SHALLOW MAGMATIC INTRUSIONS IN THE LUNAR NEARSIDE HIGHLANDS? L. M. Jozwiak$^1$ and J. W. Head$^1$, $^1$ Dept. Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02906 (lauren_jozwiak@brown.edu)

**Introduction:** The moon displays a dichotomy in mare exposure with the majority of deposits located on the lunar nearside. The nearside is also comprised of the southern nearside highlands, which lack exposed mare deposits. Morphologic and spectroscopic studies do not show evidence of cryptomare exposures in this region [1]. Additionally, maps of floor-fractured crater distributions [2] show a paucity of floor-fractured craters in this region, suggesting a lack of shallow magmatic intrusions below crater floors (Figure 1).

Data presented in Jozwiak et al. (2015) [3] builds upon a paradigm proposed by Head and Wilson (1992) [4] using crustal thickness to explain the distribution of surficial lava deposits and shallow intrusive deposits (floor-fractured craters). In this context, crust of intermediate thickness (~20-30 km) is predicted to be favorable to shallow intrusions. Despite this, the nearside highlands contain only 3 floor-fractured craters (Fig. 1).

Large craters in this region show significant infill by smooth deposits interpreted to be emplaced by secondary crater ejecta from craters and basins [5] which could obscure mare deposits or morphologies associated with floor-fractured craters. To search for evidence of potentially buried or obscured magmatic bodies, we use Clementine multispectral image data [6] to search for mafic signatures of material excavated by impact craters, M$^3$ (Moon Mineralogy Mapper [7]) data to refine our compositional analysis, and GRAIL (Gravity Recovery and Interior Laboratory) [8] data, to assess Bouguer gravity anomalies potentially associated with dense mafic intrusions.

**Dark-Halo Craters:** Dark-halo craters have been used to infer the presence of a low-albedo mafic unit underlying a higher albedo surface unit [9, 10]. Whitten and Head (2014) used the identification of excavated mafic deposits to map the spatial extent of lunar cryptomare deposits, focusing primarily on previously proposed regions of cryptomare. This study did not identify any cryptomare deposits in the nearside highland region [1].

*Crater Buch B.* Hawke et al. (2002) [11] used Clementine data to identify a dark-halo crater, Buch B (17.0°E, 39.9°S) (Figure 2a), located within the nearside highlands. They postulated that the dark rays are the result of excavated mafic deposits from a magmatic intrusion as opposed to cryptomare because of the isolated nature of the deposit and the surrounding morphology of the region [11]. Additionally, the FeO values for the low-albedo halo of Buch B are only slightly lower than lunar mare basalt values [11], strengthening the excavated magmatic intrusion formation hypothesis.

**Regional Investigation.** We used the standard Clementine RGB color composite image [12] and analyzed the nearside highlands for dark-halo craters with similar multispectral properties to Buch B, and also for exposures of similar multispectral properties within crater floors and walls. Figure 2a shows the crater Buch B in a Clementine RGB composite image where the dark halo is readily identifiable by its green color. We located 21 areas of interest using the Clementine dataset including several small dark halo craters similar to Buch B, and also several craters floors with similar multispectral properties to Buch B, for example craters superposed on the floor-fractured crater Janssen (Figure 3a).

The large crater superposed on the floor of the floor-fractured crater Janssen (41.5°E, 44.9°S) clearly displays the same spectral characteristics (green) in Clementine RGB color ratio imagery as seen in the dark halo of crater Buch B. Floor-fractured craters are postulated to form in response to magmatic intrusion and sill formation beneath the existing crater floor [2, 13]. The sills are predicted to form at a depth of a few kilometers beneath the crater floor. The superposed crater in Janssen (Figure 3b) is approximately 10 km in diameter and excavates to a depth of approximately 3 km [14]. Thus, if this crater formed after sill formation in Janssen, it is possible that the crater formation could excavate and incorporate mafic material from the intrusion, resulting in the signal observed in the Clementine composite. The large crater Fabricius is superposed on the northern rim of Janssen and is itself a floor-fractured crater. There are small exposures of possible mafic material on the floor of Fabricius, visible in the Clementine RGB composite image (Figure 2a). These signatures, if indeed basaltic in nature, could either be excavated from a pre-existing intrusion including a sill or dike, or they could represent transported mafic material from the proposed intrusion beneath Fabricius itself.

Although the geologic setting and deposit morphology suggest a mafic, magmatic intrusion source for both Buch B and the superposed crater in Janssen, the mineralogical identification using Clementine multispectral imagery is not conclusive. We are expanding our investigation to include the use of M$^3$ spectral data to better identify the mineralogy of our previously identified areas of interest.

**Investigation of Gravity Anomalies:** Data solutions from the recent GRAIL mission now resolve
gravitational anomalies at a spatial scale of $< 10$ km [15, 16]. Lunar basaltic magmas are denser than lunar crustal material [17], and as such, magmatic intrusions are predicted to produce a positive Bouguer anomaly. Sori et al. (2013) [18] used GRAIL data to investigate cryptomare locations, and identified possible cryptomare locations including the Shiller-Schickard region and the Maurolycus region. The Shiller-Schickard region was also identified by Whitten and Head (2014) as a location of cryptomare, although no cryptomare were identified in the Maurolycus region.

Using the GRGM900c spherical harmonic Bouguer solution [15] band-filtered to orders 100-600 to strongly attenuate anomaly contributions from regions deeper than 34 km, we examine the Bouguer anomaly for both Buch B and for the floor-fractured crater Janssen. The Bouguer anomaly for crater Buch B is shown in Figure 2b. There is a clear positive anomaly beneath the crater, although there are anomalies of similar magnitude throughout the crust in this region. There are several interesting features in the Bouguer solution for the crater Janssen seen in Figure 3b. A broad positive anomaly underlies the center of the crater Janssen; additionally another distinct broad positive anomaly underlies the floor of the crater Fabricius. These anomalies are most readily explained as arising from subcrater magmatic intrusions. This conclusion is strengthened by the surface observation of spectral signatures associated with mafic compositions, although the heterogeneous nature of the gravity solutions precludes identification of magmatic sources by gravity alone.

**Conclusions:** The lunar crust is predicted to host numerous intrusive magmatic features. Despite favorable crustal thickness conditions, there is a paucity of identified intrusive features in the lunar nearside highlands. We use Clementine multispectral image data and GRAIL data to search for previously unidentified magmatic intrusion in the lunar nearside highlands. Beneath our two test regions, the small crater Buch B and the large crater Janssen, we see both spectral signatures suggestive of mafic mineralogy and gravity anomalies consistent with a high density crustal component. We interpret this as support for the existence of a magmatic intrusion beneath the floor-fractured craters Janssen and Fabricius and a possible smaller intrusion, such as a dike, beneath the crater Buch B, as suggested by Hawke et al. (2002). We are extending this dual investigation to all 21 regions of interest, and expanding the mineralogical analysis to include M$^3$ data.