Morphometrics evidence of glacial features in martian highlands: Dawes crater. A.Bouquety[1], A.Séjourné[1], F.Costard[1] and Sylvain Bouley[1], [1] GEOPS-Géosciences Paris Sud, Université Paris-Sud, CNRS, Université Paris-Saclay, 91405 Orsay, France.

Introduction: The presence of branched valleys similar to Earth [1] and phases of clay alterations [2] show that during the Noachian (4.5-3.7 Ga) a hydrosphere was active on the surface of Mars with relatively warm condition. Nevertheless, recently, several studies seem to tend towards a new cold model. First, a planetary geodynamic model showed that the formation of the Tharsis dome caused the tilting of the planet without changing its axis of rotation [3]. Thus, the valley networks that were parallel to the equator are now in a southern tropical strip between 0° and 45°S [3]. Secondly, climate modeling with the pre-Tharsis Martian conditions showed that, by fixing a Martian atmospheric pressure <1 bar for a 45° obliquity it was possible to reconstruct the martian climate during Noachian [4]. When pre-Tharsis parameters are applied for the current topography, ice is not deposited at latitudes below 60°S while it is possible to find traces of glacial activities at its latitudes, notably in Dorsa Argentea Formation [5]. When pre-Tharsis parameters are applied but without taking into account the topography induced by Tharsis it can be seen that ice is deposited and stable at latitudes below 60°S and in the same strip where are the valleys for an altitude >1000m. Thus, the late Noachian climate is described by these models as "icy highlands" during which branched valley would have formed in a cold climate [4].
The purpose of this study is to find geomorphologic evidence of this early cold climate to better constrain the climatic conditions. To achieve this, we will study geometry and the morphology of martian valleys and compare them with recent martian glacial and earthly morphologies.

Data and Methods: To identify features, we used data from the Context Camera (CTX; 6 m/pixel) and to measure their geometry, we used data from High-Resolution Stereo Camera (HRSC; 10 m/pixel) with ArcGIS. The study area is located between 0° and 45°S where we tried to identify patterns of the glacial procession, especially glacial valleys and cirques. To characterize the valley, we used terrestrial valleys parameters like the « cross-section Law », glacial U-shapes VS V-shapes [6]; power laws [7,8]; width, length, depth, cumulative volume, elevation and the drainage area [9,10]. To characterize cirques, we use terrestrial cirques patterns like width, length, altitudinal range and the cirque size ($\sqrt[3]{LWH}$) [12]. Then, we studied the statistics by relating the parameters to each other and compared them with terrestrial and martian morphometric valley studies to deduce the erosive agent, namely water or ice. This new method allows us to compare all terrestrial and martian morphometric characteristics in the same way. 42 valleys and 70 cirques were identified in Dawes crater (37°7'5.387''E; 8°59'29.441''). Following [11] that studied of 71 valleys, we have increased the number of parameters studied.

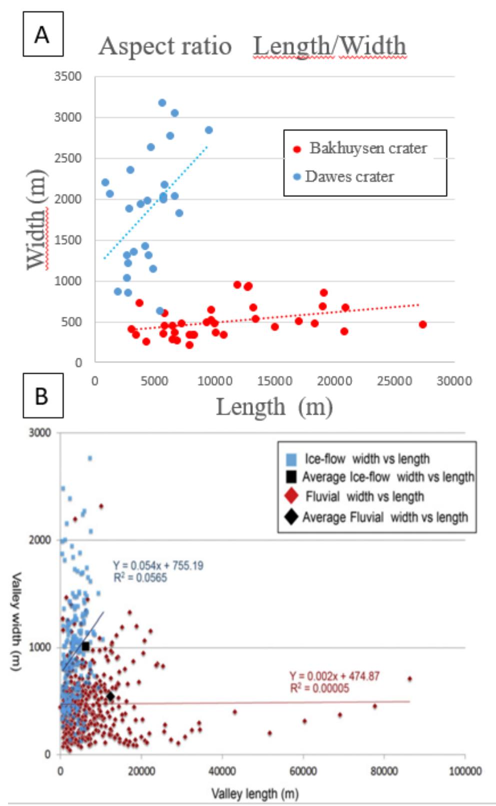

Fig 1: Aspect ratio length/ width for 2 cases. A: data from this study; B: Data from Crater valley [11]

Morphometrics comparison: First we made a Mars/Mars comparison between [11]'s results, Bakhuysen's fluvial morphology [13] and ours, then a Earth/Mars comparison between [6,7,8,9,10,12]'s results and ours. We compared measurements between our study and Hobbs study (Mars/Mars comparison) (Fig. 1). Graphic (A) shows two trends. The first one is that crater Bakhuysen morphologies are much longer and wider than crater Dawes morphologies. Those ones are clearly wider than longer and are generally shorter than crater Bakhuysen valleys. When we compare trends in graphic (A) with graphic (B), we can see that crater Bakhuysen morphologies are similar to fluvial crater valley describe by [11]. Then the most interesting is that crater Dawes morphologies are following the trend of the martian glacial valley describe by Hobbs [11] which are relatively short and wide valleys. Then, we compared morphologies from Earth [10] to our measurements (Fig.2).We can see that crater Bakhuysen morphology's whisker box are similar with fluvial Earth valley. Indeed, the ratio between the cross section area and the drainage area is low which indicates that Bakhuysen valleys are elongated and have a small cross

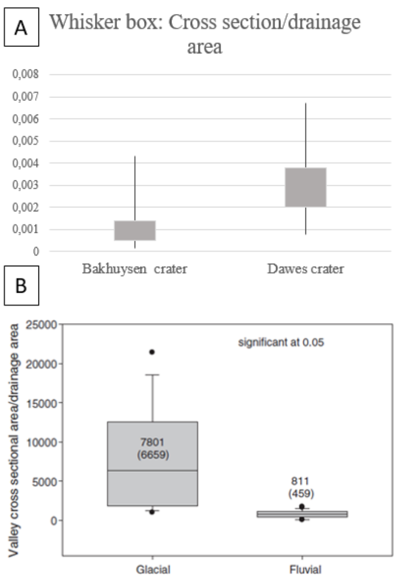

Fig. 2: Whisker box for 2 cases. A: data from this study; B: data from [10]

section area.Dawes morphologies are identical to the glacial valleys on Earth. Indeed, the ration is two times higher than Bakhuysen morphologies which means two things. First, these valleys have a short drainage area and/or are wide. Secondly, we can deduce that the erosive agent at the origin of Dawes and Earth's glacial morphology is identical but different from Bakhuysen. Finally we compare our cirque data with terrestrial cirque data from [12] (Fig.3). We can see that profil A presents a strong slope that decreases with distance and a threshold which marks the end of the cirque, exactly as the « school case » described by [12]. When we compare B and C, we can see that trends of this two cases namely Mars and Earth cirque are the same. Indeed all parameters increase when the cirque size increases. Martian cirques become wider than longer for a cirque size > 1000m.

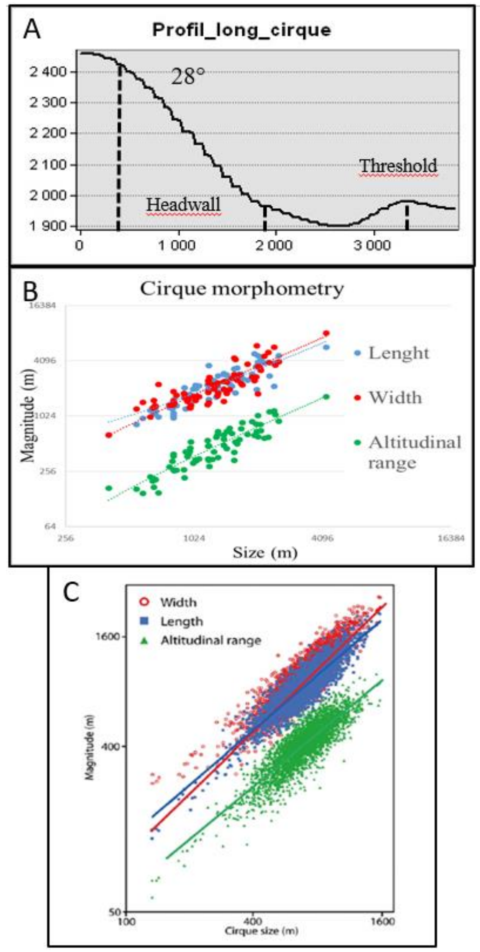

Fig 3 : A: Longitudinal profile; B: Cirque morphometry; C: Data from [12]

Conclusion: This study allows us to create a new way to characterize Martian glacial valleys by a morphometrics analysis.In this study, we identify 77 cirques and 42 glacial valleys in Dawes crater. Morphologies studied have same morphometric characteristics and trends than terrestrial cirques, glacial valley and Mars glacial valleys. To conclude, this study strongly support glacial erosive agent at the origin of crater Dawes morphologies.

References: [1] Baker, V. R., 1982. University of Texas Press, Austin [2] Bibring, JP et al. Science, Volume 312, Issue 5772, pp. 400-404. [3] Bouley, S. et al, Nature. [4] Wordsworth, R. et al. Icarus 222, 1–19 (2013). [5] Kress, A. M. & Head, J.W Planet. Space Sci. 109–110, 1–20 (2015). [6] W Planet. Space Sci. 109–110, 1–20 (2015). [6] Penck, A. 1905. [7] Paul C. A Geomorphology, 4 (1992) 347-361[8] Roberts, M.C. and Rood, K.M., 1984 Geogr. Ann. 66A. [9] Montgomery, D.R., 2002b 30 (11), 1047–1050. [10] Bridget Livers, Geomorphology 231 (2015) 72–82[11]: S.W. Hobbs et al 261 (2016) 244–272. [12] Iestyn D. Barr a,⁎, Matteo Spagnolo b Earth-Science Reviews 151 (2015) 48–78. [13] Moore, J. M., and A. D. Howard (2005) 110, E04005.