The enigmatic shatter cones of Agoudal (Imilchil, Morocco) Abderrahmane Ibhi[1] and Hassane Nachit[1]. [1]Geoheritage and Geomaterials Laboratory, Faculty of Sciences, B.P. 8106, Ibn Zohr University, Agadir, Morocco. (a.ibhi@uiz.ac.ma/Fax: +212528220100).

Abstract: The shatter cones are observed ~22 km in the south of Imilchil (Agoudal region, Morocco), the mapping of 40 individual shatter cones revealed an area of at least 1 km^2 covered by these features. The discovery indicates the presence of unknown, deeply eroded impact structure or only they are ejected of nearby impact crater.

Introduction: The work of Ibhi et al. [1] showed, that the Isli lake (32°13'N, 05°38'W) is the result of a meteorite fall 40.000 years ago. In the location of Agoudal at 22 km to the south of Isli lake Sadilenko et al. [2] mentioned the presence of a small impact crater located at the coordinates (31°59'12.7" N, 5°30'57,3"W). These two structures are situated on a north-south axis. During the June 2013 we carried out again a field survey in the area of Imilchil, which led to new discoveries of shatter cones about 20 km in the south of the Isli structure (figure 1). They are abundant and well developed in Agoudal, due in to the abundance of fine-grained carbonates in the target sequence. In this preliminary study, we will discuss the different types of chatter cones found in the Agoudal locality and their allochthonous or autochthonous origins.

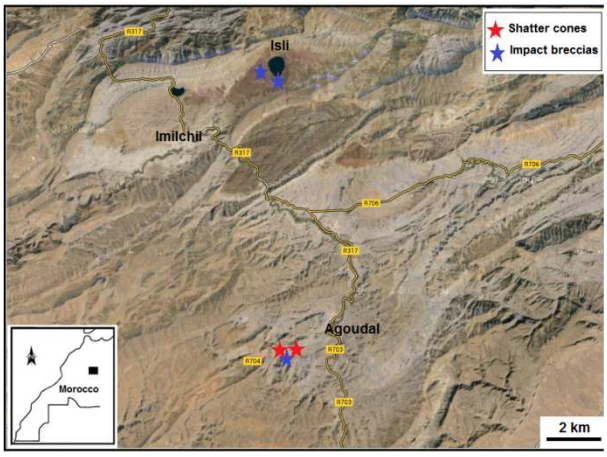

Figure 1. Topographic map showing the location of shatter cones of the Imilchil area.

Shatter cones: Shatter cones are common and extremely well developed in Agoudal area. They were first recognized by Sadilenko et al. (2013) and are bets developed in fine-grained carbonate lithologies. The excellent preservation state and exposure at Agoudal allow a detailed study of the shatter cone distribution and morphology to be conducted.

The figure 2a shows characteristic structures in «Horsetail» produced by the shock wave of the impact [3]. Indeed, the Agoudal limestone presents different series of cones in a row with angles of 60° for each series. They Agoudal shatter cones display many of the characteristics typical of shatter cones from other impact sites (striated surfaces, horsetail structures). The formation of such features can be explained by models of Baratoux and Melosh [4] and Sagy et al. [5, 6].

The important results of our shatter cones observations from Agoudal are (i) apical angles range up to 60°, (ii) While many shatter cones displayed curved (figure 2b), oblate, spoon-like surfaces [5], many are also conical, (iii) Apex often in opposite directions (figure 2c), (vi) Complete Cones are present in 10-15% of the samples studied.

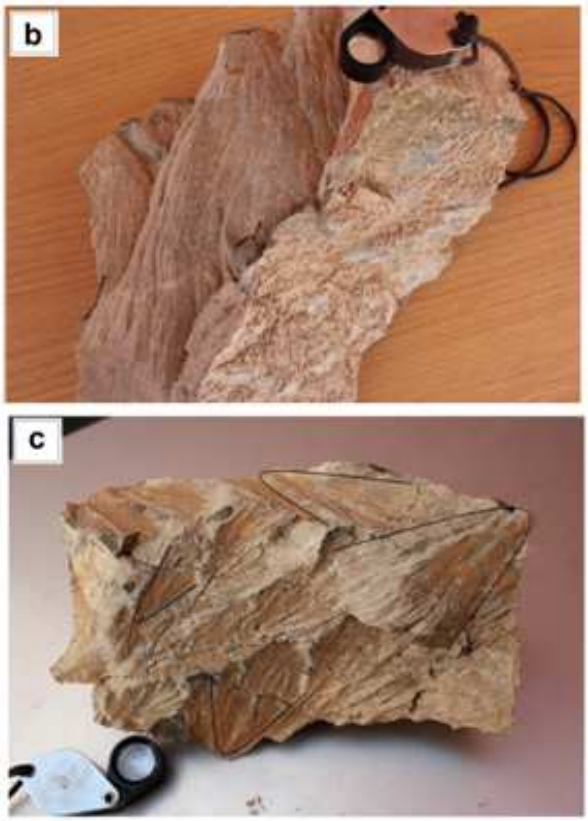

Figure 2. Hand specimen photographs of carbonate clasts with well developed shatter cones from Agoudal (Imilchil impact structure). (a) A well developed shatter cone ~15 cm in diameter. (b) Two complete curving cones. (c) Shatter cones with apices pointing in opposite directions.

Discussion and conclusion: Several models have been proposed for the formation of shatter cones. Johnson and Talbot [7] suggested that shatter cones form due to the interaction between a propagating shock wave and heterogeneities within the target rocks. However, Sagy et al. [5, 6], prefer a model in which shatter cones are fractures produced by nonlinear waves that propagate along a fracture front. In the outcrop studied possessed shatter cones with apices pointing in multiple directions, sometimes in completely opposite directions.

The beautiful shatter cones have been found in samples of Jurassic limestone wrapped in quaternary deposits, predominantly at the flanks of the dry rivers; they are not observed in the bedrock [2]. These observations can be explained by two phenomena:

- There really is a small impact crater in this region and that it has been laterally eroded.
- Shatter cones are not in place; they are ejected from another impact crater, and transported, like the Isli crater that lies to the north. Moreover, Shatter cones occur widely within marl fragments of the breccia from the main outcrop [2], and the region where the chatter cones correspond to a large delta river of a north-south direction. This phenomenon has been observed in three craters identified in the world, the shatter cones at Vrederfort are found at distances ranging from 10-60 km from the center of the crater [8]; the distribution of shatter cones in the Haughton impact structure, Canada shows that the shatter cones are found within ejecta blocks. As for the Ries crater shatter cones we note that they are not only found in crystalline rocks exposed within the crater but can be sampled also as nice specimens from the Bunte breccia ejecta. These are, probably, the same conditions as obviously fulfilled at Isli Lake: The shatter cones develop in the very beginning of the cratering process on passage of the shock wave and are then ejected with the shocked rock. This hypothesis deserves to be supported by further study.

References: [1] Ibhi A., Nachit H., Abia E., Ait Touchnt A. and Vaccaro C. (2013). International Journal of Astronomy and Astrophysics, Vol. 3 No. 2A, pp. 1-4. [2] Sadilenko D.A., Lorenz C.A., Ivanova M.A., Roshina I.A. & Korochantsev A.V.(2013). 76th Annual Meteoritical Society Meeting #5215. [3] Roach D.E., Fowler A.D., Fyson W.K., Geology 21 (1993) 759.310. [4] Baratoux, D., Melosh, HJ. (2003). Earth and Planetary Science Letters, Vol. 216 pp. 43-54. [5] Sagy A., Reches Z. and Fineberg J. (2002). Nature, Vol. 418, pp. 310-313. [6] Sagy, A., Fineberg, J., Reches, Z., (2004). Journal of Geophysical Research Vol. 109. [7] Johnson, G.P. and Talbot, R. J. (1964). Thesis, Wright- Patterson AFB, Ohio, GSF/Mech 64-35, 92 p. [8] Baratoux D., Melosh J. and Reimold U. (2009):https://www.cps-jp.org/seminar/fy2009/2009-12-8/baratoux/pub/Shattercones_Kobe.pdf