2. Approach

In order to assess quantitatively the youthfulness of mantle surfaces, small superposed craters are used to calculate crater retention ages. The technique of dating martian surfaces using the density of superposed craters is long established. Only recently have meter-scale resolution and better image datasets enabled analysis of small craters, leading to slight refinement of the isochrons (Hartmann, 2005) and inclusion of atmospheric filtering of small bolides (Popova et al., 2003). Criticism has been leveled at the crater count methodology based on interpretations of secondary cratering (McEwen et al., 2005); secondary craters result from the fallback of ejecta blocks launched by primary impacts. In the robust debate that followed, additional tests have been shown to support the crater count-based isochron system (Hartmann et al., 2008). For example, crater counts of rayed craters yield ages internally consistent with impact-size recurrence intervals anticipated from the isochrons (Hartmann et al., 2010). In the present study, we date additional rayed craters and also find ages consistent with the isochron system.

Additionally, direct observations of the impact rate (Malin et al., 2006; Daubar et al., 2010) are consistent with predictions from the isochrons (Hartmann, 2007; Kreslavsky, 2007). As developed, the crater counting system employs all scattered craters, both primaries and distant secondaries, which are very difficult to distinguish geomorphically (Calef et al., 2009). Obvious crater rays and secondary crater chains are excluded in order to measure "the age-dependent general global buildup of both large and small primary craters and secondaries that accumulate simultaneously as a background, but minimize the effects of nearby primary craters" (Hartmann, 2005). Enhanced uncertainties may arise in the use of small craters (Hartmann, 2005; Hartmann, 2007), but the crater count methodology remains a robust and useful tool to assess very young martian surfaces (e.g., Werner et al., 2009).

All count areas in this study are located on near-rim deposits (typically within 1 crater radius from the crater rim crest) of morphologically fresh craters with diameters between ~1 and several km and for which HiRISE data was available (Table 1). The topography of these areas was reset by the crater ejecta (e.g., Melosh, 1989). Therefore, the surface is of a homogeneous age and the crater retention age represents either the age of the

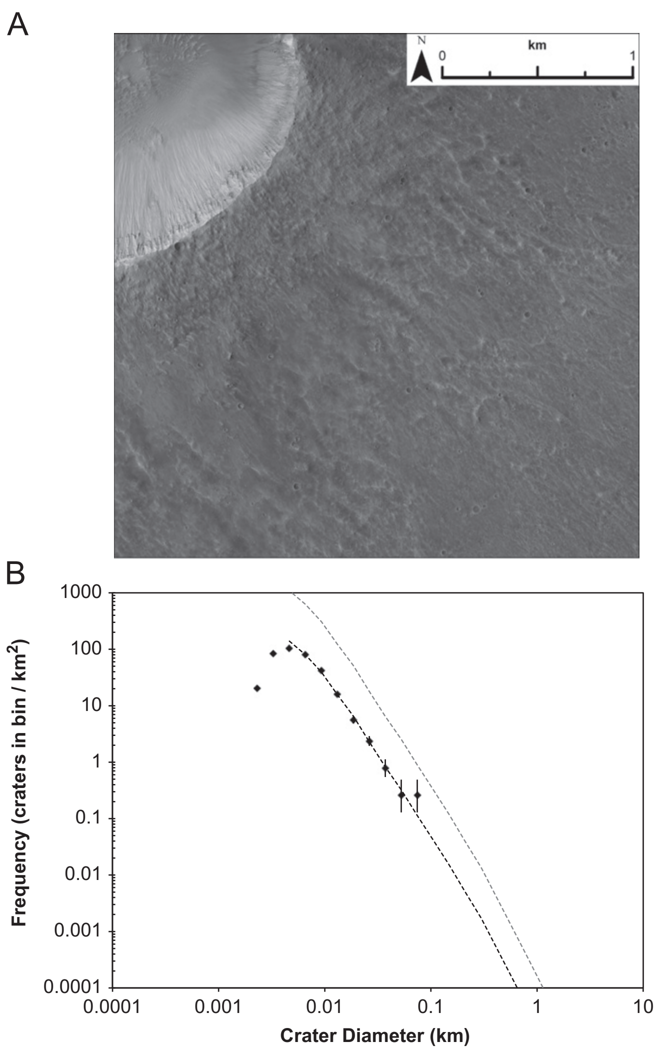

Fig. 4. (A) Dilly crater (13.3°N, 157.2°E) is 2.1-km diameter rayed crater identified by Tornabene et al. (2006) in Elysium Planitia. Portion of HiRISE: PSP_010203_1935. (B) A crater count revealed 6675 craters on 18.9 km^2 of near-rim deposits surrounding Dilly crater. Isochrons of Hartmann (2005) indicate a best-fit age of 34.4 Ma. The grey dashed line marks the Early Amazonian boundary of Hartmann (2005).

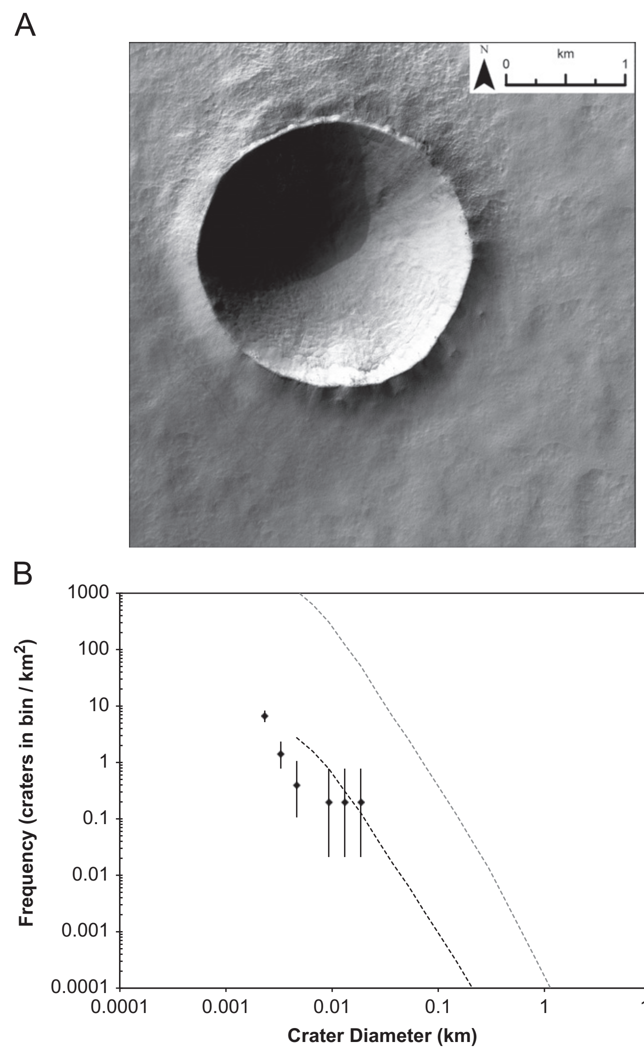

Fig. 5. (A) An unnamed 2.2-km diameter crater is found near the boundary of Noachis Terra and Hellas Planitia (55.6°S, 46.4°E). Polygonally patterned ground is found pervasively on the crater floor, wall, and rim, and on surrounding terrain. Portion of HiRISE: PSP_007030_1240. (B) A crater count revealed 129 craters on 5.0 km^2 of near-rim deposits surrounding the unnamed crater (55.6°S, 46.4°E). Isochrons of Hartmann (2005) indicate a best-fit age of 0.7 Ma. The grey dashed line marks the Early Amazonian boundary of Hartmann (2005).