Milestone SPT23KM4: Results of the Analysis of the Timber Mt., Lathrop Wells, and Yucca Mt. Aeromagnetic Data November 29, 1996

WBS 1.2.3.11.2 Surface Geophysics

M. A. Feighner, and E. L. Majer

Earth Sciences Division
Ernest Orlando Lawrence Berkeley National Laboratory
Berkeley, California 94720

Background and Introduction

The depth to basement and basement structures are an important issue for understanding the tectonic setting of Yucca Mt. One of the methods sometimes used to shed information on the basement structure is the inversion of magnetic field data. A data set available in the Yucca Mt area, but not processed prior to the work described in this report, consists of several aeromagnetic surveys flown in the early 1980's. Therefore in August of 1995, at the suggestion of DOE, LBNL procured a study from EarthField Technology Inc. (ETI) in Houston, Texas to process and invert the aeromagnetic data from the Timber Mt., Lathrop Wells, and Yucca Mt. surveys along with the available gravity data. The objective was to obtain information on the depth to basement. Unfortunately, the aeromagnetic data that ETI obtained from the Geophysical Data Center in Denver, Colorado was flawed by an incomplete and mislocated Timber Mt. survey. The error was not detected until after ETI had completed the processing. Therefore, in the summer of 1996 another attempt was made at procuring services to process the aeromagnetic data for a depth-to-basement interpretation. Shown in Appendix I are the scope of work put out for bid to two different vendors, the bid by ETI, and the final contract awarded to ETI. As can be seen, the final contact differed somewhat from the initial scope of work sought, mainly due to the high bids received. However, ETI was contracted to determine the depth to basement by interpreting the aeromagnetic data inverted with the Werner deconvolution method. LBNL checked the data beforehand to insure that the problems of an incomplete and mislocated data set did not occur again. In September of 1996 LBNL, supplied ETI with the three different data sets (see enclosed report of McCafferty). In mid-November of 1996 LBNL was contacted by ETI and informed that in the opinion of ETI the data were not of sufficient quality to derive the information sought, i.e., a reliable depth to basement. LBNL then contacted personnel within the USGS who had supplied the data to the Geophysical Data Center (Vickey Bankey and Tien Grauch) to obtain their opinion on the quality of the data, and suitability for obtaining a reliable depth to basement. They concurred that the data were not suitable for obtaining a depth to basement, mainly due to the fact that the Paleozoic basement in this region of Nevada is almost non-magnetic, and the overlying volcanics further complicate attempts to derive a "depth to basement". It is well known that the Yucca Mt. region is typical of many volcanic regions, in that it is very heterogeneous and structurally complex. The general nature of the volcanics (alternating flow properties in a vertical and horizontal direction) causes many magnetic anomalies. The magnetic method is, like gravity surveys, a potential field method with magnetic susceptibility being the significant material property variable (like density in gravity). Changes in the physical properties of subsurface rocks leads to anomalies measured by surface instruments. While gravity and magnetics use similar interpretation techniques, the magnetic method is somewhat more complicated. The magnetization of a rock (which is dependent on susceptibility), has both magnitude and direction. Magnetic anomalies can come from variation in magnitude or variation in direction of magnetization and magnetic effects can be caused by certain minerals within the rock mass. Additionally, the total magnetization of a rock mass is composed of induced and remanent magnetization. At Yucca Mountain, previous studies have found the Topopah Tuff is one of the major magnetic anomaly producing formations, depending on faulting and juxtaposition to other formations. Therefore it is very difficult to "see through" the volcanics to derive the basement structure.

Although a depth to basement was not obtained, an attempt was made to derive fault structure from the magnetic field intensity maps from the merged data sets. All of the subject data and processing described in this report has not been Quality Assured.

Data Processing and Interpretation

The aeromagnetic data was obtained from the National Geophysical Data Center in Boulder, CO. The individual flight lines had been adjusted and merged into a data grid. The merged data represents all the surveys as if flown at a constant altitude of 1000 feet above topography. The data supplied to us were in geographical coordinates and were converted to Nevada State Plane coordinates using the EarthVision software. The entire data set covers a large area and is shown in Figure 1 with the repository boundaries surrounding Yucca Mountain shown for scale. Many high frequency anomalies can be seen that are probably associated with near-surface volcanics. Short wavelength magnetic anomalies arise from shallow magnetic bodies.

Figure 2 shows an enlarged portion of the aeromagnetic data with the surface traces of faults from Sawyer et al. (1995) overlain as white lines. At this scale, there is a correlation between faulting and the magnetic anomalies. The north-south faults in the repository area match alternating highs and lows in the magnetic data. The short wavelength of these features also suggest a shallow source and probably arise from offsets in a shallow magnetic unit. Bath and Jahren (1994) have shown that many north-trending, linear magnetic anomalies are caused by vertical offset of the moderately to highly magnetic Topopah Spring Tuff.

In order to determine the depths of some longer wavelength features, we chose to use two profiles as shown in Figure 3. The first profile is REG-2 & 3, which follows the regional seismic lines, as reported by Brocher et al. (1996). This profile crosses a relatively broad magnetic high in the middle of Crater Flat. The other profile is A-A' and follows a north-south line and crosses a magnetic high. Figure 4 shows the same magnetic data 2-D continued upward to an altitude of 5000 feet above topography. This was done using the software GMT (Wessel and Smith, 1991). This eliminated the high frequency anomalies created by the shallowest magnetic bodies.

Figure 5 shows the magnetic anomaly along REG-2 & 3, along with the anomaly after upward continuation. This produces a smooth profile which can then be used to estimate the depth to the magnetic body. The Peters' Method (Dobrin, 1976) was used to estimate the depth of the magnetic body. In this method, the maximum slope of the anomaly is determined, and then the half-slope points above and below are calculated. This gives a width "S" as shown in

Figure 5. The depth is then simply estimated by (S/1.6). For this profile the S width is 12245 feet, giving a depth of 7653 feet below the level of the anomaly. Since the anomaly was continued upward to 5000 feet, this gives a depth of 2653 below the surface. This is much too shallow for the Paleozoic basement in this area (Majer et al, 1996), and this anomaly is probably due to the Topopah Spring Tuff.

Figure 6 shows the anomaly along Profile A-A'. The slope of the anomaly is even steeper than in Figure 5, resulting in a depth of the magnetic body of 1125 feet below the surface. Paleozoic basement does outcrop along this profile at the location of the magnetic high. However, Ponce and Langenheim (1995) do not consider the Paleozoic to be magnetic in their modeling, since it consists mainly of limestones and dolomites. Again, this anomaly is probably due to shallow magnetic tuffs.

Conclusions

The aeromagnetic anomalies appear to correlate well with mapped faults and seem to indicate faulted offsets in shallow magnetic tuffs, such as the Topopah Spring Tuff. Deeper magnetic anomalies may be present, but are overwhelmed by the shallow or surface volcanic signatures. The Paleozic basement is unlikely to be magnetic due to the non-magnetic nature of limestones and dolomites; thus depth to basement estimates cannot be made for this boundary.

Acknowledgements

This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between TRW Environmental Safety Systems, Inc. and the Ernest Orlando Lawrence Berkeley National Laboratory, under Contract No. DE-AC03-76SF00098. The computations and field work would not have been possible without the continued support of Berkeley Lab's Center for Computational Seismology and Geophysical Measurement Center by the Department of Energy's Office of Energy Research Basic Energy Sciences Geoscience Program and Health and Environmental Sciences Subsurface Science Program.

References

Bath, G.D. and C.E. Jahren, Investigations of an aeromagnetic anomaly on the west side of Yucca Mountain, Nye County, Nevada, USGS-OFR-85-459, 24 pp., 1985.

Dobrin, M. B., Introduction to Geophysical Prospecting, Third Ed, McGraw-Hill, New York, 630 pp., 1976.

Brocher, T.M., P.E. Hart, W.C. Hunter, and V.E. Langenheim, Hybrid-Source Seismic Reflection Profiling Across Yucca Mountain, Nevada: Regional Lines 2 and 3, USGS-OFR-96-28, 97 pp., 1996.

Majer, E.L., M. Feighner, L. Johnson, T. Daley, E. Karageorgi, K.H. Lee, K. Williams, and T. McEvilly, Synthesis of Borehole and Surface Geophysical Studies at Yucca Mountain, Nevada and Vicinity, Volume 1: Surface Geophysics, WBS 1.2.3.11.2, Lawrence Berkeley Nat. Lab, 1996.

Ponce, D.A. and Langenheim, V.E., Gravity and magnetic investigations along selected high-resolution seismic reflection traverses in the central block of Yucca Mountain, Nevada, USGS-OFR-95-667, 23 pp., 1995.

Sawyer, D.A., R.R. Wahl, J.C. Cole, S.A. Minor, R.J. Laczniak, R.G. Warren, C.M. Engle, and R.G. Vega, Preliminary digital geologic map database of the Nevada Test Site Area, Nevada, USGS-OFR-95-0567, 62 pp., 1995.

Wessel, P. and W. H. F. Smith, Free software helps map and display data, Eos Trans. AGU, 72, 441-446, 1991.

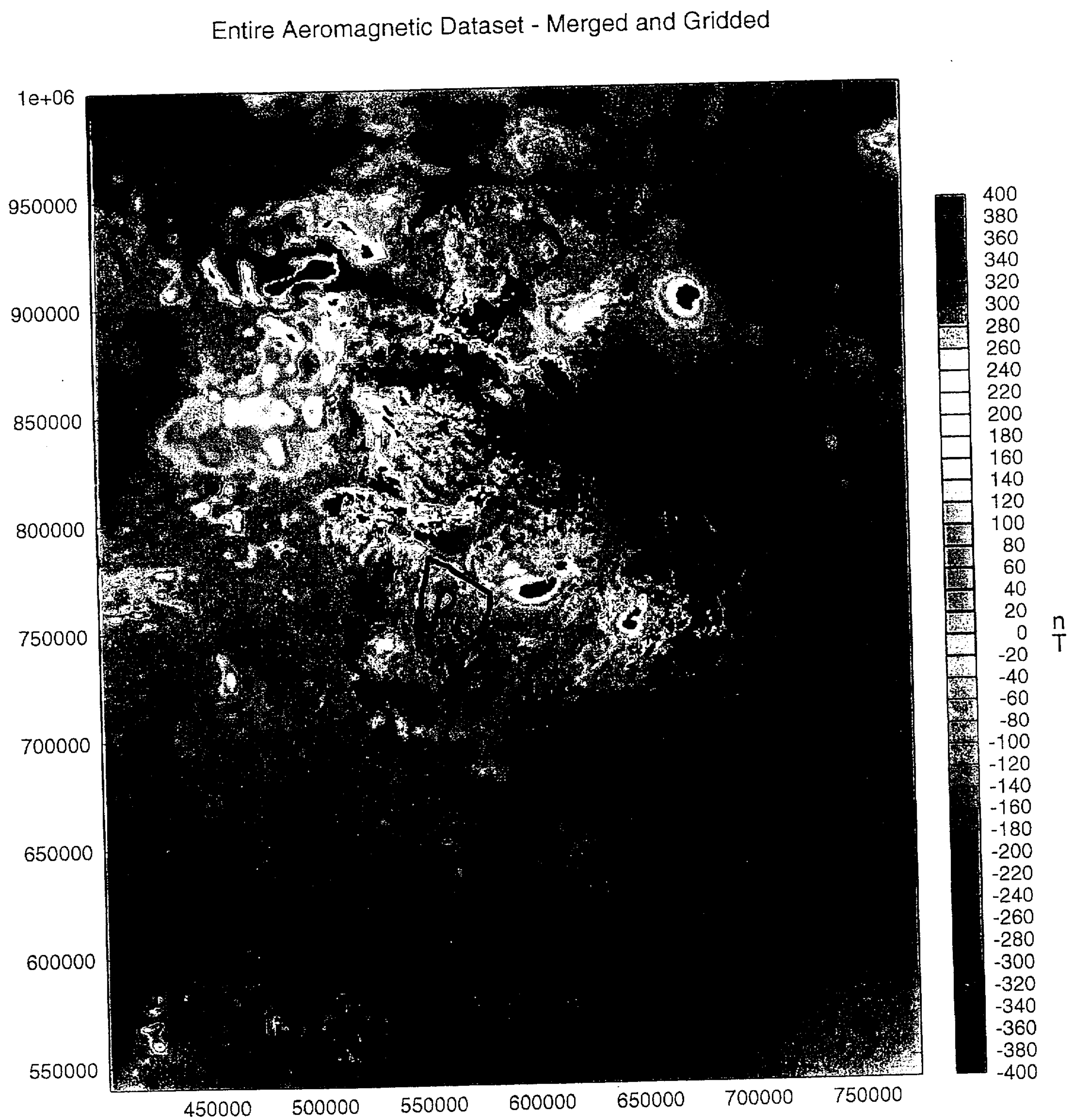


Figure 1. The entire aeromagnetic dataset of the Yucca Mountain Region. The outer black line is the conceptual boundary and the inner black line is the repository boundary. Coordinates are in Nevada State Plane feet.

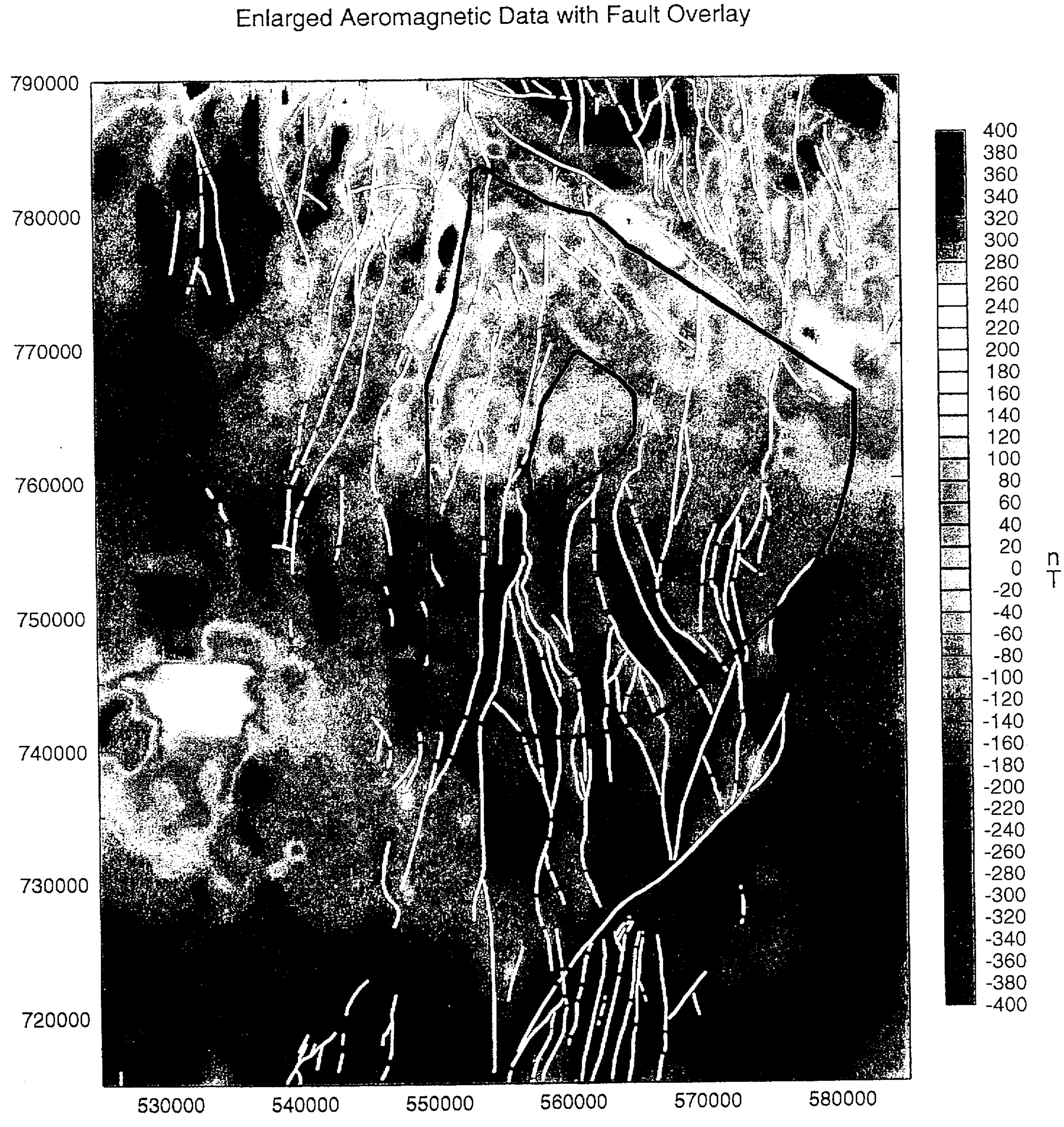


Figure 2. An enlarged section of Figure 1 with faults from Sawyer et al. (1995) overlain as white lines. Coordinates are in Nevada State Plane feet.

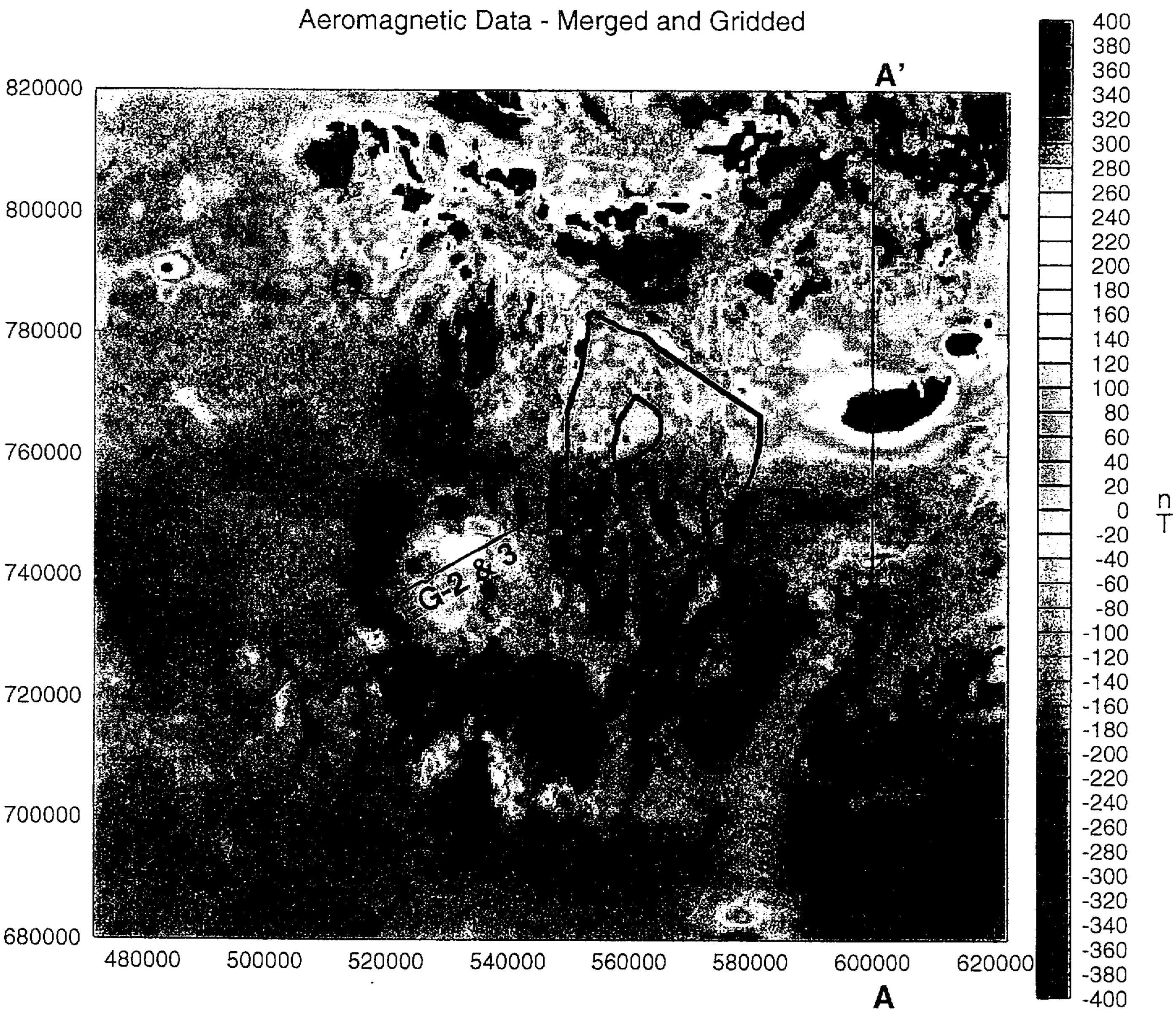


Figure 3. The location of the two profiles: REG-2 & 3 and A-A'. Both profiles cross broader magnetic anomalies to which depth estimates are made. Coordinates are in Nevada State Plane feet.

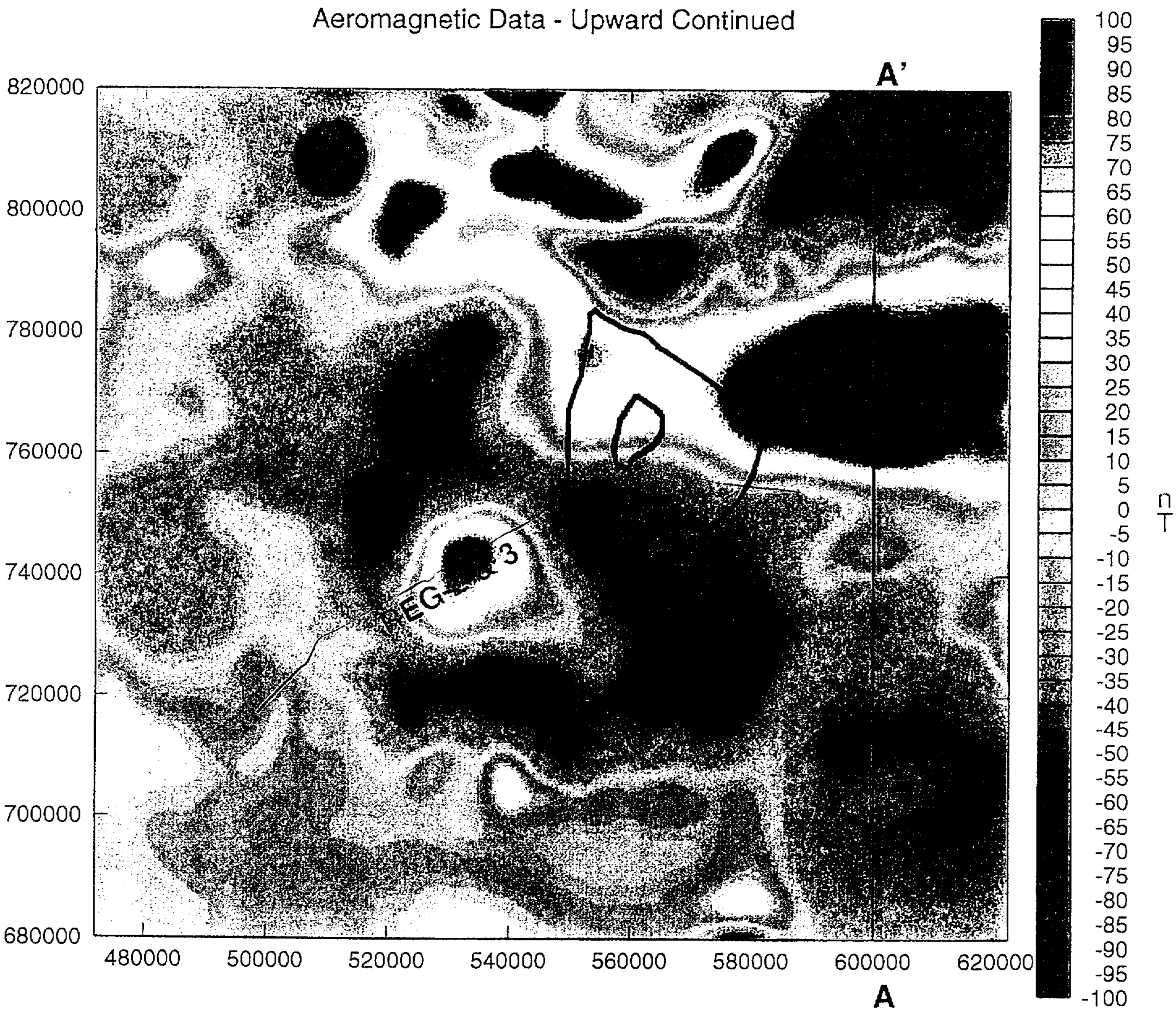


Figure 4. The upward continuation of the magnetic field in Figure 3 to 5000 feet above topography. This was done to eliminate high frequency signals. Coordinates are in Nevada State Plane feet.

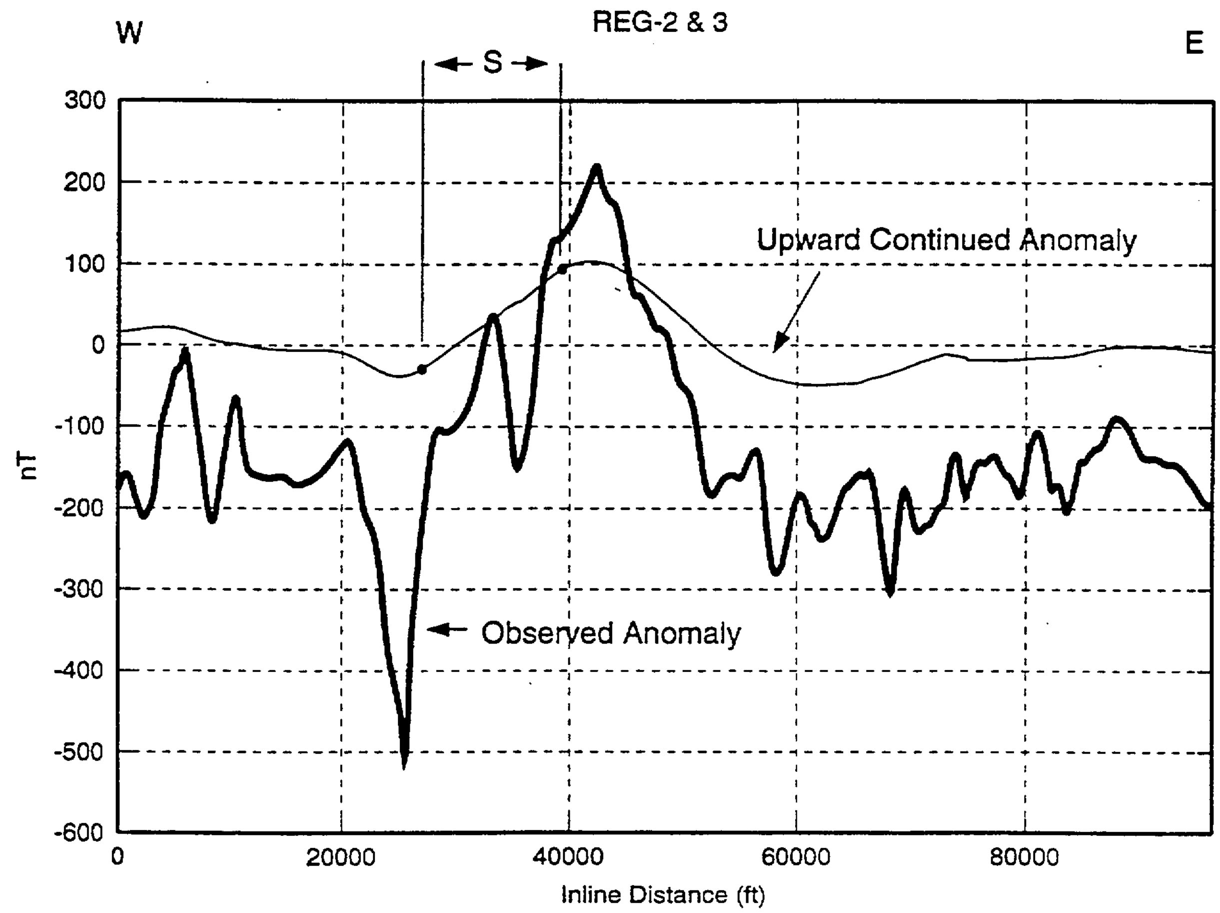


Figure 5. The magnetic anomalies along Profile REG-2 & 3. The half-slope width, S, can be used to estimate the depth of the magnetic body.

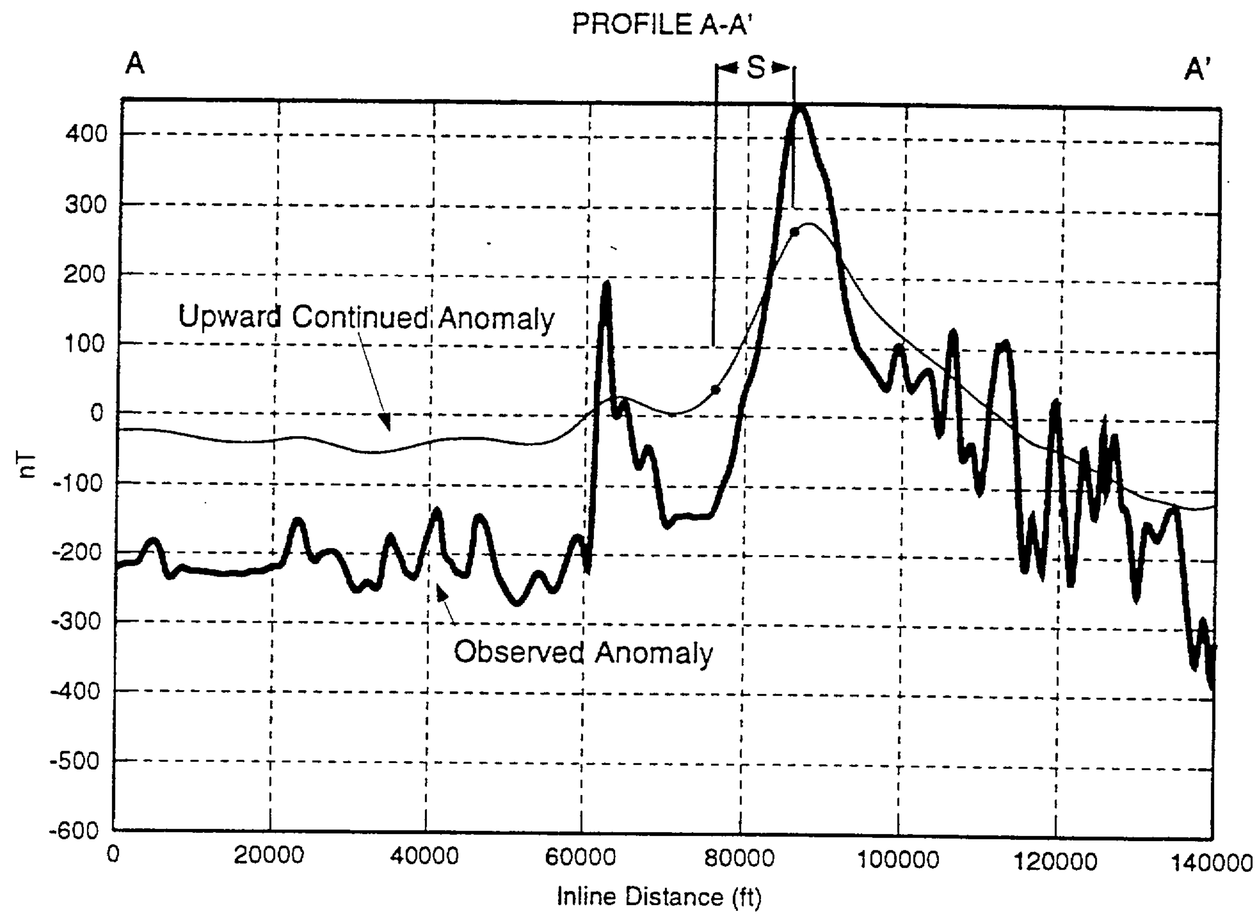


Figure 6. The magnetic anomalies along Profile A-A'. The half-slope width, S, can be used to estimate the depth of the magnetic body.

Appendix I. to Milestone SPT23KM4:

Scope of Work, Earthfield Scope of Work, and Final Contract

Scope of Work

Processing and analysis of aeomagnetic data

There will be three data sets delivered to the vendor in ASCII format as obtained from the National Geophysical Data Center 1/4 mile spacing on flight lines, see enclosed map for location of surveys

1. Lathrop Wells 8149 miles (black)
2. Yucca Mt. 1118 miles (blue)
3. Timber Mt. 9614 miles (red)

Digital and hard copies of the following results will be required, the final scale of the hard copy maps will be determined by LBNL before the final results are transmitted to LBNL. The digital versions will be in a format such that LBNL can plot the results with their plotting software, i.e., ASCII grid files with X,Y, and Z values, using Nevada state plane coordinates.
We also require the data points from which the grid files were generated.

The deliverables will be the following:

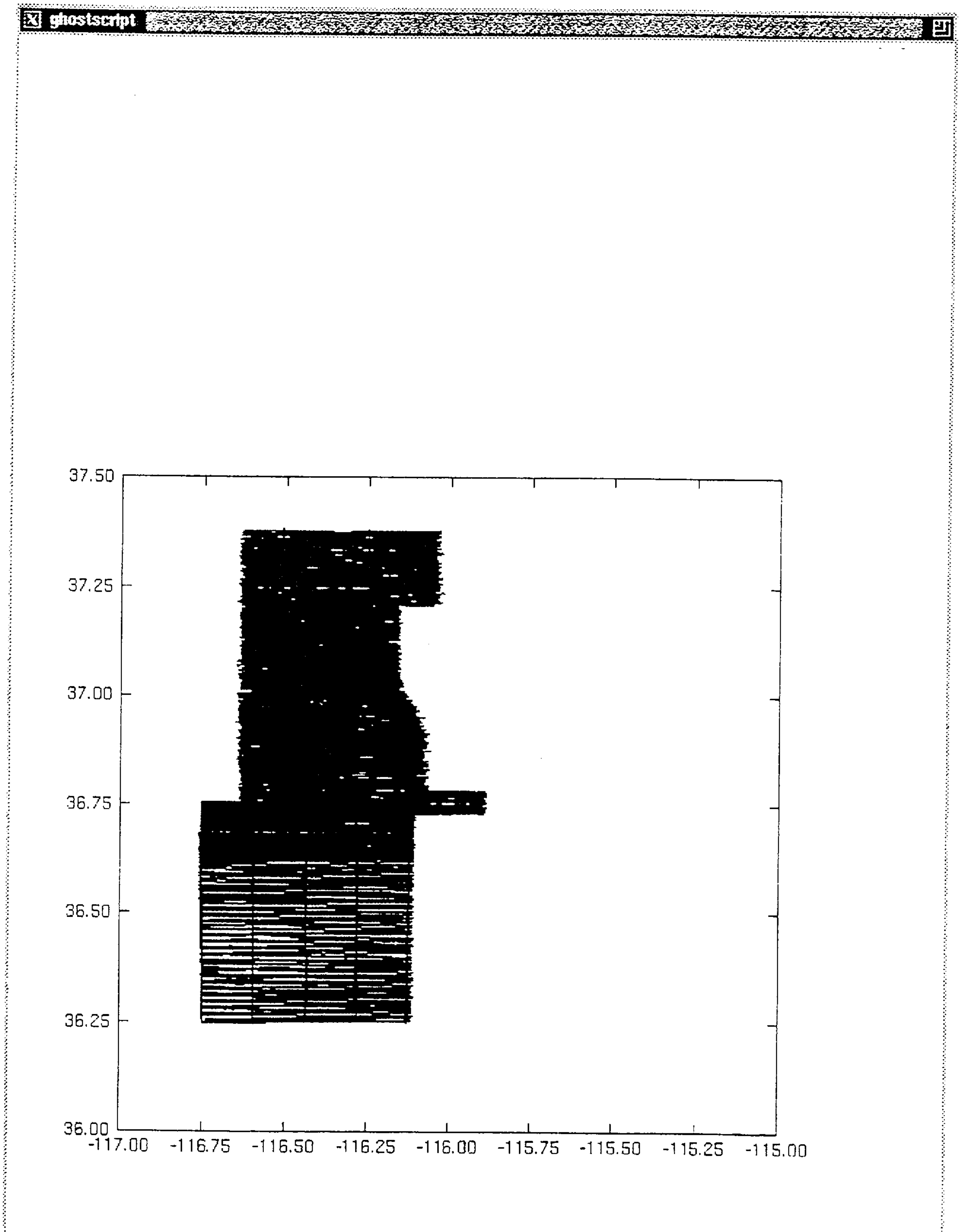
A final report describing the processing steps and methods used in sufficient detail such that a person who is knowledgeable in magnetic methods can reproduce the results if necessary.

The data will be processed to provide the following results:

1- A Total field intensity magnetic map using all three data sets merged such that the flight elevation of each survey has been properly accounted for and reduced to a common datum, as well as the diurnal drift being properly corrected for in each data set.
2-depth to magnetic basement map using at least three differnt approaches to the the inversion, the final result being a best fit to the different inversion results.
3-copies of the different profile inversions along all profiles, and interpretation if possible
4-rtp (reduced to pole) total intensity map
5-map of the near surface faults and intrusions as inferrred from the magnetic data
6-surface faults and intrusions interpretation
7-horizontal derivative (1st derivative) rtp map
8-rtp high pass 20k ft
9-rtp low pass 20k ft
10- rtp high pass 30k f
11- rtp low pass 30k ft
12-bandpass from 20-30k ft
13- 2nd derivative rtp map

In addition we would also want a presentation of the results in Berkeley at the end of the work as well as one trip by LBNL/DOE personnel in the Yucca Mt project to the vendor to view the progress of the work.

The trip function would be for the work to be seen and reviewed by oversite specialists, and some of the project management and technical specialist from the volcanism program. The date and time would be determined as the data processing and reduction continues.


ghostscript
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37.00
36.75
36.50
36.25
36.00
-117.00
-116.75
-116.50
-116.25
-116.00
-115.75
-115.50
-115.25
-115.00

earthfield
technology

June 18, 1996

Ms. Peggy Jellinghausen
University of California
Ernest Orlando Lawrence
Berkeley National Laboratory
Purchasing 69-201
1 Cyclotron Road
Berkeley, California 74920

RE: PROPOSAL #3655000

Dear Ms. Jellinghausen:

As per your request, Earthfield is pleased to provide you with a quotation for the processing and interpretation of gravity and magnetic data over your project area at Yucca Mountain, Nevada.

The objectives of this study are to:

- map basement depth

- map basement structure

AEROMAGNETIC DATA ANALYSIS

Berkeley National Laboratory will provide all digital aeromagnetic data for this study which are being acquired through the National Geophysical Data Center. As data are acquired they will be reviewed, edited, leveled and merged as necessary at which point analysis may begin.

We would like to state our belief that effective analysis of magnetic data can best be accomplished using a profile by profile approach to evaluate anomalies arising from various depths. There are a variety of automated depth calculation algorithms available, and though your "RFP" requests three profile methods, we prefer, and will only be using the Werner deconvolution method.

650 North Belt East, Suite 410 • Houston, TX 77060 • 713-847-1666 • FAX 713-847-1775

The Werner method of magnetic data interpretation is a widely accepted, profile based, inverse modelling approach. This technique utilizes the raw total intensity data along each flight line and a calculated horizontal derivative of this data to determine the depth of a causative body by assuming two simple geometric configurations of the feature. The two simple geometries used in this technique are the thin dike model, which uses the total intensity data for its calculations, and the infinite block model which uses the horizontal derivative.

By assuming these basic geometries in this fashion the depth, dip and apparent magnetic susceptibility contrast of an anomaly source can then be derived from the data. The Werner algorithm analyzes progressively longer anomaly waveforms in a series of passes along the data with an increasing operator width, thereby calculating depths to progressively deeper sources. In this manner, all types of sources are resolved regardless of the depth.

It is therefore possible to identify cultural, sedimentary, basement structural or intrabasement features on a single profile. The resultant Werner profiles display numerous depth solutions to the various sources which the geophysicist will then interpret to identify the proper depth estimates and to determine from what type of source the solution was produced. This interpretation is critical since the mapping of intrabasement sources as representing basement structure would result in an inaccurate map of the basement surface. Likewise, anomalies arising from sedimentary sources do no want to be confused with those arising from basement sources.

The interpreter will evaluate your data to determine and map sources arising from basement, sedimentary and cultural sources. Depths picks will be posted and contoured producing a structural/depth to basement mylar overlay. The interpretation will then be digitized and mapped in color.

DELIVERABLES

All magnetic maps will be laminated and will consist of the following:

- Total magnetic intensity contours of the merged data set in color with shaded relief

- rtp magnetic contours in color with shaded relief

- rtp high pass 20,000 feet in color with shaded relief

- rtp low pass 20,000 feet in color with shaded relief

- rtp high pass 30,000 feet in color with shaded relief

- rtp low pass 30,000 feet in color with shaded relief

- band-pass residual map from 20,000-30,000

- 1st derivative in color with shaded relief

- 2nd derivative in color with shaded relief

- flightline map

- Werner deconvolution profiles along each flightline approximately 18,881 line miles (not laminated)

- depth to basement/structural interpretation overlay from Werner analysis on a clear overlay

- digitized depth to basement in ASCII format

- color version of depth to basement map

- interpretation of near-surface faults derived from magnetics on a clear overlay

- digital version of each map in HPGL format and of basement surface in ASCII format.

- merged TMI in ASCII format

GRAVITY DATA ANALYSIS

Earthfield will produce the following qualitative maps from Bouguer gravity data already on-hand. These maps will be used by the project supervisor as an aid in producing the interpretation overlay listed above.

- Bouguer gravity contours in color with shaded relief

- Residual gravity contours emphasizing long wavelength anomalies

- Residual gravity contours emphasizing intermediate wavelength anomalies

- Residual gravity contours emphasizing short wavelength anomalies

- Euler 3d deconvolution solutions in color

FINAL REPORT

Earthfield will prepare a summary report detailing all work performed

PRESENTATION

This bid allows for a one day visit to Earthfield's office in Houston during the term of the project. Additional visits can be scheduled if necessary.

Upon completion, the project geophysicist will present the results of this study in your office in Berkeley,California. All costs associated with this presentation are covered by this proposal.

TIME FRAME

If project begins no later than July 1, 1996, completion will be on, or before, November 22, 1996.

COST

The cost of the project, as defined above, will be $25,000.00.

If you have any questions regarding this proposal, or if you require any additional information, please let me know and I will respond as soon as possible.

Very truly yours,

David Lane
President

NTD - Expense Type 34

certifier if different from below:

Requester: Ernie Majer	Bldg. & 90	Room: 1116	Deliver to:: Same	Bldg.	Room	Notify: E. Majer / Extension: 6709
Approved by: Andre Bell	Account no.: 8175-41		Amount of Transaction: $ 20,000.00	Stat. Code: 7112200	Req. No. 194444	

start date: 9/9/96 end date: 11/29/96

Submit correspondence to Procurement Specialist FAX: (510) 486-4380

DPAS Rating: (15 CFR 700)

From Receipt of goods or invoice whichever is later.
0 - 1/2% 10th & 25th
1 - 1/2% 10 days
C - 1% 10th & 25th
2 - 1% 10 days
9 - 1% 10th prox.
7 - Net 30 days
J - Net 01
L - Net 15
3 - 1% 30 Days
F - 2% 10th & 25th
5 - 2% 10 days
H - 2% 20 days
6 - 2% 30 days
8 - As Shown
K - Net 10
M - Net 20

Procurement Specialist:	Code:	Subcontract No:	Seller Code	Start date:	Terms:
Peggy Jellinghausen Phone:(510) 486-7210	275	6436583		9/3/96	7

To: Earthfield Technology
Attn: David Lane
650 North Belt East, Suite 410
Houston, TX 77060

University of California
Ernest Orlando Lawrence
Berkeley National Laboratory
One Cyclotron Rd. m/s 69-201, Berkeley CA 94720

R & D SUBCONTRACT

For Contract No. W-7405-ENG. 48 Or Contract No. DE-AC03-76SF00098 with the Department of Energy

Ship to: Berkeley National Laboratory
Attn: E. Majer, S/C #6436583
One Cyclotron Road, m/s 90-1116
Berkeley, CA 94720

MAIL INVOICE IN DUPLICATE TO:
University of California Ernest Orlando
Lawrence Berkeley National Laboratory
Accounting Office, S/C #6436583
P.O. Box 528, CODE JS
Berkeley, CA 94701

FOR RESALE:-State Sales Tax should not be charged, as the University holds State Sales Tax Permit SR CH 21-835970 for deliveries to University of California Ernest Orlando Lawrence Berkeley National Laboratory and Permit SR-CHA 21-135323 for deliveries to Lawrence Livermore National Laboratory.

Ship Via: (as coded) 0
1. pickup
2. Parcel Post
3. UPS
4. Federal Exp. 1
5. Motor Freight
6. Air Freight
7. Air Parcel Post
8. Federal Exp. 2
9. Air Frt. Forwarder 0. See Below

Seller's Choice

Transportation Terms (as coded) 2
1. Account of University see Article V. below
2. Account of Subcontractor Prepaid
3. See Body of Order

Shipping Point: Houston, TX

F.O.B. (as coded) 1
1. Destination
2. Shipping Point
3. Shipping Point, Freight Allowed
4. See Body of Order

Earthfield Technology, herein and in attachments hereto called "Seller" or "Subcontractor", agrees to furnish to the University of California Ernest Orlando Lawrence Berkeley National Laboratory, herein and in attachments hereto called "University", "Berkeley Lab", "LBL", and "LBNL", the following in strict accordance with the terms, conditions, and provisions of this Subcontract, herein and in attachments hereto called "Order", or "Subcontract":

I. SCOPE OF WORK

Subcontractor shall furnish the labor necessary to perform the work described under Scope of Work in the attached Appendix A which is hereby made a part of this subcontract.

II. PRICE, ACCEPTANCE AND PAYMENT

Subcontractor shall perform the work described herein for the firm fixed price of $20,000.00

Acceptance of work and payment under this subcontract shall be based on satisfactory compliance with the following:

A. Subcontractor's performance of work as set forth herein in consonance with high professional standards as determined by Berkeley Lab.

B. Compliance with the reporting requirements set forth in the Scope of Work.

III. TERM

Unless completely performed thereto or sooner terminated by either party, the work described herein shall begin September 9, 1996 and be completed by November 29, 1996.

IV. INVOICING

Invoices shall be reviewed, approved and certified for payment by Berkeley Lab's Ernie Majer. Invoices shall be submitted in arrears for work completed to:

University of California, Ernest Orlando
Lawrence Berkeley National Laboratory
Accounting Office, Subcontract #6436583
P.O. Box 528, CODE JS
Berkeley, CA 94701

V. ATTACHMENTS

In addition, the provisions or articles listed below and attached hereto are made a part of this order and are equally binding.

1. Appendix A, Scope of Work
2. Survey Map
3. Addendum to Terms and Conditions of University of California Subcontract.
4. General Provisions for Fixed Price Supplies & Services.

Authorized by: ______________________

University of California, Ernest Orlando
Lawrence Berkeley National Laboratory
Renee Jewell
Group Leader

ACCEPTED: Earthfield Technology

BY: ______________________

TITLE: ______________________

DATE: ______________________

APPENDIX A - SCOPE OF WORK
Processing and Interpretation of Aeromagnetic Data

I. BACKGROUND

This project is very similar to that performed by subcontractor under Subcontract #4613410. A full set of corrected data will be submitted to subcontractor in addition to the previous maps submitted to Berkeley Lab under the previous subcontract. Subcontractor shall rework the maps and previous findings to incorporate the corrected data. The method to be used on this project is the Werner deconvolution method.

II. SCOPE OF WORK

Subcontractor shall provide processing and interpretation of aeromagnetic data as described below.

Subcontractor shall receive the maps previously submitted by subcontractor to Berkeley Lab under Subcontract #4613410. These shall be used as reference and shall be submitted under separate cover. Additionally, subcontractor shall receive three data sets delivered in ASCII format as obtained from the National Geophysical Data Center. There shall be 1/4 mile spacing on flight lines. See enclosed map for location of surveys with descriptions shown below.

1. Lathrop Wells, 8149 miles (black)
2. Yucca Mt., 1118 miles (blue)
3. Timber Mt., 9614 miles (red)

Please note that in this particular region of Nevada the basement defined by the gravity data is not the same as the basement defined by aeromagnetic data. In interpreting the aeromagnetic data this should be considered. Berkeley Lab will have the basement structure (usually the paleozoic surface) as derived from the gravity values. In addition, Berkeley Lab will supply a regional geologic map showing the location of surface intrusions.

Digital and hard copies of the following results will be required. The final scale of the hard copy maps will be determined by Berkeley Lab before the final results are transmitted to Berkeley Lab. The digital versions will be in a format such that Berkeley Lab can plot the results with their plotting software, i.e., ASCII grid files with X, Y, and Z values, using Nevada state plane coordinates. Berkeley Lab also requires the data points from which the grid files were generated.

III. DELIVERABLES

Subcontractor shall submit a final report describing the processing steps and methods used in sufficient detail such that a person who is knowledgeable in magnetic methods can reproduce the results if necessary.

The data will be processed to provide the following results:

1. Depth to magnetic basement map
2. Digital depth to magnetic basement map
3. Magnetic lineation interpretation map
4. RTP, high pass 20,000 ft, 1st vert. derivative
5. RTP, high pass, 20,000 ft
6. RTP, low pass 30,000 ft
7. RTP
8. Total magnetic intensity

9. RTP horizontal derivative
10. Topographic map
11. Geologic map
12. Digital topography map
13. Magnetic flight path

In addition, Berkeley Lab will also require a presentation of the results in Houston, Texas upon completion of the work. Berkeley Lab also reserves the right to send Berkeley/DOE personnel from the Yucca Mt. project to subcontractor's facility to view the work in progress. The function of the trip would allow for the work to be seen and reviewed by oversite specialists as well as the project management and technical specialist from the volcanism program. The date and time would be determined as the data processing and reduction continues.

A summary report shall be written by the subcontractor summarizing the data results and all relevant information. Two (2) copies of the report shall be submitted to Berkeley Lab by November 29, 1996 to the following address:

University of California, Ernest Orlando
Lawrence Berkeley National Laboratory
Attn: E. Majer, m/s 90-1116
One Cyclotron Road
Berkeley, CA 94720

The Subcontractor shall not distribute reports of work, drawings, specifications, etc., under this Subcontract to any individual or organization other than those indicated above without the prior written approval of the Subcontract Administrator.

IV. <u>OPERATING ASSURANCE</u>

Subcontractor shall bear primary responsibility for the services. Subcontractor shall use its own best ability, skill and care in the performance of work. Specifically, subcontractor will be responsible for the professional quality, technical accuracy and the coordination of all data, reports, documentation and other services furnished by subcontractor. Subcontractor shall without additional compensation correct or revise any errors or deficiencies in its data, reports, documentation, and other services.

V. <u>KEY PERSONNEL</u>

The Principal Investigator at Earthfield Technology is William Cathey, Senior Geophysicist who: (A.) will devote a reasonable amount of time to the work; (B.) be closely involved and continuously responsible for the conduct of the work; (C.) will not be replaced unless approved by the Laboratory; and (D.) will advise the Laboratory if he will devote substantially less effort to the subcontract than anticipated.

It is understood and agreed that any key technical individual(s) assigned to this work shall not be reassigned to other work that will interfere with the research and support activities under this Subcontract without prior Berkeley Laboratory approval, except in circumstances beyond the reasonable control of Earthfield Technology. If such circumstances arise, Earthfield Technology shall inform the Technical Coordinator of such reassignments within (5) working days. A replacement individual shall be assigned by Earthfield Technology and approved by the Berkeley Laboratory Technical Coordinator within ten (10) working days. If an acceptable individual is not identified; Berkeley Laboratory reserves the right to terminate this Subcontract.

VI. SELLER/SUBCONTRACTOR CHANGE(S) TO SCOPE OF WORK

Ernest Orlando Lawrence Berkeley National Laboratory's approval is required to change the phenomenon under study, the stated objectives of the research, or the methodology.

VII. EQUIPMENT AND SUPPLIES

Equipment and supplies acquired with funds provided by this Subcontract is governed under the provisions of the Property Article from the Addendum to Terms and Conditions of University of California Subcontract.

VIII. COORDINATION AND ADMINISTRATION

The Berkeley Laboratory Technical Coordinator under this Subcontract is Ernie Majer, or his designee(s), who shall represent Berkeley Laboratory in matters relating to technical performance of this Subcontract. All other matters relating to the performance of this Subcontract are reserved to the Subcontract Administrator.

Further, any technical direction which will affect the estimated cost or time of performance under this Subcontract shall require prior formal amendment to the subcontract, or prior written direction in accordance with Clause 52, Changes-Fixed Price, of the University of California, Ernest Orlando Lawrence Berkeley National Laboratory, General Provisions for Fixed Price Supplies and Services.

The Laboratory's Subcontract Administrator is Peggy Jellinghausen or her designee. All matters relating to the interpretation and administration of this Subcontract which are not specifically delegated to the Laboratory's Technical Coordinator are reserved for the Subcontractor Administrator. The Subcontractor shall direct all notices and requests for approval to the Subcontractor Administrator, and any notice or approval from Berkeley Lab. to the Subcontractor will be issued by the Subcontract Administrator.

IX. ACCESS TO SUBCONTRACTOR'S FACILITIES

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Digital aeromagnetic grids for data centered on the Southwestern Nevada Volcanic Field, Nevada and California

by

*A. E. McCafferty

U.S. Geological Survey
P.O.Box 25046, Denver Federal Center, MS 964
Denver, CO 80225

* e-mail: anne@musette.cr.usgs.gov

Introduction

Aeromagnetic data were compiled for an area encompassing the Miocene southwestern Nevada volcanic field as part of a cooperative study between the U.S. Geological Survey (USGS) and the Department of Energy Environmental Restoration (ER) program. The overall objective of this project is to investigate the regional hydrogeologic setting of the Nevada Test Site (NTS) and vicinity and in particular, to define and characterize the ground water-flow pathways around the NTS.

The Environmental Restoration study area is located in the south central part of the northern Basin and Range Province and is centered on the Timber Mountain-Silent Canyon caldera complexes of the southwest Nevada volcanic field (figure 1). The volcanic field is comprised of a number of overlapping calderas and volcanic centers covering an area of approximately 1800 km^2, which represents one of the largest caldera systems in the United States (Snyder and Carr, 1984). Extensional normal faulting has been active previous to, throughout, and after the emplacement of the calderas, but more so during the late stages of volcanism (Christiansen and others, 1977). The region is characterized by surface outcrops of thin, relatively flat-lying deposits of ash-flow tuffs and alluvial deposits associated with the volcanic centers within and surrounding the caldera complexes that have an accumulated thickness of more than 4 km.

The exposed Cenozoic volcanic and sedimentary rocks have been extensively studied as part of the nation's nuclear testing and high-level waste disposal programs. Geologic maps exist that cover part of the ER area (Frizzell and Shulters, 1990) and the remaining areas have been revised and compiled from draft maps by the USGS (Minor and others, 1992, Carr and others, 199_). Although most of the area has been mapped in detail, these studies provide little control on the units most critical to ground water flow. Pre-Tertiary geology, mostly obscured by the volcanic units, consist of an 3.5 km-thick sedimentary package of alternating carbonates and clastic rocks that form the aquifers and aquitards respectively (Winograd and Thordarson, 1975). Additionally, little is known about buried volcanic units and their possible influence on ground water movement. The geometry and depth to buried volcanic and pre-Tertiary geologic units can only be defined by indirect methods such as regional reconnaissance geophysical mapping combined with drilling.

Regional compilations of aeromagnetic data are published that cover a large part of the ER study area (Kirchoff-Stein and others, 1989, Hildenbrand and Kucks, 1988) and were initiated by work concerned particularly with the Nevada Test Site but also included regional state studies. The data used for these previous compilations used older surveys, which have since been replaced with the surveys shown in this report. Additionally, the previously

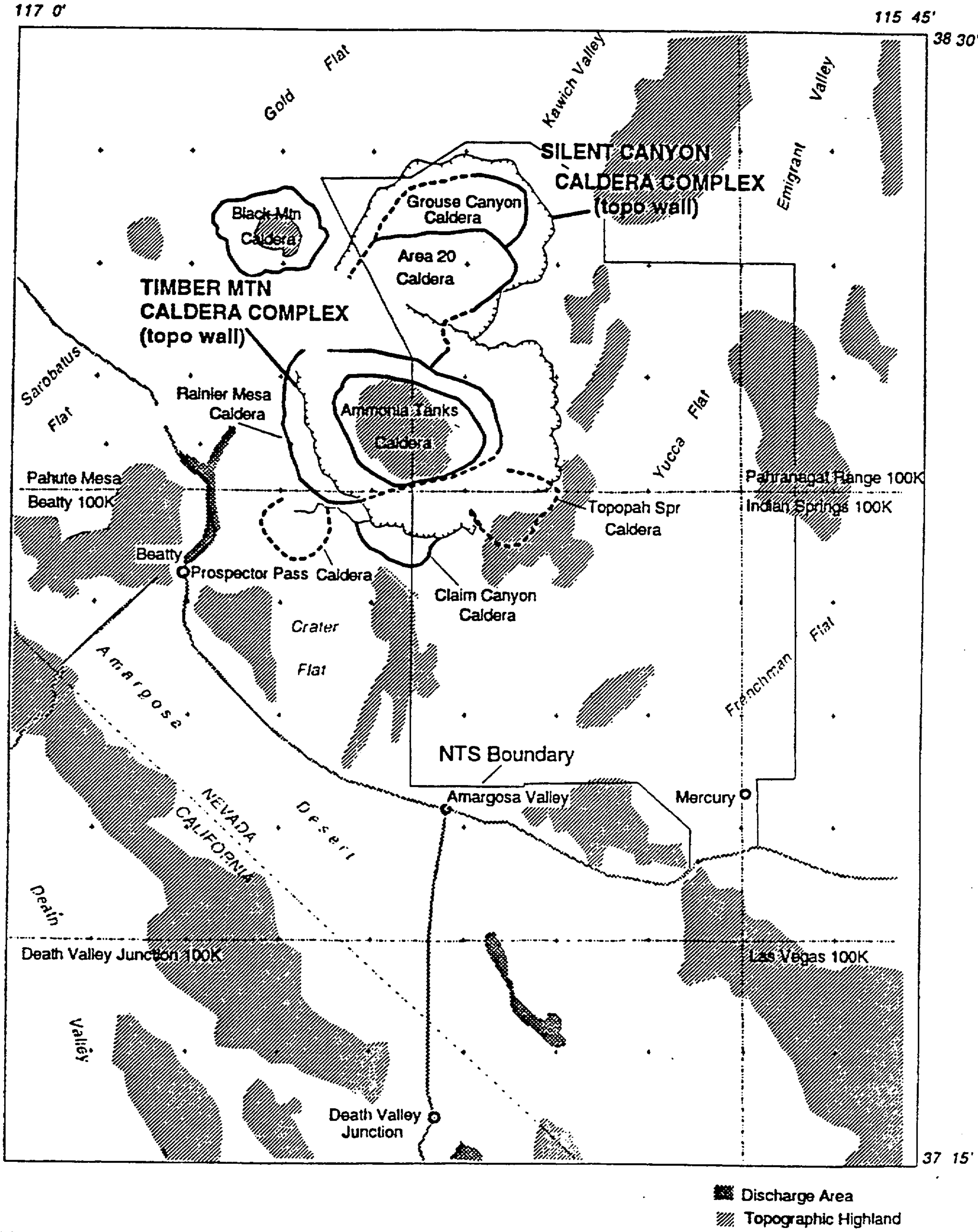


Figure 1 Map showing caldera boundaries and select topographic features modified from Frizzell and Shulters, 1990. Caldera boundaries after Sawyer (U.S. Geological Survey, unpublished data)

published aeromagnetic maps were compiled at a 1 km grid interval, an order of magnitude coarser than the 100 m grid interval used to produce the map in this study. Therefore, much of the high resolution available in the detailed survey areas was lost due to the coarseness of the 1-km grid.

The study area covers a region between lat 36° 15' N. and 37° 30' N., and long 115° 45' W. and 117° 0' W. The maps cover the entire Beatty and Pahute Mesa 30- by 60-minute (1:100,000-scale) quadrangle maps and parts of the Pahranagat Range, Indian Springs, Death Valley Junction, and Las Vegas 1:100,000-scale maps (fig. 1). The aeromagnetic anomaly grids form the basis of the geophysical contribution to this multidisiplinary study.

COMPOSITE AEROMAGNETIC ANOMALY GRID: 'ERJIGSAW.ASC'

Aeromagnetic data exist for the study area in the form of a patchwork of thirteen surveys collected in a piecemeal fashion over a period of two decades. 'ERJIGSAW.ASC' is a gridded mosaic of the surveys and shows the individual surveys in their original form before the data were further processed and merged into one data set. The surveys were flown with varying flight-line spacing, altitudes, and flight specifications. Figure 2 and table 1 outline and describe the flight specifications and detail the manner in which the data were collected.

Most of the NTS and the central part of the Environmental Restoration study area are covered by detailed, high-quality digital data (surveys 6,7,9a-c,10 and 11 in figure 2). The detailed surveys were flown at low altitude with flightline spacing of 800 m or less. The flight-line data for these surveys are archived on 9-track magnetic tapes in retrievable digital form. However, for surveys flown pre-1971, the data are archived as contour maps only and required digitization along contour-line-flight-path intersections before further processing and integration with adjacent surveys.

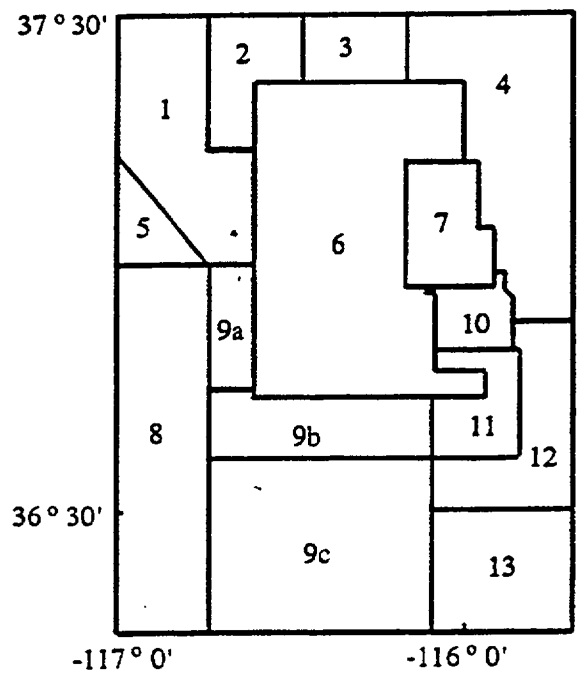


Figure 2-- Index map showing locations of aeromagnetic surveys used for this study. Numbers refer to table 1.

Table 1--Aeromagnetic data specifications for surveys used in the compilation for this study [AG, above ground; B, barometric]

Area	Name	Year Flown	Flight Elevation (m)	Flight Spacing (m)	Flight Direction	Reference
1	Sarcobatus Flat	1963	2440 B	800	E-W	Philbin and White, 1965a
2	Black Mtn	1963	2440 B	1600	E-W	Philbin and White, 1965b
3	Silent Canyon	1963	2440 B	1600	E-W	Philbin and White, 1965c
4	Climax Stock	1980	2286-2440 B	1600	E-W	Bath and others, 1983
5	Bonnie Clair	1967	2740 B	1600	E-W	U.S. Geological Survey, 1967
6	Timber Mtn	1977	122 AG	400	E-W	U.S. Geological Survey, 1977
7	Yucca Flat: ~~JPL~~ Los Alamos	1990	146 AG	400	E-W	~~Jet Propulsion Lab~~, 1990 Los Alamos unpublished
8	Death Valley	1979	122 AG	1600	N-S	Geodata International, 1979a
9a	Lathrop Wells	1978	122 AG	800	N-S	Langenheim and others, 1991
9b	" "	" "	122 AG	400	E-W	" "
9c	" "	" "	122 AG	800	E-W	" "
10	Yucca Flat	1971	122 AG	400	E-W	U.S. Geological Survey, 1971
11	Mercury	1982	122 AG	400	E-W	U.S. Geological Survey, 1984
12	Las Vegas	1982	305 AG	1600	E-W	U.S. Geological Survey, 1983
13	S. Nevada	1978	305 AG	1600	E-W	U.S. Geological Survey, 1979b

The data were projected onto a Cartesian coordinate system using a Universal Transverse Mercator (UTM) projection with a central meridian of 117° W. and a base latitude of 36° N. Data from each survey were interpolated to a square grid using a minimum-curvature algorithm (Webring, 1981); grid spacing was typically 1/4 to 1/3 the original flight-line spacing. The magnetic-anomaly grid (total field intensity minus the Definitive Geomagnetic Reference Field: DGRF) was calculated (Sweeney, 1990) for the appropriate time of year and elevation of the original survey. If an obsolete regional field other than the

DGRF had been removed, the outdated geomagnetic reference field was added back and the appropriate DGRF was subtracted from the grid.

The surveys were trimmed to the borders shown on figure 2 (program *JIGSAW*, Cordell and others, 1992). The majority of the surveys in this report have some overlap with adjacent surveys. When surveys overlapped, the survey with the higher quality data (closer spaced flight-lines, digital, low altitude) was chosen to define the trimmed edge. The white areas between surveys are 'dvals' (dummy values or areas of no data); the result of data being removed from around the survey grid periphery before plotting in order to emphasize the aerial extent of each survey used to produce the merged aeromagnetic grid.

MERGED AEROMAGNETIC ANOMALY GRID: 'ERMERGED.ASC'

This is a grid of the merged aeromagnetic anomaly data of the thirteen surveys from 'ERJIGSAW.ASC'. The grid is a representation of the data as if all surveys were flown at a constant altitude (also called draped mode) above topography. Elevations of 122 to 305 m above terrain were selected as the reduction datum levels for the merged grid. The majority of high-quality surveys for this study were flown in a draped mode. Two datum levels were chosen because the differences at the boundaries between surveys flown 122 m and surveys flown 305 m were insignificant. Therefore, the surveys would require no further data processing in order to be merged with adjacent surveys. Filtering of the data can produce distortion of anomalies and amplify the noise content of the data. Whenever possible, it is best to leave data in original form in order to avoid producing unacceptable artifacts in the resulting map. The choice to maintain two datum levels was made for this reason and because the surveys were visually and numerically continuous across the boundaries without filtering. However, some of the older aeromagnetic surveys on the periphery of the study area were flown at level barometric elevations and required filtering (downward continuation) of the data to the draped mode before merging with adjacent surveys.

For surveys flown at a constant barometric elevation, the data were analytically continued to the draped surface of 305 m above ground using the method of Cordell (1985). The method takes the gridded data from the older barometric surveys and calculates an approximation of the magnetic field data as if it had been observed on an irregular surface. The method calculates the magnetic field on a stack of horizontal levels using a fast Fourier transform method (Hildenbrand, 1985). The horizontal levels are defined such that they extend over the elevation range of the irregular surface. The magnetic field is then extrapolated from the intersections of the irregular surface and horizontal levels.

After reducing the data to an irregular surface (if necessary), each data set was regridded to a 100-m interval and compared (either visually or where the survey grid overlapped) with the Timber Mountain survey (area 6) to determine a constant to add to or subtract from the data. The Timber Mountain survey was chosen to be the baseline survey that all other surveys would be referenced to due to its' central location and the general high quality of the data. The surveys were trimmed to the boundaries shown in Map A and merged to adjacent surveys using a minimum curvature algorithm (program *MEGAPLUG*, Cordell and others, 1992).

DISCUSSION

The merged and mosaic aeromagnetic grids mutually complement each other and should be used together when analyzing and interpreting anomalies. The mosaic grid preserves the original quality of the data and should be referred to when analyzing anomalies of the merged grid that are located at or near survey boundaries. During the merging process, gradients coincident with survey boundaries were avoided whenever possible. This was feasible for the majority of the data in the study area because the surveys were flown with similar specifications. However, the older surveys were difficult to integrate with the detailed surveys and gradients at the survey boundaries between the Timber Mountain survey and the adjacent older surveys to the north and west were unavoidable. In order to preserve the anomaly texture and quality of the Timber Mountain survey data (as well as the data from other detailed surveys), a fine grid interval was chosen, which was not appropriate to the more regional surveys. Rather than degrade the data from the more detailed surveys, the older surveys were originally gridded to an interval appropriate to their flight specifications then regridded and merged at the 100-m grid interval. Gradients are evident at this boundary and the obvious textural changes from the Timber Mountain survey to the older surveys should be noted as artifacts of the merging process and differences in the quality of data and should not be attributed to any change due to different geologic sources or lithologies.

The data from the older aeromagnetic surveys are, in general, of poor quality in comparison with the more recently flown, high resolution surveys, but they do provide a synoptic view of the regional magnetic field over the study area and allow for interpretation of anomalies across survey boundaries. However, the data from the older surveys are of insufficient quality and resolution to provide proper analysis of short wavelength anomalies related to subsurface geologic structures that could have some influence on groundwater movement. The need for high quality data in this region of older surveys is necessary before any detail on the geometry of or depth to hydrologic-related source rock can be determined.

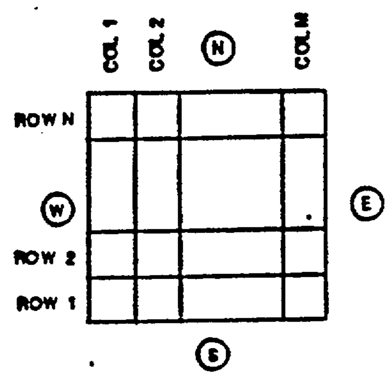
Digital Data Format

The digital data for the 2 grids are available as USGS standard format grids written with FORTRAN format. A 'row' is defined as a series of data positions that extend from west to east along a common north coordinate. The first value in each row contains a "0", which indicates an evenly spaced grid. The first row is the southernmost (see figure below). Dval (dummy values) are used to indicate areas of no data and have a value of 0.1E+31.

Line 1-10: Header record

Line 11: Magnetic values in gammas [5E16.8].

Line 12-* row1, column 1-m; row 2, column 1-n, ect.. Where line 11 contains the first 5 elements of row1, and so on, until all the elements in the grid are exhausted.



Columns and rows of USGS grids

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4/17/1997

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Summary of Water and Gas Analysis in Thermal Test

Test	Author Org.	DTN	AN	Data Linked to	Report
SHT	LLNL	LL970101104244.027	MOL.19971215.0663	SEP	1st Qtr FY97 results of chemical meas. In the SHT
SHT	LLNL	LL970409604244.030	MOL.19971218.0917 MOL.19971218.0937		2nd Qtr FY97 results of chemical meas. In the SHT
SHT	LLNL	LL970703904244.034	MOL.19980115.0122 MOL.19980115.0115	SEP	3rd Qtr FY97 results of chemical meas. In the SHT
SHT	LLNL	LL971006604244.046	MOL.19980115.0158 MOL.19980115.0159	SEP	4th Qtr FY97 results of chemical meas. In the SHT
DST	LLNL	LL980201004244.053	MOL.19980504.0573 MOL.19980507.0363	SEP	Gas Baseline data in the DST
DST	LLNL	LL980408304244.058	MOL.19980521.0002 MOL.19980629.0357(Rev 01)		1st Qtr FY98 chemical borehole studies in the DST
DST	LLNL	LL980810004244.067			2nd Qtr FY98 Gas and water chemistry
DST	LBNL	LB980420123142.005			1st Qtr FY98 Carbon Isotope Analyses in the DST
DST	LBNL	LB980715123142.003	MOL.19980921.0092 (NA) MOL.19980921.0093 (NA)	SEP	2nd Qtr FY98 Carbon Isotope Analyses in the DST
DST	LBNL	LB981016123142.004			3rd Qtr FY98 Carbon Isotope Analyses in the DST (No data is currently available)

elements		concentration
	SHT Hole 16	
	LLNL Data	
Na (mg/l)	16	
Si (mg/l)	16.8	
Ca (mg/l)	13	
K (mg/l)	2.5	
Mg (mg/l)	1.63	
pH		
HCO3 (mg/l)		
F (mg/l)		
Cl (mg/l)		
S (mg/l)	0.71	
SO4* (mg/l)	2.13	
Li (mg/l)	<0.03	
B (mg/l)	0.37	
Al (mg/l)	<0.06	
Fe (mg/l)	0.74	
Sr (mg/l)	0.2	
Br (mg/l)		
del D		
del 18O		
*LLNL SO4 is computed assuming all S is SO4		

First Quarter Results of Chemical Measurements in the Single Heater Test

W. G. Glassley

LL970101104244.027

MOL.19971218.0916

306097

YMP-023-R4
05/06/96

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
TECHNICAL DATA INFORMATION

(Check one): [X] ACQUIRED DATA (complete Parts I and II)
Data Tracking Number (DTN): LL970409604244.030

[ ] DEVELOPED DATA (complete Parts I, II and III)
Data Tracking Number (DTN):

PART I Identification of Data

Title/Description of Data: SECOND QUARTER RESULTS OF CHEMICAL MEASUREMENTS IN THE SINGLE HEATER TEST.

Principal Investigator (PI): GLASSLEY, W E
Last Name — First and Middle Initials

PI Organization: LAWRENCE LIVERMORE NATIONAL LABORATORY

Are Data Qualified?: [X] Yes [ ] No — Governing Plan: SCP

SCPB Activity Number(s): 8.3.4.2.4.4.1

WBS Number(s): 1.2.3.14.2

PART II Data Acquisition/Development Information

Method: UNDER LLNL STUDY PLAN 8.3.4.2.4.4 INDUCTIVELY COUPLED PLASMA SPECTROMETRY.

Location(s): THERMAL ALCOVE SINGLE HEATER TEST AREA IN THE ESF.

Period(s): 12/6/96 to 3/7/97
From: MM/DD/YY — To: MM/DD/YY

Sample ID Number(s):

PART III Source Data DTN(s)

Comments

LLNL MILESTONE SP9240M4

Checked by: [signature] — Signature — 4/17/97 — Date

TABLE 1: Analyses of Hole 16 Water, And Comparison With Other Waters

	16-4 LLNL	log molal	16-4 LANL	16-4 USGS##	EQ3/6 Model **	J-13*	G-4*	Rain. Mesa* Water
Na (mg/l)	16	-3.16			16.1	45.8	57	35
Si (mg/l)	16.8	-3.22			19	28.5	21	25
Ca (mg/l)	13	-3.49			13.2	13	13	8.4
K (mg/l)	2.5	-4.19			2.46	5	2.1	4.7
Mg (mg/l)	1.63	-4.17			n.e.	2.01	0.2	1.5
pH	6.2				6.08	7.4	7.7	7.5
HCO_3 (mg/l)#	84.4	-2.86				129	139	98
F (mg/l)	0.44	-4.64				2.18	2.5	0.25
Cl (mg/l)	2.54	-4.14	2.1			7.1	5.9	8.5
S (mg/l)	0.71	-4.65						
SO_4 (mg/l)	1.83	-4.72	1.5			18.4	19	15
PO_4^{3-} (mg/l)	<0.03					<10		
Nitrite (mg/l)	<0.01							
NO_3^- (mg/l)	1.1	-4.75				8.8		
Li (mg/l)	<0.03					0.048	0.067	
B (mg/l)	0.37	-4.47				0.134		
Al (mg/l)	<0.06					0.02		
Fe (mg/l)	0.74	-4.88						
Sr (mg/l)	0.2	-5.64		0.0022		0.04		
Br (mg/l)	<0.02		0.008					
del D						-98	-103	
del ^{18}O						-13	-13.8	
Tritium	0.44 ± 0.19 TU							
$^{87}Sr/^{86}Sr$				0.7124				

* From Harrar et al., 1990
\# Computed from charge balance; see text.
** EQ3/6 simulations discussed in text
n.e. not evaluated
\## Reported by Z. Peterman, 3/11/97

Simulations

The results of the simulations are shown in Table 2 and Figure 1. The measured values for the 16-4 water are indicated by arrows in Figure 1. The best match between the simulated and measured compositions is indicated by tick marks attached to the symbols in Figure 1. Note that the vertical scale in Figure 1 is in units of mg/l for Si, Na, and K, only. The pH values refer to the same axis, but are unitless.

Table 2 indicates the rate constants used for each simulation. Note also that precipitation of specific mineral phases was suppressed during the simulations (column labeled "Suppressed"). For the silica polymorphs, suppression of the indicated phases (tridymite, quartz, and chalcedony) is necessary in order to approach the elevated silica