Outline

- Resistivity Imaging Methods
- 1D, 2D, 3D and 4D
- Resistivity Inversion Theory
- Survey Design
- Data Processing
- Utilities
For each measurement, a DC electric current is injected into the ground through two electrodes (A and B)
• The resulting electric potential is measured between another two electrodes (M and N)
• An apparent resistivity value \( (\rho_a) \) is derived from injected current, measured voltage and geometric factor.
• Measured data are inverted to produce true subsurface resistivity distribution.
• Resistivity distribution is correlated to subsurface geology by a data interpreter.
Resistivity Imaging Methods

Apparent Resistivity

\[ \rho = K \frac{\Delta V}{I} \]

- \( \rho \) – Apparent resistivity (Ohm-m)
- \( \Delta V \) – Measured potential difference (V)
- \( I \) – Injected electric current (A)
- \( K \) – Geometry factor (m)

Geometric Factor – Surface Electrodes

\[ K = \frac{2\pi}{\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}} \]

- It is 4\( \pi \) full space instead of 2\( \pi \) half space
- \( A' \) is the mirror image of \( A \)
- \( B' \) is the mirror image of \( B \)

Arbitrary Electrode Location on the flat surface or in a borehole
Resistivity Imaging Methods

- A pseudosection is a fake section.
- An apparent resistivity measurement is NOT an exclusive contribution from earth materials at the pseudo data point.
- An apparent resistivity measurement should be regarded as a weighted sum of resistivity distribution in the entire earth.
- If the earth is homogeneous, the apparent resistivity equals the true earth resistivity.

Scatter Plot of Surface Apparent Resistivity Data

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Resistivity Imaging Methods

**Wenner**, highest signal to noise ratio, excellent vertical resolution but poor lateral resolution, unable to take advantage of multi-channels (only a single channel is used).

**Schlumberger**, AB/2 is 5 times more than MN. It is similar to Wenner array. Unable to take advantage of multi-channels (only a single channel is used). Inverse Schlumberger may use up to four channels.

**Dipole-dipole**, best resolution but poor signal to noise ratio. The best way to ensure an acceptable signal to noise ratio is to maintain $n \leq 8$. This array is excellent for multi-channel instruments.
**Resistivity Imaging Methods**

**Pole-dipole**, AB > (5*AM) for less than 5% error. Stronger signal than that of dipole-dipole, good resolution, but difficult handling of the infinity electrode in the field. The inverted resistivity image may be asymmetric.

**Pole-pole**, AB > (20*AM) and MN > (20*AM) for less than 5% error. Very strong signal, good resolution, but difficult handling of two infinity electrodes. A large MN may pick up plenty of cultural, SP and telluric noise.

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**Number Sense**

- **Injection electric current** ranges from 1 mA to 2 A. A current lower than 10 mA often produces noisy and unusable data. A marine resistivity survey in saltwater injects more than 1 A electric current.

- **Measured voltage** ranges from sub milli-volts to 10 volts. A measured voltage less than 0.1 mV is often noisy due to strong natural electric field in the ground, but marine data may be an exception due to its less noisy environment. Both positive and negative voltage values are acceptable.

- **Resistivity** of earth materials is a function of lithology, water content/saturation, porosity, pore fluid chemistry, temperature and so on. Here are resistivity values in Ohm-m for materials common to near surface geoscientists:

  - Saltwater: 0.1 – 1
  - Clay: 1 – 100
  - Fresh water: 10 – 100
  - Alluvium: 1 – 1,000
  - Sandstone: 1 – 1,000
  - Limestone: 10 – 10,000
  - Gravel: 100 – 10,000.
Resistivity Imaging Methods

Resistivity of soil and rock is affected by:

1) Moisture (water) content, a dominant factor
2) Porosity
3) Pore fluid chemistry (fresh water vs. saltwater)
4) Temperature of pore water (resistivity decreases with increasing temperature)
5) Resistivity of minerals

Typical Applications

- Cavity and sinkhole detection
- Geotechnical site characterization
- Groundwater exploration
- Lithologic mapping
- Mineral exploration
- Archaeological site investigation
- Detection of free products of contaminant plumes.
- Time lapse monitoring of remediation process such as steam injection, air sparging, injection of various oxidants such as hydrogen peroxide \((H_2O_2)\) and potassium permanganate \((KMnO_4)\)
- Time lapse monitoring of subsurface processes such as groundwater recharge, infiltration, saltwater intrusion, tunneling, and dam leakage
**1D, 2D, 3D and 4D**

Vertical Electrical Sounding (VES) in Schlumberger Array

1D model assumption: layered earth, $\rho = \rho(z)$

Common Array Types: Schlumberger and Wenner

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**1D, 2D, 3D and 4D**

AGI EarthImager 1D - 1D Resistivity Data Inversion

Measured and Modeled Data

Layered Resistivity Model

Advanced Resistivity Imaging Seminar
1D, 2D, 3D and 4D

- **2D model assumption**: $\rho = \rho(x, z)$. Any object on a 2D section would have an infinite length along the strike (y) direction normal to the section, and any cross section normal to the strike direction would look exactly the same. A round object on a 2D section would be an infinitely long cylinder.

- A **2D dataset** is collected with electrodes installed (1) along a straight line on the ground surface or (2) within a vertical plane for a mixed surface-borehole dataset.

- Processing of a 2D data set produces a cross section of subsurface resistivity distribution.

- The point source (an electrode) used in resistivity surveys produces a 3D electric field, so a 2D modeling problem is sometimes referred as 2D3D or **2.5D** problem.

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**AGI EarthImager 2D**
Resistivity and IP inversion software
A 2D survey can be done:

- on the ground surface
- cross boreholes
- with mixed surface and borehole electrodes
- with underwater electrodes
- with an electrode streamer for continuous resistivity profiling on the water
- on the ground surface with topography

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Data courtesy of Ocean Earth Technologies, Palm Harbor, Florida.
2D Underwater Resistivity Imaging: an offshore zone of freshwater discharge

Data courtesy of Jason Greenwood and Peter Swarzenski at the US Geological Survey in St. Petersburg, Florida.

2D Resistivity Imaging with Topography

Transformed finite element mesh fits the topography.
• **3D model assumption:** $\rho = \rho(x, y, z)$. 3D inversion has no restriction on electrical resistivity distribution in the earth. It can handle a medium with an arbitrary 3D resistivity distribution. However, there is one hidden assumption in 3D inversion: the earth material is isotropic.

• **A 3D dataset** is collected with electrodes installed (1) on the ground surface in a rectangular grid or (2) in three or more boreholes which are not within the same plane. Mixed surface and borehole electrodes which are not within the same vertical plane are also a 3D layout.

• Processing of a 3D data set produces a volume image showing 3D subsurface resistivity distribution.
Electrodes are laid out in a rectangular grid on the ground surface.
1D, 2D, 3D and 4D

- A 4D application is multiple 3D surveys in a sequential order with the same electrode layout and the same command file.
- The earth resistivity is a function of spatial coordinates and time: \( \rho = \rho(x, y, z, t) \).
- Typical applications:
  - Monitoring of environmental remediation such as steam injection or air-sparging.
  - Monitoring of salt water intrusion in a coastal area.
  - Monitoring of underground tunneling activities along a border or a building.
  - Monitoring leakage of underground storage tank.
  - Monitoring effect of ocean tides on the coastal area.
  - Monitoring earth dam leakage.

4D Time Lapse Inversion in AGI EarthImager 3D Software

- The base data is inverted in a standard approach.
- One or more monitor data sets are inverted in a sequential order.
- If three or more monitor data sets exist, an AVI movie file showing temporal resistivity changes is created and played at the end of time lapse inversion.
**1D, 2D, 3D and 4D**

**4D Time Lapse Monitoring**

Water Infiltration Experiment at Socorro, New Mexico

![Day 1, Day 2, Day 5, Day 12, Day 28, Day 51 diagrams](image)

Conductivity Change (%)

-60.0  -30.0  0.0  30.0  60.0


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**Resistivity Inversion Theory**

- Why inversion?
- Forward Modeling
- Inverse Modeling
- Modeling Mesh
- Infinity Electrode
- Starting Model
- Stop Criteria
- Thresholds for noisy data removal
- Advanced features

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Why Inversion?

Observation or Measured Data:
- Injected electric current (I)
- Induced voltage (V)
- Electrode location (K, geometry factor)
- Derived apparent resistivity = K V/I

Desired Info: Earth Resistivity Model
- Subsurface true resistivity distribution 2D ρ(x, y), or 3D ρ(x, y, z).

A measured data image (apparent resistivity pseudosection) is completely different from the corresponding earth model.
- An apparent resistivity pseudosection depends on the array type.
Forward Problem

Forward Problem – from Model to Data

Model Parameters

- Electrode Location
- Subsurface Resistivity Distribution
- Electric Current Source

Finite Difference Method

Solve a Boundary Value Problem

Electric Potential Field $V(x, y, z)$

$$\frac{\partial}{\partial x} \left( \frac{\partial V}{\partial x} \right) + \frac{\partial}{\partial y} \left( \frac{\partial V}{\partial y} \right) + \frac{\partial}{\partial z} \left( \frac{\partial V}{\partial z} \right) = -I$$

Dipole Dipole Synthetic Data

Data

Model

Inverse Problem

Inverse Problem – from Data to Model

Model Parameters

- Electrode Location
- Electric Potential Field $V(x, y, z)$
- Electric Current Source

Damped Least Squares

Solve an Optimization Problem

Resistivity Distribution $\rho(x, y, z)$

Smooth Model Inversion

Robust Inversion

Data

$$S(m) = (d_{\text{calc}} - d_{\text{meas}})^T W_d (d_{\text{calc}} - d_{\text{meas}}) + \lambda (m - m_0)^T R (m - m_0)$$

Dipole Dipole Synthetic Data

Data

Model
Inversion Flow Chart

Start EarthImager
Read Data
Generate Mesh
Click Start Inversion
Remove Noisy Data
Iteration Number $n = 0$
Set Starting Model
Forward Modeling
Compute Data Mismatch
Iteration Number $n = 1$
Solve Linearized Inv. Prob. Least squares optimization
Update Model $m_{n+1} = m_n + \Delta m_n$
Forward Modeling
Compute Data Mismatch
Meet Stop Criterion
Yes
Stop
No
Next iteration $n = n + 1$

Modeling Mesh

Number of mesh divisions between two electrodes = 2

Thickness incremental factor = $rac{\text{Thickness of the lower layer (d2)}}{\text{Thickness of the upper layer (d1)}}$
Depth of Mesh

- The depth of mesh for a surface data set is determined by the product of
  - the median depth (Edwards, L.S., 1977, A modified pseudosection for
    resistivity and induced polarization: Geophysics, 42, 1020-1036), and
  - the depth factor on the Forward Modeling Settings window in EarthImager.

- The depth of mesh for a borehole data set is determined by the depth of the deepest
  electrode.

- A mixed surface and borehole data set would reach the larger depth determined by
  both surface and borehole data.

**Median Depth**

- Wenner array: 52% of a-spacing
- Schlumberger: 19.1% of AB spacing
- Gradient: 19.1% of AB spacing
- Non-conventional: 19.1% of the largest electrode span
- Pole-pole: 60% of AM separation
- Dipole-Dipole: 14% - 25% of the largest electrode span
- Pole-Dipole: 50% - 60% of MN separation depending on AM/MN

Modeling Mesh - Irregular

- It is preferred but NOT required to have an equally-spaced electrode layout.
- An irregular electrode layout leads to a distorted model and a large numerical
  modeling error.

- Unaligned electrodes cause irregular and non-uniform modeling mesh
- Electrodes may be shifted to snap to grid nodes (Initial Settings).

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Infinity (Remote) Electrode

- Pole-dipole: AB > (5*AM) for < 5% error.

For a “true” infinity electrode (AB > 5 * AM), the infinity electrode can be placed anywhere, either perpendicular or parallel to the survey line. If the infinity electrode location does NOT satisfy AB > 5 * AM, make sure the infinity electrode is installed in the shared triangular area. EarthImager will model the response of the infinity electrode.

Infinity (Remote) Electrode

- Pole-pole: AB > (20*AM) and MN > (20*AM) for < 5% error.
- For a pole-pole array, two infinity electrodes must be installed at the opposite side of the survey line (2D) or the survey area (3D).
- In a 3D survey, the infinity electrode can be placed anywhere as far as the correct electrode coordinates are inputted into SuperSting. It is not required to honor the infinite distance.
- For a pseudo infinity electrode which does not honor the infinite distance, the depth of penetration is reduced proportionally.

3D Survey Grid
**Noisy Data Thresholds**

**Settings**

- **Criteria for Data Removal**
  - Minimum Voltage in mV
    - 0.2
  - Minimum abs(V[MV]) [ohms]
    - 0.0005
  - Max Repeat Extra [%]
    - 0
  - Min Apparent Res [ohms]
    - 0
  - Max Apparent Res [ohms]
    - 10000
  - Max Reciprocal Err [%]
    - 2
  - Remove Negative Applies
  - Keep All
  - Remove Spikes
  - Save Inversion Output

**Information**

- Number of data over Max Apples = 39
- Number of data below Min Applies = 0
- Number of data below Min Voltage = 0
- Number of data below Min V[ohm] = 0
- Number of data over Max Repeat: Error = 0
- Number of data over Max Repeat: Error > 0
- Number of surface data below Min Apples = 0
- Number of negative Apples data = 144
- Number of negative repeats of Apples = 0
- Number of negative repeats of Atts = 0
- Number of duplicates removed = 0

**Reciprocals**

**Original**

\[ A \rightarrow \text{I}_1 \rightarrow B \rightarrow \text{M} \rightarrow \text{V}_2 \rightarrow \text{N} \rightarrow \text{I}_3 \rightarrow A \]

**Reciprocal 1**

\[ M \rightarrow \text{V}_2 \rightarrow N \rightarrow \text{A} \rightarrow \text{I}_3 \rightarrow B \rightarrow \text{I}_1 \rightarrow M \]

**Reciprocal 2**

\[ N \rightarrow \text{V}_2 \rightarrow M \rightarrow \text{B} \rightarrow \text{I}_3 \rightarrow A \rightarrow \text{I}_1 \rightarrow N \]

**Scatter Plot of Reciprocal Data Errors**

\[ \frac{V_1}{I_1} = \frac{V_2}{I_2} = \frac{V_3}{I_3} \]

Demo data: reciprocals.stg

Reciprocal measurement errors are a rigorous measure of data quality and hardware integrity.
Noisy Data Thresholds

Why is removal of some data an acceptable practice?

- Each measurement is an integrated response from the entire half space and it carries information about the entire half space.
- Data redundancy due to over-sampling ensures removal of some data is not fatal on the model resolution.
- Massive removal, instead of random removal, of a large number of data points will cause poor resolution in a certain area without data coverage.

Starting Model

- The default starting model is a homogeneous half space with a resistivity value equal to the average of all apparent resistivity data.
- User options:
  - Start from raw data pseudosection in 2D
  - Start from a homogenous half space of any resistivity value.
  - Input an a-priori model manually from the menu Settings | Input Resistivity A-Priori Model.
  - Read a water conductivity file for CRP data inversion to constrain the water layer.
Starting Model

Artifacts in a pseudosection may be carried over to the inverted section through the starting model.

Stop Criteria of Inversion

- **Maximum Number of Iteration.** This is the number of times to solve the linearized inverse system iteratively. A clean data set often converges to a few percent of RMS error, say 3%, in 3 ~ 5 iterations.

- **Minimum Error Reduction.** RMS error is often reduced by more than 50% for the first few iterations. Then error reduction slows down at the later iterations. If there is no apparent RMS error reduction, say the error reduction is less than 5%, the inversion should stop.

\[
\text{Error Reduction(\%)} = \frac{\text{RMS}_{n} - \text{RMS}_{n-1}}{\text{RMS}_{n-1}} \times 100\%
\]
Noisy Data Thresholds

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  - Read a water conductivity file for CRP data inversion to constrain the water layer.
Stop Criteria of Inversion

- **RMS Error (%)**. RMS would depend on the noise level in the data. For a clean data set, 3% RMS error would be an acceptable objective.

\[
\text{RMS} = \sqrt{\frac{\sum_{i=1}^{N} \left( \frac{d_i^{\text{calc}} - d_i^{\text{meas}}}{d_i^{\text{meas}}} \right)^2}{N}} \times 100\%
\]

- **L2-Norm** is a weighted data misfit which is a key part of the objective function to be minimized. For ease of convergence comparison, our L2-norm is normalized by the number of measurements. The convergence is achieved when the normalized L2-norm is equal to or less than 1.0. Data weights play a key role in the L2-norm estimate. The weight of a data point is, by default, defined as a certain percentage (e.g., 3%) of the data value.

\[
\text{L2-Norm} = \frac{\sum_{i=1}^{N} \left( \frac{d_i^{\text{calc}} - d_i^{\text{meas}}}{W_i} \right)^2}{N} \geq \frac{\sum_{i=1}^{N} \left( 3\% \cdot d_i^{\text{meas}} \right)^2}{N}
\]

Advanced Features

Optional Features (Modules) in **EarthImager 2D and 3D**

- Use metal borehole casing as electrodes (Long Electrode module, 3D)
- Resistivity imaging in a confined domain (Sand Box module, 3D) such as in a water tank or a sand box.
- IP Survey Planner (2D)
- Time Lapse inversion (2D and 3D)
- Continuous Resistivity Profiling (CRP in 2D)
EarthImager 3D CL

- A new command line 3D inversion program without graphical user interface (GUI)
- Ideal for fast processing of huge data sets
- Support of both Windows 32-bit and 64-bit platforms
- Support of more than 2 GB memory
- Parallel processing on multi-processor or multi-core machines. The more processors, the faster processing.
- Almost four times faster than EarthImager 3D on a PC with a single dual-core CPU.
- AGI houses a computer with 8 cores and up to 48GB RAM to help customers process large 3D data sets.

Survey Design

- Electrode spacing
- Depth of investigation
- Slide-along vs roll-along
- 3D electrode layout
- Electrode geometry file (geo)
- Command file (cmd)
- Array types
- Signal strength vs. noise level
- Smooth model effect
Survey Design – Electrode Spacing

- Electrode spacing should be 2 to 4 times the dimension of the target. By default, the model block width is half of the electrode spacing, i.e., two divisions between two electrodes.
- A smaller electrode spacing leads to a higher model resolution. The resolution is about half of the electrode spacing, but it can be better in the region near an electrode.
- For the same number of electrodes, a larger electrode spacing would lead to a larger depth of penetration.

Survey Design – Depth of Investigation

- The depth of investigation depends on the largest array span during the survey but not the length of a survey line. Roll-along won’t increase the depth of investigation.
- With the same number of electrode and the same electrode spacing, the pole-pole array has the largest penetrating depth.
- As a rule of thumb, the penetrating depth is about 15% to 20% of the largest array length for any four-electrode array. An actual field survey design should be more conservative and the object of concern should be at 10 to 15% of the largest array length.
- The max depth on the inverted resistivity section is determined by the median depth defined by L.S. Edward (1977) and a depth factor.
- The actual depth of penetration also depends on subsurface resistivity distribution. A conductive overburden often decreases the penetrating depth dramatically.
- The depth of investigation also depends on the ratio of the object depth h to its dimension (diameter d). The maximum ratio is around 5.0.
Slide-along vs Roll-along

Slide-along: The entire cable slides forward. Subsections B and C are sampled with the same command file as that of Subsection A.

Disadvantage: Zones 1 & 2 are sampled twice unnecessarily. Zones 3 and 4 are missing a large number of data points. A slide-along survey is slow with compromised model resolution at the bottom.

Roll-along: Part of the cable (<= 25%) is rolled over. Subsections B and C are sampled with an automatically reduced command file of Subsection A.

Advantages: No duplicate measurements, fewer missing data points. A roll-along survey is faster than a slide-along survey and has a better model resolution at the bottom of the section.

In the roll-along mode, AGI SuperSting automatically skips the data points already sampled.
Slide-along vs Roll-along

**3D Roll-along**: move even number (2, 4, 6, …) of lines at a time.

Address Table in SuperSting
1 - 28
29 - 56

Roll-along in this direction

Layout out even number of lines of cables

3D roll along surveys can also be done along Y direction

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Survey Design – 3D Line Spacing

An ideal 3D layout is a square grid of electrodes.

Line spacing $\leq 2 \times$ Electrode spacing

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Advanced Resistivity Imaging Seminar
2D versus 3D

- The images from 2D and 3D surveys at the same location look different. A slice image from 2D inversion is more complicated than an extracted slice image from 3D inversion because of the side-looking capability of a 2D survey.
- It is an acceptable practice to combine parallel 2D lines to form a 3D data set for 3D inversion as far as the line spacing is equal to or less than twice of the electrode spacing.

Xiaojin Yang and Mats Lagmanson, Comparison of 2D and 3D resistivity imaging methods, presented at the SAGEEP, April 2 - 6, 2006, Seattle, WA

Do 3D Surveys in a Right Way

- **True 3D:** Lay out many electrodes in a rectangular grid at the same time and create a command file with cross-line measurements. This is an ideal way to conduct a 3D survey, but it requires a large number of electrodes to be laid out at the same time.
- **3D Roll Along:** Lay out at least four lines (4, 6, 8, …) of electrodes and roll over an even number (2, 4, 6, …) of lines at a time.
- **Quasi 3D:** Collect multiple 2D data sets along parallel survey lines. Lines_Spacing <= 2 * Electrode_Spacing. Combine multiple 2D data sets into a single 3D data set for 3D inversion. EarthImager 3D has a utility for “Combine Parallel 2D Lines”. A quasi 3D survey produces an acceptable 3D model resolution, and it offers an alternative for people with a limited number of electrodes to do a 3D survey.

Xiaojin Yang and Mats Lagmanson, Comparison of 2D and 3D resistivity imaging methods, presented at the SAGEEP, April 2 - 6, 2006, Seattle, WA
### Geometry (geo) File

#### 2D Surface

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<tr>
<td>17, 32, 0</td>
<td>17, 32, 0</td>
</tr>
<tr>
<td>18, 34, 0</td>
<td>18, 34, 0</td>
</tr>
<tr>
<td>19, 36, 0</td>
<td>19, 36, 0</td>
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<tr>
<td>20, 40, 0</td>
<td>20, 40, 0</td>
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<tr>
<td>21, 42, 0</td>
<td>21, 42, 0</td>
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<tr>
<td>22, 44, 0</td>
<td>22, 44, 0</td>
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<tr>
<td>23, 46, 0</td>
<td>23, 46, 0</td>
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<tr>
<td>24, 48, 0</td>
<td>24, 48, 0</td>
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<tr>
<td>25, 50, 0</td>
<td>25, 50, 0</td>
</tr>
<tr>
<td>26, 52, 0</td>
<td>26, 52, 0</td>
</tr>
<tr>
<td>27, 54, 0</td>
<td>27, 54, 0</td>
</tr>
<tr>
<td>28, 56, 0</td>
<td>28, 56, 0</td>
</tr>
<tr>
<td>29, 58, 0</td>
<td>29, 58, 0</td>
</tr>
<tr>
<td>30, 60, 0</td>
<td>30, 60, 0</td>
</tr>
</tbody>
</table>

### Command (cmd) File

#### : Sting R1 2D CMD file

- **Header**
  - `progID=pDSR1`
  - `unit m`
  - `type resi`
- **Geometry**
  - `1, 0, 0`
  - `2, 2, 0`
  - `3, 4, 0`
  - `4, 6, 0`
  - `5, 8, 0`
  - `7, 12, 0`
  - `8, 14, 0`
  - `9, 16, 0`
  - `10, 18, 0`
  - `11, 20, 0`
  - `12, 22, 0`
  - `13, 24, 0`
  - `14, 26, 0`
  - `15, 28, 0`
  - `16, 30, 0`
  - `17, 32, 0`
  - `18, 34, 0`
  - `19, 36, 0`
  - `20, 40, 0`
  - `21, 42, 0`
  - `22, 44, 0`
  - `23, 46, 0`
  - `24, 48, 0`
  - `25, 50, 0`
  - `26, 52, 0`
  - `27, 54, 0`
  - `28, 56, 0`
  - `29, 58, 0`
  - `30, 60, 0`

#### : SuperSting R1 2D CMD file

- **Header**
  - `progID=pSSR1`
  - `unit m`
  - `arraytype=3`
- **Geometry**
  - `1, 0, 0`
  - `2, 2, 0`
  - `3, 4, 0`
  - `4, 6, 0`
  - `5, 8, 0`
  - `6, 10, 0`
  - `7, 12, 0`
  - `8, 14, 0`
  - `9, 16, 0`
  - `10, 18, 0`
  - `11, 20, 0`
  - `12, 22, 0`
  - `13, 24, 0`
  - `14, 26, 0`
  - `15, 28, 0`
  - `16, 30, 0`
  - `17, 32, 0`
  - `18, 34, 0`
  - `19, 36, 0`
  - `20, 40, 0`
  - `21, 42, 0`
  - `22, 44, 0`
  - `23, 46, 0`
  - `24, 48, 0`
  - `25, 50, 0`
  - `26, 52, 0`
  - `27, 54, 0`
  - `28, 56, 0`
  - `29, 58, 0`
  - `30, 60, 0`

#### : SuperSting R8 2D command file

- **Header**
  - `progID=pSSR8`
  - `unit m`
  - `arraytype=3`
- **Geometry**
  - `1, 0, 0`
  - `2, 2, 0`
  - `3, 4, 0`
  - `4, 6, 0`
  - `5, 8, 0`
  - `6, 10, 0`
  - `7, 12, 0`
  - `8, 14, 0`
  - `9, 16, 0`
  - `10, 18, 0`
  - `11, 20, 0`
  - `12, 22, 0`
  - `13, 24, 0`
  - `14, 26, 0`
  - `15, 28, 0`
  - `16, 30, 0`
  - `17, 32, 0`
  - `18, 34, 0`
  - `19, 36, 0`
  - `20, 40, 0`
  - `21, 42, 0`
  - `22, 44, 0`
  - `23, 46, 0`
  - `24, 48, 0`
  - `25, 50, 0`
  - `26, 52, 0`
  - `27, 54, 0`
  - `28, 56, 0`
  - `29, 58, 0`
  - `30, 60, 0`

---

Advanced Resistivity Imaging Seminar

29
Array Types

**Dipole-Dipole array gives the best resolution**

**Mixed or Nonstandard Array**

- Merge command files. A command file with one or two infinity electrodes can NOT be combined with any four-electrode array such as Wenner or dipole-dipole array.
- Merge data files collected with different command files. There is no restriction on the array type when merging data files.
- Create a command file manually.
Recommended 2D Array Types

- Extended dipole-dipole array in AGI SuperSting Administrator offers excellent resolution. Set max n spacing <= 8 to ensure acceptable signal strength.
- Gradient array in EarthImager 2D offers good resolution at two ends of a section. It is recommended that one combines this gradient array with a dipole-dipole array for n <= 8.
- Mixed arrays may have advantages from all arrays combined. The common combinations are dipole-dipole + Schlumberger, dipole-dipole + gradient, dipole-dipole + Wenner + Schlumberger.
- The pole-dipole array offers better resolution than the pole-pole array and larger depth of penetration than the dipole-dipole array.

Reference

- Stummer, P., Maurer, H., and Green, A.G., 2004, Experimental design: Electrical resistivity data sets that provide optimum subsurface information, Geophysics, vol. 69, 120-139. This paper concluded that mixed non-standard dipole-dipole array and gradient array has the best resolution.
- Gharibi M. and Bentley L.R., 2005, Resolution of 3-D electrical resistivity imaging from inversions of 2-D orthogonal lines, Journal of Environmental and Engineering Geophysics, Vol. 10 No. 4, 339-349. This paper concluded that "3D electrical resistivity imaging using sets of orthogonal of 2-D survey lines provides an efficient and cost effective tool for site characterization ..."
- Zhou, B., and Greenhalph, S.A., Cross-hole resistivity tomography using different electrode configurations, Geophysical Prospecting, 2000, 48, 887-912. This paper concluded that the bipole-bipole array is an ideal array for cross borehole resistivity tomography.
- Yang, X. and Lagmanson, M., 2006, Comparison of 2D and 3D electrical resistivity imaging methods, the proceedings of the SAGEEP2006, Seattle, WA. This paper concluded that 3D inversion of combined 2D data sets collected along closely-spaced parallel lines provides acceptable 3D resolution.
Survey Planner – Signal Strength and Contrast

Resistivity Survey Planner Results - Dipole-Dipole-56

- 10% AppRes anomaly from 1000/100 resistivity contrast
- 13% AppRes anomaly from 100/10 contrast

- A 1000 Ohm-m object became < 200 Ohm-m anomaly
- A 10 Ohm-m object became > 60 Ohm-m anomaly
- A model of 100 Ohm-m background.
- A 1000 Ohm-m resistive object
- 10 Ohm-m conductive object.

Data Processing

- EarthImager File Management
- Surface Data Inversion
- Terrain Correction
- Borehole Data Inversion
- Underwater Resistivity Survey
- Continuous Resistivity Profiling
- Time Lapse Inversion
- 3D Data Inversion
Flow Chart of Data Processing

Two Required Steps:
- Read Data
- Start Inversion

Other steps are optional.

Typical Data Processing Steps
- Read Data (*.stg, *.dat, *.urf)
- Choose default settings (surface, borehole, ...)
- Edit | Data Editing Statistics (optional)
- Start Inversion
- View | Data Misfit Histogram to remove some data (optional)
- Start Inversion again after removal of some noisy data
- Change Settings
- View Inverted Resistivity Section
- Change Min/Max contour levels
- Change Vertical Exaggeration factor
- Save Image
- Save Data in XYZ Format
- Print Image
File Management – 2D vs 3D Format

→ A **2D STG data format** uses two (2) coordinates (x, y) or (x, z) to define an electrode location. This format was developed for early AGI Sting instruments for 2D resistivity surveys. The Y coordinate may be either the electrode depth or the survey line offset.

→ A **3D STG data format** uses three (3) coordinates (x, y, z) to define an electrode location. So the 3D data format may be used to define any 2D and 3D datasets. There is a flag “Type: 3D” in the first line of an Sting (STG) data file.

### Column by column explanation of 2D and 3D STG data formats

- An STG data file in the 2D format has at least 17 columns.
- An STG data file in the 3D format has at least 21 columns.
- “Type: 3D” appears in the first line of an STG data file in the 3D format.
- EarthImager reads and inverts DAT data files.
- EarthImager reads and inverts URF data files.

<table>
<thead>
<tr>
<th>Column</th>
<th>2D (X, Y)</th>
<th>3D (X, Y, Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Data-ID</td>
<td>Data-ID</td>
</tr>
<tr>
<td>2</td>
<td>USER</td>
<td>USER</td>
</tr>
<tr>
<td>3</td>
<td>Date</td>
<td>Date</td>
</tr>
<tr>
<td>4</td>
<td>Time</td>
<td>Time</td>
</tr>
<tr>
<td>5</td>
<td>V1</td>
<td>V1</td>
</tr>
<tr>
<td>6</td>
<td>Error (1/10)%</td>
<td>Error (1/10)%</td>
</tr>
<tr>
<td>7</td>
<td>Current-mA</td>
<td>Current-mA</td>
</tr>
<tr>
<td>8</td>
<td>AppRes</td>
<td>AppRes</td>
</tr>
<tr>
<td>9</td>
<td>Cmd-ID</td>
<td>Cmd-ID</td>
</tr>
<tr>
<td>10</td>
<td>Ax</td>
<td>Ax</td>
</tr>
<tr>
<td>11</td>
<td>Ay</td>
<td>Ay</td>
</tr>
<tr>
<td>12</td>
<td>bx</td>
<td>Az</td>
</tr>
<tr>
<td>13</td>
<td>By</td>
<td>Bx</td>
</tr>
<tr>
<td>14</td>
<td>Mx</td>
<td>By</td>
</tr>
<tr>
<td>15</td>
<td>My</td>
<td>Bz</td>
</tr>
<tr>
<td>16</td>
<td>Nx</td>
<td>Mx</td>
</tr>
<tr>
<td>17</td>
<td>Ny</td>
<td>My</td>
</tr>
<tr>
<td>18</td>
<td>IP. (flag)</td>
<td>Mz</td>
</tr>
<tr>
<td>19</td>
<td>IP Slot</td>
<td>Nx</td>
</tr>
<tr>
<td>20</td>
<td>IP Time</td>
<td>Ny</td>
</tr>
<tr>
<td>21</td>
<td>m1</td>
<td>Nz</td>
</tr>
<tr>
<td>22</td>
<td>m2</td>
<td>IP. (flag)</td>
</tr>
<tr>
<td>23</td>
<td>m3</td>
<td>IP Slot</td>
</tr>
<tr>
<td>24</td>
<td>m4</td>
<td>IP Time</td>
</tr>
<tr>
<td>25</td>
<td>m5</td>
<td>m1</td>
</tr>
<tr>
<td>26</td>
<td>m6</td>
<td>m2</td>
</tr>
<tr>
<td>27</td>
<td>sum(m1 m6)</td>
<td>m3</td>
</tr>
<tr>
<td>28</td>
<td>m4</td>
<td>m5</td>
</tr>
<tr>
<td>29</td>
<td>m5</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>m6</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>sum(m1 m6)</td>
<td></td>
</tr>
</tbody>
</table>
Universal Resistivity Format (URF)

This is a 3D sample Universal Resistivity Data File for testing purpose only.
Top two lines are comments and the third line defines the length unit.
Unit: meters

Geometry

<table>
<thead>
<tr>
<th>ID</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>0.00</td>
<td>3.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.00</td>
<td>4.00</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>0.00</td>
<td>5.00</td>
<td>0.00</td>
</tr>
<tr>
<td>7</td>
<td>1.00</td>
<td>5.00</td>
<td>0.00</td>
</tr>
<tr>
<td>8</td>
<td>1.00</td>
<td>4.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Measurements

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>M</th>
<th>N</th>
<th>( V_l(\text{ohm}) )</th>
<th>( I(\text{mA}) )</th>
<th>Error(%)</th>
<th>Chargeability(\text{mV}/V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2,3,4</td>
<td>-1.0e-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,2,4,5</td>
<td>-9.0e-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,2,5,6</td>
<td>-7.5e-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,2,7,8</td>
<td>8.0e-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EarthImager also processes data in a DAT format.

EarthImager File Management

- When a raw data file, e.g., StingCave1.stg, is read into EarthImager, a folder StingCave1 is created if it does not exist and a new trial subfolder is also created. The current trial number would be always the largest.
- A clean dataset (STG), inversion settings file (INI) and inversion output file (OUT) are saved in the current trial folder.
- The automatic file saving feature is on by default, but it can be disabled for the purpose of learning and program testing.
- The current trial folder may be accessed from a tool button on EarthImager.
Surface Data Inversion

Processing Steps:

- Read Data
- Choose default settings
- Start Inversion

Optional Steps:

- Default Settings
- Thresholds for Noisy Data Removal
- Data Editing Statistics
- Histogram
- Suppress Noisy Data

Primary Challenge:

- High contact resistance (> 10,000 Ohm).

Surface Data Inversion – High Contact Res.

Low current injection: 2mA

Low measured voltage < 1mV
Surface Data Inversion – Negative App. Res.

- High contact resistance.
- Leakage in the cable, especially in the cable connector due to moisture and dirt.
- Leakage from other electric equipment (grounding) near the survey area.
- The measured voltage is too low (< 0.1mV) and the noise flips the voltage polarity.
- Injected electric current is too small (< 10mA).
- Mismatch of electrode addresses in the command file and the address table.

Noisy Data Processing Tips

- Thresholds for noisy data removal
- Data editing statistics
- Manual data editing – Data misfit
- Electrode editor
- Effect of the starting model
- Effect of 3D objects on 2D inversion
- Histogram
- Suppress noisy data and L2-norm
**Suppress Noisy Data**

- Suppress Noisy Data option always down-weights some data from iteration to iteration no matter how noisy the data set is.
- Not to use “Suppress Noisy Data” if you have a clean data set, otherwise, the good data will be down-weighted or numerically ignored.
- To check the data quality, go to the menu Edit | Data Editing Statistics. As a rule of thumb, one may use “Suppress Noisy Data” option if more than 10% of the data are marked for removal.
- Use “Suppress Noisy Data” option if the histogram does not show a monotonic decay.

---

**Surface Data Inversion with Topography**

**Processing Steps:**
- Read Data
- Choose default surface settings
- **Read Terrain File**
- Start Inversion

**Survey Tips:**
- Create a command file for flat surface
- Lay out cables as if the ground is flat
- Collect data as usual
- Measure the terrain elevation
- Create a two-column (x, elevation) terrain file
Terrain File Format

- Two ways to describe the terrain elevation
- Terrain and CMD (or STG) file format agreement
- Elevation measurements should be able to define the actual topography but one does not have to survey all electrodes

Case 1: Horizontal distance

Case 2: Tape measure or slope distance

Terrain Correction

Q: What is wrong with my terrain file?
A: Here are the common errors in a terrain file:

;TRN File
unit=Meters
2 // tape measure
0, 143.3
5, 142.3
10, 141.7
15, 152.1 Error: Δh (152 - 141) >> Δx (15 - 10)
20, 140.4
25, 139.6
25, 140.3 Error: Two different elevations at the same location
30, 140.7
Surface Data with Topography

- Change settings (optional)
- Read Data (STG, DAT, URF)
- Read Terrain File (TRN)
- Change settings (optional)
- Start Inversion

Borehole Data Inversion

Processing Steps:
- Read Data
- Choose default borehole settings
- Start Inversion

Primary Challenges:
- Current channeling effect in the borehole due to conductive grout
- Aspect ratio of borehole depth to borehole separation
- Weak signal and noisy data
- Negative apparent resistivity values
- No apparent resistivity pseudosection for data visualization

Data courtesy of Dr. John Liu of Golder and Associates
Model Sensitivity

Surface Resistivity Imaging

- The model blocks near electrodes have the highest resolution.
- Cross borehole resistivity imaging has a better resolution at the depth.

Cross-borehole ERT

2D ERT Setup

- Aspect Ratio, D/S, should be greater than 1.5.
- For efficient modeling and good resolution, electrodes in different boreholes should be aligned at the same depth as close as possible.
- Surface electrodes are not required but may be used to improve near-surface resolution.
Electrodes are aligned at the same depth level, not the same elevation.

Reference:
Borehole Data Scatter Plot

- Negative AppRes
- Small Signal from the dipole-dipole array
- Bad electrode

Borehole Data Processing Tips

- Match grout and formation resistivity as close as possible to reduce electric current channeling effect in the borehole
- Ensure that the aspect ratio of borehole depth to borehole separation is not smaller than 1.5
- Add surface electrodes to improve near surface resolution
- Use dipole-dipole array or pole-pole array for large signal strength
- Choose suppress noisy data setting
- Remove negative apparent resistivity values
- Use the histogram to remove noisy data.
Underwater Data Inversion

Processing Steps:

- Read Data
- Choose default surface settings for freshwater or conductive earth settings for saltwater.
- Read an underwater terrain file.
- Start Inversion

Case 1 - Flat bottom

Case 2 - Uneven bottom

Case 3 - Mixed land and underwater

Case 4 - Mixed land and underwater with one water body at the end of a profile. This is a special case of Case 3.

Florida Oceanographic Society's Marine Park Water Intake

A resistivity imaging survey was performed by N.S. Nettles & Associates, to be used for design of two horizontal water well intakes for the Florida Oceanographic Society's marine park. The well screen is to be placed in the zone of the greatest shell content, as depicted by the increased resistivity compared to the surrounding sands.

Data for a land to sea resistivity imaging profile was acquired using the AGI SuperSting R/B/P resistivity imaging system. Data was processed using the EarthImager software. The electrodes at sea were simply placed at the bottom, no other connection was needed. The EarthImager software provided the terrain correction both under and above water.

Survey date: February 22, 2005
Electrode array: Dipole-dipole Units: Feet and Ohm-Meter
Instrument: SuperSting R/B/P
Processing: EarthImager 2.0 software

Data courtesy of N.S. Nettles & Associates, Inc. Palm Harbor, Florida, USA
**Underwater Data**

Beaver-hole and void detection in an earth dam

**Case 5:** A water body is at the beginning of a profile

Data courtesy of Dave Welch, Neil O Anderson & Associates, Sacramento, California

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**Continuous Resistivity Profiling (CRP)**

Rapid, easy and continuous resistivity imaging on the shallow water
**AGI SuperSting R8 Marine System**

- SuperSting R8 Marine resistivity meter
- Lorance GPS for positioning and water depth measurement
- A towing cable with 11 or more electrodes
- Marine Log Manager (MLM) software for data preprocessing before the inversion. MLM synchronizes the resistivity measurements and GPS positioning data and plots the boat track. It also offers the data editing capability.
- EarthImager 2D CRP module for inversion of continuous resistivity profiling (CRP) data

![SuperSting R8 Marine + Cable](image1)
![EarthImager 2D CRP](image2)

**EarthImager 2D CRP Module**

- EarthImager 2D CRP module may be used for inversion of resistivity data collected with a boat-towed array, a roll-along array or a pulled-array.
- The CRP module uses a divide-and-conquer strategy to process a very long CRP profile.

![Diagram of CRP Profile](image3)

- It divides a long profile into small sections and inverts each section individually. At the end of inversion, it combines all smaller sections together into a single long section.

![Graph of CRP](image4)

Advanced Resistivity Imaging Seminar
**A CRP Case from a Caribbean Island**

The CRP mapping of the coastal areas of Anguilla, British West Indies (BWI), were used to evaluate sand thickness over the limestone to determine the feasibility of:

1) constructing horizontal beach wells for salt water supply intake
2) map the depth to limestone and the physical characteristics of the limestone to aid in the design of storm water drainage wells
3) to provide the bathymetry and sea bottom sediment distribution as part of our analysis of beach erosion.

![Inversion result](image)

Inversion result with EarthImager 2D CRP module. The horizontal coordinates can be either linear distance or Lat/Long or UTM.


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**Time Lapse Data Inversion**

- Time Lapse inversion features can be found in both EarthImager 2D and EarthImager 3D
- The Time Lapse Inversion feature can be found from the menu Inversion | Time Lapse Inversion.

**SuperSting Remote Monitoring System** (SSRMS) is designed for unattended monitoring applications. The electrodes can be installed at the surface and/or in boreholes. The SSRMS system is a network-aware system and can send data, notification and error warning automatically via email from the remote server to any email address.
**Time Lapse Data Inversion**

Difference Inversion of Before and After Data Sets

- One base data set and one monitor data set.
- The base data set is inverted first. Then the difference between the monitor data and base data is inverted with the base model as the a-priori model.
- A difference image showing resistivity changes is produced.

**Time Lapse Data Inversion**

- The base data is inverted in a standard approach.
- One or more monitor data sets are inverted in the same way as the difference inversion. The base model is used as the a-priori model for all monitor data inversion and as the reference model for calculation of difference image.
- If three or more monitor data sets exist, an AVI movie file showing temporal resistivity changes is created and played at the end of time lapse inversion.
Time Lapse Data Inversion – Synthetic Model

Percent change in Resistivity

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Advanced Resistivity Imaging Seminar
Water Infiltration Monitoring

Socorro-New Mexico Tech Vadose Zone Facility, New Mexico, USA


Xianjin Yang, 1999, Stochastic Inversion of 3D ERT Data, PhD thesis, the University of Arizona

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Water Infiltration Monitoring

Tracking wetting fronts which show increasing electrical conductivity values

Day 1

Day 9

Day 33

Day 68

Day 133

Xianjin Yang, 1999, Stochastic Inversion of 3D ERT Data, PhD thesis, the University of Arizona
Monitoring of Steam Injection

Rising temperature caused soil electrical conductivity to increase.

Steep enhanced remediation at Portsmouth Gaseous Diffusion Plant was funded by US DOE and conducted by SteamTech Environmental Services under subcontract to Bechtel Jacobs Co LLC.


Visalia, California

Steep enhanced remediation at Visalia Pole Yard was funded by Southern California Edison and conducted partially by SteamTech Environmental Services.

http://www.sce.com/PowerandEnvironment/EnvironmentalCommitment/Restoration/VisaliaPoleYard.htm
http://www.lnl.gov/tr/Newmark.html
Monitoring of In-situ Air Sparging

A sand tank at Oregon Graduate Institute, Beaverton, Oregon. The funding was provided by American Petroleum Institute.

Yang X., et al., 2001, Monitoring of an In-Situ Air Sparging Experiment Using Electrical Resistivity Tomography, the Proceedings of SAGEEP, Denver, Colorado.
Monitoring of In-situ Air Sparging

- The percent change in resistivity provided a quantitative view of air saturation in the sand tank.
- The IAS at a flow rate of 20 cfm resulted in a larger radius of influence than the IAS at 5 cfm.
- Unlike the continuous IAS operation, the pulse operation produced a more complex air distribution.
- Skewed airflow at both 5 cfm and 20 cfm flow rates indicates that there are preferential air pathways in the tank.


Advanced Resistivity Imaging Seminar
Induced Polarization (IP)

- In a resistivity imaging survey, the ground is treated as an electric resistor. However, the ground is regarded as an equivalent circuit of resistors and capacitors in an IP survey.

Apparent chargeability:

\[ m_a = \frac{V_s}{V_p} \]

Apparent chargeability in seconds by SuperSting:

\[ m_i = \frac{\int_{0}^{t} V_s dt}{V_p} \]

### Material | Chargeability (ms)
--- | ---
Pyrite (1%) | 13.4
Graphite (1%) | 11.2
Galena (1%) | 3.7
Magnetite (1%) | 2.2
Hematite (1%) | 0.0
Precamb. Volcanics | 8–20
Alluvium | 1–4
Gravels | 3–9
Sandstone | 3–12
Limestone | < 1
Dolomite | < 1
Granite | < 1
Groundwater | 0

Adapted from Applied Geophysics by Telford et al. The chargeability was measured with a charging time of 3s and an integration time of 1s.

Typical high chargeability targets: clay, sulfides and hydrocarbon contaminated sediments.
3D Data Inversion w/ EarthImager 3D

Inversion of 3D data set with EarthImager 3D follows the same three steps as 2D data inversion, i.e.,

- Read Data
- Change Settings
- Start Inversion

EarthImager 3D Highlights:

- Function of mouse buttons
- Transparency control
- Static and dynamic slices
- Volume estimation
- 3D inversion w/ topography
- 3D Survey Planner
- 4D time lapse inversion

3D – Function of Mouse Buttons

- Click and hold the left mouse button to rotate the image
- Click and hold the right mouse button to zoom in and out
- Click and hold the middle mouse button (wheel) to move (translate) the image around.
3D – Transparency Control

3D – Static and Dynamic Slices

X Slices of Inverted Resistivity

Dynamic Slices of Inverted Resistivity
**3D Inversion with Topography**

Electrodes must be laid out in a rectangular grid based on the horizontal distance. EarthImager 3D does not support slope distance or tape measure at this time.

**Terrain File Format**

```plaintext
; TRN File  // Semicolon ";" starts a comment line
unit=meters  // Distance (length) unit
X, Y, Elevation Z
-1, -1, 102.2  // Horizontal distance X, Y and elevation Z
0.5, 4.5, 103.5
0.2, 10, 97.7
0, 15.8, 99.4
7, 13, 101.1
5.5, 6, 100
12, -1.5, 102.4
13, 4, 101
14, 11.7, 98.6
13, 16.2, 99.8
```

**3D Survey Planner**

Both surface and borehole resistivity modeling
Utilities

- 2D Command Creator
- 3D Command Creator
- Shift, scale, and reverse
- Extract 2D dataset (E3D)
- Merge command files
- Merge data files
- Combine parallel 2D lines for 3D inversion
- Modify electrode coordinates
- Multilingual support
- Upgrade
- EarthImager User Group
- Release Notes
- Instruction Manual

Combine Parallel 2D Lines for 3D Inversion

- Use the utility under EarthImager 3D | Tools | Combine Parallel 2D Lines.
- Switch X and Y coordinates if applicable.
- Make sure the line spacing is equal or less than twice the electrode spacing.
- Make sure the X-axes of all parallel lines are oriented to the same direction.
- Invert the merged data file in EarthImager 3D.
EarthImager User Group

Download the latest version of EarthImager 1D, 2D, and 3D

- Your user name and password can be found from the EarthImager menu Help | EarthImager User Group.

More Helpful Links

- Access the latest version of the instruction manual in a PDF file.
- Access the AGI home page
- Find your dongle (hardware key) serial number from the About EarthImager menu
- Activate your dongle with new features by inputting an upgrade code obtained from AGI. An upgrade can be a Time Lapse module, a CRP module, or a Sand Box module.
http://www.agiusa.com/directory.shtml

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Customer service and tech support in these languages:

English, Spanish, Chinese, Swedish, Turkish and French