BECQUEREL CRATER RADIAL FAULTS: A POSSIBLE TARGET FOR METHANE SEEPAGE INVESTIGATIONS E. Luzzi[1,2], A. P. Rossi[2], R. Pozzobon[3], D.Z. Oehler[4] and G. Etiope[5]. [1]University of Rome La Sapienza (ericaluzzi@virgilio.it), [2]Jacobs University, [3]University of Padova, [4]PSI - Planetary Science Institute, [5]INGV - Istituto Nazionale di Geofisica e Vulcanologia

Introduction: Becquerel crater is located in the broad region of Arabia Terra (Mars), roughly centered 22°N 352°E and has a diameter of ~170 km. This crater hosts a substantial stratigraphic record in its extensive Late Noachian - Early Hesperian ELDs (Equatorial Layered Deposits), sedimentary rocks heavily affected by faults and fractures. The main outcrop is ~800 meters high at a maximum and its bulged morphology culminates with a depression on the top (Fig. 1). It also shows peculiar deformation features, such as radial faults. On Earth these types of structures are often associated with natural gas (methane) seepage. The Becquerel radial faults could then be the object of gas seepage investigations through orbital methane detection (e.g., Mars Express-Planetary Fourier Spectrometer, ExoMars-TGO).

We investigated structural and stratigraphic features of Becquerel, including ELDs, with particular reference to the genesis of the ELDs and the radial faults candidates for methane release.

Data and Methods: The dataset used for this work is mainly provided by the Mars Reconnaissance Orbiter (HiRISE and CTX images and DEMs) and by the Mars Express spacecraft (HRSC images and DEMs). PDS data were processed using USGS *ISIS3*. Stereo-models were obtained either from HiRISE PDS data or via ASP [1]. Observations were made using 2D and 3D ESRI GIS systems.

Results: In the Northern sector (Fig. 1) two structural trends were recognized. One is oriented ~NW-SE producing graben-like scarps 50 meters high and other faults which affect the layered deposits with displacements around 10-20 meters. The kinematic seems extensional, probably with a small strike-slip component based on the observed horizontal displacement. The second structural trend consists of two discontinuities (N-S and NNW-SSE) bounding a triangular block characterized by layers with varying attitudes (Fig. 2A). In the Southern sector a NNE-SSW fault occurs with E-W discontinuities which resemble the facies boundaries occurring in the Eastern sector (Fig. 1). In the Top sector (Fig.1) all these structural trends follow a fan-like geometry, resulting in faults that radiate from the depressed top outwards (Fig. 2B).

At least two facies were recognized within the main outcrop, named as *P facies* and *T facies*. The P facies is characterized by light-toned deposits showing planar bedding; the T facies consists of dark deposits with trough-cross bedding, arranged in lenticular bodies. The alternations of these facies may represent changes in the depositional environment.

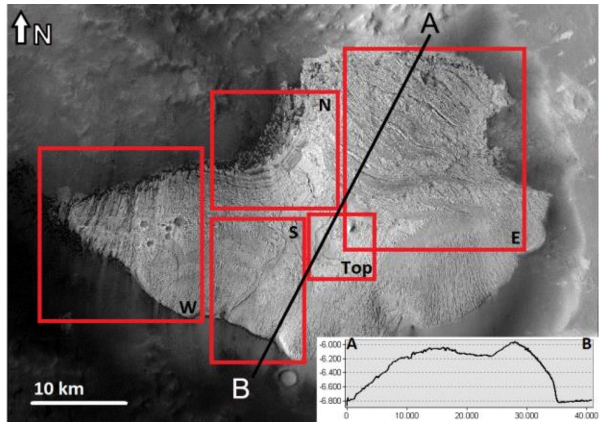

Figure 1: *Overall view of the main outcrop in Becquerel crater. The five sectors are indicated by red squares. On the right bottom a topographic profile shows the bulged shape of the outcrop, with the depressed top. HRSC h3231_0001.nd4.50.*

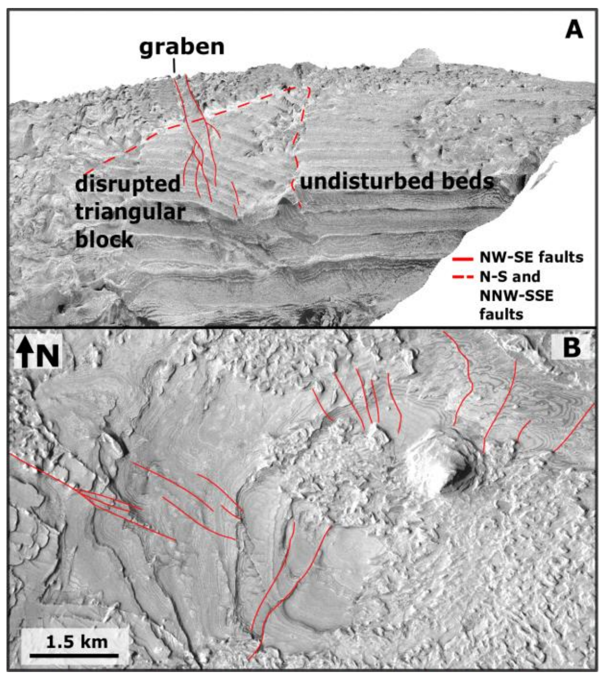

Figure 2: ***A****: Structural trends in the Northern sector (North is towards the reader).*
HiRISE PSP_001955_2015 draped on the corresponding DEM. ***B****: Faults with a radial pattern on the outcrop top. CTX P02_001955_2016_XI_21N008W.*

A possible third facies is characterized by wavy layers and may be interpreted as either a part of P facies or as a totally different facies.

Discussion: Several authors worked on Becquerel crater deposits and proposed different hypotheses for their genesis, spanning evaporitic/aeolian environments processes involving groundwater table oscillations [2], salt diapirism [3], and orbital influences on sedimentary cycles, included repeated evaporitic precipitation and accumulation of dust [4]. The hypothesis supported in the present work involves putative salt diapirism at depth to explain the observed structures. Nevertheless, it is difficult to interpret the *entire* outcrop as a salt dome [3] since in several areas the bedding appears to be undisturbed and perfectly horizontal [4]; this would not be consistent with the strong deformation commonly associated with salt diapirism.

Alternatively, we propose that the normal faults organized in a radial pattern, especially on the depressed top, may represent a surface collapse in correspondence over a buried salt diapir. This brittle deformation would have affected the overburden rock but not a salt body itself.

A schematic reconstruction of the geological evolution consistent with our structural observations is provided in Fig. 3. During the early filling stage within the crater, groundwater table oscillations may have produced environments from playa-like to lacustrine, with deposition of salt and lacustrine/evaporitic deposits corresponding to the P Facies, as also proposed by [3]. Furthermore, the appearance of the P facies and the uncertain "wavy" facies is consistent with terrestrial analogues of lacustrine deposits and evaporites respectively. Later, a groundwater table drop may have produced subaerial exposure and deposition of aeolian deposits corresponding to the T Facies. Before the final drying and the subsequent wind erosion, the estimated overburden of the salt might have been greater than 800 m, which is the current thickness.

Since the density of salt is less than that of other rocks at depth of ~1000 m, we assume that at least 200 m of overburden rocks were removed. The density contrast due to the lithostatic loading would have triggered the salt diapir rising, as already proposed for Arabia Terra [5]. A depressed top with radial normal faults can be indicative of the reactive stage of the diapirism [6]. In fact, not all the diapirs achieve the subsequent stages such as the passive stage where the salt reaches the surface and escapes.

A terrestrial analogue for reactive diapirism is in the Gulf of Mexico, where the salt diapirism causes normal radial faults and the collapse of the overburden rocks, thus developing intense natural gas seepage. Methane seeps can occur also on radial faults not related to diapirism but to basin uplift.

Conclusions: The sedimentological and structural characteristics of the main outcrop in Becquerel crater show evidences of alternation of lacustrine, aeolian and potentially evaporitic environments likely due to the groundwater table oscillations. A putative salt diapir at depth may have produced the radial pattern of normal faults clearly visible on the top. On Earth, radial faults, over collapsed salt diapirs or uplifted fault blocks, are often associated with methane seepage. It will be interesting to search for methane plumes over this crater with orbital data (e.g. ExoMars, Mars Express) and to compare this hypothesis with other processes possibly responsible of such a radial pattern.

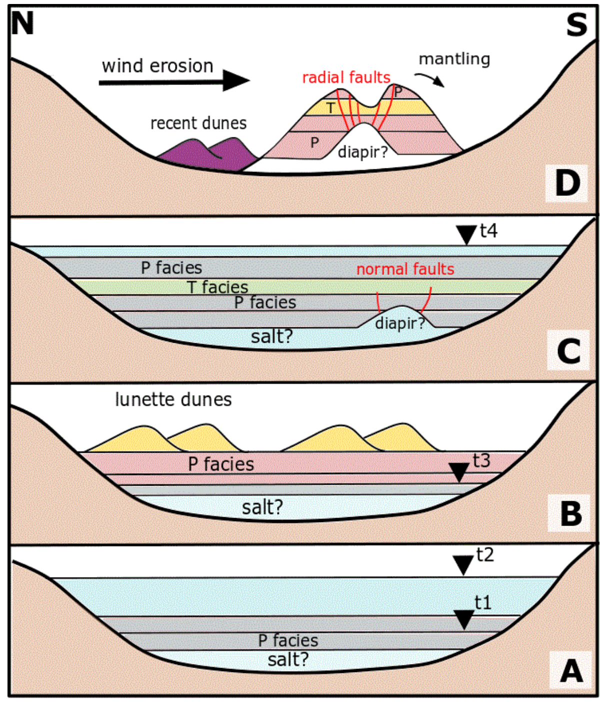

Figure 3: *One scenario for Becquerel crater.* ***A****: Evaporitic environments and salt deposition at time 1. Rise of the groundwater table and lacustrine deposition (P facies) at the time 2.* ***B****: Groundwater table drop, subaerial exposure and deposition of barchan dunes (T facies) at time 3.* ***C****: Alternations of P and T facies producing significant overburden for the salt. Salt diapirism producing normal faults at time 4.* ***D****: Final drying and wind erosion and deposition.*

References: [1] Moratto, Z. M., et al. (2010), *LPSC XVI*, #2364. [2] Andrews-Hanna, J.C. et al. (2010) *JGR-Planets*, 115:1212–1216. [3] Popa, C. et al. (2008) *LPSC XXXIX*, #1623. [4] Lewis, K.W., Aharonson, O. (2014) *JGR-Planets*, 119(6), 2014. [5] Pozzobon, R. et al. (2014) *Geophys. Res. Abstr*., 16, #12268. [6] Hudec, M. R., Jackson, M.P.A. (2007) *Earth-Science Reviews*, 82(1):1– 28.