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Evidence of stratabound liquefaction in the formation of fractured topographic margins, cone chains and pit catenas along the Martian Dichotomy Boundary and in Isidis Planitia, Mars.

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On the low-lying plains along much of the Martian Dichotomy Boundary (MDB) and in the Isidis impact basin, cones and curving chains of cones, referred to as thumbprint terrain (TPT), are common. In the same settings, pit chains (catenas) occur in orthogonal to curving and conchoidal fracture sets between mesa-like crustal blocks, generally at or near topographic margins. Many of the fractures consist of linked pits rather than simple propagated cracks. These assemblages are often associated with the more disaggregated populations of blocks comprising chaos terrain. We show that the local planimetric arrangement of the cone chains, fractures and pit catenas is strikingly similar in both shape and scale, including lateral separation, length, longitudinal slope and radius of curvature. The summits of cones tend to be closely accordant along individual cone chains. Neighbouring cone chains tend to be mutually accordant on low gradient basin surfaces but generally stepped en echelon closer to the fractured basin margins. Similarly, the crustal blocks (including very isolated block sets) are often mutually stepped, and fractures between these en echelon blocks tend to be very close to horizontal. Hence, many cone chains, fractures and pit catenas in fractures share the property of being arranged along strike. They diverge morphologically by the cone chains being positive forms separated by narrow gulfs but the pit catenas being negative forms separated by planar blocks. All of these characteristics point to the possibility that the arcuate cone chains and the arcuate pit catenas have a common origin. In particular, we hypothesise that the cone chains characteristic of TPT along the MDB and in Isidis are filled, indurated and then exhumed pit catenas revealed by the stripping-away of intervening blocks [cf. 1].

Many other surfaces on Mars are pervaded by pits and pit catenas, with evidence of former water flow through the catenas suggesting that ground-ice thaw played a role in at least one mode of catena formation [2]. As well as presenting the morphological evidence for a genetic association between TPT and pit catenas, we present corroborative evidence that fluvial channel networks on Mars have in places increased in complexity through the linking of pits arranged in linear to arcuate arrays, culminating in a pseudo-branching channel network. Such systems do not occur at topographic margins and did not disintegrate into stepped crustal blocks. However, the scale of these channels and the volumes of liquid intermittently impounded in craters along these channel systems indicate that pit chains are associated with significant excess groundwater production leading to channelized flow, including catastrophic discharges when crater-impounded lakes along-flow were breached.

Are the MDB and Isidis cone chains exhumed pit catenas and are the pits the surface expression of more deep-seated conduits? Do pit catenas indicate excess pore-water production, sufficient to link individual pits and dissect crustal blocks? Together, do these assemblages reflect the degradation of the MDB and Isidis margins and the subsequent stripping of adjacent low-lying plains? The crucial observations presented in this research (cone chains lying between crustal blocks, together with the morphometric similarities) are consistent with the interpretation of the cones and catenas having a common origin.

Consequently, we hypothesise that the translated, back-rotated, tilted and capsized disposition of en echelon blocks is very reminiscent of the morphology produced during lateral spreading [3] associated with stratabound liquefaction below a low-gradient, rigid, insensitive surface. Significantly, such liquefaction events cause extensive, arcuate ground fractures along with the discharge of sediment-laden groundwater from the liquefiable substratum to the surface through pipes and conical boils confined within inter-block fractures. These conduits and their injectite are frequently indurated by secondary mineralisation, often making them more competent and less erodible than the confining material. Most often, lateral spreads occur at coastlines, with basin-ward normal faulting and extension of the original surface. Generally, seismic shaking of susceptible materials is responsible

for lateral spreading but pore-water pressure changes, e.g. due to rapid marine recession and drawdown, may also play a role. Given the basin-and-margin setting of the martian cone, pit and block assemblages described in this research, we speculate that all three broad morphological types reflect the degradation of extensive marine margins and the deflation of the interiors of marine basins during long-term marine recession.

[1] Williams et al. (2007) in Willis et al. (eds), Utah Geological Association Publication 36.
[2] Weitz et al. (2006) Icarus 184, 436–451.
[3] Wang et al. (2005) Icarus 175, 551–555.