

UNIFORMITY OF THE URANIUM CONTENT OF LUNAR GREEN AND ORANGE GLASSES,
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Among the many puzzling features of the lunar surface are the soils that consist primarily of small spherules - green in the case of Apollo 15 soils from Stations 6a and 7 near the Apennine front and reddish-brown ("orange") in soil from Shorty Crater at Station 5 of the Apollo 17 mission. The orange soil in particular has provoked discussion as to whether its origin was from hypervelocity impacts, such as have been responsible for a wide variety of lunar surface features, or from volcanic effects such as have been sought at each lunar site that has been sampled. Reid et al. (1) note similarities to lava fountains on Hawaii, particularly the extreme compositional uniformity, but add that the case is "not conclusive". Roeder and Weiblen, (2) summarize the arguments against four specific proposals and conclude that impact on a molten lava pool is the only permitted mechanism.

Because a central point in most of the discussions has been the uniformity of composition of the glasses, we have made measurements of the uranium content of green glass (15401) and orange glass (74220) spherules. Our earlier measurements on a very limited number of green glass spherules had shown wide variations (3), which would appear to rule out a lava fountain as a source of that material.

Spherules were annealed to remove pre-existing tracks, mounted in epoxy, polished, and then studied by the track activation technique (4) used in the manner described in reference (3). The tracks of neutron-induced ^{235}U fissions were counted either in adjacent mica (with 2 p.p.b. uranium, supplied by C.W. Naeser) or Lexan polycarbonate detectors (0.1 p.p.b. uranium) or internally after grinding and polishing. In the latter case an etching efficiency η was inferred from measured values of the fission track diameters D of normal incidence tracks and from the thickness of the glass surface and the adjacent epoxy in which the glass was held. The relationship used was

$$\eta = [2 (D/2 v_G t) / (1 + [D/2 v_G t]^2)]^2,$$

which assumes that the track cone angle θ is constant and that η is given by $\cos^2 \theta$ (reference 5).

Uranium contents are measured relative to the General Electric standard glass (6), which has 0.35 ($\pm .02$) p.p.m. of uranium. Errors quoted are standard deviations due to counting statistics only.

The scatter in most of the results are compatible with expected deviations from nearly constant uranium values. For example, the data for orange glass are consistent with the uranium being remarkably constant at 121 (± 19) parts per billion.

The green glass of density $> 2.6 \text{ gm/cm}^3$, however, contains at least two separate components. Twenty-five of the spherules with specific

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gravity >2.6 are consistent with a fixed value of $44 (+7)$ p.p.b. while four spherules from our previous work are much higher: $570(+90)$ p.p.b. Individual measurements for that group were $670 (+60)$, $590 (+140)$, $205 (+140)$, and $670 (+335)$ p.p.b., using the same etching efficiencies as were derived here. Since internal tracks were counted, contamination is not a tenable explanation of these higher values. All of the values for individual spherules are lower than the average value of $900 (+110)$ p.p.b. found by Keith et al. (7) for a whole soil sample, indicating the presence of a component with greater uranium content than the spherules.

The low specific gravity fraction can be described as roughly constant at $45 (+15)$ p.p.b. This is decidedly distinct from the $5.1 (+1.5)$ p.p.b. quoted by us for the green glass from nearby sample 15426,74 (a clod of loosely compacted green spherules). However, a misunderstanding by one of us (RLF) concerning that data has been recognized. In this case, where the uranium concentration was inferred from the Lexan detectors, the resolution was poor. Re-analysis implies that the correct uranium concentration is certainly greater than 5 p.p.b., with the most likely value being ~ 50 p.p.b. This value is therefore indistinguishable from the 45 p.p.b. portion of 15401. The above data are summarized in the table.

The results do not resolve the puzzle of the origin of these samples. It is possible that the double-valued concentrations are due to admixtures of separate but similarly appearing green glasses following the original production of the main masses. Since the two values within the high specific gravity fraction of 15401 were in spherules of identical appearance, no obvious explanation or separate evidence of the differences is forthcoming.

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Uranium Concentrations in Glass Spherules

GREEN GLASSSpecific Gravity > 2.6parts/10⁹

25 spherules from 15401

44 (+ 7)

4 spherules from 15401

570 (± 90)Specific Gravity < 2.6

13 spherules from 15401

45 (± 15)

3 spherules from 15426

~ 50*

ORANGE GLASS

20 spherules from 74220

121 (± 19)

* Revised from previous value (3).