



VLF methods of geophysics utilize Very Low Frequency radio communication signals to determine electrical properties of near-surface soils and shallow bedrock. The technique is especially useful for mapping steeply dipping structures such as faults, fracture zones and areas of mineralization. In the reconnaissance mode, VLF profiles can be run quickly and inexpensively to identify anomalous areas which may require further investigation; either with more detailed geophysical measurements and/or drilling and sampling.

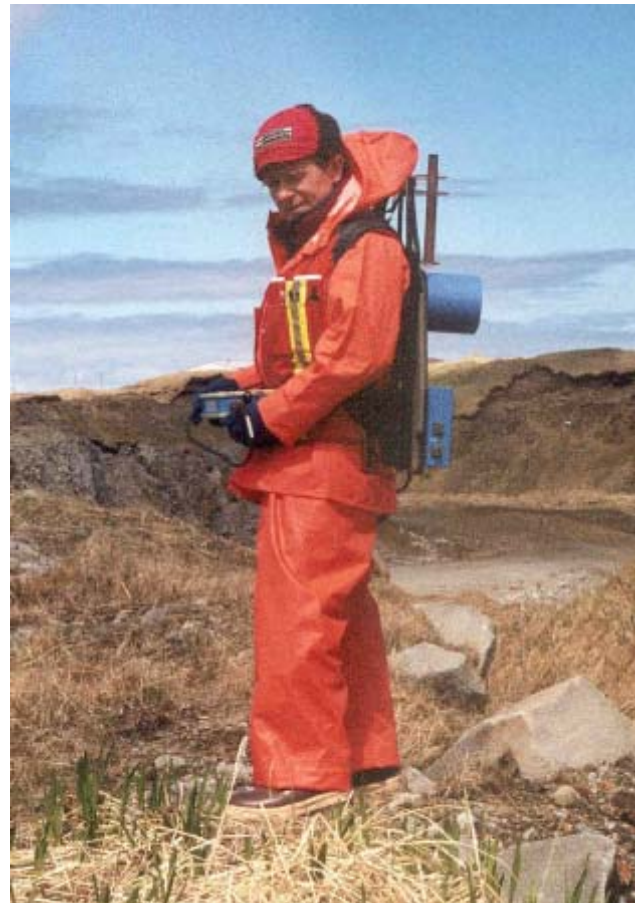
### APPLICATIONS:

VLF is an effective *reconnaissance* geophysical tool for mapping geoelectric features. It may be used wherever a electrical conductivity contrast is present between geological units. This may include:

- fault mapping,
- groundwater investigations,
- overburden mapping,
- contaminant mapping,
- mineral exploration

Electrically conductive features include fault zones, and zones of mineralization which tend to be more conductive than the surrounding bedrock or host rock. Other conductive geologic units include moist, clayey, or fine grained soils which tend to be more conductive than dry, sandy or coarse grained soils. Hence, these geologic objectives are reasonable “targets” and can be mapped using electrical or electromagnetic methods.

Depth of investigation is controlled by the electrical “skin depth” of the local geology. It



varies from 40-60 meters in highly resistive soils to 4-5 meters in conductive soils.

VLF instruments are “back pack” portable and operated by one person. Productivity depends on the terrain and vegetation, but generally several kilometers of line may be covered in a good day.

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## PRINCIPLES OF OPERATION

VLF techniques measure the perturbations in a plane-wave radio signal (15-30 kHz) emanating from one of several world-wide radio transmitters used for submarine communications. Military transmitters in Bangor, Maine; Seattle, Washington; Annapolis, Maryland; and Lualualei, Hawaii provide adequate coverage for all of North America. VLF falls in the broad category of electromagnetic (EM) methods of geophysics.

The primary field (the transmitted radio signal) causes eddy currents to be induced in conductive geologic units or structures. Faraday's principle of electromagnetic induction tell us that any oscillating magnetic field (e.g., the radio wave) will produce an electric field and hence an electric current in a conductive media. Those eddy currents in turn create a secondary magnetic field which is measured by the VLF receiver.

The secondary or perturbed field may be phase shifted and oriented in a different direction than the primary field depending on the shape or geometry of the conductor, the orientation of the conductor, and the conductivity contrast with the surrounding material (e.g., the host rock). The instrument measures both the primary and secondary fields together.

All VLF instruments measure two components of the magnetic field or equivalently the "tilt angle" and ellipticity of the field. Some instruments also measure the third magnetic component and/or the electric field. The electrical field is measured by inserting two probes in the ground, spaced about 5 meters apart, and measuring the potential difference at the transmitter frequency. The electric field provides additional information about the overburden thickness and conductivity.

## INTERPRETATION

VLF interpretation is generally qualitative or subjective in nature. Anomalous areas are identified and a gross characterization attached to the anomaly (e.g., steeply dipping conductor or thickening conductive overburden). Some simple modeling may be carried out for simple geometric structures.

## FIELD PROCEDURES

VLF instruments may be carried by a single operator and generally weigh 5-10 kg (10-20 pounds). State-of-the-art instruments include software to store the data with survey coordinates, and may be dumped to a laptop computer at the end of the day. Magnetic field measurements do not require ground contact and can be made in less than a minute at each station. Station spacing may vary from 5 to 20 meters (15 to 60 feet) depending on the geologic objective.

If electric field data are also acquired, probes must be pushed into the ground at each station and hence the measurement time at each station is increased.

## LIMITATIONS OF VLF

VLF is used primarily as a reconnaissance tool to identify anomalous areas for further investigation, either with other geophysical methods or drilling. Weaknesses of the method include:

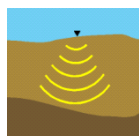
- VLF measurements are sensitive to "cultural interference" from pipelines, utilities, fences, and other linear, conductive objects.
- interpretation is generally qualitative in nature; quantitative modeling requires a high data density and a well constrained model.
- topographic effects can bias the data, are difficult to remove, and are model dependent.
- VLF transmitters are subject to outages for scheduled or unscheduled maintenance.
- unfavorable ionospheric conditions may compromise the quality of the data.

## REFERENCES

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FILE: VLF.pub, REVISION: 14-SEPT-2011



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