SOME EVIDENCE CONCERNING THE SOURCE MATERIAL OF LARGE GLASS OBJECTS FROM THE MOON. Richard V. Morris[1], Thomas H. See[2], and Friedrich Hörz[1], [1]SN4 NASA Johnson Space Center, Houston, TX 77058; [2]LOCKHEED, Houston, TX 77058

Introduction: Large glass objects (LGO's) are a class of lunar impact melts having masses larger than several grams or volumes greater than several cubic centimeters; they are thus intermediate in size between agglutinates and impact-melt rocks. They occur as thick coatings on rocks, solid or hollow spheres, and veins penetrating rocks. The source material for these impact melts is not established and the possibilities range between regolith and bedrock. This study is part of a multidisciplinary effort to characterize about 50 LGO's from Apollo 16 and thereby constrain the nature of the source material and the impacting projectiles. We discuss here the results of measurements by ferromagnetic resonance (FMR) and hysteretic-loop techniques. The procedures are described by (1) and references therein. The purpose here was to learn about the abundance and size distribution of metallic iron particles in the LGO's and compare the results to similar data on soils (1). Trace element abundances have been determined by INAA techniques (2), and we discuss here only the Ni and Co analyses.

Results and Discussion: In Figure 1 we plot Fe^o_C versus the ratio Fe^o_A/Fe^o_C for the LGO's and Apollo 16 soils. The concentration units are equivalent weight percentage of metallic iron. The subscripts refer to concentrations of metallic iron particles (either as discrete particles or particles imbedded in a matrix) in specific diameter ranges: for Fe^o_A $40 \lesssim d \lesssim 330A$, and for Fe^o_C $\gtrsim 40A$ (1,3). Fe^o_C is thus the total equivalent concentration of metallic iron to the extent there are no particles having $d \gtrsim 40A$. The small diameter metal particles are associated with agglutinitic glass so that lunar soils have high concentrations of Fe^o_A (1).

Two relationships between the LGO's and the Apollo 16 soils are evident in Figure 1. Firstly, the range in the values of Fe^o_C for the LGO's is comparable to the range for the soils. Secondly, the LGO's have significantly lower ratios of Fe^o_A/Fe^o_C; only four of the fifty LGO's have ratios that are even within an order of magnitude of the smallest ratio for soils for which there is data. These two relationships suggest the LGO's can have a regolith source material. Soils have high values of the ratio Fe^o_A/Fe^o_C because agglutinitic glass having a relatively small volume containing many clasts was formed during a rapid quench so that the metal particles do not coalesce much. If a soil is impact melted to make an LGO, the metal would coalesce resulting in relatively lower values of Fe^o_A/Fe^o_C because their larger volume results in a slower cooling rate, but the total metal concentration would remain about the same if the projectile itself does not contribute significant metal. The metallic iron content of Apollo 16 rocks (1) spans the range observed for the LGO's, but there is no corresponding Fe^o_A data available. Therefore, Apollo 16 rocks must also be considered as likely parental material on this basis.

Figure 2 is a plot of Co versus Ni for the 39 LGO's analyzed to date. Also included are soil data averaged by Apollo 16 sampling station (from (4)). A linear least squares fit of the LGO data (excluding the most Ni-rich sample) yields an intercept of 12±2 μg/g Co. Palme (5) calculate about the same value (7.5±1.2 μg/g) for Apollo 16 rocks, and, in fact, the Ni-Co data for the LGO's and rocks almost totally overlap. This indicates that the breccias and LGO's have a common source material or that the LGO's were directly derived from rocks. However, it is also possible to account for the LGO data with Apollo 16 soils as the source material. The overlap of the LGO and soil data is actually more extensive than indicated in Figure 2 since

station averages only were used for the soils. Even LGO's with especially high abundances of Ni and Co could still be formed by contamination of impacted soil with projectile material.

The Ni/Co ratio for the LGO's ranges from about 7 to 19 and averages 12.6±2.8. This is significantly less than the range of 20-23 observed for the average Ni/Co ratio of chondrites (6); therefore some indigenous Ni and Co (e.g., 5) is indicated. A significant indigenous component is present in the 4-component mixing model of (4) for the Apollo 16 regolith. In addition to a meteoritic component the components are FAN (Ni/Co = 2; Ni = 2 μg/g), KREEP (Ni/Co = 0.6; Ni = 33 μg/g), and HON (Ni/Co = 4.3, Ni = 116 μg/g). To the extent to which these three components represent the primary compositional endmembers at Apollo 16, they must be the ultimate progenitor for all impact derived materials (soils, breccias, LGO's, etc.). Since the Ni/Co ratios of FAN, KREEP, and HON are much less than chondritic values, it seems likely that the relatively lower values and wide range of Ni/Co for the LGO's (and also for Apollo 16 soils) is due to indigenous Ni and Co that is present in variable amounts depending on the relative proportions of FAN, KREEP, and HON and on the extent of meteoritic contamination.

In summary, regolith or local bedrock or both are viable source material for the LGO's. Additional chemical analyses now in progress (3) may help to resolve the question of source material.

References: (1) Morris (1980) PLPSC 11, 1697; (2) See et al. (1983) this volume; (3) Housley et al. (1976) PLSC 7, 13; (4) Korotev (1981) PLPSC 12B, 577; (5) Palme (1980) PLPSC 11, 481; (6) Mason (1979) Data of Geochemistry, Ch. B, Cosmochem, Pt. 1 Meteorites.

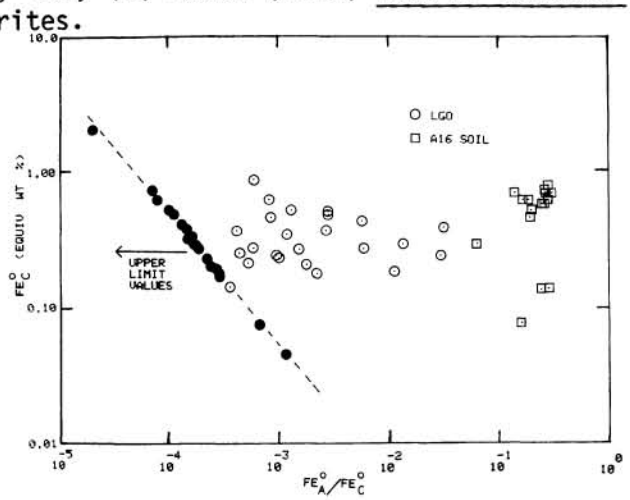

Figure 1. Fe^o_C versus Fe^o_A/Fe^o_C for Apollo 16 LGO's and soils. The filled symbols refer to LGO's whose value of Fe^o_A/Fe^o_C is an upper limit.

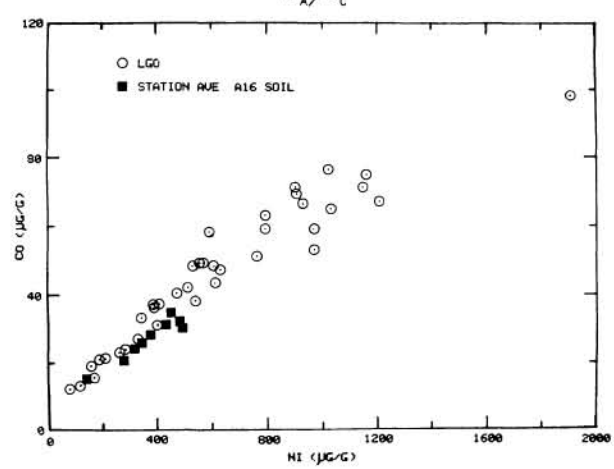

Figure 2. Co versus Ni for Apollo 16 LGO's and soil data averged by sampling station.