

REGIONAL CARBONATE- AND KAOLINITE-BEARING ROCK UNITS AND HOW PRECURSOR LITHOLOGIES CONTROL ALTERATION PRODUCTS ON MARS: AN EXAMPLE FROM THE NILI FOSSAE REGION. B. L. Ehlmann¹, J. F. Mustard¹, and the CRISM Team. ¹Department of Geological Sciences, Brown University, Providence, RI 02912 USA (bethany_ehlmann@brown.edu)

Alkaline soil chemistries revealed by Phoenix lander investigations [1] and smectite clays discovered by the OMEGA instrument on Mars Express [2-4] suggest neutral to alkaline aqueous alteration has been important on Mars in both the Amazonian and Noachian epochs, in contrast to dominantly acidic conditions indicated at both MER landing sites. The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard the Mars Reconnaissance Orbiter has discovered additional phases resulting from near-neutral/alkaline pH aqueous alteration—diverse hydrated silicates (chlorite, serpentine, illite/muscovite, kaolinite), prehnite, magnesium carbonate, and zeolites [5-7]. Here we describe regional kaolinite- and carbonate-bearing rock units found in Noachian terrain near Nili Fossae and hypotheses for their formation.

Stratigraphy: The kaolinite- and carbonate-bearing rock units are at most a few 10s of meters thick and show no bedding at HiRISE (25 cm/pixel) resolution. Both units occupy a similar stratigraphic position above a brecciated unit of Fe/Mg smectite and unaltered mafic silicates, interpreted to be ejecta and fallback from the Isidis impact [8]. In many cases, the kaolinite- and carbonate-bearing units are overlain by a mafic cap rock that shows no evidence for alteration minerals. There is a clear geographic zoning of kaolinite vs. carbonate, with the latter prevalent in the eastern portion of the Nili Fossae region, associated with a thin, regional unit enriched in olivine [6,8] (Fig. 1).

Timing: Both units definitely post-date the Isidis impact (i.e. formation mid-Noachian or later) [9]; however, both are also cut by the fossae. This indicates that at least some of the alteration occurred prior to the fossae opening, which probably occurred in the Late Noachian [10].

Formation mechanisms: As discussed in [6,8], the Mg carbonate (and also serpentine [7]), probably represents localized, partial alteration of a mostly unaltered regional olivine-rich rock unit [8]. Carbonate, serpentine, and olivine are found in laterally varying zones which show no distinctive morphologic change to coincide with the changes in unit spectral properties. One possibility for the formation of carbonate and serpentine in olivine-rich rocks is hydrothermal activity under elevated pCO₂. Emplacement of hot olivine-rich rocks as Isidis impact melt or volcanic flows on top of water-bearing phyllosilicate rocks may have initiated hydrothermal alteration in a zone along the contact. An alternative explanation is surface weathering. Mg car-

bonates are observed weathering products for olivine-rich meteorites in Antarctica [11] and terrestrial serpentinite bodies [12].

Where olivine is not detected in VNIR spectral observations, carbonate is also not detected. Kaolinite is frequently found above smectites and beneath the mafic cap. Kaolinite can form hydrothermally, though the spectrally distinct high-temperature polymorphs dickite and nacrite are not observed. Another plausible formation mechanism is pedogenic-type leaching of pre-existing smectite-bearing deposits, leading to loss of Ca, Mg, and Fe ions and precipitation of kaolinite, as in formation of kaolin-bearing soils from basalts in Hawaii [13]. Ongoing investigation of the *in-situ* bedrock and intact stratigraphy of the kaolinite- and carbonate-bearing rocks here should permit determination of constraints on the timing and processes of neutral/alkaline aqueous alteration on Mars.

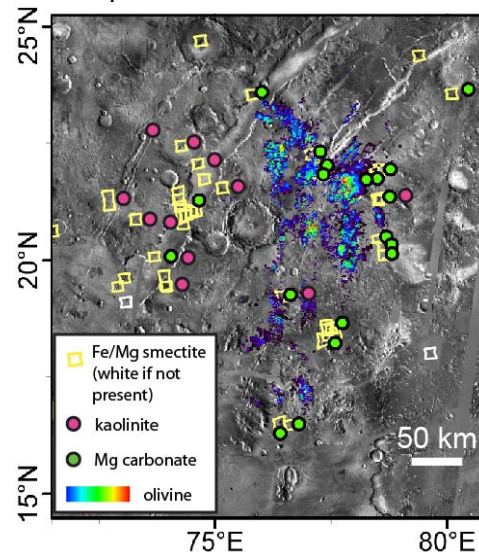


Figure 1. Distribution of kaolinite (magenta dots), magnesium carbonate (green dots), and Fe/Mg smectites (orange outlines) identified in CRISM targeted data in relation to mafic rocks with olivine spectral signatures around the Nili Fossae, mapped using OMEGA data as in [6].

References: [1] Smith P et al. (2009) *LPSC 40* #1329 [2] Poulet F et al. (2005) *Nature* 438, 623 [3] Bibring J-P et al. (2006) *Science*, 312, 400 [4] Chevrier V et al. (2007) *Nature* 448, 60 [5] Mustard J et al. (2008) *Nature* 454, 305 [6] Ehlmann B et al. (2008) *Science* 322, 1828 [7] Ehlmann B et al., in rev., *JGR*, doi:10.1029/2009JE003339 [8] Mustard J et al., in rev., *JGR*, doi:10.1029/2009JE003349 [9] Werner SC (2005) Ph.D., Berlin [10] Wichman R, Schultz P (1989) *JGR* 94 17333 [11] Jull A (1988) *Science* 242, 417 [12] Moeller P (ed.) (1989) *Magnesite*, Monograph Series on Mineral Deposits, 28, Berlin-Stuttgart [13] Ziegler K et al. (2002) *Chem. Geol.*, 461.