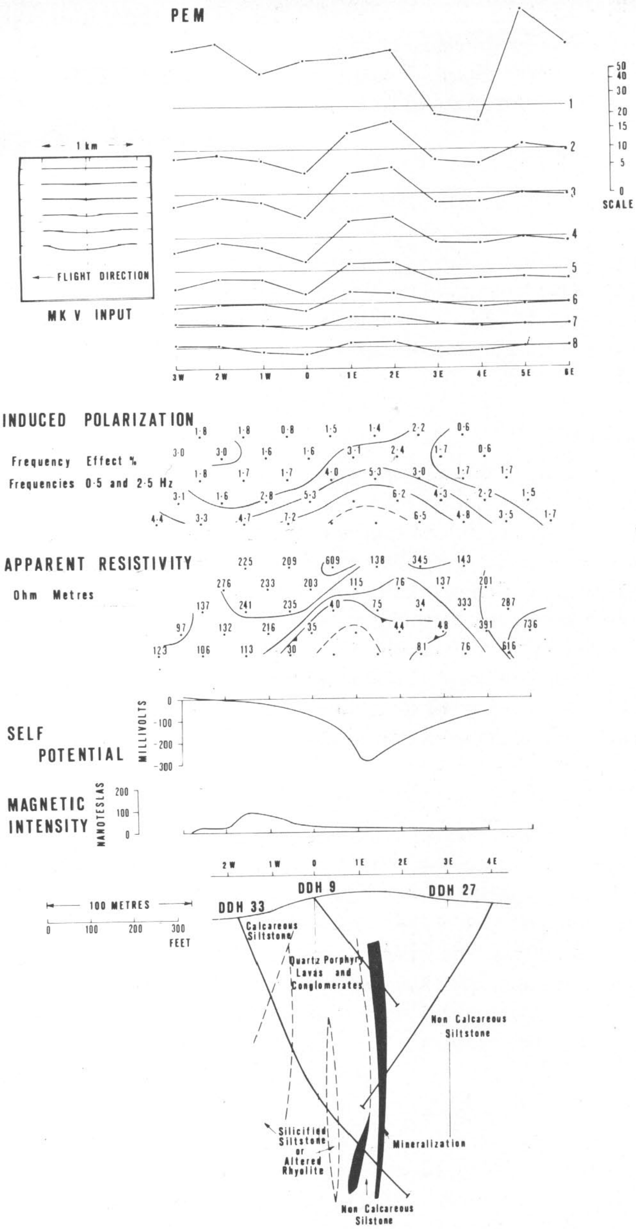

CLASSICAL ELECTRICAL & ELECTROMAGNETIC RESPONSES OVER A VERTICAL SHEET OF MASSIVE SULPHIDE MINERALIZATION

Both dipole-dipole IP and dual small horizontal loop transient EM systems have well defined responses which allow the attitude and position of conductive and chargeable sheets to be defined. A knowledge of these responses allowed most of the above anomalies to be satisfactorily explained prior to drilling.

IP provides information on chargeability as well as conductivity. PEM provides conductivity information only which is sometimes insufficient to determine whether a target may be economic. As PEM surveys are significantly faster and cheaper than dipole-dipole IP surveys, an optimum investigative approach appears to be to outline a target with PEM and then to check it with one or two dipole-dipole traverses.

SPECTRAL IP – PAST, PRESENT AND FUTURE

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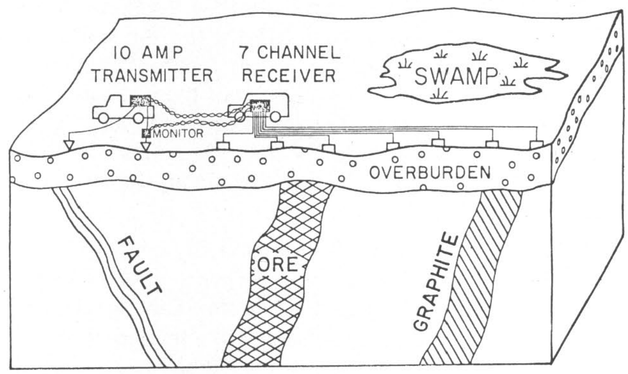
These has been considerable research and development into Spectral IP over the last five years. Some of the earliest claims have been found to be erroneous. The dominant influence on IP spectra is rock texture and grain size and not the particular electrochemical reactions taking place at the metallic-ionic interface. In spite of the inability of Spectral IP to directly identify chemical reactions and thus, specific minerals, it has been found to be a useful tool in indirectly identifying minerals through their characteristic habit. The long time constant spectra associated with the typically large effective grain size of graphite is readily distinguished from the short time constant spectra of typical "sugary" volcanogenic massive sulfide Py-Cp-Sp-Pb mineral mineralization.

The raw spectra obtained over different types of mineralization can only be directly compared if the measurements were made with small arrays in an open pit mine, where the geometry approaches the ideal homogeneous earth case. In usual exploration applications, the apparent time constant and the apparent chargeability will both be smaller than their true values due to the dilution effects of overburden and surrounding host rock. It is possible to correct for dilution effects, when host rock and overburden polariz-

SPECTRAL IP FIELD SET-UP



SPECTRAL IP

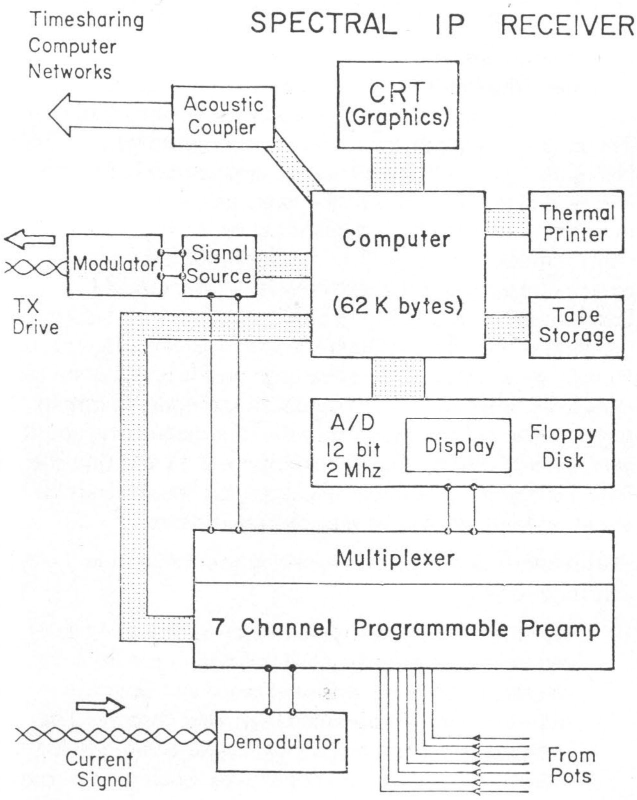
⇓ Data Acquisition

RAW FIELD DATA

⇓ Coupling Removal ⇓

APPARENT I P SPECTRA → Dilution mpensation ⇓ → TRUE SOURCE PARAMETERS → Comparison with Data Bank ⇓ → SOURCE TYPE & STATISTICS

COUPLING SPECTRA → ⇓ OD, ID, 2D, 3D Interpretation → ADDITIONAL RESISTIVITY INFORMATION



ation are small, by simply carrying out a power expansion on the apparent amplitude spectra and then conducting another non-linear inversion on the resultant spectra to find the true electrical parameters of the source.

A seven-channel truck-mounted spectral IP system has been constructed in which an on-board computer is used in the acquisition, reduction and interpretation of IP data. The frequency range which is normally used is 0.037 Hz to 2187 Hz, or eleven frequencies spaced a factor of 3 apart. Since the current and 6 n-spacing voltages are recorded simultaneously, survey work can proceed rapidly. Only 20 to 30 minutes usually elapse between current dipoles. A total of twelve 1000 ft. dipoles, n = 1 to 6, have been measured in one day for an end-to-end line coverage of 19,000 feet.

The introduction of portable, low-cost computers is significantly changing electrical methods of geophysics. With microprocessors and minicomputers to monitor multichannel data acquisition systems, we will continue to see more and more measurements being made at a faster rate. This should lead to productivity increases which more than compensate for the increased cost of equipment, while the increased number of frequencies whould result in a factor of 10 decrease in the cost per data point.

Since the highest frequency used is well into the EM range, spectral IP becomes more than just IP, and the high frequency data can be used for more than just coupling removal. The boundaries between EM and IP are only artificial: better interpretation can be made of both low frequency (IP) and high frequency (EM) data by using the combined spectra. Data acquisition hardware, mass storage capability, and portable computing power are already technologically adequate. The challenge of the present and future is combining the three into workable, efficient systems and creating the software to interpret the results.

3D NUMERICAL MODELLING OF ELECTRICAL AND ELECTROMAGNETIC METHODS

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Almost a decade has passed since solutions to the general two-dimensional electrical and electromagnetic problem appeared in the literature (e.g. Jepsen (1969), Coggon (1971), Hohmann (1971), Swift (1971) and Vozoff (1971)). In that time three-dimensional solutions have been obtained on the computer but they often require large computational resources and have not been widely distributed. As a result exploration geoscientists have had little benefit from three-dimensional modelling algorithms. It is timely to review the computational difficulties associated with these problems, illustrate the usefulness of three-dimensional computer modelling, and offer an opinion on the direction such modelling will take in the 'eighties'.

In many of the modelling techniques, the unknowns (electric fields, magnetic fields or potentials) are approximated by known functions of position with unknown coefficients. By enforcing some criteria, a linear system of equations in the unknown coefficients is obtained. In the integral equation methods the unknowns need to be approximated only where the conductivity is anomalous, whereas in the differential equation methods (finite element, finite difference) the unknowns have to be approximated in the entire region. The matrix produced by the integral equation methods contains almost all zeros. Differential equation methods have the advantage of being able to model more complex distributions of conductivity than integral equation methods, but require more computational resources than the latter methods.

The table illustrates the number of unknowns and computer storage required to solve the typical two-dimensional resistivity and frequency-domain electromagnetic problems that could be solved in the late 'sixties' and early 'seventies'. These problems have in common the fact that they may be formulated with just a scalar unknown, either electric potential in the case of resistivity, or one complex component of electric or magnetic field, in the case of electromagnetic problems. In general the solution time for these problems is the order of 2 minutes of less of c.p.u. time on modest computers such as the Univac 1108 or the CDC 6400.

Three-dimensional resistivity modelling is more complicated than two-dimensional modelling only because the scalar unknowns need to be approximated over a further dimension. Nevertheless, for differential equation methods the number of unknowns, and computer storage, as illustrated in the table, are significantly larger. Typically 40 minutes of c.p.u. time are required for a problem with no planes of symmetry, and the algorithms do not fit easily on modest computers. This is to be contrasted with a few minutes, or less, for a single body problem solved with integral equation techniques.

General three-dimensional electromagnetic modelling is far more difficult than the corresponding resistivity problem because the unknowns are complex vectors rather than real scalars. A solution which gives accurate results for a wide class of three-dimensional models has yet to be reported in the literature. Good agreement has been obtained between