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THERMAL REGIMES OF MAJOR VOLCANIC CENTERS: MAGNETOTELLURIC CONSTRAINTS

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by

John F. Hermance, Professor
Principal Investigator
Department of Geological Sciences
Brown University
Providence, Rhode Island 02912

Telephone: 401-863-3830

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DISCLAIMER

SCOPE OF WORK

The interpretation of geophysical/electromagnetic field data has been used to study dynamical processes in the crust beneath three of the major tectono-volcanic features in North America: the Long Valley/Mono Craters Volcanic Complex in eastern California, the Cascades Volcanic Belt in Oregon, and the Rio Grande Rift in the area of Socorro, New Mexico. Primary accomplishments have been in the area of creating and implementing a variety of 2-D generalized inverse computer codes, and the application of these codes to field studies on the basin structures and the deep thermal regimes of the above areas.

In order to more fully explore the space of allowable models (i.e. those inverse solutions that fit the data equally well), several distinctly different approaches to the 2-D inverse problem have been developed: 1) An overdetermined block inversion; 2) An overdetermined spline inversion; 3) A generalized underdetermined total inverse which allows one to tradeoff certain attributes of their model, such as minimum structure (flat models), roughness (smooth models), or length (small models). Moreover, we are exploring various approaches for evaluating the resolution of model parameters for the above algorithms.

In addition to these laboratory studies, Brown University is in the process of developing and evaluating a new field strategy for surface and borehole geophysical studies which offers a substantial complement to conventional magnetotellurics (MT) and gravity studies. This involves measuring only transient magnetic variations (MV) at a field site, rather than the usual electric and magnetic field variations as is done in conventional MT. To evaluate the method, during 1988 a densely spaced, wideband (10-4000 s) sequence of 24 remote referenced, three component magnetic variation measurements were deployed along an E-W profile through central New Mexico, transecting the southern margin of the Socorro "magma body", which seismic investigations show as a highly reflective, fluid-like body at mid-crustal depth, and geodetic levelling studies show as presently inflating. Although this area has been particularly troublesome for previous MT investigators in that surficial features "mask" the electric field signal of a low resistivity anomaly at depth, our results show that the magnetic data is not as affected by these surface features. In fact, our data require that a substantial zone of high crustal conductivity is present, underscoring the important function of MV measurements as a complement to conventional MT studies.

Finally, in collaboration with engineers from Sandia National Laboratories, Brown University is planning to develop the instrumentation needed to make magnetic variation measurements in the third dimension — in boreholes — with the immediate view of applying natural source field techniques to measurements in the Long Valley DOE/GTD Magma Energy Well, and, in the long term, to using this technique in oil and gas exploration, and (in collaboration with emerging programs in the NSF and the USGS) for characterizing deep structures in the continental crust.

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I. Progress in Research

A. Geophysical Constraints on Physical Processes Beneath Major Volcanic Centers

The thermal regimes and dynamical processes of major volcanic centers are being studied using a variety of geophysical techniques with emphasis on natural electromagnetic methods and gravity. Typical areas which have been or are being studied by this group include Iceland, the Long Valley/Mono Craters Volcanic Complex, the Cascades Volcanic Belt, and one of the most seismo-volcanically active regions of the Rio Grande Rift in New Mexico, the Socorro area. Some of this work is briefly reviewed below.

One of the principal tectonic elements in the Long Valley Volcanic Complex is a deep, basin-like caldera bounded by steeply dipping normal faults having characteristic offsets of several kms which appear to control recent patterns of seismicity and volcanism. Major boundary faults in the northwest sector of the caldera having virtually no surface expression were found to be buried beneath intracaldera fill several kilometers inside the physiographic boundary of the caldera; this is compatible with recent drilling at Inyo Domes where basement was encountered at unexpectedly shallow depths. Moreover, we now have clear evidence, confirmed by limited drilling data, for a buried uplift on the basement surface beneath the resurgent dome. In addition, the analysis of electromagnetic data from a set of closely spaced sites in the south moat indicate the presence of a deep zone of magma (at a depth of 5-8 km), which is sharply truncated at the front of the eastern Sierras.

Employing a new generalized 2-D inverse algorithm, the recent interpretation of magnetic variation data from the Oregon Cascades delineate several major sedimentary basins at the surface, as well as a deep, intra-crustal conductor at a depth of approximately 15 km beneath the Basin and Range province at the east end of our profile. This feature extends laterally to the west beneath the High Cascades, terminating below the older Cascades Range. The tectonic implication of this is that it now appears that modern Basin and Range extensional processes are being imprinted on pre-existing Cascades' structures.

During the summer of 1988, we undertook a new research initiative in the Rio Grande Rift of New Mexico. This rift is one of the primary elements in the tectonic fabric of North America, and our experiment involved a wide-band (10-4000s) sequence of remote-referenced magnetic variation measurements along an E-W profile centered on Socorro, NM. The reason for selecting this particular location is that this area is the most seismically active segment of the entire rift, and recent seismic studies suggest the presence of a tabular-like body of magma underlying much of this region. Our experiment was intended to assess if the Socorro magma body is electrically anomalous and, if so, whether it is physically contiguous with structures seen elsewhere along the rift.

B. The Coupling of Shallow Intrusions to Deep Magmatic Sources: New Electromagnetic Constraints from Socorro, New Mexico

The Socorro "magma body" beneath the Rio Grande Rift in Central New Mexico represents a control case which the geoscience community has come to accept as one of the prime examples of an intrusive magma body beneath a continental rift. To further study this feature, in particular its relation to large-scale features delineated elsewhere beneath the rift, we operated a sequence of densely spaced (5-10 km), wideband (10-4000 s) remote referenced, three component magnetic variation measurements along an E-W line which transected the southern margin of the magma body. Our profile was deployed so as to cross precisely above the center of the most seismically active portion of the structure mapped by Sanford and his colleagues southwest of Socorro.

Of a wide variety of models that were assessed using a generalized 2-D inversion algorithm, we conclude that no plane layered model for the crustal structure beneath the surface basins is able to account for our observations -- we absolutely require an asymmetric structure in the crustal basement, with the crust being more conductive to the east than to the west. In addition, the data absolutely require a more conductive core directly beneath the middle of our profile. These attributes place important constraints on geophysical and tectonomagmatic models for this region:

- First, the resistivity structure beneath the western end of our profile, which is physiographically adjacent to the Colorado Plateau, has properties which are remarkably similar to those reported for interior regions of the Plateau.

- Second, the intracrustal conductor subtending the area to the east of the profile has a conductance (depth integrated conductivity) which is remarkably similar to that proposed for elsewhere along the rift.

- Third, the conductive core at shallow levels in the crust appears to be associated with the zone of microseismicity described by Sanford and his colleagues, and might be a zone of diffuse magmatic intrusions, enhanced hydrothermal circulation, or a combination of both.

Thus, while certain details of our model need further evaluation, there should be little doubt that fundamental physiotectonic processes are mapped into the electrical properties of the lithosphere over a wide range of scale-sizes.

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C. Magnetic Variations in the Reconnaissance of Sedimentary Basins: Field Procedure and Generalized Inversion of Short Period Data from the Rio Grande Rift

The magnetic variation (MV) technique can substantially complement other geophysical methods in studying sedimentary basins. By measuring only the magnetic field at each site, and not the electric field, a site can be set up quickly, and often in places which might be quite unsuitable for MT measurements. This allows one to generally execute MV surveys at much closer site spacings than conventional MT surveys. Procedures for acquiring and processing MV field data are straightforward, as are methods for inverting data to obtain plausible geophysical models.

To illustrate the MV technique, particularly the utility of operating in a short period, band-limited mode to determine the depth to basement for a sedimentary basin, we employed MV transfer coefficients at periods of 50 and 63 s from 11 sites along a profile transecting the San Antonio Graben in the southern part of the Socorro Basin in central New Mexico. To invert our data, we assumed a fixed resistivity of 10 ohm-m for the basin fill and a fixed resistivity of 1000 ohm-m for the basement. We then discretized the basin into a series of adjacent rectilinear prisms and inverted for the depth below the surface of the bottom of each prism. In our case, this becomes an overdetermined problem (the number of unknown parameters is less than the number of observations) which can be readily solved using stochastic or singular value damping of the Lanczos (or SVD) inverse.

For the non-linear problem considered, our estimated model parameters are recycled back into the inversion and the process is repeated until our prediction error is reduced to an rms level of approximately 1 standard deviation. While doing so, we emphasize the utility of employing an optimized damping parameter which minimizes the prediction error (i.e. the sum of the squared residuals between the observed data and the theoretical model response) at each iteration. Although computationally costly, we have found this procedure to be an effective way to ensure stable convergence. Beginning with the first layer (the basin sediments) having a uniform thickness of 1 km, our algorithm typically converges to an acceptable solution for the depth to basement along profile in only 5-6 iterations.

As one means of assessing how well each of the model parameters is resolved, we employed the Jacobian Matrix for our final model to determine how much each model parameter can be perturbed. Our results indicate that the band-limited data we employed (50 and 63 s) were sufficient to delineate the principal characteristics of the sedimentary basin: its lateral boundaries, the position of a large displacement along the western boundary fault of the graben, and the asymmetrical character of the basement offset.

In addition to the Jacobian Matrix, we also used several well-known interpretational devices from generalized inverse theory to provide insight into the interrelationship between the observed data and the modeling parameters. The first is the Data Resolution Matrix, N , which indicates the degree to which data predicted by the model response at a point are a combination of the actual observations. Although some workers often use only the diagonal elements of N to summarize the importance of the ith datum, the so-called "data importance," such an approach is not as comprehensive as inspecting the elements of the entire matrix N . For the example presented here, N shows a very strong banding along the diagonal elements, indicating that the observed data from sites in the immediate vicinity of a particular portion of the basin are most important in delineating the predicted response at those sites. At the same time, the "width" of the information matrix is greater, while its diagonal elements are smaller, for sites located over that portion of the basin which is deeper. This is consistent with the fact that a deeper current concentration will lead to a broader anomaly on the earth's surface requiring a longer profile at the surface to delineate. Thus, the low values of data importance over the deep section of the basin (small values for the diagonal terms N_{ii} alone) need to be considered in the light of the <u>entire</u> <u>row</u> of the data resolution matrix which suggests not so much that data are <u>unimportant</u> over the middle of the basin, but that, in order to delineate the feature, data are required over a greater lateral distance at the surface.

The Model Resolution Matrix, R, for our field example shows that shallow features of the model are best resolved while deeper features are poorly resolved. The greater width of terms in the rows of R over the deeper portions of the basin show that the depth of adjacent prisms is difficult to resolve, and that there is some interaction, or tradeoff, in estimating the model parameters between neighboring prisms. The diagonal elements of the model resolution matrix, termed the "model importance," are useful to summarize certain features of the resolution question, however there is much information in the off-diagonal terms which is also of value.

Since the crosscoupling elements in neither N nor R are generally negligible, even in the relatively well-posed example considered here, we conclude that it is best to study the interrelationships between elements of the entire matrices, rather than simply the diagonal terms alone. In fact, inspecting the row elements of both N <u>and</u> R , is a powerful asset to experimental design, as well as to deciding which features of the model can be combined or averaged together to improve their overall resolution. Thus one is well-advised to interpret the aids from generalized inverse theory in the specific context of the problem being studied, and to apply the same physical insight that one usually exercises when implementing any procedure in geophysical interpretation.

In general, we would expect the resolution of the magnetic variation technique to fall between the standard five component magnetotelluric method on the one hand, and potential field methods, such as gravity, on the other. Since we have not employed measurements of the electric field in the present study, there is some ambiguity in calibrating interpretations against absolute values of conductivities, although we have yet to explore the severity of this drawback in terms of a formal resolution analysis. However, we expect that the increased density of coverage which is possible with the MV method, along with using a broader range of periods (from 10 to 100 s, say), would tend to compensate for this shortcoming, particularly when one needs to delineate vertical boundaries in areas where MT sites are simply not available, or when MT data are too contaminated by cultural, topographic, or geologic noise to be effective.

In such cases, we feel that a particularly effective field strategy would be to saturate an area with dense, broad-band MV coverage, and to obtain electric field data at only a selected number of high quality MT sites. Thus, while the method needs further evaluation, particularly in its broad-band mode, there is little doubt that the formal inversion of magnetic variation data can ultimately address a variety of field problems over a wide range of scale-sizes, offering a substantial complement to other geophysical techniques.

Relevant Publication:

Hermance, J.F. and G.A. Neumann, 1989, Short Period Magnetic Variations in the Reconnaissance of Sedimentary Basins: Field Procedure and Generalized Inversion of Data from the Rio Grande Rift, Geophysics, in press.

D. THE ANALYSIS, INVERSION, AND RESOLUTION OF DATA FROM REGIONAL ELECTROMAGNETIC STUDIES

The Inverse Problem and the Resolution of Model Parameters

Many electromagnetic field experiments require interpreting data from sites along profiles transecting two-dimensional (2-D) features. The response for such structures can be readily calculated numerically and a number of methods have been described in the literature to automate this procedure on a computer. Finding an appropriate solution is only one aspect of the "inverse problem", however. One must also recognize that part of the inversion procedure must be concerned with identifying the range of possible models that satisfy the observed data equally well.

We are exploring various alternatives for evaluating how well various model parameters are actually resolved by a given data set. Singular value decomposition can be used to conveniently classify the importance of various parameters based on the relative amplitude of singular values corresponding to each eigenparameter. In addition, the parameter eigenvectors can be used to construct a model resolution matrix whose rows can be used to determine how well each model parameter is resolved from other parameters.

Another way to evaluate resolution is to calculate error bounds on each parameter; that is to find those models which are extreme in some sense, yet which still satisfy the data constraints. We are exploring two ways to do this; first by calculating the variance of model parameters due to error or variance in the data, and, second, by calculating the extreme bounds on model eigenparameters. This latter method separately varies each independent eigenparameter, while keeping all others fixed, until the error bounds on the data are reached in some fashion. Such edge models provide a significant complement to conventional eigenvector analyses in estimating bounds on the uncertainty of model parameters.

To invert our data from our Oregon study we employed still another 2-D generalized inverse algorithm recently developed by our group. It inverts observed data in the form of complex magnetic transfer coefficients, M_{zy}, to determine a conductivity model which is a smooth, continuous function of position in the earth's interior. The intrinsic continuity and smoothness of our resulting conductivity model is assured by dividing a typical mesh (100x50 nodes, say) into a smaller number of large rectilinear subregions (10x5, say), at the corners of which (the knots) are prescribed specific values for the conductivity. Then, a set of bi-cubic splines is used to smoothly interpolate the value of conductivity throughout each subregion. The coefficients of each local spline are chosen so that the value of the conductivity, along with its first and second derivatives, is continuous across the boundaries separating these subregions. Thus, given the conductivity at each corner (or knot) of the master conductivity mesh, the bi-cubic splines are used to interpolate values of conductivity at each interior node of the model mesh. During our inverse operation, we solve for the values of the conductivity at each of the knots. Thus our original model space of 100x50 nodes is totally parameterized by our conductivity mesh of 10x5 knots. This not only results in our conductivity model being intrinsically smooth and stable, it also leads to a very efficient inverse algorithm in terms of computer storage and computation-time.

Data Parameter Estimation and Its Effect on the Generalized NonLinear Inverse Problem

The ultimate goal in processing of many geophysical data sets is the determination of a physical model. This model relies on the estimation of accurate parameters and their errors. The parameter may be an estimate which characterizes a single sequence, such as a power spectra, or an estimate which relates several sequences such as a multiple coherence or a transfer function. There are many methods available for processing data which assume a certain distribution for the data. Conventional least squares methods assume a normal distribution of the data. These methods can give misleading results in the analysis of data which do not conform to this assumption. Robust methods modify the assumptions made by least squares methods and allow for the presence of outliers in the data. We examined the distributions of data collected in a magnetic variation (MV) profile across central Oregon as part of the EMSLAB experiment. The data are processed using both conventional and robust techniques. A generalized inversion was used to produce a conductivity model from the magnetic transfer function. Two inversions were performed, one for the data set processed with conventional methods and one from the data set processed with more robust techniques. The comparison of these inversion results emphasizes the importance of accurate parameter estimation.

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E. Dynamics of Natural Electromagnetic Source Fields

Overview

This group is involved in a broad range of geophysical/electromagnetic studies of the solid earth and the near-space environment. Energetic magnetic disturbances in the ionosphere and magnetosphere are triggered by the interaction of the earth's magnetic field with charged particles and radiation emitted by the sun. These time-varying external fields, in turn, induce eddy currents in the conducting earth which lead to intense secondary magnetic fields. Such external source field transients can have amplitudes in excess of several hundred nanotesla, and have significant effects on conventional airborne and shipborne magnetic surveys, as well as on satellite surveys. Since magnetic studies have been on the forefront of advancing our knowledge of solid earth dynamics (from plate tectonics to the dynamics of the earth's core), we are exploring various techniques for compensating these types of survey data for the effects of external magnetic field transients in order to optimize the signal-to-noise ratio.

One of the most important applications of these studies is that time-varying natural electromagnetic signals from the earth's magnetosphere can be used as low frequency "radar" to probe the earth's interior to depths in excess of 1000 km in order to study physical and petrological processes on a global scale. In addition, several regional geophysical field projects using natural electromagnetic fields are underway in several of the major volcanic centers of the world such as Long Valley Caldera, the Cascades and Iceland. These data are interpreted in terms of computer-generated numerical models. In one applications, we are concerned with numerically solving the dissipative wave equation to simulate geological features in the solid earth; this involves using generalized inverse theory to invert large systems of integro-differential and partial differential equations that In other studies we begin with a set of mutually compatible field observations - electromagnetic, seismic and/or gravity data - and attempt to solve the inverse problem. That is to say, we ask what is the physical model that "best" fits the data in an optimum sense. Even with relatively simple modelling geometries, these studies require access to the finest state-of-the-art supercomputers and computer graphics.

Ground-based magnetometer arrays offer an effective means for monitoring magnetic sources in the ionosphere and magnetosphere. Even in the era of satellites, ground-based observations offer specific advantages over space-craft in studying magnetospheric processes at altitudes of less than 1000 km. This is because the dynamics of space-craft are such as to preclude their having a significant time window for investigating the temporal and spatial morphology of ionospheric/magnetospheric coupling phenomena having time scales from tens of seconds to several hours. The orbital period of satellites at altitudes less than 1000 km is less than an hour and 45 minutes (6300 sec). The scale lengths of many ionospheric/magneto-spheric coupling phenomena are on the order of 1000 km or less. Hence the high relative velocity of the satellite (greater than 7.4 km/sec) combined with the small scale size of the phenomena of interest dictates that one has sampling windows of 10-20 sec for 100 km scale-sizes and 100-200 sec for 1000 km scale-sizes. The use of satellites is quite limited therefore for studying the temporal morphology of a number of classical ionospheric/ magnetospheric phenomena, particularly those having characteristic times of 102 to 104 sec. Although the spacecraft may provide a spatial snap-shot of the in-situ magnetic and electric fields, it can place few constraints on the longer term morphology of the event.

Ground-based magnetometers, on the other hand, when used in conjunction with satellite observations provide invaluable information in this regard. It is now possible to closely coordinate data from individual satellite passes with simultaneous ground-based observations at standard magnetic observatories and temporary variometer sites. A surface map of magnetic transients can be constructed in space and time at ground level which can be compared directly against a profile of vector and scalar data sampled by a satellite during a discrete pass overhead. Robust and computationally efficient algorithms have been developed for interpolating ground-based data along the flight path of the satellite at its so-called "foot-print". A number of efficient local interpolation forms have been developed (i.e. those forms which are locally compact and rely on reference data from only a few surface points adjacent to the location of the interpolated value - as opposed, for example, to globally defined polynomials such as spherical harmonics; c.f. Rossen and Hermance, 1986). Some of these methods have been recently extended to allow for a variety of a priori constraints on the attributes of 2-D smoothing polynomials (e.g. smoothness, flatness etc.; c.f. Hermance et al., 1987, Wang et al., 1987a,b,c). The result is not only a more effective strategy for analyzing the contribution of these fields to magnetic surveys, but these techniques lead to new ways for portraying the dynamics of the source field itself. In other words, by analyzing smoothed versions of the transient field at various time slices, animated models of the regional and global source field can be reconstructed. These can be presented as simple contour plots, but are much more effective when viewed as modulations in color, hue and intensity. Such presentations lead to much greater insight into the complexity of source field dynamics (whether from pulsations, magnetic storms, or even quiet time diurnal variations) than the conventional literature would indicate.

Spatial Smoothing of Disturbed Time Magnetic Array Data: A Refined Modelling Approach

Analysis of transient magnetic field disturbances recorded by large-scale, two-dimensional arrays of magnetometers on the earth's surface can be used both to characterize the spatial and temporal morphologies of phenomena in the ionosphere and magnetosphere, and to investigate electromagnetic induction phenomena in the solid earth. A prefactory step in these types of studies involves being able to visualize the dynamics of magnetic field disturbances as they evolve and propagate across the monitoring array. We are attempting to develop an accurate and reliable method for reconstructing on a subglobal scale a smooth functional representation of transient magnetic fields observed at a set of unevenly spaced sites distributed over a limited region. Our objective is to minimize the effects of spatial aliasing (from local induction anomalies, etc.), while preserving a maximum amount of information in the broad scale characteristics of the magnetic field variations. We find that a low-degree polynomial model can be used to obtain a good smoothed fit of the disturbed time magnetic field. In addition, we have found that careful conditioning of each individual time series is essential before spatial smoothing is employed. We add a physical constraint to our smoothed model by requiring the curl of the horizontal magnetic field to be zero, thereby invoking the assumption that there are no vertical electric currents in the atmosphere. Examination of individual site residuals and of the importance of specific site locations (by using the Information Matrix from classical inverse theory) allow for prudent culling of the sites to refine the model.

Compensating Transient Magnetic Field Measurements for the Effects of Local Induction

While it is widely recognized by workers in solar-terrestrial physics that ground-based measurements of transient magnetic variations are an important tool for diagnosing conditions in the magnetosphere and ionosphere, the effects of induction in the solid earth are usually not considered in any quantitative detail. Using an actual example from the field, we have shown that induction effects in the vicinity of lateral heterogeneities can be significant on all three vector components, affecting amplitude, phase and polarization parameters. At pulsation periods, such anomalies often change dramatically within a scale-distance of a kilometer or so, and, if not identified, their contributions might be aliased into the interpretation of large scale arrays. We show, however, that because these effects are deterministic, under reasonable assumptions one may be able to employ a multivariate deconvolution operator to "correct" data from a locally anomalous site to recover a truer representation of the regional field behavior.

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Hermance, J.F. and W. Wang, 1989, Regionalized Global Induction Studies at Intermediate (6 hrs-4 days) Periods (Abstract), I.A.G.A. Meeting, July.

Hermance, J.F., 1989, Geophysical Applications of Standard Magnetic Observatory Data: Present Status and Future Needs (Abstract), I.A.G.A. Meeting, July.

Hermance, J.F. and W. Wang, 1989, Construction of Robust, Computationally Efficient Models of External Magnetic Field Transient on a Regional Scale, (Abstract), I.A.G.A. Meeting, July.

F. Numerical Modeling

While there is no problem, in principle, in solving the complete 3-D induction problem for arbitrary structures and source field geometries, such as approach is not tractable on present-day computers. As an alternative to this scheme, we have developed several simple algorithms which are computationally efficient. For example, a simple 3-D thin-sheet model has been used to evaluate the bias of long-period magnetotelluric parameters in the presence of modest current channeling at shallow depth. In terms of more refined 3-D models, a new set of finite difference operators has been developed to simulate broad-band electromagnetic induction in azimuthally symmetric 3-D structures. The accuracy of this algorithm was tested against known analytical solutions leading to accuracies of better than 2%. The methodology of our algorithm is now being extended to the general 3-D case.

Presentations at Scientific Meetings:

Hermance, J.F., 1986, Status of Efficient 3-D Modelling Algorithms Developed by Brown University (Abstract), VIII Workshop on Electromagnetic Induction, Neuchatel, Switzerland.

G. Status of the MT and MV Field System at Brown University

In order to perform the geophysical field studies described here and proposed for the future, a geophysical field system (using tellurics, magnetotellurics and geomagnetic variations; over the frequency range 40 Hz to 10^4 sec) has been developed under joint support of the Department of Energy Office of Basic Energy Sciences and several other Government agencies. The system, mounted in a 4-wheel drive GMC van, has been used for field work in the Mono Basin/Long Valley volcanic complex, the Oregon Coast Range, the Cascades, Iceland, and the Rio Grande Rift. Both hardware and software have evolved in time. In 1985 and again in 1987, the signal conditioning was completely reworked so that now a number of magnetic field sensors can be utilized -- small audio frequency induction coils, large low-frequency (Geotronics) induction coils, a cryogenic SQUID (SHE), and a recently developed ring core fluxgate magnetometer (Nanotesla). In 1987 two WWVB radio time receivers were added to our field system so that both software and hardware are now fully compatible with either single site or remote reference data acquisition strategies.

II. Current Activities

A. The Consortium on Array Magnetometers (CAM): Development of a Plan for Mobilization

Over the last few years there has been increasing interest on the part of both the solid earth and magnetospheric communities in developing a relatively low cost, digitally-recording flux-gate magnetometer for deployment in arrays of 100 or more units. Because of the broad constituency that might make use of such an array, and the common needs of such a user community, the Consortium for Array Magnetometers (CAM) has taken the initiative in organizing and assembling a large magnetometer array facility, and in formulating protocols that will maximize the scientific return on its use. The USGS has offered facilities and technical support at the Fredericksburg Geomagnetic Center to CAM for testing of prototype instruments, and for the long term maintenance and calibration of operational array magnetometers.

Funds have been requested from NSF to provide support for one year to help organize this program through holding a Workshop to identify and to broadly coordinate the interests of solid earth and magnetospheric researchers. This meeting would identify the scientific community who would make use of an array facility, including a description of specific scientific problems to be studied. Moreover, this Workshop would coordinate the interests of various Federal agencies who might potentially benefit from these studies. In addition, it would review the status of testing proposed systems, and decide if further evaluations are necessary. Finally, it would set up a management structure for the development and procurement of array magnetometers, and establish protocols for soliciting and reviewing proposals, and for coordinating the use of the facility among the national and international community. During this first year CAM will develop a long term strategy for implementing the array as a multi-agency facility so that there is a progressive increase in the number and quality of units available over a period of years. At present, the NSF Continental Lihosphere Program has declined to support a workshop, but has encouraged CAM to submit a full-fledged proposal. A new proposal was submitted to NSF on June 1, 1989.

B. A Plan to Integrate Surface and Borehole Geophysical/Electromagnetic Studies: A Potential Interagency Activity

Through joint proposals to DOE/OBES and NSF/EAR, Brown University is developing a new field strategy for surface and borehole geophysical studies which has significant potential for basic energy research; particularly in the areas of identifying and characterizing natural resources. Measurements of transient magnetic variations (MV) are being adapted into a mode which is highly portable, accurate, broad band, and offers a substantial complement to conventional magnetotelluric (MT) and gravity studies.

The resolution of the MV technique when used in a "stand-alone" mode falls between the standard MT method and gravity. By analyzing MV from closely spaced sites (2-3 km) over several decades of frequency (typically 10 to 4000 s), one is able to discriminate between structures at various depths (1 to 40 km), unlike gravity which has an intrinsic ambiguity in depth resolution. Clearly, one can place extremely powerful constraints on their geological interpretation if MV is used in conjunction with MT data from whatever sites can be occupied, as well as any available gravity data.

We are developing this technique for surface measurements in two field areas of interest to DOE, the USGS and NSF: 1) Long Valley caldera - an area where surficial geology has particularly hampered MT data from resolving whether a magma body is present at mid-levels in the crust. Work in this area would be in direct support of characterizing the environment of the DOE/GTD Magma Energy Well on the resurgent dome as an opportunity for scientific drilling. 2) The Rio Grande rift near Socorro, New Mexico, (in a joint effort with the NSF) in order to further delineate major faults bounding deep sedimentary basins in this area, and to further map the distribution of a deep-seated conductivity anomaly associated with the Socorro magma body in order to assess the deep thermal regime of this Known Geothermal Resource Area. This area has been particularly troublesome for previous MT investigations by others, the results of which have tended to discourage – quite erroneously based on our most recent MV studies– geothermal exploration and development by industry.

Finally, in collaboration with engineers from Sandia National Laboratories, we are planning to develop the instrumentation needed to make magnetic variation measurements in the third dimension — in boreholes — with the immediate view of applying this technique to measurements in the Long Valley DOE/GTD Magma Energy Well, and, in the long term, to using this technique in oil and gas exploration, and (in collaboration with emerging programs in the NSF and the USGS) for characterizing deep structures in the continental crust.