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Untangling the Flows and Swirls of Mare Ingenii

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Abstract

A tool for obtaining the best estimate of a pristine bedrock composition, called IIRNEST (Investigating Impact Rims and Nearby Ejecta for Sub-regolith Typication), was used to explore Mare Ingenii. In contrast to their optically immature nature, the swirl features appear to be areas of increased contamination of the mare surface. The basalt composition that (partially) fills the basin is 18-18.5 wt% FeO and 3.5-4 wt% TiO_2

Methodology

Detailed analysis of Mare Ingenii utilized 100 m/pixel resolution, 5-band Clementine UV-VIS data. Processing and calibration used Integrated Software for Imaging Spectrometers (ISIS) and Clementine orbital data available through Planetary Data Systems (PDS) [1]. FeO and optical maturity image data use the methods of [2]. TiO_2 image data was generated from the methods of [3].

We intend to characterize the *pristine* mare basalt unit(s) in Mare Ingenii. To achieve this we extract compositional information from pixels that depict the rims and proximal ejecta of small, immature craters (0.5-5 km in diameter) that impacted into the region of interest (ROI). These small craters act as windows through the ubiquitous, obscuring regolith, exposing the underlying, uncontaminated mare basalt [4, 5, 6, 7]. Impact cratering studies and analysis of impact ejecta mechanics demonstrate that near the crater rim the original stratigraphy of the impact target is inverted [8]. Therefore collecting data from this region provides the best approach to deriving the composition of the underlying basaltic unit [6, 9]

Mare Ingenii

Mare Ingenii is one of several isolated basalt ”ponds” in South Pole-Aitken basin. Ingenii's inner rim is discernible at $\sim$325 km in diameter [10], but an outer rim is unrecognizable due to unusual, furrowed terrain surrounding the basin. Stratigraphic relationships between this unique terrain and craters of known age indicate the furrowed terrain formed roughly contemporaneous with the Imbrium impact event [12]. In fact, the origin of the strange terrain has been attributed to the convergence of seismic waves [13, 14] and a concentration of ejected material from Imbrium impact [11, 12].

The Flows

The volume of basalt is insufficient to fill, or even resurface the floor of the impact basin for which the mare is named. Instead, the basalt flows fill and slightly spill over the bounds of two immediately adjacent impact craters of almost equal diameter (100 and 120 km). Ingenii basin contains one compositionally distinct mare unit with 18-18.5 wt% FeO and 3.5-4 wt% TiO_2. IIRNEST-derived spectra of the basalt does not distinguish more than one unit. The limited spectral diversity among the analyzed craters are clearly correlated with that crater's relative maturity or adjacent geomorphology (e.g., proximity to a mare-highland contact, and especially the swirls features).

The Swirls

The lunar swirls are regions of low optical maturity, and are associated with the locations of anomalously high magnetic fields. The intriguing nature of Mare Ingenii and other regions with swirl features has led several researchers to explore the hypothesis of a causal relationship between lunar swirl features, their magnetic anomalies and locations antipodal to Imbrian and later basin-forming impact events [15, 16, 17, 18, 14]. [19] suggested that the mag- netic property of the swirls would be sufficient to deflect the solar wind, thereby preventing the optical maturation of the lunar regolith.

Conclusions

FeO and TiO_2 abundances using IIRNEST demonstrate clearly that the swirl features are regions of increased contamination, belying their optically immature appearance. Despite this, craters located in swirl-adjacent and inter-swirl locations provided sufficient data points to tie to other locations within Mare Ingenii to arrive at a logically aesthetic interpretation. Our attention was drawn to Mare Ingenii because it was among the list of

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candidates from [7] for containing high-alumina (HA) basalt. The results from IIRNEST, however, demonstrate that the FeO abundance of the basalt unit is higher than known HA basalt compositions.

The strange dualistic properties of the swirls, namely that they appear optically immature, yet are very effectively obscuring the lithology beneath them, begs for further investigation.

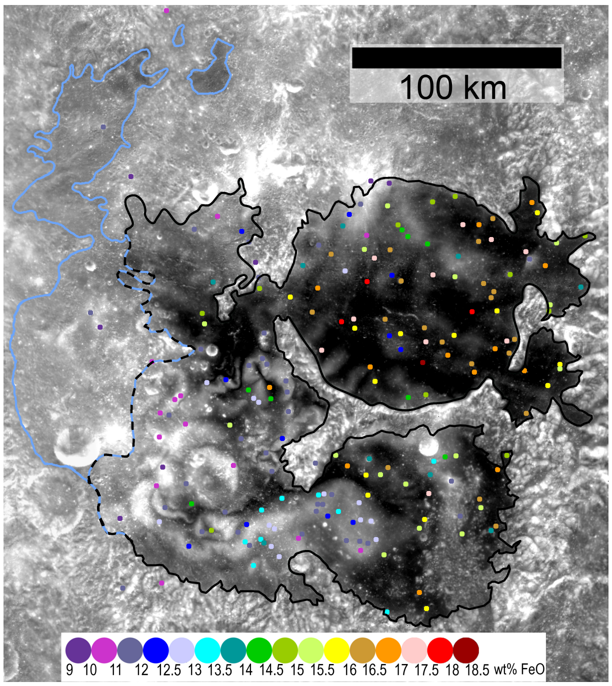

Figure 1: FeO abundance of underlying basalt at the location exposed by small, immature impacts analyzed by IIRNEST. Mare basalt unit is outlined in black on the Clementine 750 nm albedo image. Blue boundary delineates possible impact melt, mapped as the western extent of the mare by [12].

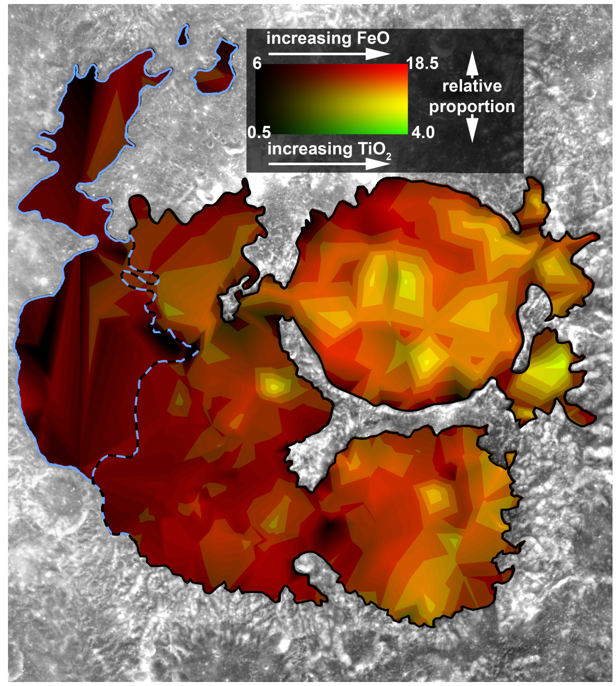

Figure 2: Contour map depicting compositional variation of mare basalt unit based on results from IIRNEST. Low-Fe and low-Ti depicted in map reflect the locations of swirl features and other anomalously high contamination effects.

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