AN INDEX OF SUBSURFACE VOLATILES ON MARS. E. Jones, [1]Division of IT, Engineering and the Environment, South Australia, Australia, eriita.jones@unisa.edu.au.

Introduction: Layered ejecta (LE) craters comprise a significant fraction of the craters on Mars, and may form from the excavation of subsurface volatiles. A number of morphological and morphometric attributes of LE craters provide information on the presence and abundance of subsurface ice. The fluidized properties of the ejecta of single layered (SLE) and double layered (DLE) ejecta craters [1], the correlations between LE crater occurrence and Martian ice-stability models [2], and the simulation of LE morphologies in analog and numerical experiments involving the vaporisation of ice [3-4], all suggest that volatiles play some role in the formation of these features. Ejecta mobility (EM) is defined as EM=Run/R where Run is the runout distance of ejecta from the crater rim and R is the crater radius. EM provides a measure of the ejecta viscosity that is independent of crater size [5]. Large values, indicating highly mobile ejecta, may result from a lowering of ejecta viscosity through the incorporation of volatiles [5, 6-8]. Ejecta lobateness is defined as $\Gamma=P/\sqrt{4\pi A}$ where P is the perimeter of the ejecta blanket and A is the area of the ejecta layer [9]. Lobateness is a measure of the sinuosity of the ejecta, with values greater than 1 indicating sinuous ejecta. High values of lobateness potentially result from the incorporation of low viscosity materials such as fluids or ices in the ejecta flow [9, 10]. Hence both EM and lobateness are morphological parameters which are likely related to crustal properties, and have the potential to provide key information on the composition (such as volatile content) and physical characteristics of the subsurface with depth. In a study of over 10,000 Martian SLE and DLE craters analyzed via principal component analysis [11], a number of significant principal components were identified for the two impact morphologies. These components were interpreted as indices of: impactor energy, target volatiles, impactor angle, resurfacing, and preservation/freshness of the impact feature. In this abstract I present some results from a principal component analysis (PCA) study of target volatile indices, and discuss their implications.

Methods: The data for the PCA were primarily extracted from the crater catalogue of [12]. At least 16 variables were examined for each morphology, with the variables consisting of crater and ejecta dimensions, a number of indices (such as crater degradation, ejecta mobility, and lobateness) calculated from the primary measurements, and several additional parameters related to surface age and crater preservation. Principal component analysis re-expresses multivariate data to reveal hidden associations between variables, thus reducing the dimensionality of the analysis. PCA captures the underlying unobserved (latent) variables that are responsible for the covariance between the observed data variables, revealing, in this case, the true independent variables controlling Martian LE crater morphologies. The output of PCA is a new set of uncorrelated latent variables – eigenvectors (termed principal components, PCs)- with associated eigenvalues. One such eigenvector identified in the analysis of both SLE and DLE craters was interpreted as an index of target volatiles (Table 1) [11]. The eigenvalues represent the fraction of the variation present in the original variables that is captured by each principal component. I determined that 23% of the variance of SLE craters and 17% of the variance in DLE crater attributes (column 2 in Table 1) are captured by the putative volatile indices.

Table 1: Principal components interpreted as volatiles indices [11].

Morphology	Fraction of total variance (%)	Strongest positive correlations (*)	Strongest negative correlations (*)
SLE	23	Ejecta runout (12.5); ejecta perimeter (10.8); ejecta mobility (8.5); ejecta area (7.6)	Depth/diameter (14.4); measured/predicted depth (14.4); crater degradation (10.8)
DLE	17	Depth/diameter (15.2); measured/predicted depth (11.3); degradation (6.1); surface-floor depth (6.0); rim-floor depth (4.8)	Layer 2 mobility (12.6); layer 1 mobility (9.3); layer 2 runout (7.2); layer 2 area (5.9)

* Numbers in brackets in Table 1 are the percentage contribution of the variable to the total variance of the principal component.

Results and Discussion: The target volatile index (VI) for SLE craters was negatively correlated with crater depth/diameter, measured/predicted depth, and crater degradation. It was positively correlated with ejecta runout, perimeter, ejecta mobility, and area (Table 1). The VI for DLE craters showed correlations with similar variables, but the correlations had the opposite sign: VI was positively correlated with measures of crater depths and modification, and negatively correlated with morphometric attributes of the ejecta. High volatile content substrates, such as ice-rich terrain, promote both mobile ejecta and post-impact degradation and infilling [13,14], consistent with the observed properties of the VI values. The VI values increase towards the poles, correlating with models of Amazonian ice-stability within the last 500 Myr [15] and with present-day ice-table depths < 1 m [16]. The location and concentration of subsurface volatiles, however, has varied greatly throughout Martian history, controlled largely by extreme variations in planetary obliquity. Combining the information contained in the target volatile indices with the other principal components related to crater age and impactor energy, provides a means of isolating impacts into ice rich terrains from different periods of geologic history [11]. Figure 1 shows the spatial variation in SLE crater diameter, for a subset of SLE craters with low values of impactor energy and high values of VI. The attributes of these craters may therefore be related to geologically recent subsurface ice. Blue colors in the map indicate regions with smaller craters, whereas red hues indicate regions of larger craters. This provides an estimate of the relative depth of recent subsurface ice at a regional scale. The resulting spatial pattern is sensitive to geologic unit boundaries (Figure 1). In addition, analysis of regions of ancient putative ice-rich deposits revealed that they partially correlate with observations of lobate debris aprons and valley fill, and modelled deposition of ice-sheets during the Noachian.

Conclusions: The morphological and morphometric attributes of Martian SLE and DLE craters are primarily related to the energy of the impact, the nature of the primary target, and to secondary processes affecting the impact feature. The most significant target factor influencing crater and ejecta characteristics is interpreted to be the volatile content. An index of target volatiles is identified and utilized to assess how the depth and concentration of volatiles has varied throughout time. Future studies of ice related morphologies should be compared to the target volatiles and other indices derived by [11] to develop a comprehensive picture of the regional concentration, stratigraphy and geological history of subsurface ices.

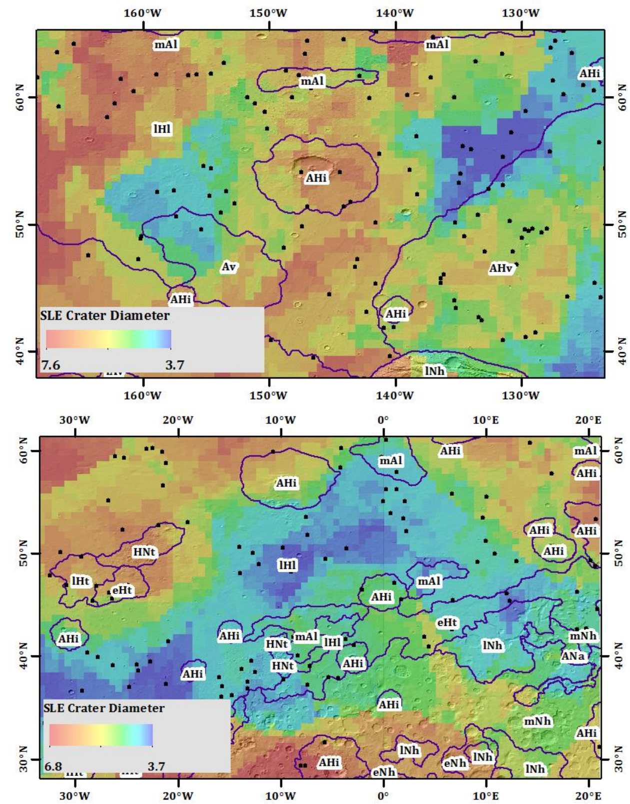

Figure 1: A small-scale subset of the SLE volatile index global map, centered in Arcadia Planitia (top) and Acidalia Planitia (bottom). The gradual change from high to low crater diameters observed in Chryse Planitia corresponds to a change from Late Hesperian to Amazonian-Hesperian terrain (geologic units from [17]). Basemap: MOLA shaded relief. Caption reproduced from Figure 11 in [11].

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