THE TINTO RIVER BASIN: AN ANALOG FOR MERIDIANI HEMATITE FORMATION ON MARS?

David Fernandez Remolar[1], Ricardo Amils[1], Richard V. Morris[2], and Andrew H. Knoll[3], [1]Centro de Astrobiología, INTA, Torrejón de Ardoz, Spain, [2]NASA Johnson Space Ctr., Houston, TX, [3]Harvard University, Cambridge, MA

Introduction: Among the leading candidates for explorations by Mars lander are Sinus Meridiani and other sites where hematite once formed, probably under aqueous conditions [1]. Effective investigation of these sites requires that we develop a sedimentological, geochemical, and geobiological understanding of potentially informative terrestrial analogs. The headwaters of the Rio Tinto in southwestern Spain provide a comparative system of unusual richness because both modern sediments and Pleistocene sedimentary rocks (preserved along river terraces) can be investigated. This circumstance allows the recognition of textural and mineralogical signatures imparted by diagenesis as well as those that reflect depositional processes. Here we present a preliminary account of field, XRD, and Mössbauer spectrometric analyses of ancient and modern iron deposits in the upper Rio Tinto basin. Procedures for laboratory analyses are described by [2].

Results and Discussion: Groundwater in the Rio Tinto source area percolates upward through Fe-rich sulfidic (mostly pyrite) ore bodies emplaced during Paleozoic hydrothermal events. This percolation results in highly acidic (pH = 0.8-2.3) headwaters that transport ferrous and possibly ferric iron in acid-sulfate waters. Natural variations in eH and pH conditions caused, for example, by dry versus wet seasons, result in precipitation of ferric-bearing minerals, including amorphous phases and the soluble iron sulfate minerals hydronium jarosite, coquimbite, and copiapite as can be seen in the XRD data (Figures 1 and 2). All modern sediments examined to date show that a predominance of hydronium jarosite; coquimbite and copiapite form locally at the margins of evaporative pools isolated during the dry season. Relatively diverse microbial communities live in Rio Tinto waters [3], but their influence on iron deposition has not been established.

If the pH of the water in which sulfate minerals are in contact increases (e.g., by addition of rainwater or seasonal flooding), these minerals become unstable relative to goethite [e.g., 3]. Goethite is also the favored precipitation product if the pH of the acid-sulfate waters increases above ~3-4 before or during oxygenation (e.g., by a neutral-water stream merging with an acid sulfate stream). In Holocene iron beds that form terrace deposits just above current river level, hydronium jarosite is completely replaced by goethite (younger terraces in Figure 3). Goethite is present as microlaminated encrustations of bioclasts and mineral grains, many of which later dissolved. Goethite laminates also fill many of the void spaces left by this dissolution. The remobilization of iron and subsequent precipitation as goethite preserves biological remains in sometimes remarkable detail.

In the oldest terrace deposits (Pleistocene, perhaps as old as one million years), hematite is present along with goethite (older terraces in Figure 3). The hematite replacement appears to be patchy, not obviously following any original texture or lamination. Hematite can be fine-grained red or more coarsely crystalline grey in color. The later is common as precipitates that line original void space. Although the fine-scale lamination found in older terrace deposits resembles microbial mat laminae, this texture appears to have originated mostly if not entirely during diagenesis. In general, hematite formation decreases the quality of paleobiological preservation. Mössbauer spectra (not shown) also show the goethite to hematite trend with increasing age.

Coquimbite and copiapite do not persist in the sedimentary environment, but they can impart a distinctive texture to iron hydroxide laminites that is persistent. Indeed, all principal textures formed during initial phases of iron precipitation can be recognized in Pleistocene terrace deposits. These include flocculation textures templated by algae or plant debris, thin lamination associated with annual rainfall cycles, breccia chips and ropey textures of laminae formed late in the annual dry period, and gas "blisters" formed by the decay of organic matter within sediments.

Preserved sedimentary textures provide evidence of continuity of process in the formation of modern, Holocene, and Pleistocene iron deposits. Within this framework, observed differences in mineralogy reflect the diagenetic evolution of the deposits. It is diagenesis, more than depositional processes, that brings Rio Tinto rocks most closely into alignment with their potential Martian analogs.

References: [1] Christensen P. R. et al. (2001), *JGR, 106*, 23,873-23-885. [2] Morris R. V. et al. (2000), *JGR, 105*, 1757-1817. [3] Lopez-Archilla, A. I. et al. (2001) *Microbial Ecol., 41*, 20-35. [4] Cornell R. M. and Schwertmann U. (1996), *The Iron Oxides,* VCH.

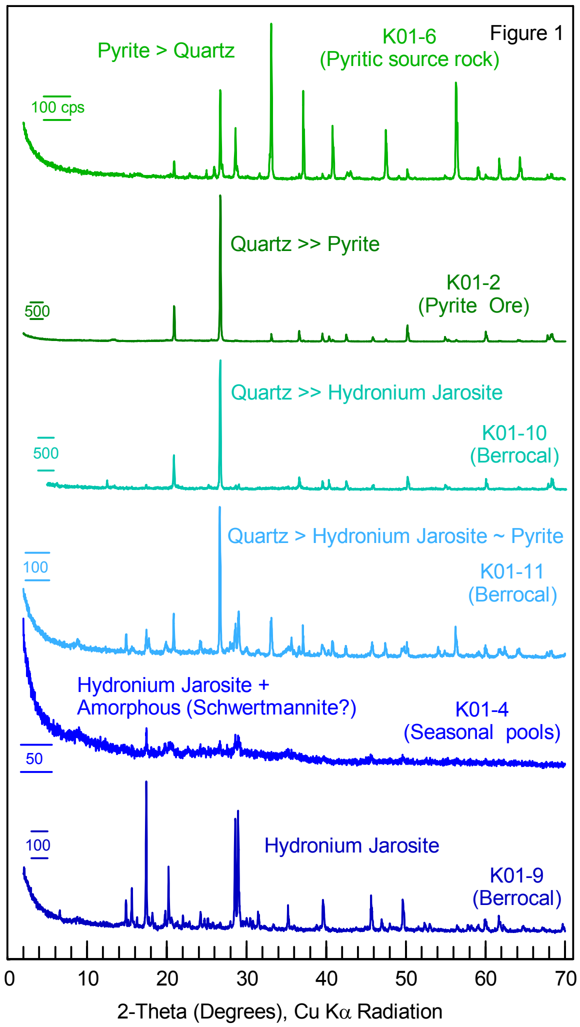
Figure 1
Pyrite > Quartz
K01-6
(Pyritic source rock)
100 cps
Quartz >> Pyrite
500
K01-2
(Pyrite Ore)
Quartz >> Hydronium Jarosite
500
K01-10
(Berrocal)
Quartz > Hydronium Jarosite ~ Pyrite
100
K01-11
(Berrocal)
Hydronium Jarosite +
Amorphous (Schwertmannite?)
K01-4
(Seasonal pools)
50
100
Hydronium Jarosite
K01-9
(Berrocal)
0 10 20 30 40 50 60 70
2-Theta (Degrees), Cu Kα Radiation

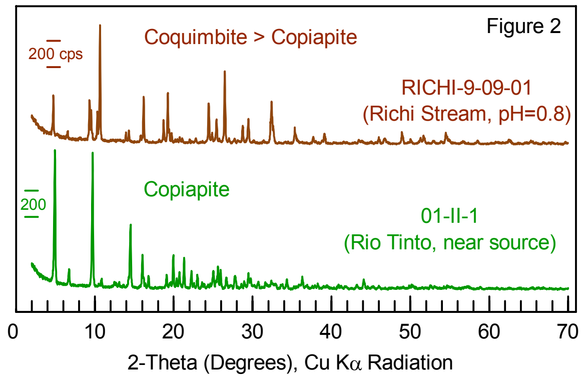
Figure 2
200 cps
Coquimbite > Copiapite
RICHI-9-09-01
(Richi Stream, pH=0.8)
200
Copiapite
01-II-1
(Rio Tinto, near source)
0 10 20 30 40 50 60 70
2-Theta (Degrees), Cu Kα Radiation

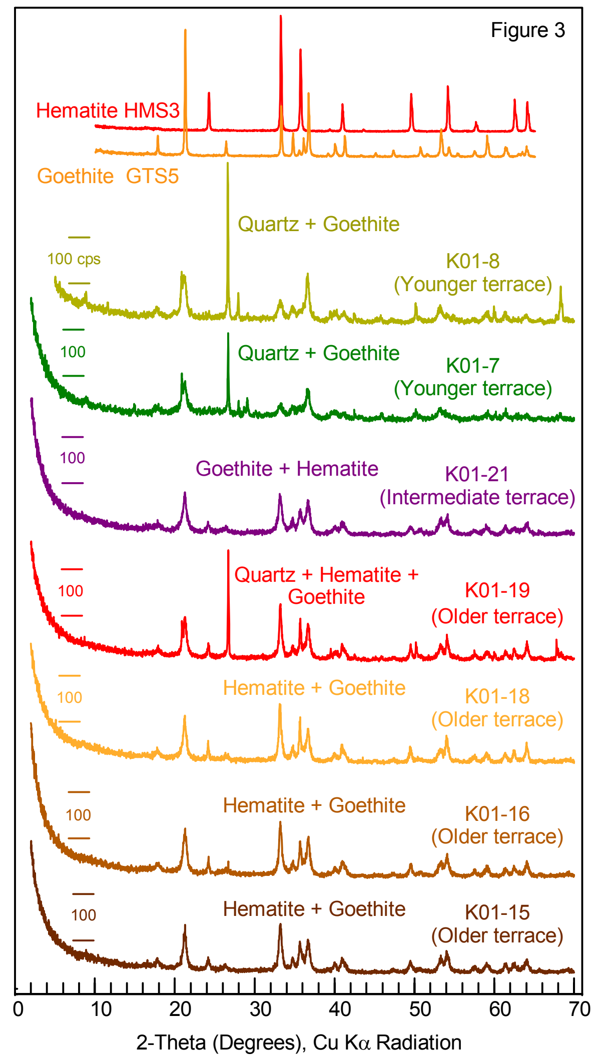
Figure 3
Hematite HMS3
Goethite GTS5
Quartz + Goethite
100 cps
K01-8
(Younger terrace)
100
Quartz + Goethite
K01-7
(Younger terrace)
100
Goethite + Hematite
K01-21
(Intermediate terrace)
100
Quartz + Hematite +
Goethite
K01-19
(Older terrace)
100
Hematite + Goethite
K01-18
(Older terrace)
100
Hematite + Goethite
K01-16
(Older terrace)
100
Hematite + Goethite
K01-15
(Older terrace)
0 10 20 30 40 50 60 70
2-Theta (Degrees), Cu Kα Radiation