# Design and Inversion of 3D Time-Domain EM Survey

### The Complete Solution

The information and value that can be obtained from geophysical surveys will always be limited by the method and survey design. Optimal survey design can be achieved by leveraging a basic understanding of the subsurface structure to meet specific exploration objectives. Computational Geosciences Inc. (CGI) helps maximize the value of geophysical exploration by assisting in the optimal survey design, inverting the data to recover high resolution 3D models, and consulting on the next steps in the exploration program.

### Survey Goals and Design

CGI can determine the best survey method based on the geologic setting, the target's characteristics, and the clients logistical/cost considerations. It then integrates prior geophysical and geologic information and runs modeling experiments to validate the survey design before conducting data acquisition. This approach reduces the risk of wasting resources and time while increasing the probability of finding and identifying geophysical targets.

In the following example, CGI was provided with a simple geologic model and some basic estimates of expected conductivity values. Given this information, a synthetic conductivity model was created (Figure 1) which contained a set of distinct conductors within a dipping zone of variable conductivity. Locating these targets would be particularly challenging because they were covered by a complex sequence of conductive and resistive folded structures. Based on this information, CGI modeled the response from several geophysical methods and determined that a 3D time-domain ground loop electromagnetic (EM) survey would provide the best results. The following were key parameters required to recover three-dimensional conductivity structures at depth:

- A high number of transmitters
- A high number of receivers for *each* transmitter
- Overlapping transmitter loops
- A high number of time channels

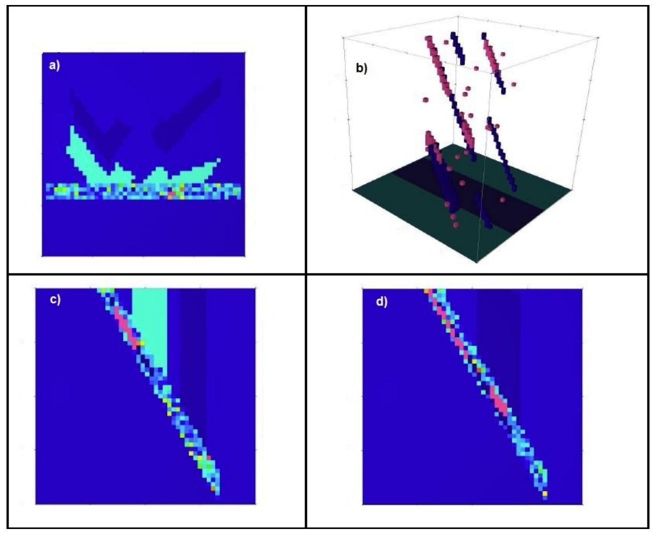


Figure 1: Synthetic conductivity model: pink is conductive, dark blue is resistive. **a)** Surface view. **b)** Showing only most conductive and resistive units. **c)** and **d)** Cross sections through the model.

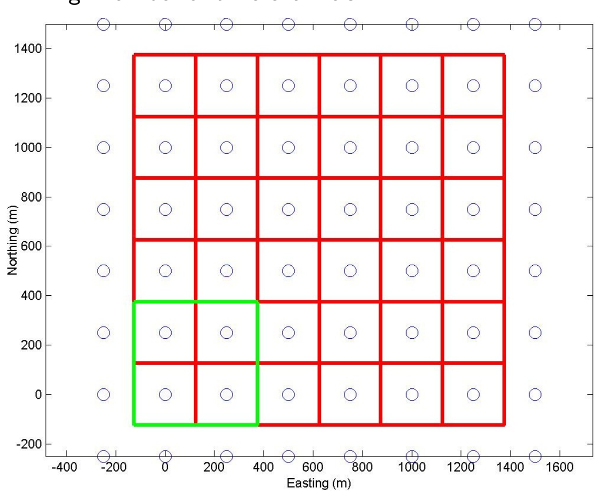


Figure 2: Survey geometry: 25 overlapping transmitter loops (**red**) on a $5 \times 5$ grid. A single transmitter loop is highlighted in green, showing the 50% overlap of each transmitter loop. The 64 receivers (**blue** circles) are on a $8 \times 8$ grid.

The optimal survey design consisted of 25 transmitter loops each with an array of 64 receivers (Figure 2). For each transmitter, the magnetic fields were measured at all of the receivers at 129 time channels between $10^{-6} - 10^{1}$ seconds. The ground loop EM survey was validated by forward modeling the conductivity model to generate 206,400 synthetic data. The data were then inverted to assess the target recovery capabilities based on this specific survey configuration.

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**Synthetic Modeling**

The inversion of the synthetic data showed that despite the difficulties of recovering structures beneath the overlying conductive units, the proposed geophysical survey would be able to detect the targets within the dipping unit down to a depth of approximately 500m (Figure 3). In addition to this, the inversion result indicated that both the structure and conductivity of the synthetic model (such as the dipping unit and the folded unit) could be accurately recovered. Following the successful survey design validation, the survey configuration with minor modifications was used to acquire data in the field.

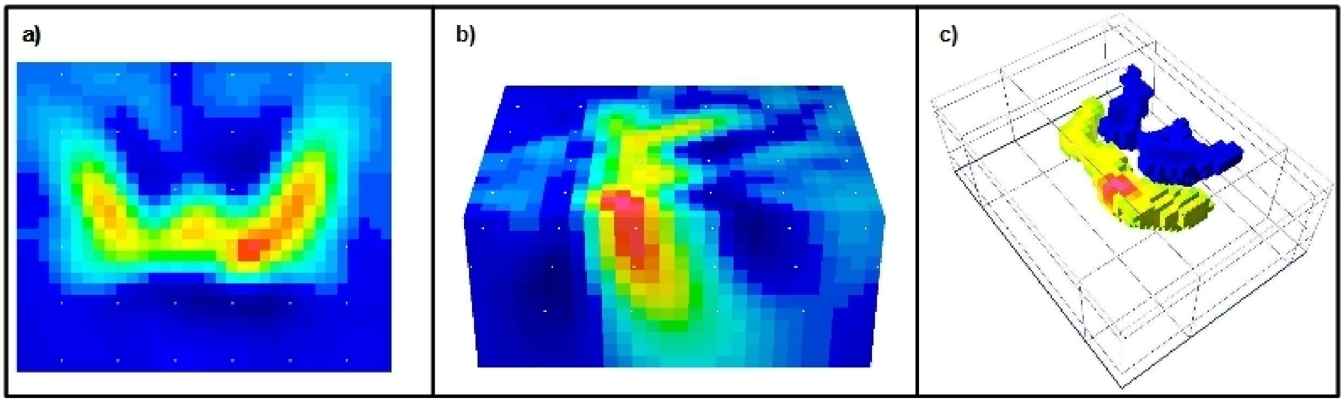


Figure 3: Conductivity model recovered from inversion of synthetic data. The W shape of the folded units is clearly discernible in all three images. The conductive targets contained within the dipping structure are shown in red in the recovered model. Even the conductivity contrast between the footwall and the hanging wall is visible. **a)** Top view. **b)** Cross section through the model. **c)** Model with conductive and resistive structures. The white dots indicate the location of the receivers.

**Field Data and Inversion**

The field survey layout was modified to cover the exploration area by changing the geometry into two overlapping rows of 5 transmitters each with a $5 \times 8$ array of 40 receivers. Magnetic fields were measured at 104 time channels, ranging from $4 \times 10^{-7} - 6.4 \times 10^{-2}$ seconds resulting in 41,600 data. The 3D inversions recovered a dipping conductor going to depth, as well as a folded unit which matched with the known geologic model (Figure 4). This multi-step exploration approach has successfully identified structures at depth that would have been difficult to recover using other methods.

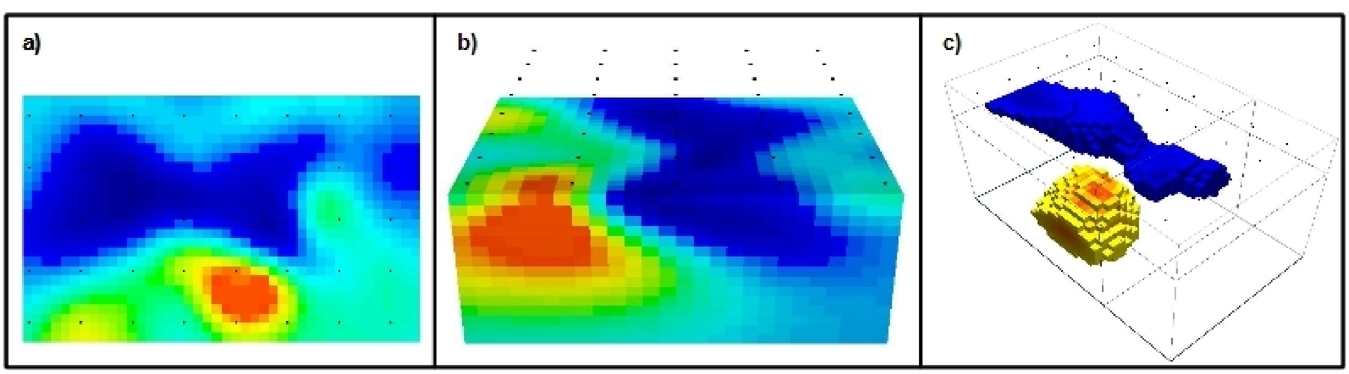


Figure 4: Conductivity model recovered from inverting the field data. Similarly to the recovered synthetic model in Figure 3, the W shape of the folded units is again visible as well as a dipping conductive target (orange). In addition, a clear delineation between the resistive and conductive units appears to indicate the location and dip of the shear zone. **a)** Top view. **b)** Cross section of the model. **c)** Model with conductive and resistive structures. Black dots indicate the location of the receivers.