SEISMIC TRIGGERING MECHANISMS OF LARGE–SCALE LANDSLIDES, VALLES MARINERIS. Paul A. Caruso[1] Blackhawk Geosciences, 301 Commercial Road B, Golden, CO, 80401 (http://carusoscave.com; paul-caruso@msn.com).
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Summary: Large–scale landslides in Valles Marineris wallrock are analyzed in order to determine what triggering mechanisms caused the landslides. These landslides occur in the locality of large faults, and therefore it is hypothesized that the landslides are the result of marsquakes triggering slope instability. This work confirms that landslides occur where the seismic hazard map forecasts highest seismic slide potential.

Introduction: To demonstrate the mechanics of large–scale Martian slides this study quantifies the magnitude of marsquakes and resulting ground motions based on terrestrial methods [1–9]. Additionally, computer modeling with XSTABL [10] is used to establish ground motion needed to induce failure of Martian slopes where previous landslides have occurred. These analyses demonstrate that faults in and around Valles Marineris are large enough to generate significant ground motions that can induce landslides (**Fig. 1**).

Results: Large paleolandslides on Earth are the result of large earthquakes and have been shown to correspond with earthquake magnitude and distance from the epicenter (**Fig. 2**) [1, 2]. Surface expression of fault lengths over 100 km is not uncommon in and around Valles Marineris, and as a result these faults are capable of producing quakes in excess of magnitude 8 (**Fig. 2**) [3]. Calculations of Arias intensity [4] ground accelerations as a result of marsquakes, reveals that marsquakes can cause ground accelerations of 0.5 m/s^2 within 10 km of the epicenter.

Mars Orbiting Laser Altimeter (MOLA) data digital elevation models were created in Arcview GIS for Valles Marineris to define slope height and angle throughout the chasmata. Furthermore, a digital geologic map was produced based on previous geologic interpretations [13, 14, 15] in order to identify faults and define seismic response of surficial materials [7, 8, 11, 12]. By digitally measuring the surface length of faults, maximum potential marsquake magnitudes are defined for all large faults in Valles Marineris because the length of fault is directly related to the maximum possible quake that can occur on that fault [6]. Additionally, seismic models were constrained by fault type as defined on previous geologic maps [13, 14, 15] using GIS to modify seismic motion models for direction of fault motion (**Fig. 2**).

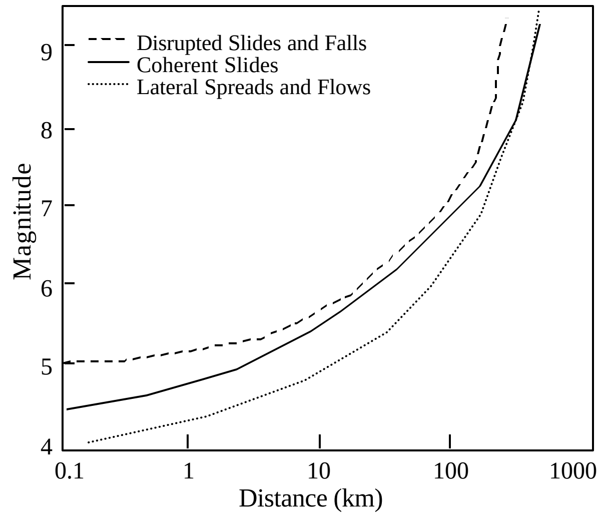

Fig. 1. The maximum distance that landslides can occur from the epicenter of an earthquake is based on an historical data set of 30 earthquakes (after *Keefer*, 1984).

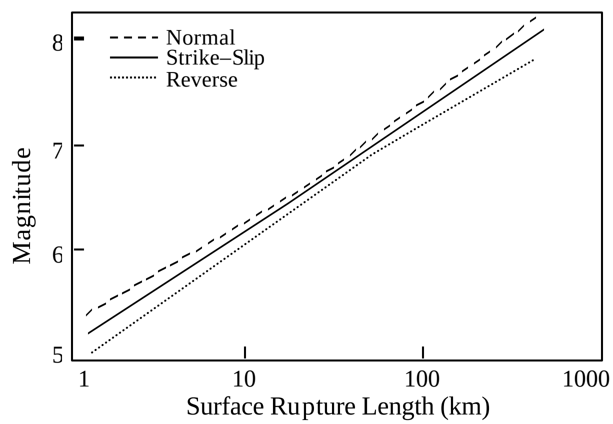

Fig. 2. To estimate magnitudes of marsquakes, surface rupture length is used. Lines represent best fit for 77 historical earthquakes (after Wells and Coppersmith, 1994).

Using XSTABL to model of landslides that have already occurred in Valles Marineris, a baseline is established identifying seismic acceleration needed to induce those slides (**Fig. 3**) [10, 16, 17]. By employing GIS, this study associates distance from fault with slope angle and lithology to devise a seismic hazard map for landslides in Valles Marineris that can be used to demonstrate where seismic landslides are most likely to occur [7, 18]. Utilizing GIS, the seismic landslide hazard map is superimposed with a map of all landslides in Valles Marineris to illustrate how predictions compare to with landslides that have previously occurred. **Fig. 4** shows where landslides are likely to occur if a large marsquake occurred today in or near Valles Marineris.

This work reveals that landslides have previously occurred where seismic landslide hazard is highest (**Fig. 4**). In fact, no large–scale landslides occur in areas not rated as highest by the seismic landslide hazard map. Therefore it is concluded that large landslides in Valles Marineris are the result of marsquakes triggering ground accelerations that induce failure (**Fig. 4**).

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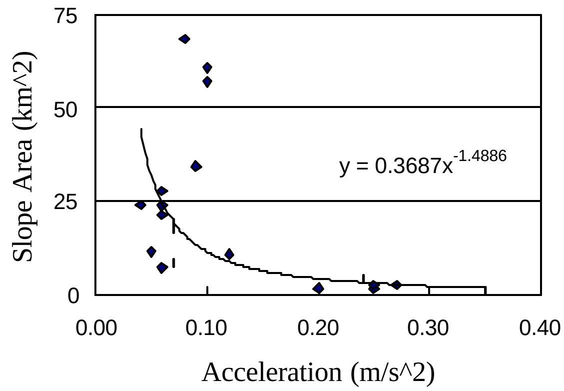

Fig. 3. Modeling of Martian landslides using XSTABL defines acceleration needed to induce failure in slopes defined by diamonds. This chart reveals that as the slope height and angle increase failure can be induced by exponentially smaller seismic events approximated by the equation $y = 0.3678x^{-1.4886}$.

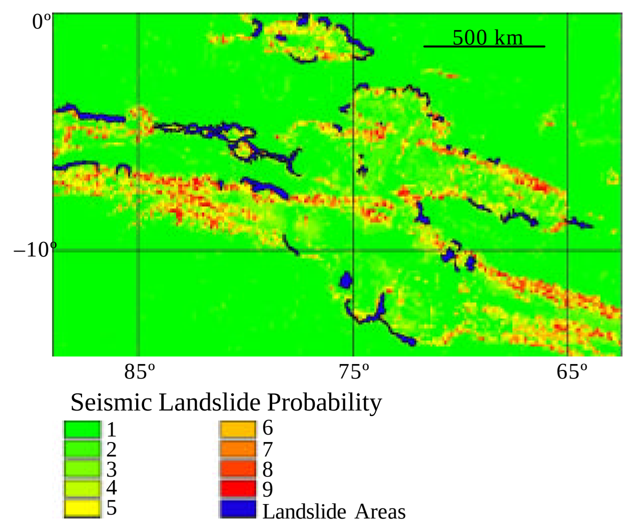

Fig. 4. Landslide hazard map of Valles Marineris, Mars showing where landslides are likely to occur as a result of large contemporary marsquakes. Created using Arcview 3.2 GIS, based on maximum possible marsquakes and acceleration potential of geology as well as amplification due to slope angle. Landslide hazard rated on a scale of 1 to 9 based on a modern day marsquake occurring on a mapped fault, where 1 indicates no hazard, 9 is the highest hazard zone and blue areas indicate mapped landslides [13, 14, 15].