Using TEM for sounding conductive and deep groundwater in Mars analog environments: Comparing two field studies

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Summary:

A TEM survey was carried out in Pima County, Arizona, in January 2003. Data was collected using 100 m Tx loops and a ferrite-cored magnetic coil Rx antenna, using a 16 Hz sounding frequency, which is sensitive to slightly salty groundwater. Prominent features in the data are the ~500 m depth of investigation and the ~120 m depth to the water table, confirmed by data from four USGS test wells surrounding the field area. Note also the conductive (~20-40 Ωm) clay-rich soil above the water table.

During May and June of 2003, a Fast-Turnoff (early time) TEM survey was carried out at the Peña de Hierro field area of the MARTE project, near the town of Nerva, Spain. Data was collected using 20 m and 40 m Tx loop antennae and 10 m loop Rx antennae, with a 32 Hz sounding frequency. Data from Line 4 (of 16) from this survey, collected using 40 m Tx loops, show ~200 m depth of investigation and a conductive high at ~90 m depth below Station 20 (second station of 10 along this line). This is the water table, matching the 431 m MSL elevation of the nearby pit lake. Data from Line 15 and Line 14 of the Rio Tinto survey, collected using 20 m Tx loops, achieve ~50 m depth of investigation and show conductive highs at ~15 m depth below Station 50 (Line 15) and Station 30 (Line 14), interpreted as subsurface water flow under mine tailings matching surface flows seen coming out from under the tailings, and shown on maps.

Both of the interpretations from Rio Tinto data (Line 4, and Lines 15 & 14) were confirmed by preliminary results from the MARTE ground truth drilling campaign carried out in September and October 2003. 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.

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].

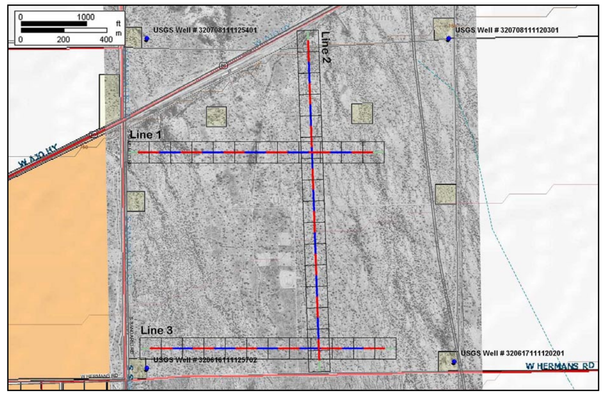

Figure 1. Pima County, Arizona Field Area.

TEM Survey, Pima County, Arizona

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 model data from 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 2. Typical TEM Setup in the Field.

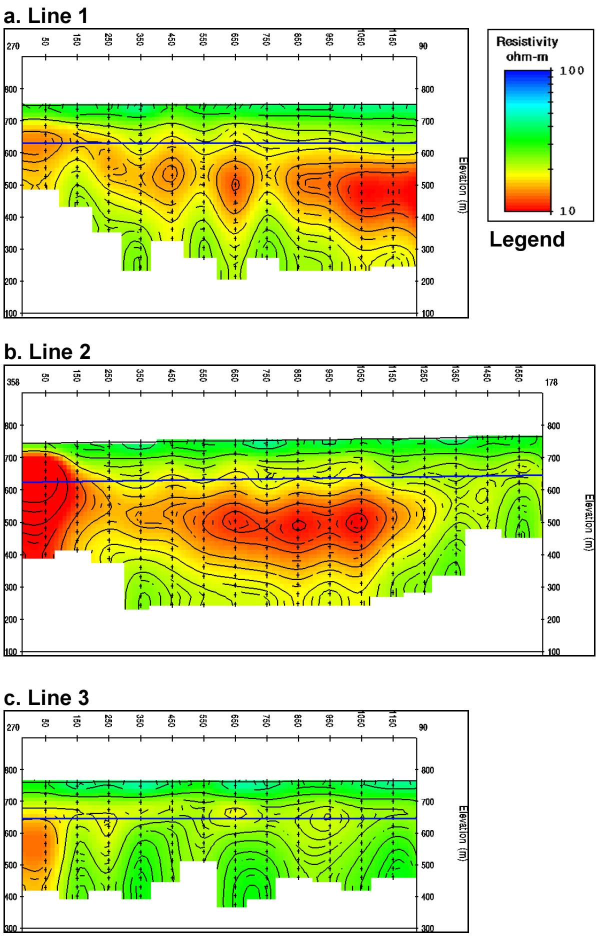

Figure 3. TEM Model Data from Arizona Survey.

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 # 320708111125401	116.27 m	381.45 ft	12/10/1991
USGS Well # 320708111120301	120.24 m	394.50 ft	12/17/1986
USGS Well # 320616111125702	119.54 m	392.18 ft	12/07/1991
USGS Well # 320617111120201	124.68 m	409.07 ft	12/27/1990

Table 1. USGS Well Data.

Fast-Turnoff TEM Survey, Rio Tinto, Spain

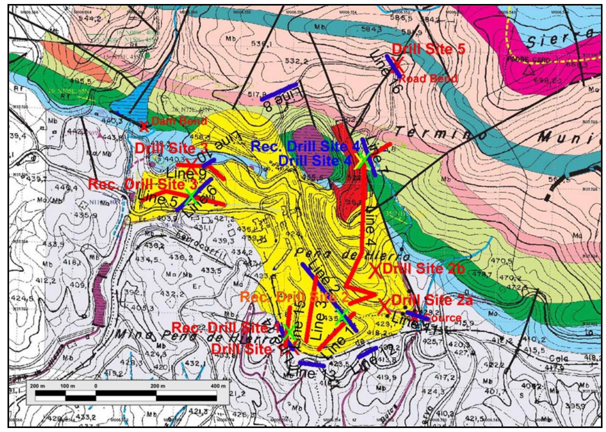

Figure 4. Peña de Hierro Field Map.

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.

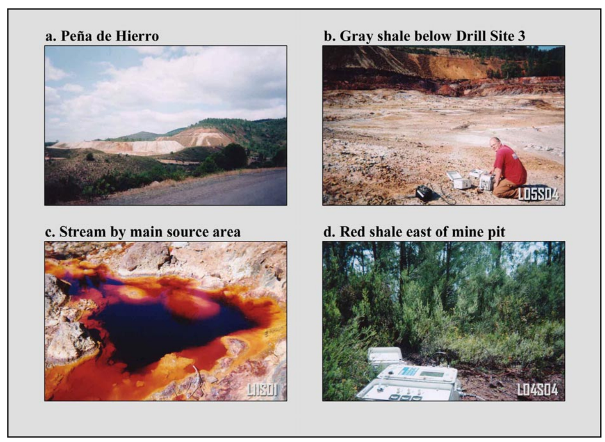

Figure 5. Peña de Hierro Working Conditions.

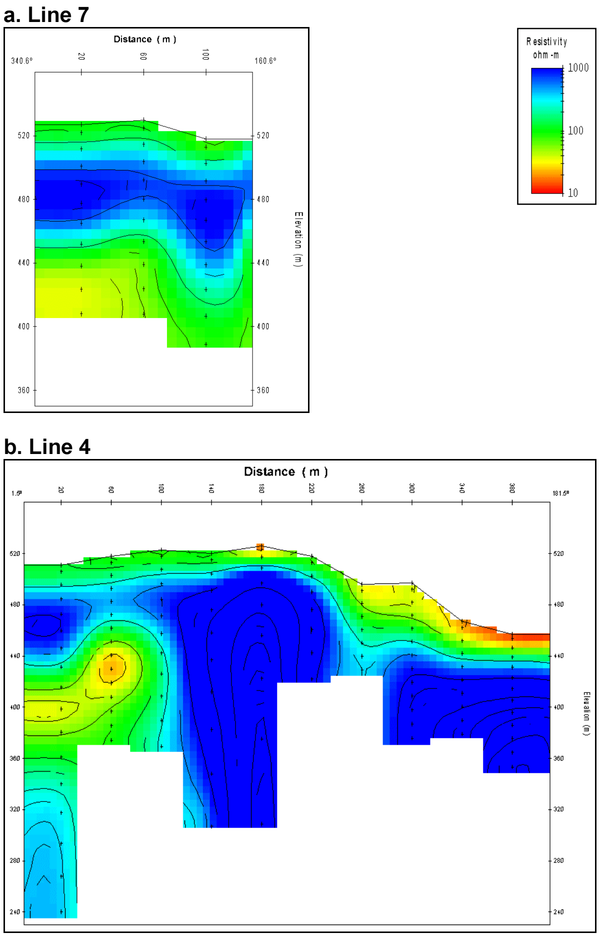

Figure 6. Drill Site 4 Fast-Turnoff Data, Rio Tinto.

Figure 6 shows data from the MARTE Drill Site 4 area (Lines 4 and 7 of 16 total) 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 of Line 4 (Figure 6b). This is the water table, matching the 431 m elevation of the nearby pit lake. The center of the "pileup" below Station 60 of Line 4 (Figure 6b) is spatially coincident with the vertical fault plane located here. Line 7 data corroborates the ~80 m depth to the water table (Figure 6a).

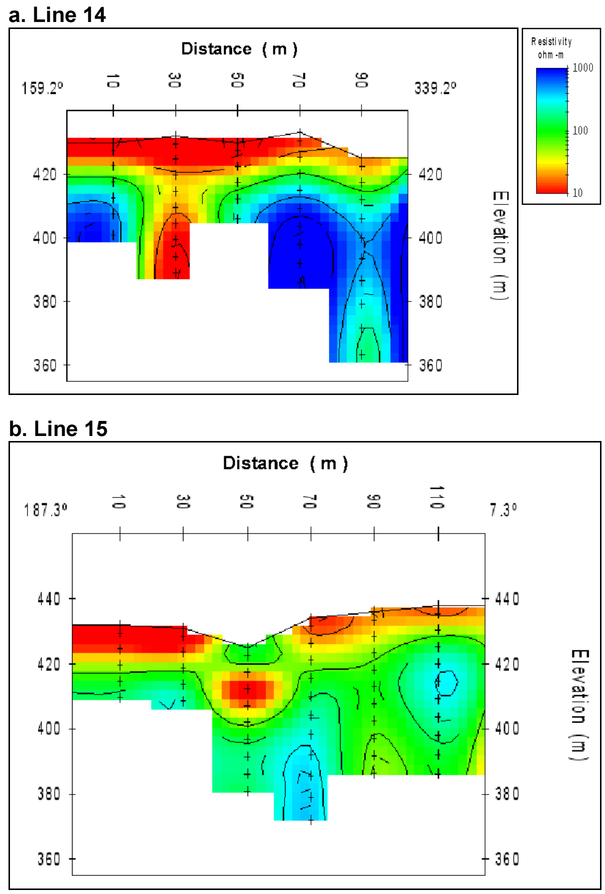

Figure 7. Drill Site 1 Fast-Turnoff Data, Rio Tinto.

Figure 7 shows Fast-Turnoff TEM data from the MARTE Drill Site 1 area (Lines 14 and 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 of Line 15 (Figure 7b) and Station 30 of Line 14 (Figure 7a), interpreted as subsurface water flow under mine tailings matching surface flows seen coming out from under the tailings, and shown on maps (Figure 4).

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.

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

Table 2. Recommended Drill Site Relocations.

References

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