INSIGHTS INTO THE EMPLACEMENT OF ROCK AVALANCHES ON MARS.

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Introduction:

The Chaos Jumbles, California (40°32'N, 121°32'W) originated from a volcanic dome that forms part of the Chaos Crags [1,2]. The initial event of the Chaos Crags eruptive sequence was the formation of a tuff cone followed by two pyroclastic flows. A series of domes then formed which were also partially destroyed by pyroclastic events. The Jumbles were formed by the collapse of a dome in cold rock avalanches that cover 6.8 km^2. Based on tree growth and lichenometry three deposits were identified [3] whose time interval has been suggested as ranging from 1000's years to a single event [1,2,3,4]. The deposit consists of a monolithologic breccia of Chaos Crags dacite blocks in a matrix of pulverized dacite. Well-defined large-scale folds, ridges and furrows can be identified on these deposits. Similar features are noted on landslides on Mars [5] as well as the Olympus Mons aureoles and their process of formation remains enigmatic. This study used geomorphic, topographic and statistical analysis of the Chaos Jumbles rock avalanches. These data have resulted in the identification of geomorphic features that were missed or unresolved in remotely sensed data. These features are evidence for previously unrecognized deposits and an emplacement mechanism that is momentum-driven requiring no interstitial medium. Our study highlights the need for combining digital datasets (such as images and topography) when attempting to interpret the emplacement of landslides on Mars.

Field Approach:

Walk over surveys were conducted at the Jumbles deposits to validate the geomorphic map [4] of deposits I, II and III. Of particular interest was the identification of deposit boundaries using both air photo interpretation and field studies. Boundaries are important for the calculation of dimensional data necessary for inputs into modeling studies and for comparisons with landslides on Mars. Our studies focused on the geomorphology of the youngest deposit III. To examine changes along the track of the deposit grain size statistics were collected at 13 points along two transects from scarp to toe [6]. In addition to recording dimensions at the Jumbles details of the characteristics of the grains were noted such as sphericity and weathered state. In addition, tree trunk-bends and lichen characteristics were recorded.

Focusing on the small-scale characteristics of the deposits revealed morphologic variations in grain characteristics consistent with the existence of more than one deposit within the boundary of III [4]. Individual rock-streams are discernable in the field that vary in width from 1 m to < 30 m but are consistently one boulder thick. Transects were walked across the mid-track of III and the boundaries of rock-streams recorded using a GPS Garmin XL. This prompted the desire to examine other mapped boundaries for older deposits II and I.

Mapping Analysis:

Given our field observations and analysis we have created a new geomorphic map using digital orthorectified air photos from 1994 and 1998 at a scale of 1:25,000. Due to the homogeneous nature of the materials at the Jumbles, the spectral returns give little indication of the boundaries of individual rock-streams. The GPS data of boundaries and transect locations were reprojected to fit the air photos and overlain. This allowed for boundaries to be located and subtleties in spectral response noted. Correlation was also noted between rock-streams and the pattern of tree growth and trunk-bends indicating an age relationship. Improvement in boundary determinations was achieved by overlaying imagery and GPS vectors on a DEM obtained from the 1980 USGS 7.5 minute topography.

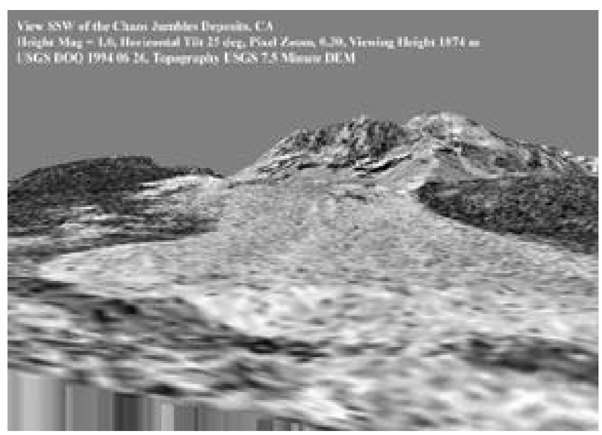

Fig. 1. Perspective view SE of the Chaos Jumbles from Table Mountain up to the Chaos Crags.

The resulting perspectives allowed for a range of viewing directions and angles plus alterations of height magnification and pixel zoom [Fig. 1]. This has allowed for improved geomorphic interpretation of available imagery. Attention was paid to deposit boundaries to improve understanding of superposition relations and to calculate volumes. The resolution of the DEM is course relative to the dimensions of the rock-streams that we have identified but more voluminous deposits can be distinguished.

Interpretation:

We have identified multiple rock-streams that are the youngest deposits in age based on superposition and grain-size analyses. They are characterized by narrow widths and are only one boulder thick. These traveled over older deposits and show flow behavior, following topographic lows and maintaining relatively constant widths. There is no evidence of any interstitial medium. At times the rock-streams show superelevation and also overtop local ridges built by older deposits. This indicates sufficient momentum to overcome the line of least resistance. The maintenance of uniform thickness along the rock-streams indicates the grains could not move through the flow during transit. No vertical sorting of grain sizes exists. Percussion marks indicate grain-to-grain strikes suggesting a high-energy state. This is further supported by the ability of the rock-streams to overcome energy loss as they traveled over older deposits that have a roughness comparable to the thickness of individual streams. In addition, evidence exists for comminution of large boulders suggesting high mechanical stresses. Calculated velocities are 10-15 m/s based on evidence of run-up.

More than one deposit of intermediate age can be distinguished in the field and they appear similar to the youngest rock-stream. This suggests that multiple failures of intermediate deposits occurred. However, one larger intermediate deposit that was too subtle to recognize in the field is well defined with a 2x height magnification perspective views [Fig. 2] and traveled down a local channel on the downslope right side of the Jumbles.

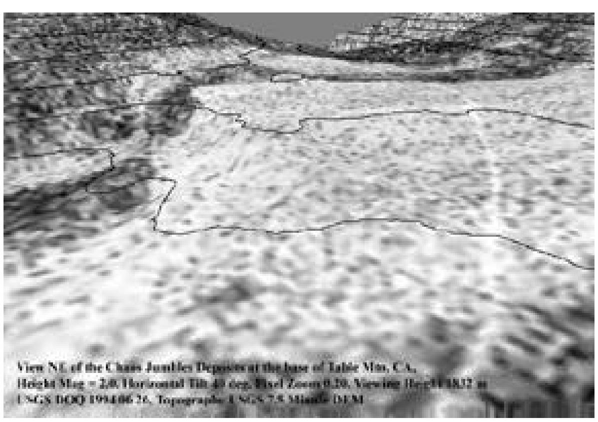

Fig. 2. View NE over the Chaos Jumbles deposits at the base of Table Mountain. The toe of the intermediate deposit is highlighted by the upper contour.

The moving mass continued downslope until the front reached the lower slopes of Table Mountain. It had insufficient energy to climb up the Mountain as older deposits had, and the flow-path turned westward to follow the regional downslope. This aligns with a larger glacial valley. The front traveled ~100 m on this new vector before stopping. There is no obvious concentration of larger grains at the toe or evidence for any interstitial medium. The deposit lies on top of an older more voluminous deposit and is itself overtopped by at least one rock-stream. Velocities are calculated at 10-15 m/s based on evidence of run-up.

Conclusions:

There is evidence at the Jumbles for multiple failures with different deposit characteristics and dimensions [6]. There is a superposition order of youngest, intermediate, and oldest deposits. The youngest deposits are smallest in dimensions, built no ridges and have run-out distances of > 2 km. Intermediate deposits are similar in volume and thickness and comparable in run-out to the youngest. Ridges appear to have formed in the intermediate deposits identified in the local channel on the downslope right side. These rock-streams and intermediate deposits have both morphologic and dimensional characteristics that indicate momentum-driven flows with no requirement for an interstitial medium. The oldest deposit has the greatest volume, thickness and travel distance, and appears to have formed ridges over which subsequent deposits were emplaced. It was a large volume event with evidence of superelevation on Table Mountain. It also behaved as a momentum-driven flow but with velocities > 20 m/s.

The characteristics of the Jumbles indicate different emplacement mechanics can occur during successive failure events at the same locality over variable time periods. The mechanics are likely governed by threshold dimensional values rather than the presence of any interstitial medium. Environmental conditioning is likely an important factor. This study demonstrates that the identification of important geomorphic features can be missed or unresolved in image data. Our study highlights the need for combining digital datasets (such as images and topography) when attempting to interpret the emplacement of landslides on Mars. Many landslides on Mars may have been momentum-driven requiring no medium such as water or carbon-dioxide.

References:

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