DESTABILIZATION OF VALLES MARINERIS WALLSLOPES BY RETREAT OF ANCIENT GLACIERS. D. Mège and O. Bourgeois, Laboratoire de planétologie et géodynamique, CNRS UMR 6112, Université de Nantes, 2 rue de la houssinière, BP 92208, 44322 Nantes cedex, France, daniel.mege@univ-nantes.fr, olivier.bourgeois@univ-nantes.fr

Summary: Most inter-chasma ridges of Valles Marineris display sackung (deep-seated gravitational spreading) features. Most terrestrial sackung cases whose genesis has been investigated in peer-reviewed literature have been ascribed to deglaciation. Geomorphology shows that this interpretation is plausible in Valles Marineris, and consistent with published mineralogical models of chasma floor deposits. It implies that a widespread, ~1 km-thick ice cover should have once (during the Hesperian?) filled in the chasmata.

Introduction: The largest mass wasting landforms of Valles Marineris are spreading horsts distributed throughout the chasma network [1]. We investigate their environmental condition from comparison with Earth-based analogues.

Sackung in Valles Marineris: Sackung is a mechanism of topographic ridge destabilization that produces normal fault scarps on ridge flanks and spectacular ridge-top splitting at summit, resulting in diagnostic narrow crestal grabens [2-6]. A breathtaking example has been identified at Geryon Montes, the central Ius Chasma horst [1]. A systematic study along Valles Marineris reveals that sackung is actually observed at almost every horst within Valles Marineris, which includes horsts at the western Coprates Chasma, Melas-Candor, and Candor-Ophir boundaries, and in Candor Chasma [7].

As an example (more will be presented), the Geryon Montes ridge displays a crestal graben (Figure 1, top) and ridge-parallel normal faults along its southern slope. Normal faulting has not affected the northern slope of the ridge, as expected from the asymmetric nature of sackung. Observed ridge-parallel floor anticlinal folding and probable thrusting at the base of the ridge [1] is predicted by sackung experiments [5,6,8,9], and observed in terrestrial sackung examples as a result of downward displacement of the sagging slope [10] as an alternative or complement to the more commonly observed slope overbulging [4,11].

Sackung mechanisms from Earth-based analogues: On Earth, ridge-top splitting has been almost exclusively observed in mountain ranges that were glaciated during the Quaternary, where they have been ascribed to ridge debuttressing after glaciation, and/or postglacial unloading (Figure 2). In an extensive search for sackung studies on Earth, 23 articles explicitely discussing the sackung triggering mechanisms have been found to be published in peer-reviewed articles, representing as many distinct sackung sites. Of these, 20 have been explicitly ascribed to postglacial processes (the Alps of Europe, Japan, and New Zealand; the Canadian and U.S. Rockies; the Cascade, Andean, and Pyrenean Ranges, and the Himalayas), 2 to seismic activity along the nearby San Andreas fault system (the sackung interpretation of the observed faults being controversial in 1 of the 2 cases), and 1 to an unknown mechanism (southern Apennines in Italy). Lacustrine ridge buttressing followed by rapid lake withdrawal is a variation on the glaciation-deglaciation mechanism that appears to be able to trigger sackung in theory but does not appear to have been identified on Earth [12].

Figure 1. Two examples of ridge-top splitting: top : Geryon Montes in Ius Chasma; bottom: Bodeneck in the Austrian Alps. Note the glacial valleys on both sides of the Bodeneck ridge. Ridge width is 20 and 8 km respectively. Images are from Mars Express/HRSC and Spot 5. There is no scale distortion.

In the postglacial environment, the mechanisms that link ridge debuttressing and sackung have not been fully understood to date; nevertheless, rock decohesion by alteration and formation of clay minerals accumulating at the bottom of the crestal graben scarps [2], or selectively weaken lithological sequences [13] probably plays a major role in ridge slope destabilization. It appears reasonable to suggest that ridge confinement by valley glaciers and saturated or nearly-saturated water conditions in the ridge rock mass is directly related to ridge weakening through stress corrosion and subcritical crack growth. In some circumstances, such as during melting/freezing cycles, hydraulic fracturing might also be involved.

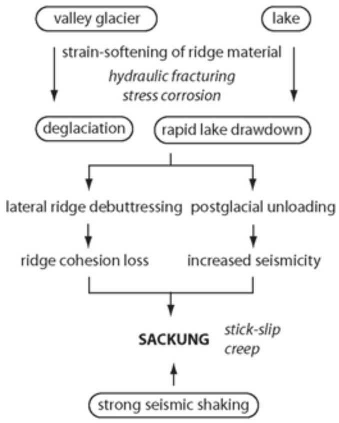

Figure 2. Genesis of sackung features. Of 23 terrestrial sackung sites published in peer-reviewed articles, 20 result from deglaciation, 2 from seismic shaking along a nearby fault, and 1 has not been elucidated.

Comparison between ridge-top splitting in Valles Marineris and formerly glaciated valleys in the European Alps is amazing (Figure 1). We argue that sackung in Valles Marineris is most likely due to deglaciation of the horst-surrounding grabens, because of the excellent statistical correlation between sackung occurrence and deglaciation on Earth.

Correlation with mineralogical models: CRISM data modeling has revealed sulphates and hydrated silica on chasma floor below the Geryon and other sackung sites [14,15]. This association has been convincingly interpreted as the product of silicate material weathering in massive ice deposits [16].

Trimlines: Supporting this interpretation is the possible existence of glacial trimlines at the bottom of the slope of many chasmata (Figure 3). The associated scarps were first interpreted as normal fault scarps [7]. However, evidence of fault offset variation along length, and scarp end tapering off [18], which would confirm this interpretation, is usually lacking. If the trimline interpretation is correct, its elevation above chasma floor gives an idea of valley glacier thickness. This thickness would be ca. 1300 m in the area displayed on Figure 1, i.e. 15% of the chasma height. For a given glacier, the trimlines are expected to define a planar surface, a feature that will be investigated in more detail for Valles Marineris before the conference.

Conclusion: Large-scale gravitational spreading of the inter-chasma ridges suggest that the Valles Marineris chasmata were once extensively covered by valley glaciers. It has been suggested that these ridges have unusual high strength, gained by groundwater fluid circulation and cement precipitation within the rock mass [19]. The results presented here argue in favor of spectacularly low cohesion ridges instead, but unambiguously supports the idea that groundwater should have once been abundant within the ridges.

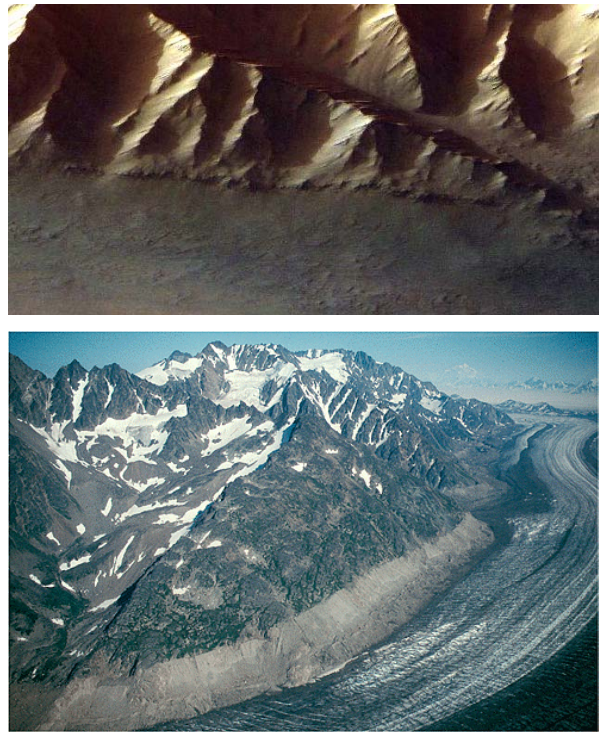

Figure 3. Top: Ius Chasma slope north of the area displayed on Figure 1. The length of the putative trimline (horizontal rock outcrop) above the basal scarp is 10 km. Bottom: trimline above the Tana glacier, Alaska, showing the maximum elevation the glacier has reached [17].

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