

# A NEW LOOK AT LUNAR REGOLITH PARTICLES WITH LIGHT, SCANNING ELECTRON AND X-RAY ULTRAMICROSCOPY

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The morphology of individual lunar regolith particles isolated from lunar soils (14259, 15101, 15301, 15427, 60601, 72501 and 74220) collected from several Apollo landing sites has been re-investigated using three complementary microscopy techniques: deep focus light microscopy; scanning electron microscopy - exploiting both backscattered and secondary electron imaging, and x-ray ultramicroscopy - an SEM based technique that uses an electron beam focused onto a platinum foil to produce a spatially coherent source of x-rays. The construction of stereo images and rotational movies provide a three dimensional view of these fascinating particles. Here are just a few examples of the many images obtained during this study.

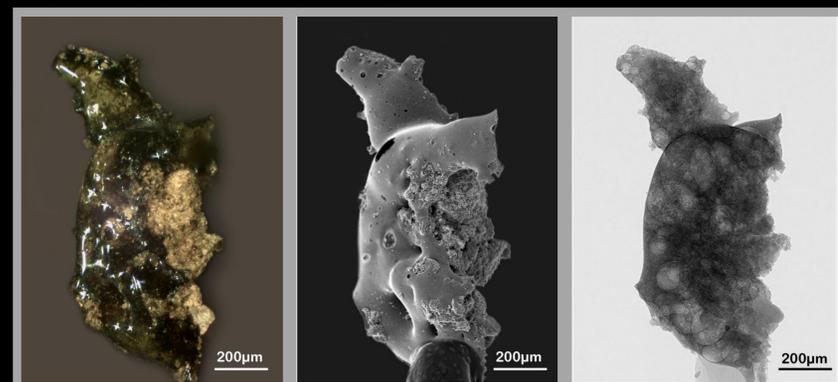
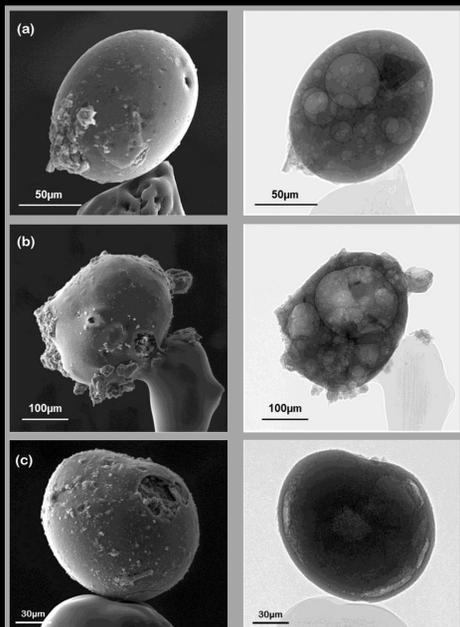
Most studies of Apollo 15 lunar spherules have been centered around the green glass spheres ejected from a fire fountain volcano over 3.3 billion years ago. While pores have been found by other research groups in some of the larger green spherules isolated from 15427 soil, we did not find any pores in the smaller spherules in this study. The same was true for the orange spherules in 74220 soil.

The spherules possessing more intricate internal structures consist of non-homogeneous mixtures of Mg,Al,Ca,Fe, silicate glass and are gray in color. On the right are the scanning electron micrographs of three of these particles, isolated from Apollo 15 soils - (a) and (b) from 15101 and (c) from 15301 - together with the corresponding x-ray micrographs.

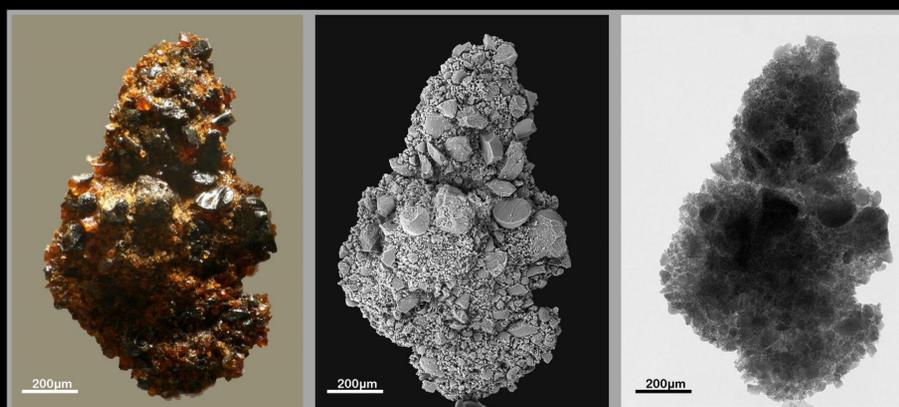
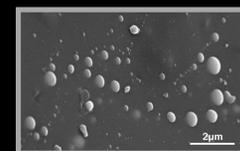
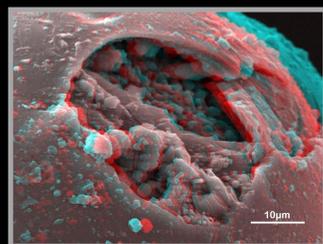
The first (a) is a relatively smooth spherule with some mineral fragments attached to its surface. It contains a lot of internal pores, the largest having a diameter ~45µm, and an inclusion of a more dense mineral. The spherical shape of these pores and the platelet morphology of the inclusion can be more readily seen in the rotational x-ray movie.

The second spherule (b) contains a myriad of tiny particles that have been encased in molten glass. There are also a large number of internal pores - their diameters range from ~180µm to a few microns - most of which are no longer spherical. The gas responsible for these internal pores has yet to be identified and will hopefully be determined in a future study.

Our third example is completely different, it looks more like a peach. There is clearly an outer skin which in some places seems separated from its internal contents which appear to consist of a myriad of much smaller particles 'welded' together (see *anaglyph*). Exactly how this particle formed remains a mystery, but we could speculate that it formed above the lunar surface shortly after a micrometeoroid impact when a group of ejected rock and mineral fragments penetrated a sheet of molten glass.



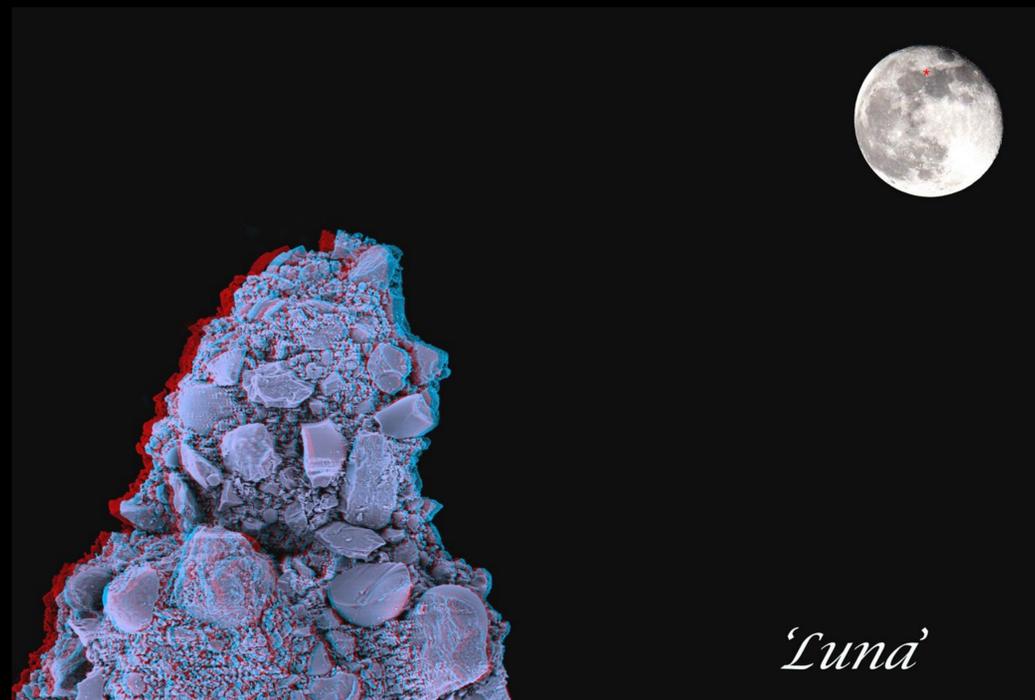
This particle isolated from 15101 soil (*above*) comprises of green impact glass which has splashed onto and partially coated a number of smaller fragments. Pores are clearly visible in the X-ray micrograph which can not be simply attributed to the contraction of glass on cooling: they almost certainly have arisen by the release of dissolved gases. The surface of the glass also contains iron globules (see *SE micrograph on the right*) formed by the reduction of iron oxide in the glass as the temperature rose during the initial meteoroid impact. These were also present on the surfaces of the Apollo 15 spherules shown on the left. It would be interesting to see if these globules were present on the internal surface of the pores.



Above are three micrographs of a breccia-like particle isolated from 74220 soil. The light micrograph reveals the variation in color of the larger components; the detailed structure of the fracture surfaces can be seen in the scanning electron micrograph, and the more absorbing fragments are highlighted in the X-ray image.

If you look closely, especially at the top right-hand-side of the X-ray micrograph, you will see the profile of a girl 'Luna'. In the anaglyph composite image, on the right, you will see her gazing at her homeland (\*). It has been over 40 years since the Apollo 17 mission, the last time man set foot on the moon and the question is

*"Will we ever go back?"*



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