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Constraining Formation Hypotheses for Irregular Mare Patches on the Moon With Orbital Reflectance Spectra

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Introduction: Irregular mare patches (IMPs) are volcanic features on the surface of the Moon (Figure 1) that appear to have formed in the past 100 million years, long after the expected end of lunar volcanism. Multiple contrasting explanations have been put forward to explain how IMPs formed, including recent eruption of volcanic material or gas explosions, versus an ancient material that only appears to have formed recently due to unique physical properties. If IMPs are the product of a recent eruption, this would require a reevaluation of the evolution of the state of the Moon's interior and the history of volcanism on its surface. We use reflectance spectra from the Moon Mineralogy Mapper spacecraft to determine the dominant minerals present and place constraints on the proposed formation hypotheses. We find that IMPs appear spectrally similar to their surrounding mare and are unlikely to have formed through the recent eruption of new material. We support previous hypotheses that collapse processes or drainage into subsurface voids or porous materials may have been the major drivers of IMP surface rejuvenation. These results suggest that an ongoing geologic process is contributing to IMPs' youthful appearance.

Methods: We analyzed remotely sensed spectral data, sunlight reflected from the Moon's surface, over the visible to near infrared wavelength range. This range is sensitive to common types of minerals on the Moon, such as olivine, pyroxene, plagioclase feldspar, and volcanic glass. These minerals absorb light at specific wavelengths called absorption features, and we analyze their shape and position in order to detect theses minerals. Based on the minerals present, we can estimate the mineralogy of volcanic rocks and tie them to certain types of volcanic eruption styles. For irregular mare patches, we looked for the presence of glass or a different mineral abundance from their surroundings. These, respectively, would imply an explosive eruption or a recent IMP-forming eruption with a different composition than its surroundings.

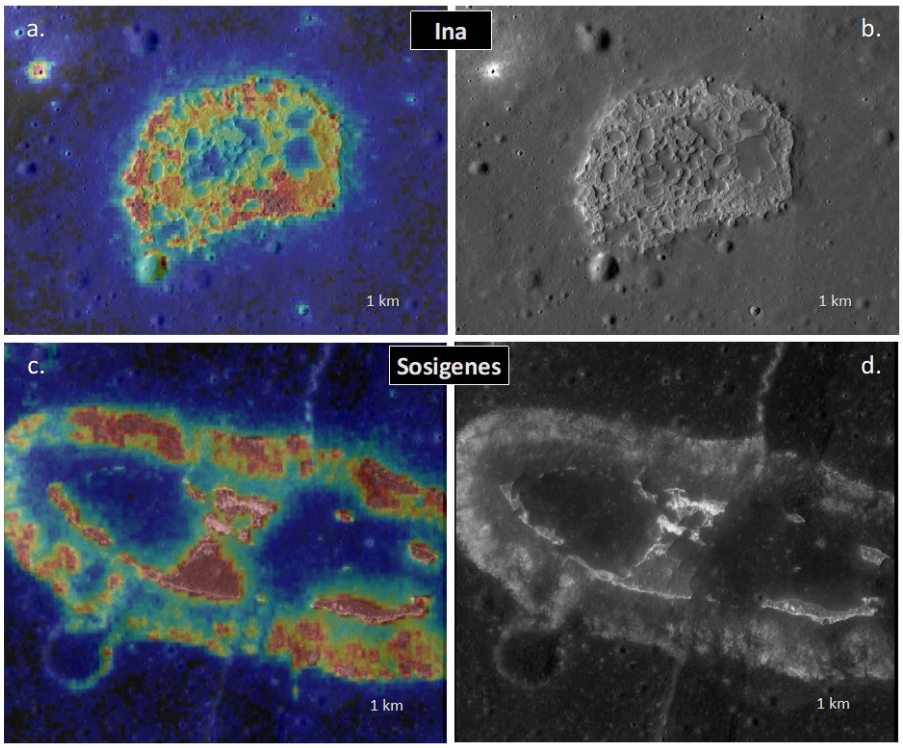

Figure 1. Two irregular mare patches, Ina and Sosigenes. The left column (a,c) show optical maturity maps where less weathered terrains are colored red and more weathered terrains are blue. The right column (b,d) shows normal colored images of Ina and Sosigenes

Main Results:

- Irregular mare patches appear to be dominated by high-calcium pyroxene, are glass-poor, and spectrally similar to their host mare and nearby fresh craters
- The lack of significant glass and similarity to their host mare do not strongly support a recent eruption of juvenile magmatic material, effusive or pyroclastic, or glassy foam exposed at the surface
- IMPs show extremely youthful surface textures and a lack of space weathering (Figure 1)
- IMPs are likely composed of mare- like materials that have been recently modified, such as through outgassing or regolith drainage into subsurface voids

FOR FURTHER READING:

Qiao, L., Head, J. W., Ling, Z., & Wilson, L. (2020). Lunar irregular mare patches: Classification, characteristics, geologic settings, updated catalog, origin, and outstanding questions. Journal of Geophysical Research: Planets, 125, e2019JE006362. https://doi.org/10.1029/2019JE006362