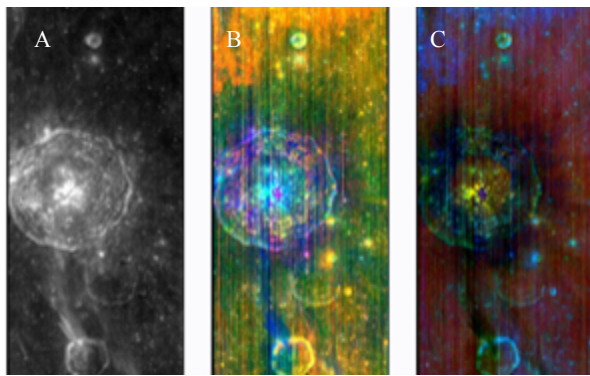


**BULLIALDUS CRATER: A RARE WINDOW INTO LUNAR PLUTONISM AND LATE-STAGE MAGMA OCEAN FLUIDS.** Rachel L. Klima (Rachel.Klima@jhuapl.edu)<sup>1</sup>, Joshua T. S. Cahill<sup>1</sup>, Justin Hagerty<sup>2</sup> and David Lawrence<sup>1</sup>, <sup>1</sup>Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA; <sup>2</sup>USGS Astrogeology Science Center, Flagstaff, AZ, USA.

**Introduction:** The central peak of Bullialdus Crater has long been recognized as having a reflectance spectrum dominated by a strong noritic signature (e.g., 1-4). Results of spectral fits to the central peak of Bullialdus suggest a relatively high Mg# ( $>Mg_{75}$ ) in the low-Ca pyroxenes (5), within the range of values observed for Mg-suite lunar samples (e.g., 5). Centered at  $-20.7^\circ$ ,  $337.5^\circ$  in Mare Nubium, Bullialdus Crater lies within the high-thorium Procellarum KREEP Terrane (e.g., 6). In fact, based on orbital gamma-ray data, Bullialdus is the location of a clear thorium (Th) enhancement, which is important because Th commonly serves as a proxy for detecting KREEP-rich materials on the lunar surface (e.g., 6-8). We examine the mineralogy of Bullialdus crater and the spatial distribution of the Th signature associated with it to investigate the character and composition of the excavated pluton.



**Fig. 1.** Mineral diversity in Bullialdus crater. (A) 0.75  $\mu$ m albedo map. (B) Mafic mineralogy depicted using an RGB composite where R=integrated 1  $\mu$ m band depth; G=integrated 2  $\mu$ m band depth, and B=reflectance at 1.5  $\mu$ m. In this color scheme, fresh material appears bright, with deep blue generally indicating feldspathic material, red indicating an enhancement in olivine, and orange and yellow indicating pyroxenes. Low-Ca pyroxene often appears as cyan, due to the overall brightness and narrow 1  $\mu$ m band. (C) Pyroxene diversity map depicted using an RGB composite where R = 1.9  $\mu$ m band depth, G = integrated 2  $\mu$ m band depth, and B = integrated 1  $\mu$ m band depth. This color scheme highlights low-Ca pyroxene as yellow, and fresh high-Ca pyroxene as cyan. Anorthositic material and highly space-weathered material appear as black.

**Bullialdus Region Mineralogy:** Bullialdus crater and the local mineralogy are shown in Fig. 1. Strong pyroxene bands indicative of a noritic composition dominate

the central peak. Anorthositic material, excavated by Bullialdus, is exposed in the crater rim and proximal ejecta (Fig. 1). Portions of the walls exhibit a gabbroic signature, potentially olivine-bearing. Fresh craters in Mare Nubium exhibit a typical basaltic spectral signature, while both mare and highland soils in the region are generally spectrally featureless.

There is a clear Th enhancement ( $\sim 6-7$  ppm Th) centered on Bullialdus crater and its northern wall outer flanks (9). However, if the source of the Th is only the material excavated in the central peak, the Th content is higher, and closer to the range of Alkali suite norites (10). Observations of the central peak of Bullialdus crater indicate that the pyroxenes exhibit a distinctive 2.8  $\mu$ m band absorption that is significantly stronger than the immediate surroundings, indicating the presence of a hydroxyl component. The hydroxyl signature persists through multiple viewing geometries and illumination conditions, suggesting that it is not transient, like the lunar surface water previously observed (11-13). The correspondence between KREEP and hydroxyl within Bullialdus suggests that hydroxyl might have been concentrated in late stage magma ocean fluids. However, KREEP-rich Apollo samples exhibit lower hydroxyl contents than mare basalts (14-16), suggesting that Bullialdus crater may sample materials not represented in our sample collection.

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