost during exposure to the terrestrial environment.

Corrosion has also penetrated rather deep into the mass along the Reichenbach lamellae and the brecciated schreibersite crystals. In a 10 mm deep near-surface zone the plessite fields are attacked, the α-phase of the duplex fields having been selectively transformed to black limonitic products.

Etched sections show a medium Widmanstätten structure of straight, long (5 x 25) kamacite lamellae with a width of 0.90±0.15 mm. The kamacite has subboundaries with 0.5-2 μm phosphide precipitates and grain interiors with numerous almost submicroscopic particles, probably phosphides. The kamacite displays more or less distinctly hatched ε-structures with hardnesses of 280±10, indicating shock hardening with little annealing.

Taenite and plessite cover 30-40% by area in a large variety of forms. Comb and net plessite fields attain sizes of 10 x 4 mm, while the smaller fields are usually martensitic or of duplex, black-etching character. A typical field will exhibit a cloudy taenite rim (HV 325±15) followed by indistinct martensitic transition zones (HV 350±15). Next come contrast-rich dark-etching martensite developed parallel to (111)γ (HV 340±25), and duplex, unresolvable α + γ structures (HV 290±20). Finally, easily resolvable duplex structures, with 1-2 μm wide γ-particles, are met in the interior (HV 250±15).

Schreibersite is common as rosette-shaped and cuneiform skeleton crystals, e.g., 5 x 0.5, 10 x 0.6 and 7 x 3 mm in size. Conspicuous 0.8-2 mm wide rims of swathing kamacite envelop the schreibersite crystals. Schreibersite also occurs as 10-60 μm wide grain boundary veinlets and as 2-30 μm angular blebs inside the plessite fields, substituting for taenite particles of similar sizes. Rhabdites are absent. The phosphides are monocry stalline but brecciated and often shear-displaced 5-10 μ. The breccias are recemented by terrestrial limonite. The bulk phosphorus content is estimated to be 0.30±0.05%.

One of the more characteristic features of Tepla is the Reichenbach lamellae which occur with a frequency of one per 10 cm². They range in size from 30 x 30 x 0.01 mm to 5 x 5 x 0.005 mm and cut through the Widmanstätten structure in three directions. One of these coincides with a Widmanstätten (111)γ plane, but the others do not. The Reichenbach lamellae are corroded, and, therefore, difficult to examine. However, where they are best preserved, it may be seen that they were originally composed of three components: (i) a backbone of very thin, straight chromite lamellae, e.g., 3-20 μ thick; (ii) an irregular coating of troilite, usually 5-10 μ thick, but locally swelling to 50 x 100 μ blebs; and (iii) discontinuous precipitates of schreibersite. These form, e.g., 50-100 μ thick flags which are differently developed on the two sides of the chromite-troilite lamellae. All lamellae have acted as nucleating agents for swathing kamacite, that now forms asymmetric 0.5-1.5 mm wide, irregular rims.

Troilite is rare but occurs locally as 5-18 mm nodules, wrapped in 0.5-1 mm schreibersite. On good sections it is further seen as very narrow (2-5 μ) winding lamellae through the large schreibersite crystals, and as 5-100 μ blebs associated with schreibersite. The troilite is monocry stalline but somewhat sheared as a result of cosmic deformation. It has been extensively altered to pentlandite on exposure to the terrestrial surroundings.

A coke-gray angular mineral, 50-150 μ across, was observed in the kamacite. It may be a phosphate, but it was not identified.

Silicates, daubreelite, carlsbergite, graphite and carbides were not detected. Cohenite, and 0.35% C in the analysis, was reported by Ježek (1923), but these results could not be supported. The carbon content is probably 10 times lower, and the “cohenite” of Ježek must be the cuneiform schreibersite crystals.

Tepla is a shock-hardened medium octahedrite which is rich in Reichenbach lamellae built around primary chromite lamellae. It appears to be related to Bartlett, Cleveland, Lenarto, Moorumbunna, Thule and Velikonikolaevskij Prišik, and probably belongs to group III, particularly to those irons transitional between group IIIA and IIIIB.

Tepla was found only about 25 km south of the Elbogen meteorite. Considering that the Tepla and Elbogen material resemble each other a good deal macroscopically, specimens from the two falls were closely scrutinized to detect an association. There does not seem to be any. Tepla is rich in chromite-based Reichenbach lamellae, and rhabdites are absent. Elbogen has numerous rhabdites, and chromite-based Reichenbach lamellae are absent. Tepla’s analysis is unknown, but it will probably be found to be poorer in nickel than Elbogen.
**Ternera, Atacama, Chile**

Approximately 27°20' S, 69°48' W

Anomalous ataxite, D. Uniform, duplex $\alpha + \gamma$, about 5 $\mu$ grain size. HV 180±2.

Group IVB. 18.1% Ni, about 0.1% P, 0.26 ppm Ga, 0.06 ppm Ge, 16 ppm Ir.

Galleguillos is an artificially reheated specimen of the Ternera shower.

**HISTORY**

A mass of 650 g was acquired in 1891 by Dr. Wilhelm Möricke while on a trip to Chile. The location is inadequately known; the mass was said to have come from Sierra de la Ternera, in Atacama; Prior (1953) and Hey (1966) gave the coordinates quoted above, which placed the site somewhat northeast of Copiapó. A slice was cut from the mass and described and analyzed by Kunz & Weinschenk (1892). Their description and photograph show that it is a meteorite of a rare, nickel-rich type. Cohen (1905: 161) reviewed the case. The mass was donated to Berlin, where Klein (1906: 134) briefly described it. Berwerth (1914: 1982) suggested that the anomalous structure was due to artificial reheating, and I (quoted in Hey 1966: 478) concurred. The present reexamination shows, however, that the iron has not been maltreated by man. Perry (1944: plate 25) presented two typical photomicrographs.

During the present study I discovered that Galleguillos, a hitherto undescribed mass from the Copiapó region, had the same unique primary structure as Ternera. Ternera is thus a small shower of at least two individual specimens of 650 g and 1,330 g, respectively. Unfortunately the Galleguillos mass has been artificially reheated; it will, therefore, be treated separately.

**COLLECTIONS**

Berlin (550 g), Washington (31 g), Los Angeles (25 g), London (5 g), Paris (2 g), Chicago (1 g), Bonn (1 g).

**DESCRIPTION**

The elongated rounded mass has the average dimensions of 10.5 x 5 x 3 cm. It is weathered and covered with 0.140 mm thick terrestrial oxides. The surface is indented by large and small pits, most of them being 5-7 mm in diameter and 1-2 mm deep. They resemble regmaglypts from the atmospheric flight. However, no fusion crust and no heat alteration structures are associated with them, and the hardness remains constant to the very edge of the polished section, indicating that the heat alteration zone proper has been lost by weathering. The pits are evidently corrosion pits, and it is estimated that at least 3 mm has been lost during terrestrial exposure. The corrosion has selectively attacked the alpha phase, while the gamma phase is preserved as discrete blebs in the oxide-shale. No indications of artificial reheating are present in the corrosion products, proving that the duplex $\alpha + \gamma$ structure is due to cosmic annealing. However, some hammering has locally cold-worked the near-surface parts. The deformation fades away below a depth of 1-2 mm.

The etched sections are remarkably homogeneous to the naked eye. Only two internal fissures, 5 and 8 mm long, respectively, disrupt the ataxitic appearance. There are no parallel macroscopic bands of the type seen in, e.g., Hoba and Chinga. High magnification reveals a duplex, anomalous structure of almost equal parts of kamacite (50-60%) and taenite (50-40%). The kamacite forms equiaxial grains, 2-10 $\mu$m across, and the taenite forms a more or less continuous sponge with veins 1-10 $\mu$m thick. The taenite is creamcolored and beset with tiny windows of kamacite, 0.5-2 $\mu$m across. Otherwise the two components resemble each other pretty much. No euhedric grains and no phosphides should be present, they must be in a form of a matrix. No schreibersite and no rhabdites were observed. If phosphides should be present, they must be in a form which may not easily be identified by microscopic examination.

The two fissures mentioned above are caused by troilitie inclusions. The troilitie forms thin, shock-melted lamellae, 5 x 0.1 and 8 x 0.1 mm in size, respectively. When in a molten state, the troilitie dissolved part of the adjacent metal and then solidified to fine-grained, 1-2 $\mu$m, iron-sulfide eutectics. It is likely that the fissures remained open on a microscopic scale after the shock. When the meteorite landed on the Earth, corrosion selectively attacked the iron phase of the eutectic and created the present complex texture of shock-melted troilitie, duplex $\alpha + \gamma$ and terrestrial oxidation products.

**TERNERA – SELECTED CHEMICAL ANALYSES**

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References: Weinschenk and Lindner arrived at approximately the correct Ni + Co values, but they failed to separate nickel and cobalt quantitatively.
Ternera - Ternera (Galleguillos)

Figure 1720A. Ternera (Humboldt University, Berlin). The main mass now weighs 550 g after a few cuts have been made. In this side view the pitted surface, typical for the Atacama conditions, is clearly seen. Length 90 mm. (Courtesy Professor G. Hoppe).

Figure 1720B. Ternera (U.S.N.M. no. 1231). This ataxite is an anomalous mixture of almost equal parts of kamacite (K) and taenite (T), each forming a continuous sponge-like network. Etched. Scale bar 20 μ. (Perry 1944: plate 25.)

Ternera is a unique nickel-rich ataxite which structurally resembles no other meteorite, except Galleguillos. It appears that its present structure is a secondary one, produced by thorough annealing in Cosmos after a shock event. If this is true, its structure is secondary, the same as, e.g., Forsyth County, Willamette and Santiago Papasquiaro on lower nickel levels. On the other hand, Ternera's present structure has left no clues as to the nature of the primary structure. However, Wasson (personal communication) found Ni, Ga, Ge and Ir values typical for the group IVB. It may, therefore, be assumed that Ternera's primary structure resembled Chinga, Kokomo, Hoba or Tlacotepec.

Specimen in the U.S. National Museum in Washington:
31 g slice (no. 1231, 5 x 3 x 0.5 cm)

Ternera (Galleguillos), Atacama, Chile
Approximately 27°3'S, 70°23'W

Anomalous ataxite, D. Fine mixture of equiaxed α- and γ-grains. HV 225±15.
Group IVB. 17.5% Ni, 0.25 ppm Ga, 0.06 ppm Ge, 15 ppm Ir,
Galleguillos is an artificially reheated fragment of Ternera.

HISTORY
In 1884 a mass of 1,330 g was sent from Chile by L. Sundt to Christiania (Oslo) University. It was provisionally connected with Copiapo by Wülfing (1897: 86 and 87), but Prior (1923a) and Hey (1966: 169) correctly assumed that there was little basis for this association and listed Galleguillos as an independent find with the coordinates quoted above. Dr. Frigstad, the present curator of the Oslo University collection, confirmed the above information and stated that, except for an old label, no written evidence was preserved concerning the meteorite. The original label reads; "Galleguillos. North of Copiapo, Atacama, Chile. Gift from L. Sundt, Valparaiso, 1884." Attached to the label is an old preliminary analysis, performed by Axel Krefting, 1884. He found 17.5% Ni + Co, a result which should have singled Galleguillos out as a very unusual meteorite long ago.

Apparently the meteorite has never been further examined or distributed.

COLLECTIONS
Oslo (main mass of 1,290 g; 12.7 g endpiece).

DESCRIPTION
In a letter dated October 20, 1971, Dr. O.F. Frigstad, Oslo, kindly provided the following information. The mass is an entire monolith measuring 13 x 7 x 4 cm in three mutually perpendicular directions. It is an elongated three-sided prism, tapering to a point at one end but flat at the opposite end. One of the "prism" faces is curved and has small pits, the two others are flat and have larger, shallower pits. There are no indications of hammering or chiseling, and the specimen is not broken from another mass.

For microscopic examination, a 12.7 g near-surface fragment from the tapered end of 22 x 18 x 8 mm was available. No fusion crust and no heat-affected α₂ zone from atmospheric penetration could be distinguished. On the contrary, terrestrial corrosion has removed several
millimeters and also attacked a sulfide pocket 4 mm below the present surface.

The etched section appears very homogeneous to the naked eye and also when using the hand lens. The prominent parallel bands so characteristic of group IVB are absent. Only minute troilite inclusions disrupt the monotonous. Low magnification reveals a two-phase structure where the minor phase (~35% by area) etches easily to dull-gray and brown tones, while the other — cream-yellow — phase is unattacked and forms a continuous spongy network. High magnification — best with an oil immersion 100x objective — discloses that the minor phase is α₅ consisting of serrated units 2-10 μ across which display ragged and somewhat diffuse borders in contact with the other phase. This other phase is a high-nickel γ-phase with little internal structure. The microhardness, integrated over both structural components, is 225±15.

The structure is highly unusual, but there is one other meteorite — Ternera — with similar characteristics although different in minor details. While all the major features of Ternera are to be found in Galleguillos, the minor deviations can be explained if we assume that Galleguillos has been artificially reheated. This hypothesis can be supported by the following structural observations. The surface of Galleguillos has been exposed to high temperature oxidation, whereby iron has been selectively transferred to the oxide crust. Here a 30-50 μ wide zone, significantly enriched in nickel, has been produced. This zone is almost entirely austenitic now, with a grain size of 10-20 μ.

The original troilite has melted, reacted with oxygen from the atmosphere and partially sweated out and wetted the free surfaces. Melted troilite is found as 1-2 μ thick intercrystalline veins in numerous parts of near-surface regions. Retained troilite has solidified to ultrafine Fe-S-O eutectics in which rounded, 5-10 μ, gray oxides are dispersed.

Most of the terrestrial limonite is decomposed to various oxides in which dispersed metal beads, less than 0.5 μ across, are found. In a few places the oxide-metal mixtures have survived intact. In such “fossil” regions the original structure (i.e., the structure before the artificial reheating) may be observed. The reason for this is the selective corrosion of the α-phase, which has left γ intact in its original pattern, a situation which is only little influenced by brief artificial reheating. The examination of the “fossil” regions clearly shows that Galleguillos, before reheating, had the same structure as Ternera.

The hardness of Ternera is 180±2; and it is very even because of thorough cosmic annealing. The hardness of Galleguillos is 225±15, higher and with a larger range, due to the brief reheating which could not result in equilibrium.

The presence of unequilibrated α₅ from air-cooling through the γ - α transformation range indicates that the temperature was briefly above 800° C. The presence of melted troilite suggests rather that the temperature was 1000° C for some time. The length of time may be estimated to be of the order of 10-30 minutes since the original 55α (low-Ni)-45γ (high-Ni) mixture did not completely homogenize but only approached equilibrium, having

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Figure 1722. Ternera. Galleguillos (Oslo). Detail of Figure 1721. The dark kamacite phase is in fact unequilibrated α₅ with diffuse edges towards taenite, due to artificial reheating. Etched. Oil immersion. Scale bar 10 μ.

Figure 1723. Ternera. Galleguillos (Oslo). The oxidized crust to the left. The adjacent metallic phase has by selective high temperature oxidation become depleted in iron and is now high-nickel taenite. To the right the duplex interior. Etched. Oil immersion. Scale bar 10 μ.
The exact place of discovery of Galleguillos is unknown, but the general location, north of Copiapo in Atacama, coincides with the general location assumed for Ternera. Since Ternera's structure is unique and since Galleguillos has an identical structure, except that it is not selectively corroded in the near-surface region, these two meteorites must be from the same fall. It is proposed to call this fall Ternera, since this smaller mass was described first and seems to have escaped artificial reheating.

**Figure 1724.** Ternera. Galleguillos (Oslo). A near-surface corroded troilite nodule which, due to artificial reheating to above 900°C, melted and reacted with the oxides and with oxygen from the air. The result is a fine-grained Fe-S-O eutectic with metallic dendrites (white). Polished. Scale bar 20 μ.

time to form a 35γ (low-Ni)-65γ (high-Ni) mixture. Upon cooling, the low-nickel γ transformed to α₂ while the high-nickel γ remained stable as is the case when γ contains more than 35% Ni in solid solution.

The exact place of discovery of Galleguillos is unknown, but the general location, north of Copiapo in Atacama, coincides with the general location assumed for Ternera. Since Ternera's structure is unique and since Galleguillos has an identical structure, except that it is not selectively corroded in the near-surface region, these two meteorites must be from the same fall. It is proposed to call this fall Ternera, since this smaller mass was described first and seems to have escaped artificial reheating.

### Reference

**Ternera, New Mexico**

35°17'N, 108°16'W; 2000 m

Coarse octahedrite, Oe. Bandwidth 1.8±0.4 mm. Neumann bands. HV 176±8.

Group I. 7.4% Ni, about 0.15% P, 74 ppm Ga, 270 ppm Ge, 1.9 ppm Ir.

Perhaps a transported fragment from the Odessa crater field.

### HISTORY

A "large mass" of unknown size was reported by LaPaz (1965: 113), who had acquired 12 grams of it for the collection of the University of New Mexico. Roy S. Clarke has kindly provided the following additional information. The location of find is in Cottonwood Gulch, near Cottonwood Creek, approximately five miles south-southwest of Thoreau, corresponding to the coordinates given above. It was found by William W. Pinch in August of 1955, partially buried in the soil. Pinch was on a mineral collecting trip with a sizable group of people.

The original weight was 500 or 600 g; about half of it was lent to Dr. Lincoln LaPaz, while the other half was purchased in 1963 by the Smithsonian Institution. LaPaz's catalog (1963), however, lists only 12.2 g of Thoreau in the collection of the Institute of Meteoritics, Albuquerque.

### COLLECTIONS

Washington (290 g), Albuquerque (12 g).

### DESCRIPTION

The specimen in the U.S. National Museum is an endpiece with the average dimensions of 9 x 4 x 2 cm. The meteorite from which it came must have measured at least 10 x 5 x 6 cm, estimating from the curvature of the surfaces. This corresponds to at least 1.2 kg. However, it is not known where the main mass is preserved.

The meteorite is corroded and irregularly covered with 0.1-1 mm thick laminated oxides. Corrosion penetrates several centimeters into the interior along grain boundaries and phosphides. The α₂-lamellae of the pearlitic plessite are selectively oxidized to "limonite" and tarnished taenite is also attacked. Surprisingly enough, remnants of the heat-affected α₂ zone are preserved locally as layers, up to 1 mm thick. In the exterior part, even micromelted phosphides are present. In such places original magnetite-wüstite fusion crust is still recognizable under the microscope, although severely altered by weathering. The hardness of the α₂ zone is 184±8. It decreases to a minimum of 155 in the recovered transition zone, and then increases to the interior value of 176±8 (hardness curve type II). The heat-affected zone is unusually thin, about 1 mm, suggesting that Thoreau is a fragment formed by late break-up in the atmosphere.

Etched sections display a coarse Widmanstätten structure of straight bulky (W 12) kamacite lamellae with a width of 1.8±0.4 mm. Local grain growth has created almost equiaxial grains 5-10 mm in diameter. The kamacite is rich in subboundaries decorated with 1-2 μ rhabdites. Neumann bands which, as usual, formed after the primary structure was fully developed and after the grain growth had occurred, are very common. They are undecorated and, therefore, not selectively corroded in the near-surface regions which otherwise are badly weathered.

Taneite and plessite cover 5-8% by area, mostly as comb plessite and as tarnished taenite ribbons. Some of the taneite ribbons, 40 μ thick, have decomposed to pearlitic plessite with 0.5 μ wide taneite lamellae in kamacite (HV 265±20). Some fields display acicular high-nickel, high-carbon martensitic interiors.

Schreibersite occurs as 20-100 μ wide grain boundary

### THOREAU - SELECTED CHEMICAL ANALYSES

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veinlets and as 1-50 µ blebs inside the comb plessite. Rhabdites are very common, both as 5-15 µ well developed prisms and as ultrafine precipitates smaller than 1 µ. The bulk phosphorus content is estimated to be about 0.15%.

On the available sections, troilite, cohenite, graphite and silicates were not detected; they may be disclosed upon further sectioning.

Thoreau is a coarse octahedrite of group I which is closely related to Canyon Diablo and almost indistinguishable from Odessa. It is unrelated to the pair Grant-Breece which were found in the vicinity (if one accepts the authenticity of the Thoreau-location). The structure, the mineralogy, the detailed chemical composition and the thin heat-affected zone are all characteristic for small fragments from the Odessa crater field.

It appears unlikely that a specimen with these characteristics should be found as a single mass.

Specimen in the U.S. National Museum in Washington:
290 g endpiece (no. 2214, 9 x 4 x 2 cm)

Thule, Greenland, Denmark
76°32'N, 67°33'W; 700 m

Medium octahedrite, Omm. Bandwidth 1.15±0.15 mm. Distorted Neumann bands. HV 175-300.
Group IIIA. 8.49% Ni, 0.55% Co, 0.20% P, 19 ppm Ga, 40 ppm Ge, 2.6 ppm Ir.

HISTORY
A mass of 48.6 kg was found in Northwest Greenland in 1955 by a group of American glaciologists who surveyed the glacier flowing from Blue Ice Valley into the Moltke Glacier. The meteorite was resting as a boulder between gneissic boulders on a nunatak protruding through the glaciers which are heading for Wolstenholme Bay (Leonard 1955). It was described by Buchwald (1961b) who gave figures of the characteristic exterior and of etched sections. A series of hardness determinations on individual phases indicated the general trend which is apparent in the present work. The ablation loss during the later stages of the atmospheric penetration was calculated to be about 1.6 mm/sec. Buchwald & Munck (1965: figures 8-11) and Brett & Henderson (1967: figure 3) gave various photomicrographs and reported the presence of Reichenbach lamellae.

During field trips to the region in 1961, 1963, 1964 and 1965, I had the opportunity to search the area for additional specimens. The foreground of the Store Landgletsjer (i.e., Big Landglacier) and also the nunatak were searched but with negative result. I was told, however, that another iron meteorite had been found in 1962 during road construction at a spot which was approximately 10 km west of the first one. The mass was estimated to weigh 50 kg, but had been divided among various military and civilian personnel on the U.S. Thule Air Force Base. Further attempts to locate the cut specimens, distributed as

Figure 1725. Thule (Copenhagen no. 1955, 186). The bird-shaped main mass of 48.6 kg. Distinct regmaglypts cover the surface, proving that the present shape is in all essential respects due to fragmentation and ablation during flight. Scale bar 5 cm.

Figure 1726. Thule. The same from a different angle, seen from A in Figure 1725. Scale bar 5 cm.
curios, were in vain, but there is reason to believe that the Thule meteorite fell as a shower.

COLLECTIONS
Copenhagen (47.5 kg), Washington (450 g), Tempe (169 g), H.H. Nininger, Sedona (143 g), Moscow (138 g), London (23 g).

DESCRIPTION
The meteorite has the shape and size of a resting goose, measuring 35 x 30 x 20 cm in the greatest dimensions and weighing 48.6 kg. The most obvious characteristic is the "neck and head," a narrow extension of the massive meteorite, measuring about 10 x 3 x 10 cm. It appears that it was formed by fragmentation and sculpturing during the atmospheric flight.

Regmaglypts cover the surface as marked grooves, generally 2-3 cm across with rounded ridges in between. Eight to ten pits are often grouped together in a larger bowl-shaped depression, e.g., 6 x 7 cm in size and 2.5 cm deep. In two places, deeper, almost cylindrical pits occur. One is 30 mm in diameter, 30 mm deep, the other is 27 x 18 mm. Both were formed during flight by selective ablation of low-melting troilite nodules exposed in the surface.

The fusion crust is preserved quite locally. It consists of an exterior, 30-60 μ thick layer of oxidic composition, decomposed to wüstite and magnetite, and an interior,

Figure 1727. Thule (Copenhagen no. 1955, 186). The heat-affected zone is seen as a smoothly curved matte rim of unequilibrated α₂ grains. A Reichenbach lamella at R. Etched. Scale bar 3 mm. See also Figures 52 and 135.

THULE - SELECTED CHEMICAL ANALYSES
The old analysis by Buchwald is inadequate with respect to nickel and cobalt. The phosphorus and sulfur determinations are believed to represent a normal range in the phosphide and sulfide distribution.

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10-100 µ thick, laminated, dendritic metallic layer. Its presence, albeit discontinuous and in a weathered form, prove that Thule has lost only a few tenths of a millimeter, on the average, by corrosion. As the temperature in North-west Greenland is below 0° C 11 months of the year, and climate is arid, corrosion is slow in the area. Therefore, the meteorite may well have fallen several hundred years ago.

Terrestrial corrosion products cover most of the surface as 0.1-0.5 mm thick crusts of limonitic shale, which are densely pock-marked by 1-2 mm wide pits of insignificant depth. Locally, the Widmanstätten structure is suggested by an indistinct grid on the surface.

All sections prepared are rimmed with a continuous 1-3 mm wide heat-affected α2 zone. Micromelted phosphides occur in the exterior half of the α2 zone and may be used as a built-in thermometer (Buchwald 1961b; 1967b). The border between melted and unmelted schreibersite indicates the 1000° C isotherm, as determined from laboratory experiments. The cloudy taenite is homogenized to a clear yellow taenite in the rim zone. The microhardness of the α2 zone is 200±20, while the recovered transition zone just below α2 is significantly softer, HV 160±5, (hardness curve type IV).

Etched sections display a medium Widmanstätten structure of straight, long (W ~ 25) kamacite lamellae with a width of 1.15±0.15 mm. The kamacite has numerous subboundaries decorated with 0.5-2 µ phosphides. Neumann bands are common, but undecorated. Some sections display straight Neumann bands and are relatively soft, i.e., 190±15. Other sections show distorted Neumann bands and are correspondingly harder, 265±35. It appears that sections only a few centimeters apart display this variation. Perhaps the abrupt atmospheric fragmentation strained the metal rather inhomogeneously.

Figure 1728. Thule. Detail of Figure 1727 at S, showing a schreibersite crystal in the heat-affected α2 zone. The friction heat invaded from above and had just melted part of the schreibersite when rapid cooling reversed the situation. Black denotes late terrestrial corrosion products. Etched. Scale bar 100 µ.

Figure 1729. Thule. Detail of Figure 1727 at R showing a Reichenbach lamella with prominent schreibersite precipitates (S). Also a large comb plessite field. Etched. Scale bar 500 µ.
TaNite and plessite cover about 35% by area. Comb and net plessite are most common, while the minor fields display martensitic or unresolvable duplex interiors. A fully developed field will usually consist of a cloudy taenite border (HV 380±50), followed by indistinct yellow martensitic transition zones (HV 400±25) and brown-etching characteristic martensite (HV 360±30) developed parallel to the bulk Widmanstätten structure. The central portions consist of duplex unresolvable α + γ zones (HV 300±20) and easily resolvable α + γ zones with 1-3 μ wide γ-blebs and a hardness similar to that of the adjacent kamacite lamellae. The hardness of the taenite phases is covariant with that of the kamacite, i.e., the highest values quoted are associated with kamacite areas containing distorted Neumann bands. Such original austenite areas which are massive and have transformed diffusionless to martensitic products (αγ) late during the primary cooling period, are now surrounded by strained kamacite. The kamacite displays families of densely spaced slipplanes, which presumably become visible by etching because they have served as nucleation sites for submicroscopic precipitates of phosphides and, perhaps, carbides.

Schreibersite occurs as occasional 2 x 0.4 or 3 x 0.3 mm crystals but otherwise particularly as 20-100 μ wide grain boundary veinlets and as 5-30 μ blebs inside plessite, substituting for taenite particles of similar sizes. Normal rhabdites are rare, but microrhabdites less than 1 μ across occur in some α-lamellae. Cohenite, graphite, carlsbergite and daubreelite were not detected.

Troilit e is common, both as large nodules and as minute blebs. On the larger bodies, discontinuous 50-200 μ wide schreibersite rims have precipitated. The egg-sized troilite nodule, originally monocrystalline, is divided by shear zones into a number of 0.5-1.1 mm passive blocks. The blocks display undulatory extinction, while the shear zones are composed of 5-35 μ recrystallized grains. Quite locally, at interfaces with metal and phosphides, the troilite has been entirely melted. After having dissolved part of the metal, it has solidified to spongy eutectics of 1-3 μ metal and sulfide with serrated metal interfaces. In other places the sulfide has been squeezed into the brecciated schreibersite rim, dislodging minor fragments.

Along the troilite-metal interface at least two other sulfides occur. One is pentlandite that forms minute light yellow veinlets and apparently arises from terrestrial corrosion. The other is probably chalcopyrite, an isotropic opaque yellow sulfide occurring in patches 20-200 μ in size.

Reichenbach lamellae are common and occur with a frequency of about one per 5 cm². They apparently consist of troilite, but this is only part of the truth. On uncorroded, carefully prepared sections, it is seen that the primary backbones are extremely long and thin lamellae of chromite. The chromite is typically 30 x 20 x 0.002 mm in dimensions and completely straight. However, the shock-deformation responsible for the increased hardening of the metallic phases somewhat brecciated the chromite lamellae and shear-displaced them a few microns.

The chromite lamellae antedate the Widmanstätten structure and the phosphate precipitation, since they distinctly cut across these components. They apparently follow a few crystallographical planes of the single parent taenite crystal, perhaps the family {120}γ, but a detailed study has not been carried out.

Because these chromite lamellae are precipitated so early from the austenite, they were available as heterogeneous nuclei for several exsolution products. Thus minute pockets of troilite, e.g., 200 x 100 μ across, separated on the chromite and schreibersite later grew to thicknesses of 100-300 μ around both. Finally, asymmetrical 0.1-1.5 mm wide rims of swathing kamacite developed. When the shock occurred, the troilite micromelted in places and solidified with imbedded fragments of the chromite lamellae dispersed randomly through the melt.

Unfortunately, the delicate structures of the Reichenbach lamellae are the first to corrode in a terrestrial

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**Figure 1730.** Thule. Detail of Figure 1729. The Reichenbach lamella consists of a thin chromite lamella upon which first troilite (T) and later schreibersite (S) nucleated and grew. Etched. Scale bar 300 μ.

**Figure 1731.** Thule (Copenhagen no. 1955, 186). X-ray scanning pictures of a Reichenbach lamella similar to Figures 1727-1730. The backbone is a thin chromite lamella (chro.), Terrestrial corrosion products have invaded and recemented the brecciated aggregates, PKα, SKα, CrKα and NiKα pictures at 30KV. Scale bar 20 μ.
environment. One reason is the microfissured assemblage that attracts the ground water by capillary action; another reason is the heterogeneous mineral association. When this formed, it created steep composition gradients in the metallic matrix, thus providing a galvanic element for corrosion. Finally, the presence of shock-melted troilite with particles of dispersed metal also encouraged corrosion.

Figure 1732. Thule (Copenhagen no. 1955, 186). Another Reichenbach lamella (R-R) with schreibersite precipitates and corrosion products (black). Two plessite fields, the black one surrounded by distorted kamacite with decorated slipplanes. Etched. Scale bar 500 μ.

Figure 1733. Thule (Copenhagen no. 1955, 186). Net plessite with a black taenite wedge surrounded by distorted kamacite, displaying decorated slipplanes. Cloudy taenite edges. Neumann bands pass the entire plessite field. Etched. Scale bar 100 μ.

Thule is a well-preserved medium octahedrite which has been exposed to a severe shock in space. Additional inhomogeneous straining occurred in our atmosphere when it burst. It is a normal member of the resolved chemical group IIIA, and closely related to Trenton, Tamentit, Thunda, Kyancutta and Drum Mountains. It is also related to Cape York, from which it is primarily distinguished by the slight differences in nickel, phosphorus and trace elements; the almost complete absence of carlsbergite, rhabdites and daubreelite; and by its better state of preservation, suggesting a somewhat lower terrestrial age.

Specimens in the U.S. National Museum in Washington:
- 90 g part slice (no. 2146, 5 x 3.5 x 0.9 cm)
- 360 g part slice (no. 4856)

Thunda, Queensland, Australia
25°42'S, 143°3'E; 150 m

Medium octahedrite, Om. Bandwidth 1.20±0.15 mm. e-structure. HV 305±15.
Group IIIA. 8.24% Ni, 0.51% Co, 0.21% P, 20 ppm Ga, 39 ppm Ge, 2.2 ppm Ir.

HISTORY
A mass of 137 pounds (62 kg) was found before 1886 at Thunda, Windorah, in the Diamantina district. It had been lightly covered in the ground and had been known some time by the natives before Liversidge (1886) could obtain it and describe it preliminarily. Half of it was cut and distributed in the following years, while half of it came to the British Museum as late as 1927. Fifty years after the discovery, Spencer (1937b) was able to add more exact information and a sketch map. According to his informer, two masses of iron, the "Old Man" and the "Old Woman," were known to the aborigines on Githa Creek on the Maroo holding. The "Old Woman" was transported about 1881 to the Thunda homestead about 25 km to the north, while the fate of the "Old Man" is unknown. The coordinates above are those of Spencer.

Brezina (1896: 283) and Cohen (1900b: 381) gave good descriptions, while Ward (1904a: plate 3) and Mauroy (1913: figure 24) presented some photomacrophographs. In more recent time Perry (1944: plate 35) and Nininger & Nininger (1950: plate 10) have given good photographs of etched sections, showing the e-structure and the Reichen—

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