RIO TINTO FAULTED VOLCANOSEDIMENTARY DEPOSITS AS ANALOG HABITATS FOR EXTANT SUBSURFACE BIOSPHERES ON MARS: A SYNTHESIS OF THE MARTE DRILLING PROJECT GEOBIOLOGY RESULTS. D. C. Fernández-Remolar[1], O. Prieto-Ballesteros [1], N. Rodríguez[1], F. Dávila[1], T. Stevens[2], R. Amils[3], J. Gómez-Elvira[1] and C. Stoker[4]. [1]Centro de Astrobiología, INTA, Ctra. Ajalvir km. 4, 28850 Torrejón de Ardoz, Spain, e-mail: fernandezrd@inta.es, [2] Department of Biology, Science Building, Portland State University, [3]Centro de Biología Molecular-UAM, [4]NASA Ames Research Center.

Introduction: Geochemistry and mineralogy on Mars surface characterized by the MER Opportunity Rover suggest that early Mars hosted acidic environments in the Meridiani Planum region [1, 2]. Such extreme paleoenvironments have been suggested to be a regional expression of the global Mars geological cycle that induced acidic conditions by sulfur complexation and iron buffering of aqueous solutions [3]. Under these assumptions, underground reservoirs of acidic brines and, thereby, putative acidic cryptobiospheres, may be expected.

The MARTE project [4, 5] has performed a drilling campaign to search for acidic and anaerobic biospheres in Río Tinto basement [6] that may be analogs of these hypothetical communities occurring in cryptic habitats of Mars. This Rio Tinto geological region is characterized by the occurrence of huge metallic deposits of iron sulfides [7]. Late intensive diagenesis of rocks driven by a compressive regimen [8] largely reduced the porosity of rocks and induced a cortical thickening through thrusting and inverse faulting and folding. Such structures play an essential role in transporting and storing water underground as any other aquifers do in the Earth. Once the underground water reservoirs of the Río Tinto basement contact the hydrothermal pyrite deposits, acidic brines are produced by the release of sulfates and iron through the oxidation of sulfides [9].

Combining geological and microbial techniques has resulted in the detection of microbial communities that are hosted by ancient non-porous volcanosedimentary deposits (see related abstract by Stoker et al, LPSC 2005 [10]). Expected energy sources for supporting these subsurface communities are sulfide and iron oxidation, but other sources such as hydrogen are also observed .

The main aim of this paper is to reconstruct the probable habitats hosting the detected microbial communities through the integration of the geobiological data emerging from the MARTE drilling campaigns, but also from the preliminary surface surveys done at the different spring sites, and geophysical soundings around the Río Tinto headwater area that occurs around the Peña de Hierro area [11].

Methodoloy: Geobiology data have been obtained using three different techniques: surface field surveys, TEM (Transient ElectroMagnetic sounding) and drilling.

Field surveying characterized the mineralogy and petrology, structural geology and hydrogeology of the volcanosedimentary complex. It was performed to select the most promising sites for drilling. In fact, different acidic springs were detected and flow paths were inferred from structural mapping. TEM techniques provided the sounding of underground conductivity, which is extremely high for acidic waters. Application of this technique to the Río Tinto basement allowed mapping those subsurface areas of acidic water. Finally, drilling provided fresh samples from the sites that supply the acidic waters, that hypothetically are produced by microbial activity [9]. Mineralogical, geochemical (i.e. pH and ion concentration) and microbial analyses were performed to search for any geobiological processes involved in the acidic weathering of the pyrite massif. After drilling operations, boreholes 1 and 4 were sampled for water, gases and microbes using in situ-sampling techniques.

Geobiology results: Field surveys enhanced by aerial photography recognized different fault-like structures that are related to the presence of acidic springs and streams. A belt of oxic and anoxic acidic springs is closely associated to a thrusting fault that affects the volcanosedimentary complex and the pyrite deposits. A simple structural analysis shows that the Peña de Hierro pyritic deposits are folded by an inverted anticline reversing the sedimentary succession at its southern flank by the thrusting fault. The stratigraphy of the Peña de Hierro area shows, from the bottom to the top, hydrothermalized volcanosediments, stockworked pyrite, massive pyrite, green volcanic tuffs, andesitic aglomerates, green ashes, and purple shales overlain by grey shales that were deposited during the middle to late Carboniferous erosion of an emerging Carboniferous orogen. Microscope observations of thin sections suggest that silica and iron mobilization/precipitation by hydrothermalism induced the reduction of rock porosity.

TEM sounding performed along tectonic and stratigraphical structures has allowed the detection of the subsurface areas in which pyrite alteration is occurring. These areas correspond to two different geological sites: (i) faulted volcanosedimentary deposits enriched in pyrite that appear along the rainfall recharge area and (ii) thrusting deposits without pyritic materials that acts as simple reservoirs of the acidic fluids coming through minor faults meeting obliquely the thrusting fault.

Underground sampling by the MARTE drilling campaign of three boreholes (2 in the massive sulfide deposit designated wells 4 and 8, and one downstream of it designated well 1)provided the geological and biological characterization of the subsurface sites. Well 1 was drilled close to a thrusting fault and penetrated 59 m of dark shales revealing three zones including (from the top to the bottom) weathered shales, fresh shales and highly fractured and decomposed shales. Ionchromatography (IC) detects higher concentration of sulfates at the bottom of well 1.

Wells 4 and 8 penetrated 166 m of (from top to bottom) orange weathered tuffs, gossan, oxidized pyritic stockwork, fresh pyrite stockwork, and pyritic stockwork with oxide filled cracks. The deepest samples contained chloritized tuffs with carbonate traces. IC and pH analyses of leached and solved samples detected in the wells 4 and 8 high concentration of sulfates in localized regions. Moreover, pH analysis of core samples dissolved in neutral water shows a positive correlation between lowering pH and increasing sulfate concentration. Preliminary XRD, FTIR and microscope analyses suggest a strong mineral zoning ranging from oxide (goethite and hematite) and ferric sulfates (H-jarosite) to secondary sulfide species (Fe-S), which support different processes depending on the oxygen concentration and pH of the underground environment. On the other hand, hydrogen and methane gas was observed in association with microbial activity within the pyrite orebody (well 4) and downstream of it (well 1)[10].

Microbial analyses of the samples (using FISH) coming from the boreholes 4 and 8 detected a high microbial concentration in the pyritic stockwork regions showing alteration due to interaction with ground water. These areas also correlate with high sulfate concentrations and low pH found in co-occurring samples. Gas analysis coming from the analyses of diffusion cells detected unusual concentrations of hydrogen and methane.

Geobiological zoning and underground habitat framework: Combining information recovered from the mineralogy, geological structure, geochemistry and microbiology obtained from the volcanosedimentary materials of Peña de Hierro, a geobiological zoning [5] can be recognized as the following: (i) upper oxidized neutral aerobic habitat represented by iron oxyhydroxides, (ii) intermediate vadose aerobic habitat composed of oxides and Fe-sulfates, (iii) lower fractured aerobic/anaerobic habitat with ferric and ferrous sulfates and (iv) lower fractured anaerobic habitat with secondary sulfides. Oxic and anoxic spring would be a surface expressions of (iii) and (iv) areas, respectively. Moreover, habitats (iii) and (iv) are isolated from the (i) and (ii) by a pyrite stockwork intermediate layer that does note show any evidence of alteration what supports that the stable water table occurs in (iii) and (iv). Therefore, deeper habitats developed in fractured and altered materials suggest water flow along the thrusting fault providing energy and matter exchange throughout the lower habitats, whereas water reaches upper habitats seasonally from the surface. As a consequence, upper regions represent disconnected habitats that are highly influenced by aerobic and oxygenic biogeochemical processes.

Having in mind that these results are preliminary, one main consequence of the MARTE project is that an aerobic habitat corresponding to the geobiological zone (iv) could have been detected, in which iron redox and methanogenesis occur [10]. Moreover, as some horizons found in the oxic zone (iii) show also methane releasing, they could also be good sites to research underground habitats analogs to Mars subsurface.

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