Glacial Origin of Landform Assemblages in Western Jezero Crater, Mars

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Abstract

HiRISE-based mapping reveals five landform assemblages in western Jezero crater, each defined by a landform association interpretable using Earth-based landsystem models and well-understood Earth analogues. 1) The northwestern assemblage hosts boulder hills rimmed by lobate ridges, mounds and mesas on a valley floor, and valley-bounding ridges superposed by striations (= parallel boulder-bearing ridges and grooves). 2) A trough zone hosts variously shaped depressions, intra-trough islands, linear and curvilinear boulder ridges, and highland strips topped by striated surfaces and rimmed by boulder-bearing ridges. 3) The steep-sided fan-shaped plateau ("western Jezero delta") hosts mesas, highland-rim boulder ridges, depressions, linear and curvilinear ridges, and a plain superposed by radially trending striations. 4) The crater-margin assemblage hosts a steep-sided ridged and pitted hummocky terrain, a terrace-like capping surface, and mounds surrounded by radially trending boulder ridges. 5) The crater-floor assemblage hosts a polished and striated terrain that displays fold-like and streamlined ridges, hummocky landforms dominated by quasi-circular depressions with raised rims, mesas exposing fold-thrust strata, flat-topped steep-sided ridges with U-shaped map traces, polygonal-grooved plains, and unconsolidated boulder mounds and ridges. Although any aforementioned landform unit could be explained by multiple formative mechanisms, the spatiotemporal relationships mapped in this study within and among the assemblages place stringent constraints for any self-consistent interpretation. A model capable of explaining the mapping results involves northeast-flowing glaciation, ice-sheet collapse with ice-fracture patterns controlling the formation of polygonal grooves via crevasse filling and ice pressing, and minor aeolian modification. In the model, the plateau and crater-margin assemblages were formed by ice-walled subglacial deposition, the trough zone by subglacial flooding, the northwestern and basin-floor assemblages by glacial deformation and deposition, circular depressions with raised rims by melt out and down pressing of spherical dead-ice blocks (i.e., thermal karsts and kettle holes), mesas by kame formation, and striations by glacial fluting.

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1. Introduction: The goal of this study is to test two competing models for the landscape evolution history of Jezero crater and its bounding plains by establishing landform associations through high-resolution mapping and a systematic comparison against Earth analogues.

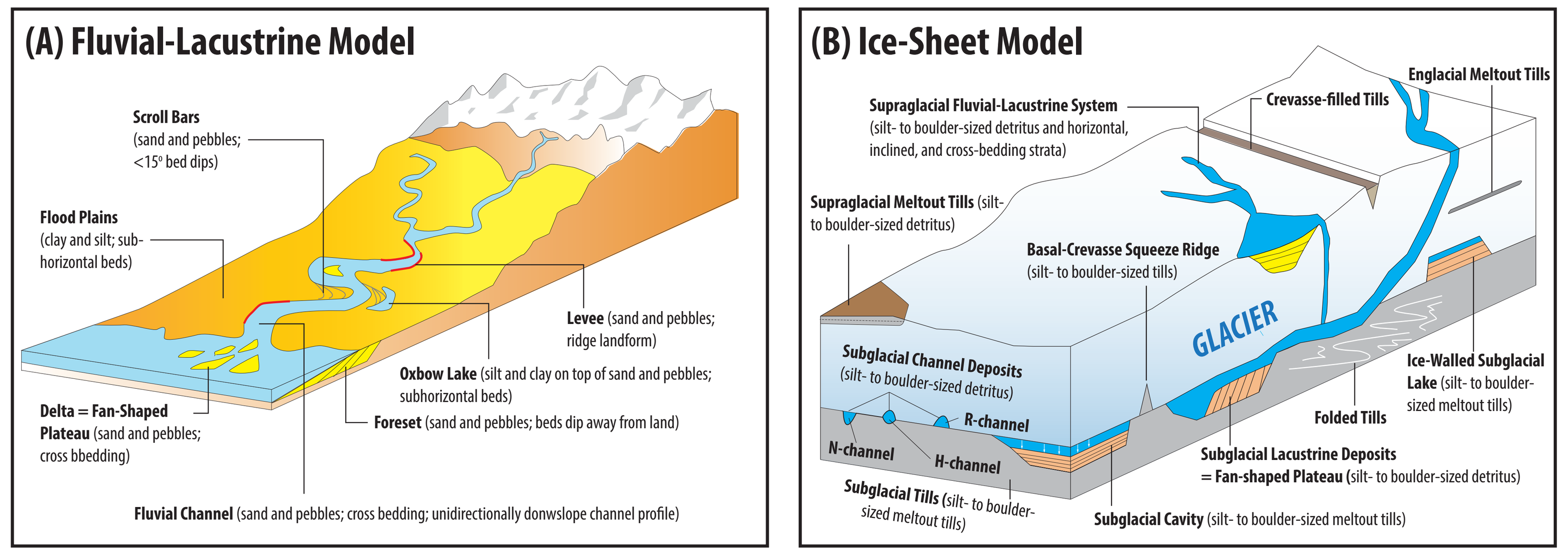

Fig. 1 Fluvial-lacustrine (A) vs. glacial (B) models for landscape evolution of Jezero crater.

2. Methods and Results: Mapping was conducted over CTX and HiRISE images. The main results are displayed as a regional map at the CTX resolution (6 m/pixel) (Fig. 2) and a detail map at the HiRISE resolution (25 cm/pixel) (Fig. 7).

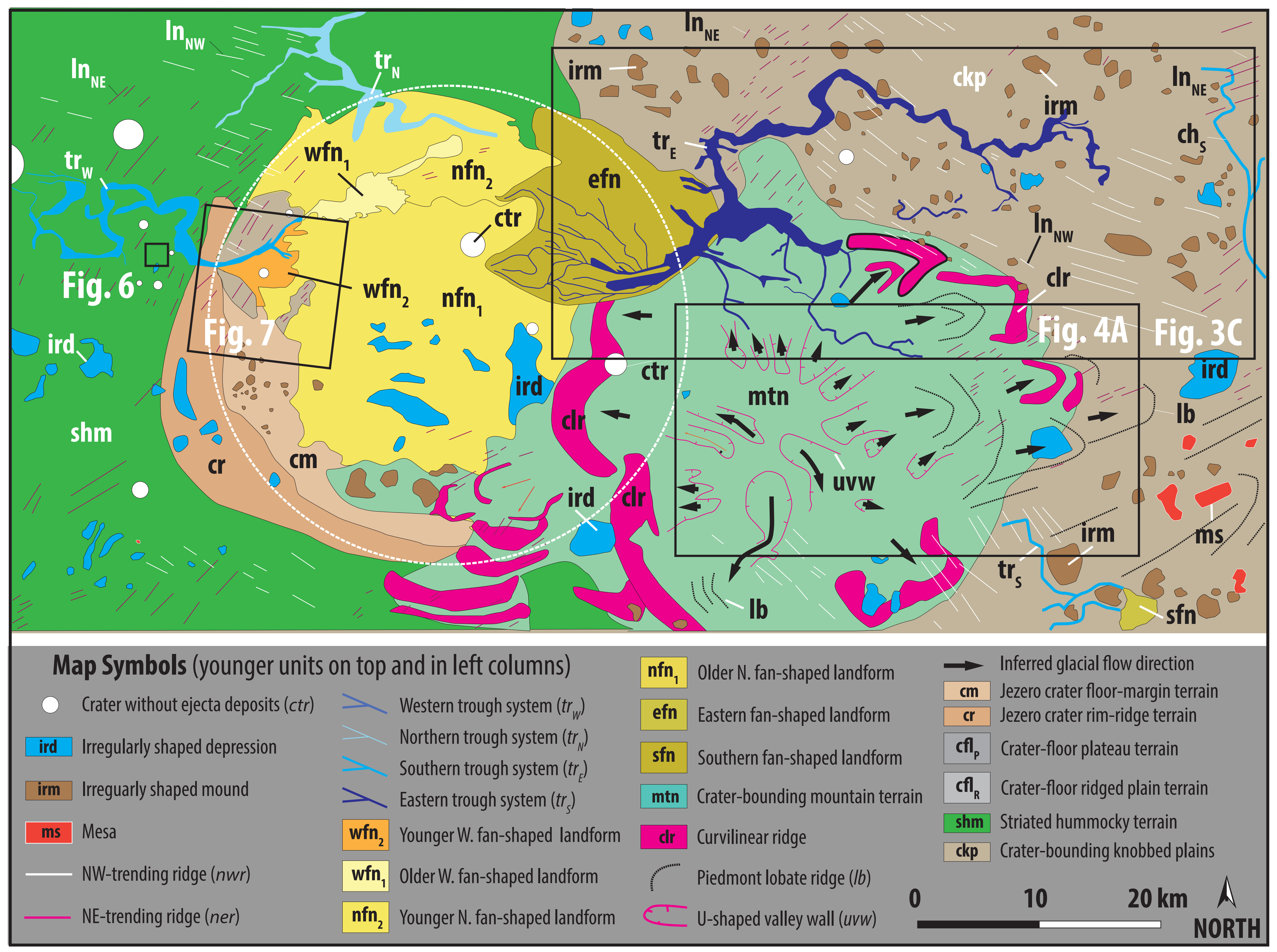

Fig. 2 Geomorphological map of Jezero crater and its hosting plains with a CTX image mosaic at 6 m/pixel as the base map.

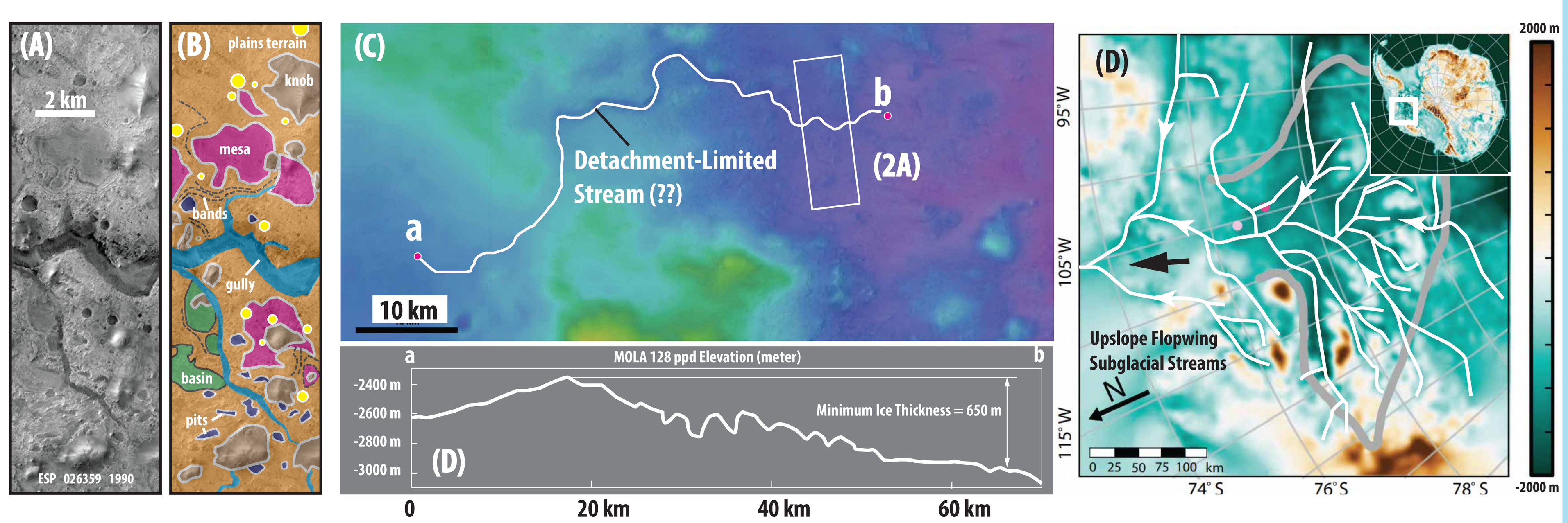

Fig. 3 Evidence for a upslope-flowing dendritic stream network and an Earth analogue from Antarctica (D) (Schroeder et al 2013 PNAS).

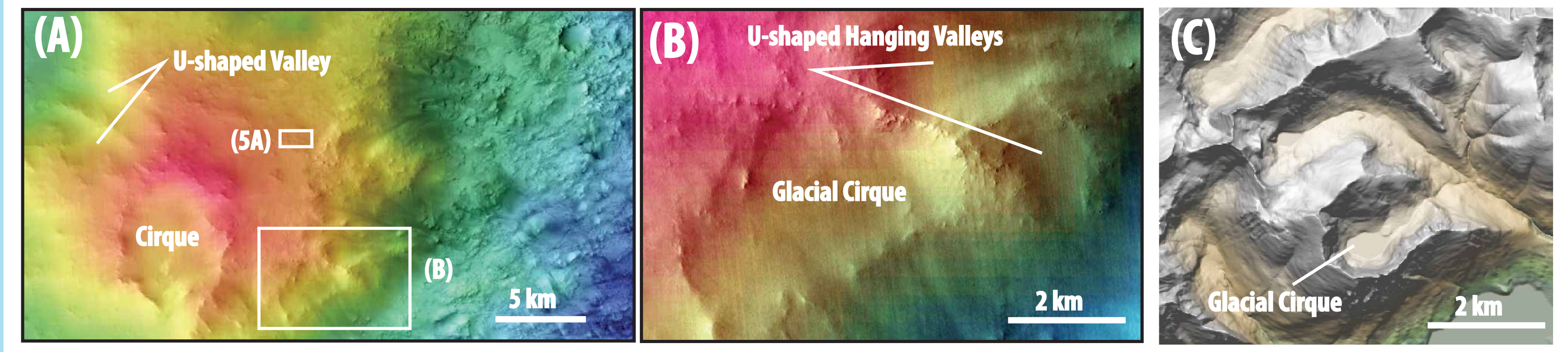

Fig. 4 Evidence for U-shaped valleys, glacial cirques, and hanging valleys (A-B) and comparison to those in Glacier Park (C) of western Montana, USA.

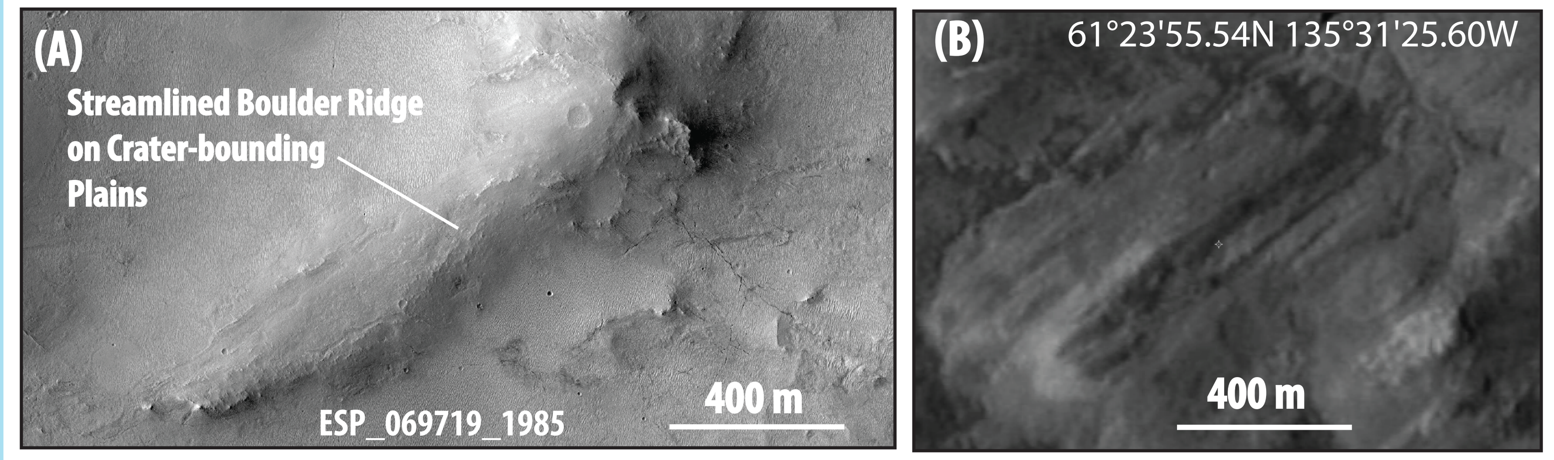

Fig. 5 Evidence for streamlined ridges interpreted as drumlins (A) and comparison to a drumlin on Earth (B) from the Alaska ice field.

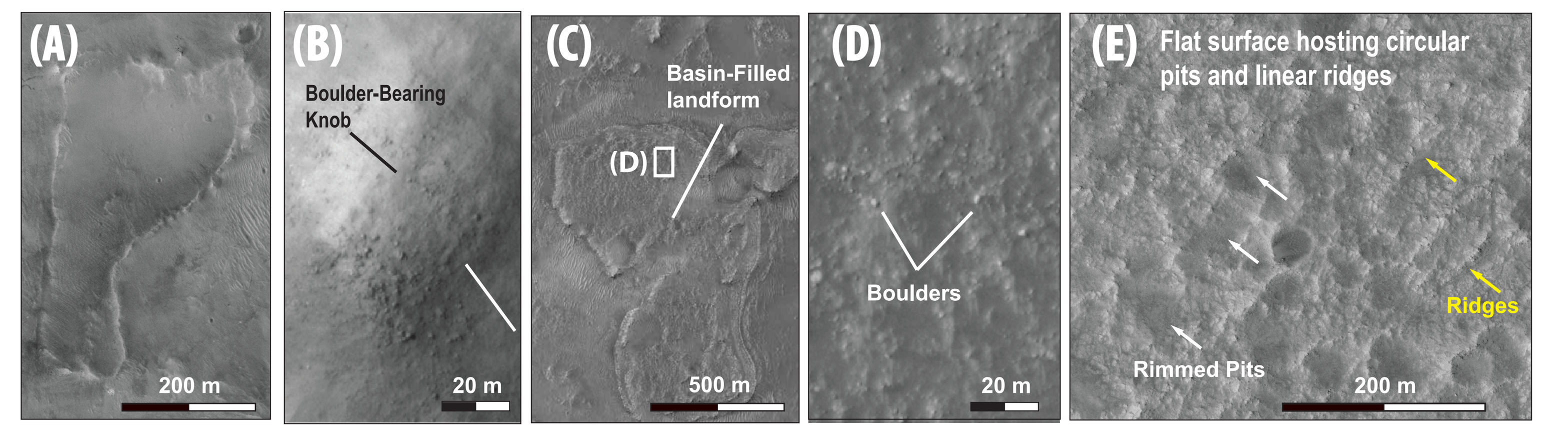

Fig. 6 Boulder-bearing landforms (ESP_058930_1985) bounding the western drainage network and resembling (A) Veiki moraines, (B) kames, (C) glaciated surface exposing (D) subglacial tills, and (E) glacial hummocky terrain.

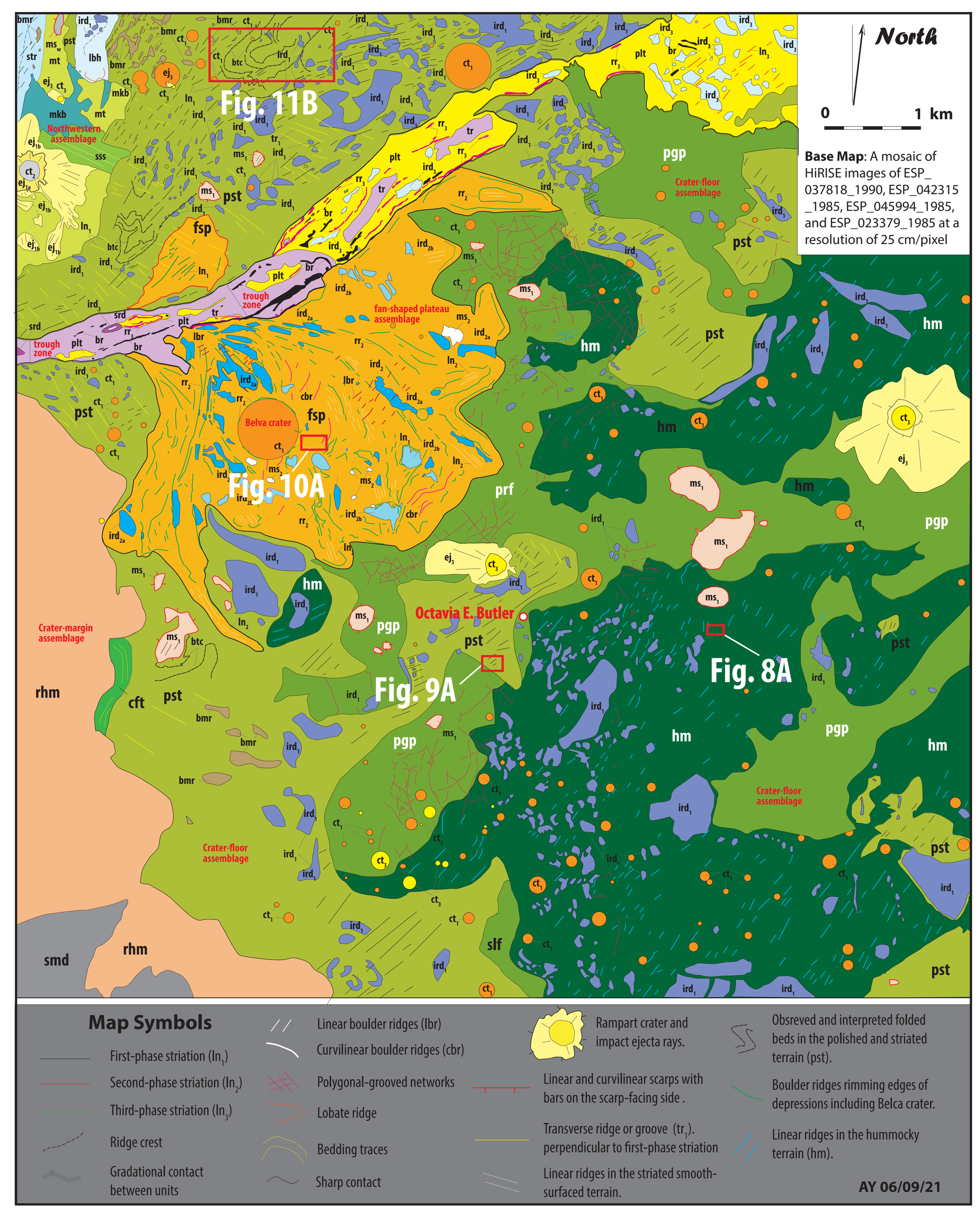

Fig. 7 Geomorphological map of western Jezero crater with a HiRISE image mosaic as the base map.

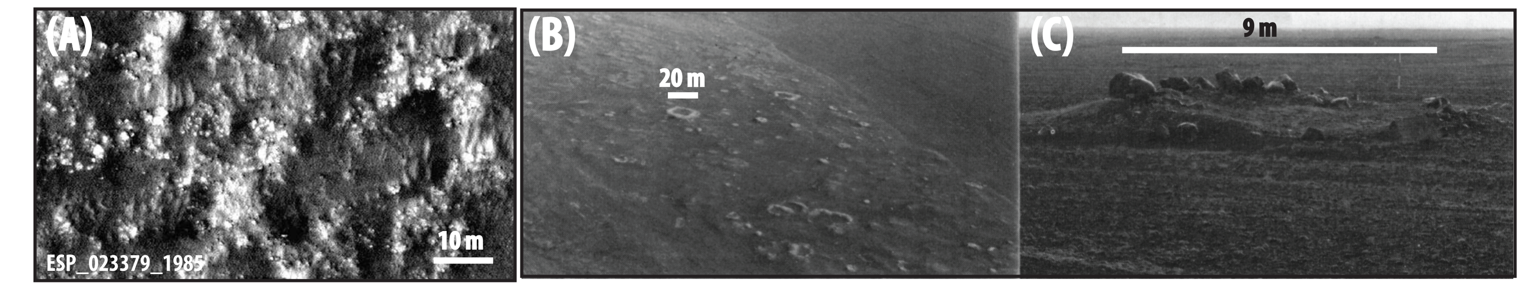

Fig. 8 Raised-rim on crater floor (A) and rimmed kettles (B-C) from Earth generated by hyperconcentrated subglacial or proglacial floodings involving transport of debris-rich ice blocks (Mailzels, 1992; Geografiska Annaler A).

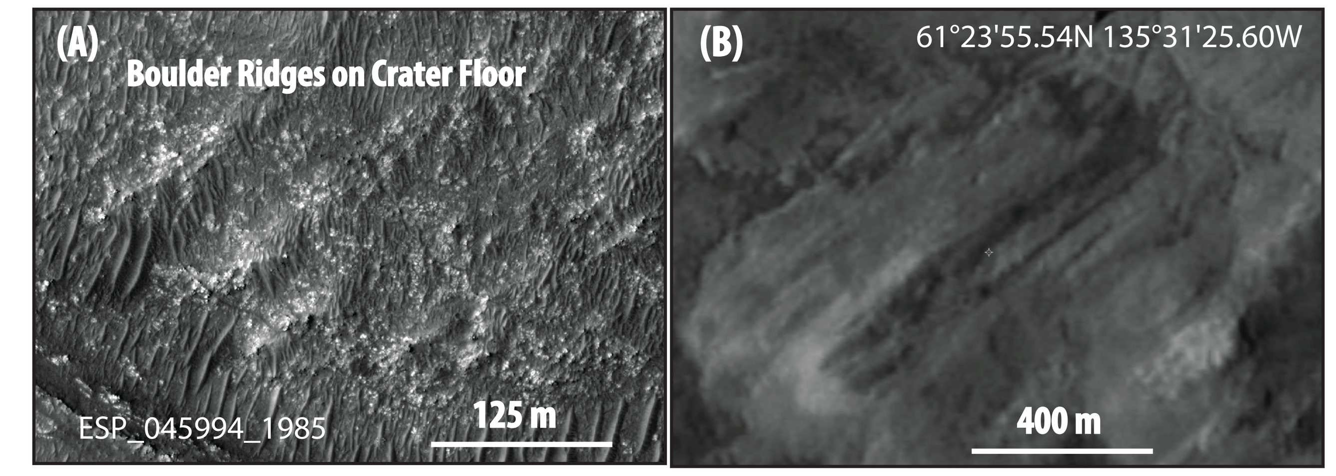

Fig. 9 NE-trending streamlined ridges on crater floor (A) are interpreted as glacial flutes, which share similar morphologies to those exposed on Earth.

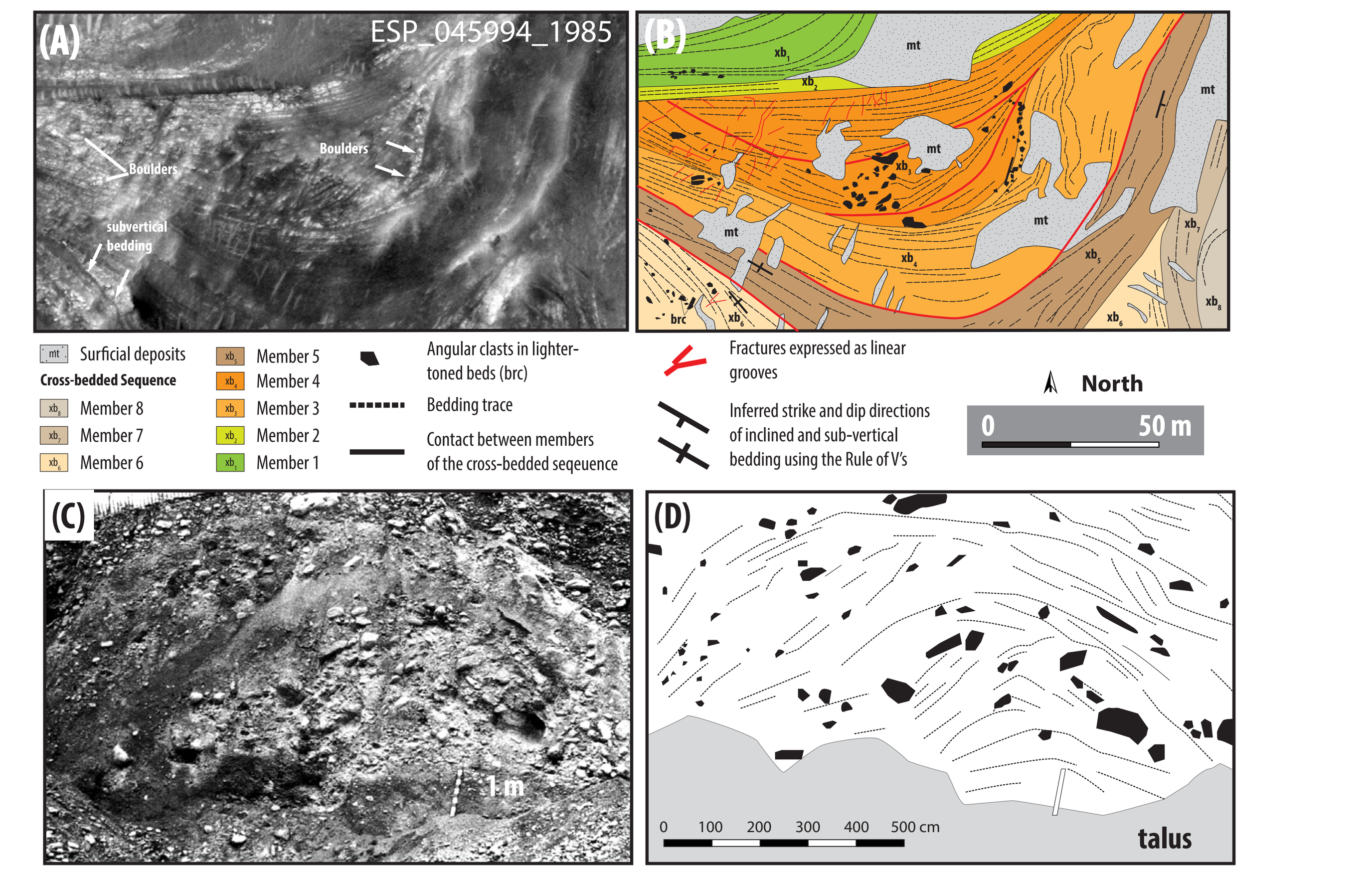

Fig. 10 Breccia and subvertical strata in a cross-bedded sequence exposed in the fan-shaped plateau of western Jezero (A-B). The presence of meter-sized boulders suggests a high-energy transport origin, possibly during the construction of eskers. A possible Earth analogue is shown in (C) and (D) from Brennand (1994, Sedimentary Geology).

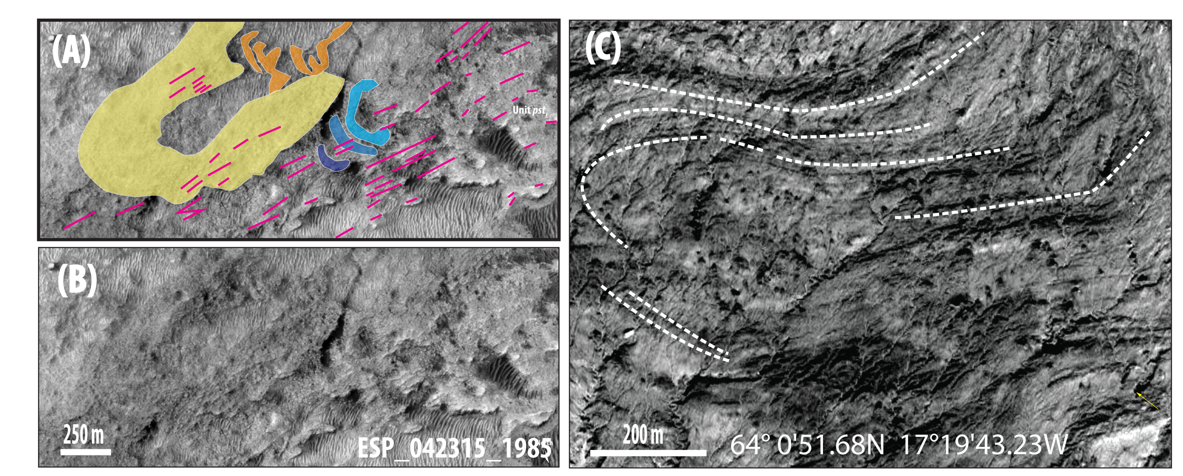

Fig. 11 Fold-like bands (A-B) in the polished and striated terrain (unit ***pst*** in Fig. 7)and an Earth analogue (C).

3. Discussion/Conclusions: Although each mapped landform may have formed by multiple possible mechanisms, to explain them simultaneously yields the most likely glacial-origin hypothesis. The model predicts (1) the fan-shaped plateau in western Jezero was constructed in a subglacial lake setting fed by a transport-limited subglacial drainage system, (2) the eastern stream network was not an outlet channel but a west-flowing and detachment-limited system, (3) mesas are ice-walled subglacial lake deposits fed by frequently surged subglacial meltwater floods, (4) the pitted and ridged hummocky terrain on the crater floor was formed by subglacial floodings through turbulent sheet flows at the ice base, (5) parallel linear ridges were created by subglacial erosion and deformation, (6) the topographic asymmetry of Jezero crater was induced by northeast-southwest glacial flows, (7) a minimum ice thickness on the crater-bounding plains was ~700 m, and (8) the Belva-crater ejecta blanket was removed by glacial erosion. A possible Earth analogue for Jezero crater is the Hiawatha crater (D = ~30 km) that lies below the 2-km thick Greenland ice sheet (Kjaer et al., 2018 Sci. Adv.).