Probable recent water/lava source fissures in the Cerberus Plains, Mars:

stratigraphic and crater count age constraints

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1. The Problem

The Cerberus Plains are one of the **youngest surfaces on Mars** [2,4], and were probably formed by outflows of **water and/or lava** [1,6] with lava flows outlasting hydrous flows [5]. The **source** of this fluid, however, is not well understood: there are problems with **Cerberus Fossae** as the source [3] and **no other specific sources** have been identified.

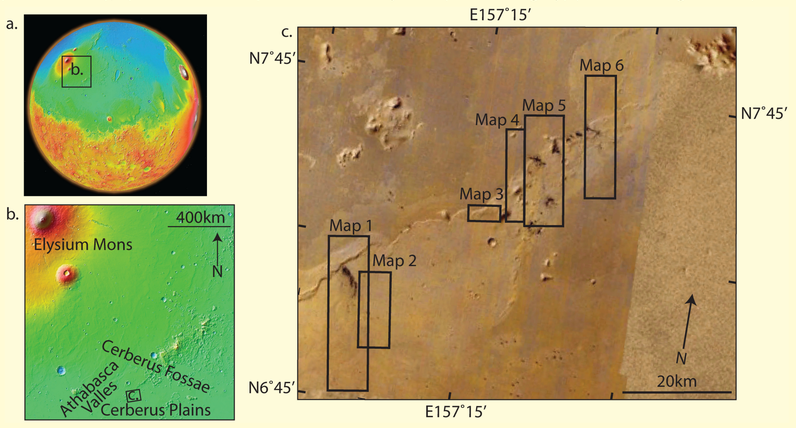
Plains volcanism often obscures its fissures so visible sources should be searched for in features **elevated above the plain**. New HiRISE images reveal just such a feature: a **wrinkle ridge** south of Cerberus Fossae **incised by a series of fissures**. Each has associated channels and deposits indicating **flow onto the plains** surrounding the ridge, showing that they are vents.

This study produced **small-scale geomorphological maps** to establish the **stratigraphic relationships** between the fissure-sourced outflows and the regional plains to determine if they were the source of the plains material. **Crater counts** were used to supplement these observations and suggest tentative absolute ages.

It was found that these fissures were the **source of the Cerberus Plains to the south** and that they were **recent**, as young as **1-10Ma**.

2. The Study Area

Figure 1: Setting. a) Global image, centred on 4°S, 180°W, b) Study area within the wider region (shaded relief), c) Small-scale maps within the study area (visible imagery) (Source: Google Earth.)



3. Methods

Geomorphological Mapping

Small-scale maps were created based on HiRISE images from Mars Reconnaisance Orbiter (Table 1) and a **regional map** was created based on a mosaic of CTX images.

Table 1: Base images for small-scale maps

Map	HiRISE image product	Map	HiRISE image product
1	ESP_016361_1870	4	ESP_016427_1875
2	ESP_020251_1870	5	ESP_016150_1875
3	TRA_000867_1875	6	PSP_007342_1875

Geomorphological mapping was performed with the aim of constraining the stratigraphic relationships between the channels, deposits and fissures. A **stratigraphic tree** was produced for each map indicating superposed and incised contacts between units.

Crater Counting

All craters **>16m diameter** were mapped. These were counted for units of specific interest and the results were binned using the scheme of Hartmann & Neukum [4]. Crater size-frequency curves were created which were compared with established isochrons [4] to give tentative absolute dates.

4. Stratigraphic Evidence

North: Regional plains overlie outflows

The regional map (Fig. 2) shows that the channel from fissure 4 (4,11-13e) is **overlain by the regional plains (Pn2) in the west**.

Fig 3. (right) shows that P11-12, thought to be overbank deposits from that same channel, are **overlain by** thick northern lavas **P15-16**.

Cf8Eb	Incised channel from F4; bank-parallel lineations, polygonal texture.
Bs	Heavily cratered surface of wrinkle ridge.
P15-16	Thick rough lava deposit from the north (Pn2).
P11-12	Smooth, finely polygonal surface flowing from the direction of Cf8.
P10	Rough sub-horizonal deposit flowing from the north (Pn1).

Figure 3: Simplified excerpt from Map 5 and stratigraphic tree.

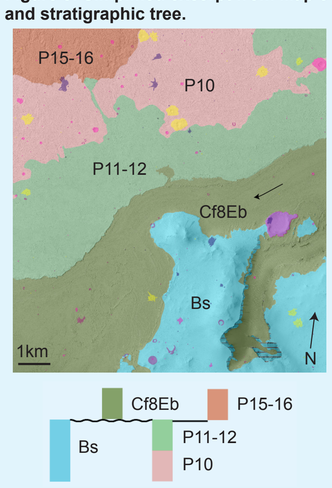


Figure 2: Simplified regional map of 156.8°E, 6.73°N - 158°E, 8.01°N.
Channels and deposits are named by source and plains material by location (see right). Unit names differ from those used in the small-scale maps in order to emphasise flow sources.

Naming conventions for Figure 2

Fissure-sourced units

Nc	Constructive channels from fissure *N*
Ncl	Deposits lateral to constructive channel *Nc*
Ni	Incised channels from fissure *N*
Nil	Deposits lateral to incised channel *Ne*

Regional plains units

PlocN

loc = **location**: s = south, se = southeast, n = north

N **= stratigraphic position** relative to other plains deposits at that location, earliest to latest

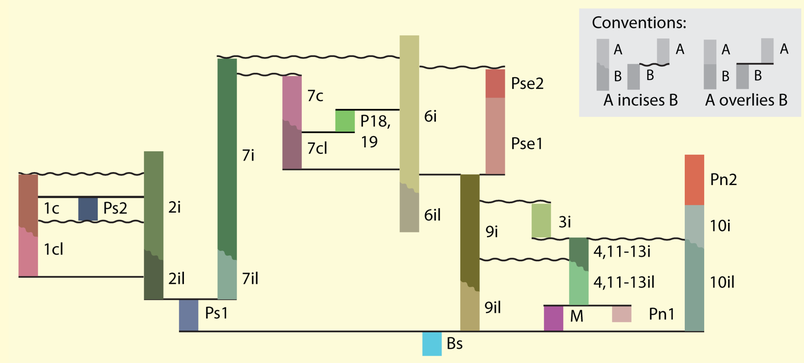
Other units

	Name	Description	Name	Description
	Bs	Wrinkle ridge basement	P18-19	Plains material, unknown source
	M	Steep-sided mounds	F*N*	Numbered fissure *N*

→ Direction of palaeoflow

Stratigraphic Tree

Diagonal contacts indicate relationship between the fill deposits of a channel and its channel-lateral deposits. The same conventions were used in all other stratigraphic trees.



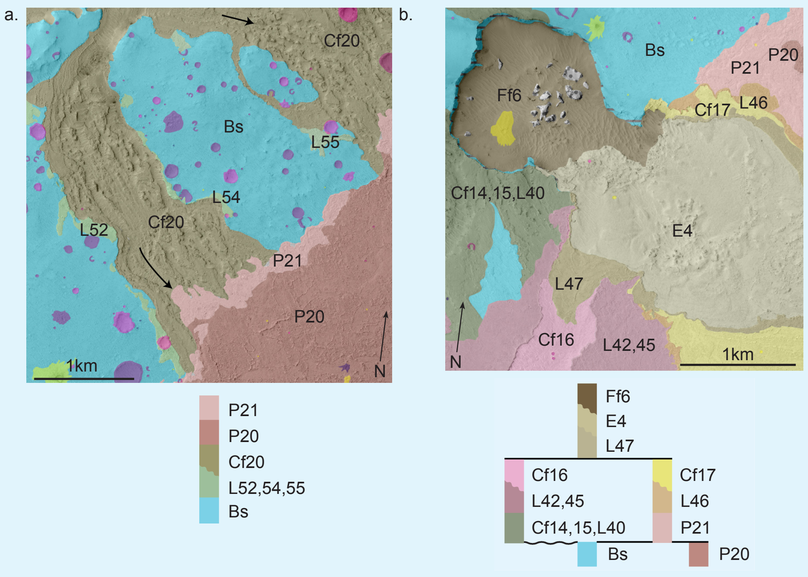
Southeast: Youngest outflows locally overlie regional plains

Regional plain **P20** and its terminal deposits P21 **overlie fissure-sourced channel** Cf20 (Figure 4a).

Further to the west, deposits lateral to channel Cf17 overlie deposits P21 which in turn overlie the regional plain P20 (Figure 4b). These very localised **fissure-sourced deposits** therefore **postdate** the deposition of the **regional plains**.

P21	Smooth deposit marginal to P20 (Pse2).
P20	Southeast plain: rough ridged areas and smooth, polygonal-textured areas (Pse1).
Cf20	Incised channel networks from F9 (9i).
L52,54,55	Semi-rough deposits lateral to Cf20.
Ff6	Fine-grained unconsolidated fissure fill.
E4	Area showing incision and deposition.
L47	Deposits lateral to E4.
Cf16	Constructional channel from F7 (7c).
L42,45	Deposits lateral to Cf16.
Cf17	Smooth channel surface with overlying rough, darker ridges.
L46	Rough material lateral to Cf17.
Cf14-15,L40	Earlier channels and deposits.
Bs	Heavily cratered surface of wrinkle ridge.

Figure 4: Simplified excerpts from a. Map 6, b. Map 5, with stratigraphic trees



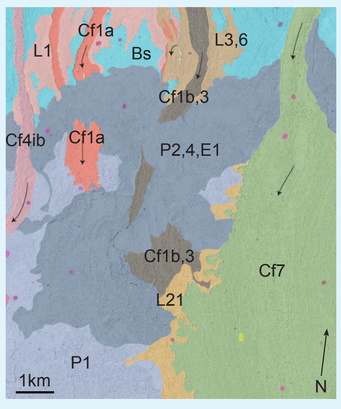
South: Outflows overlie regional plains

Outflows from the fissures at the west and centre of the ridge **overlie or incise into the plains** to the south (Fig. 2 & 5).

Subsequent to the formation of the earliest channels, there was some erosion at the ridge/ plains interface to form P2,4,E1, but outflows in channels C7 and C4 outlasted all other erosional or depositional activity.

Figure 5 (right): Simplified excerpt from Map 1 and stratigraphic tree

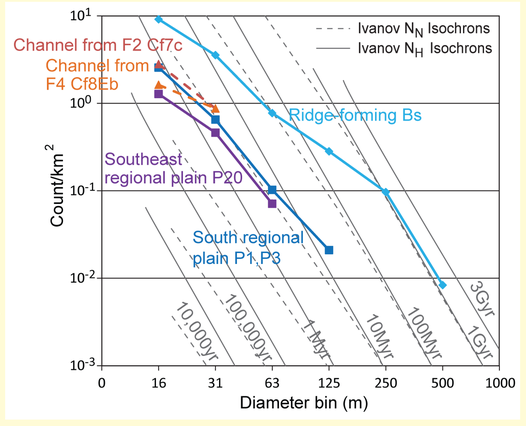
Unit	Description
Cf7	Incised channel from F2; bank-parallel lineations.
L21	Distally-fining channel-lateral deposits.
P2,4, E1	Smooth surface with closed hollows and a polygonal texture
Cf1b,3	Rough constructional channel from F1.
L3,6	Rough pitted material lateral to Cf1b.
Cf1a	Smooth, lineated incised channel from F2.
Cf4ib	Rough constructional channel from F1 (1c).
L1	Channel-lateral deposits; semi-rough.
P1	Southern plain: light and smooth with dark, ridged areas.
Bs	Heavily cratered surface of wrinkle ridge.



5. Evidence from Crater Counts

- **Surface of the ridge:** its distinct curve shows it is **older** than fissure-sourced and regional plains units.
- **Fissure-sourced and regional plains units show similar curves** suggesting similar formation dates.
- **The southeast regional flow**, **P20,** which has the largest sample size of the non-ridge units, has a curve suggesting an age of **1-10Ma**.

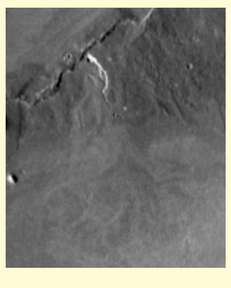
Figure 6: Crater size-frequency curves for relevant units superimposed on published absolute dating isochrons [4]



6. Conclusion: Recent outflows from these fissures formed part of the Cerberus Plains

Figure 7: THEMIS IR Day mosaic (NASA/USGS)

Sinuous features suggest earlier buried outflows from the ridge.



Source of the plains

- **The southern plains were formed by episodic flow from the fissures**. Sinuous features in Fig. 7 suggest that the visible channels are only the most recent in a longer history of outflow.
- **The north and southeast plains** are sourced from **outside the study area**.

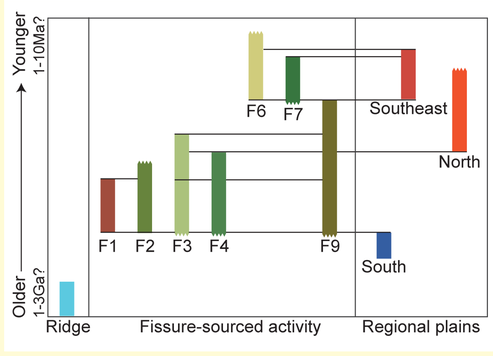
Nature of the outflows and deposits

- **Mostly water-rich outflows**: they incise sinuous channels, deposit material gradually and form plains featuring probable periglacial landforms, e.g. polygonal textures and closed hollows.
- **Localised probable lava flows** forming rare levéed channels, e.g. from F1, with rough deposits and blunt, lobate terminations. These are too localised to be plains-forming.
- **Non-fissure-sourced lava plains:** low albedo rough deposits with upstanding lobate margins.

Dating

- Fissure-related outflows were **contemporaneous** with regional plains formation in the southeast (Fig 9.) which was very recent, possibly **1-10Ma**.
- Outflows from these fissures were thus **part of a broader picture of activity** forming the Cerberus Plains at that time through water outflow from this wrinkle ridge and lava flows from elsewhere.

Figure 9: Age relationships of ridge, plains and fissure-sourced activity based on stratigraphic and crater count constraints. 'Saw-tooth': unknown boundary ages, black lines: known age relationships.



References

[1] Bargery, A.S. & Wilson, L.: Erosive flood events on the surface of Mars, Icarus, 212, pp.520-540, 2011.
[2] Berman, D.C. & Hartman, W.K.: Recent fluvial, volcanic and tectonic activity on the Cerberus Plains of Mars, Icarus, 159, pp.1-17, 2002.
[3] Edgett, K. S. & Malin, M. C.: The layered upper crust of Mars: An update on MGS MOC observations after two years in the mapping orbit, Lunar Planet. Sci. XXXIV, abstract 1124, 2003.
[4] Hartmann, W.K. & Neukum, G.: Cratering Chronology and the Evolution of Mars. Space Sci. Rev. 96, pp.165-194, 2001.
[5] Jaeger, W. L., Keszthelyi, L. P. etc: Athabasca Valles, Mars: A lava draped channel system, Science, 317, pp.1709–1711, 2007.
[6] Jaeger, W. L., Keszthelyi, L. P. etc: Emplacement of the youngest flood lava on Mars: A short, turbulent story, Icarus, 205, pp. 230-243, 2010.