LUNAR ORIENTALE BASIN: NATURE OF IMPACT MELT AND VOLCANIC FLOODING FROM CHANDRAYAAN-1 (M3, TMC, HySI).

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Introduction: Many impact basins on the Moon are filled with extensive mare basalts [1]. This obscures a) the primary structure of fresh basin interiors, including the nature and distribution of impact melts, and b) the nature of the early stages of the filling of basins with mare basalts. In contrast, the interior of the Orientale basin, the youngest and most well-preserved large basin on the Moon, has limited areas covered by mare basalt and the impact melt deposits and pristine ring structures are relatively well preserved [2-5]. In order to evaluate the evolution of selected areas in Orientale using relationships between mineralogy and morphology, we have undertaken a joint analysis of Chandrayaan-1 [6] TMC [7], HySI [8] and M^3 [9] data for a portion of the south-central Orientale basin (near 24S, 95W) where simultaneous data were acquired (Fig. 1). Initial results for the Moon Mineralogy Mapper (M3) analysis of a larger region of the Orientale basin are reported elsewhere [10]. Here we outline the M3 results for the area of joint study, and initial TMC/HySI results for this area are reported in a companion abstract [11].

Orientale Basin Background:

Maunder Formation: This unit occurs within the Outer Rook Ring of the Orientale basin [1,2] and lies stratigraphically below the maria [1-3]. It is characterized by two facies [2]: 1) a corrugated and fractured facies that is draped over pre-existing topography, and 2) a smoother, bright plains deposit that occurs adjacent to and below the basin-filling mare deposits. The Maunder Formation has been interpreted as impact melt emplaced during the basin-forming event [1,2], a hypothesis consistent with multispectral image data [4] but as yet unconfirmed by direct measurement of mineralogical relations. The two facies of the Maunder Formation were interpreted to be clast-rich (corrugated) and clast-poor, more pure ponded impact melt (fractured light plains). The impact melt was interpreted to have coated the highly brecciated interior basin floor, and to have cooled and fractured immediately following the collapse of the transient cavity [2]. Cracks, fractures, and graben in the Maunder Formation are attributed to contraction cooling and draping on pre-existing topography of the impact melt facies [12]. Rough, bright, hilly, and mountainous topography in the Maunder Formation was interpreted to be underlying coherent basin floor debris protruding through the impact melt [2].

Orientale Mare Deposits: Mare deposits consist of a thin central deposit (Mare Orientale) and two arcuate occurrences at the base of basin rings (Lacus Veris and Lacus Autumni) [1-3]. These occurrences postdate the emplacement of the Maunder Formation by more than ~100 Ma and span a time estimated to be ~800 Ma [3]. The mare deposits within the Orientale basin appear to have been thin (hundreds of meters thick), as numerous Maunder kipukas are seen protruding through the deposits [2]. Galileo multispectral image data suggested that the basalts are medium-high titanium [3,5]; more recent analysis of Clementine data supports the interpretation that there are at least two different mare basalt units in Mare Orientale.

Description and Interpretation of Chandrayaan-1 Data: The area of joint analysis is shown in Fig. 1. It is a subset of a longer M^3 image cube that spans north-south across the center of the basin [10]. Although TMC and HySI have a more narrow field of view (shown in Fig 1, left), they have high spatial resolution and are well centered within the broader view of M^3. This area within the Orientale Basin consists of two subunits of the Maunder Formation light plains facies (south and north units), a broad mare unit, and an "island" apparently surrounded by mare deposits.

Different aspects of the M^3 data for the area of joint analysis are illustrated in Fig. 1. The 750 nm image on the left documents inherent brightness variations across the scene. The middle color composite is derived from 28 near-infrared spectral bands from M^3 and is used to illustrate general differences in mineralogy. A single band at 2940 nm shown on the right contains a significant thermal emission component and is thus very sensitive to small variations in local morphology. Example single pixel spectra from selected units within the joint area are shown in Fig. 2. Since these M^3 data were acquired before the M^3 detector reached the temperature necessary for calibrated science, some noise in the spectra is unavoidable. More complete discussion of initial M^3 spectra can be found in a companion abstract [10].

The dominance of anorthositic lithologies with very little mafic component across all the Maunder Formation is inferred from M^3 data based on the pervasive distribution of high albedo materials with featureless spectra (shown in blue in the color composite with example spectra shown in Fig. 2). Although cracks are more prominent in the southern part, no compositional distinction is observed. In contrast, at the resolution of M^3 (140 m/pixel for these data), the upper surface of the smooth light plains of the Maunder Formation (which appear red in the M^3 color composite) exhibit no prominent crystalline mineral absorption features (MF spectra in Fig. 2). Where craters or cracks expose subsurface materials, or where the slopes of mountains and knobs expose relatively unweathered materials, the observed compositions are dominantly anorthositic. However, no significant crystalline anorthosite [10] is observed. Only rare exposures of mafic bearing materials are found within the Maunder Formation (e.g. S central Cr and one zone of a mountain on the "island"; see spectra of Figure 2). Thus, since the crystalline basement and ejecta debris of Orientale are now observed to be highly feldspathic [see 10], the Maunder Formation units are consistent with an impact melt origin for this deposit. Nevertheless, it is apparent that in this region the Maunder Formation overlies and is mixed with large blocks of impact debris that is essentially anorthosite with minor noritic components.

The NW mare plains are characterized by abundant high-Ca pyroxene exposed by impact craters of all sizes (see spectra in Fig. 2). No prominent mineralogical differences are seen among the basalts of this area, although a different type of basalt with more abundant opaques is common further to the north. As suggested by the morphology seen in Fig 1 (right) and the topography details documented by [11], the mare basalt pathways and cooling history across the scene are complex and would benefit from further integrated study.

In the north-central part of the region, at the margin between the Maunder Formation and the mare basalts, are A) two mounds surrounded by a terrace lying above the surrounding region (the "Island"), and B) an irregular depression surrounded by an inward facing scarp. The morphologic characteristics of the "island" and its inferred mineralogy are similar to the Maunder Formation. The later emplacement of the basalts appear to have isolated it, although the process may have left residual mare components on some parts of the "island". On the other hand, the irregular depression is clearly associated with the mare basalts. The depression might have resulted from thick deposits that have undergone slow solidification, shrinkage and contraction, forming a fault-bounded depression in the solidified lavas, similar to features in solidifying lava lakes [13]. However, the similar topographic level of the basalts in the depression to those further to the north [11] is highly suggestive of an origin linked to a common source or connected channels.

Conclusions: Our analysis confirms the impact melt origin of the Maunder Formation, but shows a distinctive preponderance of anorthosite in exposed materials, and significant unmelted (feldspathic) inclusions throughout the corrugated facies. Topography associated with the cooling of the Maunder Formation support thicknesses of the actual melt-sheet in the range of hundreds of meters, not kilometers. Mare basalts, which postdate and embay the Maunder Formation, exhibit several structural features suggestive of magma movement during cooling. These new data provide significant insight into the formation and early mare filling of a well-exposed basin.

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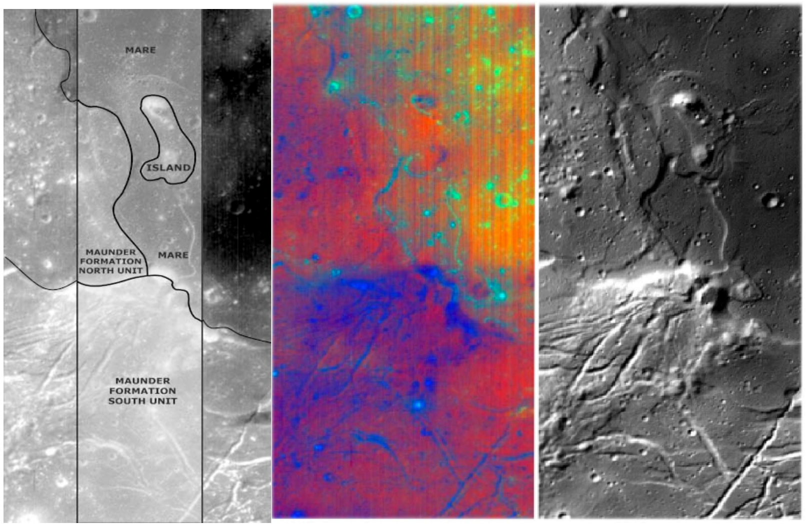

Figure 1. M^3 subscene in the Orientale Basin. (left) Brightness image and general sketchmap with the FOV of higher resolution HySI and TMC superimposed. (middle) Color composite: Red and Blue are NIR continuum (and inverse); Green is integrated 1 µm band depth after continuum removal. (right) 2840 nm band, sensitive to morphology.

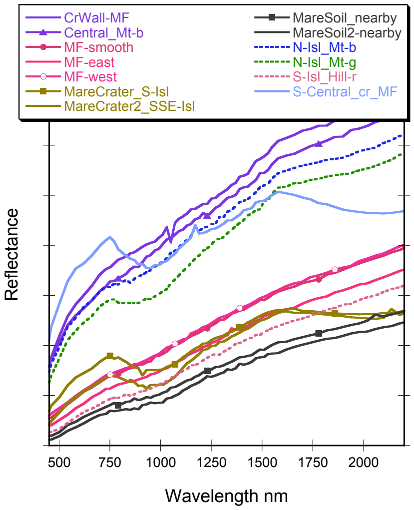

Fig. 2. Representative spectra extracted from single M^3 pixels within the joint analysis area. The location of each region is described in the legend.