GEOMETRY AND SEGMENTATION OF THE CERBERUS FOSSAE FAULT SYSTEM: IMPLICATIONS ON MARSQUAKE PROPERTIES IN ELYSIUM PLANITIA, MARS.

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Introduction: Successfully landed on Mars on past November 26th 2018, the NASA's Discovery Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission is dedicated to probe the Martian interior. The main instrument, the Seismic Experiment for Interior Structure (SEIS) seismometer is designed to record the Martian seismic activity.

The study of the seismic sources (*i.e.* their location, depth and magnitude) is mandatory to characterize the medium where seismic waves propagate. Here, we focus on one type of seismic source: the tectonic faults.

The Cerberus Fossae Fault System (CFFS) is the closest and largest morpho-tectonic structure (~1200 km long) near the landing site of the InSight lander. It is formed by five main grabens (notated "G1" to "G5") and located on the Southeast of the Elysium Mons volcanic rise. Previous studies estimated that the faults tectonic activity can generate medium-sized marsquakes ($M_w > 3$) during the nominal mission (for instance, with the moment estimation of [2]).

Fault segmentation is a common property of terrestrial fault systems. Regardless of their slip mode, tectonic context and size, geological faults are laterally divided along their traces, describing fault segments separated by structural discontinuities such as step-overs or bends. These discontinuities correspond to zones of slip deficit where local stress concentrations can take place and impact the rupture process [3].

In this work, we propose to examine the CFFS potential seismic source, by refining the faults cartography based on previous studies and MGS's MOLA DEM [4] by adding high resolution images (MRO's Context Camera CTX and High-Resolution Imaging Science Experiment HiRISE dataset). We then analyze the local morphologies along strike and investigate the segmentation of the CFFS.

Data: A detailed fault mapping centered on the CFFS (located between 6-12°N and 157-174°E), is performed, using CTX (horizontal resolution of 6m/pixel) and HiRISE (horizontal resolution of 25cm/pixel) data. These images allow to improve significantly the existing fault map presented in the study of [4] but also to identify new faults and secondary fractures. For example, the Eastern G4 fault (see figure 1.a.) is clearly visible on CTX mosaic while it is not seen on MOLA DEM due to gaps between different MGS orbits while MOLA was operating.

HiRISE and CTX images are also employed to derive high resolution DEMs of regions of interest. Fault widths and throws are then analyzed.

Results: The refined cartography presents a wide range of fault and fracture patterns. We have observed comparable structures that exist on Earth: *en-échelon* figures, relay zones, multiple fault strands and main trace throw variations.

Graben width measurements show a strong correlation with existing fault throws measurements (from the

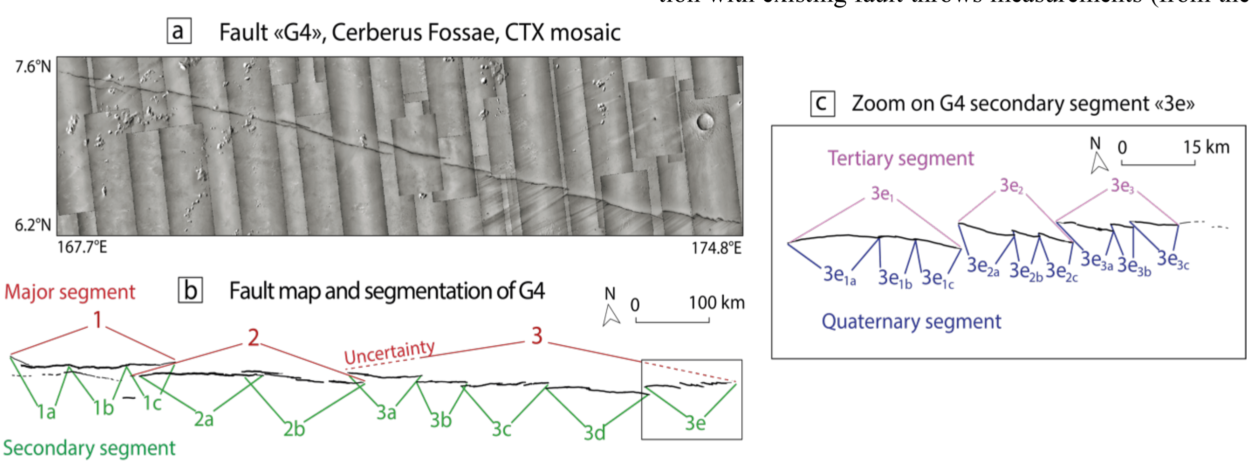

Figure 1. a. CTX mosaic on the Eastern part of CFFS (G4 major fault). **b.** Fault map of the G4 fault (black lines) and schematic representation of its major and secondary segments. **c**. Zoom on G4 secondary segment 3e and its its tertiary and quaternary segments identified in this study.

observations of [5]). Altogether they give some insights on the direction of long-term propagation of the fault system but also on fault dips at depth and how the grabens are rooted in the shallow part of the crust.

Moreover, the exceptional preservation of the grabens allows to detect up to four scales of segmentation, each formed by a similar number of 3-4 segments/sub-segments. The figure 2.a summarizes our CFFS statistics on the distribution of segments/sub-segments (I to IV) included into larger segments (major fault to III).

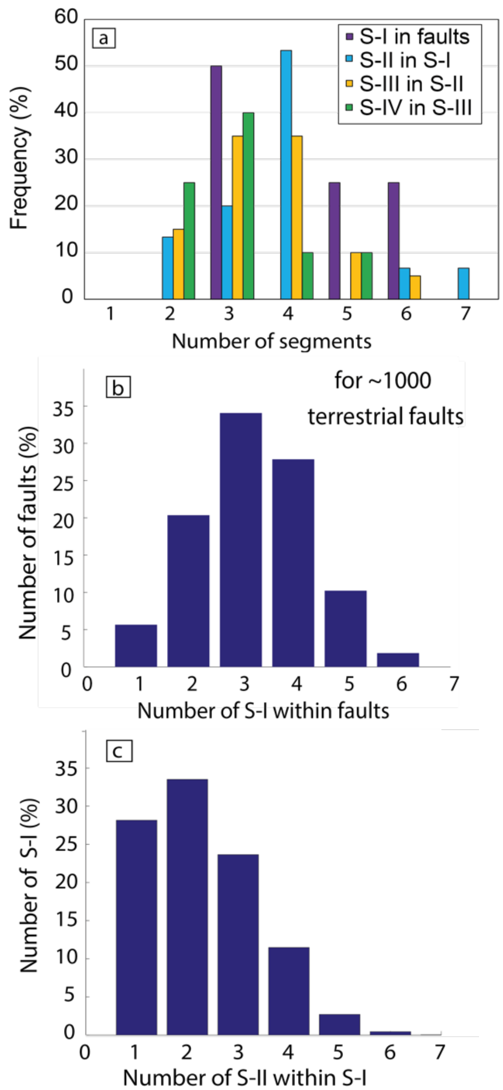

Figure 2. a. Distribution of number of segments/sub-segments within faults/segments of the CFFS. Segment orders are labeled with I-IV where I is a first order segment inside a major fault, and IV represents the smallest observed segments. **b.** Same distribution representations on Afar, East African rift, normal faults for the major segments S-I within faults and **c.** for secondary segments S-II within major segments S-I (both taken from [3]).

This generic distribution of the number of segments is similar to continental faults on Earth: [3] shown that faults on Earth are segmented into 3-4 major segments (figure 2.b) and that major segments are segmented into 2-3 secondary segments (figure 2.c). From seismic moment-rupture length scaling laws we suppose that a moderate magnitude seismic event ($M_w > 3$) could involve the smaller scale of segmentation (IV) along the CFFS.

We finally compare our surface analysis of fault traces with numerical simulations of the regional crustal stress field of the Elysium Planitia area using joint analysis of gravity field and topographic data truncated to spherical harmonic models. Tensional stresses are in agreement with a normal faulting regime on the regional scale. The stresses increase towards East where a higher seismic activity can be expected.

These results will help to constrain the seismic source properties, in the case of a CFFS generated marsquake. Especially, the direct observation of the ruptured segments will facilitate the quake location (epicentral distance and azimuth) and the seismic intensity assessments. These characteristics are directly implemented in the inversion routines to compute the seismic model of Mars.

References:

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