LAKE GENERAL CARRERA/BUENOS AIRES (CHILE/ARGENTINA) AS NATURAL LABORATORY FOR THE QUANTITATIVE UNDERSTANDING OF FAN-DELTAS: APPLICATIONS TO MARS.

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Background and scientific rationale: More than 50 possible ancient deltaic deposits have been reported on Mars [e.g. 1-6]. Among the latter deltas only a few (Jezero [1], Eberswalde [2], Sabrina and Hypanis [3], Idaeus Fossae [4]) show well-developed stratigraphy with evidence of avulsing channels and multilobate depositional patterns; they are the largest deposits (in terms of surface area and volume) and are found exclusively at the mouth of relatively large valleys with tributaries and alluvial plains that were presumably formed by sustained and persistent surface runoff discharges. The latter deposits might be strictly interpreted as *river-deltas*. Whereas, the majority of Martian deltaic deposits are small (a few km wide and long) single-lobe with deep (and often steep) delta front resembling terrestrial Gilbert-type *fan-deltas*. These deposits are tipically found at the mouth of short (often theather-headed) valleys lacking tributaries and alluvial plains.

Several questions about the formation and evolution of martian deltas remain to be answered. First of all, while there is a general consensus on assuming that the few martian *river-deltas* formed in > 10^2 yrs time-scales, the time required to form *fan-deltas*, and thus their paleoclimatic and paleoenvironmental interpretations, are controversial. Particularly, [7] suggested that fan-deltas could have also been formed in relatively short (< 10^2 yrs) and single depositional events. If this would be the case martian fan-deltas could not be uniquely used to assess whether they formed during extended epochs of clement climatic conditions (and thus if they are unequivocal indicators of favorable and durable conditions for life) or during limited (in space and time) events produced by regional factors, like for example impact craters [8], volcanism [9], or tectonics and resultant hydrothermal activities (and thus if they could have been formed also under climatic conditions not necessarily different from those of present Mars).

LGC/BA as terrestrial analog: For the abovementioned reasons and since *fan-deltas* are the majority of Martian fluvio-lacustrine deposits and often also proposed as landing sites for future missions, we are studying the fan-deltas at Lake General Carrera/Buenos Aires (LGC/BA, Chile/Argentina, Fig. 1) to gain a better quantitative understanding about the formation and evolution of ancient martian fan-deltas.

Due to climate change and the last major deglaciation of the northern Patagonian ice sheet, LGC/BA experienced significant hydrological modifications which resulted in a more than 400 m vertical retreat of the lake during the last 20-15k years. The latter overall retreat was punctuated by at least 6 highstand periods which are all testified by a series of six stacked fan-deltas in the southwestern part of the lake (Fig. 1-2). We are studying the latter region in detail through modeling, fieldwork campaigns and remote sensing using ASTRIUM Pleiades satellite stereoimages from which we derived a high-resolution (1 m/pixel) digital elevation model (DEM, see Fig. 2a) comparable to HiRISE DEM for Martian deposits.

The site provides access to a concentrate of present and past coastal lacustrine morphology, erosional and depositional features such as beach ridges, shorelines, and terraces which can be directly compared with Martian putative deposits and associated features. Particularly, the deposits from level 2 and 3 (dated approximately to 13k and 8-6k yrs ago, respectively, Fig. 3) show well-preserved beach ridges and embayments (Fig. 4a), shorelines, and terraces on the delta fronts (Fig. 4b). Therefore, the site offers the opportunity to investigate the morphometry of coastal/deltaic features to be compared to martian putative analogs and to test the scenarios put forth for explaining their formation. Moreover, the six raised deltas are entirely entrenched thus enabling potential sampling over the entire thickness of the sedimentary sequences to reconstruct paleodischarges, based on grain sizes analysis. In summary, the quali-quantative study of fan-deltas at LGC/BA has strong implications for several open issues related to martian fan-deltas and their paleoclimatic and paleohydrologic significance. Particularly, the study of the deposits at LGC/BA is important for the following puroposes: i) to understand *formation timescales* of fan-deltas from the context geology/sedimentology of the lacustrine deposits thus placing constraints for the martian analogs; ii) to assess the *observability* of martian putative features in remote sensing datasets comparing the evidence of LGC/BA in similar terrestrial satellite datasets; iii) to investigate the boundary conditions for fan-delta *entrenchment* from a quantitative point of view thus for the understanding of the erosion of the martian deposits and to infer paleoclimatic and paleohydrologic conditions during their terminal activity; finally, all the above aspects are fundamental for a iv) better implementation of martian fan-deltas *modeling* by providing Earth-validated observational and numerical constraints for the modeled processes.

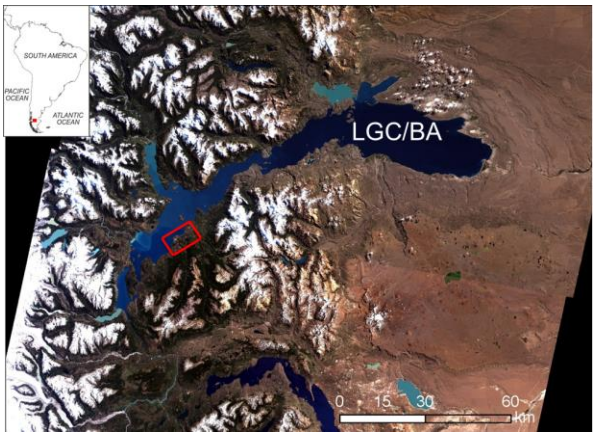

Figure 1 - Overview of the Lake General Carrera/Buenos Aires (Chile/Argentina) from LANDSAT satellite images; the red box indicates the area that we are studying in detail through field work campaigns and where we targeted and acquired new ASTRIUM Pleiades satellite images (see Fig. 2)

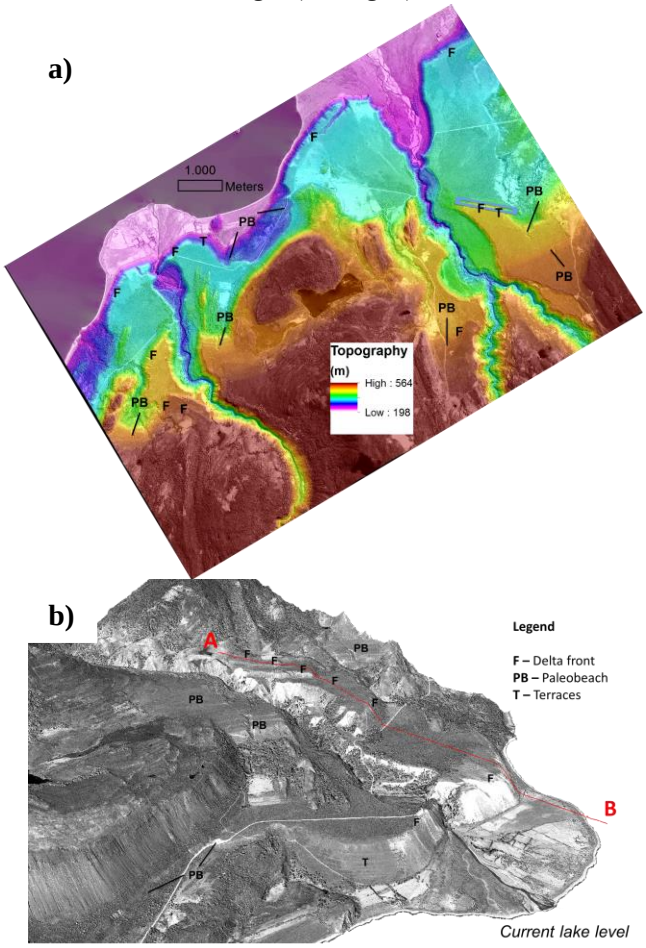

Figure 2 – a) 1 m/pixel DEM derived from ASTRIUM Pleiades satellite images; b) ortorectified stereoimage draped on derived DEM of the southwestern fan-deltas assemblage (red line - AB topographic profile of the sequence, see Fig. 3)

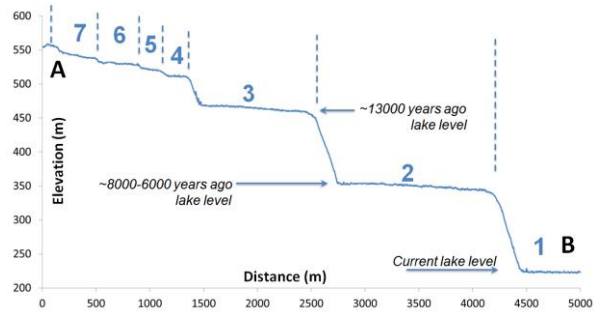

Figure 3 – Topographic profile (from the 1 m/pixel stereo derived DEM) across the series of stacked fan-deltas; see Fig. 2 for location

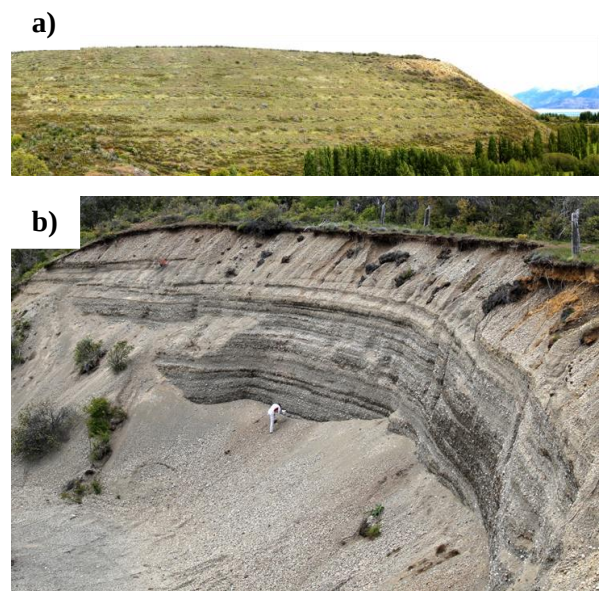

Figure 4 – (a) Terraces on the delta front #2 marking the lake retreat from about 8000-6000 yrs ago to the present time; total delta front thickness is about 120 m and terraces are a few meters high; (b) Exposed gravel beach beds along road cut

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