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Decametre scale, spiral-shaped landforms in Elysium Planitia, Mars

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We present the discovery of a new type of landform that is apparently confined to one or two locations in western Elysium Planitia, Mars. In planview, these landforms consist of spirals, a few tens of metres across, defined by low furrows and ridges. They appear singly or in loose groups or chains and are generally double-armed with a visual similarity to Kelvin-Helmholtz instability forms. About 100 examples have been found, over 90% of which occur in a single image. Almost all the examples seen have “anti-clockwise” rotation (from the edge to the centre); less than a fifth spiral the other way.

The spirals are found only in the polygonised elements of a terrain type known as Platy-Ridged-Polygonised (PRP) terrain. This distinctive surface displays a tripartite morphology comprising: 1) well-defined, kilometre-scale plates of rubbly material (clast-sizes up to a few meters in diameters), 2) complex patterns of sinuous to sub-linear rubbly ridges that are often many kilometres long, less than a few tens of metres across and less than a few metres in height, and 3) clast-free zones between the plates that display decametre scale polygonally patterned ground defined by networks of furrows and grooves. PRP terrain appears to represent the “frozen” remnants of a once liquid medium: it is extremely flat with margins defining an equipotential surface; infills craters and drapes low relief terrain; can be traced up through the 300 km long Athabasca Vallis outflow channel to a source region consisting of a pair of large (km-wide) fractures called the Cerberus Fossae. The origin of the PRP material is debated: some authors favour extremely fluid, voluminous and turbulently emplaced lavas (e.g. Keszthelyi et al., Geochem. Geophys. Geosys., 2003), others argue that this material represents a debris-covered relict frozen sea or ocean (e.g. Murray et al., Nature, 2005).

The spirals, which are visible only in HiRISE images with sub-metre spatial resolution, have been observed in only two of the dozens of HiRISE images that cover the PRP terrain in western Elysium Planitia. Almost all of the spirals have been found in one specific setting: in the polygonised material between two rubbly plates that have pulled apart. Interestingly, one of these plates is grounded against the ejecta of a c. 2km diameter impact crater (analogous to how fast-ice remains attached to the land in an oceanic sea-ice/shoreline context). The shapes of the margins of these two plates match one another such that the movement of the mobile plate can be reconstructed: it has shifted by 860 m back towards the centre of the western Elysium Basin.

Currently, it is not well understood how these features formed. One clue comes from observations of a complex spiral that is bounded by an arcuate ridge on its northeastern margin but by an arcuate fracture or fault offset by transform fractures on its northwestern margin. The transform fractures propagate away from the arcuate fracture as sets of subtly curving troughs and ridges, traceable clockwise in a widening fan-shaped zone. Similarly, the southeastern margin is characterized by a fan-shaped zone of transform troughs and ridges oriented normal to the circumference and widening with clockwise progression. The southwestern margin is bounded by a ridge, albeit subtler and shorter than its counterpart on the northeastern margin. This pattern appears to demonstrate rotation and shear of a region of the polygonised surface and is indicative of a brittle material superposing a ductile substrate.

Despite considerable effort, we have been unable to find a direct analogue for these landforms in any of the terrestrial volcanic, glacial, oceanic or periglacial literature, but we note that such quasi-spiral patterns that do exist in geomorphology tend to occur due to rotations or shear. Millimetre-scale spiral fractures have been known to occur in drying precipitates without rotation (Néda et al., Phys. Rev. Lett., 2002) and so, although at a radically different scale, this process provides an interesting alternative avenue for exploration in Elysium Planitia.