Interpreting SHARAD radargrams using interaction models and geological constraints to study faults zones in Mars. M. G. Spagnoulo[1], F. Grings[2] P. Perna[2], H. Karszenbaum[2], V. A. Ramos[1], [1]Laboratorio de Tectónica Andina. FyCEN. Pab. 2. (mauro@gl.fcen.uba.ar), [2]IAFE, Ciudad Universitaria (verderis@gmail.com).

Introduction: SHARAD (SHAllow RADar) is a radar sounder capable of discriminating layers of different materials in the martian crust. Both its vertical resolution and discrimination capabilities depends on layer relative permitivitty. Therefore, SHARAD is in principle not only able to detect subsurface layers of liquid water and ice, but also some aspects of vertical structure of the Martian crust. The objective of this work is to present evidence of the SHARAD capabilities to retrieve information about the structure of a fault zone located at North-East of Ismeniae Fossae. To this end, we will use SHARAD data of the area, a Lee based adaptive filter and interaction model to interpret radargram structure.

Geological setting: Interpreted radargram is located at North-East of Ismeniae Fossae. In order to analyze a fault zone, we have specially chosen the studied radargram from several ones, taking in account either its physiographic location and its geological setting. Despite we analysed others radargrams located in undoubtedly faults areas, like Thaumasia region or Tempe Fossae, we discarded them since its topographic complexity add a lot of noise to the radargrams. As can be seen in figure 1, we chose a radargram that pass through a simple linear scarp. The straight morphology of the scarp and its association with nearby polygonal craters, which linear rims are parallel to the studied scarp [1, 2], implies that is structurally controlled. Moreover the radargram is just in the contact between Nn and HNn units from Tanaka et al. [3].

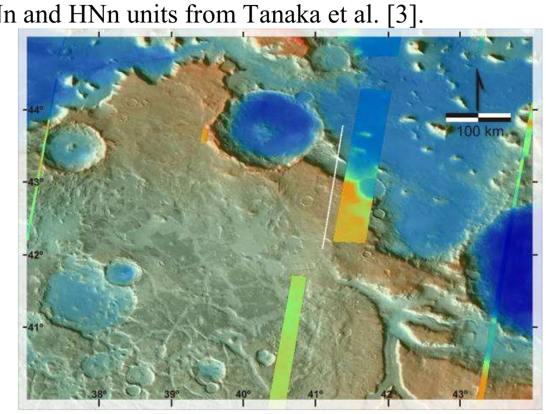

Fig 1. THEMIS IR mosaics and MOLA shaded relief composition. White line shows the footprint of the studied radargram.

Based on the interpretation of the radargram and comparing it with the topography and morphology we decided to do two models: a) for the foot wall (southern block) and b) for the hanging wall (northern block) Fig. 2. Model ‘a’ consist in 350 m of Crater Ejecta material overlying 1200 m of Layered Basalt and a High Pressure basalt basement. For model ‘b’ we chose 800 m of Fluvial Sediments overlying 1200 m of Layered Basalt and a High Pressure dense basalt basement. The dielectric properties of these materials were taken from [4].

Surface scattering simulation formulation: Is generally accepted that Martian crust is stratified medium consistent of several quasi-horizontal layers of diferent materials. The composition and thickness of these layers is still a subject to debate, since different geomorphologic theories about Mars formation and evolution predicts different layered structures.

Until now, only evidence related to Mars crust surface existed, mainly due to optical images. Since 2007 two sounding radars, MARSIS and SHARAD, are obtaining large amounts of radargrams of Martian crust. Although these radargrams carries stratigraphic information about Martian crust, the relation between a radargram and a geological model of Martian crust is not straightforward. Several approaches have been proposed to this end [4, 5], all of them based in developing interaction models between a layered media representing the Martian crust and plane electromagnetic wave.

Considering a stratified medium with boundaries at $z = d_0, d_1, .. ,d_n$, where d_0 corresponds to the martian surface, each medium i should be characterized by its thickness d_i, its complex dielectric permittivity ε_i. A plane wave normally incident on the medium should obey the following wave equations [6]:

$$\left(\nabla_\perp^2 + k_i^2 - k_{iz}^2\right) H_{iz} = 0 \quad (1)$$

$$\mathbf{H}_{i\perp} = \frac{1}{k_i^2 - k_{iz}^2}\nabla_\perp\left[\frac{\partial \mathbf{H}_{iz}}{z}\right] \quad (2)$$

$$\mathbf{E}_{i\perp} = \frac{i\omega}{k_i^2 - k_{iz}^2}\nabla_\perp \times \mathbf{H}_{iz} \quad (3)$$

Where k is the wavenumber and **E** and **H** are the electric and magnetic field respectively. Contour conditions lead to a set of constitutive relations for the incoming/outcoming waves amplitudes, which can be expressed in a recursive form [6],

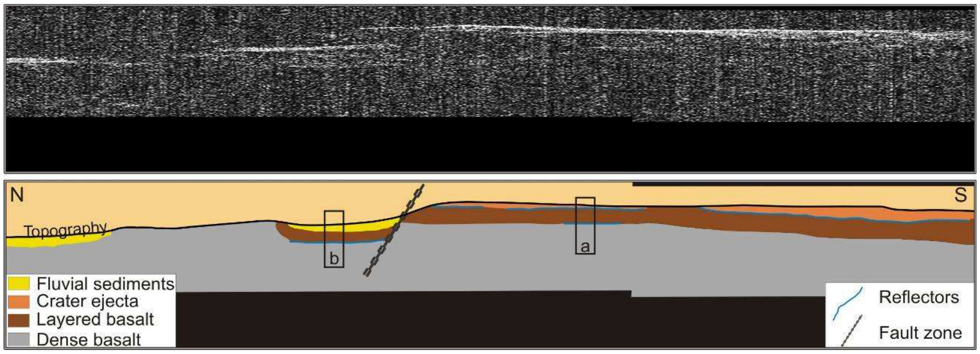

Figure 2.Geological section used to run numerical simulations to study the radargram. Boxes 'a' and 'b' show the location of the stratigrafic columns assumed in the models-

$$\frac{A_i}{B_i}e^{-i2k_{iz}d_i} = \frac{\frac{A_{i+1}}{B_{i+1}}e^{-i2k_{(i+1)z}d_{i+1}}e^{i2k_{(i+1)z}(d_{i+1}-d_i)} + R_{i(i+1)}}{\frac{A_{i+1}}{B_{i+1}}e^{-i2k_{(i+1)z}d_{i+1}}e^{i2k_{(i+1)z}(d_{i+1}-d_i)}R_{i(i+1)}+1} \qquad (4)$$

From (4), the value of the overall medium reflection coefficient $R = A_0/B_0$ can be obtained recursively. Anyway, it is important to note that (4) is a stationary solution, since it considers a continuous incoming wave, and therefore the R estimated is the average ratio of incoming reflected field intensities. For that reason, this solution is not well suited for the simulation of SHARAD signals, since we are interested in the time behavior of the reflected signal. This is so because different time carries information about the dielectric properties of the material at different depths in the Martian crust. Therefore, a numerical simulation was carried out in order to solve the wave equations (1) (2) and (3) for the geological model of figure 2. This simulation consists on the brute force solution of the wave equations given the SHARAD instrument characteristics and medium contour conditions.

Discussion: Although Layered basalt-dense basalt boundary could be identified north and south from the scarp, evidence of a fault plane is missing. The reason of this could be that each radargram compile lateral layers. A clear evidence is seen in fig. 2 where in the scarp zone a net first strong reflection due to martian surface is seen although the topography change. Furthermore, towards north that first surface reflection is missing at all.

Simulation results shows a general agreement between measured and simulated radargrams. Nevertheless, it is important to note that only the comparison in amplitude is relevant, since the agreement in time is forced by the contruction of the geological model. Radargrams can give lot of useful information about subsurface structure of Mars but they have to handle with care, not only because several layer configurations can give the same signal pattern but also for the limitations of SHARAD itself. We consider an holistic approach, using topographic as well as image and spectral information, to interpret radargrams will give better results for understanding martian crust structure.

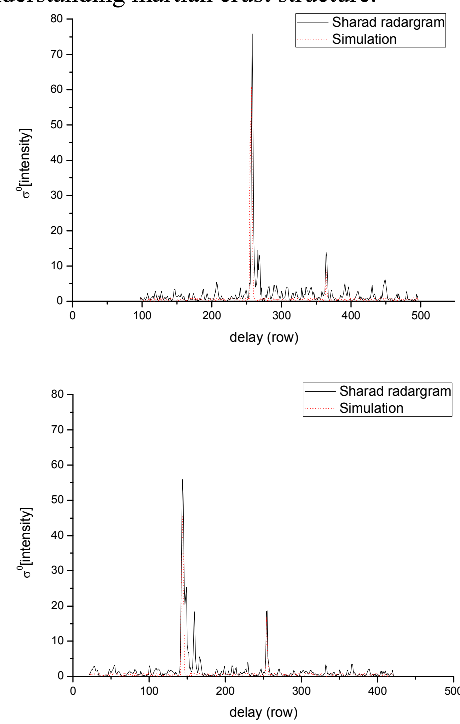

Figure 3. Comparison between SHARAD observed and simulated radargrams for the stratigrafic columns 'a' (top) and 'b' (bottom). Every row corresponds to ~15m in free space.

References: [1] Öhman T. et al. (2006) *Meteoritics & Planet. Sci.* 41, 1163-1173. [2] Aittola M. et al. (2007) EMP 101, 41-53. [3] Tanaka K. L. et. al. (2005) Scientific Investigations Map 2888. [4] Picardi, et al. *Radar Symposium, 2006. IRS* (2006) *International* , vol., no., pp.1-15. [5] Yaroslaw A. Ilyushin, (2004) *P&SS*, 52, 13, 1195-1207. [6] Tsang L. *et al.* (1985) Wiley-Interscience publication.