Introduction to CSAMT

Overview

Controlled Source Audio-frequency Magneto-tellurics (CSAMT) is a low-impact, non-intrusive, ground geophysical survey method used extensively in minerals, geothermal, and groundwater exploration since 1978 when Zonge introduced a commercial data-collection equipment system for CSAMT to the industry.

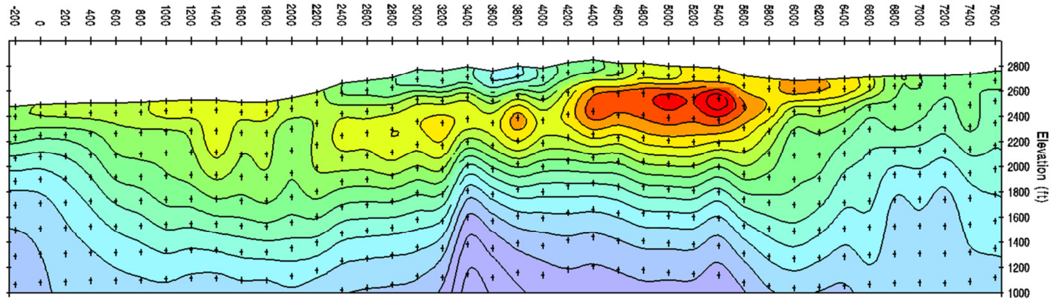
CSAMT is a geophysical investigation method for obtaining information about subsurface resistivity. Resistivity values calculated from the CSAMT data relate to geology. Primary factors affecting resistivity include rock or sediment porosity, pore fluids, and the presence of certain mineral assemblages.

For mineral, hydrological, mining and some petroleum applications, CSAMT data can provide critical information about geologic structure, lithology, water-table trends, pore fluid salinity, and contaminant concentrations.

Although resistivity information can also be obtained in IP surveys, CSAMT and IP methods each have separate, distinct advantages. CSAMT provides better resolution and much deeper information with more efficient use of field-work time. The polarization data from IP surveys, however, can add valuable information for interpretation and for prioritizing target areas. Thus CSAMT is often used for reconnaisance of larger geographic areas to determine depth to bedrock and to locate faults and resistive anomalies for further, selective IP investigation.

A CSAMT survey involves transmitting a controlled signal at a suite of frequencies into the ground from one location (the transmitter site) and measuring the received electric and magnetic fields in the area of interest (the receiver site). The ratios of orthogonal, horizontal electric and magnetic field magnitudes (e.g. E_x and H_y) are used to calculate the resistivity structure of the earth.

CSAMT is a resistivity sounding technique used often in groundwater, geothermal, hydrocarbon and minerals exploration.



CSAMT 2D smooth-model resistivity section (ohm-m) from Silver Bell mining district within the porphyry-copper province of southwestern North America.

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Field Logistics

Generator and equipment at transmitter site

Field operator at receiver site

A Zonge CSAMT field crew usually includes three or four people with one pick-up truck at the transmitter site and one at the receiver site. At the receiver site, the equipment can be carried by backpack and no off-road driving is necessary. Depending upon the depth of exploration and geologic conditions, the two sites are usually located between three and six miles (five to ten kilometers) apart.

Using a specialized, multi-channel receiver, the electric field and one or more magnetic field measurements are acquired simultaneously on several stations, greatly reducing the time spent in the field.

<u>The transmitter site</u>

A remote, grounded dipole is used for electromagnetic signals. This dipole, set up at the start of the CSAMT survey, requires insulated copper wire (2.5 mil/ 14 gauge) for making connections. The two grounded current electrodes are spaced approximately 5000 feet (1500 meters) apart. Grounded current electrodes can be constructed either by using multiple galvanized steel stakes hammered into the ground, or by constructing small, aluminum foil-lined mud pits. Salt water is typically used for insuring good electrical contact with the ground.

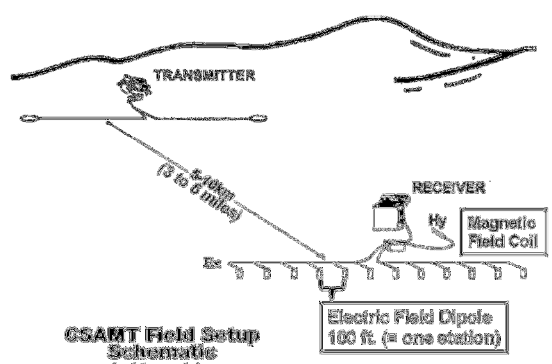
Placement of the CSAMT transmitter and the connecting wires from the transmitter to each current electrode is a function of access. Although the simplest setup is shown in the schematic, wires and transmitter can be located anywhere between these two electrodes or at reasonable distances offline wherever access is available. For high-power use, the transmitter and generator set are truck mounted.

<u>The receiver site</u>

A portable, microprocessor-controlled receiver amplifies, filters, processes, and records the received signals at individual stations. The transmitted signal is detected with short grounded dipoles (electrode pairs) and magnetic field detectors/sensors. The receiver dipoles are surface wires, grounded using small, porous ceramic "pots" buried about ½ inch into the soil. The magnetic-field detectors are cylindrical coils of wire about three to four feet long placed on the ground.

Depending on logistical considerations, usually one to seven stations can be collected in one setup. After acquiring data at one field setup, the crew moves the receiver, the pots, and the wires to the next set of stations.

Cultural features (man-made objects) such as radio transmitters, metal fences, and power lines can affect the resistivity measurements. Good survey design minimizes the effect of these features.



Lateral and Vertical Resolution

Lateral resolution is determined by station spacing. Station spacing is typically between 10 and 200 meters. The received signal strength is proportional to the size of the station spacing. For example, if the station size is cut in half, the signal strength is cut in half. This is important to remember when designing a survey because the limiting factor on depth of exploration is usually the signal strength.

The depth of investigation for CSAMT depends on the transmitted frequency and subsurface resistivity. In general, the lower the frequency, and the higher the ground resistivity, the greater is the depth of investigation.

The CSAMT method has proven useful for mapping the earth's crust in the 20 to 1,000 meter depth range. Vertical resolution is 5 to 20% of the depth.

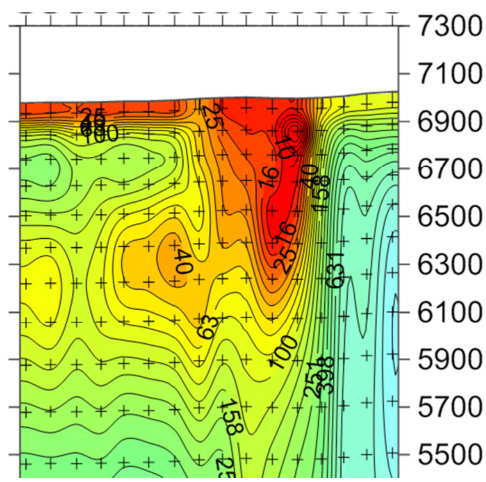
CSAMT is useful for mapping the earth's crust in the 20 to 1,000 meter depth range.

Inversion Models

Smooth-model inversion programs are used to convert the survey results to profiles of resistivity versus depth. Smooth-model inversion mathematically back-calculates (inverts) from the measured data a likely location, size and depth of the source(s) of the resistivity changes and creates modeled profiles showing these changes as smooth gradations.

Zonge provides both one- and two-dimensional inversion models with interpretation taking into account the advantages of each. 1D and 2D modeling routines use different data components and assumptions and thus contribute different information to the interpretation.

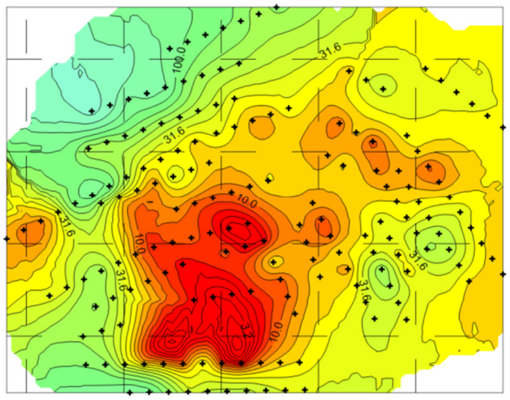
2D modeling corrects the measured data for terrain effects, uses information from adjacent stations, and does not assume that the subsurface variations in resistivity only occur vertically. Thus 2D modeling provides a better picture of the complexity of the geology at depth. 1D models preserve more near-surface detail and better reveal lateral changes such as thin, high-angle features.



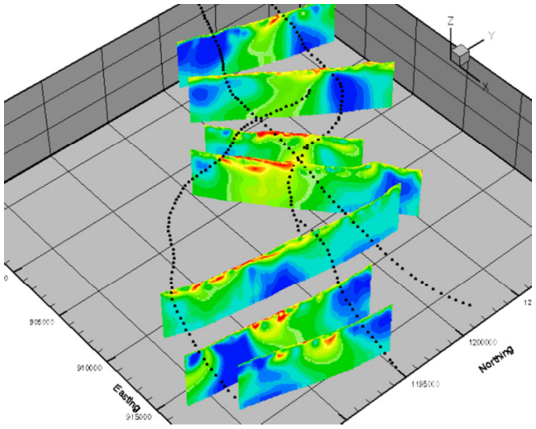
1D smooth-model resistivity section for deep groundwater investigation. Elevation is in feet.

Final Product

The results of processing and modeling CSAMT data can be presented in several forms: modeled cross sections, plan views, fence or 3D diagrams. When stations are collected along several lines in the same area, data can be displayed in plan-view plots at a constant elevation or depth. Plan views can help highlight trends between lines. Fence diagrams show 2D cross sections of the resistivity inversion results in a spatially relevant 3D context. Dotted lines in the fence diagram below represent mapped faults.



Smooth model inversion results. Plan view: 200 ft. below ground surface.



Smooth model inversion results. Fence diagrams in 3D context.

Zonge International is an employee-owned company providing ground geophysics field services, consulting and customized equipment to geoscientists and engineers worldwide.

The company is known for its expertise in the development and application of broad-band electrical and EM methods.

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Reference

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For more information, see www.zonge.com/geophysical-methods/

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