tion of grain size and density should enable direct derivation of data on average energy spectra, and may be the only method of getting long-term average energy spectra for solar flare particles in this energy region.

Conversely, detailed knowledge of these fluxes will enable (i) determination of the extent of terrestrial contamination of samples, whether collected directly or on Earth's surface, that have been outside the magnetosphere, and (ii) definitive mineralogical and chemical studies of material that can, with noble-gas anomalies, be incontrovertably shown to have been in space. Application of similar measurements to lunar surface material may enable determination of average residence times for fine-grained material on the extreme surface, and of long-term mixing or stirring parameters as a function of depth.

As we acquire detailed knowledge of the concentration and origin of rare gases in "pure" interplanetary dust, we can study long oceanic cores to determine variations in extraterrestrial influx rate and in oceanic sedimentation rates over the entire sediment column. This work provides another application of "the poor man's space probes" currently arriving at Earth.

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Evidence of Early Pyrometallurgy in the Kerman Range in Iran

Abstract. *Physical and chemical analysis of pottery fragments, including a crucible shard and ore samples from Tal-i-Iblis, Iran, suggests that copper smelting may have been well advanced late in the fifth millennium B.C.*

Despite the recent interest in the origins of metallurgy, definitive evidence relating to the locus and sequence of events that led to the production of useful metal objects from ores remains sketchy (*1, 2*). There is evidence to indicate that the first useful copper artifacts were produced by cold-working or by hammering and annealing native copper (*1*). This first use of hard metals may have occurred in the Near East as early as the 9th or 10th millennium B.C. (*2*). The transition from the use of native metals to the smelting of carbonate and oxide or sulfide ores was revolutionary.

Thompson has indicated that it would be feasible for a primitive smith to reduce copper ore and to fashion artifacts without developing the technology required for the production of the molten metal (*3*). However, there is at present no compelling evidence in support of this view when compared with the hypothesis that the smelting and casting of native copper antedated the discovery of smelting (*1*).

In the course of an archeological survey in Kerman Province, southeast Iran, certain artifacts were recovered (*4, 5*). In 1964, Stein's site of Tal-i-Iblis in the Lalihzar Valley (*6*) was revisited. The center of the mound (originally 118 meters across and 11 meters high) was being removed for fertilizer. This operation exposed successive occupation layers in profile. Radiocarbon samples and a wide variety of pottery fragments and artifacts were quickly recovered from these levels. Several crucible shards were among the artifacts recovered from Tal-i-Iblis levels 1 and 2, the earliest mound levels [4091 ± 74 B.C. (P-925) and 4083 ± 75 B.C. (P-926A), respectively]. We have examined one of the shards from level 1.

The ceramic of the crucible shard was derived from a predominately kaolinite clay (*7*). It was poorly fired, as evidenced by its high porosity and spalling at the outer edges (see Fig. 1). The inner surface of the ceramic was covered with partially vitrified material that had the appearance of dross or slag which contained small pieces of slaked lime. Also noted were two prominent copper stains. Under microscopic examination of the inner surface a general pattern of copper stain was observed. The ceramic had a definite black core that extended to within 2 mm of the outer edge; the outer surface had a tan-salmon color. These data suggest that the crucible was intentionally fired in a reducing atmosphere, because even earlier pottery at this site was fired well enough to oxidize the organic materials that are normally present in all clays (*8*). The tan-salmon color of the outer surface, together with flaky composition of the ceramic, indicates that the maximum temperature obtained during the firing process was probably below 1000°C—possibly from 700° to 800°C. These temperatures are sufficient for the reduction of copper ore (*3*), but they are well below the melting point of the metal (1083°C).

Spectrochemical analysis of the obvious copper stains on the shard's inner surface was consistent with the hypothesis that the copper metal that produced the stain originally came from a copper ore. In addition to copper, the stain contained significantly higher concentrations of cobalt, nickel, phosphorus, and tin, than the surrounding ceramic or the surface dross. If the source of the copper was an ore, these elements would be expected. They could not have been present in such amounts (0.1 to 1 percent) in a native copper sample.

Melting points for the ceramic were determined with an optical pyrometer (*6, 9*). The samples were melted on a tungten filament in flowing nitrogen. The outer surface of the crucible melted at 990° ± 50°C, and the inner surface melted at 1150° ± 50°C. The melting point of the inner layers of ceramic was the same as that of the outer surface. All samples gave clear glasses. If the crucible had been used for melting native copper there should have been no difference in the three melting points because the metal-working process would not have appreciably altered the composition of the ceramic. The fact that the unaltered ceramic melted at about 1000°C makes it seem unlikely that the crucible was used for melting copper in any form. The temperature required to melt cop-

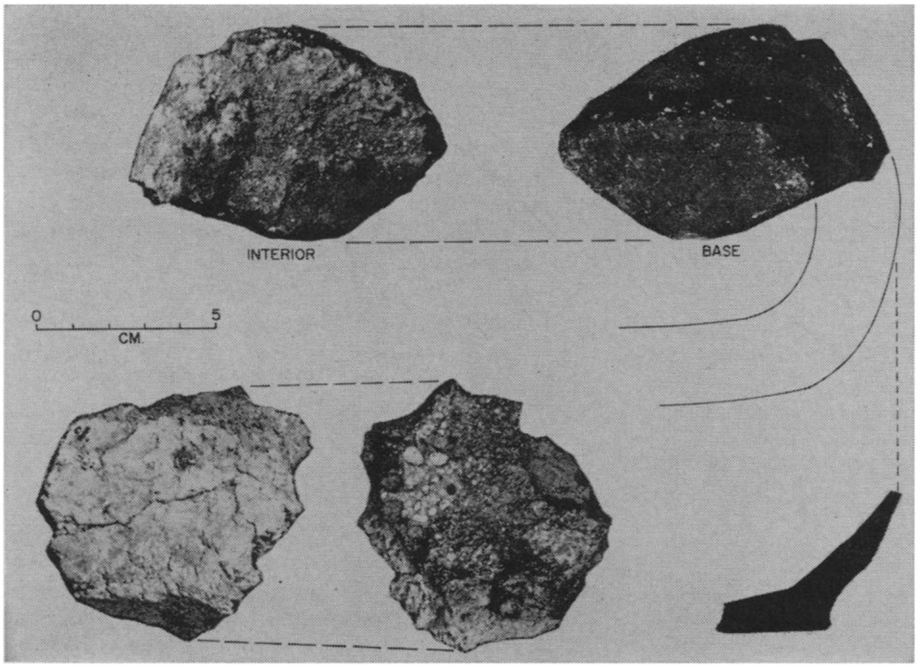

Fig. 1. Crucible fragments from Tal-i-Iblis level 1.

per would probably have reduced the crucible to a glass.

One must consider the possibility that the low melting point of the ceramic may be due to superficial deposits of water-soluble alkali. This seems unlikely because the base-exchange capacity of the clay should be relatively small (*10*), and the interior of the ceramic shard had the same melting point as the outer surface. The possibility that the copper stain and dross resulted from experiments directed toward the production of a blue-green glaze may be discounted for the following reasons: (i) the number of samples and the time span for their production (shards of this type were recovered from the first two levels of the mound); and (ii) the high degree of ceramic technology exhibited in well-made and highly fired shards from the same level.

On the basis of this evidence, it is reasonable that the crucible was used for the reduction of a copper ore. This work might be considered as support for the hypothesis that smelting antedated the melting of copper metal, as the smith did not employ a highly refactory ceramic for this process. The only ore samples found at this site have proved to be chalcocite, a sulfide ore that would require roasting. If this was the ore that was used in the 5th millenium, pyrometallurgy was well advanced at that time.

If, as Pittioni has cautiously suggested (*11*), the first use of smelting occurred in Anatolia (Catel Hüyük, level VI) not later than the 6th millenium, it would be reasonable to expect that the roasting and smelting of sulfide ores could have been accomplished by the end of the 5th millenium. Whereas more evidence concerning these events is necessary, the time scale for the development of metallurgy (*1*) will probably have to be extended.

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Luna 9 Photographs: Evidence for a Fragmental Surface Layer

Abstract. *The morphological features of the lunar surface photographed by Luna 9 indicate a surficial layer of weakly cohesive to noncohesive fragmental material. Most of this material is finer than a centimeter and probably finer than a few millimeters, although objects of centimeter size and larger are plentiful.*

The pictures transmitted by Luna 9 have provided the first views of the fine-scale texture and structure of the lunar surface. Although the total areal coverage of the surface in these pictures is very small (and may be atypical of the moon in general), the photographs nevertheless contain a wealth of information that, when combined with results from studies of impact cratering in natural materials, furnishes the most definitive evidence to date of some of the important physical properties of the surficial layer of the moon. Because much of the cratering data is of recent acquisition, the full significance of the Luna 9 photographs has not been recognized by students of the subject either in this country or abroad (*1–5*). It is for this reason that this report was prepared.

Luna 9 landed along the extreme western margin of Oceanus Procellarum at selenographic coordinates reported to be 7°00′N and 64°33′W, as shown on the Aeronautical Chart and Information Center map of the Hevelius region (*6*). The site is approximately 90 km northeast of the center of the crater Cavalerius on a narrow tongue or strip of the mare surface that extends southward between hills of upland material. However, due to a 3 km-uncertainty in the precise impact point, one cannot be certain whether the surface in the photographs is upland or mare material.

Pictures have been examined from three separate panoramic scans of the lunar surface. One full panorama available for detailed study (apparently the last transmitted by Luna 9) includes about 280° of a complete scan. Due to an easterly tilt of the camera scan axis, the horizon is below the camera field of view in the remaining (westerly) 80° of the scan. Fragments of two earlier scans duplicating 160° of the panorama have also been examined. Because of the spacecraft movement, the camera position changed at least