
Introduction: Preserved on the plains of Meridiani Planum, in the vicinity of the Opportunity landing site, is a succession of impure evaporitic sandstones [1]. Stratigraphic and sedimentological relationships indicate mixed clastic and chemical depositional environments involving a combination of aeolian and shallow water conditions such as those found in terrestrial playa lakes, sabkhas or shallow marine embayments [1,2]. These rocks also contain abundant textural and mineralogical evidence for a complex and protracted diagenetic history [1,3-5].

Provenance: Siliciclastic components comprise sand grains likely composed of mud cemented by evaporitic minerals. Grains could be of intrabasinal or extrabasinal origin but the former is more consistent with the interpreted depositional environment. Provenance of siliciclastic components is basalt and/or its weathered derivatives but no known Martian basalt, from SNC meteorites, Pathfinder, Gusev or Meridiani, is an exact fit (Fig. 1). High Ni and low Cr/Ni ratios are consistent with, but do not require, a meteoritic component of up to about 6%. Modeling of evaporitic processes [4,5] indicate that waters from which evaporitic components were precipitated were highly acidic (pH<5), Fe- and Mg-rich and thus likely derived from interaction with basaltic rocks that had olivine as a major Mg-bearing phase.

Diagenesis: Terrestrial evaporites are highly susceptible to diagenetic processes and the sedimentary rocks at Meridiani Planum preserve textural, chemical and mineralogical evidence for a complex post depositional history.

Cements. At least two and perhaps four generations of cement, likely composed of evaporitic minerals, are present. Included are (1) fine-grained (<100 µm) pore-filling cement, (2) recrystallized cement growing over concretions and in isolated patches ("popcorn"), (3) possible isopachous radial fibrous cements (may be variety of type 2) and (4) possible localized massive recrystallization (may be extreme version of type 1). Textures are consistent with phreatic (fluid-saturated) meteoric diagenesis.

Fig. 1. Plot of Cr/Ni vs Cr/Al*100. Also shown is effect of removing a component with CI composition from Meridiani outcrop.

Concretions. Embedded throughout the outcrops are massive hematite spherules interpreted to be replacive concretions. They average 4.2 mm in diameter (s.d.=0.8 mm) and consist of >50% hematite with the remainder being basaltic mud and minor evaporitic minerals. Where present, they minimally disrupt primary depositional fabrics and in a few cases, show banding and latitudinal grooves that are contiguous with bedding. They are nearly perfectly spherical and overdispersed, suggesting near-isotropic diagenetic fluid conditions. They make up about 3% of the outcrop by volume (but with considerable variability) and their presence in both aeolian
and playa-like facies suggests that they formed relatively late, during burial diagenesis. Geochemical modeling suggests that diagenetic breakdown of jarosite to form hematite or a hematite precursor (e.g., goethite) during recharge by relatively dilute water is a plausible mechanism for their formation [5].

**Vugs and Moldic Porosity.** Scattered throughout the outcrop are domains containing mm-scale vugs. Where present, they cover as much as 5% of the rock surface by area, do not appear to have any preferred orientation and do not significantly disrupt primary laminations. Vugs commonly are lozenge or tabular shaped and in places have well-defined straight edges, suggestive of a monoclinic crystal habit. They are likely the original site of a syndepositional, late stage (i.e., highly soluble) evaporitic mineral, such as melanterite, glauberite, Mg-chloride or Fe-chloride. The vugs themselves are interpreted to represent moldic porosity, rather than surface erosion features, that post-dates the concretions and the overgrowths around concretions.

**Soft Sediment Deformation.** An intriguing feature of these rocks is the remarkable coherence of primary sedimentary fabrics (laminations, cross-bedding, possible ripples) in spite of the fact that hydration-dehydration reactions and mineral transformations are very common during diagenesis of terrestrial evaporitic sediments. There is some evidence for soft sediment deformation in the presence of crinkly to undulatory laminations and a possible teepee structure. The latter is not inconsistent with periodic formation of a near surface vadose (fluid under saturated) zone during deposition, as would be expected for an evaporating playa lake or sabkha setting.

**Other Features.** There are a number of other features that may be diagenetic in origin but more likely related to relatively recent meteorite impacts. These include meter-scaled fracture patterns (if diagenetic, likely related to karsting), veins and polygonally fractured surfaces that cut across bedding.

**Diagenetic Conditions and History:** All post-depositional features are consistent with protracted syndepositional through burial diagenesis dominated by phreatic meteoric conditions. The possible occurrence of a teepee structure allows for periodic near surface vadose conditions on a local scale. The presence of only minimal disruption of primary depositional fabrics indicates that all diagenetic processes proceeded under near-isovolumetric conditions.

Cross-cutting relationships among textures allow constraints to be placed on diagenetic history (Fig. 2). Sand grains, composed of evaporite-cemented basaltic mud, were likely transported from the margins of a playa lake or sabkha by aeolian processes and reworked by both aeolian and subaqueous processes. During deposition or very early burial, highly soluble minerals formed within the sediment (vug-filling mineral) by evaporitic processes. With further burial, fine-grained pore-filling sulfate cements formed. As burial continued, during periods of very slow fluid recharge, hematitic concretions crystallized within both aeolian and water-transported sediments, filling vacant porosity and replacing relatively soluble sulfate minerals. Diagenetic hematite may have formed largely at the expense of jarosite. The margins of concretions became the site of recrystallization (or possibly the introduction of new cement material) and near the base of the section such recrystallization occurred at numerous sites in addition to concretions (forming "popcorn" textures). The final clearly diagenetic event to occur was mineral dissolution by relatively dilute (but still high ionic strength) brines to form moldic porosity.

**Fig. 2. Simplified model of diagenetic history.**