Watershed Analysis of the Eberswalde Delta (Early Hesperian), Mars

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Introduction

The Eberswalde Delta is an impressive delta fed by a complex, dendritic watershed. The delta implies there was standing water and possibly life in the crater and was a finalist candidate landing site for the Mars 2020 mission (Grant et al., 2018).

The watershed's morphometry and degradation history will be studied because it's an Earth-like dendritic river system. The study of its morphometry will constrain the controls on the incision of the watershed and its evolution. Also, the watershed has been degrading for 3.5 Ga so the evaluation of its degradation history will clarify whether the watershed could have been more complex in the past, how volumetrically large the watershed could have been.

Figure 1. Regional geological map surrounding Eberswalde from Irwin and Grant (2013). In the S. hemisphere highlands of Mars. Surface geology is Late Noachian – Early Hesperian in Age (~3.5 Ga). Holden Crater is to the south of Eberswalde, and Eberswalde incised into its ejecta.

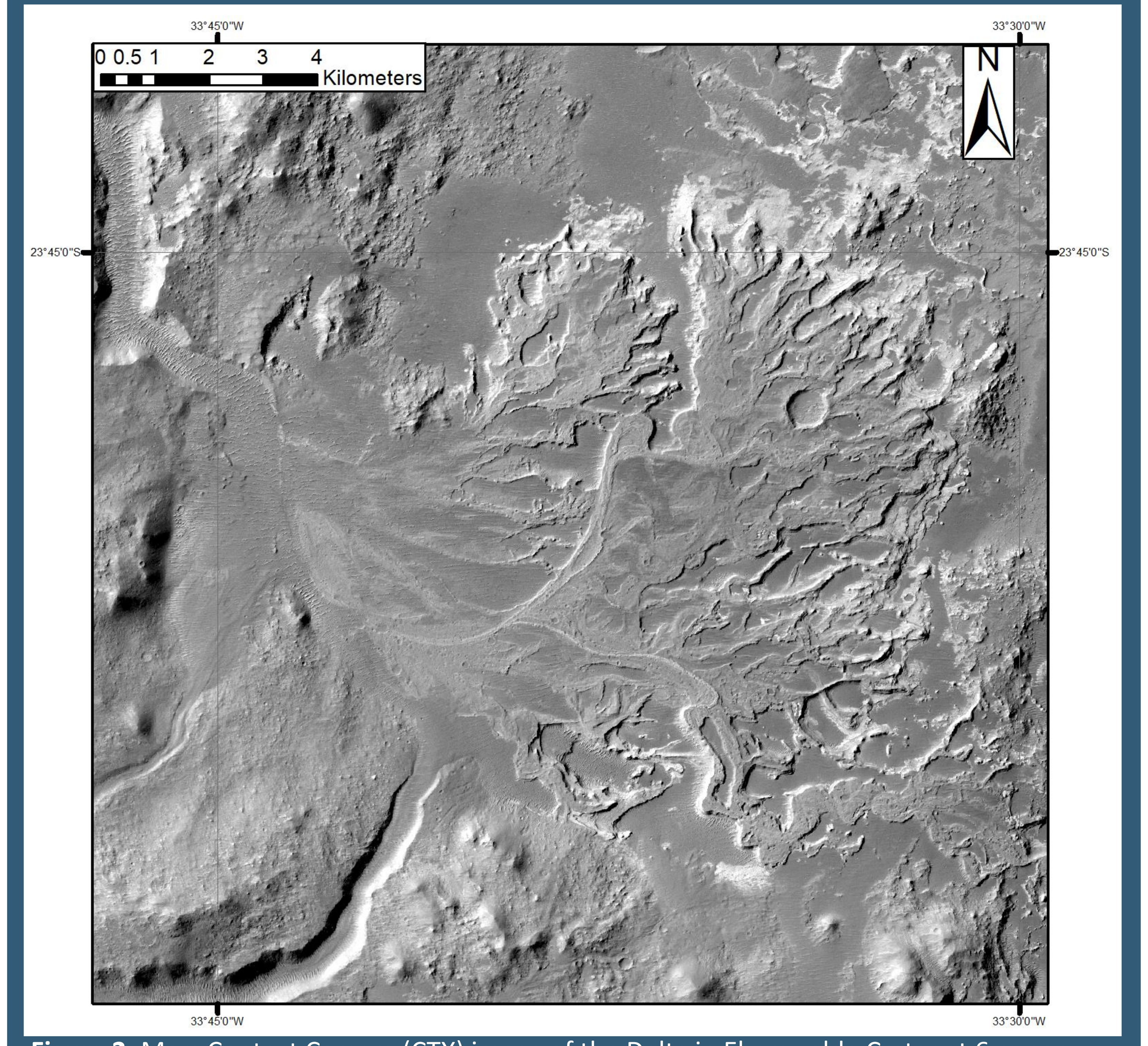

Figure 2. Mars Context Camera (CTX) image of the Delta in Eberswalde Crater at 6 m per pixel. This delta may suggest standing water and possibly life was in the crater. It was a finalist landing site for Mars 2020

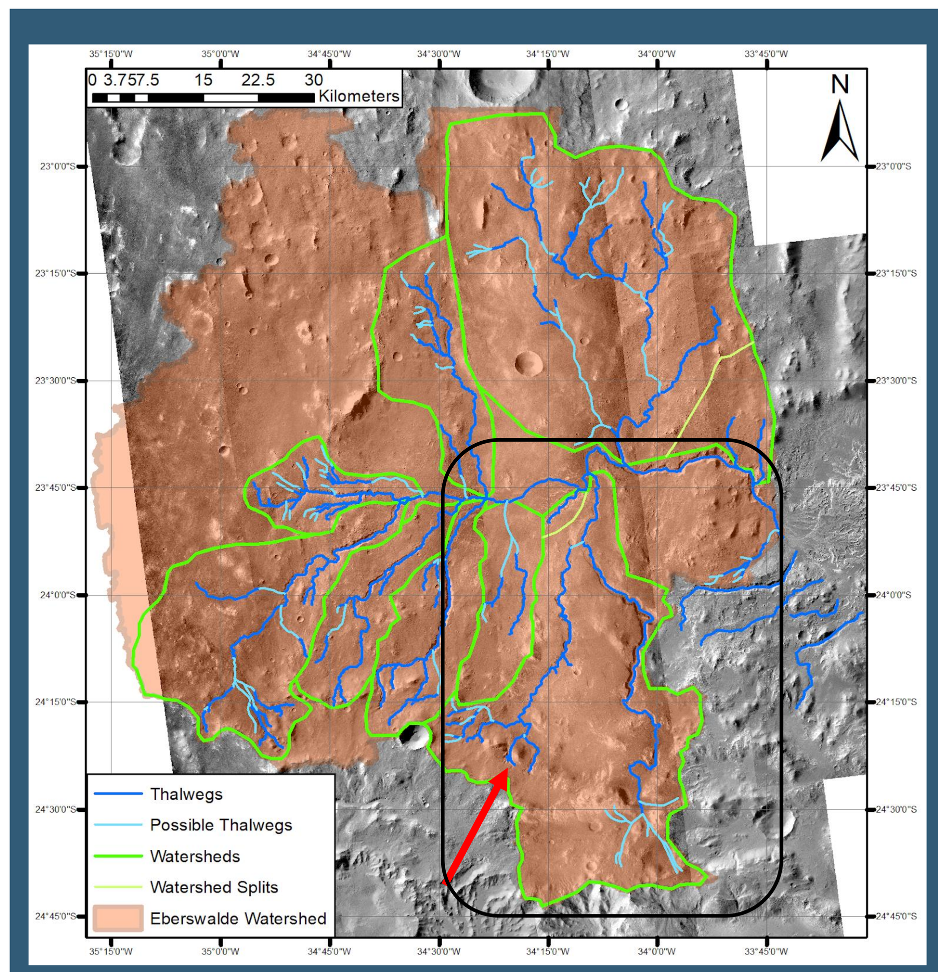

Figure 3. Map of the dendritic watershed flowing into Eberswalde created using Arc Hydro and a 17 m per pixel CTX digital elevation model (DEM). Red: whole watershed created using Arc Hydro. Green: manually mapped sub-watersheds. Dark blue: manually mapped thalwegs with DEM data. Light blue: manually mapped thalwegs without DEM data; used for stream ordering. Mapped thalwegs using imagery and/or DEM. Black box: study area for this poster. Red arrow: starting point for stream profile.

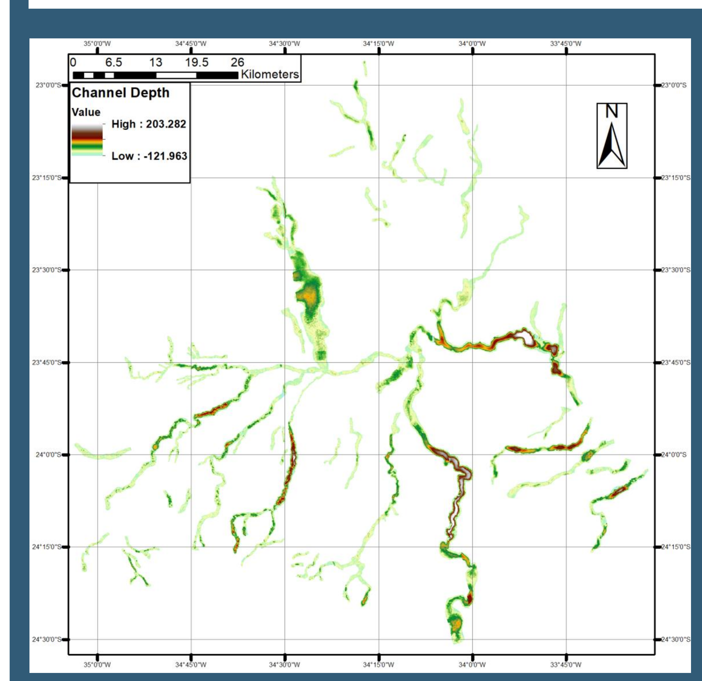

Figure 4. Depth map of the watershed. An elevation raster from bank to bank was interpolated by natural neighbor. The CTX DEM was subtracted from this to create the depth raster.

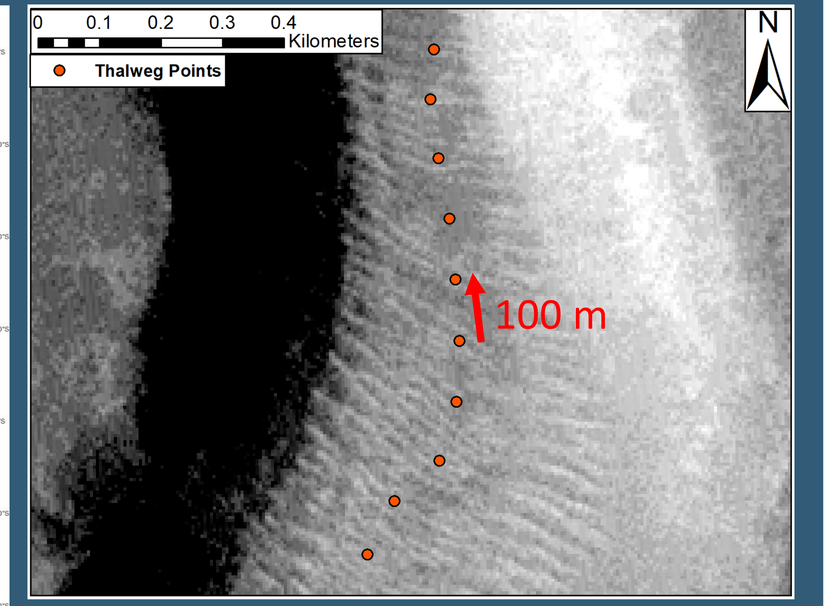

Figure 5. Sample thalweg with points space 100 m apart. The "generate points along line" tool was applied to the thalweg polylines to automatically create these points. All morphometric parameters were queried at each point.

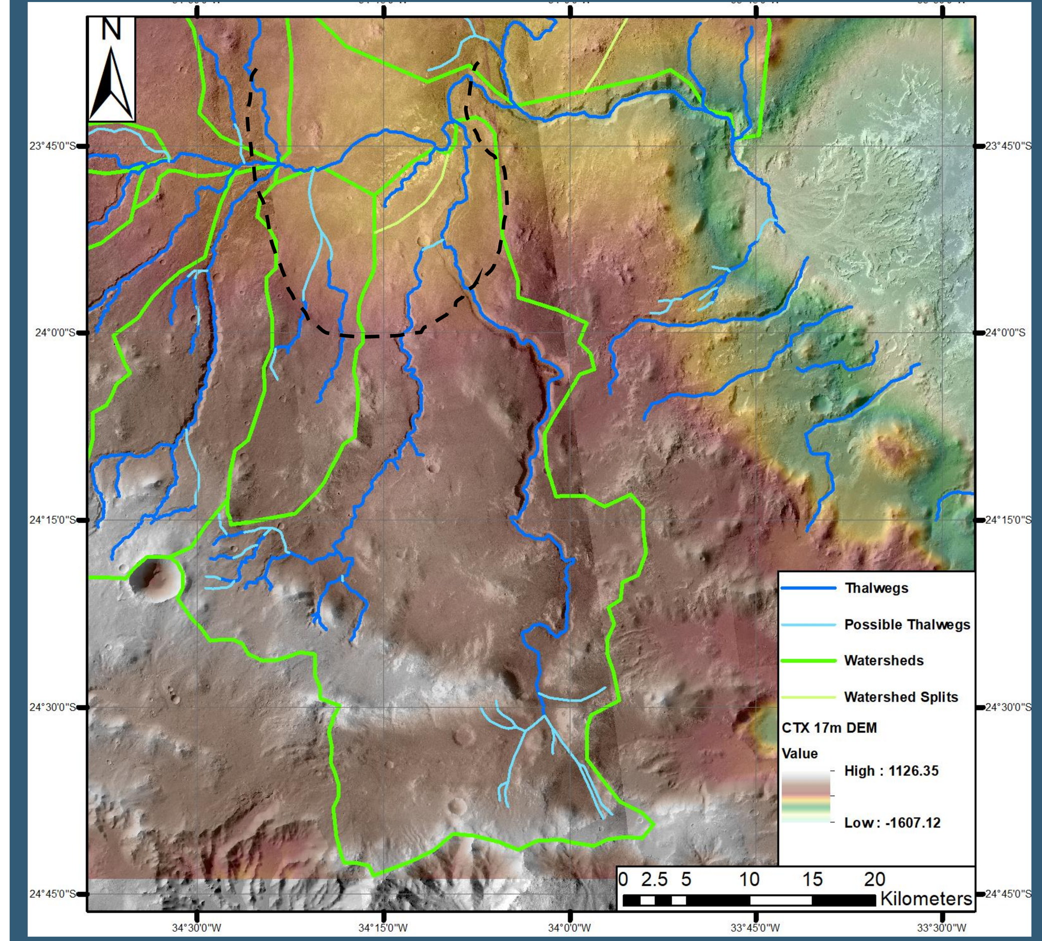

Figure 6. Map of the southern watershed. Thalwegs and watersheds on top of DEM and imagery. The highland streams emerge from near drainage divides. There is a sub-basin (black dashed-line).

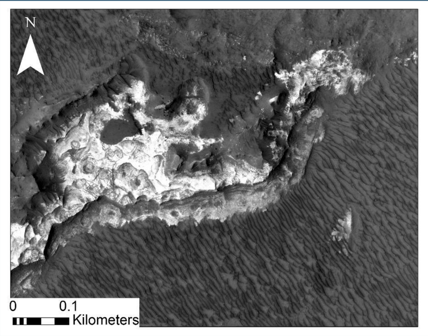

Figure 7. Alluvial deposits within the sub-basin. Suggests the sub-basin may have contained standing water.

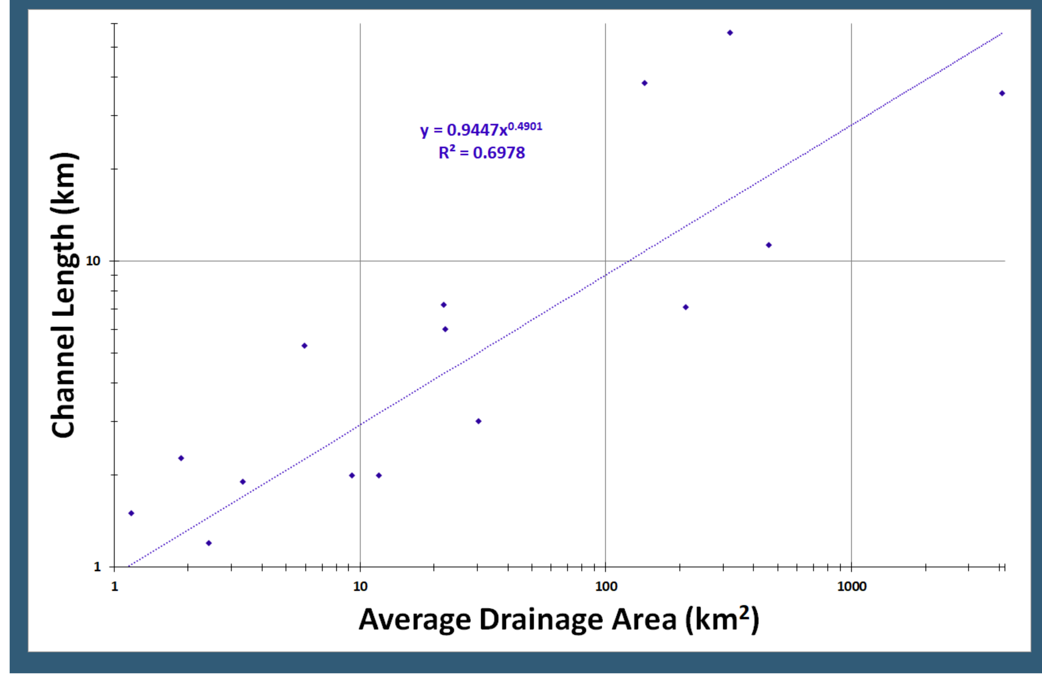

Figure 8. Average Drainage Area vs channel length plot for all channels in the southern watershed. Fit to a power function that follows Hack's Law. This law states that for terrestrial rainfall generated channels, Channel Length = (Constant)(Drainage Area)$^{0.5 \text{ to } 0.6}$ (Rigon, 1996).

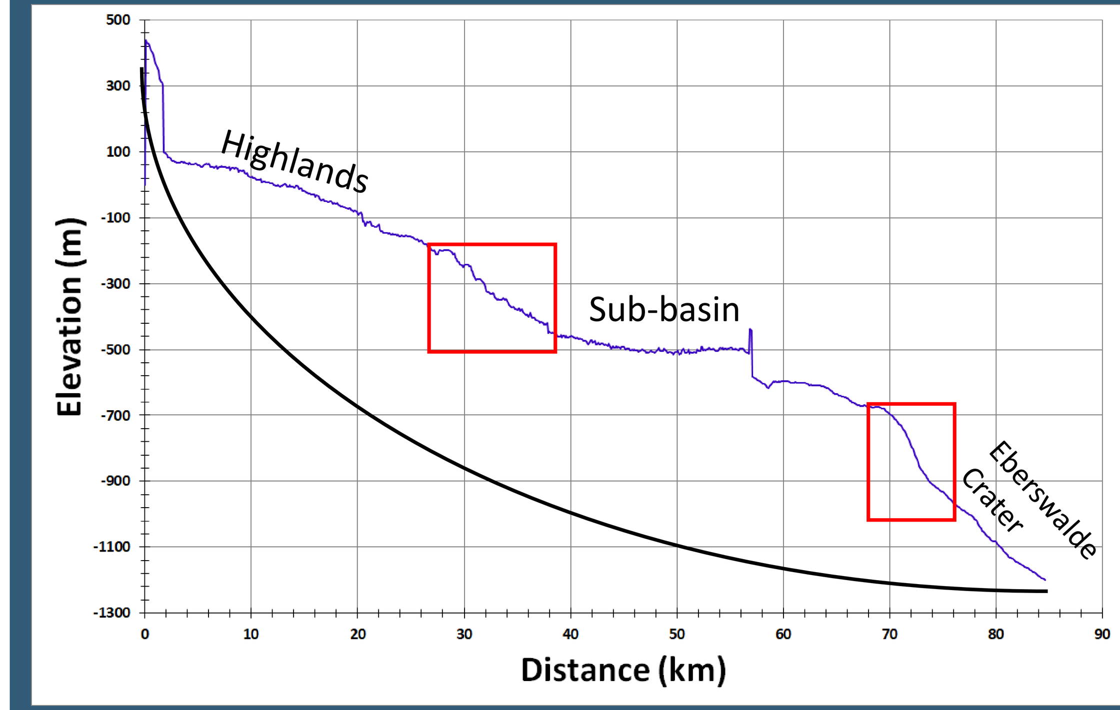

Figure 9. Stream profile (purple) from the southern watershed highlands to the delta. Unlike the mature, graded profile (black), the profile at Eberswalde is convex and contains knickzones (red). This suggests the system was youthful/short-lived.

Age of Eberswalde: 3.5 Ga (Mangold et al. 2021)
Degradation rates (Sweeney et al. 2018)

- Depth: 10^{-2} m/Myr -> 35 m of degradation by infill, mass wasting, surface erosion
- Width: 10%– 20% increase by back-wasting of channel walls

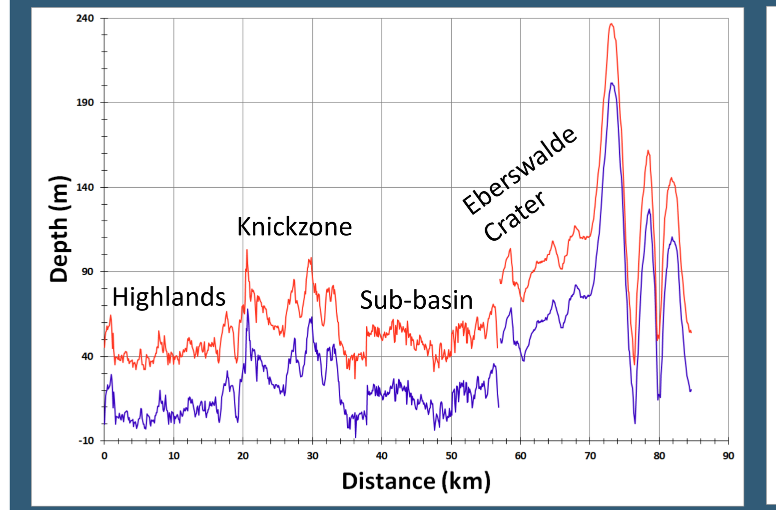

Figure 10. Channel depth vs distance downstream plot. Follows the same path as the stream profile. Purple: present depth. Red: past depth; accounts for 35 m of degradation. Depth depends on depends on water availability, slope, and lithology.

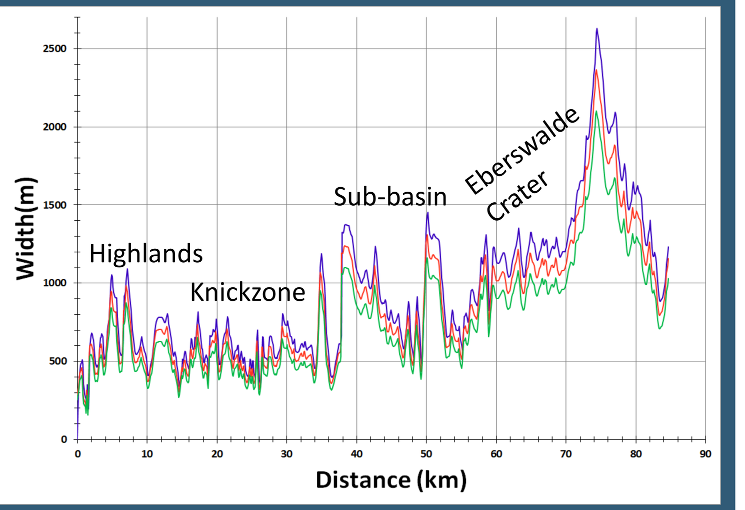

Figure 11. Channel width vs distance downstream plot. Purple: present width. Red: past width accounting for 10% width decrease. Green: past width accounting for 20% width decrease. Width depends on water availability, slope, and lithology.

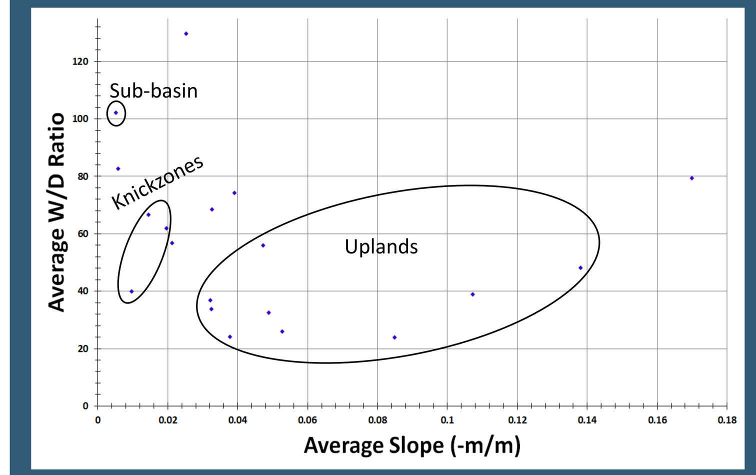

Figure 12. Average W/D Ratio vs Average Slope plot. W/D ratio depends on the lateral migration (width) vs vertical incision (depth) of a channel. Higher W/D -> relatively wide. Low W/D -> relatively narrow. W/D depended on both slope and lithology

Conclusion

The watershed is dendritic and complex, and the fact that it follows Hack's Law, and has streams near drainage divides suggest it could have been rainfall generated, although snowmelt and groundwater sapping cannot be discounted. The system was short-lived and youthful, as evident by the convex profile that preserves knicks. The data suggests that there could have been a warm/wet climate during the Early Hesperian, however it was likely short-lived. Slope and lithology controlled the width and depth of the system. W/D was greater in the sub-basin at low slopes than in the knickzones with high slopes. Highland streams with high slopes also had low W/D ratio. Lithology also controlled because the sub-basin channel was reworking alluvium. The variability in the W/D vs slope plot also suggest lithologic control from the heterogeneous ejecta of Holden Crater. Lastly, the system was volumetrically larger, but not much more complex in the past. The channels were 35 m deeper, which was larger relatively than the width decreases over 3.5 Gy. Yet, streams are presently near drainage divides, so the whole watershed could not have headward eroded further upslope than present. The whole watershed and surface age will be analyzed in the future.

References

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