YERKES CRATER CENTRAL PEAK AS A SAMPLE SITE FOR DATING CRISIUM BASIN. K. D. Runyon[1], D. Moriarty[2], B. W. Denevi[1], L. M. Jozwiak[1], B. A. Cohen[2], C. H. van der Bogert[3], H. Hiesinger[3]. [1]JHU/APL, Laurel, MD, USA (kirby.runyon@jhuapl.edu), [2]NASA/GSFC, Greenbelt, MD, USA, [3]Institut für Planetologie, Westfälische Wilhelms-Universität, Münster, Germany.

Introduction: Understanding the impact history of the Moon has important consequences for Earth's early history, including the time around the emergence of life ~4 Ga [*e.g.,* 1], as well as the larger bombardment history of the inner Solar System. The Nectaris and Crisium basins, in particular, are important anchor points in understanding this history, and dating their formation times is thus a priority. Toward this end, *Spudis and Sliz* [2] mapped 10 locations of putative impact melt outcrops (high-standing kipukas embayed by mare basalt flows) around the periphery of Mare Crisium. If these outcrops are impact melt from Crisium, they would provide areas from which to measure a crater size-frequency distribution (CSFD) and thence derive absolute model ages (AMAs) for the Crisium-forming impact event [*e.g.,* 3]; while future in situ measurements or returned samples could provide an absolute age and important constraints for lunar chronology [1]. We have further characterized the locations of proposed Crisium impact melt [4], and have discovered a previously unidentified region likely to be preserved Crisium impact melt that would lend itself toward future sampling and radiometric dating (*Fig. 1*).

Background: Mare Crisium (~400 x 580 km, centered near 17.0˚N, 58.8˚E) is the lava-flooded portion of the Nectarian-aged Crisium basin (*D* ~ 1000 km). The mare is ringed by massifs forming the basin's innermost and best-preserved rings, interpreted to be structurally equivalent to Orientale's Inner Rook ring [5]. The basin is surrounded by feldspathic highlands and is far removed (> 900 km) from the Procellarum KREEP Terrane [5]. Bouguer gravity data from the Gravity Recovery and Interior Laboratory (GRAIL; [6]) mission indicate that the Crisium impact may have removed all of the crust in portions of the basin (crustal thickness of ~zero km) [7]. Thus, Crisium impact melt should contain a significant compositional component derived from lower crustal and possibly mantle materials.

Methods: Our data sets include the global Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) monochrome basemap (100 m/px); both low and high incidence angle LROC Narrow Angle Camera (NAC) images (~1 m/px); a WAC color ratio composite mosaic [8]; the combined 59 m/px global Digital Elevation Model (DEM) from the Lunar Orbiter Laser Altimeter (LOLA) and Kaguya Terrain Camera (TC); and a photometrically normalized high-sun WAC mosaic. Map projection for the DEM and NACs was done via the USGS's online Planetary Image LOcator Tool and Projection on the Web interfaces [9,10]. We used visible to near-infrared reflectance spectra from the Moon Mineralogy Mapper (M^3) [11] to evaluate the mineralogy of the mapped kipukas compared with their surroundings. We measured fracture dimensions using the LOLA/Kaguya DEM and reported our morphometric results in [4].

Results and Discussion: Our combined geomorphological and compositional analysis of Crisium basin has allowed us to produce a geologic cross-section of the western portion of the basin and mare (*Fig. 2*). The Western Crisium Kipuka (WCK) was favored by [2] as a likely outcrop of Crisium impact melt due to its high topography embayed by the mare; its fractured surface reminiscent of impact melt elsewhere; and its felsic lithology, which matched their presumed composition for Crisium impact melt [2]. However, the morphology of the WCK is more consistent with inflationary fractures observed in floor-fractured craters than with impact melt [4]. Additionally, structural comparisons with Orientale suggest that the WCK is located in a region where the Crisium impact melt deposit was thinner [13,14]. Thus, impact melt preserved within this kipuka is likely to have experienced extensive vertical and lateral impact mixing with crustal lithologies and may not be representative of the bulk melt composition. In addition, [3] determined a younger AMA for this area than has been measured for the Crisium ejecta blanket [15].

Instead, representative surface exposures of Crisium impact melt are likely to be materials excavated from the melt sheet (estimated to be ~10-15 km thick based

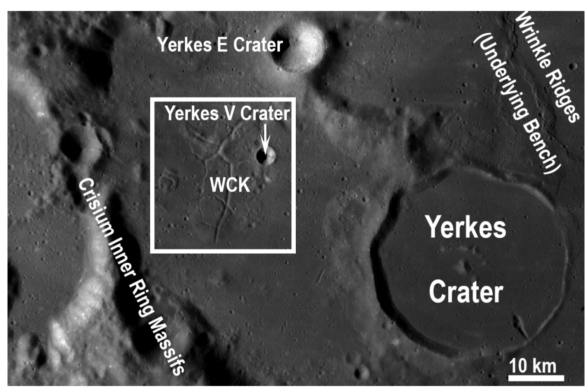

Fig. 1. Yerkes Crater (D ~ 35 km) in our study area within Crisium basin. The Western Crisium Kipuka (WCK) was originally identified by [2] as an outcrop of Crisium impact melt. Our current work favors the central peak of Yerkes as likely containing relatively pure, crystalline Crisium impact melt that could date Crisium.

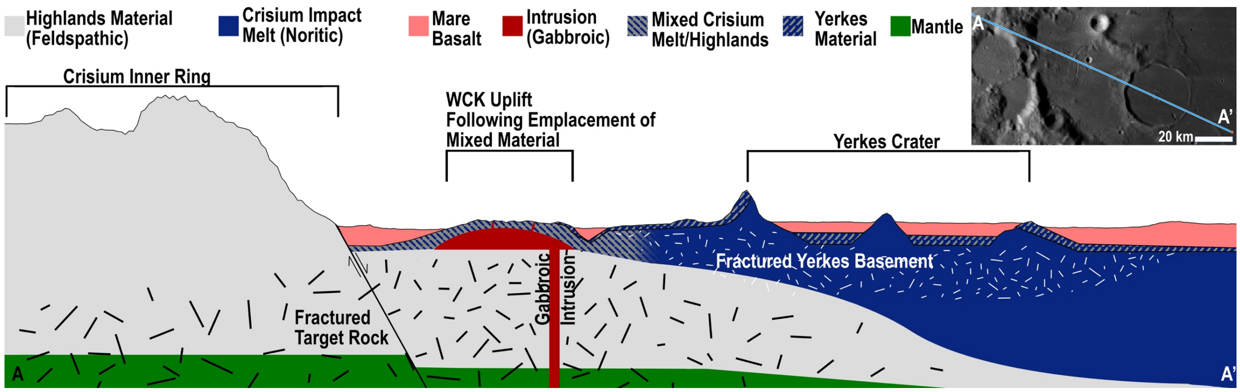

Fig. 2. A qualitative, schematic cross section along Crisium's inner massif ring, mare floor, a kipuka ("WCK"), and Yerkes Crater synthesizing results from [4] and the current work. The surface topography was extracted from the 100 m/px global LOLA DEM in QuickMap with a surface vertical exaggeration of 5x, but no vertical scale is implied by the units at depth. The near-identical sizes of Crisium and Orientale permit placing Crisium's melt sheet extents near where they are thought to be for Orientale [5;14]. We interpret the Yerkes-forming impact to have hit near the edge of the Crisium melt sheet, thereby creating a re-processed melt sheet, breccia lens, and ejecta facies ("Yerkes Material"). Ejecta, slump facies, and some Crisium melt form the "Mixed Crisium Melt/Highlands" material. The Gabbroic Intrusion subsequently intruded and uplifted the floor of Crisium, emplacing dikes within the uplift. The entire area was then subsequently flooded by embaying mare basaltic volcanism.

on comparisons with Orientale [13,14]). The central peak of Yerkes Crater (*D* ~ 35 km) is an excellent candidate for such materials. From crater scaling relations [12], we estimate that Yerkes central peak uplifted materials from depths of ~4 km, well within the Crisium melt sheet. High band depths and short-wavelengh band centers in M[3] spectra of Yerkes central peak materials indicate the presence of abundant Mg-rich orthopyroxene (Fig. 3), consistent with the composition of mantle-derived impact melts observed in impact basins such as SPA [20]. In contrast, two of the three investigated locations in the WCK have weak, basaltic pyroxene compositions, suggesting the mafic component results from mare contamination.

It is unlikely the Yerkes impact would reset the radiometric ages of Crisium impact melt that was uplifted within the Yerkes central peak—zircons dated from the central uplift of Mistastin impact structure in Labrador, Canada, show the same ages as the surrounding target rock, rather than the age of impact [16]. Pressures experienced by lunar central peaks during uplift are less than 25 GPa based on the observation of crystalline anorthosite [17,18]—pressures at which feldspar does not melt and the ages would not be reset. Thus, dating central peak material from Yerkes Crater could constrain the absolute timing of the Crisium impact.

Conclusion: Our work indicates that the central peak of Yerkes Crater is a reasonable location to access outcrops of Crisium impact melt as evidenced by depth of origin and composition. Future landed lunar missions could enable a precise dating of the Crisium forming impact by sampling from these outcrops [1].

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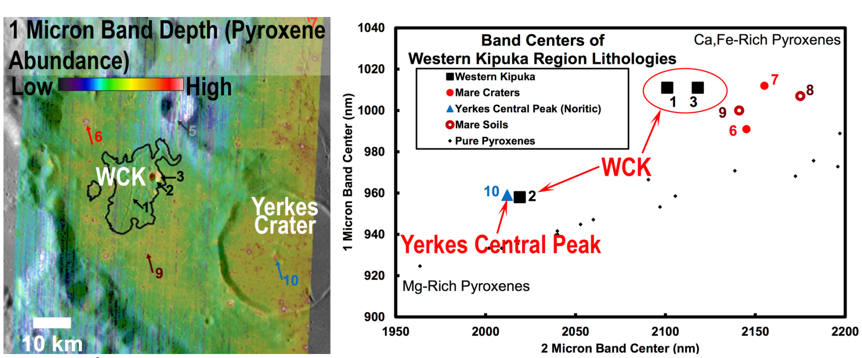

Fig. 3. M[3] spectral parameters [19] for western Crisium. Left: Yerkes central peaks are more pyroxene-rich than the WCK. Right: Pyroxene compositions for WCK and Yerkes materials.