GIANT SACKUNG SCARPS IN VALLES MARINERIS. O. Kromuszczyńska[1], D. Mège[1], A. Lucas[2], and J. Gurgurewicz[1,3], [1]WROONA Group, Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Wrocław, Podwale St. 75, PL-50449 Wrocław, Poland (okromuszczynska@twarda.pan.pl; daniel.mege@twarda.pan.pl, jgur@cbk.waw.pl), [2]California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, CA, USA (alucas@caltech.edu), [3]Space Research Centre, Polish Academy of Sciences, Bartycka 18A, PL-00-716 Warszawa, Poland.

Introduction: The southern Valles Marineris (Fig. 1a) is a complex of 4-10 km deep grabens (chasmata) striking E-W, located in the equatorial region of Mars [1, 2]. After initiation by tectonic stretching (Fig. 1.b1),they were filled in by valley glaciers (Fig. 1b.2). Glacier removal produced gravitational spreading of inter-chasma topography (Fig. 1b.3) by development of uphill-facing normal faults and crestal grabens, diagnostic of a type of topographic ridge deformation called sackung [3].

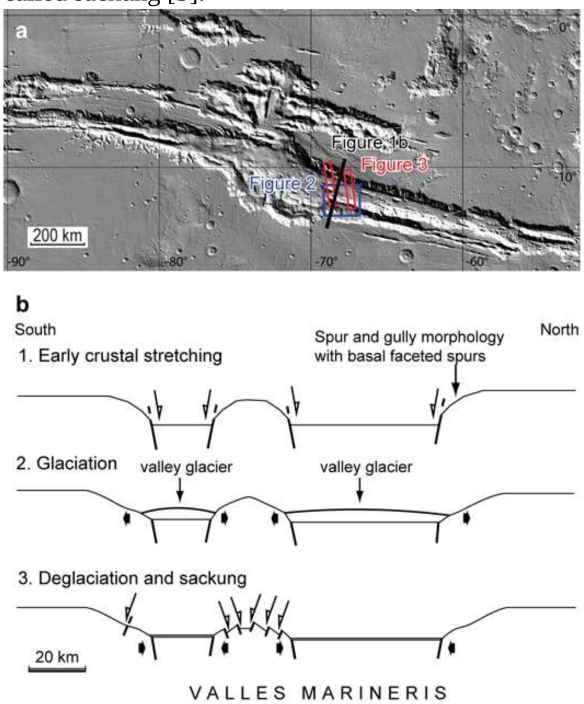

Figure 1a: Localization; b: Schematic succession of the geological events in Valles Marineris discussed here, between chasma initiation (upper Noachian-lower Hesperian) and gravitational spreading of intra-graben topography (upper Hesperian-lower Amazonian [1]). The arrows indicate direction of glacial buttressing (2) and postglacial debuttressing (3).

Sackung has been identified in many places in Valles Marineris. The sackung scarps cut across the pristine spur-and gully morphology of the chasma walls [2]. New Digital Elevation Models (DEM) obtained in western Coprates Chasma (Fig. 2) from correlation of MRO/CTX images made it possible to determine vertical throw of the uphill-facing faults.

Height of sackung scarps and fault offets in western Coprates Chasma: Two CTX DEMs (Fig. 3) cutting western Coprates Chasma from north to south were analyzed. DEM grid spacing is 30 m and vertical accuracy is estimated to be about 15 m.

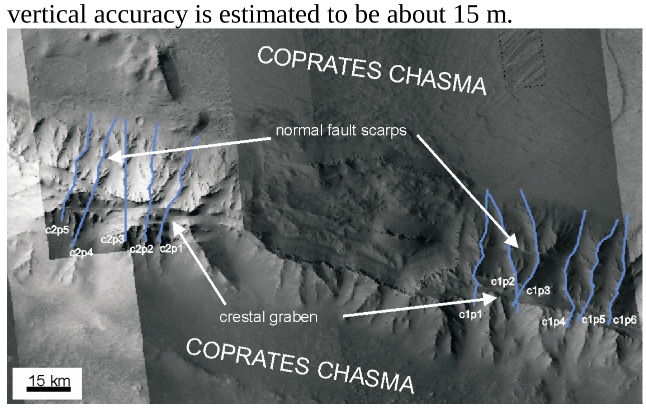

Figure 2: Sackung features affecting a horst. Location on Fig. 1a.

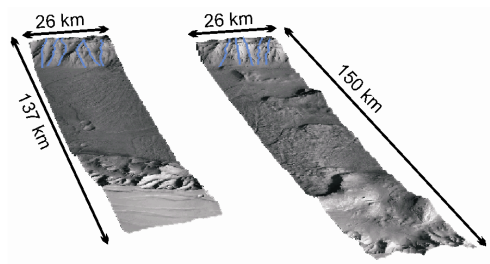

Figure 3: CTX DEM of western Coprates Chasma draped over CTX image. Blue lines - profiles. North is to the bottom right. Location on Fig. 1a.

Eleven profiles of the northern slope of the Coprates Chasma central topographic ridge (Fig. 2) were analyzed (Fig. 4). The uphill-facing normal fault scarps were mapped and their height measured. Scarp height and slope do not represent true fault offset and dip angle; however, fault offset can be retrieved if assumption is made on fault dip angles. We assumed them to be in the range 60-70º, typical of many normal faults in extensional settings on Earth [4, 5].

The results (Table 1, Fig. 5) show that the vertical offsets of faults in the eastern part of the investigated area are between 40 and 830 meters with an average value of about 280 meters. In the west, the vertical offsets are between 50 and 1000 meters. Average value in this part is about 320 meters. Total downward displacement of the ridge caused by sackung measured across the northern slope only is 615 - 1420 meters in the east, and 710 - 1660 meters in the west of the investigated area, which is consistent with observation that the elevation of the horst summit decreases from east to west.

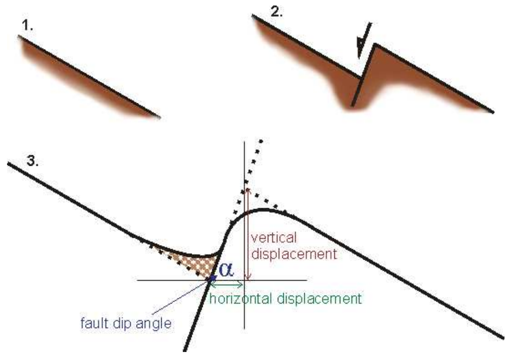

Figure 4: Parameters used for calculation of vertical displacement.

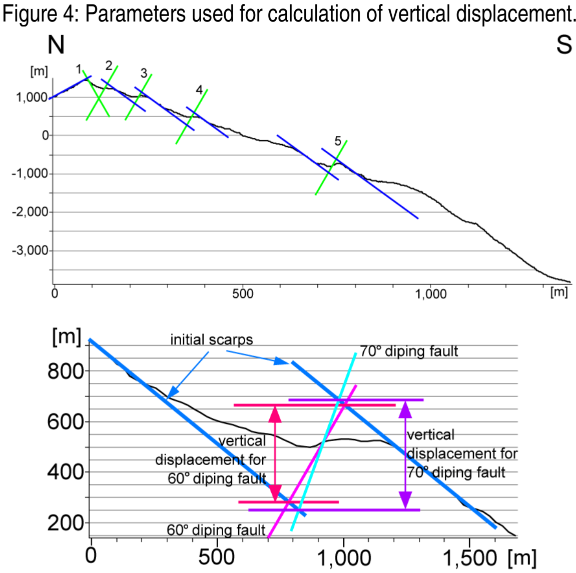

Figure 5: Example of calculation of vertical displacement (top: profile c1p5 in Table 1; bottom: fault #4 on profile c1p5).

Comparison with terrestrial sackung features: From a review of the relevant literature (supplementary table in [1]), vertical throw of individual sackung fault scarps on Earth does usually not exceed a few metres, and ridge width is a few kilometres. Therefore, one order of magnitude of difference in scale exists between the terrestrial and Coprates sackung occurences.

The height and width of sagging ridges above the surrounding valley floors on Earth is on the order of ~1000-2000 m (e.g., western European Alps, Tatra Mountains, New Zealand Alps). The minimum elevation of the horst prior to sackung H_{min} is constrained by summing the presently observed horst slope gradient h_{sg} (~5000-6000 m), the amount of horst subsidence in response to sackung as in Table 1 h_{sac} (~600-1700 m), and the thickness of the sediments located on the Coprates Chasma floor h_{sed} (estimated to ~100 m by applying Pike's relation between impact crater depth and diameter [6] to a very large crater partly buried by sediments in the Coprates graben north of the horst), giving a total of $H_{min} \approx$ 5700-7800°m. Maximum horst elevation, assuming that the horst summit prior to sackung had the same elevation as the surrounding plateau, is $H_{max} \approx$ 9500 m. It follows that the one order of magnitude difference in the scale of sackung features in Coprates Chasma and on Earth correlates with a 3-9.5 times larger topographic gradient.

Conclusions: The vertical displacement of sackung scarps in Coprates Chasma is exceptionally high in comparison with such features on Earth. The measurements indicated that gravitational collapse of the topographic ridge (sackung) was between 615 and 1660 meters, which is about 20-40% of total downward displacement of the ridge, assuming that its elevation was initially similar to the elevation of the surrounding plateau.

References: [1] Schultz R. A. and Lin J.(2001) *J. Geophys. Res. 106, B8*, 16549-16566. [2] Peulvast J.-P. et al. (2001) *Geomorphology 37*, 329-352. [3] Mège D. and Bourgeois O. (2011) *Earth Planet. Sci. Lett., 310*, 182–191. [4] Gudmundsson, A (1992) *Terra Nova*, 4, 464-471. [5] Acocella V., et al. (2003) *J. Struct. Geol., 25*, 503-513. [6] Pike R. J. (1980) *Lunar and Planetary Science XI*, 885-887.

Profile name	c1p1		c1p2		c1p3		c1p4		c1p5		c1p6		c2p1		c2p2		c2p3		c2p4		c2p5	
Dip angle [º]	60	70	60	70	60	70	60	70	60	70	60	70	60	70	60	70	60	70	60	70	60	70
Fault number	Vertical throw [m]																					
1	140	150	40	45	130	140	820	830	250	260	140	150	450	490	260	300	450	490	380	430	260	280
2	230	240	700	710	580	590	55	60	110	120	300	340	220	240	120	130	500	510	100	110	280	300
3	210	230	220	230	230	240	50	55	270	300	320	360	650	690	70	80	1000	160	50	55	200	220
4	110	120	430	480	350	380	270	300	380	430	180	200	440	390	820	930	290	240	200	230	290	330
5	340	350	-	-	-	-	240	270	370	420	-	-	560	490	160	130	450	490	230	180	340	370
6	-	-	-	-	-	-	-	-	-	-	-	-	80	90	140	160	-	-	230	260	520	420
Total vertical throw [m]	890	940	1350	1420	1160	1210	615	685	1130	1270	940	1050	1730	1660	1190	1300	1740	890	710	725	1150	1120

Table 1: Vertical displacement of investigated faults; in yellow – faults on south slope; the rest– faults on north slope. The profiles are located on Figure 2.