IRON AND TITANIUM CONCENTRATIONS IN SOUTH POLE-AITKEN BASIN: IMPLICATIONS FOR LUNAR MANTLE COMPOSITION AND BASIN FORMATION;

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Recently, we reported on a technique to determine FeO content of soils from multispectral images of the Moon and applied this technique to global, low-resolution Clementine images to create a global iron map of the Moon (1). In this abstract, we utilize FeO and a new technique that allows us to map the concentration of titanium globally across the Moon (2). Using these data we find that the composition of the interior of the huge South Pole-Aitken (SPA) basin is unlike any major lunar rock type or model lunar mantle composition, although its ejecta (the highlands terrain immediately surrounding the basin rim) is typical of the lunar highlands (FeO of about 3-4 wt.%, TiO_2 ~ 0.3 wt.%). The elevated FeO content of the basin floor may result from exposure of rocks from the mantle of the Moon (3). The TiO_2 abundances suggest that the floor of SPA could be a mixture of approximately equal parts of typical LKFM (lower crustal composition) and low-Ti mantle rocks with 10-16 wt.% FeO. This FeO content is in the range of likely mantle compositions. This mixture would have a Th concentration of about half the level in LKFM, or about 2-4 ppm, as observed in the northern floor materials of SPA basin(4).

Composition of South Pole-Aitken basin floor. FeO and TiO_2 are useful in identifying major types of lunar rocks, as shown in Fig 1. The data for mantle rocks are inferred from mass balances of model compositions of the crust and bulk moon, and from experiments on mare basalt compositions at high P and T. Our data for SPA fall between LKFM mafic impact melts, a reasonable candidate for lower crustal rocks (5), and lunar mantle compositions (Fig. 2), suggesting a roughly 1:1 mixture of these materials. There are possible alternatives. One is that the floor is a mixture of average highlands norites and troctolites with low-Ti mare basalts. There are small mare deposits within the basin and there may be ancient cryptomare deposits in which fragments of mare basalt are intimately mixed into the highlands regolith. Mare basalts would increase FeO and TiO_2, possibly producing a trend like that shown in Fig. 2, but this mixture would probably have a Th content of < 1 ppm, substantially below the 2-4 ppm measured by the Apollo gamma-ray experiment. Another possibility is that the floor consists of lower crustal impact melts that are similar in origin to LKFM found on the near side, but have lower TiO_2 and Th contents. This is possible in principle: LKFM is quite variable in its chemical characteristics and the lower crust of the Moon in the farside may not be similar to that sampled by the basins which gave rise to LKFM on the near side (6). The most straight-forward interpretation, however, is that the floor of SPA is composed of a 1:1 mixture of typical LKFM and mantle rock that contains between 10 and 16 wt.% FeO and < 0.1 wt.% TiO_2.

Cratering dynamics. The observed basin diameter of 2500 km (7), suggests that the diameter of the transient crater was on the order of 1400 km (8). Such an event would excavate material from as deep as 150 km in the Moon and would have a total excavated volume of about 103×10^6 km^3 of material. Assuming an average crustal thickness of 100 km (a value common on the lunar far side; (9)), about 95×10^6 km^3 is derived from the crust (95% of all ejecta) while almost 8×10^6 km^3 (5% of ejecta) comes from the mantle of the Moon. Thus, even though the SPA basin is large enough to have completely excavated the crust from its target site, according to the proportional growth model (8), the bulk of ejecta would come from the crust of the Moon. This is consistent with the composition of the highlands surrounding the basin (FeO of 3-4 wt.% and TiO_2 of 0.3 wt.%). According to current cratering models (10,11), the provenance of the impact melt of this large-scale event is entirely different than that of the ejecta. Current scaling relations suggest that SPA basin must have been formed by a projectile at least a few hundred kilometers in diameter. We have used the melt model of (10) to model the impact of a 250 km diameter projectile impacting the Moon at 20 km s^{-1}. Such an impact would generate about 180 x 10^6 km^3 of melt, almost twice the estimated volume of material excavated from the cavity. Moreover, this impact melt is generated largely in zones of the upper mantle; crustal rocks make up less than a few percent of the melt zone. A large fraction of this melt would be ejected from the basin cavity, but more than half would remain in and below the basin floor. Using a somewhat different approach, Warren (12) also concludes that the SPA impact melt sheet would consist virtually entirely of mantle rock.

Conclusions. It seems likely that the SPA event did excavate substantial amounts of mantle material. This mantle was low in TiO_2 (< 0.1 wt.%) and had FeO in the range 10-16 wt.%, lower than that estimated for the source regions of most types of mare basalts, except for magnesian magmas such as Apollo 15 green glass. Such a magnesian, low-Ti upper mantle composition would be expected if the mantle overturned and dense-ilmenite-rich cumulates sank (13) and Mg-rich cumulates rose. However, the basin floor does not appear to be dominantly of mantle composition, in contrast to predictions from cratering models. Our conclusion that the SPA basin interior is composed of a 1:1 mixture of mantle and lower crust suggests that current models of impact melt genesis in large basins need some modification. On the other hand, if the compositional data actually reflect a mixture of typical highlands with low-Ti mare basalts or a different type of LKFM lower crustal material, then the cratering models need drastic revision.

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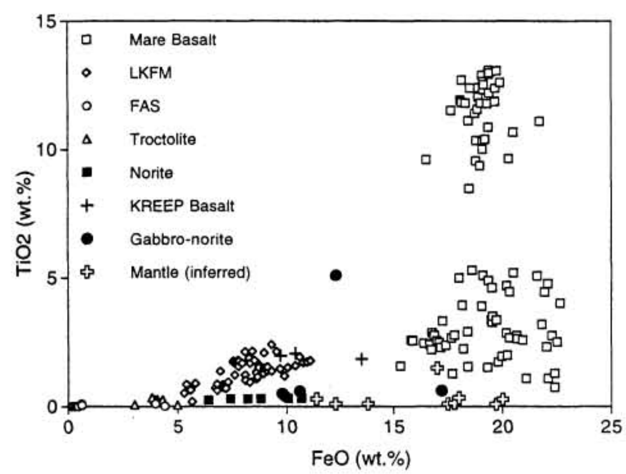

Fig. 1. Compositions of major lunar rock types.

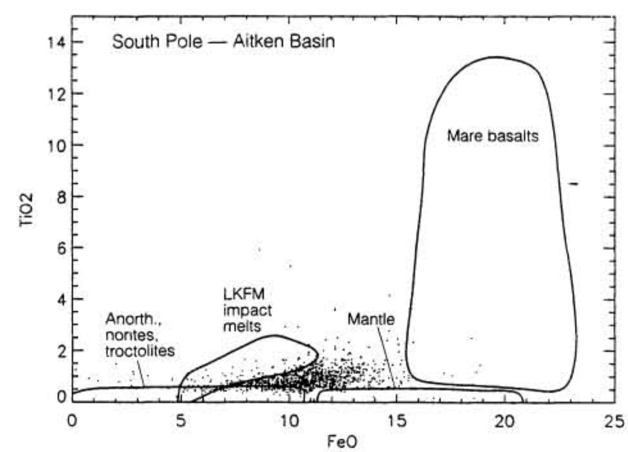

Fig. 2. Composition for the interior of South Pole-Aitken lies between fields for LKFM and mantle.