SAMPLING BASIN EJECTA IN THE OUTER - FELDSPATHIC HIGHLANDS TERRANE AT LUNA 20

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Introduction: The Russian Luna 20 sample return mission landed in the lunar highlands (3.78°N, 56.62°W) located between the Crisium and Fecunditatis basins on the eastern nearside limb of the Moon. Returned samples provide an opportunity to study material from the upper and middle highlands crust in the Outer Feldspathic Highland Terrane (FHT-O) and lower crustal material excavated by the surrounding basins [1-3]. Here we revisit the igneous lithic clast, granulite and impact melt breccia component of Luna 20 to understand the compositional heterogeneity of the lunar feldspathic highlands and investigate crust formation and impact modification processes.

Impact ejecta contributions at the Luna 20 site: Impact melts and melt breccias at Luna 20 may sample the age of the Crisium basin, a major stratigraphic boundary which ages helps to understand the relative sequence of basins and the duration of basin formation [6,7]. Reported ages of such impact melt breccias have a wide range in ages from 4.09-3.75 Ga [2,4,5], but how they are related to the Crisium event or not is debated [8]. To assess the potential impact ejecta contribution at the Luna 20 site, we used equation 1 of [9] (after [10]), using the crater inner ring radius [11] and geometric distance to the source crater centre from Luna 20 as inputs. In relative order (oldest at bottom, to youngest at top), underlying Luna 20 is 181-299 m of pre-Nectarian aged Fecunditatis proximal ejecta, overlain by 262-442 m of proximal Nectarian aged Crisium ejecta and contributions from superimposed Nectarian aged craters, including 4-11 m of ejecta from the Apollonius A crater located 33.6 km to the NNE. Our modelling suggests that 2-15 m of Imbrium distal ejecta will also be present at the Luna 20 site supporting the observations of Wilhelms [8] who note that the region around Luna 20 contains pits and furrows likely related to be Imbrium-secondary craters and ejecta emplacement. A veneer of 0.4-1.8 m of ejecta may have been added from the 12 km diameter Imbrian aged Ameghino crater located 19.2 km to the SE of the landing site. All ejecta blankets probably included a component of ballistically reworked ejecta from the older basin-forming events.

Sample Analysis Methods: Thin sections of soil grain mounts were allocated from the NASA JSC Luna 20 collection, representing material sourced from the middle portion (~19-27 cm relative position) of the extracted Luna 20 drill core [12]. We performed optical microscopy then the thin sections were then carbon coated and back-scatter electron maps made using a FEI QUANTA 650 FEG-SEM. Mineral and glass chemistry was determined using a Cameca SX100 with a 1 micron focused or a 20 micron defocused beam. Average impact melt clast compositions were estimated by averaging a variable number of 20 micron spots together.

Results: We have identified a range of clasts typical including feldspathic clast-rich and clast-poor impact melts, devitrified feldspathic glass, low-Ti mare basalts, magnesian granulites, glassy breccias and anorthositic troctolites, norities and gabbros. Anorthitic plagioclase is a common mineral fragment. Lithic and mineral grains range from pristine to highly fractured implying variable levels of impact shock processing. Agglutinates, friable lithic breccias and regolith breccia fragments and glassy splash coats surrounding grains attest to the samples' regolith residence.

Discussion: *Are the 3.9 Ga ages recorded at Luna 20 related to Imbrium or Crisium ejecta?* Imbrium impact melt breccias have characteristically elevated KREEP bulk compositions (> 9 ppm Sm) with moderately high-Ti (0.6-1.6 wt%) and FeO (7-10 wt%), whereas Crisium impact melt sheets have a similar range of FeO (8-10.5 wt%), but lower TiO_2 0.25-0.9 wt% [13]. Average Luna 20 soils are ×1.5 comparatively Sm-poorer (3.2 ppm) and Fe-richer than Apollo 16 soils, reflecting a lower component of KREEP-bearing material and a higher proportion of mafic rock. All of the crystalline impact melt clasts investigated in the Luna 20 samples in our study have lower bulk FeO (3-8 wt%) than both Imbrium and Crisium impact melts, and are more compositionally similar to lunar meteorite feldspathic impact melt breccias. However, Luna 20 soils are Sm-richer (×3) and are more normatively alkali-rich (An#94.9) than the lunar farside highlands terrane (~1.1 Sm ppm, An#96.4 [14]), suggesting that the FHT-O at Luna 20 contains a comparatively greater KREEP component than the farside FHT. Future investigations of the trace element budgets of Luna 20 impact melt breccias will shed further light on the relationships between the Luna 20, Apollo 16 and lunar meteorite feldspathic rock suites.

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