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Evidence for paleolakes in Erythraea Fossa, Mars: Implications for an ancient hydrological cycle

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ABSTRACT

There is now widespread agreement that the surface of Mars underwent some degree of fluvial modification, but there is not yet full understanding of its surface hydrological cycle and the nature of standing bodies of water, rivers, and precipitation that affected its surface. In this paper we explore Erythraea Fossa (31.5 W, 27.3 S), a graben adjacent to Holden crater, which exhibits strong evidence that it once housed a chain of three lakes, had overland water flow, and was subject to precipitation. The inlet valley, outlet valley, and fan morphologies in the paleolakes are used to qualitatively discern the hydrologic history of the paleolakes; based on topography constraints, the three basins combined once held 56 km^3 of water. Depositional features within the basins that change with drainage area and nearby valleys that start near drainage divides indicate that the paleolakes may have been fed by precipitation driven runoff. This suggests the presence of an atmosphere, at least locally, that was capable of supporting a hydrological cycle.

1. Introduction

The characteristics of geologic features formed by the action of surface water on early Mars are important to help understand the martian climate near the Noachian–Hesperian boundary. Fundamental questions, such as whether the early martian climate was cold or warm, wet or dry, remain unresolved (see for discussion: Craddock and Howard, 2002; Gaidos and Marion, 2003; Moore et al., 2003; Burr et al., 2009; Hynek et al., 2010). An assortment of evidence for past widespread fluvial activity on Mars has been found. Studies conducted on the sedimentary rock record of Mars suggest lacustrine activity and subaqueous sediment transport (Malin and Edgett, 2000; Grotzinger et al., 2005). The morphology of martian valley networks suggests that they were formed by fluvial activity (Carr, 1995; Malin and Carr, 1999; Hynek and Phillips, 2003). It has also been posited that hundreds of craters and other depressions were ancient lakes during the period when the valley networks were formed (Cabrol and Grin, 1999; Fassett and Head, 2008a, 2008b). Additionally, hydrated minerals found in valley network-related sedimentary deposits support the hypothesis of fluvial sediment transport and surface water (Ehlmann et al., 2008).

Paleolakes are a particularly important marker of water on Mars. Strong evidence for paleolakes first arose in the analysis of Viking data (e.g. Goldspiel and Squyres, 1991) and, more recently, catalogues of hundreds of potential paleolakes on Mars have been compiled by Cabrol and Grin (1999) and Fassett and Head (2008b). In this paper, we describe in detail a newly identified chain of paleolokes in Erythraea Fossa (31.5 W, 27.3 S). We also delineate evidence for precipitation and multiple phases of fluvial activity at this location.

Candidate paleolake sites are commonly found in depressions that have *inlet valleys* which postdate the depression, particularly in craters (Howard et al., 2005; Irwin et al., 2005b). In some instances *outlet valleys* are also apparent (e.g. Fassett and Head, 2008b). An inlet valley leads into the depression from a higher elevation and an outlet valley leads from the rim of the depression to areas of lower elevation. When both an inlet and an outlet valley are observed, the features are referred to as (hydrologically) *open* (e.g. Fassett and Head, 2008b). Water traveling through the inlet valley would necessarily need to fill the entire depression before breaching the impoundment and forming the outlet valley. Depressions that have only inlet valleys are known as *closed* basins, since the absence of an outlet valley does not require the basin to have filled with water (Forsythe and Zimbelman, 1995; Forsythe and Blackwelder, 1998). Since open basins have constraints on water surface elevation (i.e. inlet *and* outlet valley elevations), these features exhibit strong evidence that they once were lakes, even though closed basin lakes and even lakes regulated solely by groundwater levels are also possible. Erythraea Fossa has several inlet valleys, as well as an outlet valley, and is therefore referred to as an Open Basin Paleolake (OBP).

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