IP/Resistivity Survey

Parcel 115210090-
Old Ore Mill Site

for

City of Tucson
Environmental Services

by
Zonge Engineering & Research Organization, Inc.

Zonge Job #0667
Issue Date: 29-August-2006

Zonge Engineering & Research Organization, Inc.
3322 East Fort Lowell Road, Tucson, AZ 85716 USA
Tel (520) 327-5501 Fax (520) 325-1588 Email zonge@zonge.com

Final Report

Resistivity/IP Survey
Parcel 115210090
Old Ore Mill Site
for
City of Tucson
Environmental Services

EXECUTIVE SUMMARY

On July 14th and 18th 2006, Zonge Engineering acquired resistivity and induced polarization (IP) geophysical data on Parcel 115210090 at the request of the City of Tucson (COT), Environmental Services. The general location of the project site is shown in Figure 1. The primary contact during this project was Richard Byrd of COT Environmental Services. The goal of the survey was to determine whether or not a mine shaft or adit exists near several structures that remain from what is reportedly an early 20th century ore mill or smelter site.

Four lines of data were acquired initially (Lines A, B, C, and D) and the data were processed and modeled; based on those results, two additional lines were acquired (Lines E and F). Figure 2 shows the line and station locations overlaid on an aerial photograph of the site. The range of resistivities is consistent with prior surveys in and around the Tucson area, and the data quality is good.

Figure 3 shows the survey results in resistivity cross section form. There is no clear indication of any tunnels or voids in the area surveyed, which are usually evident in electrical surveys as anomalously high resistivity features relative to background. There is a weak high resistivity anomaly that is seen on Lines A, B, and C, along the east side of the road or path through the survey site. This anomaly could be a very small or partially filled tunnel, but it is more likely to be resistive material making up part of the path foundation. The anomaly is very similar to results from surveys over construction debris (concrete, boulders, etc.). This feature is labeled on the survey cross sections in Figure 3, and on the line location map in plan view. The path itself is slightly higher topographically than the

surrounding terrain (see the cross sections for Lines A and B in Figure 3), and the resistivity data show this slight topographic high as lower resistivity material than the surrounding native surface. This indicates that disturbed or non-native material was used as the path base.

The weak high resistivity anomaly appears to be very shallow, and could probably be investigated by trenching. It is strongest on Line C near station 143.

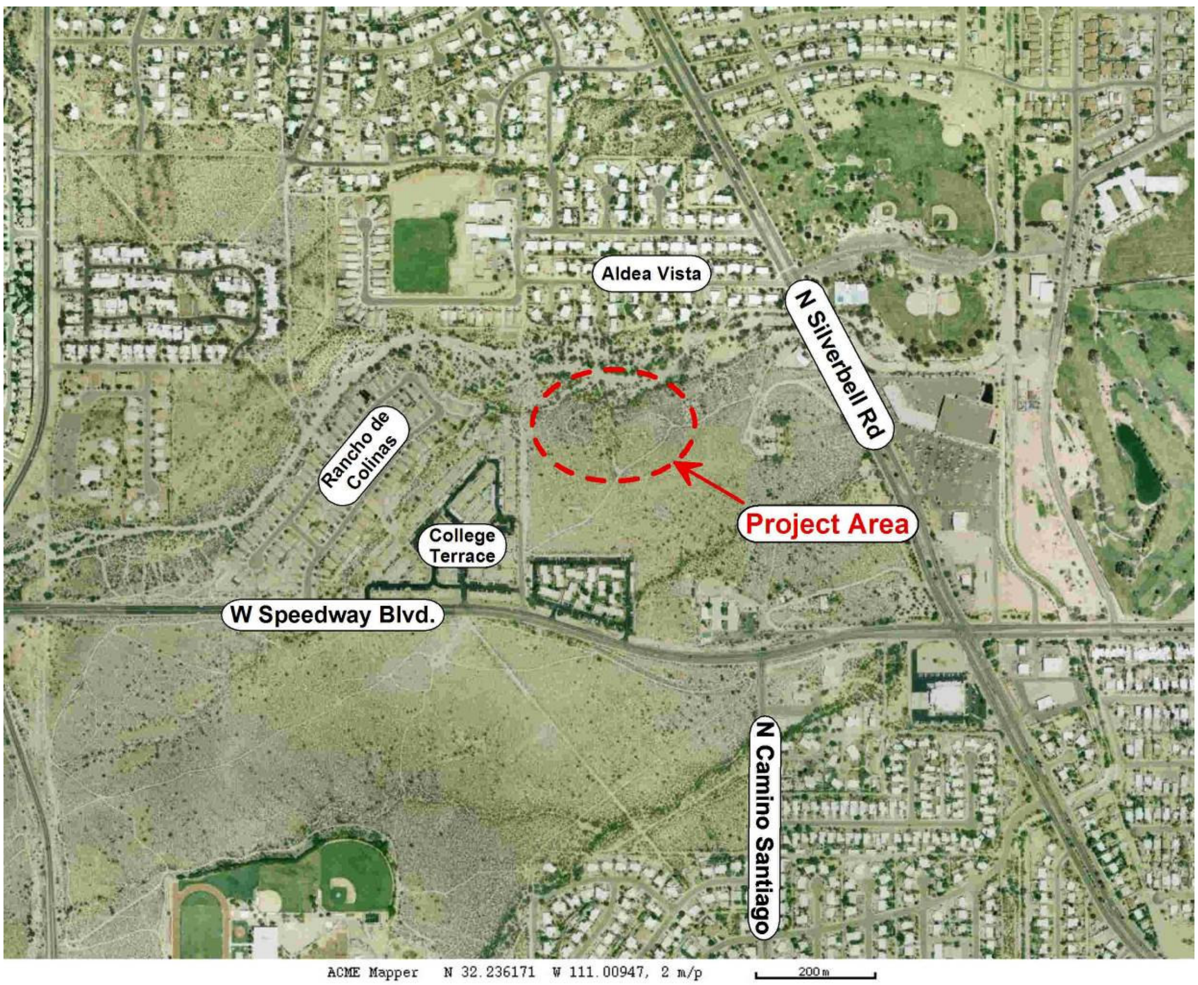


Figure 1: *General location of the project site.*

PROJECT LOGISTICS

Survey Methodology

The type of geophysical survey conducted on the Parcel 115210090 project area was an Induced Polarization (IP) and resistivity survey acquired in the dipole-dipole configuration using Zonge Engineering's ZETA (Zonge Electrical Tomography Acquisition) system. In the dipole-dipole configuration, a controlled electrical signal is transmitted into the ground via a grounded dipole (two stakes in the ground, connected to the transmitter with insulated wire). At varying distances from this dipole, the transmitted signal is received on different grounded dipoles and recorded digitally by the microprocessor controlled receiver electronics. One electrical property of the ground that can be measured in this manner is called resistivity; a change in ground resistivity (the ability of the ground to conduct electrical current) affects the strength of the received signal. A different electrical property is called chargeability, or induced polarization (IP); a change in IP (the ability of material in the ground to polarize at interfaces) affects the shape or timing of the received waveform.

Variations in subsurface moisture content, porosity, permeability, and soil or rock type can all affect resistivity measurements. Cultural features (man-made objects such as fences, power lines, pipelines, etc.) can also affect ground resistivity measurements.

Compared to changes in resistivity, there are relatively few subsurface conditions that create an IP response. Metallic mineralization, particularly disseminated sulphides, cause increased IP values. Certain dissolved solids in groundwater have been shown to increase IP response, and in some environments, some types of clay can also increase IP response if the abundance of the clay is within specific ranges (dependent on the type of clay). Extensive work over landfills has shown increased IP values, but the exact geochemical cause (or causes) of the effects have not been resolved. Like resistivity data, IP data can also be influenced by cultural features.

Survey Parameters

Six survey lines were acquired using a station (electrode) spacing of 7.5 feet and a dipole size of 15 feet. Data were acquired in the dipole-dipole array from an n-spacing of n=0.5 to n=6.0 in ½ n increments (i.e., 0.5n, 1.0n, 1.5n, etc.) to improve 2-D smooth-model inversion results.

Field Instrumentation

The receiver used for this survey was a Zonge GDP-32II multi-purpose receiver. This receiver is a backpack-portable, 16-bit, microprocessor-controlled receiver capable of gathering data on as many as 16 channels simultaneously. This receiver is manufactured and sold worldwide by Zonge Engineering. The electric-field signal was sensed at the receiver site using tin-coated copper braid electrodes, connected to the mutiplexer unit with 22 gauge insulated cadmium-bronze wire. The multiplexer unit, which allows computer-controlled switching of up to 30 transmitter and receiver locations, was an MX-30 Multiplexer, also manufactured by Zonge Engineering.

The signal source for the survey was a Zonge ZT-30 transmitter, which is battery-powered and commonly used for transient electromagnetic surveys. The transmitter was controlled directly by the receiver, eliminating the need for clock synchronization. One channel of the receiver was used to monitor and record the transmitter output. Specifications for the primary equipment used in the survey may be found in the appendix of this report.

Data Quality and Cultural Contamination

The data were of good to very good quality, based on good repeatability of raw data measurements and good repeatability of data from overlapping electrode spreads. Contact resistance of the electrodes was good, and the fit between the models and the data was very good.

Cultural features include man-made conductive objects such as pipelines, power lines, fences, etc. Cultural effects can be noise from active electrical sources such as active power lines and cathodic protection on pipelines, or from passive features which distort the electric fields such as fences or pipelines. With the exception of an old pipeline seen near Line E, no cultural noise sources intersected any of the lines, and there are no cultural features close to the survey site.

Smooth-Model Inversion

The final maps and cross-sections provided are the smooth-model inversion results of the dipole-dipole data. Since the dipole-dipole array is not a vertical sounding method, a buried IP responder can affect measurements that are not directly over the responder, making the interpretation of location, size, and depth very difficult. Briefly, smooth-model inversion mathematically "back-calculates" (or "inverts") from the measured data to determine a likely location, size and depth of the source or sources of IP and resistivity changes. The results of the smooth-model inversion are intentionally gradational, rather than showing abrupt, "blocky" changes in the subsurface.

The inversion results should not be considered a unique solution, and some ambiguity remains in any mathematical representation of the data. The likelihood that the interpretation is correct increases with corroborating information, of course. The smooth-model inversion program is called "TS2DIP", written by Scott MacInnes of Zonge Engineering & Research Organization, Inc., and discussed in more detail in his paper "Two-dimensional Inversion of Resistivity and IP Data with Topography", presented in the Geophysics Session, Northwest Mining Association Convention, December, 1996.

DATA PRESENTATION

The resistivity results are presented as cross-sections of each line with the northern most line (Line F) at the top of the page (Figure 3). The "warm" colors (yellow, orange, red) indicate low resistivity or high conductivity, and "cool" colors (shading towards blue) indicate high resistivity or low conductivity.

Figure 2 shows the location of each line relative to a structure to the west (labeled Western Structure) and a concrete pad to the south. The dashed black line marks the path of the high resistivity anomaly.

DISCUSSION OF THE DATA

The general electrical structure of the area appears to be a thin layer of moderate to high resistivity over a thicker more conductive layer. A tunnel or void corresponding to a mine shaft or adit usually appears in the resistivity data as a resistivity high relative to background. No obvious features are evident in the data that may indicate a subsurface void.

A high resistivity anomaly can be seen intersecting Lines A, B, and C at stations 135, 140, and 143, respectively. This feature is labeled on Figure 3 as the “High Resistivity Anomaly” and shown as a dashed line on Figure 2. It should be noted that the anomaly is located on the eastern edge of a topographic high that transverses through part of the project area. An asphalt path extends down the center and to the west of this topographic high. It is possible that the anomaly could represent a small or partially filled void or it could be the result of construction debris used to form the path and topographic high.

Since the high resistivity anomaly is located close to the surface, it may be relatively easy to confirm the source (construction debris or a partially collapsed tunnel or void). The strongest part of the anomaly is located at 980255E, 451641N or station 143 on Line C.

Note that there are also high resistivity values very near the surface at approximately station 155 on Line E. These values could be related to the high resistivity anomaly discussed above, but it is more likely these are the result of debris or culture near a pit that is crossed by Line E. An old, metal, partially-buried pipeline was noted in this vicinity by the field crew, and an old foundation is evident in the area of station 130 on this line.

Induced polarization (IP) data were also acquired and examined, in the event that an old tunnel existed that contained man-made metallic cultural features such powerlines, rails, or pipes, since these kinds of features would probably produce an IP effect. No consistent anomalies indicative of these kinds of features are seen along the high resistivity anomaly discussed above, under the path, or elsewhere crossing these lines.

Cris Mayerle
Geophysicist

Norman Carlson
Chief Geophysicist

Appendix A

Equipment Specifications

GDP-32^{II} Geophysical Receiver

Multi-Function Receiver

The GDP-32^{II} is Zonge Engineering's fourth generation multi-channel receiver for acquisition of controlled- and natural-source geoelectric and EM data.

ENHANCEMENTS

- **66 or 133 MHz 586 processor**
- **Expanded keyboard**
- **½-VGA graphics display**
- **Ethernet port**
- **Full Windows 95® compatibility**

UNIQUE CAPABILITIES

- **Remote control operation**
- **Broadband time-series recording**
- **High-speed data transfer**

FEATURES

- 1 to 16 channels, user expandable
- Alphanumeric keypad
- 66 or 133 MHz 586 CPU
- Easy to use menu-driven software
- Resistivity, Time/Frequency Domain IP, CR, CSAMT, Harmonic analysis CSAMT (HACSAMT), AMT, MT, TEM & NanoTEM®
- Screen graphics: plots of time-domain decay, resistivity and phase, complex plane plots, etc., on a 480x320 ½-VGA, sunlight readable LCD
- Internal humidity and temperature sensors
- Time schedule program for remote operation with the XMT-32S transmitter controller
- Use as a data logger for analog data, borehole data, etc.
- Full compatibility with GDP-16 and GDP-32 series receivers.
- 0.015625 Hz to 8 KHz frequency range standard, 0.0007 Hz minimum for MT
- One 16-bit A/D per channel for maximum speed and phase accuracy.
- 256 Mb flash RAM (up to 1 Gb) for program and data storage, sufficient to hold many days worth of data.
- 16 Mb dRAM (up to 48 Mb) for program execution.
- 4 Gb hard disk (up to 40 Gb) for time series data storage.
- Real-time data and statistics display
- Anti-alias, powerline notch, and telluric filtering
- Automatic SP buckout, gain setting, and calibration
- Rugged, portable, and environmentally sealed
- Modular design for upgrades and board replacement
- Complete support: field peripherals, service network, software, and training

Zonge Engineering and Research Organization, Inc.

Specialists in Electrical Geophysics • Field Surveys • Geophysical Consulting • Instrumentation Sales and Lease

SPECIFICATIONS FOR THE GDP-32^{II} MULTI-FUNCTION RECEIVER

General

Broadband, multichannel, multifunction digital receiver.
Frequency range: 1/64Hz - 8KHz (0.0007Hz - 8KHz for MT)
Number of channels: Large case, 1 to 16 (user expandable)
Small case, 1 to 6 (user expandable).
Standard Survey capabilities: Resistivity, Frequency- and Time-Domain IP, Complex Resistivity, CSAMT (scalar, vector, tensor), Harmonic Analysis (CSAMT, Frequency-Domain EM, Transient Electromagnetics, NanoTEM®, MMR, Magnetic IP, Magnetotellurics, Downhole Logging.
Software language: C++ and assembly.
Size: Large case 43x41x23cm (17x16x9")
Small case 43x31x23cm (17x12x9")
Weight: (including batteries and meter/connection panel):
Small case 13.7 kg (29 lb)
Large case:
8 channel, 10 amp-hr batteries, 16.6 kg (36.5 lb)
8 channel, 20 amp-hr batteries, 20.5 kg (45 lb)
16 channel, disk, 10 amp-hr batteries, 19.1 kg (42 lb)
Enclosure: Heavy-duty, environmentally sealed aluminum
Power: 12V rechargeable batteries (removable pack)
Over 10 hours nominal operation at 20°C (8 channels and 20 amp-hr batteries). External battery input for extended operation in cold climates, or for more than 8 channels.
Temperature range: -40° to +45°C (-40° to +115°F)
Humidity range: 5% to 100%
Internal temperature and humidity sensors
Time base: Oven-controlled crystal oscillator; aging rate $<5x10^{-10}$ per 24 hours (GPS disciplining optional)

Displays & Controls

High-contrast sunlight readable ½-VGA (480x320) DFT-technology LCD graphics display, with continuous view-angle adjustment (optional heater for use down to –40°C).
Sealed 80-key keyboard
Analog signal meters and analog outputs
Power On-Off

Standard Analog

Input impedance: 10 MΩ at DC
Dynamic range: 190 db
Minimum detectable signal: 0.03 μV
Maximum input voltage: ±32V
SP offset adjustment: ±2.25V in 69μV steps (automatic)
Automatic gain ranging in binary steps from 1/8 to 65,536
Common-mode rejection at 1000 Hz: >80 db
Phase accuracy: ±0.1 milliradians (0.006 degree)
Adjacent channel isolation at 100 Hz: >90 db
Filter Section: Four-pole Bessel anti-alias filter (software-controlled) Quadruple-notch digital telluric filter (50/150/250/450 Hz, 50/150/60/180 Hz, 60/180/300/540 Hz, specified by user)
Analog to Digital Converter (Standard Channel)
Resolution: 16 bits ± ½ LSB
Conversion time: 17 μsec
Continuous self calibration
One A/D per channel for maximum speed and phase accuracy

NanoTEM® Analog

Input impedance: 20 KΩ at DC
Dynamic range: 120 db
Minimum detectable signal: 4 μV
Automatic gain ranging in binary steps from 10 to 160
Analog to Digital Converter: 14 bits ± ½ LSB, 16 bits optional
Conversion time: 1.2 μsec
One A/D per channel for maximum data acquisition speed

Digital Section

Microprocessor: 66 MHz 586 (133 MHz optional)
Memory: 16 Mb dRAM (up to 48 Mb)
Mass Storage (program & data storage):
256 Mb flash RAM (up to 1 Gb).
Hard disk drives with capacities to 40 Gb optional
Serial ports: 2 RS-232C ports (16650) standard
Parallel port: 1 SPP and EPP compatible printer port
Network Adapter: Ethernet adapter standard (10Base-T)
Mouse, CRT (VGA), and standard keyboard ports
Standard Operating System: Windows 95®

Additional Options

Number of channels: (maximum of 3 NanoTEM® channels)
Large case: 1-16, Small case: 1-6
External battery and LCD heater for –40°C operation

Other Acquisition Software

External RPIP/TDIP/CR Control: Remote control through serial port on GDP-32^{II} for electrical resistance tomography (ERT).
Streaming RPIP/TDIP: Continuous acquisition of TDIP or RPIP data (time domain or resistivity/phase IP) using a towed electrode array.
Borehole TEM: Remote control through GDP-32^{II} serial port for efficient logging of borehole TEM and MMR data. Compatible with Crone and Geonics 3-component probes.
Extended Broadband Time Series Data Recording: Continuous recording of up to 5 standard analog channels sampling at 32 K samples/sec (bandwidth 8 KHz with 2x oversampling) with no loss of data. The recording time is limited only by the size of the hard disk drive. Developed for recording broadband magnetotelluric measurements.
Equal-Interval Mode TEM (TEME): Uniform sampling and storage of TEM transients as time series. Used for LOTEM data acquisition and any application that requires uniformly sampled TEM transients.

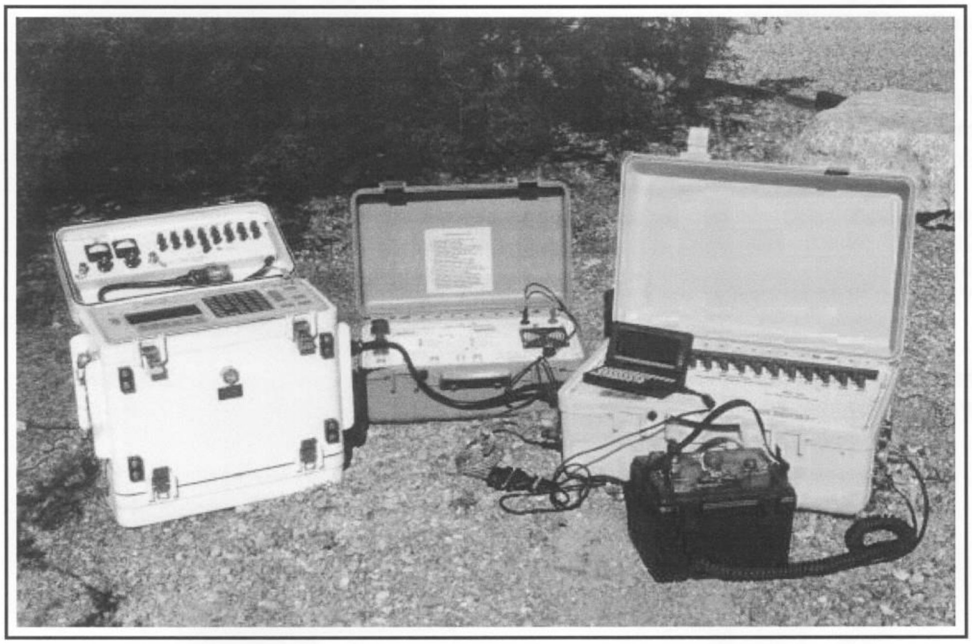
Specifications subject to change without notice

Zonge **Engineering and Research Organization, Inc.**
Offices:
Arizona, Alaska, Nevada, Australia and Chile
Headquarters:
3322 E. Ft. Lowell Road, Tucson, AZ 85716, USA (800) 523-9913
Tel: (520) 327-5501 Email: zonge@zonge.com
Fax: (520) 325-1588 Web: http://www.zonge.com

20031024

THE MX-30

Multiplex Switch



DESCRIPTION

The MX-30 was developed to provide a computer-controlled switching interface between a transmitter, a multi-channel receiver such as the GDP-32^{II}, and an array of electrodes. The MX-30 features a transmitter input multiplexer which can connect the transmitter leads to any pair of electrodes. A receiver multiplexer permits the operator to select any number of electrode pairs (up to half the number of electrodes) for input to the receiver. Multiplexer configuration is controlled by commands transmitted over an RS-232C serial communications channel. A control program is available for a laptop computer. The MX-30 is an essential component of any system designed to rapidly acquire resistivity data using cabled electrode arrays. Customers are currently using the MX-30 together with a GDP-32^{II} receiver and a ZT-30 transmitter to gather data for **Electrical Resistivity Tomography**. The MX-30 can be configured to provide fewer channels at a reduced cost. The unit can be upgraded in the field at a later date to give it increased output channel capacity.

FEATURES

- Selectable Electrode String – 30 electrodes Max
- External Control – RS-232C Serial (4800,N,8,1)
- Signal Output Channels (differential) – 16 Max
- Transmitter Output Relay Specs - ±500 Vdc 5 A
- Transmitter/Receiver Channel Isolation – 1000V
- High Speed Optical Relays on Receiver MUX
- Fully compatible with GDP-32^{II} Receiver
- MX-30's may be cascaded together to address several electrode arrays

Zonge Engineering and Research Organization, Inc.

Specialists in Electrical Geophysics • Field Surveys • Geophysical Consulting • Instrumentation Sales and Lease

SPECIFICATIONS FOR THE MX-30 MULTIPLEXOR

Mechanical Characteristics
Enclosure: Heavy-Duty Environmentally Sealed ABS Plastic Case
Size: 55 x 23 x 37 cm (22 x 9 x 15 in)
Weight: 16 kg (35 lb)

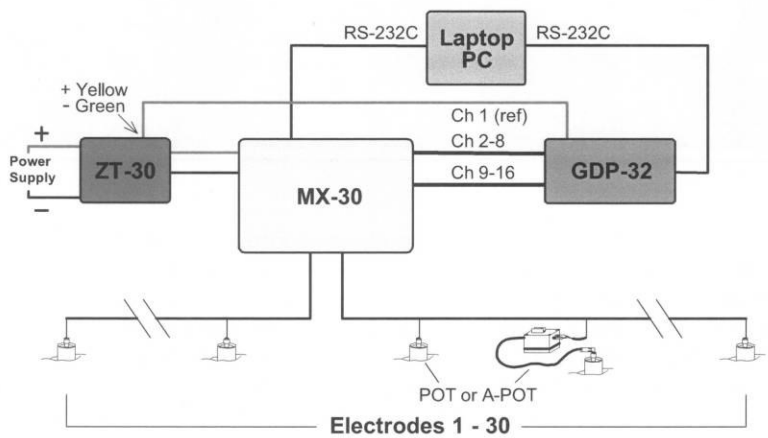
Electrical Characteristics
Transmitter Multiplexer: 500 Vdc (max); 5 A (max)
Signal Multiplexer: ±18 Vdc

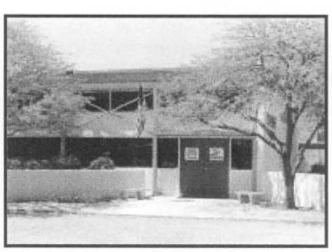
Controls & Displays
Power ON / OFF switch
LED indicators for:
POWER ON, SERIAL DATA, and CPU

Power
External battery: 10-14 Vdc
(6 Amp-hr recommended)

I/O Connectors
External Battery
RS-232C IN
RS-232C OUT
RS-485 IN
RS-485 OUT
Signal Channels 1-8
Signal Channels 9-16
TX Current IN
Electrodes IN (1-30)

Applications
Electrical Resistance Tomography
Automated Resistivity Soundings
Automated Dipole-Dipole Resistivity/IP Profiling





Zonge Engineering and Research Organization, Inc.
Offices: Arizona, Alaska, Nevada, Australia and Chile
Headquarters:
3322 East Fort Lowell Road, Tucson, AZ 85716, USA
(800) 523-9913
Tel: (520) 327-5501 Fax: (520) 325-1588
Email: zonge@zonge.com Web: www.zonge.com