A NEW METAL-RICH MESOSIDERITE FROM ANTARCTICA, RKPA79015

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***Abstract*:** A 10.0 kg iron-rich meteorite (RKPA79015) and four silicate-rich fragments (RKPA80229, 80246, 80258, and 80263) are individuals from a new Antarctic mesosiderite. The silicate minerals present are orthopyroxene of uniform composition ($Wo_2En_{74}Fs_{24}$) and calcium-rich plagioclase of somewhat variable composition (An_{86}–An_{94}). Pigeonite and olivine have been looked for and not found. Chromite containing Al_2O_3 7.0%, MgO 1.8%, MnO 1.6%, and TiO_2 0.5% is present, as is merrillite. Analysis of the metallic component gave 9.87% Ni, 0.52% Co, 0.15% P, and 2.14% FeS. Metallic areas consist of polycrystalline kamacite with grain boundaries containing cloudy taenite and schreibersite. Cloudy taenite areas have thick borders of tetrataenite. These metallographic associations indicate a low-temperature cooling history identical to that of well known mesosiderites.

1. Introduction

A metal-rich silicate-containing meteorite specimen, RKPA79015, was found by a United States field party under the direction of Dr. William A. CASSIDY in the area of Reckling Peak, Victoria Land, in 1979 (CASSIDY and RANCITELLI, 1982). Preliminary investigation indicates that it is an unusual mesosiderite, paired with four other small silicate-rich fragments found in 1980: RKPA80229, 80246, 80258, and 80263. These five specimens represent the second mesosiderite found in Antarctica. The first one, ALHA77219, was found near the Allan Hills, Victoria Land, in 1977 (AGOSTO *et al.*, 1980; PRINZ *et al.*, 1980). The weight of RKPA79015 as recovered was 10.0 kg. The specimen has been divided into two pieces under clean conditions in a controlled atmosphere at the Antarctic Meteorite Curatorial Laboratory, Lyndon B. Johnson Space Center, Houston. One piece remains in the protective environment in Houston. The other piece weighing 5.52 kg was sent to the Smithsonian Institution, Washington for preliminary characterization and distribution to interested scientists for study. A 530 g slice was removed (Fig. 1), and it is this slice that has provided material to several groups for study.

2. Hand Specimen Petrography

RKPA79015 is a dense mass that has undergone severe external weathering resulting in an appearance similar to that of many weathered iron meteorites. It is covered with reddish-brown iron oxide that is layered in places and thick enough to flake off in centimeter-size pieces. No fusion crust remains, and the original shape of the speci-

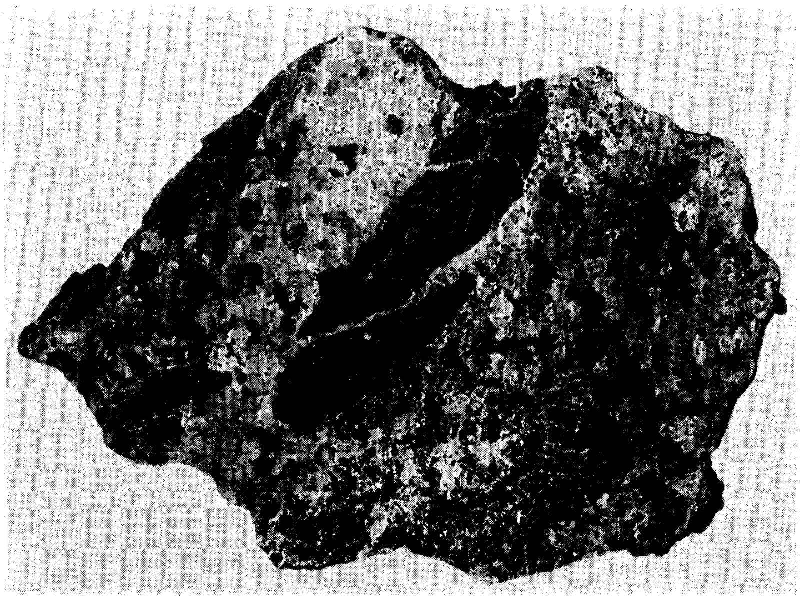

Fig. 1. *Median slice 15.5 cm wide through RKPA79015 showing brecciated structure and heterogeneous distribution of minerals. The etched surface reveals large areas of metal and sulfide, large areas of orthopyroxene that contain very coarsely to finely crystalline material, and areas rich in troilite that also contain significant amounts of both metal and pyroxene. Much of the surface is gradational between these three types of areas. Silicate compositional data on RKPA79015 up to this writing has all come from several polished thin sections prepared from a small fragment from the silicate-rich area near the middle of the upper left edge of the slice.*

Fig. 2. *An enlargement of the top central area in Fig. 1. Central area is orthopyroxene containing veins of kamacite and disseminated troilite. The pyroxene grains range in size from very fine to very coarse, and many of the large grains have been broken along cleavage planes. The right side of the photograph is a comparatively metal-rich area containing troilite and small to medium pyroxene grains. The left side illustrates the polycrystalline nature of the metallic areas, with individual kamacite areas containing rounded to subhedral troilites that are frequently centrally located. Width 4.8 cm.*

men has undoubtedly been somewhat modified. Occasional cleavage faces of large pyroxene crystals are exposed. It is their presence that led to the initial characterization of this specimen as an iron meteorite with silicate inclusions (SCORE *et al.*, 1981).

The brecciated and heterogeneous character of RKPA79015 is shown in Fig. 1, a photograph of the polished and etched surface of the slice. The meteorite is composed of major amounts of metal, orthopyroxene, and troilite, each with associated minor or trace minerals. The three major minerals tend to be in close association with each other, even though in given areas one mineral may predominate by far over the other two.

The large dark area at the top center of Fig. 1 trending downward and to the left is predominantly orthopyroxene ranging in crystal size from small to very coarse (see also Fig. 2). Pyroxene grain boundaries contain fine-grained metal and troilite in various proportions. Occasional veins of metal penetrate into the silicates, and a large vein appears to separate the bottom third from the rest of the silicate-rich area. A similar area of mineral associations and texture is present along the upper left-hand edge of Fig. 1. It is from this area that polished thin sections have been prepared for study.

To the left of the large central orthopyroxene area in Fig. 1 is a large metallic area that is about 3 cm wide for much of its length and extends from the top to the bottom of the slice (see also left side of Fig. 2). This area consists of mm-sized grains of kamacite containing globular troilite, cloudy taenite-tetrataenite areas, and schreibersite in association with grain boundaries. An area in the upper right of Fig. 1, difficult to see in this photograph, contains a troilite-rich region that is approximately 1 cm by 3 cm. The area is predominantly troilite with dispersed silicate, minor amounts of kamacite-cloudy taenite-tetrataenite association, and secondary iron oxides due to terrestrial weathering. The remaining area of the slice, about half the total area, contains small areas of silicate-rich, metal-rich, or troilite-rich material, or some gradation between these three types. The kamacite in the metal at the upper right edge in Fig. 1 has been heat-altered to martensite (α_2) by atmospheric ablation. This area of the specimen surface may be the least affected by terrestrial weathering.

3. Silicate Mineralogy

Silicates make up about 30 weight percent of RKPA79015. As noted above, they are concentrated in silicate-rich areas but are also found at least in small amounts in all regions of the meteorite. Microscopic study in transmitted light and electron microprobe examination of silicate minerals has so far been restricted to our one polished thin section from the silicate-rich area on the upper left-hand edge of the slice as shown in Fig. 1. The silicates in this section were found to be entirely orthopyroxene of uniform composition (Table 1).

Four other silicate-rich meteorite fragments with similar texture, mineralogy, and metallographic relationship were found in the Reckling Peak area during the 1980–1981 field season (SCORE *et al.*, 1982). On the basis of field locality and the similarity of orthopyroxene compositions, we suggest that all five specimens are part of the same fall. RKPA80258 also contains a little calcium-rich plagioclase of somewhat variable

Table 1. Weights, and orthopyroxene compositions calculated from electron microprobe data, of paired Reckling Peak meteorite specimens ($Wo=CaSiO_3$, $En=MgSiO_3$, $Fs=FeSiO_3$).

Specimen No	Weight (g)	Composition
RKPA79015	10,000	$Wo_2En_{74}Fs_{24}$
RKPA80229	14	$Wo_2En_{74}Fs_{24}$
RKPA80246	6	$Wo_2En_{74}Fs_{24}$
RKPA80258	4	$Wo_{2.3-2.9}En_{77-80}Fs_{17-21}$
RKPA80263	17	$Wo_2En_{74}Fs_{24}$

composition (An_{86}–An_{94}), and it also has slightly variable orthopyroxene composition. The metal in the RKPA80258 section shows clear evidence of heat alteration due to atmospheric ablation. Ablation heating of this small fragment may account for the variable orthopyroxene composition, by oxidation of some Fe^{2+} and removal as magnetite.

Chromite (Al_2O_3 7.0%, MgO 1.8%, MnO 1.6%, and TiO_2 0.5%) and merrillite were also analyzed in RKPA79015. Olivine and pigeonite were looked for and not found. Our results on the orthopyroxenes and related minerals are in general agreement with those reported by PRINZ *et al.* (1982).

4. Metallography

A sample from the metallic area at the top left in Fig. 1 (also left edge of Fig. 2) was taken for chemical analysis, and material from adjoining areas was examined microscopically. Eugene JAROSEWICH reports a composition of 9.87 wt% Ni, 0.52 wt% Co, 0.15 wt% P, and 2.14 wt% FeS. The structure of these areas is shown in more detail in Fig. 3. It is dominated by 1 to 3 mm kamacite grains that appear to have formed upon cooling of pre-existing taenite of that same grain size. The kamacite grains contain globular or subhedral troilites, frequently at grain centers. Kamacite-kamacite grain boundaries contain abundant cloudy taenite lamellae bordered by tetrataenite, and frequent schreibersites. The dark cracks along these grain boundaries are the result of the penetration of terrestrial weathering. Neumann bands are present in some kamacites, but they are not abundant. Areas at the junctures of kamacite grains contain larger, irregularly-shaped areas of cloudy taenite, and lamellae of cloudy taenite in kamacite areas containing numerous subgrain boundaries. Occasional unusually large areas of cloudy taenite have martensitic plessite at their centers. Wide bands of tetrataenite separate all cloudy taenite areas from kamacite. Cloudy taenite lamellae typically have 8 to 15 μm wide tetrataenite borders that exhibit clearly discernible optical anisotropy at high magnification (Figs. 4a, 4b). In more complex cloudy taenite areas, tetrataenite borders become even wider (Figs. 4c, 4d). Where cloudy taenite lamellae become narrow, only a faint suggestion of the cloudy taenite structure develops on etching and the optical anisotropy of tetrataenite becomes the dominant feature under crossed polarizers (Figs. 4e, 4f).

The metallographic relationships described above have been confirmed by detailed electron microprobe traverses of typical structures for Ni, Co, and P. Compositions

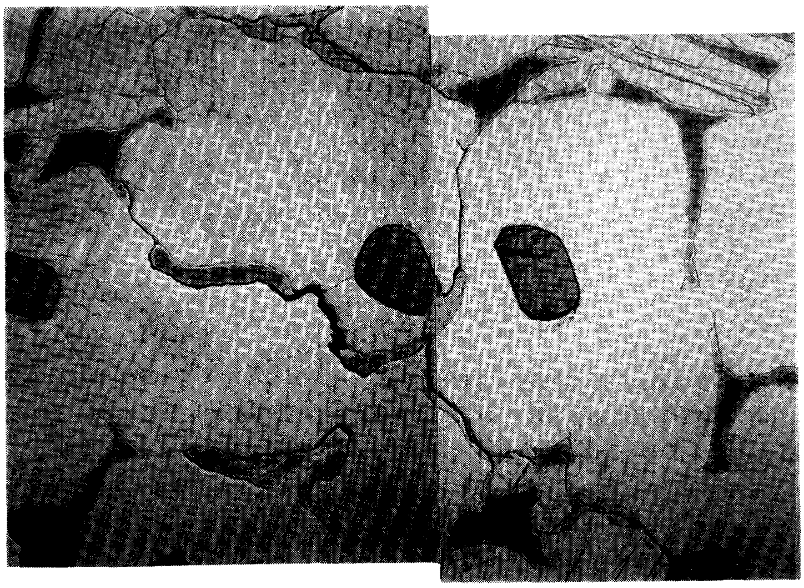

Fig. 3. Metallography of an etched metallic area of RKPA79015, to the upper left in Fig. 1, 4.7 mm wide. Separate kamacite areas in the several mm size range with included troilite and grain boundary cloudy taenite and schreibersite are present. The troilites are the three large dark grey subhedral to rounded crystals across the center of the photograph. Schreibersite is the frequently cracked medium grey mineral along the grain boundaries at the lower right, in contact with the central troilite, and along the upper edge left of center. Residual cloudy taenite with tetrataenite borders occupies much of the grain boundaries and expands into larger cloudy taenite areas at junctures of the large kamacite grains. A comb plessite area is at the upper right, and kamacite containing numerous grain boundaries is at the upper left. Neumann band can be seen at the lower right, and the dark areas along the grain boundaries in the center are the result of terrestrial weathering.

closely match those for similar associations reported earlier for the first Antarctic mesosiderite (AGOSTO *et al.*, 1980). This work will be reported in detail elsewhere.

5. Discussion

This preliminary investigation of five Reckling Peak fragments that appear to be from a single fall leads us to conclude that an important new mesosiderite, one that is atypical of the mesosiderite group as presently understood, has been provided for study by the Antarctic meteorite recovery programs. One of these fragments is a large metal-rich mass, while the other four are small silicate-rich fragments. Study of the large mass has been cursory up to this time, and examination of the smaller fragments, all of which are similar to the silicate-rich areas of the larger mass, forces us to realize that we have no way of knowing what the actual silicate to metal ratio was in the rock that brought these fragments into our upper atmosphere. Obviously the four small fragments can not be considered representative of that rock. It is probably also an over-simplification to assume that the large mass is. Continued field work in the Reckling Peak area should be encouraged in the hope of finding further major pieces of this fall.

All five of the pieces have undergone severe external weathering. In the case of the silicate-rich specimens, at least moderately severe weathering has also penetrated

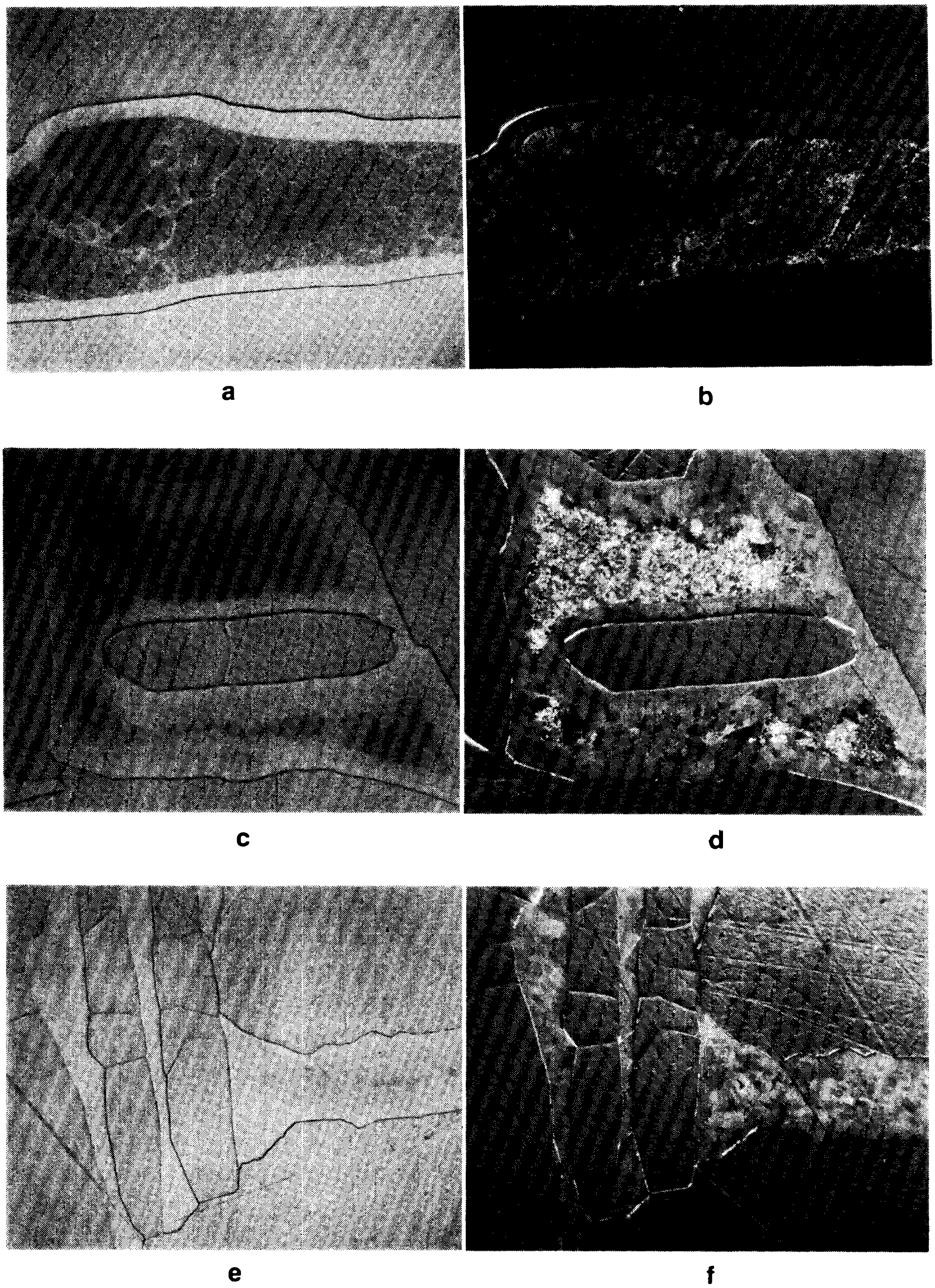

Fig. 4. Oil immersion, crossed polarizers (b, d, f) pairs 225 μm wide, of three mildly etched structures containing tetrataenite. a. b: Cloudy taenite lamella with 8 to 15 μm wide tetrataenite border in kamacite. Optical anisotropy can be seen in the tetrataenite. Black and white photography only partially reproduces the effect the anisotropy actually gives under the microscope. Changes in color aid in its visibility. c, d: More complex cloudy taenite areas frequently develope broader tetrataenite borders. The patchiness in d of the clear borders in e indicate tetrataenitete. e, f: Thin lamellae are essentially unaffected by etching. Almost complete conversion to optically anisotropic tetrataenite has taken place.

their interiors. RKPA80258 has also undergone ablative heating in the atmosphere, as is indicated by the transformation of its kamacite to martensite. It must therefore either be a residue of a small individual that landed or an external fragment broken from a larger individual. External weathering of RKPA79015 has been generally severe, but one area of surface retains heat-altered kamacite indicating milder corrosion. The high proportion of metal in this specimen, however, has provided a protective environment for interior material. Only mild corrosion penetration has taken place along some of the major grain boundaries.

Classification of these Reckling Peak fragments presents problems, particularly when heavy reliance is placed on silicate petrography. Magnesium-rich orthopyroxene is the major silicate present, and it is present in overwhelming proportion compared to other silicates. Only a small amount of calcium-rich plagioclase has been observed, and this in a section of the 4 g fragment RKPA80258. Pigeonite and olivine have not been observed, but it may be premature to conclude that they will not be found on more thorough investigation. Tridymite has not been observed by us, but PRINZ *et al.* (1982) indicate that it is present in small amounts. They report 0.2 vol% SiO_2 in a modal analysis done by an automated electron microprobe technique. The minor minerals merrillite and chromite are present. Although they are not silicates, they are normally considered as part of the silicate assemblage.

The silicates and associated minerals that are present have compositions that correspond to those observed in known mesosiderites. The Reckling Peak orthopyroxene composition is close to that found in the metal-rich mesosiderite Chinguetti (MASON and JAROSEWICH, 1973). The previously described Antarctic mesosiderite, ALHA-77219, has compositionally heterogeneous orthopyroxene, but its average composition is close to that of the homogeneous orthopyroxene observed in the Reckling Peak specimens (AGOSTO *et al.*, 1980; PRINZ *et al.*, 1980). The Allan Hills meteorite has the full suite of recognized mesosiderite silicates, but so far only one small clast containing olivine has been observed. The mesosiderites are heterogeneous breccias.

Strong justification for grouping these Reckling Peak specimens with the mesosiderites comes from their metallographic associations. Whether metal areas from silicate-rich, troilite-rich, or metallic portions of these specimens are examined, cloudy taenite areas bordered by broad bands of tetrataenite are observed. It is becoming increasingly clear from studies of cloudy taenite (SCOTT, 1973) and associated tetrataenite (CLARKE and SCOTT, 1980; AGOSTO *et al.,* 1980) that the distinctive and microscopically readily identifiable metallographic associations observed here are a signature for the mesosiderite group of meteorites. The unique cooling history of mesosiderites was emphasized by POWELL (1969) in terms of cooling rates. The recognition of tetrataenite as an important phase in this association permits the recognition of this cooling history under the microscope and without the need for detailed electron microprobe studies.

RKPA79015 and associated fragments are deficient in certain silicates for a comfortable classification as a typical mesosiderite. However, their bulk metal compositions and metallographic structures indicate that they cooled in a low-temperature thermal environment (500° to 250°C) identical to that in which the well known mesosiderites cooled, an environment that is distinct from other known meteorite groups. We expect that further investigation of these specimens will reinforce the mesosiderite relationships.

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