THE "JUBOT" DEPRESSIONS AS TERRESTRIAL ANALOGS FOR PLANETARY PITS. R. Naor[1,2], A. Mushkin[2], I. Halevy[1], [1]The Department of Earth and Planetary Sciences, Weizmann Institute of Science, Israel (roy.naor@weizmann.ac.il); [2]The Geological Survey of Israel.

Introduction: The nature of many geological depressions on the surface of Mars and other planetary bodies remains poorly constrained partially due to the paucity of terrestrial analogs. A better understanding of possible formation mechanisms for martian depressions may provide valuable information about subsurface stratigraphy and Mars' climatic and hydrological history. Here, we explored the formation mechanisms for terrestrial geologic depressions that occur within a stratigraphy analogous to martian terrains and the possibility that some of the martian depressions may have been formed by collapse into subsurface voids.

We focus on a series of terrestrial depressions in the northwest margins of the Levantine volcanic field of Harrat Ash-Shaam. These depressions are locally named "jubot" (singular "juba") and morphologically resemble martian bowl-shaped pit craters [1]. The jubot occur on a moderately sloping Pleistocene basaltic plateau, which is underlain by Mesozoic to Cenozoic sedimentary rocks. The underlying sedimentary units record past tectonic stress fields, and are comprised mostly of carbonates, which are regionally known to be susceptible to karst. Several depressions, morphologically similar to the jubot, occur on carbonate rocks that outcrop near the jubot [2]. This stratigraphy bears similarities to many locations on the surface of Mars, where volume changing geochemical processes could induce surface collapse.

We tested two previously suggested formation mechanisms for the terrestrial jubot:

i) explosion by volcanic gas eruption.
ii) collapse into subsurface karstic or volcanic voids.

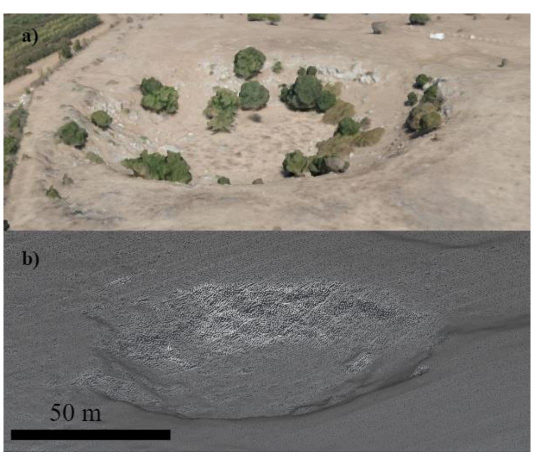

Figure 1: A typical bowl-shaped juba. a) DSM from drone photogrammetry. b) DEM from airborne LiDAR.

Methods: We mapped stratigraphy and measured fracture orientation at the jubot sites. Surface morphology was characterized with a 0.25 m/pixel digital elevation model (DEM) (from 8 pts/m^2 airborne LiDAR) covering 35 km^2 (Fig. 1b) and a cm-scale ground-based LiDAR scan of a bell-shaped pit (Bell Juba) with an interior hidden from aerial view (Fig. 2). Orthophotos and digital surface models (DSM) from drone imagery were acquired for selected sites (Fig. 1a and 2).

Morphometric Analysis: Most basaltic jubot are of similar scale except one juba, known as the Big Juba, with a volume that is at least an order of magnitude larger than all others. The limestone depressions are within the scale of the majority of the jubot by every measured geometric aspect (Fig. 3).

The depth to diameter ratio (d/D) of martian pit craters ranges between 0.08 and 1.99 [1]. Existing analogs for martian pits, pit craters in Hawaii's east and southwest rift zones, cover only a part of this d/D range (between 0.17 and 1.7) [3], whereas the d/D range of morphologically mature jubot is 0.06 to 0.31 (neglecting a bell-shaped cave, which has an anomalous geometry). Thus, in certain aspects, the jubot are an analog for martian pits with d/D in the lower part of the range (Fig. 3). The bell-shaped cave, known as the Bell Juba, has d/D within the range of martian type 1 (bell - shaped caverns) atypical pit craters [4].

Jubot with wider sediment-filled bottoms tend to display greater asymmetry between their north and south wall slopes. Each of these two independent measures implies that the jubot vary in geomorphological maturity, suggesting different timing of collapse, or even different timing of subsurface void formation that triggered the collapse (Fig. 4).

Figure 2: DSM of the Bell Juba and its surface (credit: Iyad Swaed).

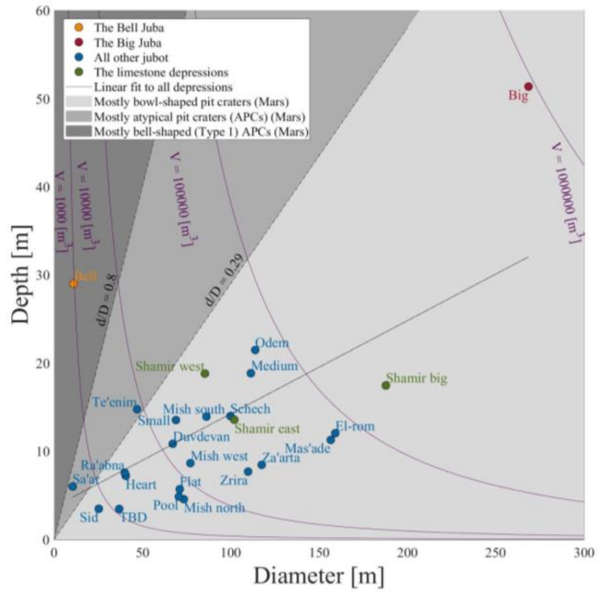

Figure 3. Jubot depth vs. diameter. d/D ranges of martian pit craters are colored in gray. The purple lines are contours of equal volume of a cone with a given depth and diameter.

The jubot form linear clusters and have weakly elongated shapes in plan view. Individual jubot elongation trends peak in the directions north and east-northeast, and are either quasi-parallel or perpendicular to the azimuthal trend of the cluster to which the individual jubot belong. Similar trends can be seen in the surrounding geologic structures, like cinder cone lines and Dead Sea Transform-associated faults. To test the hypothesis of jubot formation by collapse into subsurface voids we looked for morphologies consistent with a collapse origin. We detected:

i) Outer quasi-concentric stairs (slump scars?).
ii) Subsided surroundings that may predate or postdate the main collapse.
iii) Wall and floor stairs and inner depressions of secondary/gradual collapse.

To test formation by explosion, we looked for the remnants of elevated topography around the rims of the depressions. No elevated rim morphology was found for any depression, at all scales resolvable in the DEM.

Conclusions: The basaltic, limestone and bell-shaped depressions are all surface expressions of the same formation mechanism. The varied morphological maturity of the jubot implies different formation times. Their spatial distribution, elongation axis and cluster azimuthal trends suggest a response to past and present stress fields.

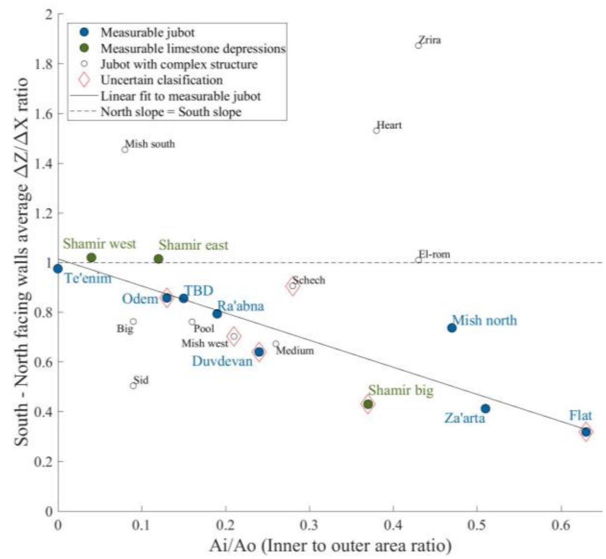

Figure 4. Ratio between average slopes of south- and north-facing jubot walls, vs. the ratio between jubot floor and rim surface area (Ai/Ao). Empty circles are disturbed jubot.

We reject the explosion hypothesis due to the lack of elevated rims, and conclude that the jubot formed by surface collapse into subsurface voids. The origin of the voids, karstic or volcano-tectonic, cannot be discerned with the existing data, and we are currently investigating these two possibilities with a combination of detailed field mapping and tomographic methods.

The jubot provide a special opportunity to develop the linkage between subsurface processes and their surface morphological expression. Application of the insights gained in this study to martian depressions may yield valuable information on the subsurface and history of Mars.

References: [1] Wyrick D. et al. (2004) *JGR, 109,* E06005. [2] Mor, D. (1973) Hebrew University, Jerusalem TAHAL Rep. 01/73/27 p. 179. [3] Okubo, C. H. and Martel, S. J. (1998) *Vol. Geotherm. R., 86,* 1-18 [4] Cushing, G. E. et al. (2015) *N. J. Geophys. Res. Planets. 120,* 1023–1043.