A 4.4-GRAM, MOSTLY METAL ROCK FROM APOLLO 14 WITH ATTACHED, COGENETIC SILICATES

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Apollo 14 4.4-g rock 14286 was previously unstudied, except for a binocular-microscopic description [1], which mentioned "an unusual metal coating up to 1 mm thick over half of it," and "glass lined zap pits up to 2 mm in diameter." The total metal content was estimated to be 5% (by volume) [1]. We have studied a 470-mg chip (using INAA) and two thin sections. It now seems clear that the metallic surfaces are actually not a coating, but areas where the main component of the rock crops out through a surface coating of silicates. More than half of the rock, even on a volume basis, appears to be metal.

The metal component is kamacite, with 91.5-95.3 wt% Fe, 4.7-6.2 wt% Ni, 0.51-0.63 wt% Co, and ~0.1 wt% P. The silicate component appears from binocular observations to be of two types: a fine-grained, soil-like material that is probably a thin coating over parts of the surface, and a relatively coarse-grained lithology composed of subequal proportions of plagioclase (maskelynitized) and a greenish pyroxene, both of which occur as equant, 0.5-1.0 mm grains. The fine-grained silicate component is not found in the two thin sections studied. The first thin section that we were sent is virtually pure FeNi. However, roughly 10 vol% of thin section 14286,11 consists of the coarse-grained silicate material. The silicates (essentially bimineralic plagioclase and low-Ca pyroxene) are confined to roughly hemispherical niches along the outer fringe of the thin section. The boundaries of the silicate grains are typically smooth, highly curved arcs, which fit neatly within corresponding rounded cavities in the adjacent metal. The smoothness of the interfaces between the silicate enclaves and the metal clearly indicates that the silicates and the metal crystallized appproximately contemporaneously, from a common parent magma.

Viewed under binocular microscope, parts of the surface of the rock show a high density of circular depressions, 1-2 mm in diameter, described as "glass lined zap pits up to 2 mm in diameter" by Carlson and Walton [1]. It seems unlikely that they are zap pits, however, because pits in the 1-2 mm diameter range outnumber pits in smaller diameter ranges, and because most of the pits have unusually high (~1) depth/diameter ratios, for impact craters. These pits are probably cavities created when roundish enclaves of brittle silicates were jarred loose from the more maleable metallic core of the fragment, probably during one or more episodes in which the fragment was jostled within an ejecta blanket. (Such a process would inevitably work to selectively winnow off silicates, leaving the largest surviving fragments with higher metal/silicate ratios than their parental materials).

The three largest enclaves in the thin section each contain 1-3 grains of pyroxene and 1-2 grains of plagioclase/maskelynite. The typical grain size appears to be ~0.5 mm for plag./maskelynite, and ~1 mm for pyroxene. The largest pyroxene visible is 1.2 mm in maximum dimension, and the largest plag./maskelynite is 1.0 mm (but only 0.8 mm if a vein-like structure, possibly a brecciation product, is excluded). Schreibersite, $(Fe,Ni)_3P$, is an accessory mineral. Mostly it is found as isolated grains apparently deep within the kamacite. These grains tend to be long (up to 0.9 mm, with typical aspect ratios of 5-10), slightly vermicular, and even veinlike. However, much of the schreibersite occurs as relatively equant, anhedral grains sandwiched between the kamacite and the silicates. The metallic portion of the rock also contains a much smaller trace of troilite. The plag./maskelynite is $An_{89.1-94.0}$, and averages $An_{91.9}$. It is relatively FeO-poor, averaging 0.096 wt%. All of it has been maskelynitized, but some areas have partly devitrified. The pyroxene, which has been brecciated but is not diaplectic, is $En_{76.0-69.9}Wo_{2.0-4.4}$, averaging $En_{71.9}Wo_{3.4}$; the range in *mg* ratio is 0.729-0.775, averaging 0.745. The schreibersite averages 52.4 wt% Fe, 32.9 wt% Ni, 15.2 wt% P, and 0.10 wt% Co, with little difference in composition between the silicate-associated type and the isolated type. The pyroxene contains an average of 0.49 wt% Cr_2O_3 and 0.79 wt% TiO_2. Data for MnO and FeO are shown in Fig. 1. Except for points within a few μm of FeNi or $(Fe,Ni)_3P$, the MnO/FeO ratios are consistent with a purely lunar pedigree for the noritic portion of the rock. The incompatible-element concentrations of our bulk-rock INAA sample provide another indication that the silicate portion of the rock is not exotic to the Apollo 14 region of the

Moon. Corrected for dilution with ~95 wt% metal, the REE concentrations are at levels ~0.6 x average high-K KREEP [2]. It seems unlikely, although by no means inconceivable, that such a REE-rich material could form in contact with FeNi-metal within an asteroid-sized parent body.

The bulk-rock Ir content is 1690 ng/g, or 3.4 x CI chondrites. However, Ni (4.7 x CI) and Au (7.1 x CI) are even more enriched. Elevated Ni/Ir and especially Au/Ir are distinctive characteristics of Apollo 14 highlands samples [3], as well as samples from the nearby Apollo 16 site [4]. These elevated Ni/Ir and Au/Ir ratios have long been controversial [4,5,3]. Warren et al. [3] used lunar meteorite data to show that elevated Ni/Ir and Au/Ir are not general features of the global megaregolith, but rather peculiarities of the central nearside. This observation tends to support Korotev's [4] proposal that the elevated Ni/Ir and Au/Ir ratios resulted from the impact in the Apollo 16 region of "one or a few metal-rich, probably iron, meteorites." The notion of multiple impacts of a peculiar type of meteorite focused over a particular region of the Moon seems dynamically implausible. What mechanism would steer all meteorites of a given deep-space provenance towards a particular region of the Moon?; or break apart a large object immediately before collision with the central nearside? Former proximity of the Moon to the Earth would only serve to weakly focus accreting objects towards the farside [6]. If a single impact is invoked as the source of the enhanced Ni/Ir and Au/Ir at both the Apollo 14 and 16 sites (1020 km apart), that impact must have produced an uncommonly large pool of impact melt. One possible origin for 14286 is by settling of metal and impact-melted silicates at the bottom (and thus, most slowly-cooled) portion of the impact-melt pool required by Korotev's [4] hypothesis. Most of the projectile in a large impact is vaporized, and thus widely disseminated, but a minor proportion probably survives in relatively intact form [7]. Alternatively, 14286 might have formed by fortuitous accretion of a small metal-rich projectile fragment into a pre-existing flow or shallow intrusion of endogenously generated magma. (Of course, if 14286 formed in the earliest phase of lunar magmatism, when accretional energy probably helped generate even "endogenous" melts, these two alternatives would merge into a single complex scenario).

Indeed, if the medium-grained (by lunar standards), igneous texture of the 14286 silicate enclaves were found in isolation from the metal (or from most of the metal), an incautious petrologist might be tempted to assume that the lithology formed as a pristine rock, i.e., by endogenously lunar magmatism. In that event, with its combination of plag./maskelynite An and pyroxene *mg*, 14286 would resemble a typical Mg-suite norite. In view of 14286, we advise lunar petrologists to exercise greater caution before classifying medium-grained nonmare rocks as pristine or "plutonic."

References: [1] Carlson I. C. and Walton J. A. (1978) *Apollo 14 Rock Samples*, NASA JSC 14240. [2] Warren P. H. (1989) p. 149-153 in *Workshop on Moon in Transition*, LPI Tech. Rpt. 89-03. [3] Warren P. H. et al. (1989) *EPSL* 91, 245-260. [4] Korotev (1987) *PLPSC 17th*, E447-E461. [5] Ringwood A. E. et al. (1987) *EPSL* 81, 105-117. [6] Bandermann L. W. and Singer S. F. (1973) *Icarus* 19, 108-113. [7] Melosh (1989) *Impact Cratering — A Geologic Process*, p. 73.

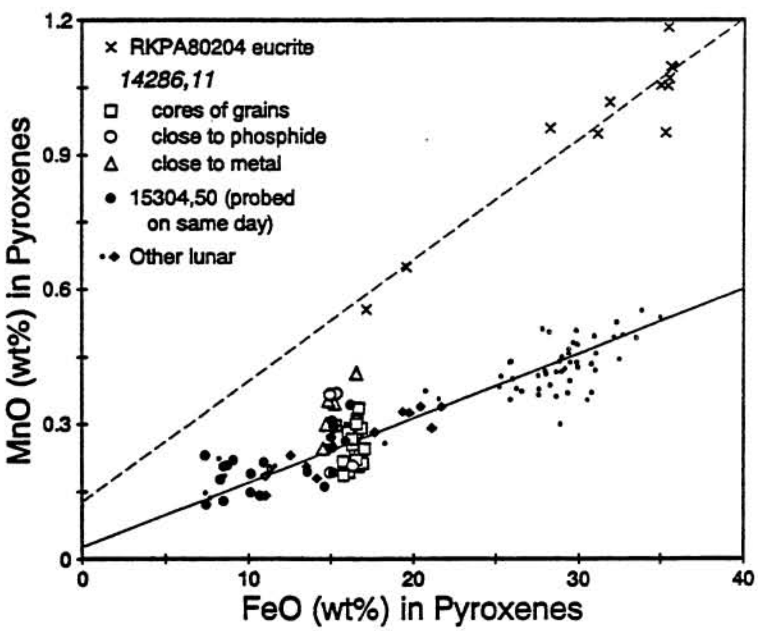

Fig. 1