HYDROGEOLOGICAL STUDY OF THE THE RIO TINTO MARS ANALOG: IMPLICATIONS FOR MARS UNDERGROUND WATER FLUXES. D. Gómez-Ortiz[1], D. C. Fernández-Remolar[2], O. Prieto-Ballesteros[2], F. Gómez[2], R. Amils[2]. [1]ESCET-Área de Geología, Universidad Rey Juan Carlos, 28933 Móstoles, Madrid, Spain (david.gomez@urjc.es), [2]Centro de Astrobiología-INTA, 28850 Torrejón de Ardoz. Spain (fernandezrd@inta.es, prietobo@inta.es, gomezgf@inta.es).

Introduction: The Iberian Pyritic Belt (IPB) consists of a 250-km long geological unit included into the South-Portuguese geotectonical zone of the Iberian Peninsula. It is comprised by an acid volcano-sedimentary complex ranging in age from upper Devonian to Carboniferous where different metallic ores were formed in response to hydrotermalism and tectonic related to the Variscan Orogeny [1, 2]. Inside the IPB, the Rio Tinto area contains some of the largest world's massive sulfide deposits.

In Río Tinto, the interaction between groundwater and sulfide deposits and sulfide-free rocks provides geochemical processes controlling the geochemistry of both surface fluids and groundwater. The resulting waters are characterized by an acidic chemistry and high concentrations of sulfur and iron in solution, which control the formation of analogous mineral associations that have been recognized in Meridiani [3, 4, 5].

As Mars basement has been intensively fractured by meteoritic and geological events, same geochemical reactions ending in the formation of sulfates and oxides that occur in the Río Tinto system may have occurred in the Mars early environments.

To understand the processes that drive the mineral formation of sulfur and iron bearing phases, special attention has been paid to the aquifer located on Peña de Hierro, North of Rio Tinto, which are the headwaters that supply the acidic waters of Río Tinto. Given that Peña de Hierro aquifer is mainly controlled by the recharge from rainwater through the present fault system, a hydrogeological study has been conducted in order to accurately characterize underground water fluxes of the aquifer.

Geological setting: Peña de Hierro is located at the contact between two different tectonic units included inside the IPB, Concepcion Unit to the North and RioTinto-Nerva Unit to the South (Fig. 1). The first one is composed by shales acidic tuffs and volcanic materials. The second one is composed of dark shales and greywackes. A highly deformed thin unit of purple shales delineates the contact between both units, defined by the San Miguel-Minas del Castillo Shear Zone (SMCSZ). The SMCSZ formed during the second phase of deformation associated to the Variscan Orogeny (Fig. 1) and corresponds to a transpressional ductile deformation with associated penetrative foliation [1, 2].

A Late-Variscan episode of deformation is responsible for the development of a conjugate strike-slip system of brittle fractures trending NNW-SSE (dextral) and NNE-SSW (sinistral) respectively. These fractures are extensively distributed all around the IPB and represents the transition form ductile transpressional deformation to a brittle transtensional event related to the collapse of the Variscan Orogen. The tectonic framework of Peña de Hierro aquifer has been analysed using satellite imaginery analysis and artifical shading of a Digital Elevation Model [6]

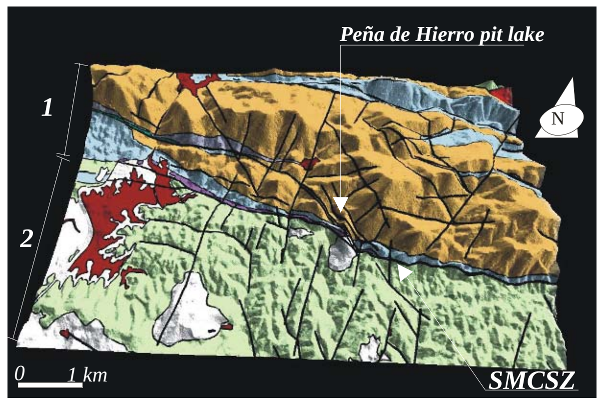

Figure 1. Geological map of the study area. 1: Concepcion Unit. 2: Rio Tinto Nerva Unit. The contact between both tectonic units corresponds to the San Miguel-Minas del Castillo Shear Zone (SMCSZ). The lineaments mapped, corresponding to the fracture patern, are shown in black.

Three different orientations have been outlined: ESE-WNW, NNE-SSW and NNW-SSE. The three fault systems clearly control the drainage pattern in the area. It has been previously proposed [6,7] that the fracture pattern in Peña de Hierro aquifer controls the headwaters that supply the acidic waters of Río Tinto.

The control of the fault pattern on the surface and subsurface water flows has been confirmed by means of a geophysical survey using ERI technique [8]. The resistivity profiles were carried out at two acidic springs belonging to the origin of the rio Tinto river, and on the location of a borehole used for sampling and monitoring of the acidic waters. In all cases, sharp vertical or subvertical contacts between different units were recognized confirming the occurrence of subvertical fracture zones affecting the shales. The location of these fractures always corresponds to the presence of the acidic springs and/or surface waterflows, confirming the tectonic control that the fracture pattern exerts on the acidic water flows.

Unravelling the water fluxes: Once confirmed the control of the faults on the fracture aquifer, the flow scheme that connects the springs, the pit lake and the surface waters have been studied by means of artificial tracers. In a first stage an during the wet season, Iodine-131 was injected in BH8, located NE of the pit lake (Fig. 2). In a second stage and during the dry season, Fluorescein and Rhodamine B were respectively injected in two monitoring boreholes: BH 8 and BH 1, being the latest located south of the pit lake. Continuous water sampling revealed the occurrence of Iodine-131 in BH 4, located about 50 m south of BH 8, confirming the connection of both boreholes by means of the fracture system. From the distance between BH8 and BH4 and the travel time of the tracer (29 hours), the hydraulic conductivity can be estimated in 25 m/day, a high value for a fractured aquifer. Regarding the tracers injected during the dry season, Fluorescein was detected in BH1 one year after the injection, corresponding to a lower hydraulic conductivity of about 2 m/day, more typical for a fractured aquifer, and confirming the connection between the boreholes located to the noth and south of the pit lake. The general groundwater flow direction obtained is NNE-SSW in good agreement with one of the three main fracture systems obtained in the tectonic study. The different range of hydraulic conductivity values obtained (from 2 to 25 m/day) can be a consequence of different water flow velocities related to the variations in weather conditions. During the wet season, rainwater infiltration can lead to a fast water recharge of the aquifer from the surface by means of the fracture system. This would correspond to the fastest velocities observed at short distances. Opposite to this, during the dry season the recharge of the aquifer from the surface is reduced to a minimum and, in consequence, the groundwater flow is considerably reduced, especially at longer distances. Laboratory analysis are currently being carried out in order to detect the presence of the tracers in different springs around the area, allowing us to obtain a more complete scheme of the groundwater flow system and the connections between the mapped fractures.

Implications for Mars undeground water fluxes: Fractures affecting to the Mars volcanic basement have probably played an essential role in storaging and transporting underground fluids through physicochemical gradients controlled by pH changes and oxidant concentration. In this sense, the Rio Tinto subsurface research provides some insights to understand the formation of sulfur bearing compounds observed in Meridiani [9-12] and many other regions of Mars. As observed in the Río Tinto aquifers, long-term subsurface sulfur storage in form of secondary sulfides can be a reasonable source for sulfates after oxidation by meteoric solutions provided by formation of acidifying and oxidizing compounds that are sourced in photochemical reactionships in the Noachian Mars atmosphere [13, 14].

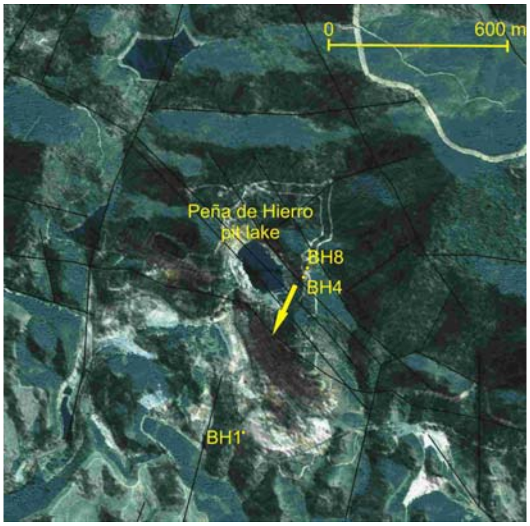

Figure 2. QuickBird image of the Peña de Hierro area. The main fracture systems are indicated as solid black lines. Three different boreholes has been used as tracers test. The obtained groundwater flow direction is indicated by a yellow solid arrow.

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