DIFFERENCES IN FLUVIAL GEOMORPHOLOGY BETWEEN EARTH AND MARS.

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Introduction: Preserved geomorphological landforms on the surface of Mars indicate the presence of abundant liquid water in the early history of Mars. Researchers have observed depositional channels [e.g. 1], valleys and valley networks [e.g. 2-4], deltas [e.g. 3, 5-8], outflow channels [e.g. 9-11], open (or chain) crater lakes [e.g. 12-15], alluvial fans [e.g. 7, 16-17] and more on orbital images. Ground observations from the rovers have confirmed these interpretations [e.g. 18-19]. These geomorphic features were developed by erosion and deposition of sediments by water. It is therefore important to understand how fluvial sediment transport works on Mars and how it is different from Earth.

Due to the lower gravity on Mars water flows down slope with less energy, resulting in lower bed shear stresses, lower flow velocities and higher water depths or lower discharges. Nonetheless, fluvial sediment transport is more efficient. Due to the lower gravity the mobility of the sediment is higher. Bigger grains are brought into motion [20-21], larger grains are brought into suspension [20-21] and the magnitude of suspended transport is significantly higher [22], as is the total transport flux [23]. In addition, the settling of sediment is slower, resulting in larger transport distances on Mars compared to Earth.

Based on the differences in entrainment due to gravity, different grain size mixtures are transported and settle out in a different manner [23]. Therefore, the geomorphology and stratigraphy of geomorphic landforms might be different than we expect from Earth observations. In this study, we investigate how fluvial geomorphology differs on Mars through theoretical sediment transport calculations on Mars based on our terrestrial knowledge and experience. Additionally, we run preliminary numerical hydro-morphodynamic model simulations that allow to quantify some of these differences at a larger scale.

Methods: We use two methods: 1) standard parameterized equations to calculate sediment transport fluxes, and 2) numerical hydro-morphodynamic modelling of rivers and deltas.

Parameterised equations: We use standard hydraulic equations, like the Chézy formula, to calculate hydrodynamic conditions based on a slope, channel width and discharge. From these conditions we calculate sediment transport fluxes using a large number of sediment transport predictors for both bedload and suspended load transport. The majority of the predictors use the critical shields number for initiation of motion and use a reference concentration and Rouse profiles to calculate suspended sediment transport. Total load predictors are not suitable for Mars, as they do not account for a variable gravity effect with grain size.

Hydro-morphodynamic numerical modelling: In addition to estimations of sediment transport fluxes on Earth and Mars, we also run model scenarios to compare the evolution of fluvial geomorphic features with Earth and Mars gravity. We use the software package Delft3D-FM, developed for terrestrial river and coastal research and engineering [24], and amended the code to work on Mars. The code is based on the shallow water equation and different sediment transport predictors can be selected. We run scenarios with both Earth and Mars gravity for a river and a delta model and compare their results.

Results: Simple sediment transport calculation indicate that the sediment fraction at the bedload-suspended load boundary is most affected by gravity. In our examples transport could be up to 6 times higher for this fraction. Overall, the magnitude of the total transport flux on Mars is also bigger, predominantly because of increased suspended transport. As the bedload fraction is the ‘channel-building’ fractions and suspended transport determined channel-floodplain interaction, we hypothesise that floodplain deposition will increase. Additionally, with more sediment entering the floodplain levee accretion will increase, as will cut-off infilling and crevasse splays. We also hypothesise that increased suspension will reduce channel migration, reduce branching, increase the avulsion rate, and create more sinuous, narrow channels [25]. However, on Earth, more suspended sediment is generally correlated with more cohesion. Due to larger sediment sizes being suspended on Mars that are not cohesive, some of the effects might be different from what we expect and are still under investigation.

The preliminary model outcomes confirm our hypothesis that depositional slopes are lower due to longer advections lengths related to lower settling velocities. For example, this will transport more sediment to the delta front and pro-delta, impacting deltas foresets [26].

Finally, the models agree that geomorphic features develop faster on Mars. Or in other words, on Mars a larger landform develops than on Earth over the same time period. Our study assumes constant bankfull discharge. Next steps include looking at the effect of intermittency, since the intermittency on Mars might be lower than on Earth [27].

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