VOLCANIC LANDING SITES ON THE MOON: THE COMPACT AND DIVERSE HARBINGER REGION.
J. Korteniemi[1], D. L. Eldridge[2], K. I. Singer[3], T. Lough[4], L. Werblin[5] and D. A. Kring[6], [1]Astronomy, Department of Physics, University of Oulu, Finland (jarmo.korteniemi@oulu.fi), [2]University of Colorado at Boulder, CO, USA, [3]University of Tennessee, Knoxville, TN, USA, [4]University at Buffalo, NY, USA, [5]Mount Holyoke College, South Hadley, MA, USA, [6]Lunar and Planetary institute, Houston, TX, USA.

Introduction: The Harbinger region is located at 25.71°N, 44.47°W (Fig. 1) between Oceanus Procellarum and Mare Imbrium [1-5]. It exhibits a mixture of volcanic deposits and features, including the youngest mare flood basalt [6] – similar to nearby Aristharcus Plateau (AP), but within a much smaller area. Harbinger also provides access to a km-high (traversable?) cross-section of ancient pre-mare materials.

Here we briefly describe the geology of the Harbinger region, provide our interpretations of new data, and map out potential landing sites for future missions. Harbinger provides and opportunity to address most lunar scientific goals [7], particularly those concerning volcanism, internal activity, dating, and impact processes.

Methodology: Lunar Orbiter, Apollo and Clementine images were used for morphological analysis, and Clementine and Lunar Prospector spectral data for mineralogy [see also 8]. Kaguya LALT provided topographic data. Due to its 1.875 km resolution and the interpolation required for the gridded DTM, elevations show only general trends. Small-scale roughness undetected by LALT contributes to real traversability.

Geological setting: The roughly 150x150 km Harbinger region lies on a gentle N-NE-facing slope within a complex geological setting in the middle of nearside maria. Compositionally the Harbinger region varies within a small area, representing a location where multiple unsampled lava types can potentially be found, and is a likely candidate site for KREEP volcanism [8]. [1-3] give thorough overviews and interpretations of the region.

Montes Harbinger, a series of 0.5–2.0 km high remnant highland massifs, interpreted to be covered with pyroclastic materials [e.g., 9], surround an area of hummocky terrain that forms a plateau roughly 50–100 m higher than the surrounding mare plains [1-5]. This "Harbinger plateau" (HP) extends SE of the Montes via "islands" of hummocky unit in a mare region, bounded by a prominent wrinkle ridge (Figs. 1 and 2a). In effect, the plateau is (on) a gentle rise, possibly related to local magmatic activity.

The SW end of HP is occupied by the 49-km crater Prinz, suggesting that some of the hummocky plateau may be ejecta. Prinz's inner rim provides a km-thick cross-section of the pre-impact materials. No layering in the crater wall has yet been identified. The Prinz rims have generally steep 7–15° slopes. There is an exception on the northernmost part, which is only 200 m high with 1.2–2.2° slopes (Fig. 3). This break was caused by an impact of a cluster of Aristharcus ejecta or a small primary impactor onto the rim, and may have been intensified by mass wasting.

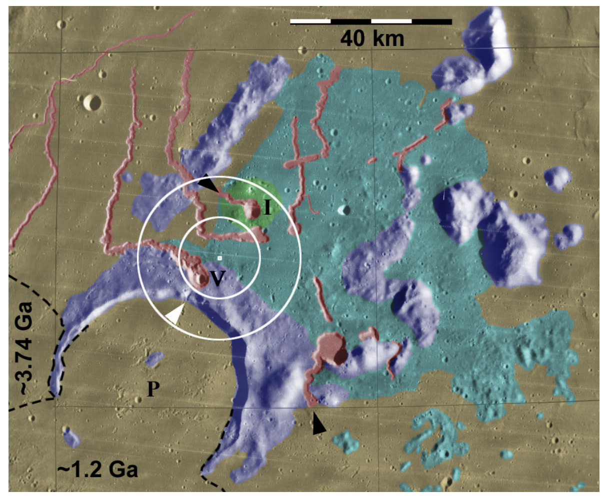

Figure 1. Geological sketch of the Harbinger region [see also 1-4]. P: Prinz crater; V: Vera; I: Ivan; blue: massif outcrops (incl. Prinz rim); cyan: hummocky terrain; green: volcanic dome; red: sinuous rilles; yellow: mare basalts. Circles represent 10 and 20 km radial distances from the suggested landing site. Arrows show access points to rilles (black) and up the Prinz rim (white). Basalt unit model ages and approximate flow boundaries (dotted lines) from [6].

Volcanism: The top of HP is occupied by at least 8 volcanic vents that are the sources of sinuous rilles (Rimae Prinz) [1,3]. The longest rille (~80 km) originates from the depression "Vera" on Prinz's rim. This rille has a secondary, more sinuous channel on its floor (similarly to e.g., Vallis Schröteri), suggesting multiple volcanic episodes, possibly with long-lasting eruptions of turbulent/erosive lava. Most rille heads on HP are either circular or similar to cobra heads. However, rilles in the north, east and south originate from various elongated, E(NE)-W(SW) -oriented linear depressions. This suggests that these rille-forming eruptions were tectonically controlled and occurred directly from such fissures. The sinuous rille heads closest to Prinz extend tens of meters deeper than the current crater floor. Some rilles may have been embayed by the surrounding lava plains, but their overall relationship(s) with the mare basalts are not at all clear. The rille wall slopes are likely to be steeper than what current data reveals (1–5°). Rille widths are typically 1–2 km, while the heads can be up to 4.5 km wide. A shallow dome-like volcanic edifice (with a summit caldera "Ivan" (Fig. 1) and a short rille) is situated 25 km north from Prinz [3].

HP also provides a good locality to sample mare basalts with widely varying ages (Fig. 1; [10]). A mare flow unit, potentially the youngest on the Moon (model age ~1.2 Ga), extends from the region between AP and Marius Hills and embays Prinz crater, while adjacent flows date back to ~3.74 Ga [6,10].

Landing site: We suggest that the optimal landing site within the region is between the Ivan and Vera depressions on the plateau (26.597°N, 43.185°W). This locale provides access to most features of volcanic interest, including rilles, a possible volcanic dome, in-situ pyroclastic deposits, as well as Prinz rim. If the crater wall can be descended, the evolution history of the plateau may be seen in the exposures, and samples of what may be the youngest lunar mare basalt flow can be collected from the crater floor. Aristharcus ejecta should be collected from the area to 1) accurately date the impact event and 2) provide info on the characteristics of AP 100–200 km west of HP.

More detailed data are needed before the landing site can be fully justified. Further work includes 1) understanding the rilles and their embayment/superposition relationships with mare basalts, 2) identify if layering is present on Prinz wall, 3) find tectonic fault lines on HP, 4) find a traversable path up the Prinz rim and down to rille floors. The hills and hummocky terrain should be analyzed to distinguish possible volcanic cones and small domes from highland outcrop materials [e.g., 11]. Depending on future findings, alternative landing sites may be located N-NE of the Ivan dome, on Prinz floor, or at the mouth of the sinouos rille E of Prinz.

Summary: The Harbinger region provides a compact and complex study site. It potentially sheds light on most key scientific questions described by the NRC [7]. It provides access to (a) impact craters for chronology and studies of secondaries; and (b) to pyroclastic deposits, multiple basalt flows, including young and old mare and KREEP lavas. Its diverse evolution and easy-to-reach location should be taken into account when planning future missions, especially for in-situ sampling and analysis by robotic or manned missions. Its variety in structures and materials are within a very compact area, unlike most other volcanically interesting sites (eg. Aristharcus Plateau or Marius Hills). The Harbinger region should, thus, prove to be a key site for understainding the volcanic history of the Moon.

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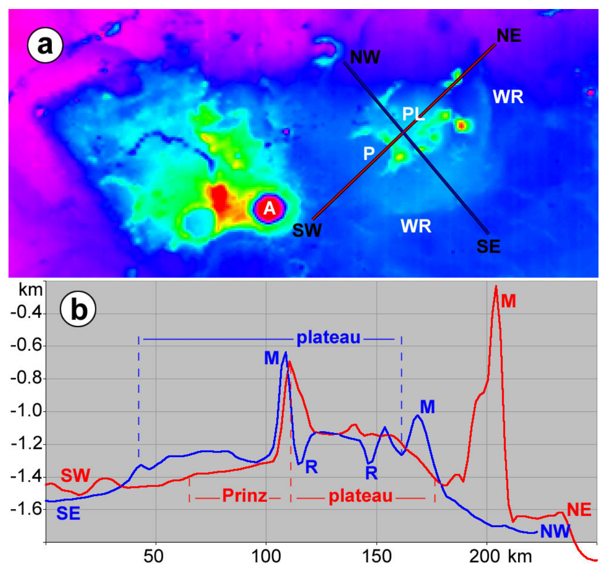

Figure 2. (a) DTM from Aristharcus and Harbinger regions (red=high, purple=low). Lines show locations of profiles in (b). A: Aristharcus; P: Prinz; PL: Harbinger plateau; WR: wrinkle ridge; M: massifs; R: sinuous rille head.

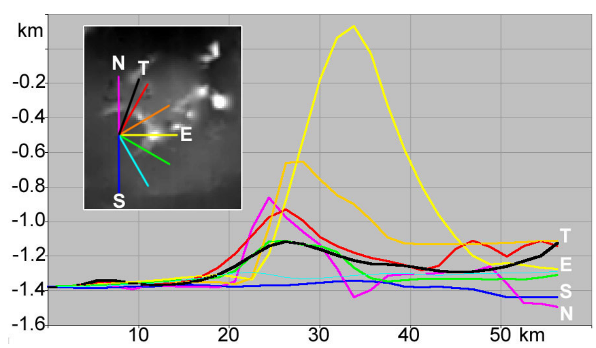

Figure 3: Colored lines show elevation profiles of the Prinz crater at 30 degree intervals (directions shown in the inset). The black line shows a very shallow, possibly traversable slope profile "T" towards N-NE.