Geomorphologic Evidence for Ice-sheet Glaciation on Pluto's Largest Moon Charon H. Z. Chen[1] and A. Yin[1], [1]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095-1567, USA, hanzchen@g.ucla.edu.

Introduction: The surface of Pluto's largest moon Charon is characterized by mutually terminating north- and east-trending troughs on the northern highlands of the Oz Terra and scattered polygon-shaped mounds and depressions on the southern lowlands of the Vulcan Planitia [1][2]. The highland troughs have been interpreted as extensional rifts, whereas the angular mounds have been interpreted as either exotic blocks or *in situ* mega-breccias overlain by emplaced cryo-volcanic flows [1] [2]. To test these hypotheses, we conducted systematic structural analysis and geomorphologic mapping that show the surface of Charon may have experienced an early phase of constrictional deformation followed by ice-sheet glaciation across the imaged side of Charon.

Data and Methods: We use the global mosaic and DEM data for mapping Charon [4], and the Bedmap2 dataset [5] for establishing the Antarctica ice sheet as an Earth analogue. Our interpreted landform-forming mechanisms are based on a landsystem approach [6] aiming at explaining a suite of coeval and spatially related morphological features using an Earth-analogue-based landscape-evolution model.

Results: Built upon the earlier work [1][2][3] we mapped the following units in the northern highlands (Fig. 1): (1) a linear-trough assemblage consisting mutually terminating shallow (~3 km) and wide (~30 km) north- and east-trending troughs bounded by north-striking thrusts and east-striking normal faults (*feature 1*), (2) a dendritic-trough assemblage (*i*) consisting of hanging-valley-like (*feature 2*), arête-like (*feature 3*) and cirque-like (*feature 4*) landforms and (*ii*) terminating at irregularly shaped depressions (*feature 5*) or the southern lowlands, (3) a linear-landform assemblage across the highlands (*feature 6*), (4) a curvilinear-pitted-chain terrain dotted by isolated cone-shaped mounds (*feature 7*), (5) muted craters lacking raised rims and central uplifts (*feature 8*), (6) a trough-floor assemblage consisting of valley steps (*feature 9*) and features resembling streamlined drumlins (*feature 10*) and roches moutonnées (*features 11*). In the lowlands, we mapped (1) a lobate landform assemblage that consists of convex southward belts dotted by angular blocks with (*feature 12*) or without (*feature 13*) bounding moats, angular depressions (*feature 14*), (2) range-front-parallel curvilinear wrinkle ridges (*feature 15*), and (3) a triple-junction-connected fracture system (*feature 16*) that cuts across all landforms in the lowlands. Linear and curvilinear troughs with striated floors rim the northern lowland margin (*feature 17*).

Constrictional Deformation: Evidence for north-striking thrusts comes from truncated crater basins (*feature 18)* and regional tilting of back-limb range surfaces (*feature 19*) [3], whereas evidence for east-trending rifts comes from linear range-front escarpments and their bounded tilted blocks [1][2]. Because troughs bounded by thrust and normal faults terminate at one another (Fig. 1), their formation must have occurred coevally during constrictional deformation (i.e., synchronous north-south extension and east-west compression).

Regional Glaciation: Second-order and post-tectonic deformation landforms on the highlands resemble subglacial landforms of the Antarctica ice sheet (Fig. 2), whereas the pitted terrain in the highlands and the lobate assemblage represent terminal moraines of outlet glaciers. The ice sheet was flowing eastward indicated by streamlined landforms, whereas the younger outlet glaciers were flowing southward required by convex-southward lobate features. Regional glaciation was followed by local mountain glaciation in the highlands that created arêtes, cirques, and hanging valleys. The angular blocks in the lowlands represent glacial erratics with a density lower than the glacier, whereas angular depressions represent sink holes of glacial erratics with a density higher than the glacier.

Implications: Constrictional deformation may have resulted from combined southward gravitational spreading of the highlands and despinning-generated east-west compression [7]. Glaciation requires a lasting atmosphere capable of maintaining hydrological cycles. The triple-junction-connected fracture system may have resulted from glacial rebound. The glacier could be ammonia ice, lower-density erratics pure water ice, and the inferred higher-density erratics a mixture of rock debris and water ice excavated by the largest impacts to the surface of the satellite before regional glaciation.

References: [1] Moore J.M. et al. (2016) Science, 351, 1284-1293. [2] Beyer R.A. et al. (2017) Icarus, 287, 161-174. [3] Chen and Yin. (2019) Pluto System after New Horizons, Abstr. 7007. [4] Schenk P.M. et al. (2018) Icarus, 315, 124-145. [5] Fretwell P. et al. (2013) Cryosphere, 7, 375-393. [6] Evans J.A. Glacial landsystems, (2003) [7] Melosh H. J. et al. (1977) Icarus, 31, 221-243.

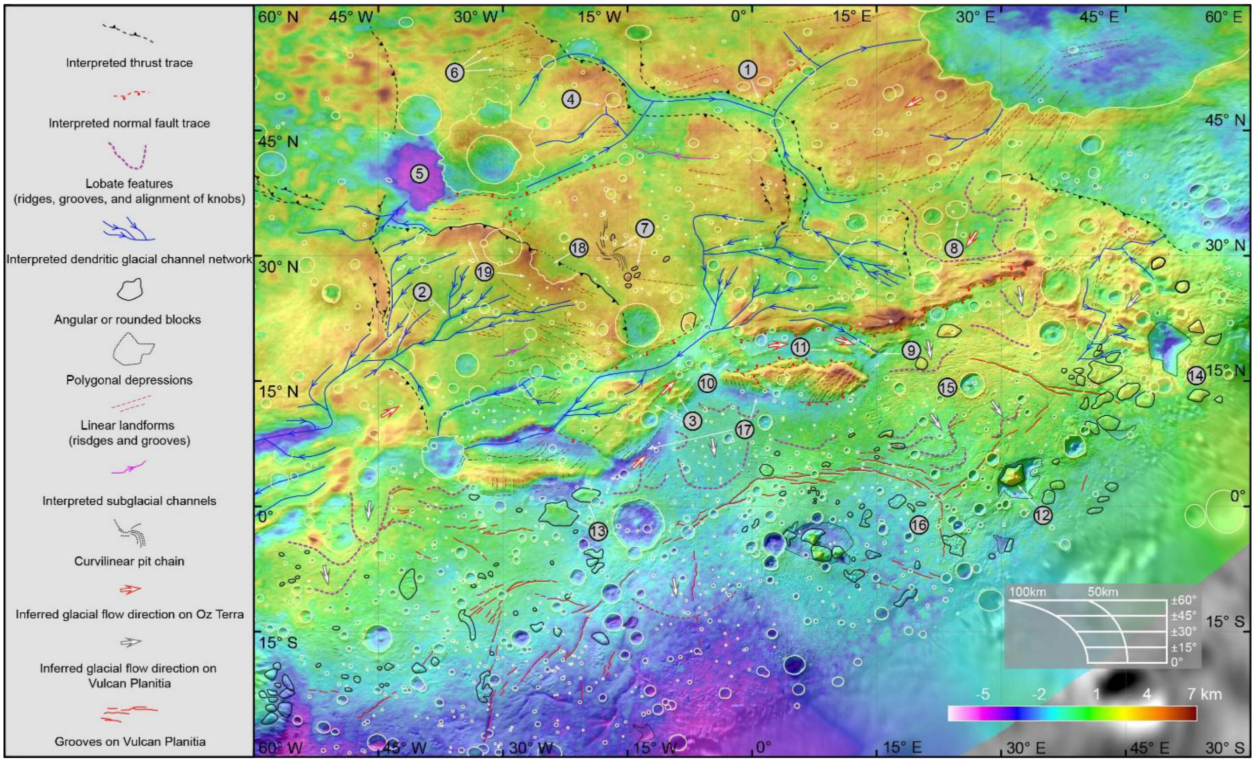

Figure 1. Structural-geomorphologic map centered near the sub-Pluto point. The base map is superposed global image mosaic and global DEM at a 300 m/pixel resolution. Numbers are features mentioned in the text.

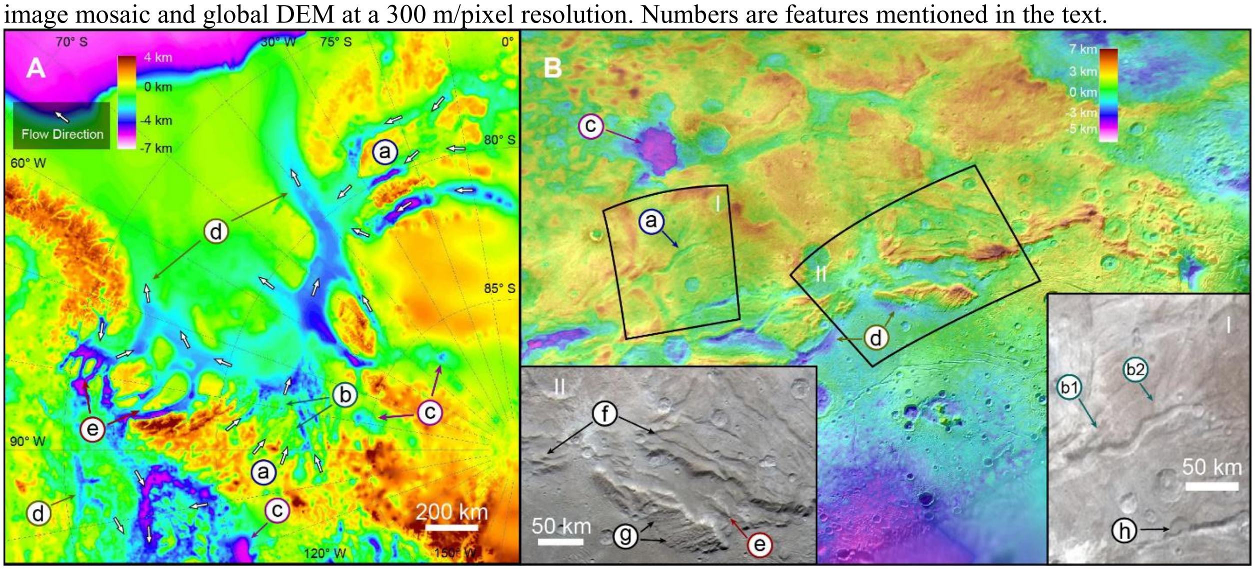

Figure 2. Comparison between geomorphology of subglacial landforms on Antarctica (A) derived from Bedmap2 dataset and (B) landforms on Charon displayed in a map created by the superposed global image mosaic and global DEM data: (a) dendritic glacial channel network, (b) hanging valleys terminating at trunk valleys, (c) irregular depressions on subglacial plateau plains, (d) curvilinear deep-cutting troughs with overdeepenings along lowland margins, (e) streamlined landform, (f) arêtes, formed by erosion of mountain glaciers, (g)striated surface possibly resembling mega-scale glacial lineations (MSGLs) on Earth, (h) crater lacking raised rim and central uplift. Insets (I) and (II) in (B) are high-resolution images with their locations. (I) Hanging valleys (b1) and (b2) terminating at a trunk valley. (II) An inclined bedrock surface displaying mega-scale lineations (~4 km wide and ~50 km long) (g), a roche moutonnée-like feature, and U-shaped troughs bounded by arêtes (f).