SOURCES OF MATERIALS AT THE THREE HIGH-PRIORITY LANDING SITES OF THE LUNA-GLOB MISSION

M.A. Ivanov[1], A.M. Abdrakhimov[1], A.T. Basilevsky[1], N.E. Demidov[1], E.N. Guseva[1], J.W. Head[2], H. Hiesinger[3], A.A. Kohanov[4], S.S. Krasilnikov[1]
[1]Vernadsky Institute of Geochemistry and Analytical Chemistry Russian Academy of Sciences, 19, Kosygin st., 119991 Moscow, Russia; mikhail_ivanov@brown.edu;
[2]Department of Geological Sciences, Brown University, Providence, RI 02912 USA;
[3]Institut fürPlanetologie, WestfälischeWilhelms-UniversitätMünster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany;
[4]Moscow State University of Geodesy and Cartography (MiiGAIK), Moscow, Russia

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INTRODUCTION:

The Luna-Glob landing zone is in the southern sub-polar region within the heavily cratered highlands, near the southern portion of the rim of the South Pole-Aitken (SPA) basin [1], [2]. In the landing zone, numerous large craters (up to 100-120 km in diameter and a few kilometers deep) form a very rough surface at tens of kilometers scale. During their formation, these craters have redistributed materials emplaced within the Luna-Glob landing zone by the lunar basins. Which sources are the most important at the top-three landing sites? Determination of the sources will help to facilitate the final selection of a landing site and the following interpretation of the in-situ analyses.

THE HIGH-PRIORITY LANDING SITES:

Three major criteria were applied for selection of the landing sites. (1) The surface within the landing ellipses should be relatively smooth. (2) The sites must have optimal illumination and communication conditions for the 2019 launch windows. (3) The sites must be characterized by as high content of hydrogen as possible. Application of these criteria resulted in the selection of twelve potential sites [3], [4]. The combination of the 60-m-baseline roughness of the surface, the Sun and Earth visibility, and the specific WEH values were used to collectively define landing ellipses 1 (68.77°S, 21.21°E), 4 (68.65°S, 11.55°E), and 6 (69.55°S, 43.54°E) as the higher priority sites [3], [4].

SOURCES OF MATERIALS IN THE LANDING ELLIPSES:

Although the ejecta from the SPA basin should strongly dominate the Luna-Glob landing zone, most of the younger lunar basins also have contributed materials to this region but at much smaller proportions. The mean model thickness of the post-SPA basin ejecta in the Luna-Glob area is ~3.2 km, which is ~96% of the total thickness of ejecta of all lunar basins in the Luna-Glob landing zone [5]. Assuming a no-mixing scenario for the ejecta emplacement, which represents an extreme case [6], a layer of the post-SPA basin ejecta will overlay the SPA ejecta. Constant impact gardening will eventually redistribute material of this layer and mix it with the SPA ejecta. In the Luna-Glob landing zone, there are 72 craters larger than 20 km in diameter [7], [8]. Their diameters vary from 20 km to 128 km, and the mean diameter is ~68 km. The total area of these craters comprises ~50% of the landing region and the mean nearest neighbor distance for these craters is ~36.3±15.5 km, which is close to the mean radius of the larger craters. Thus, even under a conservative assumption of no mixing during the basin ejecta emplacement, the larger craters alone appear to be able to remix ejecta from the lunar basins in the landing zone.

MAJOR TERRAIN TYPES AT LANDING SITES:

The proportions of the basin-related ejecta estimated for the Luna-Glob landing zone as a whole could be different at the specific landing sites. For example, flat, light-toned plains make up either the majority or significant portions of landing ellipses 1 and 4. The other occurrences of flat plains are scattered throughout the southern sub-polar area [1] and likely belong to a class of the lunar smooth plains known as Cayley Formation [9], [10]. These plains originally were interpreted as having a volcanic origin [9] but samples collected by the Apollo 16 mission imply that an impact-related origin of the plains is more plausible [11]. This interpretation is often applied to all occurrences of light plains [12[, [13], [14], [15], although a volcanic origin of some light plains [17], [18], [19] cannot be ruled out [20], [21].

MODELS OF THE LIGHT PLAINS FORMATION:

The volcanic hypothesis for the formation of light plains in the Luna-Glob landing zone faces the difficulty of the absence of volcanic sources and volcanic features (flow fronts, domes, edifices, lava channels, or vents) in association with the occurrences of the plains. In contrast, the impact-related hypotheses do not have this problem and are strongly supported by the observations made at the Apollo 16 landing site [22] and by the samples delivered to the Earth [23]. Three types of models for the impact related origin of light plains were proposed: (1) emplacement of ejecta of the Imbrium and Orientale basins [11], (2) emplacement of ejecta of large craters in the vicinity of the light plains occurrences [13], and (3) formation of light plains due to the emplacement of impact melt [14].

Neither landing ellipse 1 nor ellipse 4 show any evidence for the presence of volcanic activity in their surroundings. The topographic analysis of the light plains occurrences around crater Manzinus suggests that these plains likely have a non-volcanic nature [24]. Thus, we favor an impact-related origin of light plains in the Luna-Glob landing sites. In [20] and [21] it was shown that light plains have a rather broad range of absolute model ages ranging from ~4.1 to ~3.7 Ga [21]. Such a wide variation of the model ages disfavors the hypothesis of the preferential relation of light plains to either Imbrium or Orientale events [21], although a large number of light plains patches are associated with Orientale and occur as far as about 2000 km from the basin rim or ~4 basin radii [16]. The photogeologic analysis of the light plains occurrences shows that they typically lack characteristic features of impact melt pools such as cooling cracks, flow-like features, and lower albedo of the pools [21]. These observations disfavor the impact melt hypothesis for the light plains formation. Thus, the emplacement of the finer-grained facies of ejecta from a variety of sources appears as the most plausible explanation of the nature of light plains 13].

SOURCES OF MATERIALS AT THE LUNA-GLOB SITES:

Ellipse 1. What is the possible source of light plains in landing ellipse 1? CSFD measurements for these plains suggest their age of emplacement to be ~3.82+0.02/-0.02 Ga (Fig. 1). Some of the chains of secondary craters on the surface of the flat plains point toward Schomberger crater and the CSFD measurements on the floor of this crater indicate its age to be ~3.82+0.03/-0.03 Ga (Fig. 2).The identical absolute model ages of the flat plains in the ellipse 1 and the Schomberger floor suggest that the plains represent a distal portion of ejecta of this crater. The excavation depth of the Schomberger event exceeds the total thickness of the basin ejecta in the Luna-Glob landing zone. In this case, the flat plains within ellipse 1 would represent materials that underlie the SPA ejecta blanket and represent the oldest periods of the geologic history of the Moon.

The hilly unit within the landing ellipse 1 corresponds to the contiguous ejecta of pre-Nectarian crater Manzinus. The size of this crater (~100 km in diameter) suggests that its impact was also able to penetrate through the SPA ejecta blanket and excavate material from beneath of it. The continuous ejecta of an impact crater represent the lowermost portions of the target stratigraphy [25] and, thus, hilly unit in ellipse 1 likely consists of materials pre-dating the SPA event.

Ellipse 4. At the landing ellipse 4, two units make up the surface in about equal proportions. The hilly unit obviously represents rough ejecta of Moretus crater. The chains of secondary craters and the floor of Moretus have identical absolute model ages of ~3.81+0.02/-0.03 Ga (Moretus, Fig. 2) and ~3.82+0.06/-0.09 Ga (hilly unit, Fig. 1). Because of its diameter, it is very likely that the Moretus impact has penetrated through the entire layer of basin ejecta in the Luna-Glob landing zone. This means that the Moretus ejecta (unit 1) in landing ellipse 4 may consist of materials predating the SPA event.

The absolute model age for the flat plains in the ellipse 4 is ~3.69+0.03/-0.03 Ga (Fig. 1), which corresponds to the Upper Imbrian period [26]. Large craters

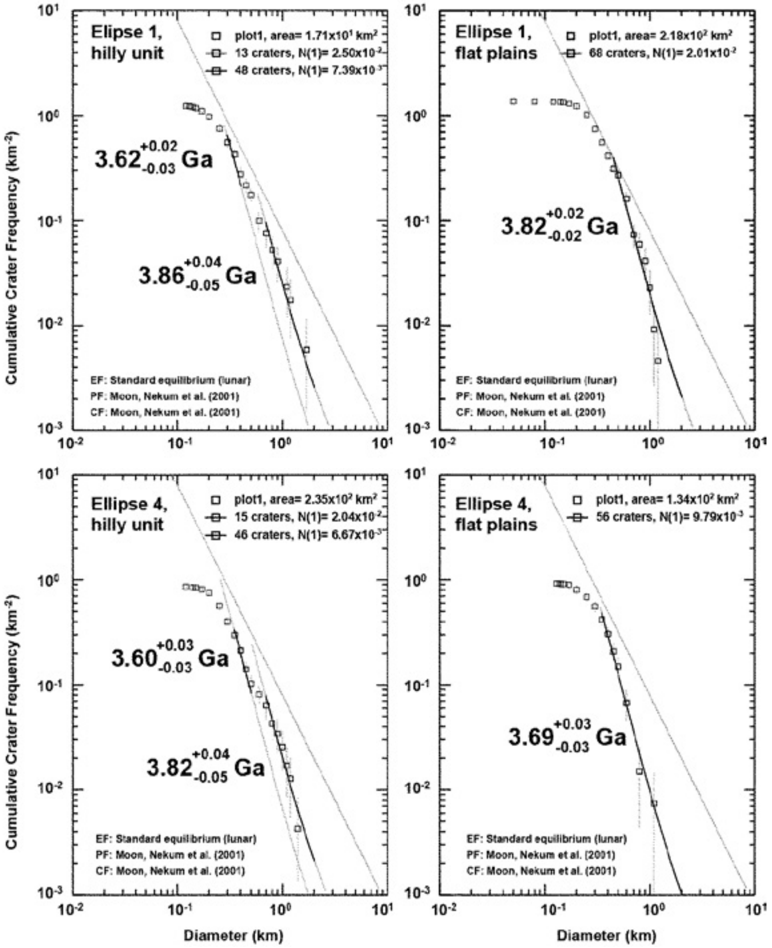
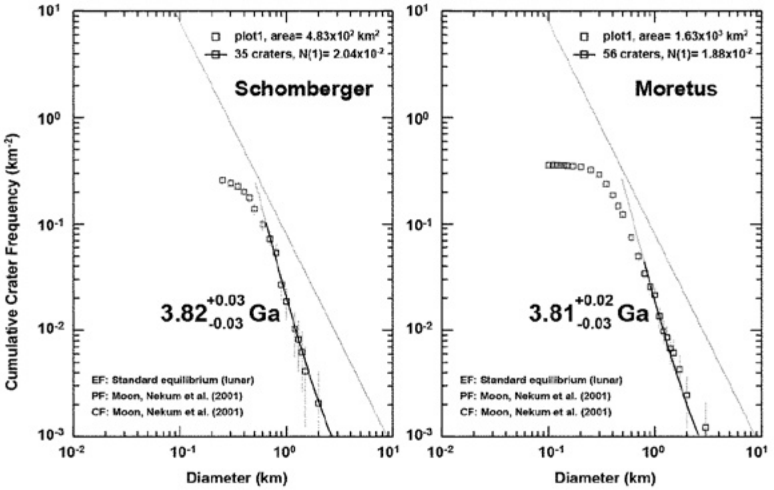


Fig. 1. Absolute model ages of units within ellipses 1 and 4



of this age are absent in the broad surroundings of landing ellipse 4 [1]. Thus, the Schrödinger basin is the best candidate for the source of the flat plains material in the ellipse. If this is the case, the flat plains also represent materials that predated the SPA event, have been excavated from a depth of tens of kilometers [27], and characterize the lower crustal (or upper mantle) material of the early Moon.

Ellipse 6. Landing ellipse 6 appears to have the simplest geology among the top three landing sites. The bulk of materials in ellipse 6 (unit 1) consists of superposed and mixed contiguous ejecta of the craters Boguslawsky, Boussingault, and an unnamed crater at 66.9oS, 46.7oE. All these craters are large (100-120 km in diameter) and potentially could excavate materials from beneath the entire layer of basin ejecta. Because the contiguous ejecta are samples of the lowermost layers of the target, unit 1 would largely consist of materials predating the SPA basin with a minor fraction of ejecta of this basin. Unit 2 in ellipse 6 likely represents mass-wasted materials derived from the surrounding hills of unit 1. Thus, the composition of both units in the ellipse 6 is expected to be identical to each other.

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