DUCTILE DEFORMATION IN HELLAS FLOOR: SALT DIAPIRS OR CRUSTAL DOMES? N. Mangold[1], and P. Allemand[2]. [1]Orsay-Terre, FRE2566, CNRS et Université Paris-Sud, Bat. 509, 91405 ORSAY Cedex, France, mangold@geol.u-psud.fr, [2]Lab. Dynamique de la lithosphere, Univ. CB Lyon, France.

Introduction: Periodic concentric features named "honeycomb terrains" are observed in the North-Western part of Hellas (Fig. 1). These terrains cover the lowest part of the Hellas basin at elevations of –7 to –5 km, thus also the lowest points on Mars. Each "honeycomb cell" is about 5 to 10 km large. At MOC scale these features shows lot of deformed materials. Some authors speculate about possible ice blocks and soft muddy deformation to explain the formation of these concentric features [1]. In this study we show that the structural analysis of MOC images favors a ductile formation by doming inside a soft medium. Structural patterns typical of ductile shear zones are also observed. We discuss if this doming better correspond to salt diapirs or lower crustal tectonism. We propose that these features could correspond to ductile deformations similar to those observed on outcrops of the lower crust of the Archean period on Earth.

Fig. 1: Honeycomb terrains in Hellas at Viking resolution. Each circular feature is about 5 to 10 km large.

Observations of structural domes: Figure 2 is located in the middle of the honeycomb terrains. The two concentric patterns correspond to two of the circular cells observed at larger scale. Their geometry can not be explained by the erosion of horizontal layers. Deformation in the zone T is on a flat surface. Patterns must be explained by structural deformation. The concentric feature in the lower part of the image shows foliation typical of flattening in the central part. This especially visible on E that may result from a sub-horizontal cross-section through the vertical axis of a dome. These concentric patterns correspond to a round shaped deformation of layers like those due to the intrusion of plutonic domes on Earth cut by erosion. So, in the following, by referring to "dome" we consider the structural pattern and not the topographic feature. Triangle zones are specific areas at the intersection of three or more circular patterns due to the interference of several domes (Fig. 3). The triangle zone T on figure 3 is composed by strongly deformed layers that could correspond to the material deformed between diapirs. Other MOC images of other triple zones bordering concentric patterns shows that the layers inside these triple zones are strongly folded with an apparent sub-vertical axis. The occurrence of vertical folds and highly deformed materials in triple junctions are typical of deformation involving the sinking of material in response to doming [2,3]. Figure 2 may thus correspond to sub-horizontal cross-sections inside domes and belts similar to the region Y of figure 3 where the triangle zone are submitted to downward deformation in response to strong doming.

Observations of shear zones: Figure 4 shows a kind of soft deformation different from doming. This image is located close to the images of domes at same elevations. The highly folded material is not tighten between two domes like on figure 2 despite that the folds also show sub-vertical axes. The material inside the apparent shear zone is highly and heterogeneously deformed like rocky materials at high temperatures near melting point. Indeed, many layers show disharmonic deformation at various wavelengths with frequent variations of the thickness of layers. Areas with small blocks are located inside channels (C on figure 4) in which the material seems to have partially melted, or, at least, which had a viscosity strongly lower than the blocks during deformation. The sigmoïdal geometry suggested by the MOC image is usually observed in terrestrial shear zones whatever the scale from the size of minerals to mountain ranges [3]. Such interpretation is consistent with the occurrence of vertical folds. Transcurrent shear zones are typical of horizontal deformations like those due to plate tectonics on Earth; such observation is thus very unexpected on Mars. On the other hand, the center axis E of the diapir on figure 3b is shifted from the central position of the dome. This geometry involves non-coaxial doming, i.e. a transcurrent component in the doming. Non-coaxial doming could show the coexistence of sub-vertical transcurrent shear zones with diapirism at same period.

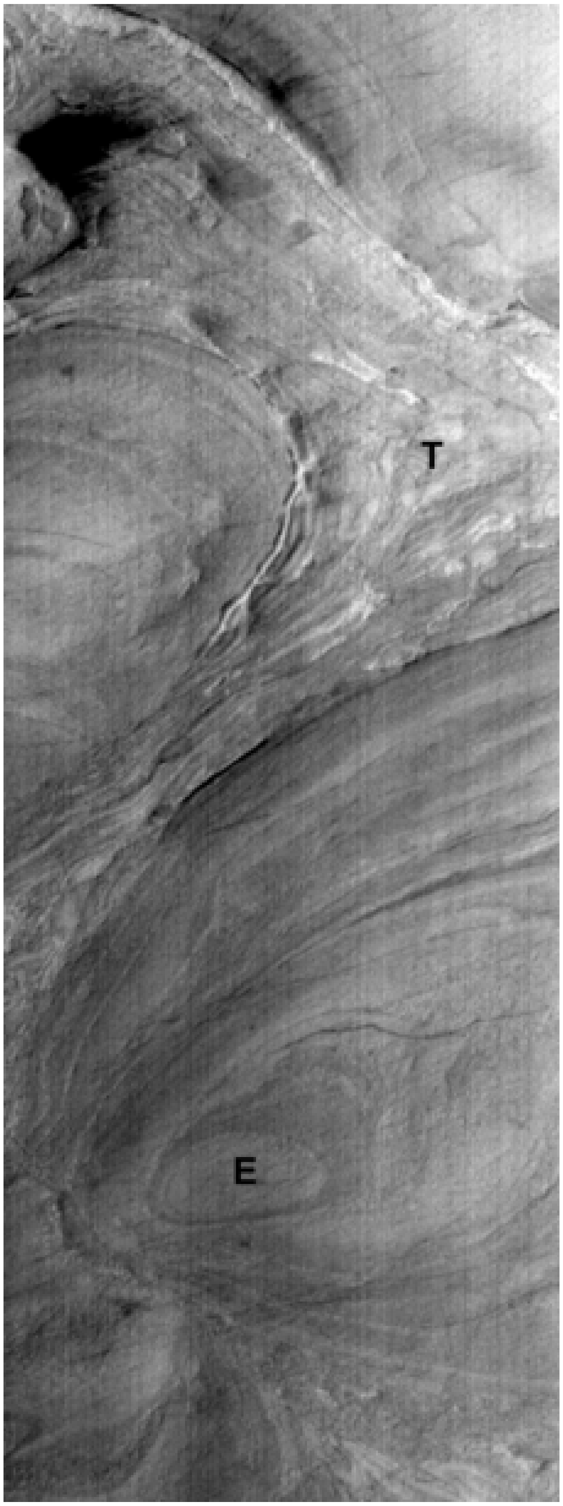

Fig. 2: MOC image in West Hellas (2 km large). T represents zone of strong ductile deformation with vertical folds. E represents the center of a circular pattern interpreted as structural domes cut by erosion.

Fig. 3: Structural patterns of domes intruding soft layers [figure in 3]. Figure 2 is very similar to zone Y of this structural scheme.

Interpretations: Deformation typical of vertical tectonism with diapirs is observed on 8 MOC images separated by several hundreds of kilometers in NE Hellas whereas 4 MOC images show possible shear zones. Several other images shows the occurrence of soft deformation but they are difficult to interpret because the size of the images is not sufficient or because the deformed terrain is only partially visible under blankets of younger material.

Diapirism and related tectonic features are due to reversed density gradient, i.e. dense rocks over a lighter medium, combined with the viscous behavior of the lower layer. The regular spacing produced by diapirs is usually related to the thickness and the viscosity of the material involved. Diapirs of 5-10 km large usually imply thicknesses of 2-3 km of layers involved in the deformation [e.g. 4]. On Earth, diapirism at this scale is usually observed in two contexts: salt layers buried under denser sediments and plutons of the lower crust [e.g. 3]. Such kind of deformation rules out processes of formation by mass wasting or glacier deformation which both produce horizontal displacements at the surface and not structural domes.

Large accumulation of sediments, including salts, were possible during periods of thicker atmosphere in the Noachian epoch [5]. Layers of 2 or 3 km of salt may be possible assuming long period of lacustrine activity in Hellas. However, structural observations are better explained by crustal rocks than salt diapirs. First, the soft deformation of salt deposits occurs at temperatures of only 100°C or less, so the layers of the overburden over diapirs should display brittle deformation as it is the case on Earth [4]. On the contrary, these layers are softly folded without any faults typical of brittle deformation (Fig. 2). The soft deformation of both upwelling and downwelling material is usual in doming inside the lower crust. The presence of possible partial melting in shear zones is also more typical of lower crust rocks near anatexis (Fig. 4). The alternation of bright/dark material (Fig. 2, Fig. 4), looks like migmatite gneiss, i.e. mixing of acid and basic material typically observed in the lower crust at anatexis [6]. The apparent high albedo and smooth texture of most of the surface in all images may not correspond directly to rocks because of an apparent mantling of cemented dust or duricrust like in many places on Mars. Nevertheless, the dark spot at the top of figure 2 may be due to a fresh outcrop of material. It could show that the material under the dust mantling, here inside the belt between domes, could be dark like mafic lava flows.

Discussion and conclusion: Vertical tectonism on the Earth is observed especially on the Archean crust in Dharwar, India and Pilbara, Australia, where it is named dome-and-basin or dome-and-keel. These regions show granite or gneiss domes surrounded by greenstone or greenschist belts corresponding to metamorphic rocks of volcanic origin [7]. Their geometry is very similar to what is observed on the MOC images. Fold axes in triple junctions of the greenstone belts are always sub-vertical like in figure 3.

Archean vertical tectonism is supposed to result from the large accumulation of ultramafic lavas, known as komatiites [e.g. 3]. These lavas are triggered by a mantle plume that produced a strong heating of the lower crust. The piling of lavas induces an increase of the crustal temperature by thermal blanketing. The result of these conjugated heatings is a widespread anatexis of the sialic crustal material which reduces considerably the strength of the substrate [8]. Numerical models show that the piling of 5 to 10 km of dense lavas can produce their sinking, also named sagduction, inside the molten lighter sialic crust where plutons grow [7].

Hellas floor could thus represents the remnant of such early tectonics likely resulting of a kind of tectonism consequent to the impact of Hellas. The exhumation of this material would permit to have this window inside the lower crustal rocks of Mars. On the other hand, we can not exclude that the presence of permanent lake inside Hellas at that time would have lead to unexpected style of layers with a muddy soft rheology of unconsolidated sediments. More data are needed to conclude definitively because the salt hypothesis remains attractive in the understanding of the evolution water on Mars.

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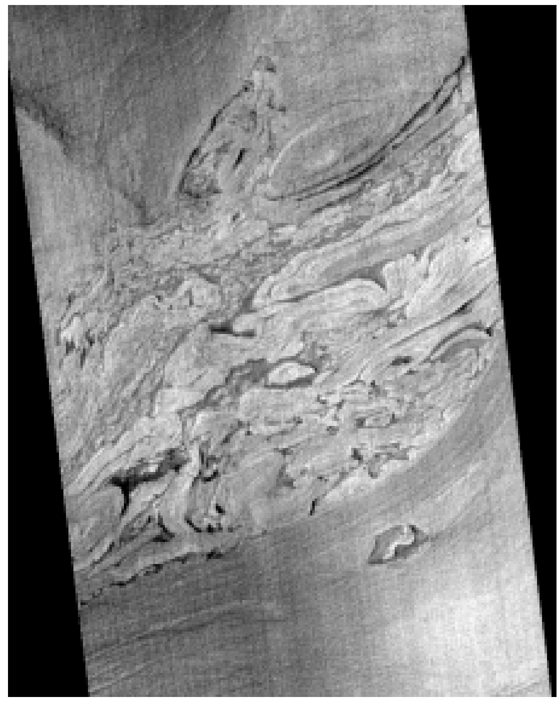

Fig. 4: MOC image of highly deformed zone. The sigmoidal shape and the presence of strongly mixed vertical folding favors hypothesis of shear zones similar to terrestrial shear zones in lower crust outcrops.