MARTIAN INVERTED CHANNEL CLASSIFICATION: ARABIA TERRA CASE STUDY.
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Introduction: Recent geological remote sensing observations have revealed the presence of a network of sinuous ridges in the Arabia Terra region [e.g. 1], one of the oldest parts of Mars, dating from the mid-to late Noachian [2]. These sinuous ridges were interpreted as inverted channels, ancient fluvial systems, which developed an ‘inversion of relief’ [e.g., 3] that occurred because valley or channel floors are formed from (or filled in by) an intrinsically more erosion resistant material. After burial and then erosion, adjacent terrain was removed leaving the channel body with positive relief (e.g. [3], Fig. 1). Previous authors e.g. [4,5,6]), highlighted variations in Martian inverted channel morphology. Since inverted channels in Arabia Terra were formed during the Late Noachian to Early Hesperian [e.g. 7], a deeper study of their morphological differences is important to understand fluvial, erosional and paleo-climatic processes in Mars’ ancient past.

Here, we present a morphological classification and morphometric data for inverted channels in Arabia Terra. The aim is to understand the events behind these morphological differences to better interpret the hydrological history of the region and to facilitate comparison with terrestrial analogues for further analysis.

Methodology: The inverted channels were examined in ArcGIS using Mars Orbiter Laser Altimeter [MOLA; 8], 6 m/pixel ConTeXt images [CTX; 9], and 25 cm/pixel High Resolution Imaging Science Experiment [HiRISE; 10] images. We classified the spatial variations in: (i) planimetric morphology, (ii) cross section shape, and (iii) ridge top surface.

The planimetric morphology classification was divided into two parts: primary ‘Network Type’, and secondary ‘Planview Complexity’. Primary ‘network shape’ describe the whole exposure of an inverted channel segment (i.e., at the ~10 km scale) and include ‘single channels’ (Fig.1 A-B) and ‘networked channels’ (Fig.1 C). The secondary class describes the km-scale planview morphology and includes: i) ‘connected’ (Fig.1 C), ii) ‘multi-level’ iii) and ‘parallel’ inverted channels. The cross section types (e.g. Fig. A-B-C) mainly applies the scheme and nomenclature of [5] and includes many divisions and sub-divisions. The upper surface morphology (e.g Fig 1 B) classification refers to the meter–scale morphology of the upper surface of the inverted channel and includes these types: i) smooth, ii) rugged, iii) cratered, or iv) polygonised (with fractures or ridges at ~10 m scale).

Figure 1: Example of inverted channels in Arabia Terra. Both A and B can be classified as a single channels, with a rugged upper surface and a rectangular cross section. The main differences are: in A) the inversion of relief was developed inside a valley, B) the channel is upstanding compared with the surrounding areas and the upper surface morphology is more visible at a meter scale. C) is an example of a connected network with rounded cross section and cratered upper surface.

For morphometric analysis we calculated sinuosity and slope of the inverted channels upper surface. Inverted channels were categorized as either: Straight (S<1.05), Sinuous (1.05<S<1.50) or Meandering (S>1.5). The observable inverted channel segments have a wide range of lengths, so to understand the effect of this on the sinuosity results, a range of different segment lengths (5-10-20-40 km) were considered.
This was done to see if there was any scale-dependence, as this could isolate different sensuositites for different stream orders (assuming longest sections are generally the highest order streams). The slope angle was calculated from the start and end point of the inverted channel segment, by sampling the MOLA height of each. The relationship between inverted channel slope and sinuosity was studied separately for each of the classes of the classification scheme (e.g., Fig. 2 bottom). Our classification was applied to 870 inverted channels in Arabia Terra region.

**Results:** The longest inverted channels have more morphological variability along their paths than shorter ones, including different zones with different classifications. 80% of the inverted channels in Arabia Terra are classified as ‘single channel’ network type, the rest are ‘networked’. 89% had a second planar view morphology of ‘connected’, so other styles are rare. 65% of the channels had at least two cross section styles along their path, and 12%, usually corresponding to the longest channels, have four or more different cross sections types.

Few inverted channels showed much variation across their path length in ‘upper surface’ morphologies, and ~37% are smooth, ~39% rugged, and ~34% are cratered. Just 2% of the samples are polygonised, but this morphology can only be recognized in HiRISE images, so a follow-up study of only those channels with HiRISE coverage is underway.

There is little evidence for spatial control of inverted channel morphology in Arabia Terra, suggesting that many aspects of the classification represent inverted channel evolution, rather than being a consequence of local phenomena during deposition.

We think that the cross section types and the diversity of the upper surface textures highlight different levels of erosion stages, from exhumation to today.

Inverted channels in Arabia Terra are mainly classified as Sinuous, with a Sinuosity value between 1-1.25, and have slopes of between 0.1°-0.6°. We found that lower slope channel segments have higher sinuosity for segment lengths of 10-20 km, but there is not a strong correlation in general between inverted channel sinuosity and slope. This result is perhaps not surprising, as Arabia Terra is a highly eroded region. Lower values of sinuosity are mainly associated with higher values of slope, as might be expected for fluvial systems. Longer channel segments generally have slightly higher sinuosity than shorter ones.

**Conclusions:** Based on a regional survey we produced a classification to summarize the morphological characteristics of inverted channels in Arabia Terra, Mars.

![Figure 2: Slope (top-left) and sinuosity (top-right) values calculated for different length-segments of inverted channels in Arabia Terra. On the bottom the graph sinuosity-slope for all the inverted channel up to 10 km length.](image)

The final classification was applied to 870 different inverted channels, demonstrating that the scheme is widely applicable, and could even be used for comparison with terrestrial analogues. The absence of a specific pattern in the distribution of inverted channel morphologies across Arabia Terra suggests that there is no regional control over the depositional style that has been recorded in their geomorphology. The sinuosity-slope calculations seem to follow terrestrial river system patterns, but there is no statistically significant pattern. The absence of a strong correlation of sinuosity with slope should be taken into account in further hydrogeological models and calculations based on inverted channel features.

**References:**