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Spectrally Distinctive Material Excavated by the Imbrium Basin on the Moon

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Abstract

It has long been recognized, from telescopic and orbital data, that some of the massifs surrounding the Imbrium basin excavate noritic material. This material has generally been interpreted as possible Mg-suite norites, either ejected or uplifted during the Imbrium basin-forming impact. With new orbital data, it has become clear that there is great spectral diversity in the massifs. We will examine the spectral properties of these massifs and examine the lithological contacts between materials of different composition to better constrain the crustal provenance of these materials.

1. Introduction

As an early crystallizing mineral, orthopyroxene provides important clues for understanding the evolution of the lunar surface, from the earliest magma ocean cumulates, through the anorthositic flotation crust, to later stage intrusive magmatism. Using data from the Moon Mineralogy Mapper (M^3) to search for Mg-suite norites, concentrations of low-Ca, high-Mg pyroxene have been characterized around the Imbrium and Apollo Basins [1]. These deposits may be exposures of Mg-suite plutons, may represent excavated material from deeper within the primary lower crust or mantle, or may be remnants of melt sheets (differentiated or undifferentiated). Iron-rich orthopyroxenes have been identified elsewhere, in smaller craters throughout the highlands crust.

The Imbrium basin has been extensively studied for many years [e.g., 2-3]. Though the bulk of the basin is flooded by mare basalts, massifs consisting of more generally feldspathic material surround the edges of Mare Imbrium in the northwest, northeast, and southeast (Fig. 1). Telescopic measurements of Apennine mountains revealed regions spectrally dominated by orthopyroxene or pigeonite [3]. Later radiative transfer modeling of Clementine data suggested that Mg-suite-like norites may surround much of the Imbrium basin [4]. In the initial global to have the highest Mg# were found in the Montes Alpes region near Vallis Alpes [1].

The Imbrium basin is large enough to have excavated between 60-85 km into the Moon [3], deep enough to penetrate through the crust and into the mantle. It is also associated with the strongest thorium detections by Lunar Prospector [5], and is likely to be rich in KREEP [6].

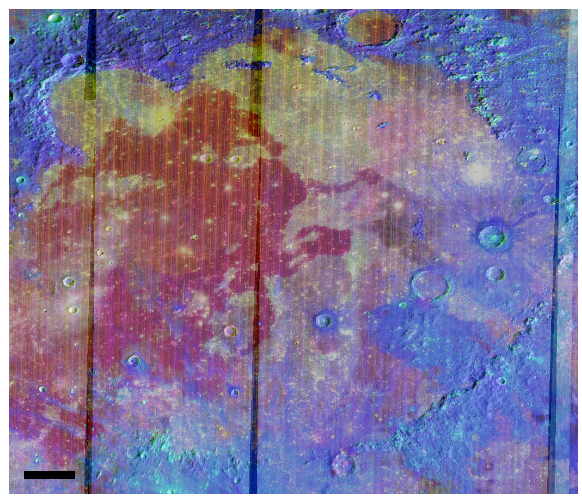

Figure 1: M3 standard color composite (R=integrated 1 μm band depth, G=integrated 2 μm band depth, B=1.58 μm reflectance). Orthopyroxene-rich regions appear as cyan. The highest concentration of Mg-rich orthopyroxene is in the massifs of Montes Alpes (NE corner). The center of Imbrium basin is located at 32.8°N 15.6°W and the scale bar is 100 km across.

2. Geological Occurrence and Spectral Properties of Imbrium Massifs

Orthopyroxenes around the boundary of the Imbrium basin are primarily associated with material mapped as crater slope material or undifferentiated terra material [eg. 7-8]. This material occurs throughout

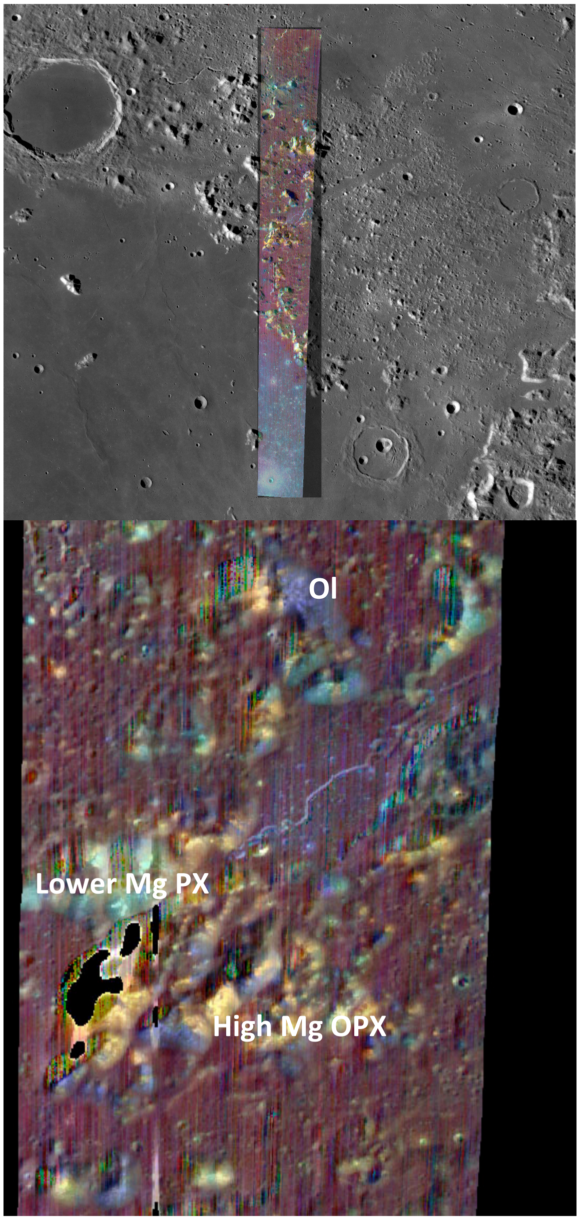

Figure 2: (top) Context image and (bottom) full resolution color composite of a section of Montes Alpes highlighting pyroxene diversity (R= 1.9 μm band depth, G=integrated 2 μm band depth, B= integrated 1 μm band depth).

the Alpes formation, which has been interpreted as deformed pre-Imbrium material, and Fra Mauro formation, which is defined as thick basin ejecta. The massifs in which the orthopyroxenes are found are primarily distinguished from the surrounding formations by their occurrence on steep slopes and their medium to high albedo, and their origin, as currently mapped, may be either uplifted material or crater ejecta. Using a color composite designed to highlight the diversity in pyroxene compositions (Fig. 2), it is clear that the massifs in the Montes Alpes are not dominated by a single lithology. High-Mg orthopyroxene, olivine, and a second pyroxene—either higher iron orthopyroxene or more Ca-rich pyroxene, are located in immediate contact with one another on the ~10 km-scale massifs.

3. Summary and Next Steps

Work is currently underway to search for the lithological boundaries at higher resolution using LROC imagery. The specific mineralogy of the deposits is being investigated by a combination of NIR spectral modeling and by incorporating measurements taken by the Diviner thermal infrared spectrometer. Diviner data will be used to analyze the position of the Christiansen feature (CF). The CF shifts in wavelength depending on the silicate polymerization of the bulk rock being measured, and is thus extremely effective at distinguishing relative proportions of minerals in a two-component mixture of a highly polymerized silicate such as anorthite and a less polymerized silicate such as pyroxene. Though fine-grained materials in the NIR and in the vibrational Reststrahlen bands are nonlinear, mixing at the CF have been shown to be essentially linear [9]. The assumption of linear mixing of endmember CFs may cause uncertainties in absolute mineral abundances of up to ~10% but will not affect relative abundances between sites [e.g. 10].

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