Hydrothermal Activity recorded in Post Noachian-Aged Impact Craters on Mars

Stuart M. R. Turner1*, J. C. Bridges1, S. Grebby2 and B. L. Ehlmann3,4.

1University of Leicester, Space Research Centre, Dept. Physics & Astronomy, Leicester, LE1 7RH, UK (*smrt1@leicester.ac.uk). 2British Geological Survey, Nottingham, NG12 5GG, UK. 3Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, USA. 4Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA.

Introduction

The search for past habitable environments for microbial life on Mars requires the assessment of mineral assemblies that have been altered by a water-related process. It has previously been shown that impact-induced hydrothermal systems in the volatile-bearing crust of Mars have the potential to last for up to ~10 Myr [1], resulting in various phyllosilicate alteration phases [2]. Such systems have been associated with complex impact craters of 7 km diameter and above [1,2], which were of interest in this study [4].

The nakhlite meteorite parent rocks have recently been shown to have been partially altered by a hydrothermal brine at ~200 °C during the last 0.7Myr [3], in a near surface setting [6], producing the alteration minerals: smectite, serpentine, siderite, gel (figure 1). The presence of the gel indicates that the nakhlites underwent rapid cooling, suggesting an origin at the margins of an impact. It has also been shown by [5] that the phyllosilicate forming stage occurred at habitable temperatures (~50 °C) in a neutral to alkaline diluted brine, which carried elements essential for life [5]. This suggests that two shock events occurred; the first inducing a hydrothermal system that altered the near-surface nakhlite parent rocks and the second launching the nakhlites off Mars. The ejection event was shown to be 11 Myr ago [6] and radiometric dating has confirmed their age to be ~1.3 Ga [6]. Therefore the nakhlites originated from an early to mid Amazonian type locality.

This study [4] used the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) with the aim to identify the type of craters that the nakhlite alteration minerals – smectite, serpentine, siderite, gel – were identified in. The study highlighted here [4] focused on 158 impact craters and found that three of these impact craters contained hydrated minerals. LaBelle et al. [14] have identified hydrated minerals in heavily eroded sediment around the southwest region of the central uplift. The sediments appear to postdate the crater with no obvious link to the crater’s formation or potential impact hydrothermal activity.

The previously studied [11] 62 km diameter Stokes complex impact crater (figure 5) shows a suite of alteration minerals (serpentine, chlorite, nontronite, kaolinite and montmorillonite) that have been proposed to have formed pre-impact. However, studies have shown that Al-phyllosilicates might form as a result of partial alteration by a hydrothermal brine at ~200 °C during the last 670Ma [3], probably megabreccia blocks, rocky alcoves at the head of each of the gullies, and alluvial fans (figure 3) that have been partially eroded to reveal an older pre-existing secondary mineral assemblage [15].

Analysis Techniques

144 post Noachian-aged impact craters ≥7 km diameter and 14 smaller craters 3-7 km diameter were selected using the most recent Mars crater database [10] and the latest geologic map of Mars [8] (figure 2), in ArcGIS [4]. CRISM data for this subset of impact craters was then obtained for mineral characterisation in a near surface setting [5], producing the alteration minerals: smectite, serpentine, siderite, gel (figure 1). The CRISM spectral data was processed to remove all instrumental effects and to calibrate scene images to coincide radiance, from which I/F data is calculated [14]. The CRISM Analysis Toolkit (CAT) extension to ENVI was used for processing the CRISM I/F data. The photometric and atmospheric effects were corrected by division of the cosine of the solar incidence angle and by scaling the atmospheric transmission of CO2 [14].

The CRISM spectral data was processed to remove all instrumental effects and to calibrate scene images to coincide radiance, from which I/F data is calculated [14]. The CRISM Analysis Toolkit (CAT) extension to ENVI was used for processing the CRISM I/F data. The photometric and atmospheric effects were corrected by division of the cosine of the solar incidence angle and by scaling the atmospheric transmission of CO2 [14].

Conclusions

Gullies, alluvial fans, and upland breccia in the central uplift of an unnamed 20 km diameter impact crater (located at 52.42°N, 141.28°E in Elysium quadrangle) show spectral evidence for a chloride or Fe-serpentine that may have formed through erosion and redeposition of impact-induced hydrothermal mineral assemblages during the Amazonian epoch, although the exposure of pre-existing secondary minerals cannot be completely ruled out [4].

The study highlighted here [4] focused on 158 impact craters and found that three of these impact craters showed spectral features that suggest a hydrated mineralogy (figure 2). However, lack of clear spectral signatures due to small regions of interest and surface dust coverage has hindered the investigation [4].

References

[1] Abramov, O., and D. A. Kring, JGR: Planets, 110(E12), 2005. [2] Schwbringer, S. P., and D. A. Kring, Geology, 37(12), 1091-1094, 2009. [3] Swindle, T. D., et al. Meteor. Planet. Sci., 35, 107-115, 2000. [4] Turner, S. M. R., et al., JGR: Planets (in press), 2016. [5] Bridges, J. C. and S. P. Schwbringer, Earth and Planetary Science Letters, 359, 117-128, 2012. [6] Nyquist, L. E., et al., Chronology and Evolution of Mars, 105-164, 2001. [7] Hicks L. J., et al., JGR: Planets, 112, 1091-1094, 2009. [8] Changela, H. G., and J. C. Bridges, Earth and Planetary Science Letters, 359, 117-128, 2012. [9] Nyquist, L. E., et al., Chronology and Evolution of Mars, 105-164, 2001. [10] Changela, H. G., and J. C. Bridges, Earth and Planetary Science Letters, 359, 117-128, 2012. [11] Carter, J. C., et al., JGR: Planets, 112, 2007. [12] Carter, J. C., et al., JGR: Planets, 112, 2007. [13] Carter, J. C., et al., JGR: Planets, 112, 2007. [14] Rietmeijer, C. M., et al., JGR: Planets, 112, 2007. [15] Pelkey, S. M., et al., JGR: Planets, 112, 2007.