Icarus 275 (2016) 163–182

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Eridania Basin: An ancient paleolake floor as the next landing site for the Mars 2020 rover

Maurizio Pajola[a,b,*], Sandro Rossato[c], John Carter[d], Emanuele Baratti[e], Riccardo Pozzobon[c], Marco Sergio Erculiani[b], Marcello Coradini[f,g], Karen McBride[h]

[a] NASA Ames Research Center, Moffett Field, CA 94035, USA
[b] Center of Studies and Activities for Space "G.Colombo", University of Padova, Via Venezia 15, 35131 Padova, Italy
[c] Geosciences Department, University of Padova, Padova 3513, Italy
[d] IAS, Paris-Sud University, Orsay 91405, France
[e] School of Civil Engineering, Department DICAM - University of Bologna, Bologna 40136, Italy
[f] European Space Agency, Paris 75015, France
[g] Jet Propulsion Laboratory, Pasadena, CA 91109, USA
[h] University of California Los Angeles, Los Angeles, CA 90024, USA

ARTICLE INFO

Article history:
Received 4 September 2015
Revised 29 January 2016
Accepted 31 March 2016
Available online 16 April 2016

Keywords:
Mars, surface
Geological processes
Spectroscopy
Image processing
Exobiology

ABSTRACT

The search for traces of past Martian life is directly connected to ancient paleolakes, where ponding water or low-energy water fluxes were present for long time intervals. The Eridania paleolakes system, located along the 180° meridian, is one of the largest lacustrine environments that were once present on Mars. Morphological features suggest that it was constituted by connected depressions filled by water to maximum depths of ~2400 m and a volume of at least 562,000 km^3. We focused our attention on the northern side of the Eridania Basin, where high-albedo, uneven patches of material characterized by the absence of dust are present. Based on OMEGA and CRISM orbital imaging spectroscopy data, a large clay-bearing unit has been identified there. In particular, a set of aqueous minerals in present in the stratigraphy, being visible through erosional windows in the first several tens of meters of the sedimentary sequence. Below this capping unit, a thin Al-rich clay stratum attributable to Al-smectite and/or kaolins is present. This overlies a Fe-rich clay stratum, attributable to the nontronite smectite. At the base of the mineralogic sequence a stratum that could be either a zeolite or more likely a hydrated sulfate is present. In addition, small deposits of alunite (a rare phase on Mars), and jarosite are here found at several locations. Such stratigraphy is interpreted as originating from a surface weathering process similar to terrestrial abiotic pedogenesis; nonetheless, possible exobiologic processes can be also invoked to explain it. NASA's Spirit rover landed on Gusev crater in 2004, near the mouth of the Ma'adim Vallis, which connects this crater with the considered paleolakes system. The Eridania site provides the unique opportunity to complete the measurements obtained in Gusev crater, while investigating the exposed mineralogical sequence in its depositionary setting. In addition, the extremely favorable landing parameters, such as elevation, slope, roughness, rock distribution, thermal inertia and dust coverage, support this location as **a** possible landing site for the NASA Mars 2020 rover.

1. Introduction

One of the major foci of Mars studies is the investigation of surface aqueous processes on early Mars and their possible connection with the rise and spread of life or prebiotic chemistry (Ori et al., 2000) on Mars. The most valuable candidates localities for the preservation of indications of microbial life are long-lasting environments characterized by the presence of ponding water (Ori et al., 2000; Cabrol and Grin, 1999, 2001, Pajola et al., 2016). As such, paleolakes represent depositional settings where, in ancient times, the development of primordial organisms may have been favored by the presence of standing water, low-energy water fluxes and nutrients (Scott et al., 1991; Ori et al., 2000; Cabrol and Grin, 2001, 2010; Grotzinger, 2014). For this reason, the exploration of mineralogies resulting from low-energy depositional settings can be considered one of the primary targets of Mars exploration missions (Cabrol and Grin, 2010; Mustard et al., 2013).

* Corresponding author at: NASA Ames Research Center, Moffett Field, CA 94035, USA.

E-mail address: maurizio.pajola@nasa.gov, maurizio.pajola@unipd.it, maurizio.pajola@gmail.com (M. Pajola).

http://dx.doi.org/10.1016/j.icarus.2016.03.029

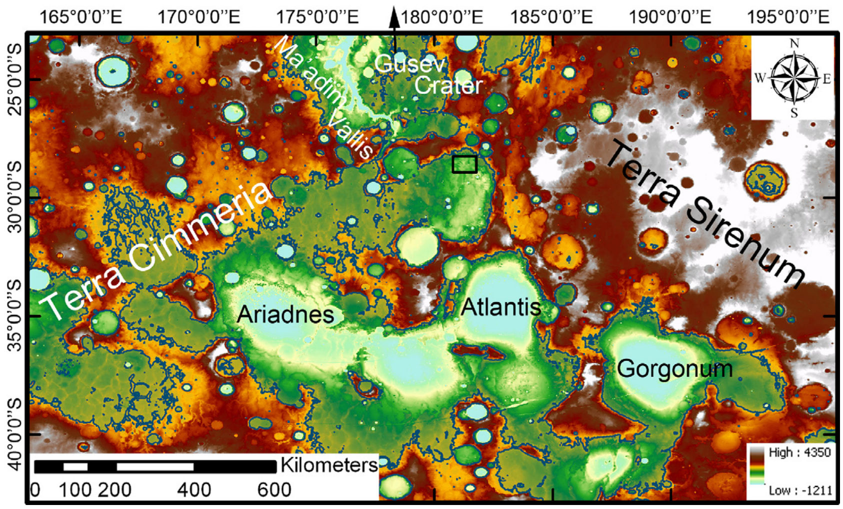

Fig. 1. MOLA elevation map showing the Eridania palaeolake system, its three major depressions, i.e. Ariadnes, Atlantis and Gorgonum and the Ma'adim Vallis. The black box corresponds to Fig. 2. The blue contour line indicates the 950 m MOLA elevation that corresponds to the Eridania lake shoreline as from Irwin et al. (2004a). The black arrow shows the flow direction of the Ma'adim Vallis towards Gusev Crater (which is located far north outside this figure.). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

From the Viking data to the Mars global topography measured by the Mars Orbiter Laser Altimeter, (MOLA), on Mars Global Surveyor (Zuber et al., 1992; Smith et al., 2001), various paleolakes have been discovered, together with valley networks and outflow channels (Cabrol and Grin, 1999, 2001; DeHon, 1992). Indeed, many impact craters located on the Mars surface may have once hosted paleolakes (Irwin et al., 2002; Di Achille et al., 2006; Mangold and Ansan, 2006; Cabrol and Grin, 2010; Mangold et al., 2012). In particular the Martian southern highland plateau shows evidence of many paleolakes, connected through valley networks and paleorivers (Pieri, 1976; Carr et al., 1981; Goldspiel and Squyres, 1991, Fassett and Head, 2008; Baratti et al., 2015), whose end of formation appears to be constrained at the Late Noachian – Early Hesperian boundary (Fassett and Head, 2008).

The entire region between Aeolis, Memnonia, Eridania and Phaetontis quadrangles (Davies et al., 1992), is characterized by connected and interrelated depressions along the 180° meridian, reaching the lowest elevations between the south pole and the northern lowlands (Smith et al., 2001). In particular, the Eridania area, located between 27° and 55°S latitude and 150°–210°E longitude, is considered the floor of one of the biggest closed drainage basins on Mars, which gave birth to the Ma'adim Vallis through catastrophic overflow (Irwin et al., 2002, 2004a, b).

Despite the fact that Eridania floor has been mapped as a volcanic ridged plain (Scott et al., 1986; Greeley and Guest, 1987), several sedimentary mineralogies have been recognized there (Irwin et al., 2004a, b), corroborating i) a low-energy and long-lasting (Late Noachian to Early Hesperian) depositional environment characterized by the presence of ponding water (Irwin et al., 2004a), and ii) a warm Martian paleoclimate with a stable highland water table more than ~3.5 billion years ago (Irwin et al., 2002).

For all the above reasons, the Eridania surface provides great potential to search for prebiotic chemistry and past exobiological life: thus we are proposing this region as the Mars 2020 landing site.

The paper is organized as follows: Section 2 provides the geographical as well as the geological setting; in Section 3 the dataset and the material and methods are given, while in Section 4 the geological analysis of the study area is reported. Section 5 focuses on the determination of the crater retention age; Section 6 details the mineralogical analysis of the identified sedimentary sequence, while in Section 7 the exobiologic implications of the Eridania site are presented. The last part of the paper, Section 8, evaluates the fulfillment of the engineering constraints required to propose Eridania Basin floor as a possible Mars 2020 landing site.

2. Geographical and geological setting

The Eridania Basin is located in the western hemisphere of Mars (Memnonia Quadrangle) between Terra Cimmeria and Terra Sirenum (Fig. 1). The study area is part of a region which is considered, both from morphological and mineralogical analyses, to have hosted a complex palaeolakes system (Irwin et al., 2002). As a whole, the Eridania lake is believed to have been from 1.1×10^6 km^2 (Irwin et al., 2002, 2004a, b) to 3×10^6 km^2 wide (Baker and Head, 2012) hosting an amount of water of at least 562,000 km^3, thus being one of the largest Martian lacustrine systems (Baker and Head, 2012). Due to the lack of major tributaries flowing into this basin, its existence is believed to have been related to groundwater springs, with minor contributions from overland flow (Andrews-Hanna et al., 2007).

The Eridania paleolake system is composed by three major depressions (see Fig. 1), named, from west to east, Ariadnes, Atlantis and Gorgonum (e.g. Molina et al., 2014; Adeli et al., 2012;Howard and Moore, 2011) and by several smaller depressions that may have hosted interconnected lakes too (Irwin et al., 2004a). The evolution of the system lowered its shoreline from around 1200–1250 m down to 950 m MOLA (Irwin et al., 2004a), consequently splitting the three main paleolakes into smaller water bodies (Michalski et al., 2015a).

This area hosts one of the largest valleys in the Martian highlands: the Ma'adim Vallis (Irwin et al 2004a). This vallis extends for about 900 km, from the Ariadnes basin to the Gusev crater/lake, which lies in the northern plains (Cabrol et al., 1998). The Ma'adim Vallis originates from a breach in the Eridania paleolake perimeter, that occurred during the Late Noachian (3.71–3.83 Ga) and caused a catastrophic flood (Irwin III et al., 2004a; Kuzmin et al., 2000). Afterwards, a more homogeneous and long-lasting flux of 1–5 millions of m^3/s took place (Irwin et al., 2004a) and shaped the valley into its present-day form.[1] Towards the end of this flow, the

[1] Subsequent, and still active erosive processes can be considered negligible at large scale.