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Locations and Geology of the Soviet Lunar Rover and Sample Return Missions

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The US and USSR sent a series of robotic spacecraft to the Moon as preludes to human missions, to make measurements and return samples. The locations of the US Surveyor spacecraft were precisely established and in some cases were imaged from orbit; thus, the context of their observations were well understood. For the USSR Luna landers/Lunokhod rovers (Luna 17, 21) and sample return (Luna 16, 20, 24) missions, the locations were not precisely determined and thus, the in situ observations and the sample context were poorly constrained. Using the Lunar Reconnaissance Orbiter Camera [1], these spacecraft were imaged and their positions established allowing the geologic context to be established.

Luna 17, carrying the Lunokhod 1, landed in northwest Mare Imbrium. Tracks from the rover are easily identified allowing for a detailed analysis of the traverse. Locating the rover has allowed it to be recovered using Earth-based lunar laser ranging. Recovering the rover allows for enhanced geophysical analysis of the orbital dynamics of the Moon as it provides an additional station, and one which is considerably north and west of the others. Luna 21, with the Lunokhod 2 rover, landed on the floor of Le Monnier crater. The Lunokhod 2 rover is $\sim$500 m east of the NNE-trending rille in a relatively flat mare surface with scattered impact craters. Its traverse across the mare surface is easily recognized. Tracks within the highlands material on the southern rim of Le Monnier have been difficult to locate.

Samples returned by Luna 24 (Mare Crisium) were different from what had been expected based on remote sensing – samples were immature and dominated by igneous lithic fragments (e.g., gabbro), mineral grains, agglutinates, glasses and breccia; the material is derived from very-low-titanium basalt. In contrast, remote sensing data suggested high-titanium materials. The original interpretation was that the mission sampled distal ejecta from the crater Fahrenheit. However, the spacecraft landed on the flank of a fresh $\sim$64 m diameter crater, $\sim$10 m from the rim on the northwest flank within the continuous ejecta. The returned material was thus largely ejecta excavated from the crater, rather than surficial Crisium material or ejecta from Fahrenheit. Luna 23, a failed sample return mission, was located about 2.3 km to the southwest of Lunar 24.

Luna 20 landed in the highlands NW of Apollonius. The lander is on a relatively level highland surface and there are two 3 m craters immediately north of the lander. There are no unusual geologic features nearby. Based on the shadow of the vehicle and sampling mechanism, the sample was acquired to the northeast of the lander.

Luna 16 landed in Imbrian-age mare of northeastern Mare Fecunditatis on a level mare with scattered craters. Rays of ejecta from the craters Langrenus, Taruntius, Theophilus and Tycho cross the landing area. Samples would are of a typical mare surface.

Precise locations of several Apollo SIVB impact events have also been determined. These updated locations, combined with a precise measurement of the impact crater diameter, will provide important constraints on the velocity model of the lunar crust. Apollo-era model assumed locations based on preliminary tracking data.

References: [1] Robinson, M. S. et al. (2010) Space Sci. Rev., 150, 81-124.