STRUCTURAL ANALYSIS OF THE SOUTHERN VALLES MARINERIS TROUGH ZONES AND IMPLICATIONS FOR LARGE-SCALE LEFT-SLIP FAULTING ON MARS. An Yin (Department of Earth and Space Sciences and Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA; yin@ess.ucla.edu).

Introduction: The 4000-km long Valles Marineris is the longest trough system in the solar system, yet its origin remains elusive. Its formation mechanism has been variably related to (1) rifting, (2) sub-surface removal of dissolvable materials or magmatic withdraw, (3) massive dike emplacement causing ground-ice melting and thus catastrophic formation of outflow channels, and (4) large-scale strike-slip faulting related to plate tectonics, lateral extrusion, or large landslide emplacement. The purpose of this study is to test the above models by analyzing satellite images across the two longest and most linear trough zones in the Valles Marineris: the Ius Chasma trough zone in the west and Coprates Chasma trough zone in the east. The main purpose of this study is to use shape, orientation, spatial association, and cross-cutting relationships of key geologic features to infer fault kinematics and the deformation history of the linear and continuous Ius-Melas-Coprates (IMC) trough system. The structures examined in this study are mainly exposed on the trough floors and on the plateau margins.

Data and Methods: The following data available publically were used in the structural analysis: (1) Thermal Emission Imaging System (THEMIS) satellite images obtained from the Mars Odyssey spacecraft with a typical spatial resolution of ~18 m/pixel, (2) High Resolution Stereo Camera (HRSC) satellite images from the Mars Express spacecraft with a typical spatial resolution of about 12.5 m/pixel; (3) the Context Camera (CTX) (with a typical spatial resolution of ~ 5.2 m/pixel) and High Resolution Imaging Science Experiment (HiRISE) (with a typical spatial resolution of 30-60 cm/pixel) satellite images from the Mars Reconnaissance Orbiter spacecraft, and (4) Mars Obiter Camera (MOC) images from Mars Global Surveyer spacecraft with a spatial resolution of 30 cm/pixel to 5 m/pixel.

For every segment of the Ius-Melas-Coprates (IMC) trough system mapped in this study, the first-order structures were examined first, which allows unambiguous interpretations of smaller structures in a regional context. For example, a large fold with a single trend may contain numerous smaller parasitic folds that have highly variable trends, which may differ significantly from that for the main fold. Also, as fold hinges may migrate with time, two phases of folds may occur in the same area with drastically different trends and kinematics during a single structural-formation process.

In order to determine the attitudes of geologic features such as bedding and faults, two approaches were taken. First, the dip direction of an inclined planar feature was estimated using the “Rules of Vs”. This allows determination of fold shape where topographic data are not available or too coarse to be useful. HRSC DTM maps created by level-4 data were used using the commercially available ORION software from © Pangaea Scientific. This data set is most useful when analyzing planar structures larger than 5-10 km that have simple geometry and are exposed in high-relief regions (> hundreds of meters).

Results: Structures in the northern and southern trough zones of Ius Chasma are dominated by NW-trending folds, E-striking left-slip faults and NE-trending extensional structures (joints and normal faults). These structures cut across many trough-fill units and are thus interpreted to be tectonic in origin. This geometric association is consistent with the trough-bounding faults to have moved in a left-lateral sense. Locally, parallel NNW-striking right-slip faults are also present between E-striking left-slip fault zones. Their occurrence may be related bookshelf faulting in a left-slip shear zone. The occurrence of folded intraformational soft-sediment structures in southern Ius Chasma suggests coeval development of basin fills, slump structures, and NW-trending folds. Rocks involving soft-sediment deformation are thinly bedded and light-toned, which do not match rocks on trough walls. thus broken beds via soft-sediment deformation, possibly involving water, were most likely transported from margins of the basins. The high intensity of deformation (e.g., formation of < 15 m angular breccias) and the lack of relief from basin margins to the basin center suggest that the fragmentation and transport of the broken bed unit was induced by seismic activity along trough-boudning faults.

Observations from Coprates Chasma also support its formation as being controlled by left-slip faulting, such as the presence of a left-slip trough-bounding fault associated with prominent drag folds. Development of northwest-trending contractional structures (folds, lobate scarps and thrusts), northeast-trending normal faults, and west-northwest trending left-slip shear zones in the trough zones are also compatible with left-slip faulting for its structural development.

The east-striking left-slip faults and NW-trending folds in Ius and Coprates Chasmata cut or involve Late Amonzoinian strata. Also, many trough-bounding left-slip faults display prominent fault scarps. These observations, together with the occurrence of Late Amazonian syn-tectonic soft-sediment structures, suggest that the inferred left-slip faulting in the study area may still be active.

The strongest evidence for left-slip faulting across Coprates Chasma is the presence of left-slip faults on its plateau margins. There, left-slip deformation is indicated by the formation of closely spaced, trough-parallel left-slip faults. These structures are linked with northeast-striking normal faults and northwest-trending

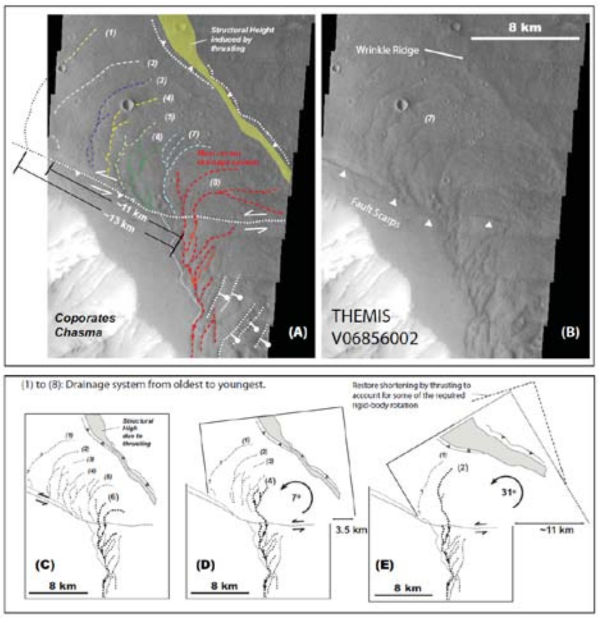

Figure 1. (A) Left-lateral deflection of a drainage system along a left-slip fault on plateau margin, north of Coprates Chasma. Background is a THEMIS image V06856002. (B) Uninterpreted THEMIS image corresponding to (A). Diagrams (C), (D) and (E) are kinematic restorations of the drainage system by sequentially removing left-slip motion.

contractional structures, requiring the occurrence of broad and distributed left-slip shear deformation across the plateau margins. The fresh fault scarps and left-lateral deflection of recent drainages all indicate that left-slip faulting on plateau margins occurred recently, similar to the age of faulting within the trough in the Late Amazonian. Another interesting observation, consistent with those from the trough floor, is that left-slip faulting must have been coeval with rather continuous development of surface drainage system (Fig. 1), as a south-flowing channel into Coprates Chasma has been systematically offset and deflected in a left-lateral sense.

Minimum Magnitude of Left-slip Motion: Individual left-slip faults and the main trough-bounding faults on the trough floors typically display <8 km of left-slip motion. There, the offset markers are all recent trough fills including slumping structures and thus the offset sediments must have been depsited after the initiation of the trough-bouding left-slip faults. As a result, the observed slip magnitudes must be regarded as minimum estimates. On the plateau margin, offsets on subsidiary faults are on the order of 1-2 km (Fig. 2). These faults all display a normal-slip component, which may require that the formation of the Ius-Coprates trough system was induced by left-lateral transtensional deformation.

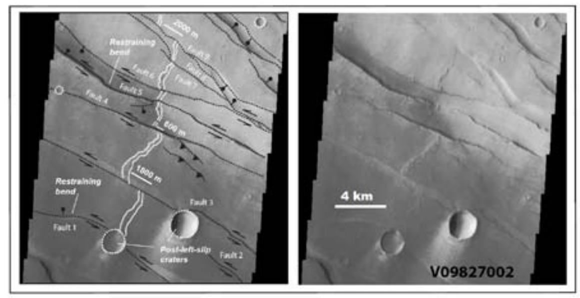

Figure 2. (A) Left-slip faults on plateau margin north of Coprates Chasma. Background is THEMIS image V09827002. (B) Uninterpreted THEMIS image corresponding to (A).

Inferred Total Magnitude of Left-slip Motion: The total left-slip offset on the combined Ius-Coprates trough-bunding fault system may be on the order of ~ 150 km. This estimate, though highly speculative, is based on consistent offsets of three geologic features: (1) the north-trending Thaumasia thrust belt, (2) a possible impact crater across Melas Chasma, and (3) a plutonic complex at the eastern end of Coprates Chasma.

Broad Implications: It appears difficult to generate a left-slip system with >100-km motion purely by flexural loading of the Tharsis rise, not mentioning that the Valles Marineris itself is part of this load. It is also unclear how such a large-scale strike-slip fault zone was initiated by a rising plume so late in the Mars history. From a kinematic point of view, large-scale strike-slip faulting requires some form of horizontally driven tectonics on Mars, which may either be expressed by relative motion between rigid plates as for the oceanic lithosphere on Earth, or by accommodating differential continuum deformation as for terrestrial continental lithosphere (e.g., the Altyn Tagh fault in Tibet and the Garlock fault in the western U.S.). The selection of the end-member modes of deformation on Mars requires much more detailed and systeamtic research.