A PLANETARY EXAMPLE OF TECTONIC INVERSION: FOLDING AND THRUSTING IN THE VALLES MARINERIS GRABEN SYSTEM ON MARS. Daniel Mège[1], Jean-Pierre Peulvast[2], and Philippe Masson[3] ([1] UMR CNRS 6112, Laboratoire de Planétologie et Géodynamique, Université de Nantes, 2 rue de la Houssinière, 44322 Nantes cedex, France, daniel.mege@chimie.univ-nantes.fr; [2] UMR CNRS 8148, Institut de Géographie, Université Paris-Sorbonne, 191 rue Saint-Jacques, 75005 Paris, peulvast@geol.u-psud.fr; [3] UMR CNRS 8148, IDES, Université Paris-Sud, 91405 Orsay cedex, France, masson@geol.u-psud.fr)

Summary: We used Themis, MOC, and MOLA data to reinterpret the floor of the southern Ius Chasma graben in Valles Marineris between 81°W and 82°W (Figure 1). We confirm earlier interpretations based on Viking imagery [1, 2] that this part of the graben has been inverted. Shortening is thought to result from the body forces exerted by the topography of Geryon Montes, the E-W horst between the two Ius Chasma grabens. Shortening is expected to balance Geryon Montes wall spreading through sackung. Based on the distribution of bifid crests in Valles Marineris, shortening is expected to have occurred in other areas in Valles Marineris as well.

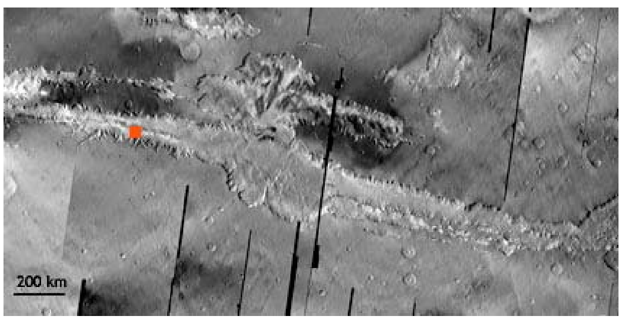

Figure 1. Location of the study area (Themis IR mosaic 20041008A by courtesy of NASA/JPL/ASU).

Introduction: In 1977 Blasius et al. [3] showed stereoscopic Viking images of a portion of Ius Chasma on which the southern graben displays a deformed structural topography, the prominent feature being a N-dipping monocline in the southern part of the graben (Figure 2). This area was interpreted to be folded, with two E-W anticlines surrounding a syncline [1, 2]. It was proposed that these folds formed as a push-up structure during a transtensional tectonic event in Valles Marineris [1].

Here we re-evaluate this interpretation in the light of Themis and MOC imagery and MOLA altimetry. First we discuss the stratigraphy and paleogeography of the area, then we propose a geologic cross section of the graben. Graben folding is confirmed, following the same geometry as expected; in addition, Themis imagery shows graben floor overthrusting. Noting that Geryon Montes displays sackung (gravity spreading through ridge top splitting) above the graben floor, we propose that shortening results from (and balances) Geryon Montes spreading under its own weight, and stress the consequences for the water conditions in the wallrock.

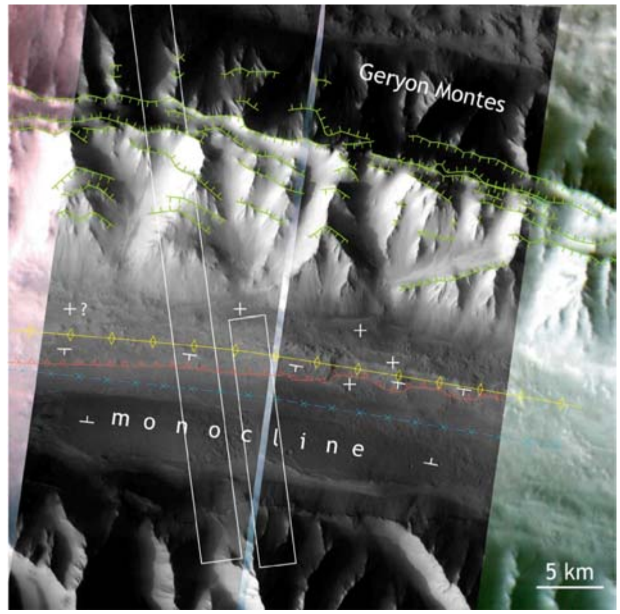

Figure 2. Study area (Themis V+IR mosaic by courtesy of NASA/JPL/ASU), simplified structural interpretation (*white*: dip angles; *red*: thrust fault; *yellow*: anticlinal axis; *blue*: approximate (inferred) synclinal axis; green: sackung-related normal fault scarps in Geryon Montes), and location of the MOC images interpreted on Figure 3.

Stratigraphy: A basic stratigraphy of the Valles Marineris walls and floor in the studied area can be sketched from MOC images (Figure 3). In chronological order:

Formation 1. Wallrock is made of a thick stack of layered materials, probably akin to traps [4, 5].

Formation 2. Based on cratering density, the oldest formation observed on graben floor is exhumed, resistant, layered material that makes up the monocline surface. This material is widespread in Ius and Melas chasmata. Its thickness in Ius Chasma cannot be determined using MOLA data, however in Melas Chasma it may be at least 3500 m. Its thickness, widespread occurrence, oldness, and layering suggest that it might correspond to detrital sediments (conglomerate, sandstone) resulting from the major processes of chasma wall erosion (spurs and gullies formation and sapping) in water environment.

Formation 3. Formation 2 is overlain by a thinly layered pile of weak materials displaying a very smooth surface. One of the layers is brighter than the others and can be used as a reference level for stratigraphic correlations. MOC imagery reveals that these layers are frequently carved by aeolian abrasion, the resulting troughs being subsequently filled by dunes. Formation 3 also displays tabular circular mounds, possibly guyots, an interpretation that would imply that these layers also formed, at least partly, under water. However, the surface of the resistant layer underneath displays tens of meters wide channels, suggesting that the water body may have receded between the two deposition periods.

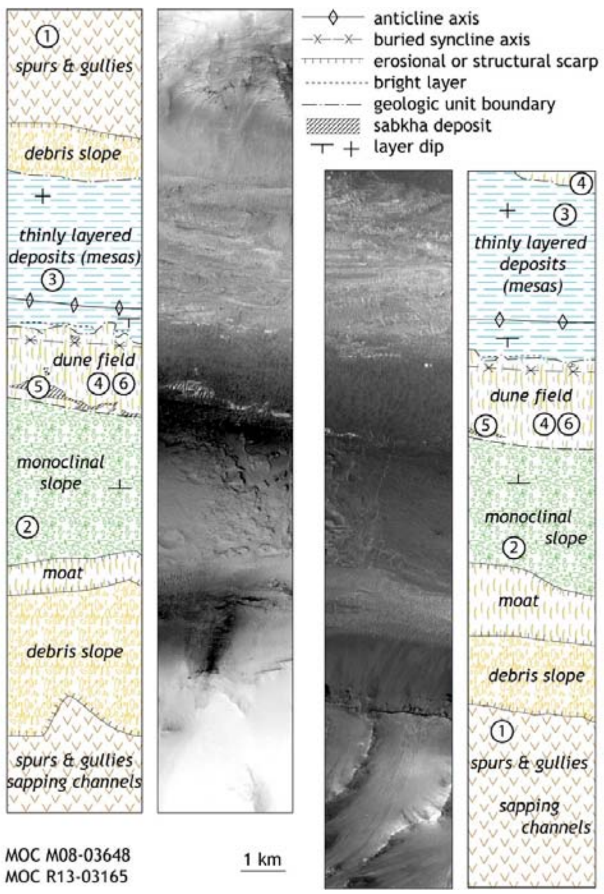

Figure 3. Geologic interpretation of two of the available MOC images in the studied graben (images by courtesy of NASA/JPL/MSSS). The numbers refer to the formation numbers discussed in the text.

Formation 4. Formation 3 is capped by a thin dark resistant cap.

Formation 5. Probable sabkha deposits are observed to have formed on Formation 3, including on its eroded remnants, and Formation 4.

Formation 6 is for dune fields that have systematically developed on Formation 4, and usually (though not always) Formation 5, and might rework finr granular materials eroded from formations 3 to 5.

Structural interpretation: Figure 2 shows two series of major tectonic structures: Geryon Montes normal faults, and graben floor folds. The anticline on Figure 2 overthrusts the graben floor. Figure 4 shows a synthetic geologic cross section of the graben from Themis, MOC, and MOLA data. The fold and thrust fault are interpreted to balance Geryon Montes spreading in response to its own load, rather than a consequence of regional shortening, because there is no evidence of compatible regional-scale shortening on the plateau in the Valles Marineris surroundings.

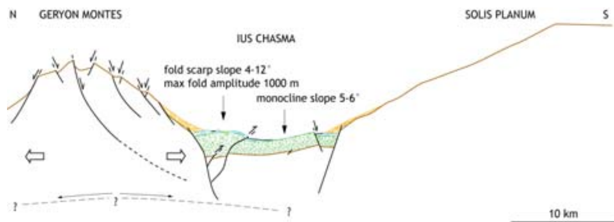

Figure 4. Proposed cross-section of Geryon Montes and the southern Ius graben. Symbols as on Figure 3.

Bifid crests and sackung: Spreading is a consequence of Geryon Montes ridge top splitting, a feature called sackung. Although the mechanisms involved in sackung are not yet elucidated in full, it probably requires that the Geryon Montes walls were once water-saturated so that the pore pressure could decrease the wall shear stress [6], or that they were initially confined by glaciers and subsequently unconfined [7]. The paleogeography sketched above from stratigraphic analysis is consistent with the first hypothesis.

Implications for water history: We found evidence of one or two distinct periods of water flooding in Ius Chasma. Probability is strong that abundant groundwater existed at that time, and that, as argued earlier [2], many of the dramatic mass wasting processes in Valles Marineris may have occurred in response to subsequent wall desiccation.

Perspectives: Sackung is one of the precursory mechanisms leading to landsliding. Ridge top splitting is observed in many places in Ius, Melas, and Coprates chasmata in areas that are rich in large mass movements, especially landslides. Detailed analysis of topography, stratigraphy, and structures in other sackung and landslide sites will be carried to identifiy other sites where graben floor may have been shortened. 1-D and areal shortening may be estimated in the studied area using structural methods (scaled cross-sections, displacement-length scaling) and may be used to quantitatively constrain ridge spreading in Valles Marineris.

References: [1] Mège, D. (1994), Ph.D. Thesis, Université Paris-Sud, Orsay, France, 384 p. [2] Peulvast, J.-P., et al. (2001), Geomorphology, 37, 329-352. [3] Blasius, K.R., et al. (1977) JGR, 82, 4067-4091. [4] McEwen, A.S., et al. (1999), Nature, 397, 584-586. [5] Mège, D. (2001), GSA Sp. Pap. 352, 141-164. [6] Rogers, D.J., and Watkins, C.M. (2003), Univ. Missouri-Rolla, web.umr.edu\~rogersda\sturzstroms&sackungen. [7] e.g., Kinakin, D.J., and Stead, D. (2005), Geomorphology, in press.