Introduction: Sulfate minerals of the alunite-jarosite family have been identified in stratified deposits at numerous locations across Mars, including two of the rover landing sites [e.g., 1,2,3, 4]. Because these minerals typically precipitate from aqueous solutions and are stable only under acidic conditions, there has been considerable interest in studying their occurrence in martian settings as indicators of depositional and diagenetic conditions on early Mars [e.g., 3]. Many terrestrial occurrences of jarosite and alunite that have been proposed as analogs for these minerals have no clear relevance to the geologic setting where they occur on Mars. In southern Utah, however, Jurassic sandstones at Mollies Nipple (MN) contain jarosite and alunite cements whose characteristics may be very similar to the stratified deposits on Mars. In addition, previous studies have indicated these deposits to be spectrally similar to many of the martian deposits [5,6].

Although the rocks at MN are early to middle Jurassic, the diagenetic history that resulted in the precipitation of the jarosite and alunite cements is not understood. The results of the investigation will be used to gain insights into the origin and persistence of mineral from the alunite-jarosite family in martian settings. The principal objective of this study is to understand the origin of the jarosite and alunite cements that are present in the sandstones at MN and to use this information to interpret depositional environment and subsequent diagenetic conditions that may have affected the stratified rocks containing these minerals on Mars.

Geologic Setting: MN is a butte in southern Utah composed of eolian Navajo Sandstone (Fig.1A). It is resistant to erosion due to the presence of a well-cemented, finer-grained caprock. The jarosite and alunite cements are present only in this caprock; however, float rock from erosion of this caprock gives the entire mountain a jarosite spectral signature in airborne data [5,6].

Methods and Results: Field methods are used to determine the sedimentological properties of the jarosite-bearing rocks. The base of MN is bleached Navajo Sandstone where original iron oxide grain coatings would have been reduced and mobilized during infiltration of a reducing solution (Fig.1A). Based on our initial investigation of sedimentary structures and mineralogy, the caprock, although mapped as Navajo Sandstone in photogeologic maps, may actually be an intertonguing of the Page Sandstone and Carmel Formation that overly the Navajo Sandstone in the region. Jarosite and alunite cements are segregated within this caprock, but the mineral zones crosscut lithology as well as fractures, so no visible lithological or structural features control this differentiation of cement (Fig.1B).

Scanning electron microscopy is used to observe euhedral jarosite cubes in the yellow portions of the rock (Fig. 1B, 2A). Alunite is present with abundant kaolinite (an aluminosilicates precipitated in acidic conditions) in the white portions of the rock, but clay
minerals are very sparse in the jarosite-bearing rocks (Fig. 1B, 2B). Some jarosite-bearing rocks exhibit red rims where decomposition of the jarosite leads to hematite formation. In these transition zones decomposition of jarosite cubes is visible leaving malformed “shells” filled with fuzzy jarosite (Fig. 2C). Also present are microbial fossils in close proximity to jarosite with both euhedral and unusual habits (Fig. 2D).

Conclusions: Likely explanations for the origin of jarosite and alunite cements include: (1) Precipitation from highly acidic pore waters during deposition in an sabkha/eolian depositional environment. (Thick sulfate deposits are present within the Carmel Formation ~20km to the NW), or (2) the sulfates precipitated from acidic fluids during burial or late-stage diagenesis long after the sandstones were deposited (1’s-10’s Ma time scales). In either case, a puzzling aspect of the occurrence of the jarosite-alunite cements is that they have likely been exposed to circumneutral groundwater for at least 10 Ma (in the case of scenario 2) and up to 170 Ma (in the case of scenario 1) since their precipitation, which would seemingly contradict experimental studies suggesting that dissolution of these minerals is relatively rapid under such conditions [7,8].

Possible explanations for the recalcitrant jarosite and alunite cements include: 1. Previous laboratory studies underestimate the stability of jarosite-alunite in natural settings and on geologic time scales, or 2. Interaction with organic polymers [9] or inclusion of trace elements such as silicon [10] renders the crystal structure resistant to transformation to hematite similar to examples of iron oxyhydroxides. It is noted that most crystal morphologies in these ancient sedimentary examples are similar to abiotic examples from volcanic environments, except where they coexist with putative microbial fossils. This study has implications for the interpretation of martian sedimentary settings and their habitability because these environments may have had much more neutral fluids than previously interpreted.


Fig. 2. SEM images. A. Euhedral jarosite cubes (arrow) on a quartz grain. B. Small euhedral alunite cubes (solid arrow) from J zone (in Fig. 1B) and kaolinite (dashed arrow) from A zone. C. Degraded jarosite cubes (arrow) from a transition zone of jarosite to hematite. D. Apparent microbial fossils (solid arrow) in thin section adjacent to jarosite with both euhedral (left dashed arrow) and unusual (right dashed arrow) crystal habits.