ADVANCED GEOSCIENCE, INC.
Geology and Geophysics
Subsurface Exploration Non-Destructive Evaluation

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January 26, 2017

Department of the Air Force
US Air Force Europe
USAFE A4/A7K

Attention: Justin A. Williams, TSgt, Contracting Officer
Steven G. Joseph, 1st Lt, Contracting Officer
Jacob A. Botello, Maj, Base Civil Engineer

Re: **Final Report for Contract No. FA5422-16-M-3132**
Geophysical Investigation for Groundwater Exploration
At Chabelley Airfield (CADJ)
Djibouti, Africa

In accordance with the referenced contract, Advanced Geoscience, Inc. presents this report summarizing our field survey procedures and methods of data processing and evaluation for this geophysical investigation for groundwater exploration.

In response to your statement of work (SOW) Advanced Geoscience has used this geophysical investigation to evaluate whether a groundwater aquifer exists beneath the CADJ and specified a location for drilling a deep groundwater well.

Advanced Geoscience appreciates this opportunity to be of service to the US Air Force.

Sincerely,
Advanced Geoscience, Inc.

Mark G. Olson
Principal Geophysicist and Hydrogeologist

California Registered Professional Geophysicist No. GP970
California Registered Professional Geologist No. 6239
California Certified Hydrogeologist No. 326

REPORT
GEOPHYSICAL INVESTIGATION
FOR
GROUNDWATER EXPLORATION
CHABELLEY AIRFIELD, DJIBOUTI
CADJ PROJECT 16-0005

FINAL REPORT
January 26, 2017

Prepared for:

Jacob A. Botello, Maj, USAF
Base Civil Engineer
870th Air Expeditionary Squadron
Chabelley Airfield, Republic of Djibouti, Africa

Prepared by:

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1.0 INTRODUCTION

This report presents the results of the geophysical investigation recently completed by Advanced Geoscience, Inc. This investigation was conducted in general accordance with our proposal dated August 30, 2016 for the purposes of groundwater exploration at the Chabelley Airfield in Djibouti, Africa (CADJ) shown in Figure 1.

In response to the U.S. Air Force Statement of Work (SOW) dated August 6, 2016, Advanced Geoscience first performed subsurface geophysical surveys and research on the area's hydrogeology to evaluate whether a groundwater aquifer exists beneath the CADJ. Two geophysical surveying methods were performed that were previously used for groundwater exploration in other basalt bedrock desert terrains similar to the CADJ. Transient electromagnetic (TEM) resistivity and magnetometer surveys were performed along transects set up across the CADJ. The TEM resistivity surveys were used to prepare subsurface profiles showing electrical resistivity variations within the deeper basalt bedrock. These profiles were used to evaluate water-saturated layering within the basalt bedrock and deeper structural geologic conditions. The magnetometer surveys were performed along paralleling transects and used to measure localized variations in the magnetic field readings. These magnetometer surveys were used to help identify possible bedrock structures which could control groundwater flow. Localized magnetic field variations were expected to result from interfaces between basalt layers where the depletion of magnetic minerals (caused by weathering and groundwater flow) would cause decreases in the magnetization (magnetic susceptibility) within the bedrock. Magnetometer surveys were previously used in Saudi Arabia by Al-Garni (2009) for groundwater exploration in complex magnetic bedrock terrains intersected by wadis. TEM resistivity surveying also has been used extensively by Advanced Geoscience and others such as Taylor, et al. (1995) in the Western U.S. for groundwater exploration. In areas where there is mostly horizontal subsurface layering the one-dimensional, resistivity-versus-depth profiles derived from TEM measurements compare very well with long-normal resistivity profiles from borehole electric logs.

To help evaluate groundwater conditions from this geophysical data we also researched documents and data on the hydrogeology of the area and consulted with a local hydrogeologist from Batiland Construction in Djibouti with knowledge of groundwater conditions in Djibouti and Sub-Saharan Africa.

In accordance with the SOW, this report now provides recommendations for the positioning of groundwater extraction wells on the CADJ. These recommendations are based on the results of this geophysical investigation and discussions with the hydrogeologist from Batiland Construction and project member Mr. Phil Oberlander.

The following section summarizes our geophysical field investigation procedures and methods of data processing and evaluation. The concluding sections discuss the current results of this groundwater exploration and our recommendations for the positioning of groundwater extraction wells. This geophysical data evaluation may be revised once direct subsurface data is available from future well investigations at the CADJ and possible future testing of the existing wells surrounding the CADJ.

2.0 GEOPHYSICAL FIELD INVESTIGATION

Advanced Geoscience mobilized a survey team and geophysical equipment to Djibouti to conduct the field investigation from November 15 through 30, 2016. This survey team consisted of Mr. Mark Olson, Advanced Geoscience's Lead Geophysicist and Hydrogeologist and two other geophysical survey specialists.

The TEM resistivity equipment and magnetometers used for this investigation were leased from companies manufacturing the equipment. The TEM equipment was provided by Geonics, Ltd. in Canada and the magnetometers were provided by Geometrics, Inc. in the USA. Prior to shipping the equipment to Djibouti it was tested by the manufacturers to make sure it was properly calibrated and in good working order.

Before starting the field investigation we met with Captain Ryan Amedee at the CADJ to discuss the set up and positioning of the geophysical surveys. At this time it was decided that the geophysical surveys should be conducted along a series of traverses set up across the north edge of the CADJ following the three kilometer-long dirt road. This road was positioned where the perimeter fence line was to be constructed for the future base expansion.

Our survey team first set up a series of measurement points along the survey line traverses on the north edge of the CADJ. A differentially-corrected, global positioning system (GPS) system was used to stake out and map the locations of these measurement points. The GPS coordinates of the measurement points were then transferred to a Google Earth location data base to prepare various maps of the geophysical survey lines.

Prior to starting the geophysical surveys we also met with the consulting hydrogeologist from Batiland Construction to discuss the objectives of our geophysical investigation and the hydrogeology of the area surrounding the CADJ. We also reviewed data made available on groundwater conditions from the existing wells in this area.

2.1 Transient Electromagnetic (TEM) Resistivity Surveys

The TEM resistivity survey data was recorded along a series of measurement points set up to follow the road on the north edge of the CADJ. The positions of these measurement points identified as TEM-1 through TEM-14 are shown on the site map in Figure 2. The TEM surveys were positioned in this area to prepare a two-dimensional resistivity profile to evaluate across the CADJ subsurface resistivity variations associated with hydrogeologic conditions. The surveys were also positioned in this area to be away from interference from structures on the ground surface and sources of power line and other electromagnetic noise.

The TEM resistivity surveys were performed using a Geonics TEM57-MK2A transmitter (powered by a 2,000-watt electrical generator) and Protem digital receiver. Square wire "transmitter loops" measuring 250 by 250 meters (shown in Figure 2) were set up at each survey location to transmit an on-off pulsed current pattern into the wire loop. This pulsed current pattern induced electrical "eddy" currents into the earth that were measured by receiver coils set up at two positions located inside and outside the transmitter loop. Following procedures recommended by Geonics, the TEM data were recorded from the two receiver coil positions using the transmitter current frequency rates, receiver coils, and output current ranges listed below.

Receiver Coil Position on Loop Center Line	**Transmitter Frequency Rates (Hertz)**	**Type of Receiver Coil Used**	**Current Output Range (Amps)**
66- 69 meters inside loop	75 and 62.5*	Medium Frequency	5.2 to 5.4
30- 36 meters outside loop	7.5 and 6.25*	Low Frequency	14.1 to 15.2

*Transmitter rates changed later to these settings to minimize possible inference from power lines near the east side of the survey area.

Initially, we planned to use these procedures with 300 by 300 meter transmitter loops and with both a TEM57 transmitter and extra TEM67A power module for added current output for the SOW desired 500-meter depth of resolution. However, after discussions with the hydrogeologist from Batiland Construction it was decided that this deeper depth of resolution was not necessary because the usable groundwater resources in this area were mostly above the 300-meter depth level. Therefore, the TEM57 transmitter was used with the 250 by 250 meter loops to allow better resolution of resistivity layering in the upper 300 meters and a maximum depth of resolution of about 400 meters.

2.2 Magnetometer Surveys

The magnetometer surveys were performed along the paralleling survey line transects shown in Figure 3. The three paralleling sets of surveys lines designated as Lines 101 through 403 were set up to follow the TEM measurement points. These survey lines were spaced about 120-130 meters apart in the north-south direction.

Two Geometrics G857 proton precession magnetometers were used for the magnetometer surveys. One magnetometer was used to record measurements of the earth's total magnetic field at 10-meters intervals along the survey lines. The other magnetometer was set up as a base station at a fixed location to record diurnal variations in the earth's total magnetic field at closely-spaced time intervals. These measurements were used to correct the magnetic field measurements for the diurnal variations.

Both magnetometers were configured with their sensors orientated to the north in a horizontal position to measure the near 10-degree south magnetic field inclination in Djibouti.

3.0 DATA PROCESSING AND DISPLAY

3.1 TEM Resistivity Data

The TEM data from measurement points TEM-1 through TEM-14 were processed using the computer modeling program IX1D developed by Interpex, Ltd. (Golden, Colorado). The data were first pre-processed using the Geonics computer program PROTIX64 to edit the voltage "decay curves" recorded from several receiver gain settings used for each transmitter frequency rate. The decay curves from the two transmitter frequency rates were merged together in IX1D to prepare final decay curves for each measurement point by masking (eliminating from modeling) the earlier time segments of the 6.25 and 7.5 Hertz decay curves. These segments of the lower frequency curves incorrectly deviated from the overlapping 62.5 and 75 Hertz decay curves due to the higher transmitter current levels and the more conductive layering near the surface. The final voltage decay curves from each TEM measurement point were then converted to "apparent resistivity" versus time curves.

The apparent resistivity curves underwent several rounds of computer modeling with IX1D to fit various one-dimensional (1D) profiles of resistivity layering to the data. Initially, a smoothed, 30-layer model of resistivity layering was calculated for each measurement point. This smoothed model was then used to calculate seven to ten-layer resistivity models that were further refined until a consistent set of 1D resistivity profiles was obtained for all 14 TEM measurement points. The resulting 1D resistivity depth profiles and apparent resistivity curves are shown in Appendix 1.

A two-dimensional (2D) profile of subsurface resistivity variations was prepared for the transect from TEM-1 through TEM-14. To prepare this 2D profile the 1D resistivity profile data underwent spatial gridding and contouring in IX1D. The resulting west-to-east, color-contoured, subsurface resistivity profile is shown in Figure 4. Note that the vertical scale on this subsurface profile is converted to elevation relative to sea level.

The 2D resistivity profile in Figure 4 and our knowledge of geologic conditions in this area supports our assumption that 1D modeling of lateral variations in resistivity layering beneath TEM-1 through TEM-14 is appropriate. This is shown by the gradual variations in the shape of the apparent resistivity curves and the consistency in the resistivity layering. However, on the east end of this profile the resistivity layering shown for the upper 100 meters is probably incorrect at TEM-14. The east edge of the transmitter loop in this area was close to a north-south overhead wire line that appears to have affected the earlier-time portion of the voltage decay and apparent resistivity curves.

3.2 Magnetometer Data

The magnetic field data from the magnetometer surveys along Lines 101-403 underwent computer processing using the Geometrics program MAGMAP. The magnetic field readings recorded at constant time intervals by the base station magnetometer were used to correct the survey magnetometer readings for diurnal variations of the earth's magnetic field. The corrected "magnetic field anomaly" measurements were plotted versus the total distance along each set of connecting survey lines. Figure 5 shows these magnetic field anomaly profiles along the three paralleling sets of survey line traverses.

The magnetic anomaly profiles in Figure 5 show numerous higher-amplitude magnetic field variations that occur within measurement intervals of 30 meters or less. These "sharper" magnetic anomalies are most likely not caused by deeper subsurface geologic structures. These anomalies are probably caused by the various basalt boulder piles on the ground surface from grading operations and the areas with near-surface accumulations of boulder-size basalt rocks east of survey station 1500 meters.

4.0 RESULTS OF GROUNDWATER EXPLORATION

4.1 Area Hydrogeology and Groundwater Wells

The following summarizes the available information on the hydrogeology of the area and the data from the groundwater wells surrounding the CADJ.

The CADJ is within the volcanic bedrock terrain mapped as the "Gulf Basalts" which range in age from 1 to 3.4 million years. The most productive aquifers in Djibouti occur within these basalt bedrock units. These bedrock aquifers receive their recharge from water movement through the alluvium in the surrounding ephemeral stream channels known as "wadis". Constant rate pumping tests conducted on the wells in these aquifers estimated transmissivity values (flow rates through the well screen area) averaging around 200 m^2/hour with a maximum value of 1,100 m^2/hour estimated at one location. The older (deeper) part of these basalt units is highly weathered and subject to hydrothermal alternation and can have silica and calcite deposition filling the pore spaces and fissures (Jalludin and Razack, 2004). This indicates that in certain areas the deeper part of these basalt units could be much less productive than the upper part.

The basalt bedrock near the CADJ appears to be well stratified. The lithologic logs from wells Wehad 1 and Wehad 2 (less than 1.5 kilometers east of the CADJ) show that the basalt stratigraphy in the upper 125 meters consists of intact basalt units separated by layers of unconsolidated to consolidated basalt debris and older mixed grain-size alluvium with basalt pebbles and gravels. The matrix within this older alluvium also contains intervals of clay. The intact basalt units range in thickness up to about 25 meters and have zones of fissures (fractured basalt) and scoriaceous basalt. This basalt stratigraphy appears to have mostly horizontal bedding based on our field reconnaissance of the rock outcrops on the wadi canyon walls immediately east of the site.

The upper groundwater aquifer in this area also appears to respond as an unconfined groundwater system. The regional groundwater flow direction is to the northeast towards Djibouti City (NAVFAC/USGS, 2011). Jalludin and Razack (2004) and other researchers report that the exploitation of this aquifer has resulted in sea water intrusion and a lowering of the piezometric surface. Because the Gulf of Tadjoura is 8 kilometers to the north and 12 kilometers to east, it is expected that this deeper salt water interface has extended inland to beneath the CADJ. Sea water intrusion induced from pumping wells in an unconfined groundwater system typically causes a "wedge shaped" layer of denser salt water to migrate inland beneath the fresh water aquifer.

The map in Figure 1 shows the locations of the existing groundwater wells surrounding the CADJ. Table 1 shows the data made available from these wells. These data show three active groundwater extraction wells with flow rates ranging from 25 to 34 m^3/hour. All of these wells are within a 3-kilometer radius from the center of the CADJ. The estimated static water level elevations at nearby wells Awrofoul 1, Awrofoul 4, Awrofoul 5, and Whad 4 range from 14.8 to 24 meters above sea level. Well Awrofoul 1 is located northwest of the CADJ and has water with the lowest electrical conductivity of 1,104 µS/cm. According to our local hydrogeologist this electrical conductivity value indicates a relativity good salinity and total dissolved solids (TDS) level for the groundwater in this area of Djibouti. However, Freeze and Cherry (1979) report that most municipal aquifers have groundwater electrical conductivity levels of less than 667 µS/cm (which is equivalent to a water resistivity of 15 ohm-meters). It is expected that the electrical conductivity of the groundwater beneath the CADJ will also exceed 667 µS/cm. This indicates groundwater at CADJ may need water treatment if water quality parameters exceed U.S. Environmental Protection Agency's primary drinking water standards for potable (drinking and cooking) water. If the well water is to be used for non-potable (washing and toilet flushing) purposes the water quality may be of much less concern. The water temperature measurements in nearby wells in the range of 45.5 to 55.8 degrees Celsius also indicate there is geothermal activity in this area and water temperatures in the deeper basalt aquifers could be higher.

4.2 Geophysical Data Evaluation

Our evaluation of the data from the TEM resistivity surveys and the existing wells indicates that a groundwater aquifer exists beneath the CADJ. The resistivity profiles across the northern edge of the CADJ (in Figure 4 and Appendix 1) are the primary basis for this conclusion. They first revealed lower formation resistivities of less than 100 ohm-meter starting at 20 to 30 meters below the ground surface and continuing to the maximum depth of beyond 300 meters. These lower resistivity values in this basalt stratigraphy indicate fluid conductivity due to saturated to partially-saturated groundwater conditions. If there were significant layers of relatively dry alluvium and basalt in this area the formation resistivities would be much higher than 200 ohm-meters.

The well data in Table 1 was used to estimate the expected resistivity range for a "usable" (acceptable quality) aquifer formation in this area. After first converting the measured electrical conductivity of the water samples from these wells to resistivity in ohm-meters, a simplified form of Archie's Law was used to estimate the resistivity ranges for the aquifer formations at the surrounding well sites. The spreadsheet for these calculations is shown in Table 1. These calculations are based on aquifer porosity values ranging from 20 to 30 percent and formation factor values ranging from 1 to 1.4. These same formation factor values were used for a similar groundwater exploration project in the USA in Nevada within a Tertiary volcanic rock terrain (Taylor, et al., 1992). The spreadsheet uses these “end values” to calculate a highest and lowest aquifer formation resistivity for each well site. If we exclude the wells Hayel 2 and Wehad 4 with the highest electrical conductivities, we estimate a formation resistivity range of 15 to 86 ohm-meters for a useable aquifer at the CADJ. In areas where there are thicker intervals of clay within this aquifer the formation resistivity would be below 10 ohm-meters.

Based on this evaluation, the most usable aquifers occur on the west side of the subsurface resistivity profile in Figure 4, beneath locations TEM-1 to TEM-5. In this area the 1D resistivity profiles in Appendix 1 show a shallower resistivity layer above the 120 to 130-meter depth level that is within this 15 to 86 ohm-meter range for a useable aquifer. Starting at depth levels of 130 to 150 meters there is also another deeper resistivity layer that is within this resistivity range. These two aquifer zones are separated by a thinner layer of lower resistivity around 10 ohm-meters. Figure 4 also shows a much lower resistivity layer starting at about 150 meters below sea level that could be due to sea water intrusion and/or geothermal brines.

The magnetic anomaly profiles in Figure 5 exhibit some patterns of broader, higher-amplitude magnetic field anomalies measured over intervals greater than 30 meters which could be due to subsurface geologic structures such as fault deformation within the basalt bedrock. All except one of these weakly identified anomaly patterns fall within the area from TEM-1 to TEM-5, along survey Lines 101 through 203.

Near TEM-3 both the magnetic anomaly profiles in Figure 5 and the site map in Figure 3 show evidence of a possible north-west trending fault. This fault is probably best evidenced by the topographic escarpment in Figure 3, where it is visible in the Google Earth satellite imagery and can be traced further to the southeast. This more recent fault deformation expressed at the ground surface indicates there could be groundwater flow within an open fracture zones in the bedrock along this fault. Existing groundwater production wells Awrofoul 1 and 2 also appear to be along the trend of this possible fault alignment.

5.0 RECOMMENDATIONS

Based on our current evaluation of the geophysical data we recommend that one or more small-diameter, exploratory pilot boreholes first be drilled at a planned well site location near the location of TEM-3. The boreholes should be drilled through the upper aquifer zone and into the lower aquifer zone to a total depth of about 180 meters (as shown in Figure 4). If the groundwater testing results from the borehole show an adequate flow rate and the salinity and TDS concentration levels are within acceptable limits (to be defined based on the intended water use) a groundwater extraction well could then be constructed at this location with multiple well screen intervals.

The Naval Facility Engineering Service Center Trip Report (NFESC, 2007) on Djiboutian groundwater resources provides recommendations for the drilling and construction of deeper wells in basalt aquifers. We recommend that procedures in this report and the experience from the previous well installation attempt at the CADJ be studied to plan the technical approach, design, and construction methodology for this extraction well. As discussed in the NFESC report, borehole lithologic logging, geophysical logging, and formation sampling for grain-size distribution analysis will provide very useful data in the design phase to enhance the well's performance and life expectancy. Geophysical logs such as long-normal electromagnetic induction and natural gamma logs could be easily run inside a stable borehole or a temporary well casing placed in the pilot borehole to help better determine the positioning of the well screen intervals. In addition, well testing for flow rate, water level drawdown during pumping, and water quality testing should also be conducted to estimate the well capabilities.

Difficult well drilling conditions will most likely be encountered. The previous well installation attempt at the CADJ reported several intervals of groundwater flow into the borehole below the 20-meter depth, and at the maximum depth of 61 meters the borehole wall became unstable and began collapsing. Based on the limited information available it appears this previous well installation was abandoned. This experience and our own experience with well installations in basalt bedrock terrain suggest that the drilling method and well bore diameter should be adjusted based on the drilling equipment available. If possible, an air-rotary drilling system should be used with a down hole hammer while advancing a casing to prevent borehole collapse.

6.0 REFERENCES

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Jalludin and Razack, 2004, Assessment of Hydraulic Properties of Sedimentary and Volcanic Aquifer Systems Under Arid Conditions in the Republic of Djibouti (Horn of Africa), Mohamed Jalludin and Moumtaz Razack, Hydrogeology Journal, Vol. 12, 2004.

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Taylor, et al., 1992, Use of Transient Electromagnetics to Define Local Hydrogeology in an Arid Alluvial Environment, Kendrick Taylor, Micheal Widmer, and Matthew Chesley, Geophysics, Vol. 57, No. 2, 1992

Table 1 Data from Groundwater Wells Surrounding Chabelley Airfield

Well Name	Well Depth (m)	Surface Elevation (m)	Static Water Level* (m)	Pumping Water Level* (m)	Static Water Elevation (m)	Water Temperature (°C)	Electrical Conductivity (μS/cm)	Chloride Conc. (mg/l)	Well Flow Rate (m^3/h)	Year Comissioned	Observations
WEHAD 4	140	77	61		16		3500		34		
CHEBELLE	150	134	91		43		1230		25		
WEHAD 1	108.4	62	59		3	55	2090				
AWROFOUL. 1	128	107.23	86.58	90.75	20.65	45.5	1104	190	25	2007	In service
AWROFOUL. 2	150	119	86.98	90.88	32.02	59.4	1320	221	35	2012	In service
AWROFOUL. 3	160	106.1	92.67		13.43	44	2209		10	2012	Abandoned- Low flow
AWROFOUL. 4	157	101	77	134.4	24	53	1300		10	2012	Abandoned- Low flow
AWROFOUL. 5	160	87.8	73	77.82	14.8	55.8	1978		30	2012	
AWROFOUL. 6	206	102.1	114.43	130.62	-12.33	52.8	1380		30	2012	
HAYEL. 2	55	38	46.4	46.68	-8.4	40.8	3693		25.4	2014	
BOLDOGO	122	82	70.11	95.03	11.89	53.5	1467		7.5	2015	Not in service

Available Data Provided by Consulting Hydrogeologist from Batiland Construction, Djibouti
* Depth Below Ground Surface

Spreadsheet for Archie's Law Estimates of Aquifer Formation Resistivity

Formation Resistivity= Resistivity Water x 1/(Porosity)^{FF}

Well Name	Electrical Conductivity (μS/cm)	Resistivity Water (ohm-m)	Porosity 1	Formation Factor (FF) 1	Porosity 2	Formation Factor (FF) 2	Aquifer Formation Resistivity 1	Aquifer Formation Resistivity 2
WEHAD 4	3500	2.86	0.2	1.4	0.3	1	27	10
CHEBELLE	1230	8.13	0.2	1.4	0.3	1	77	27
WEHAD 1	2090	4.78	0.2	1.4	0.3	1	46	16
AWROFOUL. 1	1104	9.06	0.2	1.4	0.3	1	86	30
AWROFOUL. 2	1320	7.58	0.2	1.4	0.3	1	72	25
AWROFOUL. 3	2209	4.53	0.2	1.4	0.3	1	43	15
AWROFOUL. 4	1300	7.69	0.2	1.4	0.3	1	73	26
AWROFOUL. 5	1978	5.06	0.2	1.4	0.3	1	48	17
AWROFOUL. 6	1380	7.25	0.2	1.4	0.3	1	69	24
HAYEL. 2	3693	2.71	0.2	1.4	0.3	1	26	9
BOLDOGO	1467	6.82	0.2	1.4	0.3	1	65	23

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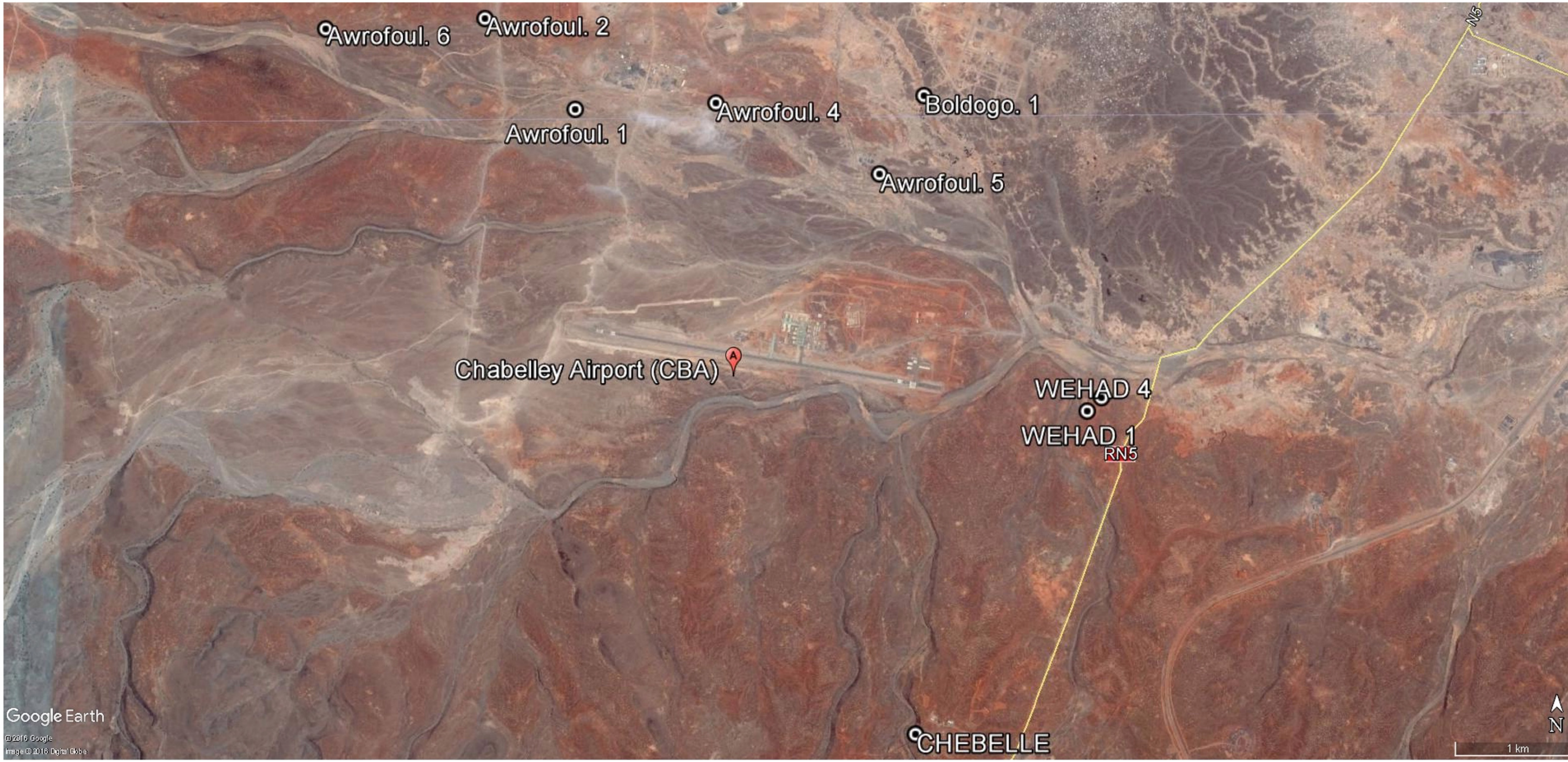
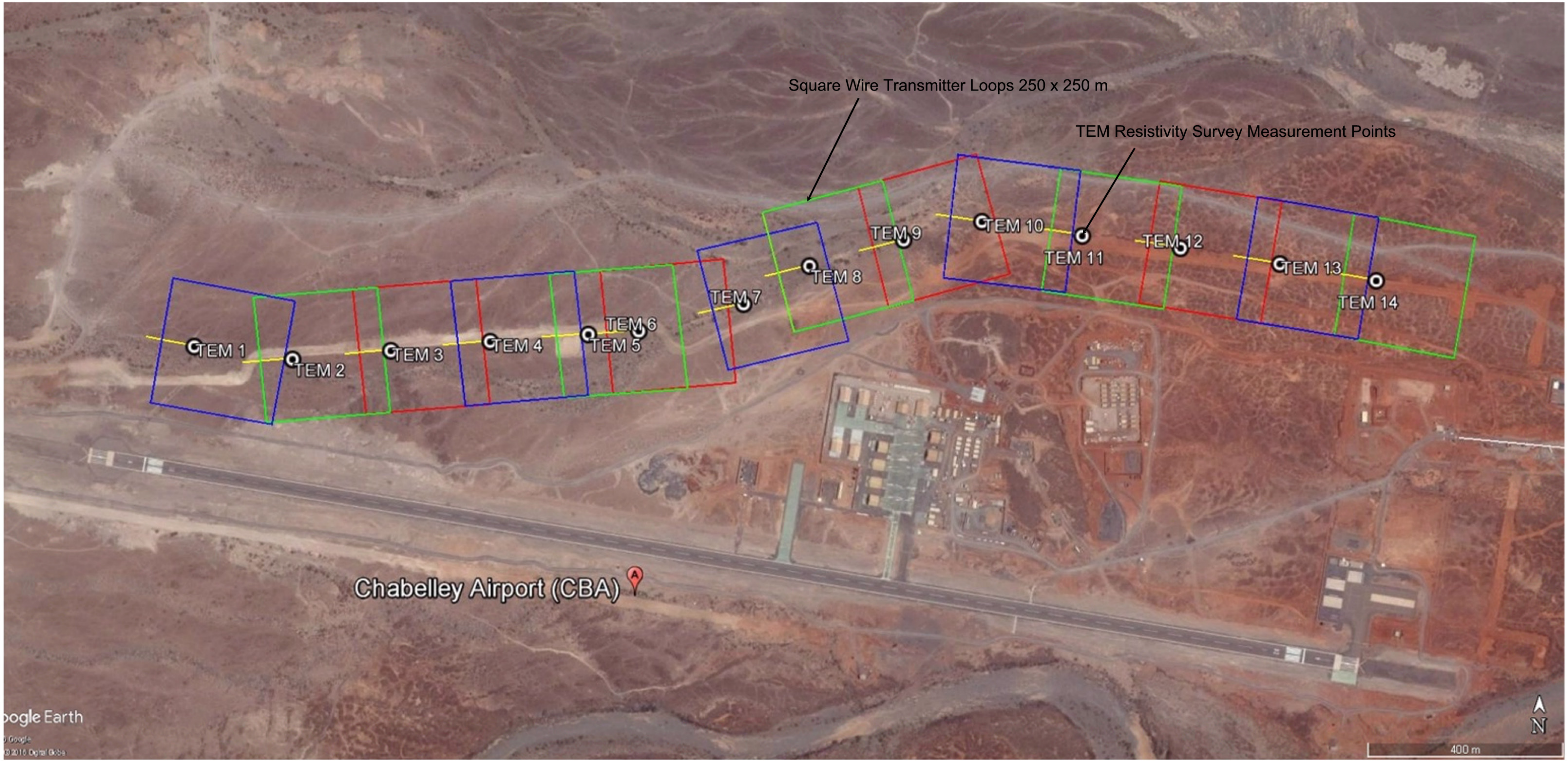
December, 2016



Map Scale 1 inch= 1 km

Google Earth Site Map Showing Chabelley Airfield and
Existing Groundwater Well Locations
Geophysical Investigation for Groundwater Exploration at CADJ

Figure 1
Advanced Geoscience, Inc.



Map Scale 1 inch= 200 m

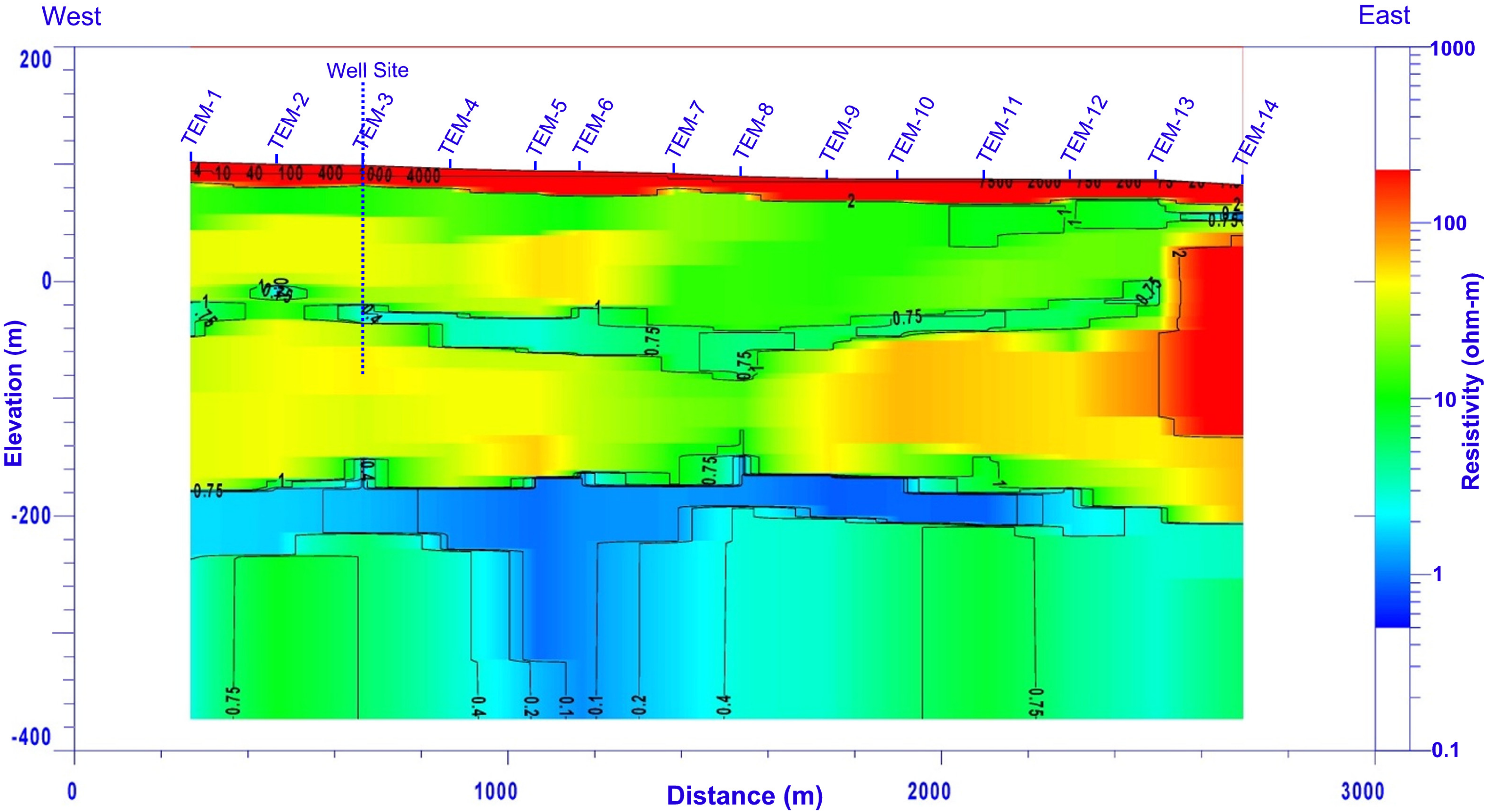
Google Earth Site Map Showing
Locations of TEM Resistivity Surveys
Geophysical Investigation for Groundwater Exploration at CADJ

Figure 2
Advanced Geoscience, Inc.

Map Scale 1 inch= 200 m

Google Earth Site Map Showing
Locations of Magnetometer and TEM Resistivity Surveys
Geophysical Investigation for Groundwater Exploration at CADJ

Figure 3
Advanced Geoscience, Inc.



Resistivity Elevation Profile Generated by Program IX1D Developed by Interpex, Ltd.
Based on Computer Gridding and Contouring of 1D TEM Resitivity Models
Contour Lines Show Logarithmic Values

Vertical Scale 1 inch= 80 m
Contour Lines Show Logarithmic Values

Subsurface Electrical Resistiviity Profile
Along Transect from Measurement Points TEM-1 to TEM-14
Geophysical Investigation for Groundwater Exploration at CADJ

Figure 4
Advanced Geoscience, Inc.

Dashed lines show interpretation of broader magnetic anomalies measured over intervals greater than 30 m
These anomaly trends could be caused by deeper subsurface structures such as faults in the basalt bedrock.

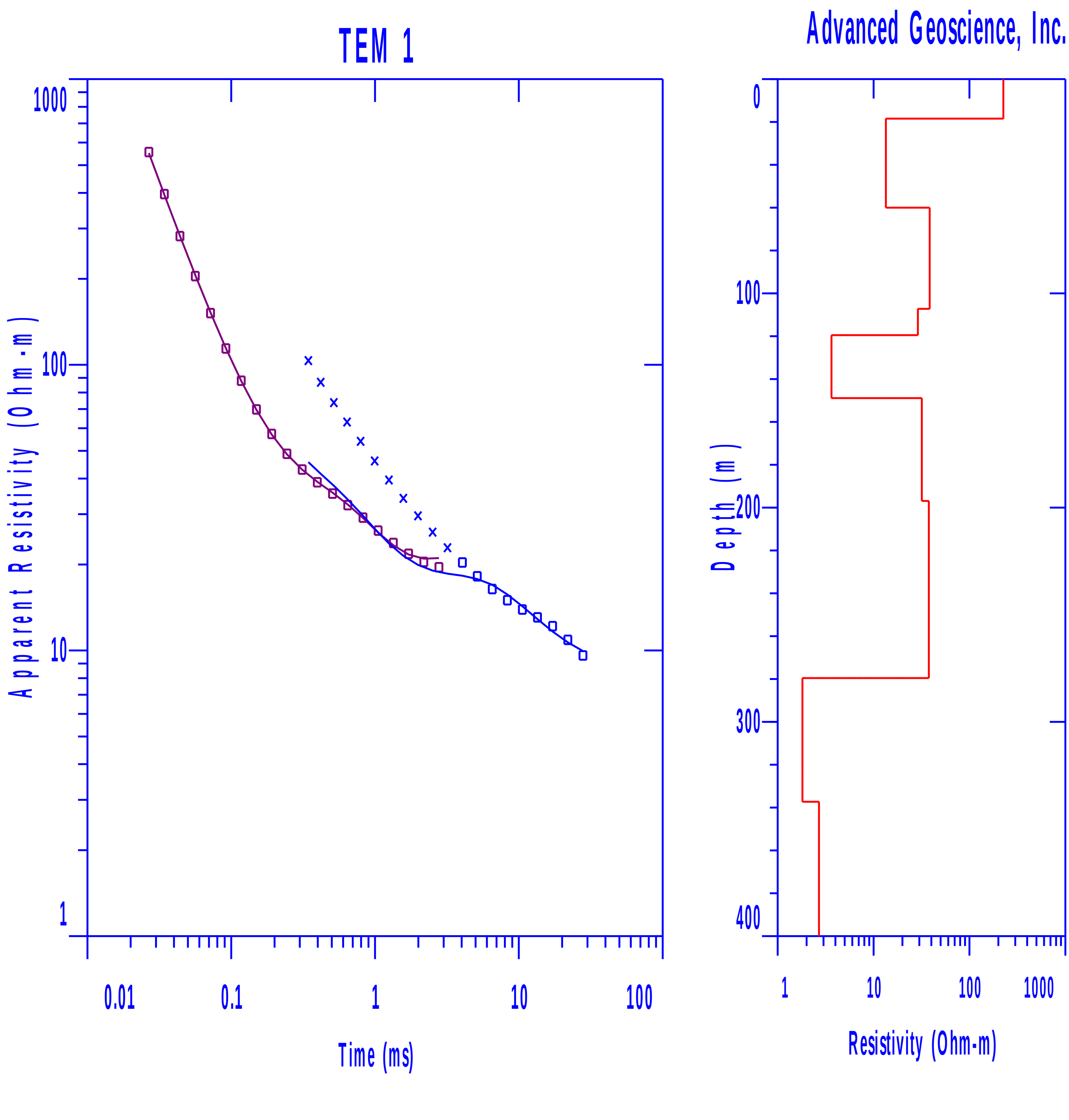
Magnetic Field Anomaly Profiles
Along Survey Lines 101- 403
Geophysical Investigation for Groundwater Exploration at CADJ

Figure 5
Advanced Geoscience, Inc.

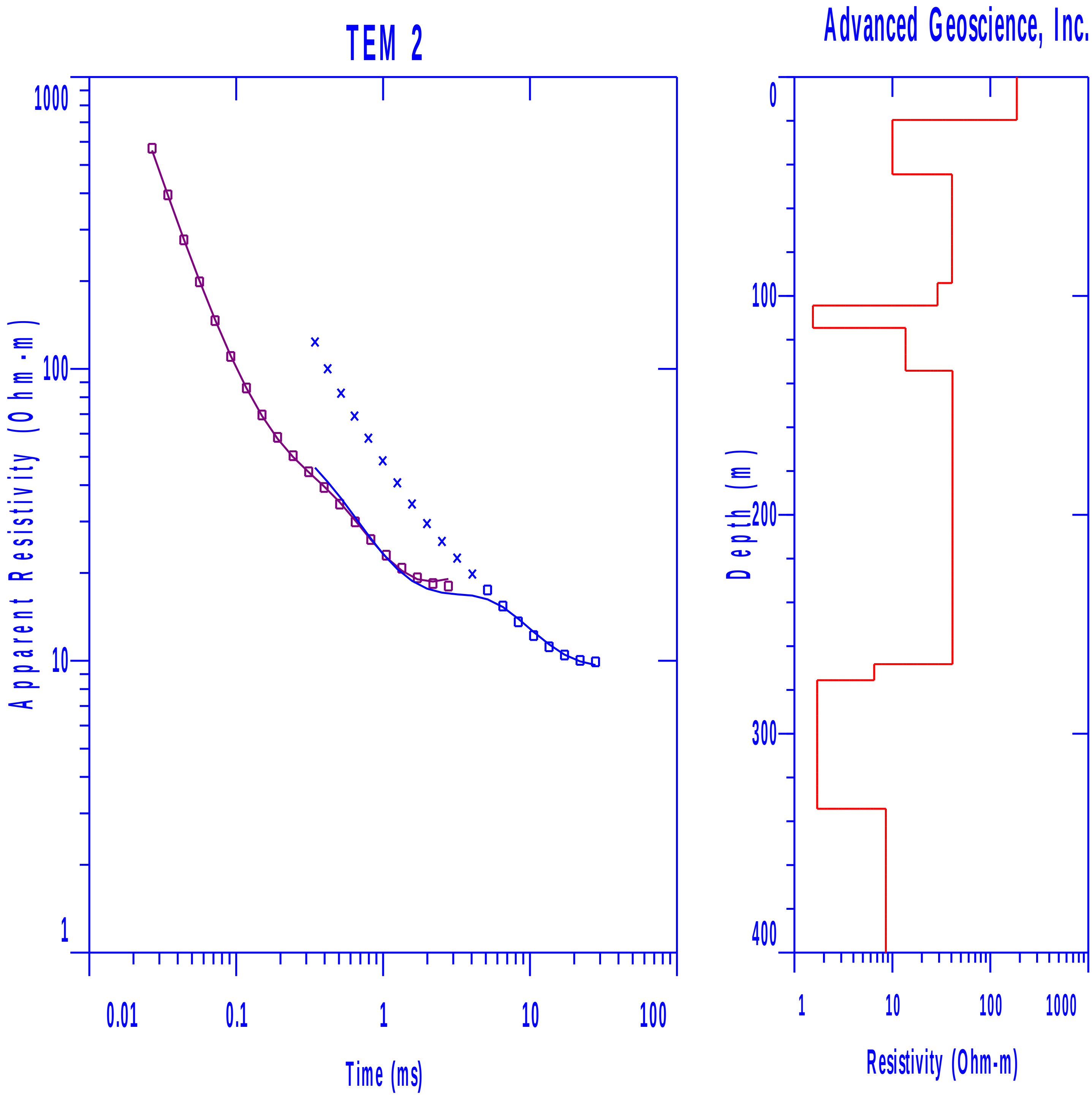
APPRENDIX 1

Appendix 1 contains the one-dimensional (1D) resistivity versus depth profiles and apparent resistivity curves for the transient electromagnetic (TEM) resistivity surveys at measurement points TEM-1 to TEM-14 at the Chabelley Airfield, Djibouti.

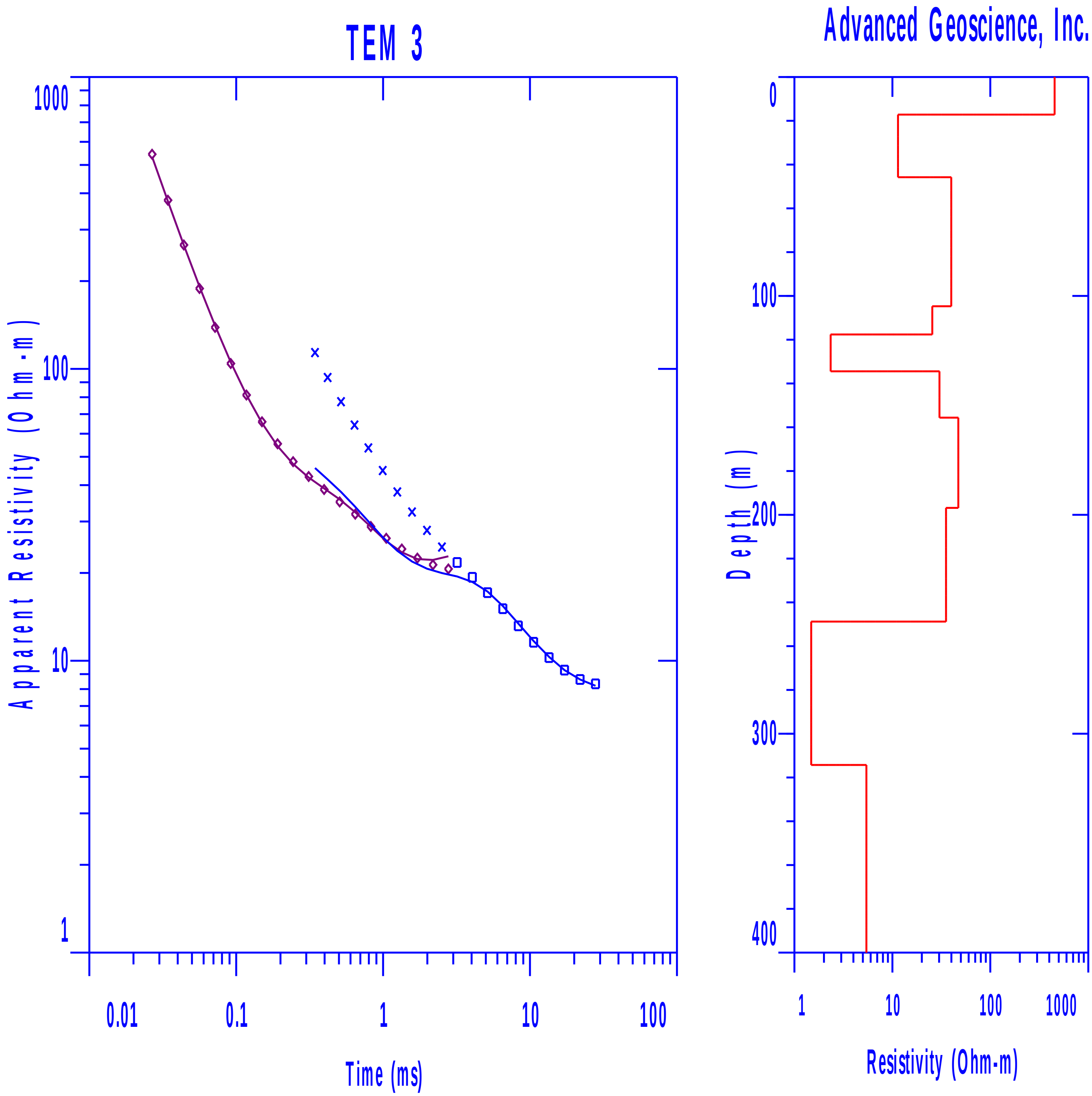
The 1D resistivity depth profiles for TEM-1 through TEM-14 were generated using the computer modeling program IX1D developed by Interpex, Ltd. (Golden, Colorado USA)



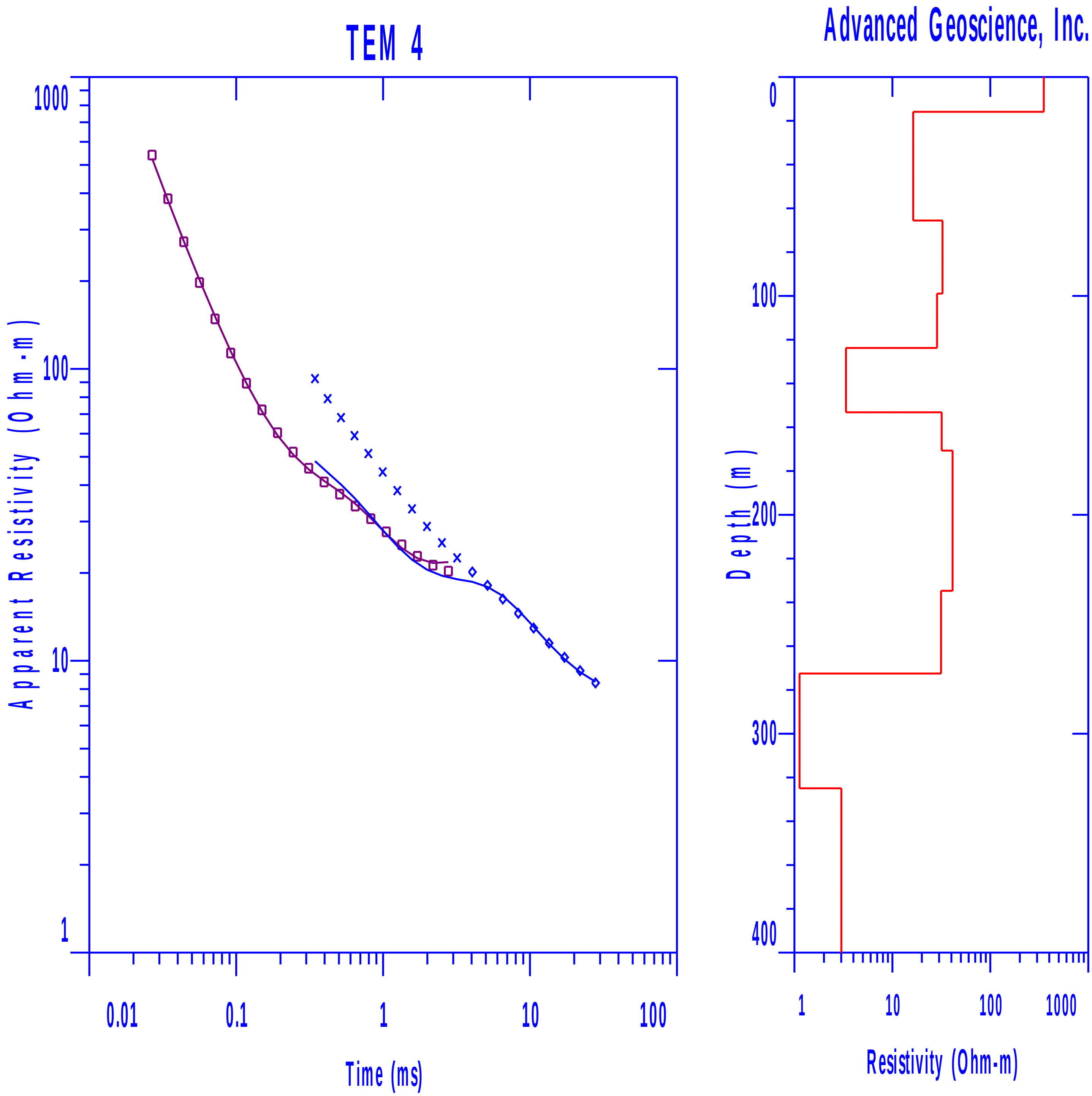
TEM 1
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
1
10
100
1000
Resistivity (Ohm-m)



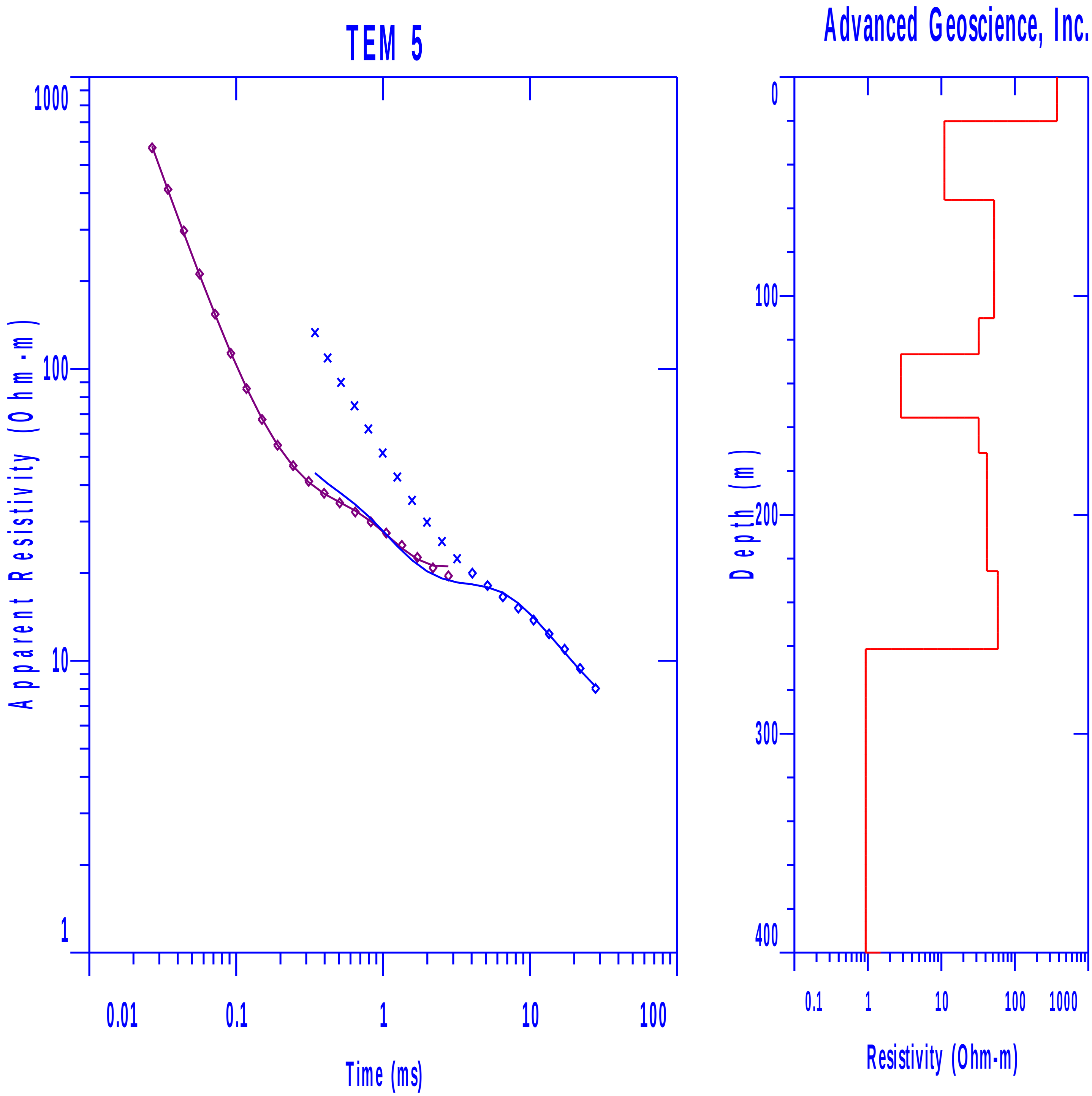
TEM 2
Advanced Geoscience, Inc.
1000
100
10
1
Apparent Resistivity (Ohm-m)
0.01
0.1
1
10
100
Time (ms)
0
100
200
300
400
Depth (m)
1
10
100
1000
Resistivity (Ohm-m)



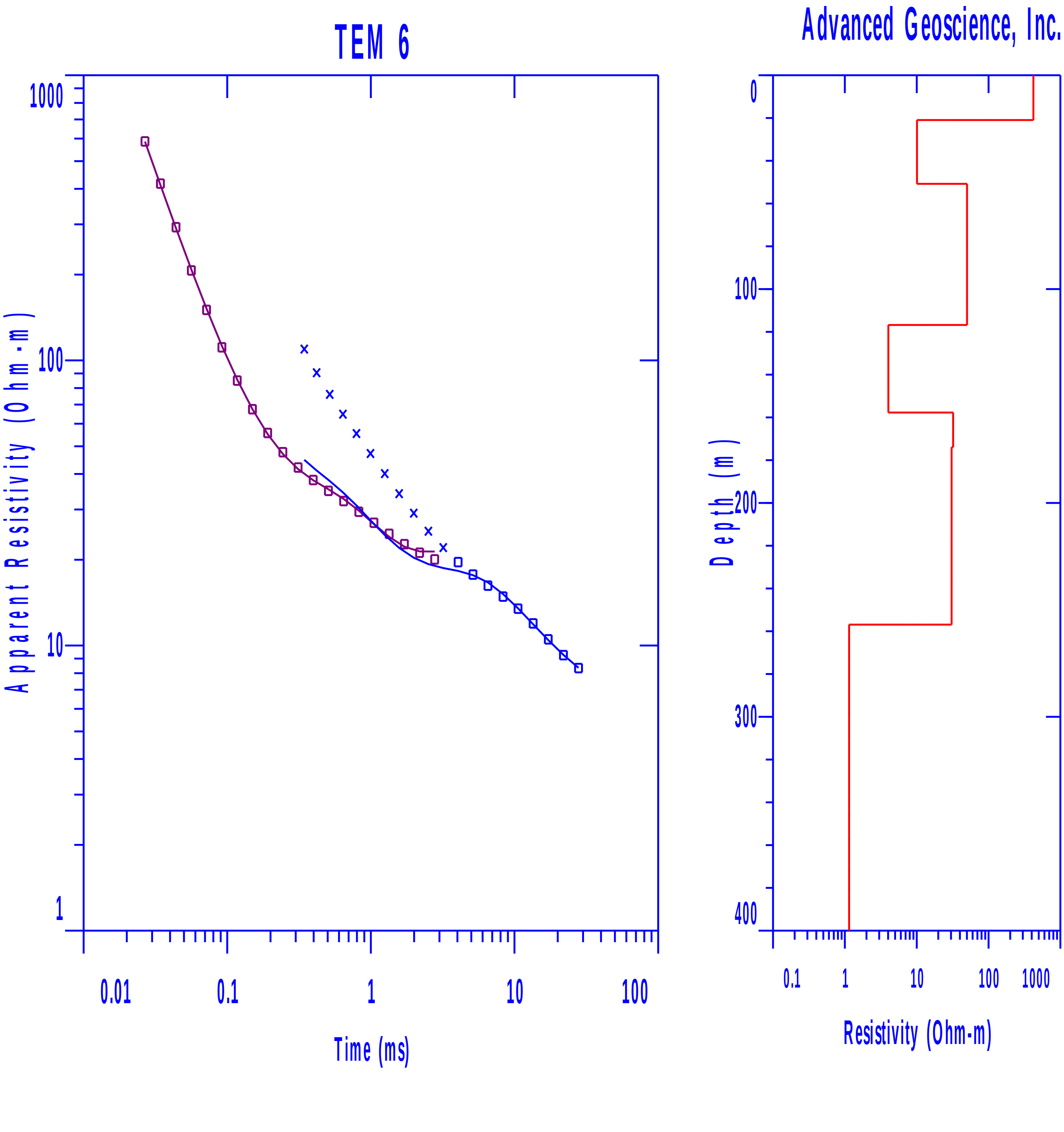
TEM 3
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
1
10
100
1000
Resistivity (Ohm-m)



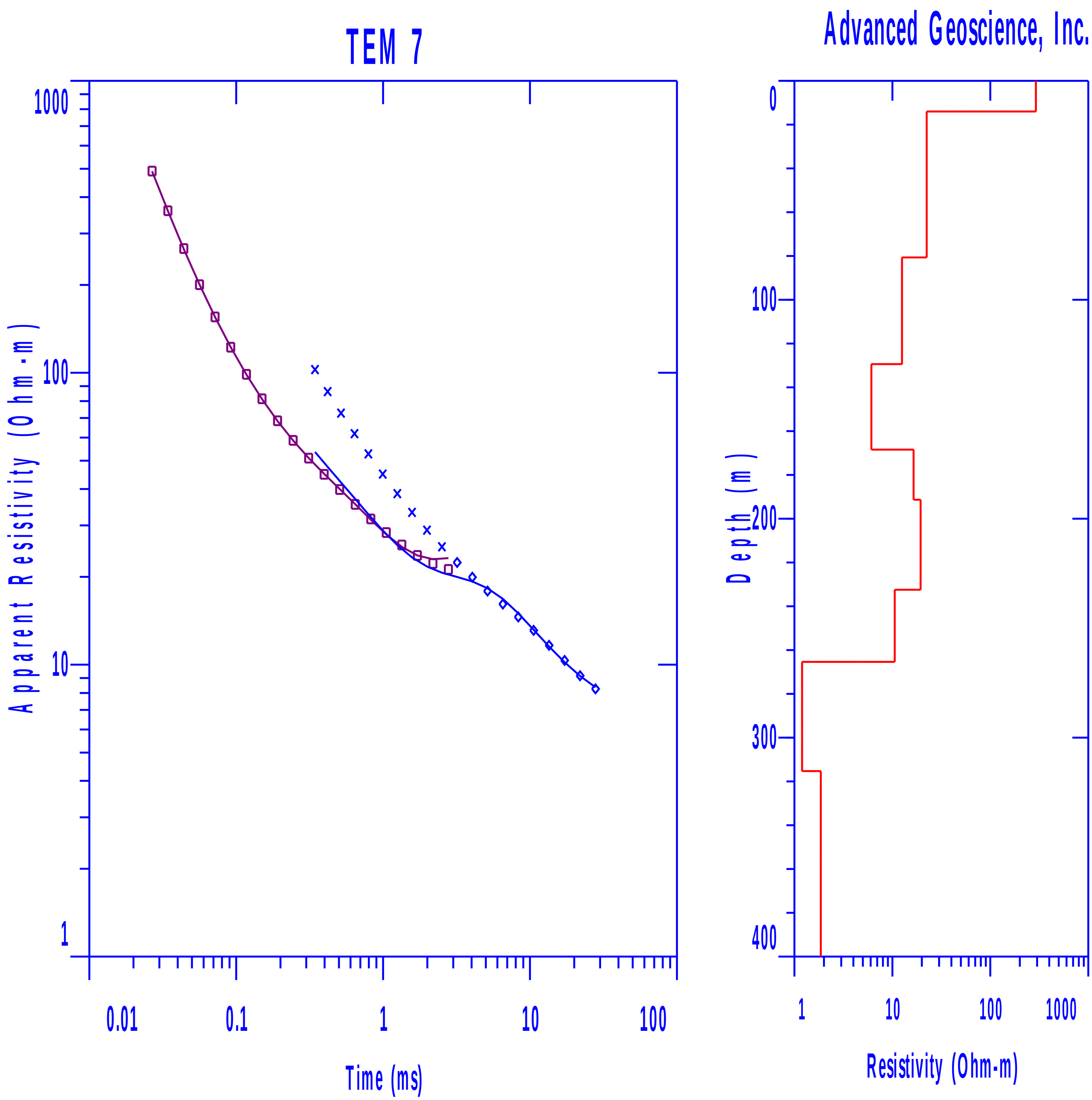
TEM 4
Advanced Geoscience, Inc.
1000
100
10
1
Apparent Resistivity (Ohm-m)
0.01
0.1
1
10
100
Time (ms)
0
100
200
300
400
Depth (m)
1
10
100
1000
Resistivity (Ohm-m)

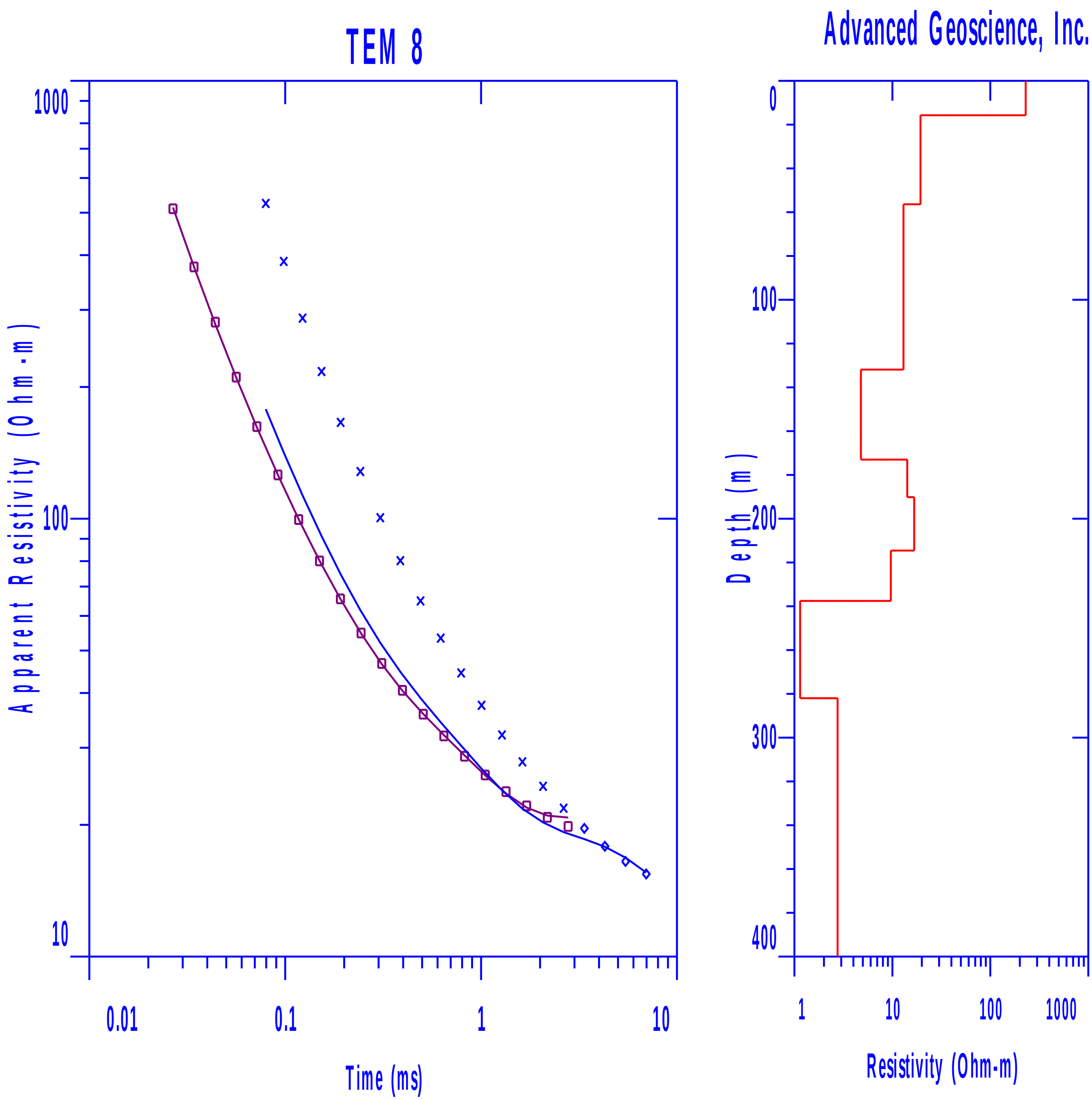


TEM 5
Advanced Geoscience, Inc.
1000
100
10
1
Apparent Resistivity (Ohm·m)
0.01
0.1
1
10
100
Time (ms)
0
100
200
300
400
Depth (m)
0.1
1
10
100
1000
Resistivity (Ohm-m)

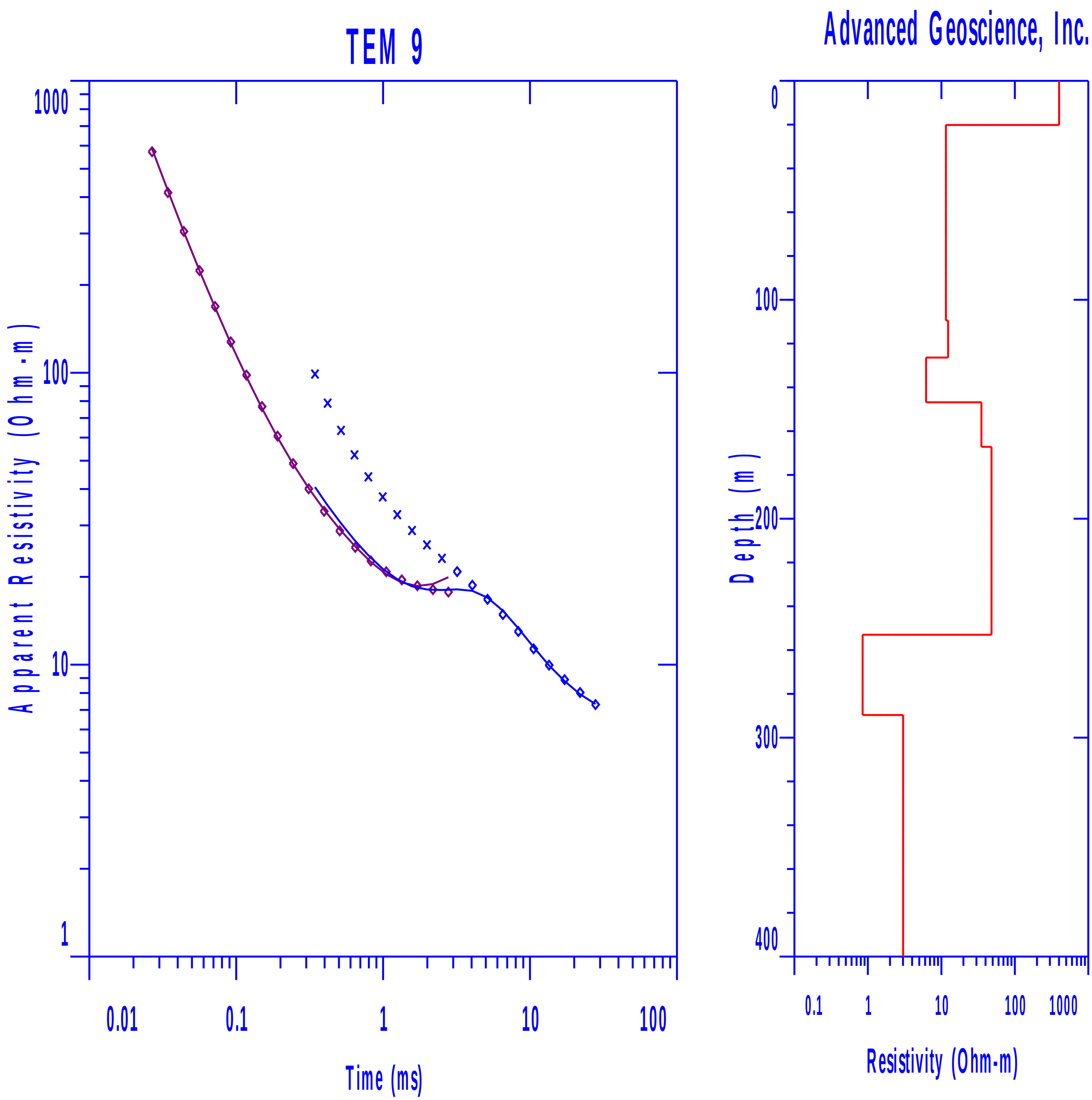


TEM 6
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
0
100
200
300
400
Depth (m)
0.1
1
10
100
1000
Resistivity (Ohm-m)

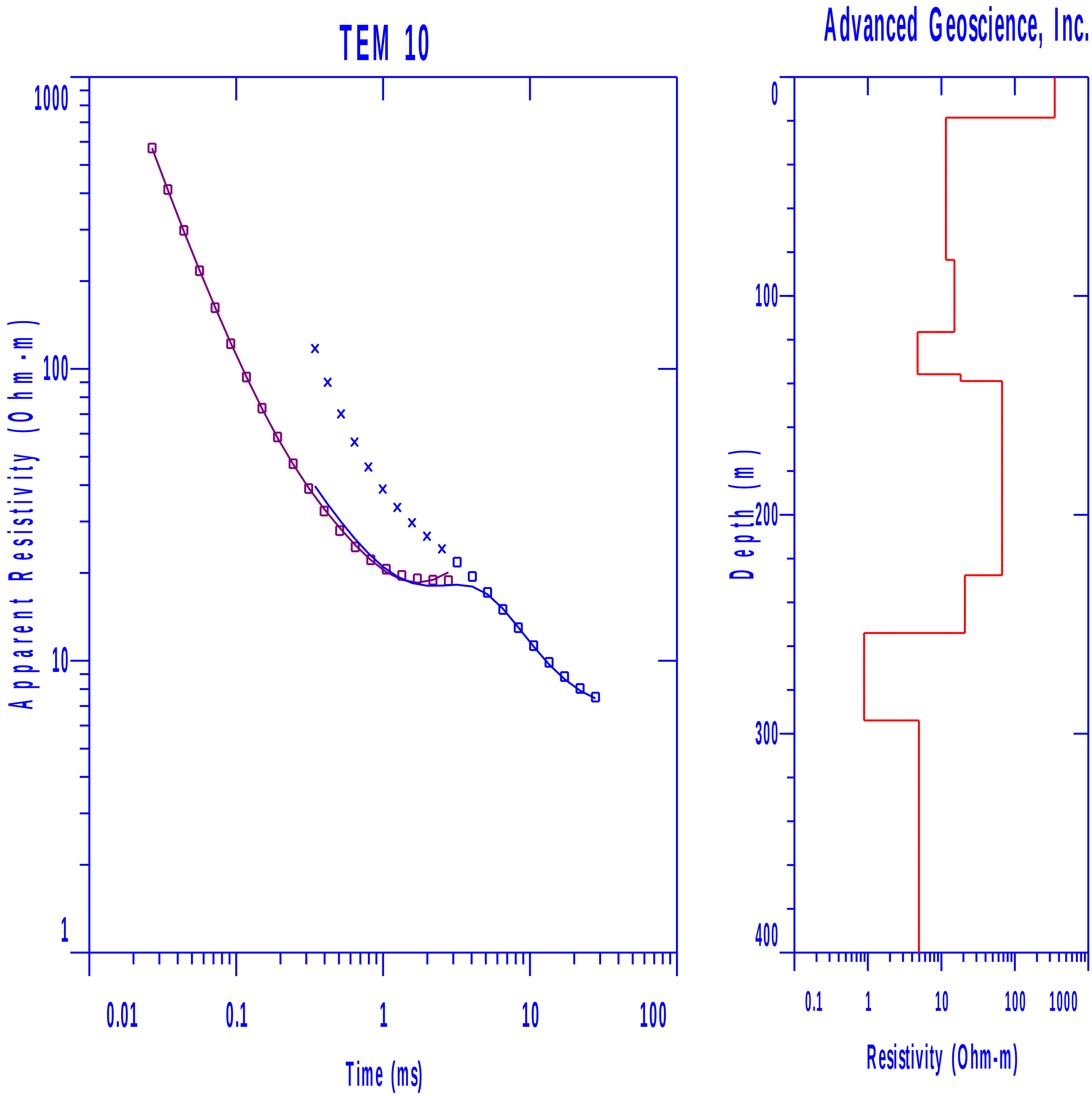

TEM 7
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
1
10
100
1000
Resistivity (Ohm-m)



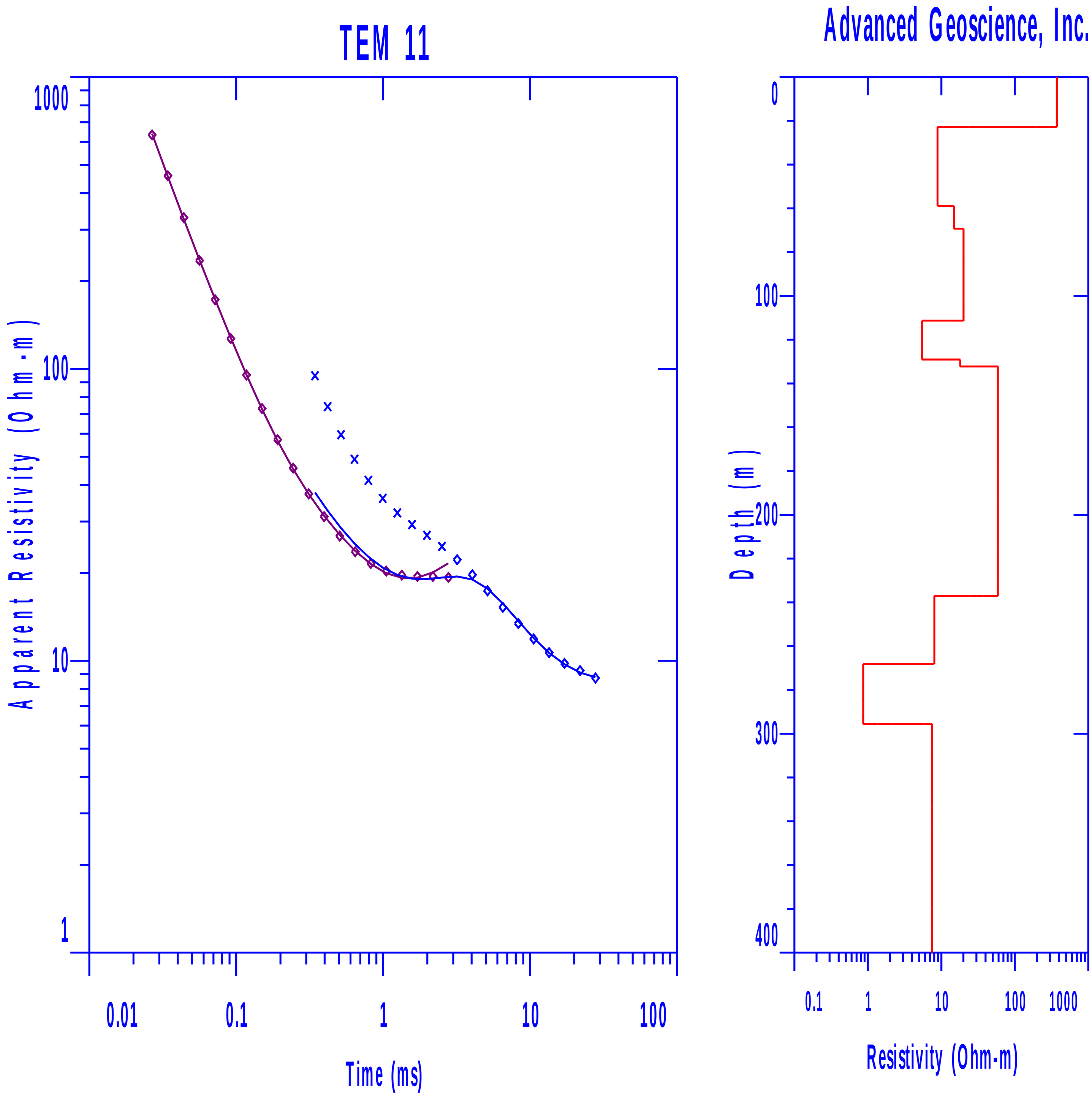
TEM 8
Advanced Geoscience, Inc.
1000
100
10
Apparent Resistivity (Ohm-m)
0.01
0.1
1
10
Time (ms)
0
100
200
300
400
Depth (m)
1
10
100
1000
Resistivity (Ohm-m)



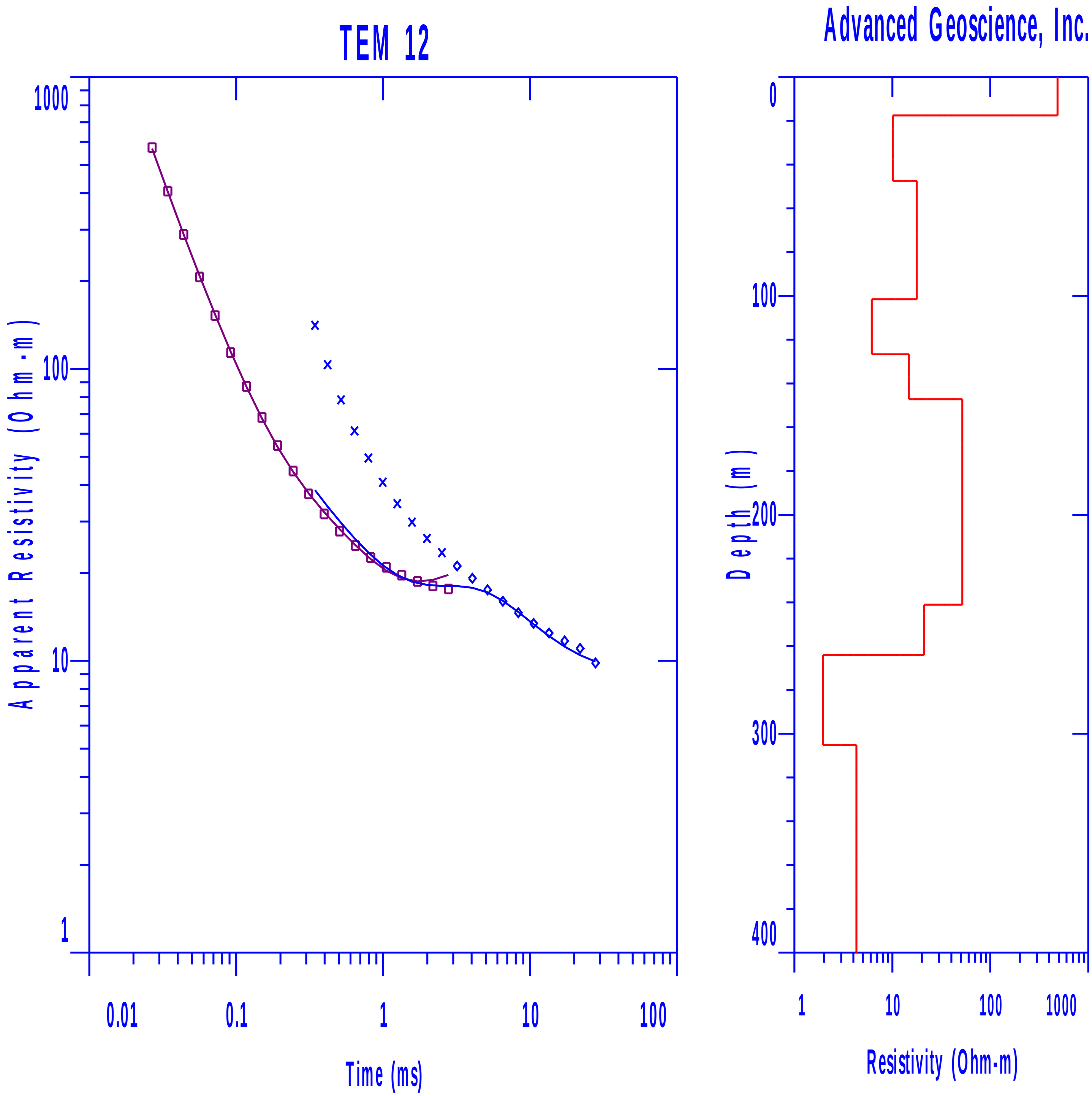
TEM 9
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
0.1
1
10
100
1000
Resistivity (Ohm-m)



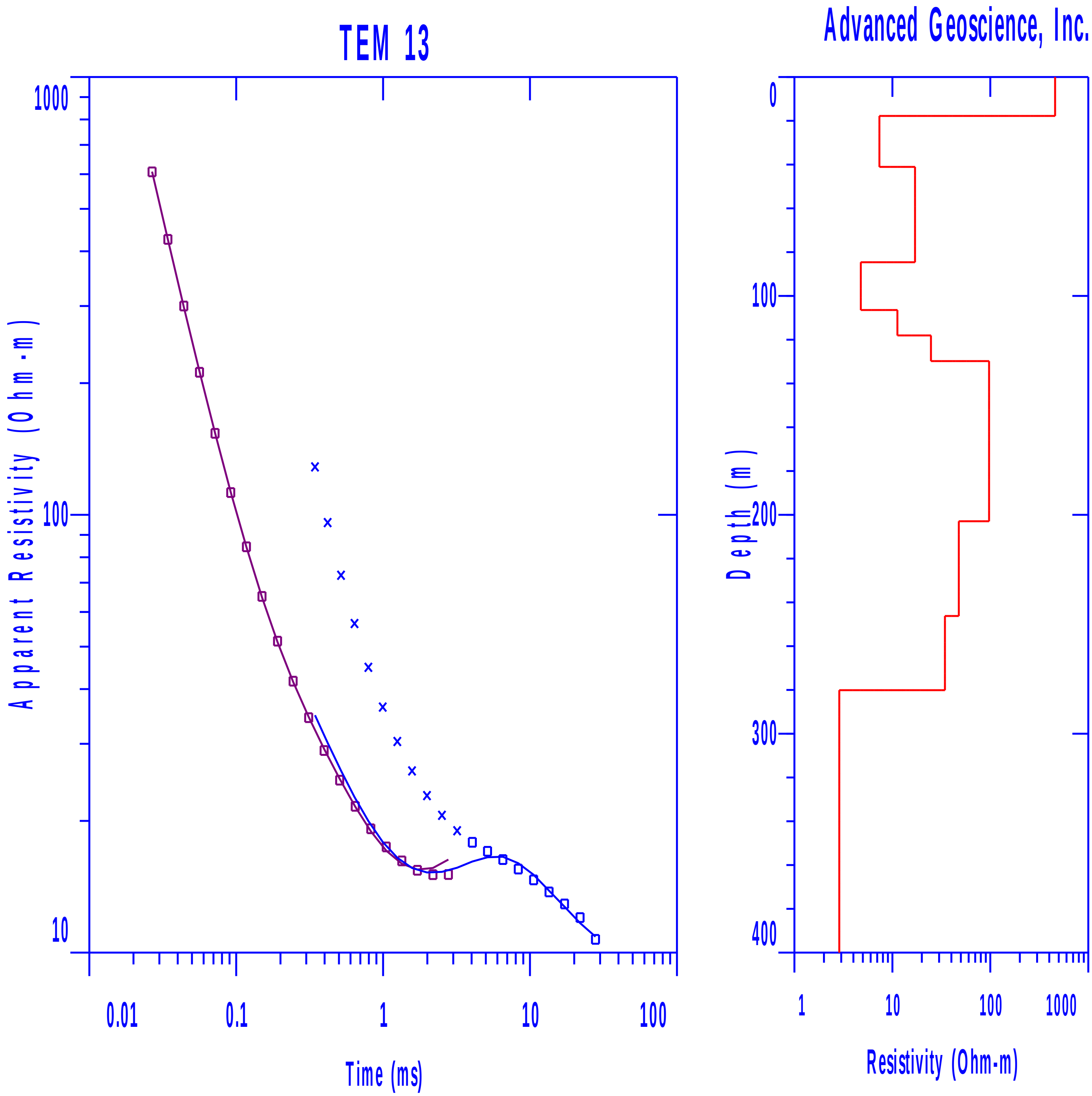
TEM 10
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
0.1
1
10
100
1000
Resistivity (Ohm-m)



TEM 11
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
0.1
1
10
100
1000
Resistivity (Ohm-m)

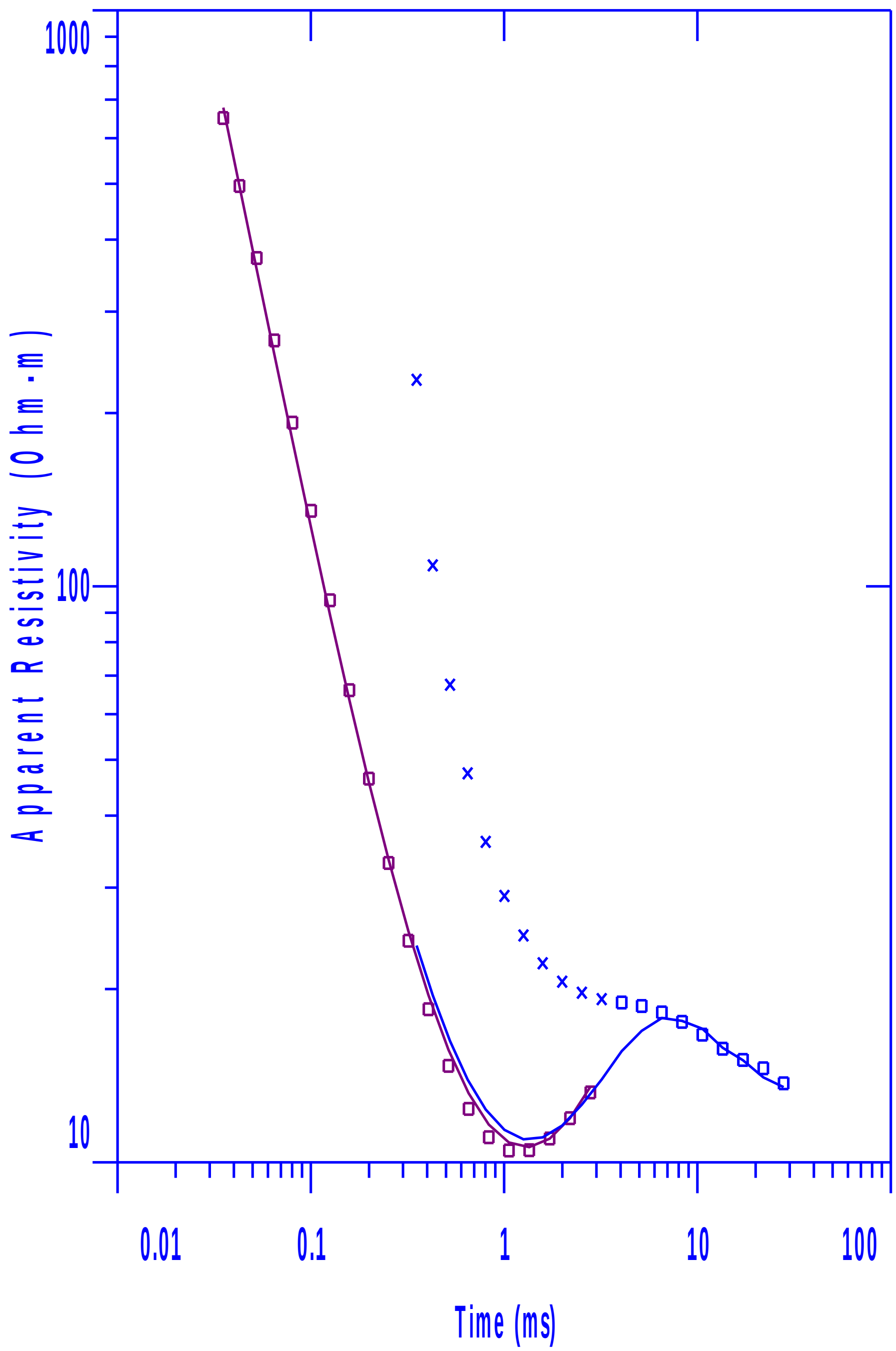


TEM 12
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
1
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
1
10
100
1000
Resistivity (Ohm-m)



TEM 13
Advanced Geoscience, Inc.
Apparent Resistivity (Ohm-m)
1000
100
10
0.01
0.1
1
10
100
Time (ms)
Depth (m)
0
100
200
300
400
1
10
100
1000
Resistivity (Ohm-m)

TEM 14



Advanced Geoscience, Inc.