

ATHABASCA VALLES, MARS: (NOT) A LAVA-DRAPE CHANNEL SYSTEM. D. P. Page, PSSRI, The Open University, Milton Keynes MK7 6AA, UK. Email D.P.Page@open.ac.uk.

Introduction: The authors of [1] present HiRISE imagery of Athabasca Valles, Mars, asserting that this resolves the 'ice or lava' debate that has surrounded the deposits of this region for three decades [2-4]. Their case rests upon observations of ring-mound landforms (RMLs) and polygonal terrain, both of which they interpret to be primary volcanic landforms formed during deposition. This interpretation is part of a wider general theory of a volcanic Cerberus plain based on morphology [5, 6], numerical modelling [7], and implied association with the young martian meteorites [8]. Here we demonstrate that the RMLs and polygonal terrain central to this interpretation are both post-depositional in origin [cf. 9, 10].

Impact craters postdate the surface they occupy. Hence, any landform that superposes an impact crater rim must itself be post-depositional, and postdate impact: a sign of relative age in all but the most contrived scenarios [11]. Figure 1 shows that both RMLs and polygons superpose impact craters. This simple observation exposes the flaw in the authors' argument, these landforms and the substrate separated by *time* (and in all probability, a great deal of it). Any explanation that does not acknowledge this fact has no geological validity. Hence, their assertion that the RMLs form explosively during lava flow emplacement, the polygons resulting where lava cracked "...under the weight of RMLs", is without rational basis, supposed cause and effect separated by an indeterminate period of time documented by the formation of large numbers of impact craters.

Such craters are created by hypervelocity ($> 1 \text{ km s}^{-1}$) impact, an inherently non-conservative event that vaporises the impactor and obliterates pre-existing surface features out to 1.6 crater radii [12]. So, we ask the authors of [1] two questions, one stratigraphic, one energetic: how can impact craters get 'under' primary-formed polygonal fractures in solid rock, and how do RMLs within the rim survive hypervelocity impact?

To clarify the true effects of such impact, we show an RML superposed by an impact crater (Figs. 1b, 2b). This RML is clearly deformed by the impact, its eastern wall completely obliterated at the impact point, even the wall opposite shifted outwards. Contrast this with Figs. 1a (2a), where the RMLs within the rim are not deformed, even though the crater is larger (= more energetic impact), and 1d (2d), where the crater is one-third covered by an RML. These craters are all secondaries from the primary impact 'Zunil', 800 km to the east [13], and formed within minutes of each other.

The authors' suggestion that HiRISE does not bear out the superposition relations described by (9) is to misunderstand both how such superposition should be expressed, and its significance. That some RMLs superpose impact craters while others are superposed by craters is hardly a surprise: the RMLs are suggested to be intrusive, permafrost features in a variety of stages of growth and decay [9, 14]. If some are cut by craters, then all well and good – such RMLs precede cratering – but only one need cut a crater rim to establish the post-depositional origin of the whole. That other supposedly primary landforms in these deposits – i.e., the polygons – are seen to superpose craters in their thousands [10] only serves to reinforce this message.

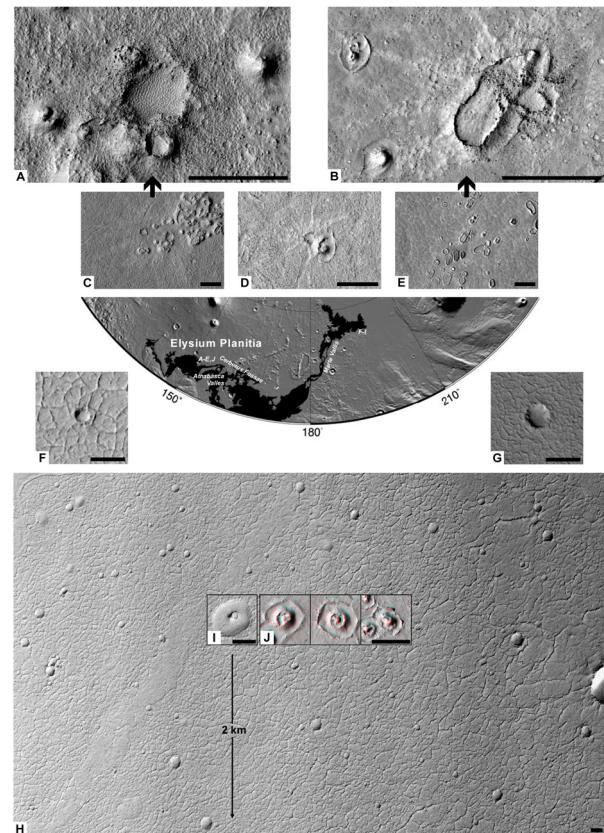


Fig. 1. RMLs and polygons in Athabasca Valles and Cerberus plains. Scale bars 100 m. a): Two RMLs superpose impact crater (PSP_002292_1875). b): RML superposed by crater (PSP_002661_1895). 1d): Crater covered by an RML (PSP_002371_1890). 1f-g): Impact craters superposed by polygonal sculpture (R23-00683 and R14-01144). 1h): Polygonal sculpture superposing craters (S09-02331). 1i): RML from same MOC image (S09-02331), 2 km south of 1h (cf. 1j). 1j): Fig. 3 of [1] showing typology of polygons.

Where the authors consider the relationship of the RMLs to the substrate what they show is telling, for it illustrates how each RML is located within a six-sided polygon (their Fig. 3, reproduced here as Fig. 1j). They draw attention to the form of these polygons, but fail to relate this to structure, a regional view of such polygons (Fig. 1f-h) showing that these too superpose impact craters, close to 100% of craters in Fig. 1h post-dated this way. At resolution, one might argue that the craters simply appear superposed by the polygons, age erasing all proximal-medial ejecta. However, the largest crater in Fig. 1h ($D = \sim 400$ m, at far right), with polygonal sculpture continuous with that in the substrate reaching right up to the crater rim ($H = \sim 80$ m), should dispel this notion. There is no escaping the fact that many millions of years have passed between deposition of the substrate and the formation of polygons and RMLs. Neither is there any reason to suppose that this distinctive patterned ground is secondary here and primary elsewhere in these deposits.

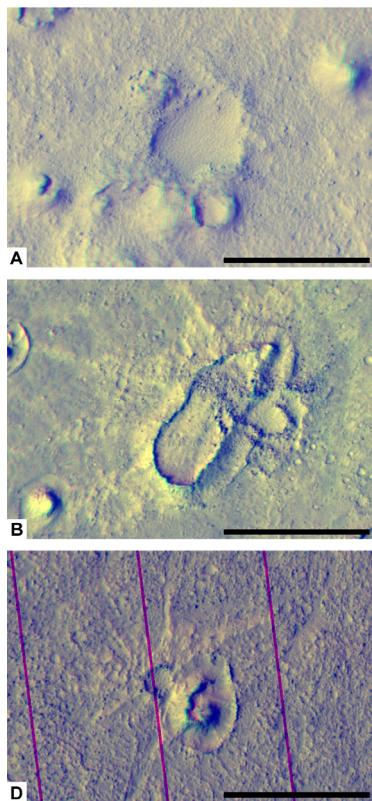


Fig. 2. Stereo red/green anaglyphs of Fig. 1a, b and d (red lens over right eye). a): 002292_1875 and 002147_1875. b): 002661_1895 and 003924_1895. d): 002371_1890 and 001540_1890.

The authors suggest that previous evidence for superposition of the crater [9, 10] in Fig. 1a (their Fig. S7b) is based on the circularity of the crater. They have missed the point. It is the fact that these landforms are

formed *within* the crater rim that is crucial, not crater shape. They further suggest that ejecta on top of the RML shows that the crater is later. However, surface material would remain on top of an intrusive landform. Thus this observation is not discriminatory of process.

While the authors make a number of interesting morphological comparisons and rightly point out that the surface roughness, thermal-inertia, and lack of a hydrogen signal appear consistent with volcanism, each of these has multiple explanations. This superposition does not. They state that HiRISE allows "...divergent hypotheses to be tested", but focus on those observations that support their interpretation, while ignoring or dismissing those that do not. Because refutation has not accompanied growth of their theory (and that of 'plains-forming' volcanism in the Cerberus plain generally), the evidence in one place breaks down in another.

It is a geological truism that we objectively record the nature of the stratigraphic record before considering the processes that were responsible for what we observe [15]. The pitfalls of not doing so, of taking a 'genetic' approach, where theory drives observation rather than the other way around, are amply demonstrated in [1]. In contrast, this refutation proceeds free of all but the most basic of hypotheses: that geological events can be ordered in space and time.

Superposition tells us the order in which events happened. However much individual or collective landform similarities may impress us, if interpretation is not consistent with stratigraphy, then it did not happen that way – and may not have happened at all. These are not lavas.

References: [1] Jaeger, W.L. et al. (2007) *Science*, 317, 1709-1711. [2] Scott, D. and Tanaka, K.L. (1986) *USGS misc. investigation series MAP I-1802-A*. [3] Greeley, R. and Guest, J. (1987) *USGS misc. investigation series MAP I-1802-B*. [4] Rice, J.W. et al. (2002) *LPS XXXIII*, Abstract #2026. [5] Plescia, J.B. (1990) *Icarus*, 88, 465-490. [6] Lanagan, P.D. et al. (2001) *Geophys. Res. Lett.*, 28, 2365-2367. [7] Keszthelyi, L. et al. (2000) *J. Geophys. Res.*, 105, 15027-15049. [8] Hartmann, W.K. (2005) *Icarus*, 174, 294-320. [9] Page, D.P. and Murray, J.B. (2006) *Icarus*, 183, 46-54. [10] Page, D.P. (2007) *Icarus*, 189, 83-117. [11] Wilhelms, D.E. (1987) *USGS Prof. Pap.* 1348. [12] Melosh, H.J. (1989) *Impact Cratering: A Geologic Process*, Oxford University Press. [13] McEwen, A.S. et al. (2005) *Icarus*, 176, 351-381. [14] Burr, D.M. et al. (2005) *Icarus*, 178, 56-73. [15] Wilson, R.C.L. (1998) *Geol. Soc. Spec. Pub.*, 143, 303-314. The author acknowledges valuable discussions with Matt Balme.