Introduction to CSAMT

NOVEMBER 2009

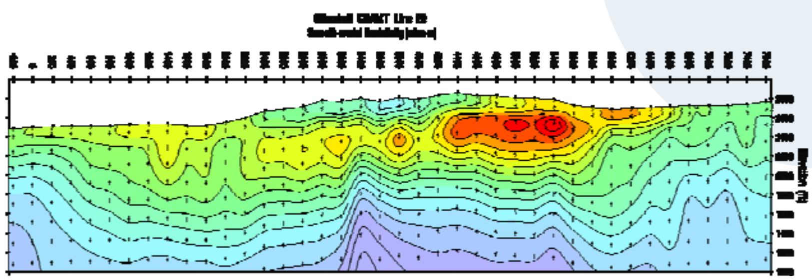
CSAMT is a resistivity sounding method used commonly in the minerals, geothermal, hydrocarbon and groundwater exploration industries.

Overview of CSAMT

CSAMT (controlled source audio-frequency magnetotellurics) is a commonly-used, surface-based geophysical method which provides resistivity information of the subsurface. This low-impact, non-intrusive technique has been used extensively by the minerals, geothermal, hydrocarbon, and groundwater exploration industries since 1978 when CSAMT equipment systems first became commercially available.

The CSAMT method involves transmitting a controlled signal at a suite of frequencies into the ground from one location (transmitter site) and measuring the received electric and magnetic fields in the area of interest (receiver site). The ratio 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.

Calculated resistivity values from CSAMT data relate to geology. Primary factors affecting resistivities include rock or sediment porosity, pore fluids, and the presence of certain mineral assemblages. For hydrological investigations, CSAMT data may provide critical information about geologic structure, lithology, water table trends, and trends in pore fluid salinity or contaminant

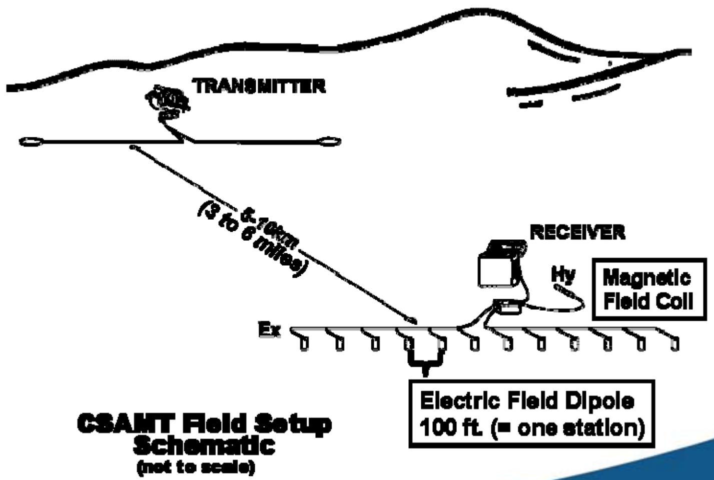


The CSAMT method has proven useful for mapping the earth's crust in the 20 to 2,000 m depth range.

Field Logistics

With a multi-channel receiver, the electric field on several stations (and one magnetic field) can be acquired simultaneously, greatly reducing the time spent in the field. The field crew usually includes 3 or 4 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, the two sites are usually located 3-6 miles (5-10 km) apart.

Zonge GDP-32II multichannel receiver



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Generator and equipment at transmitter site.

Field Logistics (cont…)

The transmitter site consists of a thin, insulated surface wire grounded at each end (typically 1 to 2 km apart) using ½ inch diameter conduit stakes pounded about ½ to 1 foot into the soil. To increase contact between the stakes and the ground the area is watered daily with salt water. The wire is laid out by walking along the ground, and vehicle access along the length of the transmitter is not necessary. The wire does not need to be straight, and can be angled or bent around areas where access or walking is not permitted. At a convenient location between the end electrodes, the transmitter electronics are connected to the surface wire. This equipment is usually in a pick-up truck with a generator mounted in the back or on a small trailer behind the truck.

At the receiver site, a portable microprocessor controlled receiver amplifies, filters, processes, and records the received signals at individual stations. The signal that is being transmitted is detected with short grounded dipoles and magnetic field detectors. The grounded dipoles at the receiver are also surface wires, grounded using small porous ceramic "pots" buried about ½ inch in the soil. The magnetic field detectors are cylindrical coils of wire placed on the ground, usually about 3 to 4 feet long. Depending upon equipment and logistic considerations, typically one to seven stations can be collected in one setup. After acquiring data at a setup, the crew moves the receiver, pots, and wires to the next "set" of stations.

Cultural features (man-made objects such as radio transmitters, metallic fences, power lines, etc.) can affect the resistivity measurements. The survey should be designed to minimize the effects from these features.

No trenching, drilling, road-making, or blasting is involved, and the majority of the survey can be done on foot using backpackable equipment.

Lateral and Vertical Resolutions

Lateral resolution is mainly controlled by the station spacing. The received signal strength is proportional to the length of the station spacing, so if the station size is cut in half, the signal strength in cut in half. The station spacings are usually between 10 to 200 m.

The depth of investigation for CSAMT depends on frequency and on subsurface resistivity. In general, the lower the frequency the greater the depth of investigation, and the higher the ground resistivity, the greater the depth of investigation. The limiting factor on depth of exploration is usually signal level. Most surveys are run with receiver-transmitter separations between 5 and 10 kilometers.

The CSAMT method has proven useful for mapping the earth's crust in the 20 to 2,000 m depth range. Vertical resolution is generally 5 to 20% of the depth.

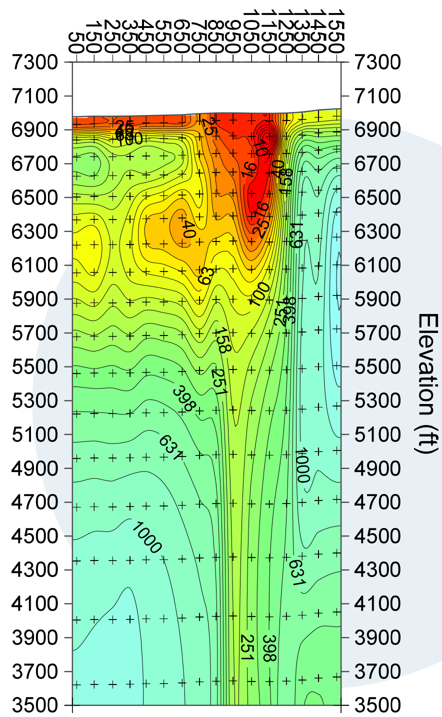
1-D and 2-D modeling programs can be used to convert the measured results to profiles of resistivity versus depth.

Inversion Models

One-dimensional and 2-D modeling programs can be used to convert the measured results to profiles of resistivity versus depth. 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 resistivity changes. The results of the smooth-model inversion are intentionally gradational, rather than showing abrupt, "blocky" changes in the subsurface.

2D models differ from the 1D models in that the iterative adjustment utilizes information from adjacent stations, and when modeling a given station, it does not assume that the subsurface variations in resistivity only occur vertically. As a result, 2D results are usually smoother horizontally than the 1D results. However, 2D results also often smooth out real, but weak, lateral changes.

Resistivity Model Section



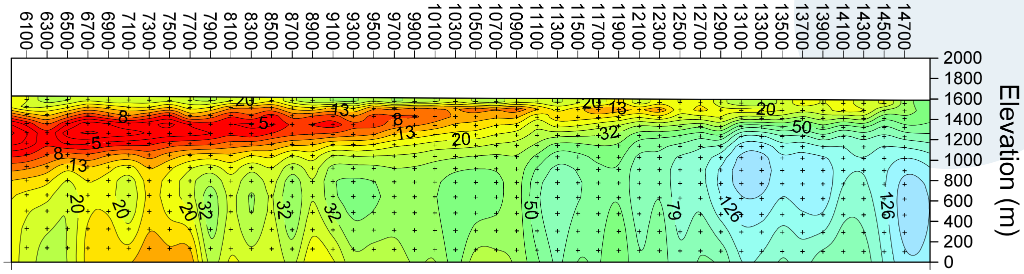
Final Product

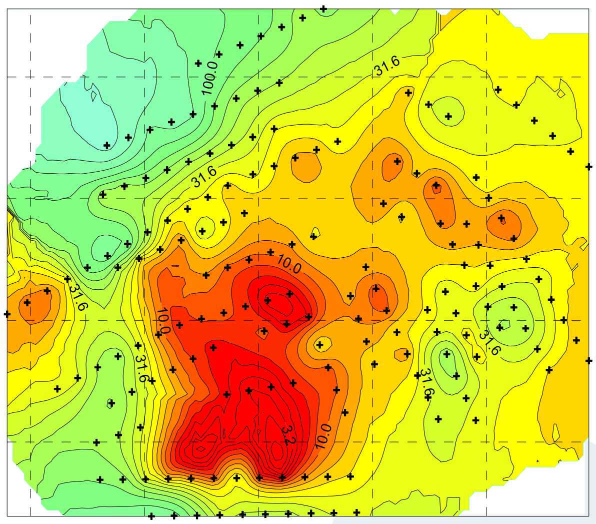
The results of processing and modeling the CSAMT data can be presented in several forms:

- modeled cross sections
- plan views
- fence or 3 D diagrams.

Field operator and re-ceiver underground.

Resistivity Model Section

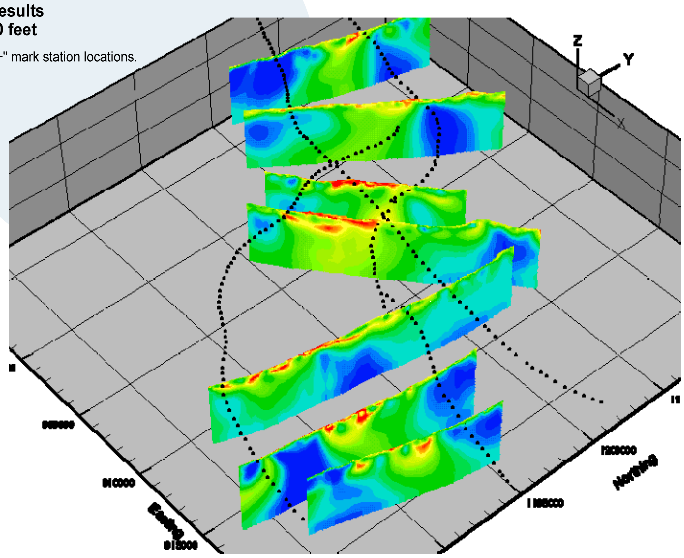




Smooth-model Inversion Results
Depth Below Surface: 200 feet

Resistivity contours at 200 feet below the surface. "+" mark station locations.

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 2-D cross sections of the resistivity inversion results in a spatially relevant context. Dotted lines represents mapped faults.

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CSAMT Reference Material

Cagniard, L. 1953, Basic Theory of the magnetotelluric method of geophysical prospecting, Geophysics, 18, pp. 605-635.

Goldstein, M.A., and Strangway, D.W., 1975, Audio-frequency magnetotellurics with a grounded electric dipole source: Geophysics, 40, 669-683.

Zonge, K.L. and Hughes, L.J., 1991, "Controlled source audio-frequency magnetotellurics", ***in*** Electromagnetic Methods in Applied Geophysics, ed. Nabighian, M.N., Vol. 2, Society of Exploration Geophysicists, pp. 713-809.

Zonge, K. L., 1992, "Broad Band Electromagnetic Systems", ***in*** Practical Geophysics II for the Exploration Geologist", ed. Richard Van Blaricom, Northwest Mining Association, pp. 439-523.

(Some parts of this document have been extracted from Practical Geophysics II, Northwest Mining association, 1992)