THE FORMATION OF INVERTED FLUVIAL CHANNELS IN GREEN RIVER AND HANKSVILLE, UTAH AS AN ANALOGUE FOR ARABIA TERRA, MARS. J.M. Davis[1], P. Fawdon[2], M. Balme[2], R. Barnes[3], S. Banham[3], M. Mirino[2], P.M. Grindrod[1], [1]Dept. of Earth Sciences, Natural History Museum, London, UK, joel.davis@nhm.ac.uk, [2]Dept. of Physical Sciences, Open University, Milton Keynes, UK, [3]Dept. of Earth Science and Engineering, Imperial College, London, UK.

Introduction: Inverted fluvial channels are common geomorphic features on Noachian (> 3.7 Ga) terrains across Mars [e.g., 1-3] as well as in semi-arid and arid environments on Earth [e.g., 1, 2]. Inverted channels comprise indurated palaeo-fluvial channel sediments which have been exhumed as ridges due to differential erosion [1]. Martian inverted channels have previously been used to derive palaeodischarge estimates [2] and inform about the nature of the early Mars climate [3].

The planform geometry and fluvial characteristics of inverted channels (i.e., anabranching, meandering, etc) on Mars have been used to characterize the Noachian fluvial environment [3, 4]. However, relatively little work has been done to compare orbital-scale interpretations of inverted channels with outcrop-scale observations. Both the ExoMars 2020 and NASA 2020 rovers may land on Noachian terrains where inverted channels are common [5, 6]; comparison between orbital and outcrop scale observations is thus critical for (1) deciding relevant outcrops to investigate and (2) interpreting martian palaeo-fluvial environments.

In this study, we investigated two clusters of inverted channels in the Green River and Hanksville regions of southeast Utah, both of which have previously been used as an analogue for inverted channels on Mars [7, 8]. We have used a combination of orbital and field observations to interpret the palaeo-fluvial environment of these channel systems and their development and preservation as ridges. Finally, we have applied our combined orbital and field observations to the Arabia Terra region of Mars, where numerous inverted channels are present [3] to test predictions about the nature of the Noachian palaeo-environment.

Geologic Setting: The Green River and Hanksville inverted channels in southeast Utah comprise three members from the Morrison (U. Jurassic) and Cedar Mountain (L. Cretaceous) Formations: the Salt Wash (M. fm), Brushy Basin (M. fm), and Ruby Ranch (C.M. fm) members [7, 9]. All three members are generally formed of interbedded packages of conglomerates, sandstones, and mudstones: alluvial sediments deposited after erosion of the Sevier orogenic belt to the west [7]. The fluvial systems were indurated due to the formation of silica and carbonate cements and later exhumed as ridges by the uplift and subsequent erosion which formed the Colorado Plateau [7].

We used the Williams et al. [7] field guide for site selection in Green River, and a site near the Mars Desert Research Station in Hanksville, which has been used for multiple Mars rover trials [e.g., 8]. Numerous inverted channels are present across the different field sites and there is good exposures of all three different stratigraphic members.

Orbital Observations: To investigate the sedimentary and geomorphic characteristics of the Green River and Hanksville inverted channels we used World View 2 (0.39 m/pixel, RGB) and National Agriculture Imaging Program (NAIP; 1 m/pixel, RGB; Fig. 1) orbital datasets and an NAIP digital terrain model (DTM; 5 m/pixel) of Utah to make topographic measurements.

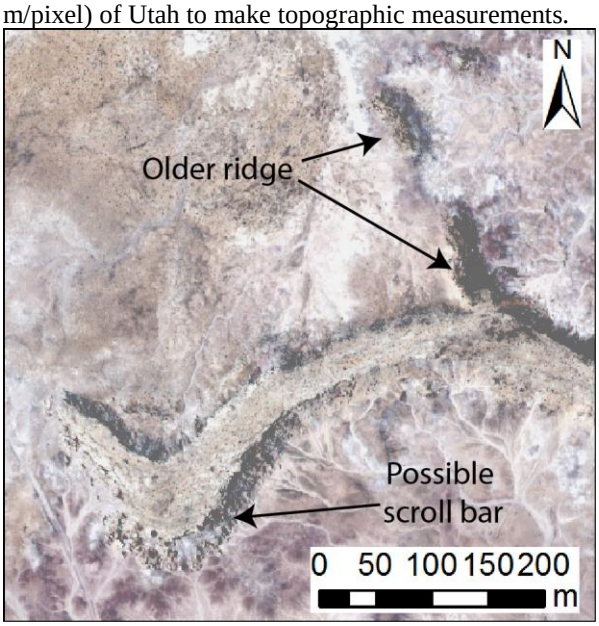

Figure 1: Orbital view of inverted channel in Green River visible in NAIP data.

Inverted channels are exposed at multiple points in the stratigraphy within all three members (Fig. 1), as indicated by the DTM. In the Brushy Basin and Ruby Ranch members, the ridges appear to comprise single-threaded channels up to 50 meters high. These inverted channels generally have a low sinuosity, although features interpreted as scroll bars are present in the Ruby Ranch inverted channels at Green River (Fig. 1), suggesting at least local lateral migration. Color changes within the layering exposed in the walls of the Brushy Basin inverted channels indicate possible textural or compositional variations vertically within the channels.

In contrast, what appear to be multiple laterally extensive, multi-thread channel systems are visible within the Salt Wash at Green River, indicating possible variations in fluvial or preservation style between the Salt Wash and the other members. The Salt Wash inverted channel deposits are generally only up to a few meters high and in both sites, the Salt Wash appears best exposed where the terrain have been incised by canyons.

Field Observations: We examined the sedimentary structures and grain-size variations exposed in the walls and top-surfaces of the inverted channel ridges. The inverted channels are generally capped by a resistant layer of conglomerates and/or medium to coarse sandstones. At both field sites the inverted channels are composed of interbedded packages of sandstones, mudstones, and conglomerates, rather than a single fining-upwards sandstone channel (Fig. 2), which was suggested by the single-threaded planform geometry of some the inverted channels, as observed from orbit.

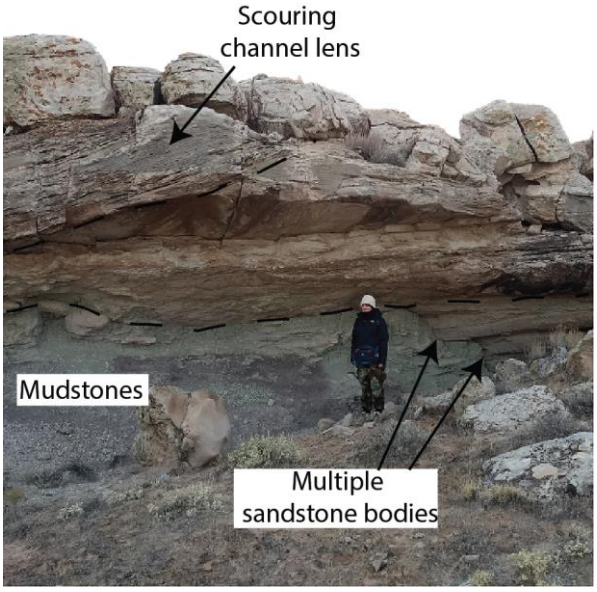

Figure 2: Outcrop view of Green River inverted channel comprised of multiple, interbedded sandstones and mudstones. Dashed lines show scoured channel surfaces.

Multiple fining-upwards channel lenses, channel scours, cross-stratification, and lateral accretion structures are present within the walls of the inverted channels, which are divided by laminated packages of mudstones (Fig. 2). Fewer mudstone layers are present in the Salt Wash inverted channels, although, significant thicknesses of mudstones are present in both the Brushy Basin and Ruby Ranch; mudstones are also observed in the flat terrains adjacent to the inverted channels in both these members.

Few, if any, of these sedimentary structures were clearly visible in orbital remote sensing data. Textures on the surface of the channels observed in remote sensing data did correlates to structures observed in the field. In the locations where potential scroll bars were observed from orbit, we did find several examples of low-angle troughs, consistent with lateral accretion surfaces exposed in the topmost part of the ridge. These observations are generally consistent with the inverted channels in Green River and Hanksville representing a former channel belt and flood plain.

Discussion and Implications for Mars: The vertical sand to mud ratio appears to be an important control on the topographic development of the inverted channels. In the sand-rich Salt Wash, the inverted channels are poorly expressed in topography (up to a few meters high), whereas in the mud-rich Brushy Basin and Ruby Ranch members, the inverted channels are up to 50 meters high. Mudstones are generally more susceptible to erosion than sandstones, thus faster erosion may have led to the Brushy Basin and Ruby Ranch forming higher ridges than the Salt Wash.

Applying these observations to Mars, the topographic exposure of many of the Noachian inverted channels in Arabia Terra (up to 50 meters [3]) is thus strong evidence that they do not represent a single fluvial event, but instead are probably comprised of multiple conglomerates, sandstones, and mudstones which formed as part of a channel belt and flood plain. As in the Utah sites, several of the inverted channels in Arabia Terra show exposed layers at their margins, also colour and erosional profile variations [3]. This suggests textural and/or compositional variation of the sediment within the inverted channels.

However, as inverted channels are not ubiquitous across Arabia Terra, there may have been variations in sediment transport and supply during the Noachian which has led to different styles of preservation (e.g., the emplacement of very mud-rich, particularly erosion-susceptible terrains could explain the absence of inverted channels in some areas). Thus, if Noachian Arabia Terra was characterized by channel belts and flood plains, we might expect the terrains now adjacent to the inverted channels to be composed of mudstones.

Finally, the planform geometry of the inverted channels can be deceptive. The single-threaded inverted channels do not necessarily represent a single fluvial event; this geometry instead reflects the preservation style of the uppermost layers of the fluvial deposits only.

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