strong signs of fluvial origin, including inner channels with widths of ~30 m to ~80 m (e.g. Irwin et al., 2005a) and intervening islands (Fig. 5 inset). From the extent of the inner channelization and overall incision, it is likely that this valley actively supported fluvial activity for an extended period of time (e.g. Mangold et al., 2004; Wood, 2006). The two outlet valleys have different morphologies (the large valley is straight and without preserved inner channels, whereas the smaller valley is more sinuous and has preserved inner channels); they also have different widths, which is consistent with different water discharges (e.g. Leopold and Maddock, 1953). Based on this, we postulate that the hydrological conditions of Erythraea Fossa were likely different when each of the outlet valleys were operating. However, we cannot rule out the possibility that at one time both valleys were active simultaneously, and the smaller valley was abandoned by a more gradual process due to higher incision rates and progressive capture of flow by the larger valley.

## 5. Implications

An active hydrological cycle in Erythraea Fossa would have ramifications for the paleoclimate in the nearby area, including Holden and Eberswalde craters, which are currently candidate landing sites for the Mars Science Laboratory (e.g. Griffes et al., 2009). The evidence for fluvial activity in Erythraea Fossa extends the evidence for paleolakes in Holden and Eberswalde craters to a broader region, as well as providing context for the climatologic factors to which they were subject.

The evidence that precipitation was an important source of water for the Erythraea Fossa system likely implies that precipitation was also a source of water for Holden and the surrounding area. While the OBPs in Erythraea Fossa could also have been supported in part by groundwater, based on observations elsewhere on Mars, precipitation is probably required to close the hydrological cycle and recharge aquifers (e.g. discussions in Grant, 2000; Craddock and Howard, 2002; Irwin et al., 2005b; Lamb et al., 2006; Di Achille et al., 2007; Williams and Malin, 2008).

It is also possible that there was a localized active hydrological cycle prior to the Holden impact, if dike formation associated with the formation of Erythraea Fossa interacted with the cryosphere or hydrosphere. This could potentially allow release of groundwater and/or cryospheric melt to the local environment, as may have happened in Cerberus Fossa (Head et al., 2003). However, the Holden impact likely would have obliterated any signs of that activity due to its size and proximity, and the features we see appear to be unrelated to the formation of the fossa.

The evidence of pervasive hydrological activity in Erythraea Fossa also has implications for the global martian paleoclimate. For example, the findings in this location imply that this region of Mars once had an atmosphere in a pressure and temperature range that permitted precipitation and liquid surface water (see Carr, 1996; Hynek et al., 2010). However, there is insufficient evidence to show whether the precipitation was rain, atmospheric condensation, or whether surface hydrology was dominated by snow, as it is today in the Antarctic dry valleys (Hecht, 2002; Costard et al., 2002; Christensen et al., 2003; Balme et al., 2006; Dickson et al., 2007; Marchant and Head, 2007; Dickson and Head, 2009). Also, sweeping generalizations about the entire hydrological cycle of Mars cannot be inferred solely from this investigation; just as local terrestrial environments vary widely, those on Mars probably also varied (e.g. discussion in Di Achille et al. (2007)).

## 6. Conclusion

Erythraea Fossa is a graben in close proximity to Holden crater that exhibits signs of extensive fluvial modification. We find three sub-basins connected to each other via a series of valleys that are likely of fluvial origin, forming a chain of three Open Basin Paleolakes (OBPs). The OBP chain has the capacity to hold 56 $km^3$ of water. Light-toned sedimentary deposits that are likely of deltaic or alluvial origin are observed on the graben floor.

Valleys at high elevation that were likely to have been carved by fluvial activity, along with fans and mass-wasting features in conjunction with catchment areas suggest that precipitation (or precipitation recharged aquifers) is at least one of the sources for water in the Erythraea Fossa OBP chain. Additionally, an abandoned distributary channel at the outlet of the West sub-basin of Erythraea Fossa with well preserved inner channels suggests that an avulsion took place that might have been caused by changes in hydrologic conditions either abruptly (e.g. a flood) or more gradually.

The findings at Erythraea Fossa have important consequences both for the local and the global paleoclimate. Their formation appears to require a climate that was at the correct pressure and temperature range to support surface water and precipitation and give clues about the nature of the Holden and Eberswalde hydrological cycles.

Future work examining the mineralogy of Erythraea Fossa, particularly in the high albedo tips of the fans, would further our understanding of the processes that took place in Erythraea Fossa. Additional high resolution images of the area, especially of the inner channels in the avulsed outlet from West sub-basin and of the fans, will also facilitate additional investigation into channel forming processes and allow us to look for layering in the fans.

## Acknowledgments

Buhler thanks Brown University and the Summer Undergraduate Research Fellowship program (Richter Scholarship) at the California Institute of Technology for financial support for this research. JWH gratefully acknowledges financial support as part of the NASA/ESA participation in the Mars Express High-Resolution Stereo Camera Team under JPL Grant 1237163, and the Mars Data Analysis Program, MDAP Grant NNX09A146G. Reviews from Paul McKay and technical help from and informative discussions with Ailish Kress, Laura Kerber, Jennifer Griffes, and Debra Hurwitz are greatly appreciated. We also extend our gratitude to Jules Goldspiel and Rebecca Williams for their insightful reviews that increased the quality of this paper.

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