DETECTION OF ZOISITE FROM EOS CHAOS – IMPLICATION FOR HYDROTHERMAL ALTERATION ON MARS. Asif Iqbal Kakkassery[1], V. J. Rajesh[1], [1]Department of Earth and Space Sciences, Indian Institute of Space Science and Technology, Valiamala P.O., Thiruvananthapuram 695 547, India (asifiqbalka@gmail.com; rajeshvj@iist.ac.in)

Introduction: Fluvial features along eastern Valles Marineris have been considered as significant evidences for the past aqueous activities persisted on Mars [1,2]. Conspicuous mineralogical and morphological evidences for past fluvial activity have been observed while exploring a morphological terrain of eastern Valles Marineris, viz. Eos chaos region (Figure 1). A number of hydrated and hydrous clay minerals have been reported from numerous locations on Mars [3, 4,5]. Minerals indicative of metamorphism in prehnite-pumpellyite facies to lower green schist facies such as prehnite and chlorite have also been reported [5,6,7] . Zoisite, a hydrous mineral belongs to epidote group and usually associated with low grade minerals such as prehnite, pumpelleyite and chlorite, has rarely been described on Mars [7]. We report here an occurrence of zoisite in association with mono hydrated sulphates, poly hydrated sulphates, chlorite and pyroxenes from western Eos Chaos region and proposes a model for the formation of zoisite from hydrothermal water interaction in Martian subsurface where temperature is high when compared with low surface temperatures.

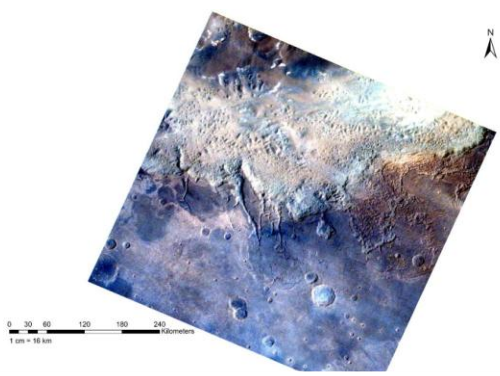

Figure 1: Mars Color Camera image which covers Eos Chaos located towards Eastern Valles Marineris.

Data sets and methodology: We used datasets of Mars Color Camera (MCC) of ISRO's Mars Orbiter Mission (MOM-I), Context Camera (CTX), High Resolution Imaging Science Experiment (HiRISE) and Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) hyperspectral data on board Mars Reconnaissance Orbiter. CRISM Map Projected Target Reduced Data Record (MTRDR) and browse products were downloaded from NASA's Planetary Data System (PDS) archive. CRISM images have been analysed using ENVI software and CRISM Analysis Tool (CAT 7.3.1) provided by the CRISM team. We detected monohydrated and poly hydrated sulphates in different locations within the CRISM scene FRT000063C5. Red pixels in PFM browse products indicate the presence of prehnite, chlorite or epidote [8]. Absorption features of the obtained spectra from the CRISM scene have been compared with absorption features of library spectra and spectra gathered from various literatures.

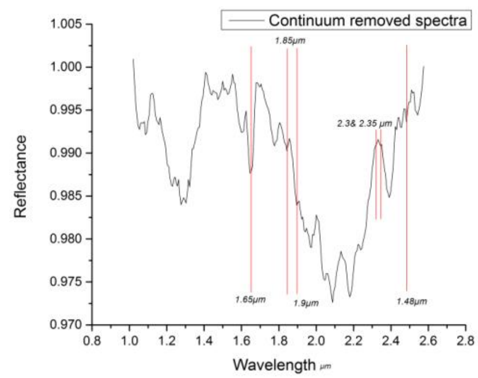

Figure 2: Possible zoisite spectra obtained from Eos Chaos region. Absorption due to OH at 1.65 μm instead of usual 1.4 μm is unique spectral feature of zoisite. Similar to zoisite spectra a weak absorption feature is present at 1.85 µm. It also have an absorption similar to water feature at 1.9 µm in zoisite spectra.The doubled features at 2.3 µm and 2.35 µm, and another band at 2.48 µm are also found in this spectra. Red lines have been drawn to indicate the absorption features described in USGS spectral library.

Results and discussions: Light-toned layered deposits have often been considered as supporting evidence for past aqueous activity and was reported from nearby Capri region [9]. Fluvial land forms such as out flow channels, chaotic mount with distinct layering, gullies etc. have also been identified in this study (Fig. 3).

Metamorphic minerals such as prehnite, chlorite, hydrated silica and analcimite has been identified from breccia blocks, isolated outcrops and eroded debris [6]. Present Martian environmental conditions are not favourable for the formation of metamorphic minerals such as prehnite which forms under highly restricted environment. This pinpoints a hydrothermally active subsurface condition with low pressure and temperature varying approximately from 250-380 ^oC where these minerals has been formed[7]. It also indicate rich aqueous environment and CO_2 poor condition. These minerals may have brought to the surface by various processes including impact cratering. We have detected spectra with dominant absorption feature at 1.6513µm (Fig2) from the slope of a wall of western Eos chaos where the surface has been subjected to intense erosional activity (Fig4). The absorption feature at 1.65µm is explained as a diagnostic absorption feature of zoisite due to the presence of OH group in mineral zoisite [10].

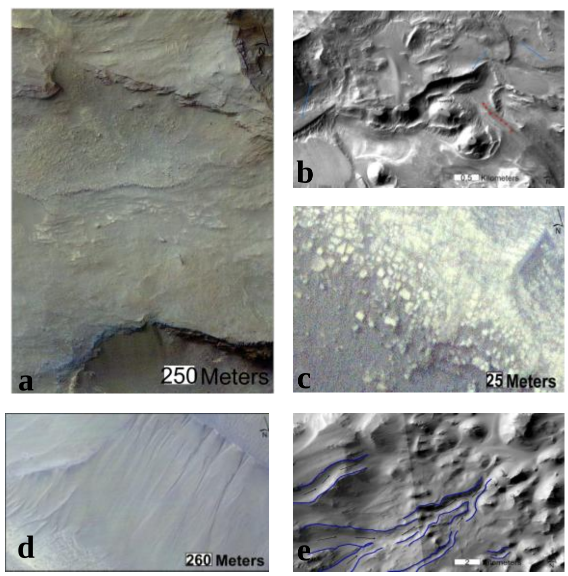

Figure 3: (a) Portion of HiRISE image showing distinct sedimentary layering. (b) Mesa units possibly formed as a result of erosional activity by running water. Blue arrow shows continues rock stratum. Black arrow shows the mesas. Area from Romerite spectra obtained is marked with red dots. (c) Angular fragmented light toned boulders. Kieserite spectra are obtained from these deposits (d) Gullies formed by possibly by fluvial activity. (e) Channels partially filled by Aeolian sediments. Black arrows indicate the direction of flow.

Conclusion: It has been interpreted that low Al_2O_3 content preclude generation of zoisite in Martian surface [5,11] though it is stable at higher temperature interval when compared with minerals of usual assemblages. Petrogenetic grid in [7] for mafic rocks of lowgrade metamorphic facies is explains stability field for Zoisite and its common assemblages. It is certain that zoisite is not a widely occurring mineral in Martian surface. But the surface features which shed light on the past aqueous environment along with eroded nature of surface from where the spectra has been detected indicates the subsurface hydrothermal fluid and water interaction that perhaps lasted in the formation of zoisite. As zoisite formation is not possible in present Martian conditions where temperature is extremely low, we can interpret that hydrothermal circulation of water with basaltic rock in subsurface environment and later erosional activity has brought them to surface.

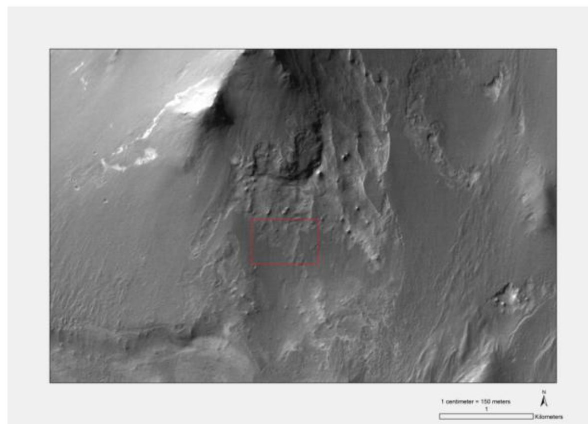

Figure 4: Portion of CTX mosaic of Eos Chaos showing SW dipping wall slope. Red box covers the area from where possible zoisite spectra is detected.

References: [1] Warner et al. (2013) Geology 41. [2] Wagner, N.H. Warner, and S. Gupta, (2016) *LPS XLVII*, Abstract #2214. [3] Thomas F. Bristow et al. (2015) *Ame.Mineralogist*, 100, 824-836[4] Ehlmann B.L et al. (2011) *Nature* 479:53–60. [5]Ehlmann B.L et al. (2011*) Clays and Clay Min., Vol*. 59, No. 4, 359–377[6] Ehlmann B.L et al. (2009) *JGR* 114, E00D08. [7] McSween H.Y et al. (2015) *Meteoritics & Planet. Sci.* 50, Nr 4, 590–603[8] Viviano beck et al. (2014) *JGR* 119, 1403–1431 [9] Flahaut et al.(2010) *JGR* 115, E11007 [10] Clark, R.N. et al. (1990) *JGR* 95, 12,653-12,680. [11] H. Y. McSween et al. (2011) *LPS XLII*, Abstract # 1064.