IDENTIFICATION OF PRIMARY NOACHIAN CRUSTAL BLOCKS ON MARS WITH CRISM OBSERVATIONS. J. R. Skok[1], J. F. Mustard[1], S. L. Murchie[2]. [1]Dept. of Geological Sciences, Box 1846, Brown University, Providence, RI 02912 John_Skok@brown.edu. [2]APL, John Hopkins Univ., Laurel, MD 20723

Introduction: The nature, origin and evolution of Mars' Noachian crust is relatively unknown [1]. Detailed analyses of meteorites point to an early differentiation event for the planet but the only rock definitively of Noachian age is the Martian meteorite; ALH84001, comprised of >95% orthopyroxene [2]. Our understanding of the composition of the Martian crust is derived mostly from Amazonian-aged meteorites that are basaltic or cumulates derived from basaltic magmas [1]. Remotely sensed data show a primarily basaltic surface as well for the Hesperian-Late Noachian ridged plains [3,4]. It has been recently shown that phyllosilicates formed by alteration of igneous rocks are common in Noachain terrains [5,6]. Four billion years of impact gardening, aqueous alteration, and resurfacing has left few coherent sections of early Noachian crust exposed at the surface [7]. Apparently what remains exists largely in breccia blocks often embedded in a matrix containing alteration minerals. These remnants of ancient Martian crust offer a significant sampling of the earliest crustal formation on Mars and a starting mineralogy for the wide-spread aqueous alteration that occurred in the early Noachian.

One hypothesis is that Mars initially had a magma ocean surface that crystallized mafic minerals [8]. Alternatively the crust may be an accumulation of extrusive and intrusive magmatism. Subsequent aqueous alteration of the mafics into phyllosilicates seems to be very widespread globally but constrained to the earliest Noachian period [9]. The identification and characterization of the earliest mafic crust will provide critical constraints on the early history of Mars.

This work defines the indentifying characteristics of the early Noachian mafic crust and documents the initial search and cataloging of the features with observations from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument [10]. We consider which regions on Mars are most likely to preserve exposures of the early mafic blocks and search the existing hyperspectral data for mineralogical signatures of the Noachian crustal blocks.

Datasets and Methods: The brecciated nature of the remnant early crust requires high-resolution observations to discern individual blocks and the component mineralogy. The CRISM instrument on the Mars Reconnaissance Orbiter (MRO) is capable of 18 m/pixel full resolution images and is used to detect the Noachian crustal blocks by their unique mafic mineralogy. The decimeter-scale resolution of the High Resolution Imaging Science Experiment (HiRISE) camera [11] also on board MRO will be used to understand morphology and associate it to mineralogy.

Identification of Noachian mafic crust has been both contextual and spectral. We have considered crater counting to estimate general surface ages and focus on areas either in Noachian-aged terrain or where ancient terrain may have been exposed by impact, tectonic, or erosional processes. Previous work has shown that Noachian crust is enriched in low-calcium pyroxenes (LCP) such as enstatite and pigeonite [4].

Cataloging these crustal blocks provides a database of features to probe the earliest crust on Mars. In areas of good exposure, many examples allow for the careful constraining of mafic compositions and local variations. We compare well-characterized areas to other areas of limited exposure to research regional and global variations.

Initial spectral characterization involves understanding the component minerals and mineralogical context. Starting with CRISM and OMEGA data, initially we evaluate Fe-bearing mafic minerals; pyroxene and olivine and work to constrain their compositions. Where exposures are large enough we will employ thermal infrared data to constrain the broader silicate mineralogy. We also observe the mineralogy of the matrix and adjacent lithologies that may have altered from the early mafics in an attempt to constrain the alteration process.

Results: To study the early Martian crust we focus initially on a few selected regions that offer the opportunity to preserve and expose early mafic crust: the well exposed Noachian-aged highlands near Nili Fossae, deep crustal sections exposed in Valles Marineris, and large impacts in the northern plains that excavate Noachian-aged basement rocks.

The Nili Fossae region northwest of the Isidis Basin has an excellent exposures in scarp walls, impact craters, and also in deeply eroded sections. This region has undergone intense aqueous alteration leaving isolated blocks of well-exposed early Noachian crust. Figure 1 shows an example of LCP spectra from Noachian crustal blocks imaged in CRISM observation FRT0000BFD1.

Next, we examined the floor of Valles Marineris. The deep chasms of Valles Marineris cut through thick Hesperian volcanic deposits to the Noachian-aged basement. Observations of these regions have shown strong mafic signatures. One example comes from CRISM observation FRT00005F84 in Coprates Chasma with a typical LCP-rich spectrum shown in Figure 1.

While much of the Northern Plains have experienced recent resurfacing [12] that has obscured exposures of Noachian-aged terrain, large impacts have excavated Noachian-aged material from below the surface. One such example is a central peak captured by CRISM image FRT0000CF84 with a typical LCP spectrum shown in Figure 1. This crater has a diameter of 23 km and a current depth of ~1 km, with a central peak likely excavating material from >2 km. A mafic parameter map of this observation is shown in Figure 2. The central peak has distinct regions of olivine and LCP with little mixing, while the dark mobile material down slope contains a mixture of olivine and HCP. Further work will investigate the nature of the abrupt change in central peak mineralogy such as if it is adjacent megabreccia blocks or a boundary between intrusive magmatic bodies.

Discussion: The identification, cataloging, and initial characterization of early Noachian mafic crustal blocks is the first step toward understanding the composition, formation, and spatial variation of Mars' oldest surface. Presented here are three examples of early Noachian crustal blocks located in diverse regions of Mars. Although LCP is seen in all exposures, the example from Vallis Marineris has a 2 μm pyroxene band center at a lower wavelength indicating a higher proportion of LCP minerals. These variations were observed between exposures and will be combined to systematically map variations in pyroxene ratios between regions on Mars. These observations will constrain the crustal formation hypotheses and provide information on the heterogeneity inherent to the original Martian crust.

Mineral compatibility is also examined at these sites. In FRT0000C4E6, we see that olivine and LCP exist in distinct regions, while HCP is often seen together with olivine. Multiple observations will allow these relationships to be further explored and understood. Understanding the mineralogy of Noachian-age crustal blocks we expect to constrain the initial conditions of the Martian crust and how it may have formed.

References:[1]Taylor et al. (2008) *The Martian Surface.: Composition, Mineralogy, and Physical Properties*, ed J.F. Bell III, Chapter 22, Cambridge University Press [2]Gleason et al., (1996) *Geochimica at Cosmochimica Acta*, 61, 16, 3503-3512 [3]Christensen et al. (2000) J. Geophys.. Res., 105, E4, 9609-9621 [4]Mustard et al. (2005) Science 307, 5715, 1594-1597 [5]Poulet et al (2005) Nature 438, 7068, 623-627 [6]Bibring et al. (2006) Science, 312, 5772,400-404 [7]McEwen et al. (2008) AGU Fall Meeting P43D-03 [8]Elkins-Tanton et al., (2005) *J. Geophys. Res.*, 110, E12S01 [9]Mustard et al. (2007) *J. Geophys. Res.*, 112, E08S03 [10] Murchie et al. (2007) J. Geophys. Res. 112, E05S03 [11] McEwen et al. (2007) J. Geophys. Res., 112, E05S02 [12]Tanaka, K.L. et al, (2003) *J. Geophys. Res.*, 108, E4, 8043[13] Pelkey et al. (2007) *J. Geophys. Res.*, 112, E08S14

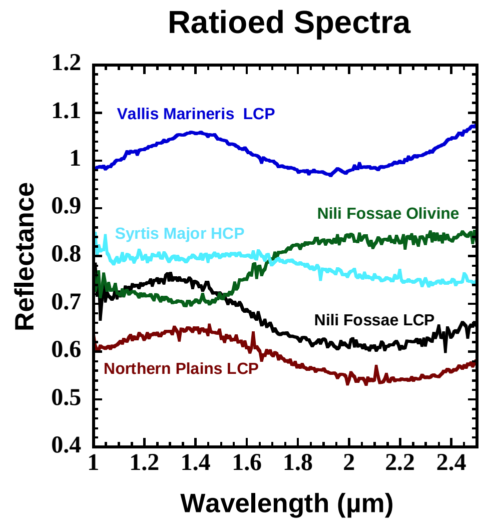

Figure 1. Example mafic signatures from Noachian terrains throughout Mars. All spectra are ratioed to dust. LCP spectra are shown from the three locations discussed. A Nili Fossae olivine spectrum is shown to illustrate the mafic diversity seen in these sites. For comparison a high-calcium pyroxene spectrum from Syrtis Major is included.

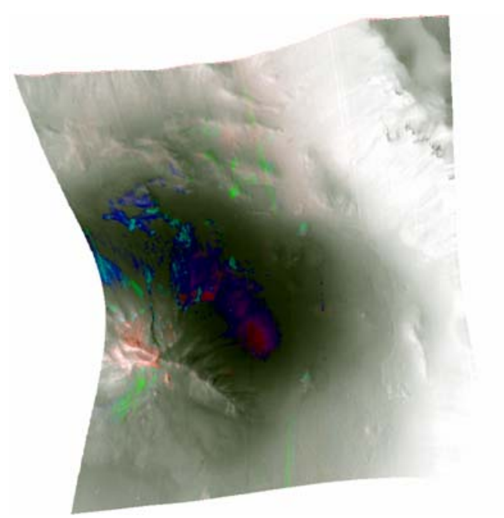

Figure 2. Mafic parameter map of CRISM observation FRT0000C4E6, R: Olivine index, G: LCP index, B: HCP index[13]. Bottom left is center peak of 23 km diameter Northern Plains crater. Peak shows distinct olivine and LCP exposures. Below peak is dark mobile material with a mix of HCP and olivine. Image is ~10km across. (15.2E 52.7N)