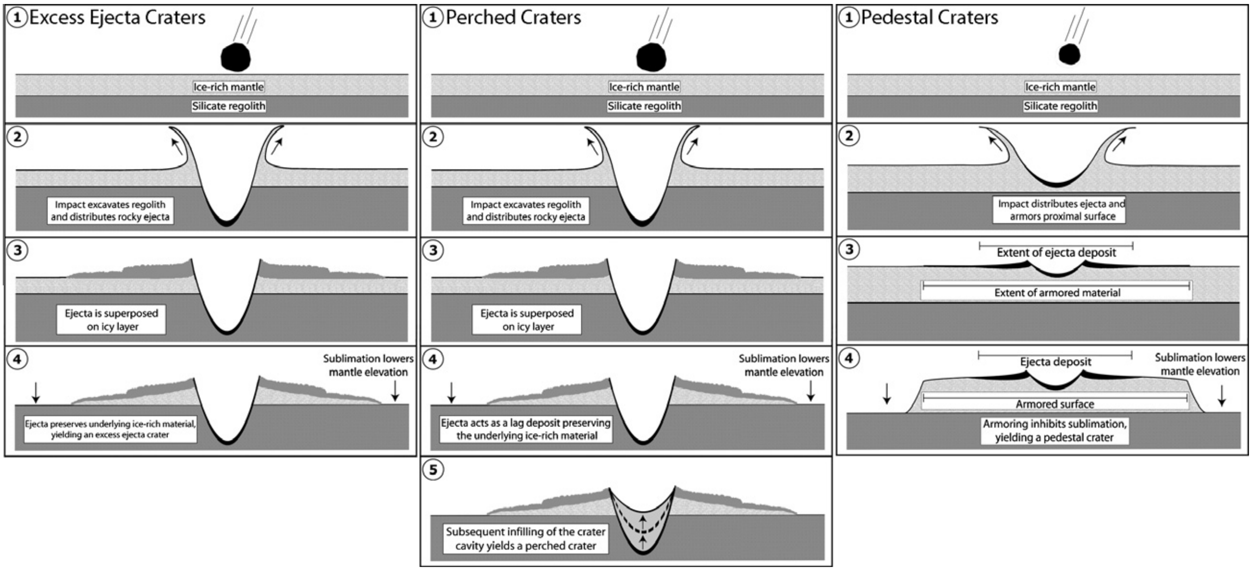

Fig. 8. Schematic illustrations highlighting the primary steps in the formation of excess ejecta craters (left), perched craters (middle), and pedestal craters (right). These process models for EE, Pr, and Pd have been adapted from Black and Stewart (2008), Meresse et al. (2006), and Kadish et al. (2009), respectively. Note the primary commonalities between the models, which include: (1) An impact into an ice-rich surface layer overlying the regolith. In the EE and Pr models, this impact completely penetrates through icy deposit to the underlying regolith, but this does not occur in the Pd model. (2) Sublimation/deflation of the ice-rich layer from the intercrater terrain, resulting in the lowering of the elevation of the surrounding plains. (3) Preservation of the icy layer proximal to the crater interior, either due to ejecta cover or related armoring processes. This results in the anomalously high volume of material around the crater in the form of excess ejecta or a pedestal. The only notable difference between the EE and Pr models is that, in the Pr model, the crater interior becomes infilled to the point that the floor of the basin is above the elevation of the surrounding terrain.

that were tens of meters thick, and to the production of these crater types upon impact of projectiles into this substrate, which is consistent with our observations (Kadish et al., 2010; Kadish and Head, 2011). Further, this sequence of events is necessary in order to maintain the presence of EE, which lose their classification as EE upon significant degradation or burial by mantling.

Formation mechanisms for EE, Pr, and Pd have been proposed on the basis of their topography, morphology, and distribution. The specific process models for EE, Pr, and Pd, which have been schematically detailed by Black and Stewart (2008), Meresse et al. (2006), and Kadish et al. (2009) respectively (Fig. 8), each begin with an ice-rich unit overlying a silicate regolith. This ice-rich material is interpreted to be the result of obliquity-driven climate change, and the redistribution of polar ice to lower latitudes (Head and Marchant, 2009). In the EE model, the ejecta, which is a mixture of ice and the underlying regolith, is distributed over the icy layer surrounding the crater cavity (Fig. 8A). During return to lower obliquity, the ice from the intercrater terrain sublimates, and the remaining dusty lag deposit is susceptible to erosion. The silicate-rich ejecta deposit, however, preserves the ice-rich layer surrounding the crater by insulating the ice fraction and inhibiting sublimation (Black and Stewart, 2008; Kadish et al., 2009; Meresse et al., 2006). Consequently, the terrain surrounding the ejecta is lower than the surface was at the time of impact, so that the ejecta appears thicker than expected. The excess ejecta may be composed purely of a sublimation lag deposit left from the former icy substrate, or it may also contain some fraction of the original ice (Black and Stewart, 2008).

The model for Pr formation proposed by Meresse et al. (2006) follows a sequence similar to that interpreted to have occurred during the production of EE (Black and Stewart, 2008), beginning with an impact that penetrated an ice-rich deposit superposed on a silicate-rich regolith and excavated the regolith material. The resulting lobate ejecta is distributed in the region proximal to the crater rim crest and interior, on top of the ice-rich layer. In their process model, Meresse et al. (2006) propose that, after impact, the crater interior acts as a trap for debris, and is slowly infilled by the eolian transport of material, as well as by nearby impact ejecta and possible deposition from the atmosphere; this aspect of the model has yet to be tested using quantitative modeling. Meresse et al. (2006) claim that, if the crater is sufficiently small, the infilling will raise the elevation of the crater floor above the elevation of the surrounding terrain. Meanwhile, thermal variations and wind deflation respectively sublimate and erode the icy surface layer. The changes in temperature may be due to orbital changes (i.e. eccentricity and obliquity) and/or seasonal effects. The Pr ejecta deposits, however, have low thermal inertia (Meresse et al., 2006), possibly due to a thin insulating layer of fine-grained material. As a result, the ejecta is preferentially protected from the thermal fluctuations, helping to preserve the ice content of the ejecta. Although the ejecta itself is also subject to eolian erosion, it is removed at a much lower rate than the intercrater plains. The result is a crater that has both its ejecta and crater interior perched above the surrounding terrain (Meresse et al., 2006).

In the general proposed Pd formation model (Kadish et al., 2009), an impact occurs into a layer of ice and snow, mixed with dust, but the excavation cavity does not necessarily reach the underlying silicate regolith. The impact event distributes ejecta and possibly impact melt on and around the crater rim; due to the composition of the target material, the ejecta itself is likely to be largely ice and snow. The surface proximal to the crater becomes indurated in some manner as a result of the impact process (Arvidson et al., 1976; Osinski, 2006; Schultz and Mustard, 2004; Skorov et al., 2001; Wrobel et al., 2006). The resulting armored surface can extend to a distance of multiple crater radii, exceeding the lateral extent of the ejecta deposit. Subsequent obliquity-driven climate change leads to the sublimation of volatiles from the unarmored intercrater terrain, lowering the elevation of the plains. The armoring, however, inhibits sublimation from beneath the hardened pedestal surface. This produces a symmetrical, circular scarp around the edge of the armored crater and its ejecta. The result is a crater centered on a pedestal that is composed of the initial icy layer that was deposited on the silicate regolith. In this model, the crater interior is usually above the elevation of the surrounding