

TIME DOMAIN ELECTROMAGNETICS FOR MAPPING MINERALIZED AND DEEP GROUNDWATER IN MARS ANALOG ENVIRONMENTS. J. A. Jernsletten, 1917 Florida Dr., Seabrook, TX 77586, joern@jernsletten.name.

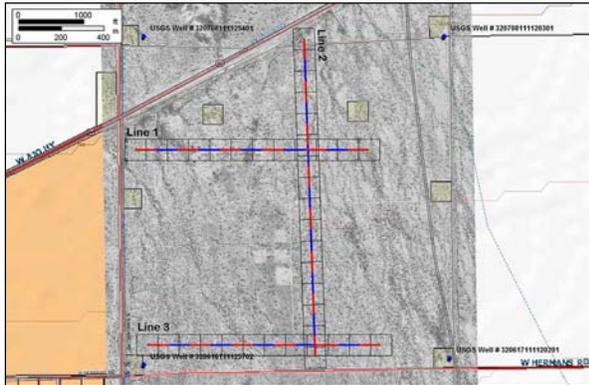


Figure 1. Pima County, Arizona Field Area.

Introduction: The purpose of this study is to evaluate the use of (diffusive) Time Domain Electromagnetics (TEM) for sounding of subsurface water in conductive Mars analog environments. To provide a baseline for such studies, I show data from two field studies: 1) Diffusive sounding data (TEM) from Pima County, Arizona; and 2) Shallower sounding data using the Fast-Turnoff TEM method [11] from Peña de Hierro in the Rio Tinto region of Spain. The latter is data from work conducted under the auspices of the Mars Analog Research and Technology Experiment (MARTE) [1-6].



Figure 2. Typical TEM Setup in the Field.

Potential of TEM: The TEM method has been widely used for mapping of groundwater [7-8], and of metal-bearing acid solutions in leaching operations. Figure 1 shows a map of the field area of a TEM survey that was carried out in Pima County, Arizona, in January 2003. Figure 2 shows a typical TEM setup in the field, and Figure 3 shows data from Line 2 of this

survey. Data was collected using 100 m Tx loops and a ferrite-cored magnetic coil Rx antenna, and processed using commercial software [8-9]. The survey used a 16 Hz sounding frequency, which is sensitive to slightly salty groundwater [8, 10].

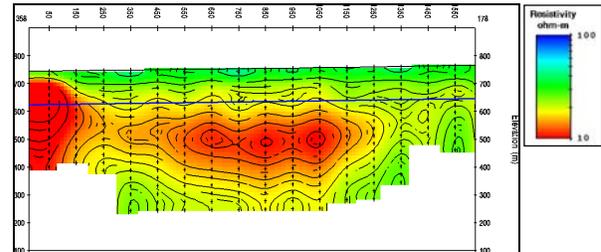


Figure 3. Line 2 TEM Data from Arizona Survey.

Prominent features in Figure 3 are the ~500 m depth of investigation and the ~120 m depth to the water table (horiz. blue line). Note also the conductive (~20-40 Ωm) clay-rich soil above the water table. The blue line marks the ~120 m depth to the water table found in several USGS test wells in the area (Table 1).

Well Site Label	Water Depth (m)	Water Depth (ft)	Date of Latest Reading
USGS Well # 32070811125401	116.27 m	381.45 ft	12/10/1991
USGS Well # 32070811120301	120.24 m	394.50 ft	12/17/1986
USGS Well # 32061611125702	119.54 m	392.18 ft	12/07/1991
USGS Well # 32061711120201	124.68 m	409.07 ft	12/27/1990

Table 1. USGS Well Data.

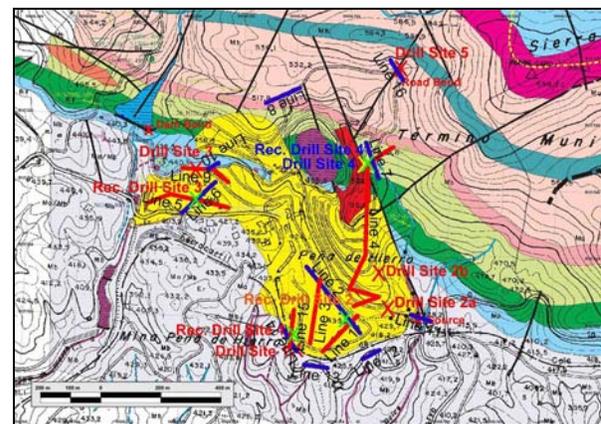


Figure 4. Peña de Hierro Field Map.

Figure 4 shows a map of the Peña de Hierro field area, near the town of Nerva, while Figure 5 shows photographs of Peña de Hierro and the working conditions in the field area.

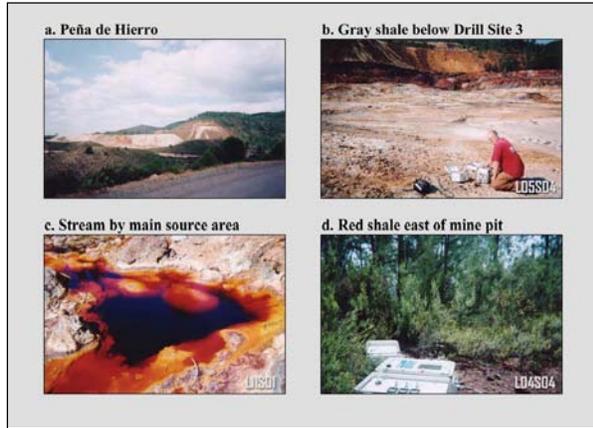


Figure 5. Peña de Hierro Working Conditions.

Figure 6 shows data from Line 4 (of 16) from this survey, collected using 40 m Tx loops, 10 m Rx loops, and 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 water table, matching the 431 m elevation of the nearby pit lake. The center of the “pileup” below Station 60 is spatially coincident with the vertical fault plane located here.

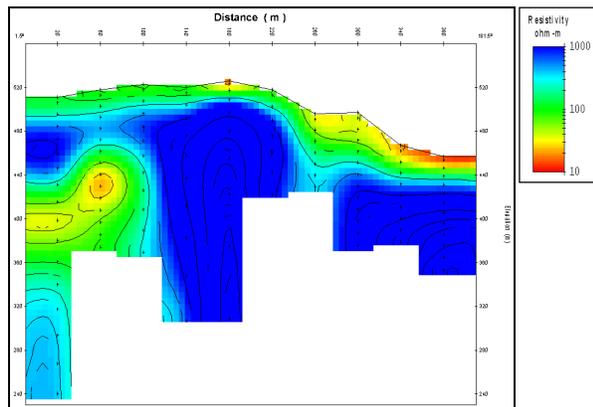


Figure 6. Line 4 Fast-Turnoff Data, Rio Tinto.

Figure 7 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 below Station 50, interpreted as subsurface water flow under mine tailings matching surface flows seen coming out from under the tailings, and shown on maps.

Conclusions: Results from the Pima County TEM survey were in good agreement with control data from four USGS test wells located around the field area (Figure 3, Table 1; for locations see Figure 1). This survey also achieved a very acceptable 500+ m depth of investigation.

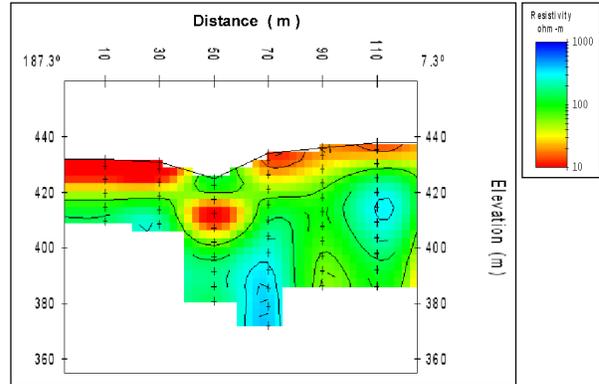


Figure 7. Line 15 Fast-Turnoff Data, Rio Tinto.

Both of the interpretations from Rio Tinto data (Line 4, Figure 6; and Line 15, Figure 7) were confirmed by preliminary results from the MARTE ground truth drilling campaign carried out in September and October 2003 [1, 6]. Drill Site 1 was moved ~50 m based on recommendations built on data from Line 15 and Line 14 of the Fast-Turnoff TEM survey (Table 2).

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 2. 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.