AN ARGUMENT FOR ZEOLITES IN MARS ROCKS AND AN EARTH ANALOG.
Abhijit Basu¹, James Schmitt², and Laura J. Crossey³,
¹Dept. Geol. Sci., Indiana University, Bloomington, IN 47405 (basu@indiana.edu); ²Dept. Earth Sci., Montana State University, Bozeman, MT 59717 (uesjs@trex.oscs.montana.edu); ³Dept. Earth Planet. Sci, University of New Mexico, Albuquerque, NM 87131 (lcrossey@unm.edu)

Our geological knowledge of Mars comes from spacecraft observations, Viking and Pathfinder Landers, and SNC meteorites. Near surface material of Mars are primarily the products of volcanic, impact, hydrologic, atmospheric, and debatably, biological processes. The volcanic rocks are principally basaltic in composition, impact-shocked and fractured to various degrees [11,13,19,22,23], and weathered to produce oxide, carbonate, sulfate, and clay minerals [3,10,25]. It is not known if biological activity [16] produced any mineral in Martian rocks as is common on the Earth [2]. Petrologic studies on SNC meteorites and terrestrial analogs have so far concentrated on igneous, evaporative, and fracture-filling secondary minerals. Possible diagenetic processes have not received much attention. We argue below that diagenetic processes that might have operated on Mars should have produced zeolites in Martian volcaniclastic rocks.

Water on Mars was likely stored as permafrost [1,6,21]. If Martian climate alternated between short-term warm-wet and long-term cold-dry conditions [1], salts would precipitate in playa settings [24]. Otherwise, volcanic and impact processes would melt the permafrost driving a geothermal circulation pattern [5,6,7,21] that closely resembles models of hydrothermal circulation around terrestrial impact structures [14]. Material and ambiance would be different on Mars, where we expect volcaniclastic and cataclastic debris derived from basaltic rocks as the principal sediment, normally a low liquid water/rock ratio except for brief periods, virtually no constraint on pH (although the presence of carbonates in SNC meteorites indicates high pH at places/times), and a very high oxidative state (high Eh) at the surface. Zeolites are common alteration products of volcanic glass and feldspars, and occur as cement in volcaniclastic sandstones on Earth. Biogenic SiO₂ aids in zeolite precipitation [9].

We have begun an appraisal of zeolite distribution in the volcaniclastic sedimentary aprons surrounding the Late Cretaceous bimodal Elkhorn Mountains and mafic Adel Mountain volcanic centers in western Montana. These strata comprise the Upper Cretaceous Two Medicine (TMF) and Judith River (JRF) Formations, and contain syn-eruptive pyroclastic sediment, primary lava flows, and epiclastic debris shed from erosion of volcanic edifices during dormant phases, interbedded with non-volcanic sediments delivered from eroding thrust sheets of the nearby Cordilleran thrust belt. Zeolites occur as alteration products, in veins and vesicles of the primary igneous and pyroclastic rocks, and as cement in volcaniclastic sandstones of the TMF and JRF. Sandstones derived from eroded thrust plates are rich in quartz and lithic fragments (recycled orogen provenance) and have primarily clay and calcite cements with little zeolite. Although zeolite and calcite are not mutually exclusive cements, zeolite is the most common cement in volcaniclastic sandstones; calcite cement dominates lithic sandstones. It appears that sandstone composition is the driving factor in determining the primary cementing minerals. We conclude that had there been no sediment input from thrust sheets, all volcaniclastic sediments would have been cemented
primarily by zeolite and subordinate clays and calcite. Zeolite cementation is spatially distributed in a somewhat annular pattern surrounding the Adel Mountain volcanic field. We attribute this pattern to development of a hydrothermal circulation system set up around the Adel Mountain eruptive center, which in our opinion resembles models devised for terrestrial impact craters [14] and Mars [21]. We suggest that zeolites appear to be the best candidate for cementing the volcaniclastic sediments of Mars.

Our initial search of the literature on SNC meteorites reveals that although carbonates and sulfates occur as alteration or weathering products [10,18], no report of any zeolite as a diagenetic mineral exists. Zeolites are found in association with both calcite and gypsum in terrestrial rocks. Although at relatively low temperatures high CO$_2$ may impede zeolite precipitation [15], zeolite is found in rapidly quenched high temperature carbonate globules immiscible in an alkali basalt in Hungary [8]. It is interesting to note that the hotly debated carbonates in ALH84001 [17] are morphologically similar to the Hungarian occurrence but do not have any zeolite despite evidence of presumably H$_2$O-bearing vapor being present.

The absence of zeolites in SNC meteorites is intriguing and may cast some doubts on the origin of SNC meteorites [12], the postulated hydrothermal circulation system so convincingly argued at the Conference on Early Mars [6], or even on the amount of liquid water present on Mars [5]. We believe that the absence may simply be an artifact of paucity of Martian meteorites and suggest that future “Landers” on Mars carry instruments capable of detecting zeolites in rocks that appear to be conglomerates and sandstones (i.e., sedimentary rocks) to the next “Sojourner”.