Fast-Turnoff Transient Electromagnetic (TEM) Field Study at the Mars Analog Site of Rio Tinto, Spain.

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Introduction: This report describes the outcome of a Fast-Turnoff Transient Electromagnetic (TEM) [11] geophysical survey carried out in the Peña de Hierro ("Berg of Iron") field area of the Mars Analog Research and Technology Experiment (MARTE) [1-6]. The Peña de Hierro field area of the MARTE project is located between the towns of Rio Tinto and Nerva in the Andalucia region of Spain. It is about one hour drive West of the city of Sevilla, and also about one hour drive North of Huelva.

Figure 1. Peña de Hierro Main Source Area.

The high concentration of dissolved iron (and smaller amounts of other metals) in the very acidic water in the Rio Tinto area gives the water its high conductivity and its characteristic wine red color (Figure 1), and such an acidic and conductive fluid is highly suited for exploration by electromagnetic methods. The TEM method has been used extensively for mapping of groundwater [7-8], and of metal-bearing acid solutions in in-situ mine leaching operations.

The Peña de Hierro field area is located within an area of extensive pyretic ore deposits, which have been mined extensively in the past. A majority of remaining natural topography consists of hills with relatively smooth and rounded tops that roll off into steeper sides and are intersected by narrow gullies with numerous small streams. There are few natural lakes of any size in the area, but a number of artificial lakes (dams). The original natural topography is widely modified by past mining activity, which stripped most of the hillsides in the field area, added mine tailings piles as an artificial topographic element, and also added several large open mining pits.

Method: Figure 2 shows a map of the field area, with a coarse geologic map overlain on a topographic map. The general topography as outlined above is illustrated in this map. The large area in geologic map marked in yellow is mostly covered in mine tailings; the purple, roughly oval shape just North of the center of the map is the lake in the open pit remaining from the mining activity; and the band marked in light blue trailing roughly West-Northwest to East-Southeast through the map is a shale unit.

The steepness and extent of the mine pit is apparent from the density and extent of the 20 m contour lines surrounding the pit lake. The water in the pit lake is the very conductive acidic groundwater common in the area, and has a dark wine-red color. Marked in red on the map, just to the East and Southeast of the mine pit, is rust-red rock unit (shale). Note also the artificial lake of relatively fresh water behind the dam close to the Northwest corner of the map (marked in blue, with horizontal hash marks), as well as the elongated lake holding acidic metal-rich water near the Southwest corner of the map (marked in purple, again with horizontal hash marks).

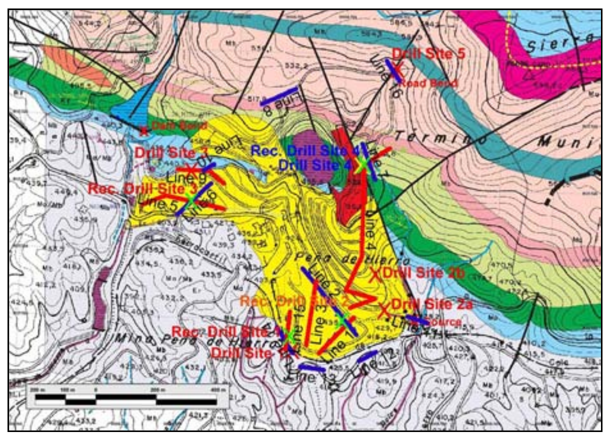

Figure 2. Peña de Hierro Field Area.

The locations of the lines of geophysical soundings collected in this survey are marked with thick red lines (▬, Lines 1, 3, 4, 5, 9, and 15) and thick blue lines (▬, Lines 2, 6, 7, 8, 10, 11, 12, 13, 14, and 16). Drill site locations from the MARTE Drilling Campaign Plan (Stoker et al., 2003a; Stoker et al., 2003b) are marked with large red X's, except for Drill Site 4 (located on the edge of the geologic map unit marked in red), which is marked with a large yellow X. Recommended relocations of Lines 1-4 are all marked with large green X's.

Drill Site 4: Figure 3 shows data from Line 4 (of 16) from the Rio Tinto Fast-Turnoff TEM survey, collected using 40 m Tx loops and 10 m Rx loops with a

32 Hz sounding frequency [1, 11]. Note the ~200 m depth of investigation and the conductive high at ~80 m depth below Station 20. This is the local water table, with the same 431 m MSL elevation as the nearby pit lake. The center of the "pileup" below Station 60 is spatially coincident with the vertical fault plane located here.

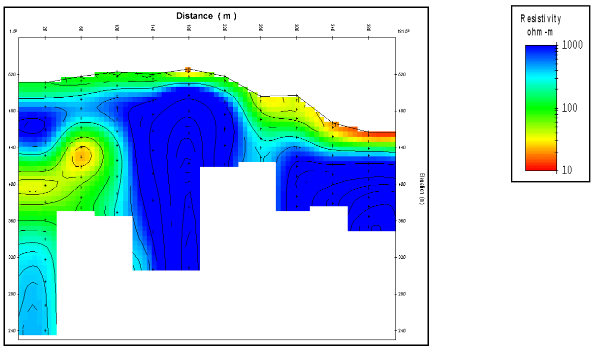

Figure 3. Line 4 Fast-Turnoff Data, Rio Tinto.

Drill Site 1: Figure 4 shows Fast-Turnoff TEM data from Line 15 of the Rio Tinto survey, collected using 20 m Tx loops and 10 m Rx loops, again with a 32 Hz sounding frequency [1, 11]. Note the ~50 m depth of investigation and the conductive high at ~15 m depth under the third station (interpreted as subsurface water flow under mine tailings matching surface flows seen coming out from under the tailings, and shown on maps; Figure 2).

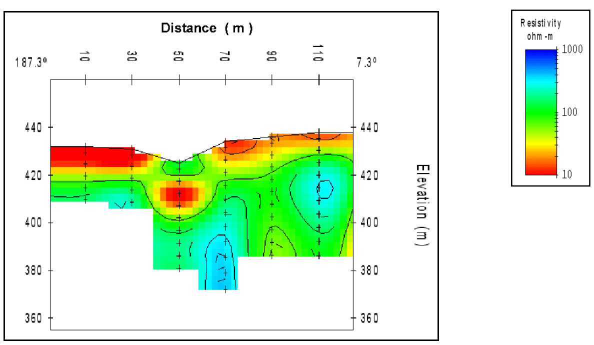

Figure 4. Line 15 Fast-Turnoff Data, Rio Tinto.

Conclusions: Both of these interpretations were roughly confirmed by preliminary results from the MARTE ground truth drilling campaign carried out in September and October 2003 [1, 6]. Figure 5 shows a map of the original MARTE drill site plan locations and the relocations recommended in the report, with the bearing and distance between the two marked by green lines. Table 1 shows the location, bearing, and distance data for these recommendations. Note that the recommended relocation of Drill Site 4 is very small, and overlaps with the current plan location on this map.

Description	Latitude Longitude	Bearing from Plan	Distance from Plan	Elevation
Rec. reloc. of Drill Site 1	N 37.721510° W 6.555848°	335.5°	52.98 m	Unknown (L15S02: 431 m)
Rec. reloc. of Drill Site 4	N 37.726676° W 6.553161°	70.1°	10.92 m	Unknown (L04S02: 518 m)
Rec. reloc. of Drill Site 3	N 37.725473° W 6.559679°	180.9°	98.26 m	Unknown (L05S05: 421 m)
Rec. reloc. of Drill site 2	N 37.722011° W 6.553806°	254.5° (2a) 214.9° (2b)	146.05 m (2a) 189.79 m (2b)	Unknown (L02S06: 443 m)

Table 1. Recommended Drill Site Relocations.

Based on the locations of conductive features in the TEM data, relocations were recommended for Drill Site 1 and Drill Site 2, and a possible relocation for Drill Site 3. Due to logistical concerns that take precedence over interpretations of the geophysical data, it was recommended that Drill Site 4 be drilled at its current Drilling Campaign Plan location. Based on these recommendations, Drill Site 1 was moved ~50 m, while Drill Site 4 was drilled at the plan location – in agreement with the conclusion of the survey report.

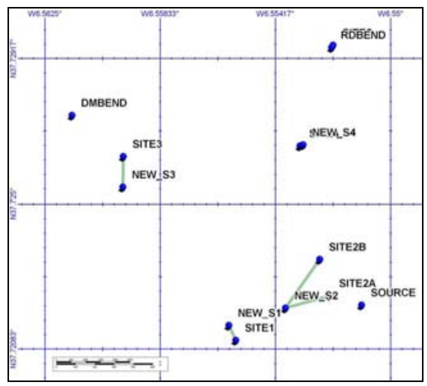

Figure 5. Recommended Drill Site Relocations.

References: [1] Jernsletten J. A. (2003) *Fast-Turnoff Transient Electro-Magnetic (TEM) Geophysical Survey*. MARTE field report. [2] Fernández-Remolar et al. (2003) *JGR*, 108/E7, 16-1 – 16-15. [3] Stoker C. R. et al. (2003) *Drilling Campaign Plan V0.1*. MARTE working document. [4] Stoker C. R. et al. (2003) *Drilling Plan CRS 4-20-2003*. MARTE working document. [5] Stoker C. R. et al. (2003) *LPSC 34*, abstract no. 1076. [6] Stoker C. R. et al. (2003) *Initial Results From the 2003 Ground Truth Drilling Campaign*. MARTE working document. [7] Reynolds J. M. (1997) *An Introduction to Applied and Environmental Geophysics*. [8] Zonge K. L. (1992) *Introduction to TEM*. In: *Practical Geophysics II, for the Exploration Geologist*. [9] MacInnes S. and Raymond M. (1996) *Zonge STEMINV manual*. [10] Palacky G. J. (1987). In: *Electromagnetic Methods in Applied Geophysics, Volume 1, Theory*. Nabighian M. N., editor. [11] Zonge K. L. (2001) *NanoTEM – A Very Fast-Turnoff TEM System*. Zonge Engineering case study.