EQUATORIAL GROUND ICE AND MEANDERING RIVERS ON MARS

A. G. Fairén[1], N. S. Davies[2] and S. W. Squyres[1].
[1]Department of Astronomy, Cornell University, USA (agfairen@cornell.edu), [2]Department of Geology and Soil Science, Ghent University, Belgium.

Introduction

On Earth, vegetation is the most common provider of the fundamental control element determining scroll-bar and meander formation in fluvial channels [1]. Studies of ancient terrestrial alluvium have demonstrated that there is little evidence for heterolithic meandering fluvial systems in strata deposited prior to the evolution of land plants [2], indirectly demonstrating that the bank stability, bed roughness, and channel-corralling necessary to promote meandering are, on Earth, most often provided by vegetation [1,3]. However, lateral accretion and meander belts on Mars (Figs. 1 and 2), and occasionally within Precambrian alluvium [4], attest to the existence of alternative mediators for the prevention of continuous reworking of meanders.

Possible sources for bank stability on Martian meandering channels preserved in inverted relief

Ruling out vegetation, a different source for bank stability in the Mars channels should be invoked, because some Martian meanders do not display evidence for incipient chute cut-off, which might otherwise be expected in the absence of bank stability [5]. This stability could be conceivably provided by hardpan chemical precipitates, an extremely high content of fine-grained sediments, or ground ice [6]. Chemical cementation of the floodplain into hardpan sediments is a feasible medium for binding surrounding sediment, but not for the Martian channels preserved in inverted relief: it is clear that, subsequent to their formation, the channel fills were more resistant than the surrounding floodplains. Chemical cementation may be expected to have provided strong permanent protection to the surrounding floodplain sediments, including protection against later winnowing. Therefore, it is highly questionable that hardpan chemical precipitates could be the source for bank stability in the Martian meandering channels preserved in inverted relief. We present hereafter arguments to consider ground ice as the main source of bank stability on the Martian positive-relief channels, and also outline our current line of investigation aimed at determining the actual contribution of fine-grained sediments.

Ground ice

We suggest that ground ice significantly contributed to the cohesive bank sediments on early Mars. Although it is unlikely to provide much surface roughness, ice or ground ice could be a prime candidate for increasing bank stability in Martian rivers: initially, preventing river channels from widening and taking on a braided form, but also, if temporally persistent, retarding channel migration long enough for a supply of fine-grained sediment sufficient to prevent reworking by chute channels. In instances where meander development was sustained enough to repeatedly proceed to a state of neck cutoff, bank stability would have had to be particularly high. Ground ice could feasibly have provided the means necessary to bind unconsolidated substrates at channel margins and, in conjunction with a supply of fines, promote self-sustained meandering. The existence of tight, high-sinuosity meanders, therefore, is consistent with the existence of formerly frozen substrates, perhaps partially in conjunction with fine-grained sediments.

Ongoing work

With the aim of understanding the actual contribution of fine grained sediments to the stability of Martian river banks, we are currently analyzing the association of fines with several positive-relief meanders on Mars. There are 3 regions on Mars where highly sinuous channels are particularly abundant [7]. We have started our analyses on the most extensive of these channel systems: the Aeolis and Zephyria Plana region in the western-most portion of the Medusae Fossae Formation (MFF), where the meandering channel features stand in positive relief (Figs. 1 and 2). The MFF is situated along the global dichotomy boundary between 130^o and 240^o E, overlies both the northern Amazonian lowland terrains and the Noachian highlands, and is dated from the Hesperian to Amazonian epochs [8].

Conclusions

Ancient ground ice-rich surfaces would be a compelling explanation for the existence of inverted meandering rivers on Mars. As meandering rivers can require significant time spans to develop and mature, the emerging picture might reveal direct evidence of long-standing salty liquid water flowing over equatorial ice-cemented surfaces during the Hesperian and/or later, in agreement with the concept of a “cold and wet” Mars [9].

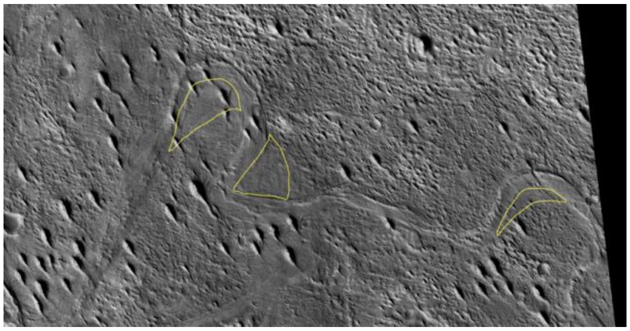

Fig 1: The accretionary scroll bars highlighted (in yellow) in this HiRISE image ESP_021728_1740 are strong evidence from fluvial geomorphology for an ancient ground ice-dominated terrain. The accretion indicates that the channels were formed by a fluid with a free fluid surface. Bar preservation indicates that bank strength exceeded any sediment-bedload strength during the time the channel was active, pointing to a source of bank stability.

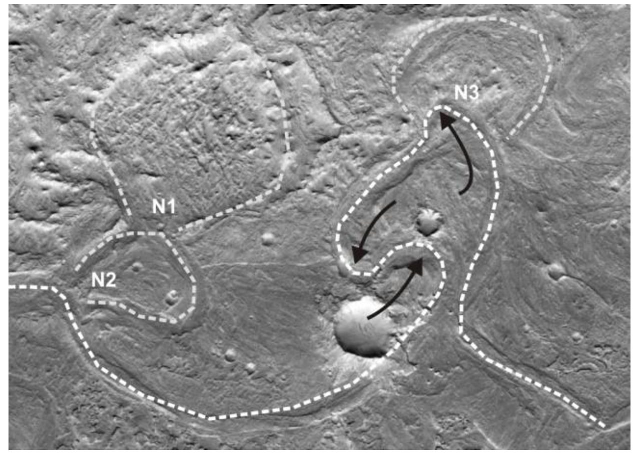

Fig. 2: HiRISE image ESP_022862_1740 showing additional characteristics of former river channels that provide supporting evidence for ground ice conditions at the time of their formation. The image shows a series of former meander loops within a highly sinuous part of a river channel (sinuosity index 2.05 for the dashed white line, which outlines the most recent channel). Well-developed scroll-bar topographies can be seen within the meander loops (black arrows), recording lateral accretion of sediment on the inner bends of the rivers and erosion at the outer bends. The channels can also be seen to have undergone periodic neck cutoff (N1-3) of three former meander loops, attesting to channel shortening through a sustained increase in sinuosity, as opposed to through the incision of chute channels. The channels closely resemble terrestrial meanders formed by helical flow of fluids with a free water surface (i.e., laterally-accreting river meanders, but not those in tidal or submarine channels).

References

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