FORMATION OF PALEOSOL (FOSSIL SOIL) IN DECCAN CONTINENTAL FLOOD BASALT: ALTERATION STYLE AND IMPLICATIONS TOWARDS AQUEOUS ENVIRONMENT OF EARLY MARS.

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Introduction: Deccan CFB (~65-67 Ma) in India are tholeiitic in composition and chemically similar to martian basalt (low Al_2O_3 and high FeO) thus may be considered as useful analogue of Martian crust [1]. Therefore, given that bulk of the Martian crust is mafic to ultramafic in composition, abundant Fe/Mg-rich hydrated phases are predicted to form [2]. The paleosols or red-boles in Deccan CFB are common horizons generally found to occur between the two basalt flows and represent either as weathering product of the neighbouring basalts or hydrothermal alteration of volcanic ash falls or weathered pyroclasts during the quiescence time-interval between two eruptions (Fig. 1) [1,2,3].

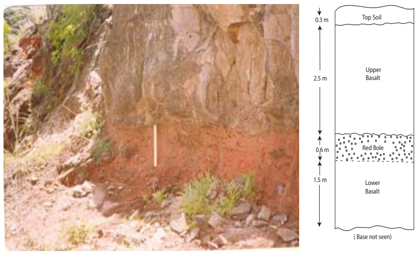

Fig. 1 Typical profile of red-bole horizon in Deccan CFB province (near Saswad area, Pune, Maharashtra) India

Phyllosilicates form under variety of environmental conditions and therefore can be used as important clues for weathering processes. Orbiter and rover based studies revealed the most common phyllosilicates on Mars include Fe/Mg-rich smectites (~49%) followed by Al-rich hydrated silicates (~49%) which are useful environmental indicators on ancient Mars [4,5,6]. Stratigraphic correlation is poorly defined in Mars due to vast dust exposure. However, aluminous clay (kaolinite) are generally found to overlie the ferromagnesian clay (smectite) [7]. The exact reason of these particular mineral assemblages in a stratigraphic succession is not fully understood yet. Several hypotheses exist to explain their formation mechanisms: e.g. regional scale leaching, sedimentary deposition or even weathering and sublimation under icy environments [8,9]. Recent analyses by APXS, ChemCam and CheMin XRD data provide an excellent opportunity to examine in-situ chemistry and mineralogy of Martian surface and therefore reasonable to compare with terrestrial paleoweathering profiles [10, 11].

In lieu of sample return, using synthesis of chemical, mineralogical and geochemical analyses of terrestrial phyllosilicate are therefore useful and significant in establishing constraints for the ancient aqueous conditions on Mars in regions where phylosilicates are detected by hyper spectral remote sensing and recently by onboard payloads Mars Science Laboratory. Therefore, we have carried out a mineralogical and geochemical study of paleosol (fossil soil) from terrestrial weathering profiles of Deccan CFB and compare our data with Martian crust and smectite in order to understand and compare the paleoweathering process of Earth versus Mars.

Geological setting and Analytical techniques: Present samples were collected from different sectors of red bole horizon in order to assess trend of alteration, viz. contact zone with underlying and/ overlying basalt flow, bottom most flow and top flow from Deccan CFB.

Characteristic identification of terrestrial phyllosilicate were carried out though XRD. Bulk chemical analyses were obtained using XRF. The accuracy of international rock standard BHVO-2 is better than ±5%. Mineral chemical compositions were performed using EPMA following usual routines. Natural and synthetic standards are employed too check the precision and accuracy.

Martian mineral chemical and bulk chemical data are obtained from Mudstone at Yellowknife Bay, Gale crater, Mars [10,12]. Gale crater (~155 km diameter) mainly represents the Noachian age and located along geomorphic and topographic boundary (dichotomic boundary) between northern lowland and heavily cratered southern highland, Mars.

Mineralogy and Geochemistry: XRD analyses revealed the presence of smectite with characteristic peak at d=15Å (Fig. 2). FTIR further confirms they are ferruginous smectite and or near montmorillonite.

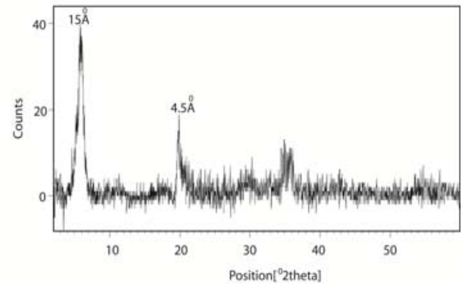

Fig. 2 Typical XRD pattern of red bole

Deccan BSE image of altered basalt chips as found within red-bole show alteration Fe-Ti rinds correspond to weathering of terrestrial basalts (Fig. 3). By contrast, Martian smectite at Gale crater shows a range of XRD pattern, e.g. 12 to 9.4 Å and 12 to 17 Å respectively.

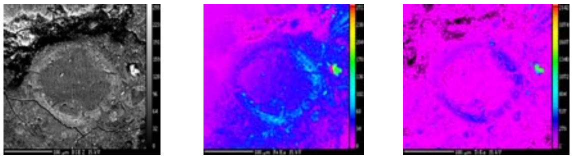

Fig. 3 BSE image and X-ray mapping (for Fe and Ti)

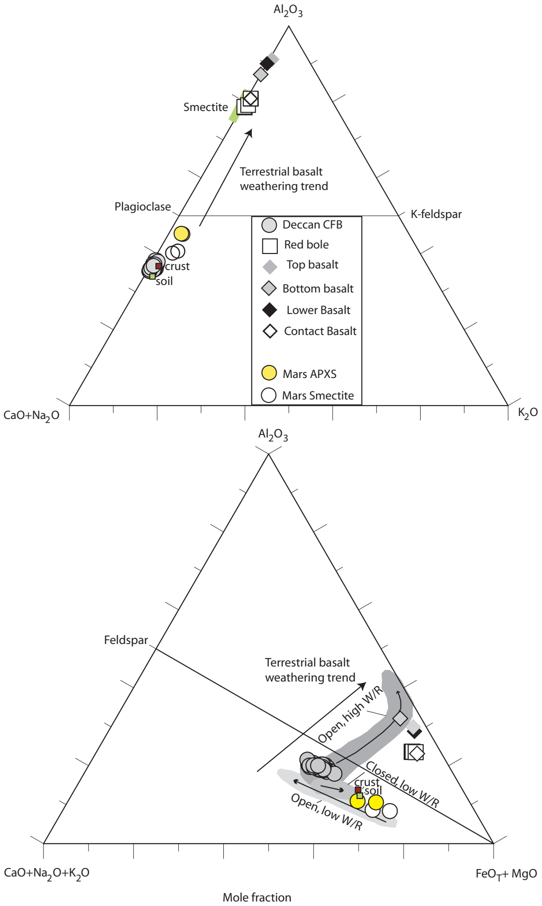

Fig. 4 $(CaO+Na_2O)$-K_2O-Al_2O_3 and $(CaO+Na_2O+K_2O)$-Al_2O_3-(FeO_t+MgO) triangular plots of terrestrial and Martian crust and soils [10, 11, 13]

Phase chemistry of smectite group of minerals reveals they are Al and Fe-rich variety (Al_2O_3 and FeO_t up to 21 wt% and 17 wt% respectively) and agree with the whole-rock composition as well (Al_2O_3 13-14 wt% and FeO_t 20 wt%).The Deccan red bole samples fall on smectite field and follow the terrestrial weathering trend (Fig. 4). Top most basalt inhibits the highest Al_2O_3 content. Lower basaltic flow in contact with red bole is chemically indistinguishable. In-situ analyses of Martian crust and smectite fall below the feldspar line. CIA (Chemical index of alteration) values of Deccan red bole is almost uniform (~80) as compared to top lava flow (~91) and bottom one (~87). By contrast, CIA of Martian counterpart refers to lower value (40-45).

Discussion: Based on the mineralogy and geochemistry, it is ascertained that Fe smectite is the predominant clay mineral in Deccan red bole and likely to be formed due to weathering of underlying basalt flow. Climatic condition also played a major role towards formation of clays as elemental mobility varies under weathering conditions: Mg is more mobile than Si, which is more mobile than Al [14]. Based on stable O isotopic data it is further suggested that rainfall amount was significantly high during the late Cretaceous, i.e. the time of Deccan lava eruption [3]. Therefore smectite formation of Deccan red bole was much conducive in a temperate-humid climatic condition (also in high W/R ratio and open system) which allow release of Fe^{2+} , Mg^{2+} and Si^{4+} cations in solutions followed by evaporation leading to super saturation of smectite minerals. By contrast, Martian smectite does not support substantial chemical weathering. Instead, a closed system, subsurface water is more important for formation of phyllosilicate on Mars. Limited chemical fractionation is also evident as alkali oxides are less mobile as compared to terrestrial counterpart. The mineralogy and geochemistry of phyllosilicate of Gale crater suggest there may be a transition of water-rich to water-poor climatic condition during the late Noachian-Hesperian (Phyllosian-Theiikian).

In summary the present work suggests that the weathering-induced clay formation processes on Earth and Mars appear to be contrasting in nature. The high W/R, open system and substantial leaching of elements are more common on Earth, while on Mars, low W/R, preferably in closed subsurface system and isochemical changes play the major role in the clay formation.

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