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USE OF ELF MEASUREMENTS TO SUPPLEMENT VLF AND MAGNETO TELLURIC SIGNALS IN ELECTROMAGNETIC PROSPECTING

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The Johns Hopkins University/ Applied Physics Laboratory has looked at the use of the coherent ELF transmissions from the U.S. Navy's SANGUINE transmitter in Wisconsin in prospecting for geothermal brines and other anomalous conductivity regions in the earth. The advantage of using these signals is that, first, they come from a powerful transmitter and antenna system, and, second, the coherent transmissions afford signal integration times of hours (if necessary). While the skin depth of these signals (45 and 75 Hz) restricts accurate measurements to depths of 2-5 kms, the precision with which they may be made provides significant information about subsurface geology. It is important to process VLF signals as well (12-18 KHz) to help separate the effects of surface terrain features, as well as magneto-telluric (MT) signals for probing deeper into the earth to obtain the full story of the structure of the anomalies being measured. In addition to the use of coherent integration with signals at each antenna location, it is possible to obtain coherent information from a set of antenna locations. These may be used to fit the spatial pattern of signal scattering from deep anomalies to obtain further improvement in signal processing and anomaly identification: it is these features which make the method of great power in geological prospecting.

An example of the scattered signature on the surface above a local high conductivity volume of spherical or paraboloidal shape is shown in Fig. 1 on several traverses near the anomaly. This coherent pattern should be compared with the pattern in Fig. 2 of a high conductivity dike anomaly to show the possibilities of anomaly identification.

The dominant background noise is the MT background at the SANGUINE frequencies. The former consists of two parts — the first from distant thunderstorms and magnetospheric disturbances, while additional pulse type interference may be generated by nearby thunderstorms. These interfering pulses will be edited from the measured data before integration to obtain the best possible signal to noise ratio. The mean noise amplitude ($E_\perp$) is expected to be

$$-76 \text{ dB (re 1 V/m } \sqrt{\text{Hz}}) .$$

For

$$\sigma = 10^{-2} \text{ mho/m and } \varepsilon = \varepsilon_o ,$$

the corresponding

$$E_\parallel \text{ is } -144 \text{ dB}$$

or

$$6 \times 10^{-8} \text{ V/m } \sqrt{\text{Hz}} .$$

The incident $E_\parallel$ is expected to be

$$2 \times 10^{-8} \text{ V/m } \sqrt{\text{Hz}} .$$

Figure 3 is a plot of the signal to noise anticipated for typical anomalies at various depths showing that integration times of half an hour to an hour are adequate.

The incident $E_\parallel$ amplitude was estimated from the measurements by P. R. Bannister, while the noise background used here is based upon the measurements by E. L. Maxwell.

In all geological prospecting, it is necessary to use to the utmost the very few data points which are available to decipher the complexity of the various geological structures. It is desirable, for example, to make gravity and magnetic anomaly measurements at each of the antenna locations in the electromagnetic survey to get additional structure-dependent information for later data processing on the computer to obtain a self-consistent determination of the geothermal source. Our studies to date show that the ELF measurements can make a significant contribution to the understanding of the subsurface structure.

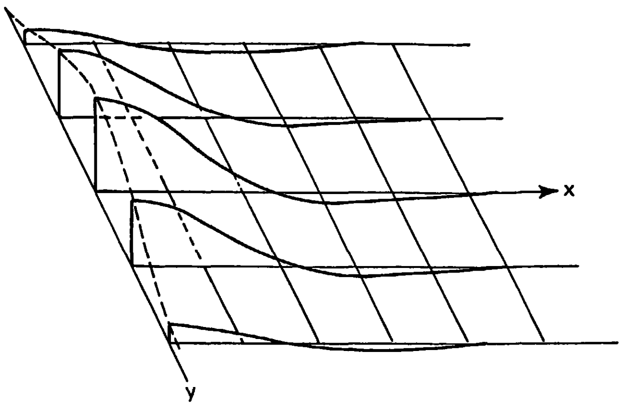

Fig. 1 Scattered Wave Signature Due to an Underground High Conductivity Anomaly

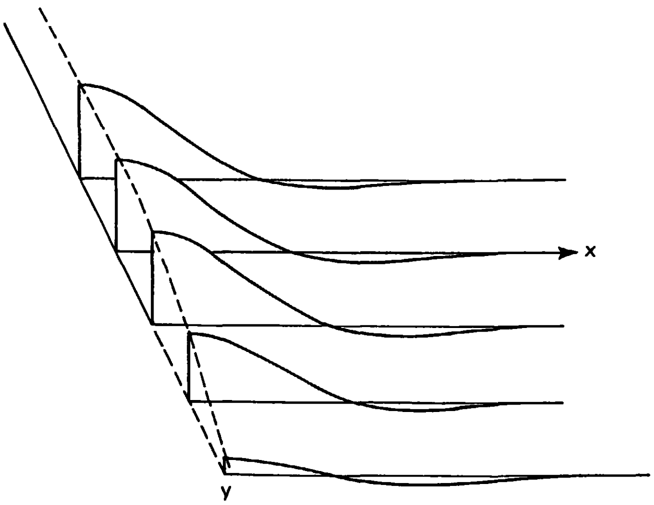

Fig. 2 Scattered Signature Due to a High Conductivity Dike

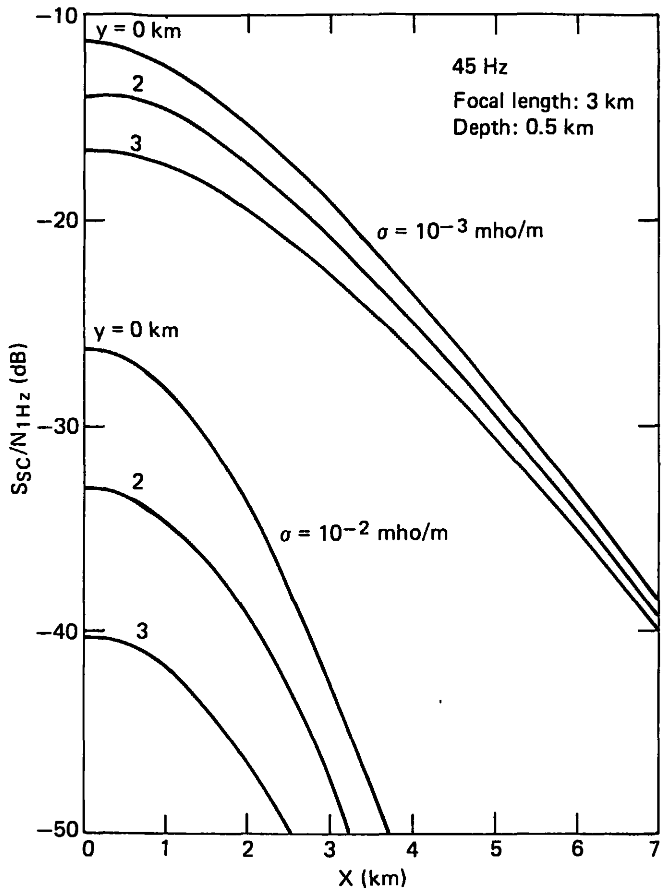

Fig. 3 Signal to Noise Ratios (in 1 Hz Band) for Several Traverses Near a High Conductivity Anomaly