EVIDENCE FOR EARLY EXTENSION AND PRESSURE DROP RELATED TO MAGMA PLUMBING IN NOCTIS LABYRINTHUS (MARS). M.El Yazidi[1,2], C.Orgel[2], G.De Marchi[2], D.Baratoux[3,4], S.Bouley,[5,6], G.Leone[7], P.D'Incecco[8], J. Filiberto[9], and E.Sefton-Nash[2],[1]Center for Studies and Activities for Space (CISAS), University of Padova, via Venezia 15, 35134, Padova, Italy (elyazidimayssa@gmail.com), [2]ESTEC-European Space Agency, Keplerlaan 1, 2201 AZ, Noordwijk, The Netherlands,[3] Géosciences Environnement Toulouse, CNRS, UPS & IRD, 14, Avenue Edouard Belin, 31400, Toulouse, France, [4]UFR des Sciences de la Terrre et des Ressources Minières, Université Félix Houphouët-Boigny, Abidjan Cocody, Côte d'Ivoire, [5]Université Paris-Saclay, CNRS, GEOPS, 91405 Orsay, France, [6]IMCCE, Observatoire de Paris, 77 avenue Denfert-Rochereau, 75005 Paris, France, [7]Instituto de Investigación en Astronomía y Ciencias Planetarias, Universidad de Atacama, Avenida Copayapu 485, Copiapó 1531772, Chile, [8]INAF- Astronomical Observatory of Abruzzo, via Mentore Maggini, snc, 64100, Teramo, Italy, [9]Astromaterials Research and Exploration Science (ARES) Division, X13, NASA Johnson Space Center, Houston, TX, 77058, USA,

Introduction: Noctis Labyrinthus is a complex district located between the western side of Valles Marineris' large outflow channel and the Tharsis volcanic plateau. This region is characterized by a system of steep-walled canyons and an inter-connected network of scalloped pits that manifest in various orientations and size. The formation history of this area has been a topic of substantial discussion in the past. Previous studies have proposed a karst landscape with associated caves and water-related processes [1,2,3] a network of lava tubes [4,5], or a volcano-tectonic activity as a driving process for the formation of Noctis Labyrinthus [6,7,8,9]. However, none of these models have been confirmed or entirely accepted; although, the erosional nature of Noctis Labyrinthus is supported by the presence of channelized lava flows still visible on its floor [5]. In this work, we use MOLA and HRSC data to produce a new structural map of the region, we analyse fault systems (chronology and orientation), the relationships between faults and pit chains, and we finally propose a deformational model that can explain the sequences of events responsible about the formation of Noctis Labyrinthus.

Data and Methods: The data set includes the panchromatic mosaic from High-Resolution Stereo Camera (HRSC) h3210_0000 and h3221_0000 orthoimages (ND2 nadir channel). The mosaic has a resolution of ~19.5 m/pixel. For the topography we use the MEGR00N180HB derived data from the Mission Experiment Gridded Data Record (MEGDR) of Mars Orbiter Laser Altimeter (MOLA) onboard Mars Global Surveyor (MGS), bearing a resolution of 463m/pixel. Faults and grabens have been mapped by a polyline shapefile, including branching, segmented and single isolated faults. Pits appear with irregular shapes and flat-floored; thus, we symbolized these features by a polygon shapefile. The steep-sided edge of the pit chains helped tracking the orientation or these depressions, so we mapped their boundaries by a continuous polyline. The scatter of faults and pit chains azimuths is derived from the polyline length for the faults and pit chains edge. We analyzed the faults crosscutting relationship to group faults in different systems and analyze the tectonic events. We also achieved a morphometric analysis for the pits to decipher different stages of evolution and understand their relationship to the fault systems.

Results: Our structural map presents a large distribution of faults, which led to identify three fault systems based on the faults crosscutting relationship and superimposition. The first system contains faults oriented on the NS and NNE-SSW, mainly expressed in the north and they seem to be older compared to the faults of the second system of faults oriented on ENE-WSW and EW. The second system presented by a swarm of concentric graben, starting as ENE-WSW and end perfectly oriented in the EW, significantly observed on the south. The third system of faults is mainly oriented in the NNW-SSE, NW-SE and NW-SE, remarkably connected to the pit chains. We identified that some faults from the first two systems are holding a dual-behavior, to be eventually related to reactivation of an inherited faults, subsequently the identification of the tectonic phases was ambiguous. Furthermore, pits and pit chains have been investigated to be post-faulting, since they are always observed to cut and overlap grabens and faults; although, some faults of the third system appear to seldom overlap the pit chains. Additional observations show that pit chains are often expressed along the graben floors, bounded by two parallel faults, frequently in conjunction and spatially closer to faults and grabens, and following the same directions. The polar plots for the pit chains orientation show that these features are oriented on NNE-SSW, ENE-WSW and NE-SW, and this is in agreement with the fault orientations from the three fault systems. Based on their size and shape, the pit chains have been classified in four progressive evolutionary stages, which seems to be controlled mainly by the Pit chains' maturity, and probably also by erosional processes, as already seen in Coprates Catena [5].

Discussions and conclusions: The first system consist of NE and NNE-SSW faults sets, clearly observed on the north where pit chains are absent. The right-lateral transtentional kinematics that have been identified within this system with the stepovers and enechelon faults reflecting an extensional regime. The driving stress tensor responsible for this system is most probably associated with Valles Marineris opening, in the frame of a coeval lateral extension, i.e., two phases of bidirectional deformation (Successive phases of ⊥ uniaxial extension), since this system appears orthogonal and spatially close to the Valles Marineris vertical to sub-vertical extension. The first phase produced the NS faults in Noctis Labyrinthus with the western EW slight bending of Valles Marineris, while the NNE-SSW fault sets are produced with the ESE-WNW bending. The ENE-WSW and EW faults of the second systems, are not coeval with the faults from the NE and NNE-SSW, and they seem to be generated by a diverse stress becausethey appear densely present on the south and they display diverse orientations compared to the previous system. Faults from the second system appear mainly concentric to Syria Planum. The volcano-tectonic background of this district suggests that the prominent arcuate fault swarms in Noctis Labyrinthus are most probably formed by a flexural uplift, accompanied by the formation of Syria Planum small shield volcanoes. The ENE-WSW and EW arcuate faults are interpreted as an inclined sheet for a magma chamber underneath in Syria Planum province, generated in the context of synchronous bidirectional extension: ⊥ uniaxial extensions on the NS and NNW-SSE within one extensional phase. The third fault system appears to be associated with regional driving process, associated mainly with the Tharsis province. The development of the pit chains within some grabens' floors, in alignment with the pre-existing parallel faults, suggest the involvement of a common process for their formation. The evolutionary stages for the pits conducted to identify that these features are passing by diverse maturity levels that cannot be driven only by an extensional tectonic, and this has been supported by their vertical displacement that seems to be controlled by an additional stress, rather than the shear strain. This stress can be explained by the magma-plumbing system underneath the graben floor, which leads to a possible second collapse whenthe graben floor starts to fall once the magma chamber initiates its deflation. The deformed shape and the proportional relationship between the pit's geometrical attributes (i.e., length, width, vertical displacement, and curvature shape), led to classify them as a surface feature related to volcanic channel. These channels form within intensively tectonised areas or shear zones, where faults and graben are intensively present, preparing suitable areas for the pit chains formation.

In this work, we propose a model based on extensional tectonism and magmatic plumbing [4,5] as a reasonable assumption to explain the articulated network of scalloped troughs and pit chains in Noctis Labyrinthus [**Fig.1**]. The magma is transported to the surface through the dikes. Dikes in this model are potentially the feeder system to the magma flow that comes from Syria Planum volcanic province; although, they are not expressed on the surface in our map, but they are fundamental in the scenario that we are proposing. When the magma is extruding from the reservoir, the magma chamber is deflating, after a curst uplift, which will end by a surface collapse and subsequently the formation of the pit chains. Syria Planum shields volcanoes probably extending under the Noctis Labyrinthus bulk, the deflation of the magma chamber and the related stress field, generate the formation of concentric grabens, around the magma source represented by an inclined sheet, which explains the presence of a swarm of ENE-WSW faults that diverge afterwards to be oriented on EW.

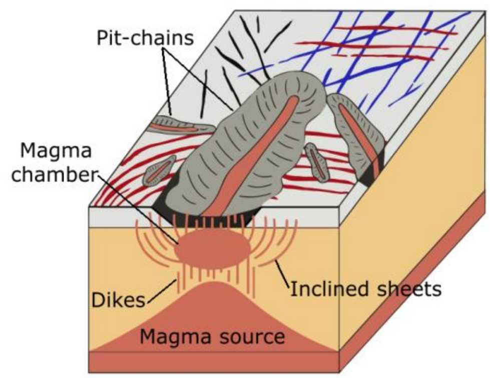

Fig. 1. Sketch of the pit chains and faults formation. The magmatic plumbing generates a flexural uplift, accompanied later by a magma chamber deflating and surface collapse.

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