AN ANALYSIS AND SYNTHESIS OF 1976-1987 GEOSCIENTIFIC DATA RELATED TO EXPLORATION FOR AND DEVELOPMENT OF GEOTHERMAL RESOURCES AT COVE FORT-SULPHURDALE, MILLARD AND BEAVER COUNTIES, UTAH

For

Mother Earth Industries, Inc.
7350 East Evans - Suite B
Scottsdale, Arizona 85260

February, 1988

GEOTHERMAL MANAGEMENT Co., Inc. P.O. Box 2980 Evergreen, CO. 80439-2980

related to

EXPLORATION FOR AND DEVELOPMENT OF GEOTHERMAL RESOURCES

at

COVE FORT-SULPHURDALE, MILLARD AND BEAVER COUNTIES, UTAH

GEOTHERMAL MANAGEMENT CO., INC.

February, 1988

ILLUSTRATIONS

AN ANALYSIS AND SYNTHESIS OF 1976-1987 GEOSCIENTIFIC DATA
related to
EXPLORATION FOR AND DEVELOPMENT OF GEOTHERMAL RESOURCES
at
COVE FORT-SULPHURDALE, MILLARD AND BEAVER COUNTIES, UTAH

GEOTHERMAL MANAGEMENT CO., INC.
February, 1988

ILLUSTRATIONS

By
Geothermal Management Company, Inc.

EXECUTIVE SUMMARY

In 1983, Mother Earth Industries, Inc. (MEI) began exploration of approximately 13,800 acres of federal and fee geothermal leases in the Cove Fort-Sulphurdale KGRA of southwest-central Utah. Between 1975 and 1983, the area was extensively explored by Union Oil Company, the first KGRA lessee, with supplemental investigations conducted by the University of Utah Research Institute (UURI) and by the U.S. Geological Survey. The studies conducted by these entities (plus MEI) and by their subcontracted consultants included: geologic mapping, magnetic, gravity, electrical resistivity, self-potential, CSAMT, and soil mercury surveys together with air photo analysis, soil, water, and drill-cutting geochemistry, petrographic examinations of drill-cuttings, thermal gradient drilling, and relatively deep slim-hole and production-scale well drilling.

In June 1987, MEI contracted with Geothermal Mangement Company (GMC) to review all the reports written to document the studies listed above and to analyze the data, interpret it, and synthesize the findings into a form that would guide MEI in its continued development of the property.

p. 1-7
26, 27
31-33

1. There exists at Sulphurdale a dry steam geothermal resource that was discovered at 940-1165 feet by MEI and which is now being produced to generate 2.3 MW (net) of electricity. The dry steam resource should support about 20 more wells in the area explored to date thereby allowing production of an additional 60-80 MW of electricity. The steam is of high quality and deliverability.

2. The steam now being produced by MEI is localized along N15E trending faults that may be connected to the main range-front fault which at depth, transects the hot water reservior. Additional steam can probably be found by drilling:

A. Along the N15E faults that form the east boundary of the Sulphur Pit.

B. At the intersection of these N15E faults with the N40W fault that forms the southwest boundary of the Sulphur Pit.

C. Under the Pit itself to intersect faults that are known to conduct the high temperature gasses that emanate at the surface as fumaroles, and,

D. In or near the east-trending gulley in which the MEI maintenance building is located.

3. The hot water resource probably underlies the whole KGRA area and beyond. Nevertheless, the waters are likely to be most producible from highly fractured areas that will be found in the vicinity of major faults. The initial hot water drilling targets that can be delineated on the basis of the various studies reviewed are:

A. The main range-front fault at or near where it crosses the Sulphurdale access road.

just northwest of the low hill that is immediately west of the production area).

C. Along the northwest side of Popeye Valley where a major fault trends southwestward across the Cove Fort basalt field towards Woodtick volcano and,

D. At depth beneath the Sulphur Pit and current production areas.

The hot water resource should initially be drilled in the target areas listed above. These cover about 5 square miles, should support up to 80 wells, and produce 160-240 MW (gross) of electric power, depending on the ultimate depth, temperature and attainable production rates.

4. The hill just west of dry hole 24-7 is anomalous in many respects. It is unclear whether these anomalies are geothermally related, but the area should be explored further as a second priority to the several targets listed above.

5. Finally, the west side of the Beaver Valley, on the east and northeast flanks of Woodtick volcano should be drilled. There is evidence that the heat source for the entire geothermal system may be in this region and that thermal waters circulate along the major fractures that transect it. It is recognized that MEI does not, at this time, have a leassehold in this area, but it is something to consider for the future.

It is recommended, on the basis of the exploration work accomplished to date, that the MEI exploration model include geologic mapping, soil mercury traverses across prospective faults, thermal gradient drilling to 100 feet in and near high mercury areas and slim hole exploratory drilling

6. The risk/reward profile at Cove Fort-Sulphurdale is extraordinarily low. Resource depths are not great, much fruitful exploration has already delineated new drilling targets and power sales contracts (plus expansions thereof) are in hand. A low risk, profitable business venture with large up-side potential exists.

Accompanying this report is a set of maps that have been drawn on transparent material. These maps depict the most important data revealed by each of the studies reviewed and they show the anomalous areas (drilling targets) that can be defined on the basis of each study. The maps can be placed over one another in any sequence so that the locations of the anomalous areas can be compared and an accurate overall picture of the geothermally prospective areas acquired. Perhaps even more than the text, these maps represent the data synthesis that can make future development of the MEI properties most cost-effective.

RESOURCES AT COVE FORT-SULPHURDALE, MILLARD AND BEAVER COUNTIES, UTAH

PART I - CONCLUSIONS REGARDING THE COVE FORT-SULPHURDALE GEOTHERMAL RESOURCE

Introduction

In Part I, the geothermal resource being developed by MEI is described, the near term potential for expanded development is quantified, an MEI exploration plan is presented and the risk-reward profile of the area is examined. All of this is done in light of information summarized in Part II in which is discussed the rationales for and the results of the several exploration techniques used at Cove Fort-Sulphurdale by Union Oil Company, Mother Earth Industries and their various subcontractors and collaborators.

Geothermal Resource Description

The Cove Fort-Sulphurdale geothermal resource comprises 1) dry steam discovered and currently being produced and used to generate electricity by MEI and 2) hot water, encountered in every deep well drilled to date by Union Oil and MEI, and believed to underlie most of the land geothermally controlled by MEI.

The dry steam resource is of high quality, with a low and stable non-condensible gas content, very low moisture and excellent deliverability. The well-head temperatures and pressures, though lower than those at The Geysers in California, are more than adequate for power generation using Topping Turbines and state-of-the-art binary (Organic into turbines and/or heat exchangers, and it is thus a most cost-effective fuel for power generation. MEI's production dry steam from wells 34-7A and 34-7B during the past three years has shown that the steam resource is extensive (very minor pressure decreases) and that it is flowing along fault conduits having very high permeability and significant vertical and lateral extent (very minor declines in steam flow rates). It is important to note that the steam has been produced from zones between 900 and 1,100 feet deep in wells that are only 250 feet apart without diminution of flow in either well. Additionally, production of dry steam from slim-hole S-87-4 just 300 feet from 34-7A caused no discernable reaction in 34-7A or in 34-7B during a preliminary flow test.

The hot water resource has been encountered in all of the wells drilled through the water table (1,200-1,400 feet) by Union Oil Company and MEI. Temperatures up to 315^{0}F have been recorded, and geothermometric studies of produced waters suggest that equilibrium resource temperatures are approximately 450^{0}F. Like the steam resource, the hot water resource reservoir is fracture controlled rather than strata-bound. It will be important, therefore, to drill at fault intersetions and in seismically active fault planes so as to maximize the chances of penetrating interconnected fracture networks through which the hot waters can be produced.

Though there has not, to date, been any hot water produced and utilized at Cove Fort-Sulphurdale, it is known that temperatures are high enough for binary system power production. If the geothermometric caluclations are accurate, then artesian wells may be expected and the use of flash and/or "total flow" power generation fomats will be possible.

less than 7,000 feet. Since Geyser's wells are 4,000 to 10,000 feet deep and Imperial Valley wells are 3,000 to 12,000 feet deep, the Cove Fort-Sulphurdale resource will be found at a depth that is reasonable and economically achievable.

There is an old addage that says, "When hunting for elephants, go to elephant country." Cove Fort-Sulphurdale is truely in geothermal "elephant country", and it is, therefore, an excellent hunting ground for the following reasons:

1) Cove Fort-Sulphurdale lies at the intersection of the Wasatch-Front-Basin and Range "Geomorphic Hinge Line" and the Pioche-Beaver-Marysvale Mineral Belt. Both of these features are loci of long-term tectonic activity, associated intrusion of hydrothermally active magmatic bodies, and periodic eruption of volcanic lavas and ashes.

2) Cove Fort-Sulphurdale has as geothermal neighbors: Hatten and Meadow hot springs and recent lavas to the north, Richfield, Monroe, and Joseph hot springs, faults and calderas to the east, the Marysvale caldera and hydrothermal mineral complex to the southeast, the Manderville low temperature uranium and gold district to the south, Thermo Hot Springs and the Juab Mountain Caldera to the southwest and the Roosevelt Hot Springs Geothermal Field to the west.

The "elephant country" described above includes almost three thousand square miles of thermally anomalous land. Cove Fort-Sulphurdale is right in the heart of this region and is, therefore, ideally located with respect to geothermal development potential.

structrures can be greatly facilitated by studying airphotos in addition to traditional ground mapping surveys. For the Cove Fort area, airphotos at two scales were studied: a small scale (1" = 5,240') color infrared, stereo pair (HAP-84F, N^{OS}239-86 and 87; 9-3-84) and an enlargement of #239-87 at 1" - 2,130'.

The study revealed five strong fracture trends labeled on Plate VI: N15E (1 and 1A), N75E (2 and 2A), N40W (3), N45E (4 and 6) and N10W (5). The N15E set includes both the fault(s) that bounds the east side of the Sulphur Pit and the "main range front fault" west of Sulphurdale. The subparallelism of these structures suggests that they are part of the same system and that fluids (steam) found east of the Sulpur Pit originated on the range front fault and migrated up related faults. The existence and trends of these faults have been confirmed by regional gravity data.

The N75E faults are the "older" set that transect the northern and central parts of the Sulphur Pit. They are less obvious on the airphotos than the N15E set, perhaps due to lack of recent movement along their trends. It is, however, interesting to note that these N75E faults could be radial faults extending outward from the crater of Woodtick Volcano and that they could conduct geothermal rsources away from this possible heat source.

The N40W fracture that stands out on the airphotos extends about one mile southeast of the Sulphur Pit along the trace of Sulphur Creek and about one mile northwest of the pit towards the intersection of I-70 and I-15. It seems to transect both of the N15E faults without discernable offset of either structure set. This may indicate very steep dips and predominently dip-slip motion. The location of this fault appears to

Next, there is one N45E striking structure that controls the trend of an anomalously straight gully one-half mile east of the Surphur Pit. This fault is subparallel to many others that are evident in the mountains southeast of the pit (No. 6 on Plate VI), and it may be that this N45E trend is related to stresses created by the quartz monzonite intrusion to the southeast.

Finally, there are visible on the airphotos two N10W trending lineaments that extend for at least 2.5 miles southeast from the Sulphur Pit. They seem to coincide with a regional scale magnetic lineament and may be geothermally important. Their trends should therefore be field checked by mapping and some soil mercury traverses.

Exploration and development targets suggested by the airphoto analyses are: 1) the two intersections of the N40W and the N15E fault systems and 2) the extensions of the "Range-front fault" N15E set to the northeast. It will be prudent to pin down the actual locations of the N15E faults on the ground by using more mercury surveys, because their trends are not clear, even on the enlarged airphotos.

From the airphoto lineaments, it appears as if Wells 42-7 and 47-6 were both drilled into the footwall of the N15E striking fault that conducts steam at 34-7. It is possible that more steam might be found if wells were to be drilled into the hanging wall of this fault as located by soil mercury traverses run on a bearing of S75E across their suspected traces.

the Cove Fort Sulphurdale KGRA for the sole purpose of recording the rate of increase of temperature with depth (thermal gradient). The wells have been drilled by virtually all of the firms holding KGRA leases, and some other entities. These companies include MEI, Union Oil Company, Phillips Geothermal, Hunt Minerals, Amax, and the USGS. The holes were distributed rather evenly across the KGRA and were drilled to depths ranging from less than 100 feet to more than 2,000 feet with most of the wells being 250 to 300 feet deep.

In order to "Normalize" the gradients from holes of such different depths, the convention of Higginson-Barnett (1987) was adopted. This scheme utilized only temperatures from 25' to 100 feet and then divided by 0.75 to convert to gradients in degrees Fahrenheit per 100 feet.

In the cases of the "S" series of holes, drilled by Phillips and the six deep exploratory wells drilled by Union Oil Company and MEI, gradients were measured utilizing the best fit for the entire well depth. Interestingly, the gradients thus calculated fit in well with the gradients based solely on the 25-100-foot readings.

The CFS-KGRA is characterized by extremely high thermal gradients over a very large area. The World-wide gradient average is about 1.7^{0}F/100' and at Cove Fort, gradients range from 2.0 to 80^{0}F/100' with a local background between 10 and 20^{0}F/100'. The background is thus ten times "normal."

Plate VIII is a contour map showing iso-gradient lines at 10^{0}F/100' intervals. The most striking feature is the slightly curvalinear trend of thermal gradient maxima that extends north from the Sulphur Pit, through hole #77-2 to the prospect pits in the vicinity of Union Well "disturbed zone."

A second, slightly less obvious trend is one of higher than average gradients along the N37E striking fault that transects the Woodtick Volcano and which forms the southeastern boundary of Popeye Valley (Directly west of Dog Valley Peak). It is important to note the existance of sulphur, fluorite and copper mineralization in prospect pits excavated along this fault and the fact that a large number of microearthquake hypocenters have been identified on the down-dip projection of this fault. Both the former and the latter faults seem to be regionally important with penetration to significant depths.

Exploration and development targets exist all along both of these faults, however, the two most obvious centers of interest are still near Forminco #1 and at the Sulphur Pit.

Forminco #1 was plugged and abandoned at a depth of 1,051 feet, without logging temperatures, due to difficulty in penetrating hydrothermally altered dolomite "sand" 600 ppm of H_2S was encountered at the top of this dolomite and at a depth of 1,094' within the unit. Maximum mud temperature, 100^0F at 797' compares favorably with mud temperatures recorded in MEI wells 34-7A, B and S-87-4 just above steam entries. Had Union Oil Company not plugged off the H_2S zone, it is possible that Forminco #1 might have also been a steam producer. This target should be explored further.

and the Sulphur Pit, at the southwestern end of the curvilinear thermal gradient trend of maxima, is known to overlie economic dry steam resources. The ten-well 1987 MEI thermal gradient program (Plate IX) reveals the following:

1) TG-8, with a gradient of 31.2^{0}F/100' suggests that a steam-bearing N15E fault exists at least as far south as the MEI trailer access road.

2) TG-7 (38.4^{0}F/100') is evidence of the high potential of the intersection area of the N15E and N45W fault systems at the south end of the pit. If firm ground can be found, it is a promising site for a slim-exploration well.

3) TG-9 no doubt indicates a resource at shallow depth. If a well can be collared on solid ground and perhaps angle-drilled eastward under the pit, production might be possible.

4) Most of the area near the Sulphur Pit exhibits thermal gradients more than ten times "normal." Nevertheless, to date, steam has been discovered only in those areas having gradients in excess of 30^{0}F/100'! Incredible as it seems, initial thermal-gradient drilling targets near the Sulphur Pit should be along the N15E faults on the east side of the pit (possibly no further south than the MEI trailer access road), at the extreme south end of the pit and beneath the middle of the pit beginning near TG-9.

...equency Magnetotellurics (CSAMT)

During the summer of 1987, Zonge Engineering and Research Organization (ZERO) conducted magnetic, Self-Potential (SP), and CSAMT surveys in and around the geothermal production area controlled by Mother Earth Industries. The surveys were undertaken at the request of MEI and had as their objectives the delineation of subsurface geologic structures related to the geothermal resource and the improved definition of the lithologic sequence beneath the interest area. The magnetic and SP surveys were run on a 250' x 250' grid, while the CSAMT was run on a 500' x 500' grid with " spider lines" projecting to the northeast, east, south, and west. Presented below is a summary of the results of the CSAMT survey as gleaned from ZERO's final report and from numerous conversations with N. Carlson, the investigative principal. The referenced Stations, Lines, and anomalies are depicted on Plates XIV.

Despite the fact that the CSAMT survey should have been run on a more closely spaced grid so as to better define the relatively narrow structures that seem to exist at Sulfurdale, the following important data interpretations can be made:

1. The area west of the cattle guard on the Sulphurdale access road has a CSAMT resistivity signature characteristic of "deep basement". This confirms the existance of the main range-front fault between the cattle guard and the north-south frontage road and suggests that this fault is indeed a major one with enough downthrow on the west side to yield the CSAMT "deep basement" signals.

2. The areas explored via spider lines 14 and 18, to the northeast and south of the main grid respectively, also show the "deep basement" CSAMT characteristics. In the absence of a range-front fault in these areas, one acceptable interpretation of this situation is the existance of

...essive (Q-M). This interpretation is supported by the fact the Q-M was found in Union Oil well 42-7 and because Q-M crops out on the ground surface of the terrace southwest of the Sulphur Pit at Stations 24 and 34 of Line 18.

3. Stations 5 of Lines 5 and 7 both show the "high over low" resistivity, phase differences greatly exceeding 785 milliradians, and low resistivities in the frequency ranges of interest (4-8 Hz) that are characteristic of production zones elsewhere in the world. Accordingly, these two stations have been considered to be "templates" or models for other prospective areas at Sulphurdale.

4. By applying the templates to other survey results, it appears as if two more potentially productive areas can be delineated: one at the south end of the Sulphur Pit near Stations 4 and 5 of Line 18 and the second in the vicinity of the access road to the MEI trailer near Stations 3 on Lines 9 and 11. ZERO hedges a bit in its enthusiasm concerning the Line 18 region because they believe that the area may be transitional between the Pit and the Deep Basement regimes. Likewise, they are cautious and say that the "trailer" anomaly is less well defined than the template stations.

5. The CSAMT data reveals a resistivity low under the hill that lies just west of dry hole 24-7. This hill is also characterized by a magnetic high, an SP low, and a soil mercury high, all of which make the hill an anomalous area. It is possible that the hill is significantly mineralized, that it is transected by several faults that have not been recognized during surface mapping, or that the hill overlies an extension of the geothermal field. Despite the failure of 24-7 to penetrate a resource, the need for more exploration beneath this hill is indicated.

...nally, the CSAMT data revealed the existance of a peculiar high resistivity zone roughly over the Sulphur Pit, between the production wells and the Line 18 area south of the Pit. Normally, areas such as this that are topographically low or that are hydrothermally altered have low resistivities; however, in this case, it seems possible that the high resistivity is a reflection of steam that occupies the several fault planes known to cross the area. If this is so, then the steam-bearing fault zone at the south end of the Pit may be up to 1000 feet wide, judging by the extent of the CSAMT anomaly.

At the beginning of this section, it was stated that the CSAMT grid was too wide. This is evident from the inability of ZERO to define the complex geologic structural patterns that appear to exist between wells 34-7 and 24-7, northeast of 34-7B and east of 42-7 and south of Stations 3 on Lines 5 and 7. CSAMT is indeed the electrical technique having the best horizontal discrimination, nevertheless, receiving stations on 100-foot spacings seem to be required to successfully study the rapid lateral changes in the Sulphurdale area. Perhaps some day a closely spaced follow-up survey can be conducted.

In summary, the CSAMT confirmed the presence of geothermal targets along the east side of the Sulphur Pit near the MEI trailer access road and at the south end of the Pit near the intersections of the N15E and the N40W faults mapped by UURI and by the writer on the basis of Mercury Soil Survey data. In addition, the CSAMT data suggested the presence of steam along N15E faults subparallel to the east side of the Pit, the existance of anomalous conditions beneath the hill west of well 24-7, and it confirmed a change from "shallow" to "deep" basement conditions between the cattle guard on the Sulphurdale access road and the north-south frontage road explored by Line 19. The latter condition must be evaluat...

best possible site can be selected for a well or wells to explore the range-front fault and related steam and/or hot water geothermal resources.

The electrical resistivity of the rocks underlying an area is reduced (that is to say, the conductivity is increased), in the presence of brines, clays, metallic mineral deposits, graphite and several other physical and/or chemical conditions. Most geothermal areas are also characterized by low resistivity for the following reasons:

1. The anomalously high temperatures of rocks and fluids in geothermal areas increases the solubilities of most minerals in water thereby creating brines that are electrically conductive.

2. The gasses associated with geothermal deposits dissolve in waters and/or brines resulting in the formation of acids that create conductive clays as rock alteration products and,

3. Geothermal fluids often contain dissolved metals that originated either in the rocks through which the hot waters migrated or in the magma that furnishes heat to the geothermal system. These minerals commonly precipitate as thermal fluids cool, and the geothermal "trail" thereby becomes more electrically conductive.

Because the resistivities recorded in most geothermal areas are 10 ohm-meters or less, and because non-thermal, unaltered, unmineralized, dry rocks can have resistivities that range from 20 to more than 100 ohm-meters, electrical resistivity surveys of several types have been found to be cost effective for the delineation of large scale geothermally prospective areas. The ambiguities of interpretation and the problems in precise anomaly location make the technique less useful for pinpointing actual drilling sites.

During the initial exploration of the Cove Fort-Sulphurdale KGRA lands in 1976, Union Oil conducted a dipole-dipole electrical resistivity survey comprising three, long, widely-spaced lines and ten Schlumberger traverse lines, some Induced Potential (IP) studies, and reinterpreted the Union work.

The studies referenced above identified two basic types of geothermal anomalies: those due to the existance of clayey, mineralized fault zones that appear to be conduits for thermal waters and areas of warm to hot, hydrothermally altered (clay-rich), gassey, briney ground.

The main areas of interest delineated by the two surveys are as follows (Plate XV):

1. A roughly circular area of approximately 5 square miles centered at Sulphurdale. This includes the Sulphur Pit and the ground for 2500 to 4000 feet in all directions from the Pit. The obvious reason for the anomaly is the alteration and mineralization of the volcanic bedrock by the geothermal fluids. The little IP data that was generated showed the existance of 1.5-2.0% metallic sulphides in the local rocks. This figure confirms findings based on analysis of drill cuttings from 42-7 and from the MEI production wells.

2. An area about 2500 feet northwest of Sulphurdale, near where the power line crosses the road to the Delano Greenhouses. Low resistivities in this location are interpreted to extend down more than 2000 feet and they are thought to be caused by a major fault that is a conduit for the hot waters that underlie the whole Cove Fort-Sulphurdale region. This is probably the main range-front fault whose position in this area can be confirmed by gravity and magnetic data.

3. An area about 2000 feet west of Cove Fort that trends northeastward and that follows the N37E strike of several important Basin and Range normal faults radiating away from Woodtick volcano. URRI

, ... evidence that the low resistivity is due to circulation of thermal waters on these prominent faults. UURI hydrologists further believe that this fault system and its carried thermal waters are part of a major geothermal exploration target that includes the Cove Fort Basalt Flow and the recent volcanic pile that is due west of Sulphurdale. This theory is supported by the gravity and the magnetic survey information which also identifies the electrically conductive faults (and other, orthogonal features) as young, and throughgoing fractures of regional significance.

The resistivity surveys yielded one fairly negative result that is curious. Neither the Union Oil nor the UURI interpreters found any geothermally encouraging data in the vicinity of the Union wells Forminco #1, 31-33, or 14-29. All recorded resistivities were high despite the proven existance of very high borehole temperatures, numerous mappable, mineralized faults and extensive hydrothermal alteration. Unless the area is saturated with infinitely resistive steam, (a condition that is unlikely in view of the several exploraiton wells that have not discovered steam), the findings are hard to explain. Despite the resistivity survey results, I believe that further exploration of the area is warranted.

The overlay sheet (Plate XV) that accompanies this report depicts the electrical resistivity survey lines and the areas whose anomalously low resistivity is thought to be caused by geothermal factors. It is obvious that several other techniques have already refined the gross targets near Sulphurdale that were delineated 10-12 years ago. Interestingly, little exploration has been undertaken in the western areas of interest, in and southwest of the Cove Fort basalt flows. This should be done once the full potential of the dry steam geothermal resource has been developed.

Agreement for the Purchase and Sale
of Cove Fort Station No. 1 and Related Rights and Assets among
M.E.I., Cove Creek Geothermal and Provo City, Utah
Dated: November 23, 1988 (Three Copies)

Agreement for Purchase and Sale of the
Phase 1, Phase 2 and the Expansion of Phase 3 to the
Cove Fort Station No. 1 Geothermal Plant by and between
The City of Provo and M.E.I.

Cove Fort Geothermal Field **Data Review and Recommendations** for
Future Action to Supplement the Developed Resource for UMPA
Dated: March 16, 1990 (Three Copies)

Project Plan for **Generating Electricity from Geothermal Resources**
near Cove Fort/Sulphurdale, Utah
Prepared for Provo City Power, Presented by M.E.I.
Dated: April, 1983

Assessment of Geothermal Energy Potential
Sulphurdale Geothermal Field
For M.E.I.
Dated: October, 1984 (Four Copies)

Cove Creek Geothermal **Financing of Cove Fort Station No. 1 Volume 2**
Dated: June 13, 1985 (Two Copies)

Proposal for Cove Fort Geothermal Power Plant Phase III
prepared for UMPA and Provo City
Dated: January, 1989 (Two Copies)

Cove Fort Geothermal Project **Phase 1 Agreements**
Joint Development and Management Agreement
Development Participation Agreement
Auxiliary Services Agreement
Dated: July 3, 1985

Final Report on CSAMT, SP, and Magnetics Data Sulphurdale KGRA
for MEI (Two Copies)

Critique of Energy Services Performance on 34-7 and 34-7B
by Thermasource, Inc.

Amended Plan of Operation for Geothermal Development on
Lease &-29558 of Cove fort/Sulphurdale KGRA Involving
Section 7, T. 26 S., R. 6 W., SLB&M in Beaver County, Utah
Dated September 13, 1984 (Revised)

Production Test of Wells P88-1 and P88-2 also in box 5
Cove Fort Geothermal Field take 1 from box 5
Prepared for Ben Holt Co. by Mesquite Group
Dated: May, 1989

Final Report SP and Magnetics surveys
Sulphurdale Project for MEI by Zonge Engineering and Research
Dated: February, 1987

North
1-800-997-8672
Leon or

Cove Fort
Box 2

8:30-9:00 am
Tomorrow

Completion Report, Geothermal Exploratory Well S-88-1 *
for MEI
Dated: November, 1988 (Two Copies)

Completion Report, Geothermal Production Well P-88-1A *
for MEI
Dated: July, 1989 (Three Copies)

Completion Report, Geothermal Production Well P-88-2 *
for MEI
Dated: July, 1989 (Five Copies)

Completion Report, Geothermal Production Well P-88-3 missing
for MEI
Dated: August, 1989

Completion Report, Geothermal Production Well S-88-3 *
for MEI
Dated: August, 1989 (Sixteen Copies)

Completion Report, Geothermal Production Well S-89-1
for MEI
Dated: June, 1989 (Eight Copies) *

Completion Report, Geothermal Production Well S-89-2 *
for MEI
Dated: November, 1989 (Two Copies)

Completion Report, Geothermal Production Well P91-4 *
for MEI
Dated: December, 1992 (Two Copies)

Cove Fort
Box 3

Completion Report, Geothermal Production Well S-89-1
for MEI
Dated: June, 1989 (Four Copies) +8

Completion Report, Geothermal Production Well S-89-5
for MEI
Dated: November, 1989 (Three Copies)

Completion Report, Geothermal Production Well S-89-2
for MEI
Dated: November, 1989 (Three Copies) +2

Completion Report, Geothermal Production Well P-88-1A
for MEI
Dated: July, 1989 (Eight Copies) +3

Completion Report, Geothermal Production Well P-88-2
for MEI
Dated: July, 1989 (Nine Copies)

Casing Minimum I.D. Caliper Log, Well 42-7
Dated: September 11, 1992 (Three Copies

Technical Report, Well #31-33, Permit #0049 have
by Union Geothermal Division
Dated: July, 1978 (Three Copies)

Memorandum Report to: MEI from: Mesquite Group no
RE: **Evaluation of Alternatives to Develop and Exploit the Hot Water Resource as a Potential Replacement for Steam Zone Production**
Dated: October 25, 1990

Final Report SP and Magnetics Surveys no
for MEI by Zonge Engineering and Research
Dated: February, 1987 (Three Copies)

Completion Report, Well 34-7A
for MEI prepared by Higginson-Barnett, Consultants check
Dated: March, 1985 (Five Copies)

Pre-Lease Evaluation
Dated: 1974

Cove Creek Geothermal, **Financing of Cove Fort Station No. 1, Volume 1**
Dated: June 13, 1985 (Four Copies)

Joint Resource Ownership and Development Agreement
Between MEI and Provo City, Utah
Dated: December 15, 1988 (Two Copies)

Geo. Investment and Policy Analysis with evaluation of California and **Utah**
Prepared for: U.S. Dept. of Energy
Dated: October, 1979

The Industry Coupled Case Study Program Final Report
Prepared for: U.S. Dept. of Energy
Dated: October, 1982

Final Report on CSAMT, SP, & Magnetics Data, Sulphurdale KGRA
for MEI
Dated: May, 1987

Cove Fort Geoth. Field Data Review and Recommendations for Future Action to Supplement the Developed Resource check

Cove Fort
Box 5

MMS Royalty Management Program, Oil and Gas Payor Handbook
Volume III
Dated: July 21, 1993

Report on **Screening Study**
for: UMPA by: Burns & McDonnell
Dated: 1983

Final Report on CSAMT, SP, and Magnetics Data, Sulphurdale KGRA
for MEI
Dated: May, 1987 (Five Copies)

Production Tests of Wells P88-1 & P88-2, Mesquite Report
Dated May 9, 1989

Completion Report, Well 34-71, Cove Creek Geothermal
Prepared by Higginson-Barnett, Consultants
Dated: March, 1985

Drilling & Completion Program for Geoth. Exploration Well 24-7
for MEI, Revised
Dated: September 1, 1986

34-7 Redrill, May 6, 1991 - August 1, 1991, T.D. 2010 Feet
Prepared by Wayne Portanova
Dated: November 27, 1991

Technical Report, Well #31-33, Permit #0049
by Union Geothermal Division
Dated: July, 1978

Cove Creek Geothermal **Financing of Cove Fort Station No. 1, Volume Two**
Dated: June 13, 1985

Agreement for **Purchase and Sale of Cove Fort Station No. 1** and Related Rights and Assets among MEI and Provo City, Utah
Dated: November 23, 1988

Deepening & Completion Report, Well 34-7B
Prepared by Higginson-Barnett, Consultants
Dated: May, 1985

Production Tests of Wells P88-1 & P88-2
Mesquite Report
Dated: May 9, 1989 (Two Copies) +1 +1

The Cove Fort-Sulphurdale KGRA, **A Geologic & Geophysical Case Study**
by: Earth Science Laboratory for: U.S. Dept. of Energy
Dated: September, 1982

Geology of the Cove Fort-Sulphurdale KGRA
by: J.N. Moore and S.M. Samberg for: U.S. Dept. of Energy
Dated: May, 1979 (Two Copies)

Joint Resource Ownership & Development Agreement
between MEI and Provo City, Utah
Dated: December 15, 1988

Proposal to Provide Engineering Service for the: Cove Fort Phase III
by: Power Engineering Inc.
Dated: January, 1989

Proposal for Engineering Consulting Services for: Cove Fort Phase III
by: SAI Engineers, Inc.
Dated: January 27, 1989

Proposal for Project Engineer of Cove Fort Phase III
by Ben Holt Co.
Dated: January 31, 1989

Fast Track Design and Construction on Cove Fort Phase III
by Ben Holt Co.
Dated: September 5, 1989

Cove Fort Injection Test
by Calpine Corp.
Dated: June 26, 1989

Proposal for Project Management and Engineering Services for Cove Fort Phase III
by: Calpine Corp.
Dated: January 31, 1989 (Two Copies)

Study and Report Phase III
by: Ben Holt Co.
Dated: June 21, 1989 (Six Copies)

Proposal for Testing, Design and Installation of a Noncondensable Gas Injection System
by: Calpine Corp.
Dated: March 3, 1989

Temperature Survey Log, Well #42-7
Dated: November, 1982

Assessment of Geoth. Energy Potential
for: MEI by: TSI Inc.
Dated: October, 1984

Completion Programs for MEI
by: TSI INC.
Dated: February 17, 1984

Completion Report on Well #34-7B
for: MEI by: Energy Service Inc.
Dated: April, 1984

Drill Site Recommendation for MEI by Earth Science Lab. ✓
Dated: December, 1982 (Four Copies)

Economic Analysis of Steam Prod. at the Geysers Geoth. Field, California
Dated: August, 1988

Union Oil Company of California, Formico #1, Geologic Report, Well Samples and Observations (Two Copies)

Geochemical Data, Well: Union Oil Comp. of California, Cove Fort-Sulphurdale Unit #31-33

Geophysical Investigation of the Cove Fort-Sulphurdale geothermal system, Utah

Key Issues affecting Future Electric Power Supply in the United States
World Electricity Conference of the Financial Times
Dated: November 12, 1990

Misc. Site Plan Maps

Preliminary Assessment of Cove Fort Geothermal Field
by Ormat
Dated: December 11, 1987

Preliminary Conclusions from October, November Testing
by: Energy Services Inc.
Dated: November 19, 1982

Preliminary Design Phase III
by: Ben Holt Company
Dated: August 24, 1989

Cove Fort Phase III Preliminary Grading Plan (Blue Print)
by: Ben Holt Co.
Dated: October 13, 1989

Cove Fort Field-Production Pumps for Hot Water Resource

Cove Fort Geothermal Well #42-7, Report of Testing
prepared for: MEI by: Energy Services
Dated: October 21, 1982

Review of Drill Site Recommendations
made to: MEI by: Higginson-Barnett, Consultants
Dated: March, 1983 (Three Copies)

Slim Hole Well Cost Analysis
for: MEI by: TSI Inc.
Dated: August 28, 1986 (Two Copies)

Sub-Surface Temperature Survey check
by: Pruett Industries
Dated: July 16, 1985 (25 Copies) 25

Statement pertaining to the Apparent Longevity of the Cove Fort/Sulphurdale Geothermal Reservoir Leases of MEI
by: Energy Service inc.
Dated: July 18, 1983

Misc. Survey Maps

Cove Fort
Box 7

Feasibility Report, Sulphur Deposits
by: Thermochem Industries Limited
Dated: March 6, 1969

Review of Drill Site Recommendations
to: MEI by: Higginson-Barnett, Consultants
Dated: March 1983

Ben Holt Co. Qualifications and Experience

Qualifications-Power Generation Projects, Evaluation and Management
by: Calpine

Proposal for MEI by Zonge Engineering (Three Copies)

Proposal for Project Management/Engineering Services- Cove Fort Phase III
by: Hill International

Proposal to UMPA for Project Engineer Phase III
by: Stone & Webster Engineering (Three Copies)

Proposal to UMPA for Phase III Generation Project
by: Barber-Nichols
Dated: January 30, 1989 (Two Copies)

Production Tests of Wells P88-1 and P88-2 ← dupl.
by: Ben Holt Company
Dated: May, 1989

Purchase and Sale of Cove Fort Station No. 1
and Related Rights and Assets among MEI and Provo City, Utah
1-46
Dated: December 1988

Completion Report, Well 34-7
prepared by: Energy Services, Inc.
Dated: February, 1984

34-7 Redrill, May 6, 1991 - August 1, 1991
T.D. 2010 Feet
prepared by: Wayne Portanova
Dated: November 26, 1991 (Five Copies)

Deepening & Completion Report, Well 34-7B *
prepared by: Higginson-Barnett
Dated: May, 1985 (Three Copies)

Completion Report, Well 34-7B NO
prepared by: Energy Services, Inc.
Dated: April, 1984 (THREE Copies)

Completion Report, Well P-89-1 *
prepared by: Geothermal Management Co.
Dated: January, 1990 (Seven Copies)

Completion Report, Well S-87-4 *
prepared by: Geothermal Management Co.
Dated: October, 1987 (Two Copies)

Completion Report, Well 34-30 O
prepared by: Higginson-Barnett
Dated: August, 1985

Completion Report, Well 47-6 O
prepared by: Higginson-Barnett
Dated: August, 1985

Technical Report, Well #42-07, Permit #0045
prepared by: Union Geothermal Division
Dated: May, 1986

Completion Report, Well 66-28 1of2
prepared by: Higginson-Barnett
Dated: August 1985

dupl.

Completion Report, Well 34-7B
prepared by: Energy Services
Dated: April, 1984

Technical Report, Well #42-7, Permit #0045
prepared by: Union Geothermal Division
Dated May, 1986

Completion Report, Well 34-30 have
prepared by: Higginson-Barnett
Dated: August, 1985

Completion Report, Well S-87-1
prepared by: Geothermal Management
Dated: October, 1987 (Two copies)

Completion Report, Well P-88-1A have
prepared by: Geothermal Management
Dated: July, 1989 (Three Copies)

Completion Report, Well S-89-4
prepared by: Geothermal Management
Dated: July, 1989 (Fifteen Copies)

Completion Report, Well S-89-5 have
prepared by: Geothermal Management
Dated: November, 1989 (Eight Copies) +

Completion Report, Well P91-4 have
prepared by: Geothermal Management
Dated: December, 1992

Production Tests of Wells P88-1 & P33-2
prepared by: Mesquite Group
Dated: May 9, 1989

Letter to Gerry Goodman/**U.S Dept. of Interior** from Wayne Portanova/**MEI**
RE: Geothermal Leases U-29553,U29554,U-29555 & U-29557
Dated: June 30, 1994 (Two Copies)

Letter to Mr. Al McKee/**U.S. Dept. of Interior** from John P. Williams/**Duncan & Allen**
Dated: July 1, 1994

Letter to G. Richard Judd/**UMPA** from Bob Wright/**Robert L Wright Consulting**
Dated: July 5, 1994

Letter to **All Mother Earth Consultants** from Wayne Portanova/MEI
RE: Sale of MEI to UMPA
Dated: June 28, 1994

Letter to Wayne Portanova/**MEI** from **Utah State Tax Commission**
RE: Federal Royalty Issue Letter (Misc. documents attached)

Amendment to Plan Of Operation
Federal Geothermal Leases U-29555-U29556 and U-29557-U-29558-U-37918
Prepared by: Wayne Portanova and Leon Pexton
Dated: June 28, 1994

Memo to: Mr. Lynn Finley/**USFS, Richfield Office**
Mr. Michael Jackson/**BLM, Richfield Office**
Mr. Al McKee/**BLM, State Office**
RE: Request to Calculate Volumetric Equivalent Annually
Dated: June 27, 1994

Proprietary & Confidential Information/MEI
Dated: June, 1994

Monthly Report of Geothermal Operations
by: Wayne Portanova
Dated: June 24, 1994

Plan for Production (PFP), on leases U-29558, U-37918, U-29555, U-29556, U-29557
by: Forsgren-Perkins Engineering
Dated: September, 1985

Baseline Data Report (BDR), on leases U-29555, U-29556,
U-29557, U-29558 & U-37918
by: Forsgren-Perkins Engineering
Dated: September, 1985

Amended Plan of Operation for leases U-29555, U-29556, U--29557, U-29558 & U-37918
Dated: March 1, 1985

Letter to Wayne Portanova/**MEI** from Jerry W. Goodman/**BLM**
RE: Approval plans of operations related to MEI's Federal Geoth. Lease.
Dated: February 25, 1992

Amended Plan of Operations for Geothermal Exploration and Dev. of Federal Geoth. Leases U-29555 & U-29557
Dated: July 1, 1986

Second Amendment to the Plan of Operation for Federal Geoth. Leases U-29555 & U-29557
Dated: November, 1985

Letter to **Forsgren-Perkins Engineering** from **U.S. Forrest Service**
RE: Plans of Operation for Geoth. Exploration and Development on Leases U-29553, U-29554, U-20556, U-20557, U-29558, and U-37918.
Dated: May 6, 1985

Amended Plant of Operation for Leases U-29555, U-29556, U-29557, U-29558 and U-37918
Dated: March 1, 1985

Plans of Operation of Geoth. Development
Prepared for MEI by: Forsgren-Perkins Engineering
Dated: March, 1985

Amended Plan of Operation for Geothermal Development on lease U-29558
Dated: September 13, 1984 (Revised)

Letter to **MEI** from **BLM**
RE: Special Conditions of Approval on Leases U-29556, U-29557 and U-29558
Dated: June 27, 1983

Plans of Operation for Geoth. Development

Fax to Mr. G. Richard Judd/**UMPA** from Mr. John P. Williams/
Duncan & Allen
RE: Closing documents Under the Final Settlement Agreement with MEI
Dated: June 20, 1994

Fax to John Williams/**Duncan & Allen** from **Bob Wright**
RE: MEI-UMPA deal "JRODA" Agreement
Dated: June 28, 1994

Letter to **MEI** from **BLM**
RE: Decision: Geothermal Leases U-29553, U-29554, and U-29555
Dated February 25, 1993 (Three Copies)

Letter to Michael Jackson/**BLM** from John P. Williams/**Duncan & Allen**
RE: Geothermal Lease No. U-29557: Geothermal Sundry Noticed Filed by Provo on May 25, 1993
Dated: June 29, 1993

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Request for Additional Information; Geothermal Sundry Notice for Restoring Injection Well 42-7, Lease U-29557
Dated: March 15, 1993

Certified Mail to Clearview Geothermal, Paradise Valley, AZ
RE: Notice, Geothermal Resource Lease Terminated, Reinstatement Procedures
Dated: August 1, 1991

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Written Order--Metering for Producing Geothermal Wells, 34-7A & 34-7B, Lease & 29557, Meter Stations A and B; Monthly Reports of Operations
Dated: September 10, 1992 (Two Copies)

Letter to Tobias Martinez, Forest Supervisor/**Fishlake National Forest** from Jerry Goodman/**BLM**
RE: special Use Permit for Utilizing Well 42-7, Lease &-29557, for Disposal of off-lease Geothermal Fluid
Dated: November, 3, 1992 (Three Copies)

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Written Order, Reports of Operations
Dated: November 3, 1992 (Four Copies)

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Lease Operations
Dated: Dec;ember 18, 1992 (Four Copies)

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Meeting with Provo City
Dated: January 7, 1993 (Seven Copies)

Letter to Ron Rydman/**Provo City** from Jerry Goodman/**BLM**
RE: Conference call about disposal of condensate
Dated: January 13, 1993 (Two Copies)

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Restoration of Production on Federal Lease u-29557 & Reconditioning of Injection on Well 42-7
Dated: January 29, 1993 (Two Copies)

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE:Plan of Injection, Amendment, Geothermal Lease U-29557
Dated: May 4, 1993 (Two Copies)

Letter to Wayne Portanova/**MEI** from Jerry Goodman/**BLM**
RE: Caliper Logging of Injection Well 42-7, Lease U-29557
Dated: July 2, 1993 (Two Copies)

Letter to Ron Rydman/**Provo City** from Jerry Goodman/**BLM**
RE: Geothermal Sundry Notice for Metering, Lease U-29557
Dated: July 2, 1993 (Two Copies)

Letter to Jerry Goodman/**BLM** from John Williams/**Duncan&Allan**
RE: Letter No. 3260 (U-052) Concerning the Geothermal Sundry Notice for Metering, Lease U-29557
Dated: July 21, 1993 (Five Copies)

Engineering Plant Program for Repair/Modification Cove Creek Geo. Power Plant
Prepared by Ormat Inc.
Dated: November 19, 1987

Drilling and Testing Program for the Cove Fort Geothermal Project
by: Thermasource, Inc.
Dated: March 20, 1985

Completion Report, Well 34-7B, Cove Creek Geothermal
Prepared by: Energy Services, Inc.
Dated: April, 1984

Final Report on CSAMT, SP, and Magnetics Data, Sulphurdale KGRA
by: Zonge Engineering and Research Organization
Dated: 1987

Technical Report Well #31-33, Permit #0049 ← Union
by: Union Geothermal Division
Dated: August, 1978

Drilling and Completion Program for a Geothermal Exploration Well 24-7 ←
by: TSI
Dated: September 1, 1986

Critique of Energy Serviced Performance on 34-7 & 34-7B
by TSI
Dated: January 31, 1985

Energy Conversion Systems for Sulphurdale, Utah Geothermal Resource
by: Ronald DiPippo
Dated: February, 1985

Mesquite Report, Production Tests of Wells P88-1 & P88-2 dupl
by: Mesquite Group
Dated: May 9, 1989

34-7 Redrill, May 6, 1991 - August 1, 1991, T.D. 2010 Feet ← note this
Prepared by: Wayne Portanova
Dated: November 27, 1991

Plans of Operation for Cove Fort
Prepared by Energy Services
Dated: February, 1983

Plans of Operation of Geothermal Development
by: Forsgren-Perkins Engineering
Dated: March, 1985

Completion Report, Well 34-7A ←
Prepared by: Higginson-Barnett

Cove Fort Environmental Volume II
Dated: January 22, 1975 (Two Copies)

Assessment of Geothermal Energy Potential
by: TSI
Dated: October, 1984

Completion Programs
by: TSI
Dated: February 17, 1984
Analysis and Synthesis of 1976-1987 Geoscientific Data related to Exploration for and Development of Geothermal Resources at Cove Fort-Sulphurdale
by: Geothermal Management co.
Dated: February, 1988

Amended Plan of Operation for Geoth. Development on Lease U-29558
Dated: September 13, 1984 (Revised)

Drill Site Recommendations for MEI
by: Joseph N. Moore & Howard P. Ross/Earth Science Lab.
Dated: December, 1982

Data Report, October-November 1989 Well Testing, Cove Fort
by: Jay Hauth
Dated: December 4, 1989

Estimation of Reservoir Volumes in the Cove Fort Field
by: Joseph N. Moore and Gerald Hunter
Dated: October, 1990

Geophysical Investigations of the Cove Fort Geothermal System, Utah
by: Howard P. Ross and Joseph N. Moore (Copies of Article from Magazine)
Dated: November, 1985

Letter to Daniel Schochet/**Ormat** from James R. McNitt/**Geotherm EX, Inc.**
RE: Preliminary Assessment of Cove Fort Geothermal Field
Dated: December 11, 1987

Cove Fort Geoth. Well #42-8 Report of Testing
by: Energy Services
Dated: October 21, 1982

Review of Drill Site Rec. made to MEI
by: Higginson Barnett
Dated: March, 1983

Letter to Wayne Portanova/**MEI** from Louis Capuano/**TSI**
RE: Slim Hole Well Cost Analysis
Dated: August 28, 1986

Sub-Surface Temperature Survey
by: Pruett Industries
Dated: July 16, 1985

Proposal to MEI for Valuation of the MEI Leases in the Cove Fort Field
by: GeothermEX, Inc.
Dated: August 28, 1989

Testing Report, Cove Fort Well 42-7
by: Energy Services
Dated: November 1982

Cove Fort Sulphurdale Unit #14-29 Report (Union)

Sample Reports
Dated: July, 1985

Cove Fort KGRA Well Test Reduced Pressure Data
Dated: 1989 (Two Copies)

Deepening & Completion Report, Well 34-7B
by Higginson-Barnett
Dated: May, 1985

Completion Report, Well 34-7
by Energy Services
Dated: February, 1984

Completion Report, Well 66-28 (dupl.)
by: Higginson-Barnett
Dated: August, 1985

Completion Report, Geothermal Exploratory Well S-87-4 (dupl.)
by: Geothermal Management Co.
Dated: October, 1987

Completion Report, Well 34-30 dupl
by: Higginson-Barnett
Dated: August, 1985

Completion Report, Well P-89-1 dupl
by: Geothermal Management Co.
Dated: January, 1990

United States Dept. of the Interior, Geological Survey, Conservation Div. Office of the Area Geothermal Supervisor, Environmental Analysis
Prepared for leases U-28947, U-28948, U-29215A, Phillips Petroleum Comp. and U-29553 through U-29558, Union Oil Company, Cove Fort-Sulphurdale KGRA, Utah.
Dated: June 22, 1977

US Dept. of the Interior, Geological Survey, Environmental Base Line Report
Dated: 1974

Completion Report, Well S-88-3 dupl
by: Geothermal Management Co.
Dated: August, 1989

Completion Report, Well P-88-2 dupl
by: Geothermal Management Co.
Dated: July, 1989

Cove Fort Geothermal Project, Phase 1 Agreements
Joint Development and Management Agreement among MEI and Provo City
Dated: July 3, 1985

Completion Report, Well 34-7A dupl
by: Higginson-Barnett
Dated: March 1985

Letter to Donald Pendleton/**US Dept. of Interior** from Wayne Portanova/**MEI**
RE: Well 24-7 Completion Report Transmittal
Dated: January 23, 1987

Water Supply & Water Right Consideration
by: Higginson-Barnett
Dated: December, 1985

Completion Report, Well P-88-1A
by: Geothermal Management
Dated: July, 1989

dupl

Completion Report, Well S-87-1
by: Geothermal Management
Dated: October, 1987

dupl

Completion Report, Well S-89-1
by: Geothermal Management
Dated: June, 1989

dupl

Maintenance Record File
Ormat Energy Converter 500

Maintenance Record File
Ormat Energy Converter 200

Maintenance Record File
Ormat Energy Converter 400

Maintenance Record File
Ormat Energy Converter 300

Maintenance Record File
Cooling Water System

Maintenance Record File
Compressed Air Station

Maintenance Record File
Motive Fluid - Filling/Emptying System

Maintenance Record File
Cooling Water Pump

Maintenance Record File
Steam System

Provo Geothermal Power Plant, **Training Seminar**
by: Ormat Systems Inc.
Dated: May, 1989

Provo Geothermal Substation Blue Prints
Dated: September 27, 1984

Provo Geothermal Substation No. 1 Construction Drawings
Dated: 1984

ADT Focus-48 System, Proposal for Brent Thomas/MEI
by: ADT Security Systems
Dated: January 22, 1985

MEI Topping Turbine Manual

MEI Parts List
by: Barber-Nichols
Dated: November, 1987 (Two Copies)

Geothermal Plant Facility No. 1 Steam Line Alignment Map
Dated: January 31, 1985

Blue Print: Cooling Tower Spring Collection System
by: Sunrise Engineering
Dated: November 18, 1988 (Four Copies)

Material Safety Data Sheet
For: Isopentane by: Phillips Petroleum
Dated: March, 1986

Topping Turbine I Drawings (all in manilla folder)

Blue Print: Turbine Piping Layout
by: Barber-Nichols
Dated: October 30, 1987 (Four Copies)

Flow Measurement Systems, Installation & Operating Manual
by: Dieterich Standard Corporation

Blue Print: Cove Fort Spring Development
by: Provo City Corp.
Dated: July, 1989

Blue Print: Provo Geothermal Substation No. 1
by: Burns & McDonnell
Dated: September 27, 1984

Blue Print: Mother Earth Industries Plant Site
by: Sunrise Engineering
Dated: September 3, 1987

Blue Print: Cove Fort 100,000 Gallon Reservoir
by: Provo City Corp.
Dated: September, 1989

Spare Parts List for Cove Fort
by: Geothermal Development Assoc.
Dated: January 8, 1991

Memorandum to Wayne Portanova/**MEI** from Ron Rydman/**Provo City Corp.**
RE: Minutes of Management Committee Meeting Held in Provo
Dated: May 14, 1992

FAX to George Morse/**Provo City Corp.** from Steve Russell/Analog & digital Systems
RE: Computer System Upgrade
Dated: May 15, 1992

Letter to Bud Bonnett/**UMPA** from Dean Deines/**Ben Holt Co.**
RE: Additional Spare Parts List for Cove Fort Phase III
Dated: September 5, 1990 (Two Copies)

FAX to George Morse/**Provo City Corp.** from Joe Moore/**Univ. of Utah Research Institute**
RE: Copy of lighologic log and report on P-91-4
Dated: May 19, 1992

Letter to Bud Bonnett/**UMPA** from Dean Deines/**Ben Holt Co.**
RE: Recommended Spare Parts List for Phase
Dated: August 13, 1990

Letter to Ron Rydman/**Provo City Corp.** from Cheryl Wirtz/**MEI**
RE: Copy of MEI's BLM approved permit to operate the 20: steam line crossover
Dated: April 1, 1991

Letter to Bud Bonnett/**UMPA** from Norma Swinea/**Nitram Energy**
RE: U-1A Manufacturers Data Report
Dated: March 16, 1991

Site Drawing of Cove Fort from MEI
Dated: May 12, 1989

Rotork Electrical Spec. Diagram

Instruction for the Selection, Installation and use of the Type 91 Series Adapter Set
by: Fisher Controls
Dated: February 1984

Correct Dart Installation, Weatherproof & General Purpose Units

Errata Sheet for 5190 Series Temp. Controllers
by: Fisher Controls
Dated: February, 1984

Analysis of Acceptance Test Data for MEI Binary Geothermal
by: Ronald DiPippio
Dated: October 22, 1985

Diagram: SCADA System at Cove Fort
by: Lectrol Inc.
Dated: June 113, 1985

MEI Power Statio Operating Procedures Manual

Operation & Maint. Procedures for the MEI Topping Turbine
by: Barber-Nichols
Dated: November, 1988

MEI Topping Turbine Manual
by: Barber-Nochols
Dated:

Operation & Maint. Manual, Ormat Geoth. Power Plant, Cove Creek, Utah
Dated: June, 1985 (Revision 1)

MEI Parts List
by: Barber-Nichols
Dated: November, 1987

FINAL REPORT ON CSAMT, SP, AND MAGNETICS DATA SULPHURDALE KGRA for MOTHER EARTH INDUSTRIES, INC

FINAL REPORT ON CSAMT, SP,
AND MAGNETICS SURVEYS
SULPHURDALE PROJECT
BEAVER COUNTY, UTAH
for MOTHER EARTH INDUSTRIES, INC.

INTRODUCTION

At the request of Wayne Portanova of Mother Earth Industries, Zonge Engineering and Research Organization conducted SP, Magnetics, and CSAMT surveys at the Sulphurdale KGRA in order to assist in continuing development of the site. The surveys were originally scheduled to be run in February, 1987, but weather problems delayed some of the SP and all of the CSAMT until May, 1987. The original SP and Magnetics were discussed in a final report already issued, although this report includes references to that data and its correlation to the CSAMT data.

The primary intent of the surveys was to assist in the understanding of the subsurface structure, particularly faults and fractures, and fluid properties as they may relate to the geothermal activity. Two producing wells (34-7A and the 34-7B) were in place at the time of the survey. A dry well (24-7) was located only 450 feet from one of the producers, thus lateral resolution and station density were considered of primary importance. CSAMT was chosen as the principle mapping tool because of its superior lateral resolution compared to other electrical methods. In addition, CSAMT has been used very successfully in other geothermal projects, including detailed monitoring of a geothermal reservoir during exploitation.

A 250'-by-250' grid was suggested, in light of the short distance between the dry well and the producers. The 250' grid was used for the SP and Magnetics surveys, but a 500'-by-500' grid was used for the CSAMT survey because of budget constraints. The E-field dipole size was 250 feet.

The three-person crew mobilized from Tucson, Arizona on May 17, 1987. Hank Giclas was the crew chief in charge of operations, with Jeff Wallace and Arnie Ostrander (degreed geologists) acting as field technicians. Transmitter location and permit problems delayed data acquisition until May 21, but the survey proceeded relatively smoothly after that. The original survey estimate had been for each receiver to acquire 6 stations per production day. Only one receiver was available for this job, but the crew was able to achieve 5.8 stations per day, or very nearly the original job estimate. The crew completed the CSAMT work on June 1, 1987 and returned to Tucson on June 3, 1987. On June 2, 1987, an additional crew chief was sent to Sulphurdale to finalize the SP survey, which was

LINE AND STATION LOCATION - Station locations were determined in the field using Brunton compasses and a chain. The main grid itself was originally located by establishing station 6 of Line 6 (the center of the grid) between the producing geothermal wells Olga and Linda. From station 6 of Line 6, Olga was due west, and Linda was at a bearing of N 85 E. From this point, stations were chained and bearings were maintained with Bruntons. Using locations of these two wells (relative to the northwest section corner of Section 7) provided by the client after the survey, it appears that the station locations are less than 40 feet off on the west side of the grid and less than 50 feet off on the east side of grid, according to landmarks described by the crew in the field notes (for example, the west section line fence of Section 7 and its intersection of Line 1 of the grid). Large discrepancies were originally suspected when the grid was plotted relative to the dry well 42-7. Based upon the legal description and location of the well provided by the client, it is now obvious that the 42-7 well is plotted incorrectly on the University of Utah's "Geologic Map of the Cove Fort-Sulphurdale KGRA", which was originally being used as a base map. The discrepancy (approximately 300 feet) accounts for the original problems in correlating field notes with known map features. All stations in the grid were marked on the ground with wood stakes during the first phase of the survey (SP and Mag).

Spider lines (Lines 12, 14, 15, 16, 17, 18, and 19) were also located using Bruntons and chains. Lines 16, 17, and 19 were along roads shown on the USGS Cove Fort 15' quadrangle. Stations 1 through 5 of lines 16 and 17 were marked on the ground with wood stakes; the remaining stations of these three lines were marked with flagging only, primarily because the field crew was told that the property was unpermitted.

Integral stations (stations 1, 2, 3, and 4) of lines 14 and 15 were marked with wood stakes; fractional stations were marked with flagging.

Line 12 was along a dirt road not shown on the USGS topo map; stations were marked with wood stakes. (Note: a road is shown on the map in the general area, although the road shown is approximately 250 feet north of the road actually used for Line 12. The map is dated 1962, however, and the road used may be more recent.)

Stations on Line 13 were marked with wood stakes, and were chained from station 8 of Line 11.

The bearing of Line 18 was due South, along the eastern perimeter of the sulphur pit. Stations 1, 2, and 3 were marked with wood stakes. Stations 13 and 23 were positioned due east and west (respectively) of station 3, and both were 500 feet from station 3. Station 4 was located due south of station 3, and was 30 feet from the thermal gradient hole. Stations 24 and

34 were due west of station 4, and were 500 and 1000 feet away, respectively. Station 5 was 500 feet due south of station 4. These stations were marked on the ground with flagging.

The orientation of the grid itself was chosen based upon the optimum transmitter location. CSAMT transmitters are best located in areas of deep basement in low resistivity ground, if possible. Two sites near the Sulphurdale project were considered to be suitable, one northwest of the target area and one to the southwest. The northwest site was used, with a transmitter orientation of N 27 E. This required that the E-field dipole also be N 27 E, and to make movement between stations as fast as possible, the main grid lines were also oriented N 27 E.

DATA PLOTS- Included in this report are pseudosections of raw Cagniard resistivity for all lines, as well as filtered, corrected resistivity for selected lines and cross-sections. The filtered data are included primarily to highlight features which are seen in the raw data, but which may be somewhat obscured by noise. The filter used was a 3-point "comb" filter on a station-by-station basis. In addition, since static offset effects are present, all the filtered data were also corrected for static offset using the phase difference data, since phase difference is not affected by static offset. All data were corrected using the same resistivity and phase normalization values (8.5 ohm-meters and 851 milliradians, respectively) at 64 Hz., effectively stripping off the upper frequencies which were strongly affected by powerline noise. These plots are labeled "CORRECTED RESISTIVITY" and include data only up to 64 Hz., as compared to the raw Cagniard resistivity plots which are labeled "CAGNIARD RESISTIVITY" and contain data up to 4096 Hz. The filtered, corrected data are an excellent method for looking a fundamental differences in resistivity curve shape. Changes in curve shape are a definite indication of resistivity changes from station-to-station. Static offsets may cause an apparent change in resistivity between stations when in fact the change results only from a small, near-surface feature which is causing a complete shift of the resistivity curve.

Also included are pseudosection plots of phase difference data for all lines, as well as resistivity vs frequency curves for all stations (plotted on a log-log scale, referred to in the report as log-log curves).

SUMMARY AND CONCLUSIONS

The region examined on the Sulphurdale project can be divided into several distinct areas based upon the electrical data. The region west of the main grid area (comprised of most of Lines 16 and 17, and all of Line 19) is characterized by high-over-low resistivities, generally higher resistivities than the main grid area, and a 2 Hz. transition zone notch. This area shows relatively uniform data, and a definite decrease in resistivity to the east. No distinctly anomalous areas are noted in this region, and the decrease in resistivity to the east is smooth and gradational. The lower frequency transition zone notch (compared to the main grid area) suggests a deeper basement in this "regime" west of the grid.

Line 14, north of the main grid, exhibits characteristics very similar the "regime" west of the grid. Stations 1 and 3 both show a distinct 2 Hz. notch, as well as higher resistivities than the main grid. In addition, several of the northeastern stations of the grid also show a 2 Hz. notch, suggesting that the region northeast of the main grid area may be similar to the region already described west of the grid, i.e., a deeper basement. With only 2 stations on Line 14 and the northeast end stations of the grid lines, there is not sufficient data to determine definitely if this is the case.

The main grid area (Lines 1, 3, 5, 7, 9, and 11) shows localized variations as well as a "regional" trend superimposed on these local variations. Contrary to the "regime" west of the main grid, data for the main grid show a gradual increase in resistivity to the northeast. Most of the stations are characterized by a generally uniform resistivity curve, rather than a distinctly high-over-low curve as seen on Lines 16, 17, and 19. Several stations within the grid show anomalously conductive values, however, similar to data gathered over other known geothermal sites. Station 5 of Line 5 and station 5 of Line 7 both exhibit anomalously conductive values in the frequency range of interest. Both stations also exhibit phase difference values which are higher than surrounding stations, and suggest a stronger high-over-low resistivity contrast than other areas of the grid. Since these two stations are near the production wells 34-7A and 34-7B, and since the data are similar to data at other known geothermal sites, these stations are taken as the "template" anomaly for the Sulphurdale site. (There are other electrical indications of potential geothermal targets of course; comparison of the "template" area to the surrounding data is intended to assist in evaluating extensions of the current production site, or areas very similar to the production site.)

Within the grid area, other anomalous stations include station 3 of Line 11 and, very weakly, station 3 of Line 9. Station 3 of Line 11 exhibits a distinct high-over-low curve shape, low resistivities in the range of interest, and high phase difference values, similar to station 5 of Lines 5 and 7.

South of the grid, on Line 18, anomalous stations are also seen at stations 4 and 5. This portion of Line 18 looks very similar to the data around the production area, exhibiting distinct high-over-low layering, low resistivity at depth, and high phase values. Without stations further to the south, however, it is not possible to determine whether the low resistivities seen at stations 4 and 5 of Line 18 are the result of an anomalously conductive area similar to the production area, or whether these are transitional stations between the grid area and another "regime" south of the grid which is similar to the areas west of the grid and north of the grid. Stations 24 and 34, which are due west of station 4 of Line 18, both show distinct high-over-low layering and a 2 Hz. notch, identical to the Line 16, 17, and 19 "regime". Thus stations 4 and 5 may be transitional, similar to station 1 of Line 17, which shows similarities to the main production area, but is interpreted to be transitional between the "regime" west of the grid and the grid itself.

A very distinctive high resistivity area is noted in the southern part of the grid, characterized by a strong low-over-high resistivity environment. This well defined area is comprised of stations 3, 2, and 1 of Line 18, and stations 1 of Lines 5 and 7. Nearby stations are similar, but the high-over-low character is not quite as strong, such as at stations 3 of Lines 3 and 5. No other stations in the grid or on the spider lines are similar to this high resistivity area, which is clearly evident in the Cagniard resistivity data, and is most obvious in the corrected resistivity for cross-sections B-B' and C-C'. This region separates the low resistivity region near the production wells from the low resistivity region on Line 18 already discussed. It should be noted that in some geothermal environments, areas of steam caps (as compared to fluids) will appear as anomalously high resistivities, compared to the normal low resistivity targets in standard geothermal exploration. This high resistivity area coincides with a north-south fault, although the high resistivities cover a fairly broad area, based upon the interpretation of stations 13 and 23 of Line 18.

Comparison of the CSAMT data with the previously gathered Magnetics data shows some interesting correlations. The high resistivity area in the southern part of the grid discussed above is well defined in the magnetics data as a magnetic low. Areas of intense hydrothermal alteration are normally characterized by magnetic lows, but it must be pointed out that the production area at the Sulphurdale site is defined by anomalously high magnetic readings.

As noted, the area surrounding the production wells is characterized by low resistivities, which would be expected for a geothermal target. These low resistivities coincide very well with a high magnetic anomaly (which is contrary to the norm, geothermal areas normally being associated with magnetic lows), both showing signs of possible extensions to the northeast, but both showing a slight decrease in response between the central production area and the possibly anomalous area on the northeast end of Lines 7 and 9. In addition, a positive SP anomaly is also well correlated with the other two data sets.

Another correlation weakly seen between the different sets of data is in the area of a small hill west of the dry hole 24-7. This area is a magnetic high (similar to the production area), a negative SP anomaly (contrary to the production area) and may be a very slight resistivity low in the CSAMT data (similar to the production area). All three data sets delineate the area as being anomalous, although the nature of the anomaly is inconsistent.

Comparison of the three data sets also serves to highlight the extreme lateral variation in the area, and the need for high density data at this site. For example, the area near the dry well 42-7 on the northeastern part of the grid is seen in the magnetics data as being very rapidly varying over a relatively short distance (less than 250 feet). In the CSAMT data at 500 foot intervals, the nearest station to the dry hole is station 11 of Line 7, a conductive station, which therefore might be interpreted to be an attractive target. Station 11 of Line 7 is also a magnetic high, again similar to the production in the center of the grid. Yet the very close spacing of the magnetic data on Line 15 near the dry hole reveals a rapid decrease in the magnetic anomaly, suggesting that the 42-7 site may be on the edge of an attractive area, but not necessarily within the anomaly. Similarly, other locations within the grid are seen to be rapidly varying in the magnetic data over very short distances, such as between station 6 of Line 2 and station 7 of Line 2 (a distance of 250 feet). The CSAMT data, at 500 foot intervals, tends to physically filter out many of these changes, making identification of small narrow features particularly difficult. Location of faults is similarly difficult in the CSAMT data at this station density.

Differences in the data sets are also evident, although this is to be expected since the SP and Magnetics are point measurements while CSAMT is a vertical sounding, thus providing depth information. For example, in the Magnetic data, the spider lines 16, 17, and 19 are not seen to be significantly different from the main grid area. In the CSAMT data, however, this region is substantially different, particularly in the deeper data. Similarly, the spider lines northeast of the main grid are not particularly different in the magnetic data relative to the main grid, but deep CSAMT data on Line 14 suggest a definite change in this area.

To summarize, a small area near the current production wells is found to be anomalous in all three data sets. This area appears to be conductive in the CSAMT, which is consistent with previous geothermal CSAMT work. Geothermal areas are normally conductive as a result of the changes in pore spaces and pore fluids due to the geothermal conditions. The area is also found to be anomalously high in the Magnetic data, although a Magnetic low is usually associated with areas of geothermal alteration. Also evident in this central production area is an SP high. Geothermal alteration areas are normally associated with SP lows, but the correlation of the SP anomaly with the Magnetic and CSAMT anomalies is extremely good. This anomalous area consists of stations 5 and 6 of Line 5, stations 5 and 6 of Line 6, and in the CSAMT data, station 5 of Line 7. The anomalous area does not extend to the west beyond Line 4, and does not extend to the south beyond station 3 of Lines 5 and 7.

An extension of this anomalous area is possible to the northeast. Conductive values are seen at stations 9 and 11 of Line 7, and at stations 9 and 11 of Line 5. Stations 9, 10, and 11 of Line 7 are also anomalously high in the Magnetics data, making this area very similar to the main production area. Lines 14 and 15 of the magnetic data do not indicate a continuation to the northeast of this extension beyond station 11 of Lines 7 and 9, however, and Line 14 of the CSAMT data suggests a change of "regime" to the northeast.

It should be noted that the region in between these two anomalous areas (the main production area and the area to the northeast) is also conductive and high magnetically, but less so than the two described anomalous zones. The fact that the two regions are separate in both data sets is encouraging as far as data consistency is concerned, but it suggests a very complicated picture with regards to attractive target sites.

A third conductive region is seen in the CSAMT data on the extreme southern end of Line 18, at stations 4 and 5. This area was not covered by the magnetic survey however. These two stations indicate conductive values and curve shapes similar to the production area, but without data surrounding the stations, it is also possible that these two stations are not anomalously low by virtue of geothermal conditions, but merely as transition stations between the high resistivities of Line 18 and a different "regime" to the south. Stations 24 and 34 of Line 18 (due west of station 4) appear to be similar to the Line 16, 17, and 19 "regime". Additional data would have to be gathered before this site could be considered an attractive target.

No other areas of conductive values are observed which would indicate the presence of geothermal targets. Magnetic data indicate a possible target associated with the small hill west of the dry hole 24-7, but the CSAMT data stations are not dense enough to verify this definitely as a low resistivity target.

DETAILED DISCUSSION OF THE DATA

Much of the interpretation of the CSAMT data is based upon the shape of the resistivity curves (resistivity vs. frequency). Since depth of investigation is frequency dependent, changes in resistivity with depth are can be seen by examining the change in resistivity with frequency. The resistivity curves at the Sulphurdale site can be divided into three general curve types, which are shown in Figure 1. Most of the curves are relatively flat, and approximately homogeneous in the frequency range of interest. The stations near the production wells and north-northeast of the production wells, as well as stations 4 and 5 of Line 18 exhibit a definite high-over-low resistivity environment in the range of interest, suggesting low resistivities at the target depth. A few stations (stations 1 and 2 of Line 18, stations 1 of Lines 5 and 7, and stations 3 of Lines 3 and 5) exhibit a definite low-over-high environment, suggesting high resistivities at the target depth. The small, limited area of high resistivities may also be of interest, depending upon the known or suspected hydrology of the reservoir. In some environments, steam has been known to produce similar high resistivities. This small area of high resistivity (comprised of only six stations oriented approximately north-south, from station 2 of Line 18 to station 3 of Lines 3 and 5) may be an indication of an area of steam, rather than liquid water.

<u>LINE 1</u>

Line 1 raw data are relatively uniform. At depth, resistivities gradually increase to the northeast along the line. In the shallow data, the high resistivities at stations 5 and 7 are coincident with a small hill; it should also be noted that it is possible that station 9 is lower in resistivity than normal due to the topographic low at that location. If the latter is the case, Line 1 exhibits increasingly high resistivities to the northeast, or at least a thickening of the near-surface high resistivities to the northeast.

<u>LINE 3</u>

Line 3 raw data are similar to Line 1 in that a general trend toward higher resistivities is seen to the northeast. Stations 5 and 7 are on the same hill as stations 5 and 7 of Line 1 (although not as high on the hill), but no shallow high resistivities are seen on this line. Station 9 of this line falls in the same drainage as station 9 of Line 1, but values at station 9 of Line 3 are not low relative to surrounding Station 5 of this line is interesting in that it is

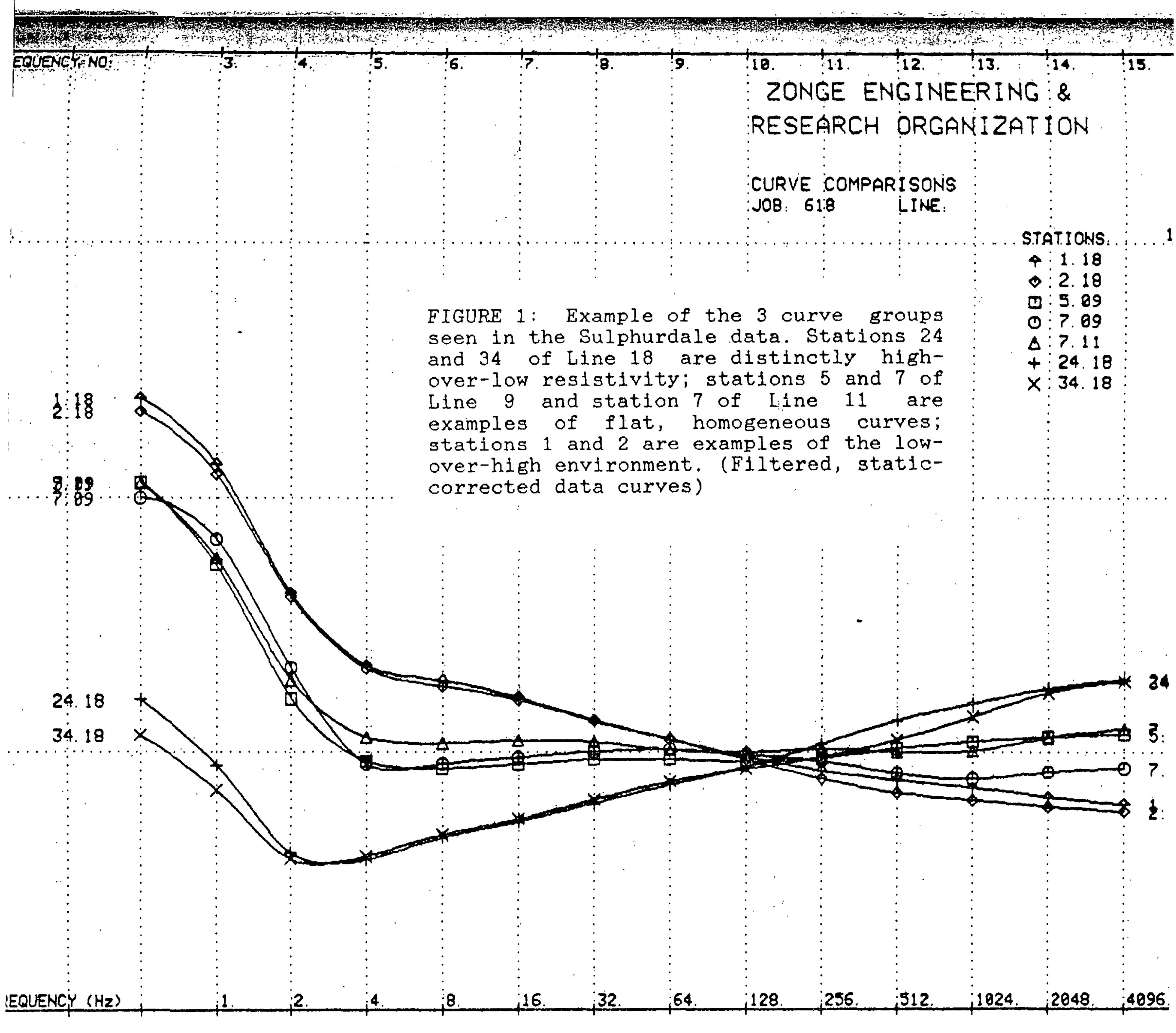


FIGURE 1: Example of the 3 curve groups seen in the Sulphurdale data. Stations 24 and 34 of Line 18 are distinctly high-over-low resistivity; stations 5 and 7 of Line 9 and station 7 of Line 11 are examples of flat, homogeneous curves; stations 1 and 2 are examples of the low-over-high environment. (Filtered, static-corrected data curves)

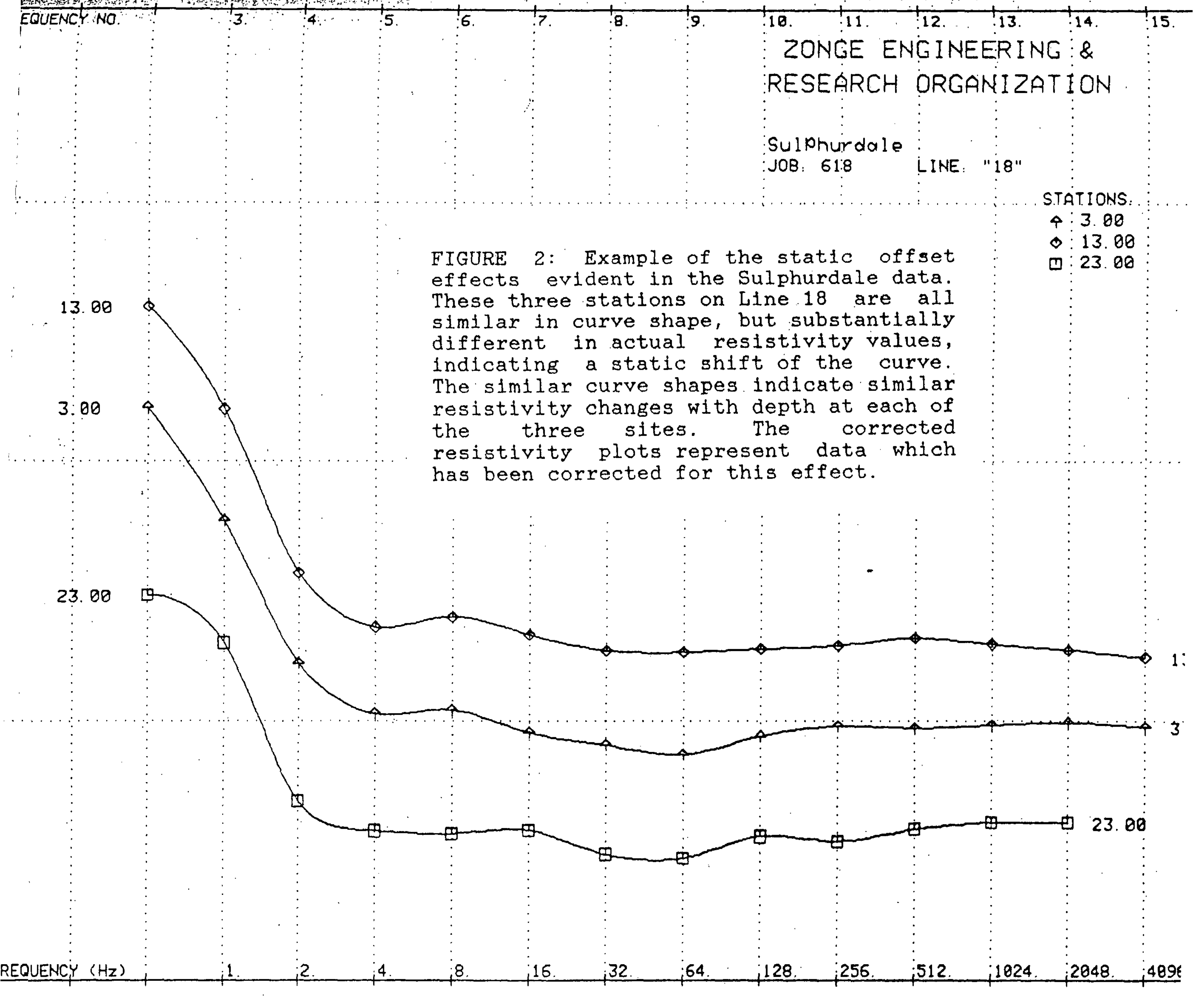


FIGURE 2: Example of the static offset effects evident in the Sulphurdale data. These three stations on Line 18 are all similar in curve shape, but substantially different in actual resistivity values, indicating a static shift of the curve. The similar curve shapes indicate similar resistivity changes with depth at each of the three sites. The corrected resistivity plots represent data which has been corrected for this effect.

slightly lower in resistivity than the other stations, although the contrast is not as great as is seen at station 5 of Line 5. Phase difference data do not show an increase in the frequency range of interest, while station 5 of Line 5 does exhibit such an increase.

LINE 5

Line 5 shows more variation in the raw data than Lines 1 and 3. The same general trend toward higher resistivities to the northeast is evident, although this trend is interrupted by anomalously low values at depth at station 5 and station 9. Station 5 is characterized by consistently high phases down to 4 Hz., and exhibits its lowest resistivity value at 4 Hz. Station 9 also has high phases, although not as consistently as station 5. (Station 11 exhibits a steep notch at 2 Hz, similar to stations on Lines 16, 17, 19, and 14.)

Station 5 of Line 5, as well as station 5 of Line 7 are seen to be anomalous at approximately the depth of interest, and are the basis for comparison in examining data at other stations with respect to possible geothermal targets. Due to the possible small size of the targets, and the absence of any immediately adjacent stations to these two anomalous stations, these two stations must be used with caution as "template" stations. If stations 4 and 6 of Lines 5 and 7 had also been acquired as CSAMT stations, a better understanding of the production area could be developed. In the absence of such data, the low resistivities at the depth of interest are consistent enough with previous geothermal work to interpret as being the result of the geothermal target.

LINE 7

Raw data for Line 7 also indicate low resistivities at station 5, very similar to station 5 of Line 5. The lowest values are at 4 Hz., and high phase values are evident (although not as consistently as on Line 5). Again, a trend toward higher resistivities to the northeast is apparent along this line. A region of high phase values is seen at station 9 and 11 at frequencies of 64 Hz. through 8 Hz.

LINES 9 and 14

Comparison of the Line 9-14 combination to cross-sections A-A' and C-C' shows similar trends in both the Cagniard Resistivity and phase difference data. The northeast end of Line 9 and both stations of Line 14 are characterized by higher resistivities than the main grid area, and the transition zone notch is at 2 Hz., as compared to the main grid area where the notch is seen at 4 Hz. Moving northeast along Lines 9-14, an increase in resistivity is seen between stations 7 and 9, and between stations 9 and 11 the notch shifts from 4 Hz. to 2 Hz. Continuing northeast, station 1 of Line 14 exhibits a very steep notch at 2 Hz,, and the data are very similar to the "regime" west of the main grid evident in the Line 16, 17, and 19 data. A similar change is seen on cross-section B-B', although the data are noisier and the change to the northeast is less well-defined on cross-section B-B'.

Station 1 of Line 9 is very similar to stations 1 and 2 of Line 18, as well as station 1 of Line 7, all of which exhibit a definite high-over-low resistivity environment. Stations 3 through 9 are relatively homogeneous, and station 11 exhibits a well-defined notch at 2 Hz. Stations 1 and 3 of Line 14 also exhibit a 2 Hz. notch, appearing very similar to the curves of Lines 16, 17, and 19.

In the filtered, corrected data, Lines 9 and 14 are very uniform, with a change in the deeper data between station 11 of Line 9 and station 1 of Line 14 which is very similar to the change seen along the A-A' cross-section. (In the filtered pseudosection, station 11 of Line 9 exhibits a notch at 4 Hz.; this is an artifact of the filtering process. The transition zone notch is at 2 Hz., as seen the Cagniard resistivity curves.)

<u>LINE 11</u>

Raw resistivity values for Line 11 are generally higher than the other lines; a trend towards higher resistivities to the northeast is not seen on this line, however. Station 3 of this line is anomalous compared to the other stations, showing a stronger high-over-low contrast. All other stations show relatively little variation with depth, and phase values indicate only a very weak high-over-low environment. Station 3 shows both high phase values and a well-defined resistivity low in the 8 Hz. and 16 Hz. values. While this is not identical to the data near the production wells, it may be an indication of a low resistivity region at a slightly shallower depth (than the production area). In the filtered, corrected data, station 3 appears similar to station 3 of Line 7 (see the S-3 pseudosection), which is between the high resistivity feature and the anomalous production area. Thus, station 3 of Line 11 may be near but not directly over a potential target area. The small target size versus the station spacing does not rule out this possibility, unfortunately, and a narrow target area may exist between stations 2 and 4 of this line, but not necessarily directly beneath station 3. Conceivably, such a narrow target could extend from near station 3 of Line 11 and into the central grid area without strongly affecting the stations gathered in this survey.

CROSS-SECTION A-A' (LINE 16 and GRID STATIONS 9)

This cross-section delineates very well the two different "regimes" evident in the data. All of the stations of Line 16 (with the exception of station 1) show a well-defined transition zone notch at 2 Hz. in both the raw and filtered data. In contrast to this, all grid stations 9 (and station 1 of Line 16) do not show a steep notch at 2 Hz. Low resistivities are evident on Line 5, station 9 and Line 7, station 9, with the lowest values at 4 Hz. This region is similar to the conductive area near the production wells (see the S-5 pseudosection), although this region may also be transitional between two regimes, i.e. similar to station 2 of Line 16. Line 14, and several of the grid stations 11 show a definite notch at 2 Hz., similar to the Line 16, 17, and 19 data. Thus the conductive grid stations 9 (Line 5 and Line 7) may be only transitional stations between the main grid area and a northern "regime" similar to the regime west of the grid (i.e. Lines 16, 17, and 19).

CROSS-SECTION B-B' (LINE 18 and LINE 7)

This cross-section crosses the grid approximately north-south, and passes near the production well 34-7B and the dry hole 42-7. Stations 3, 2, and 1 of Line 18 as well as station 1 of Line 7 are seen to be substantially different in curve shape from the rest of the line. These high resistivity stations show a continuous increase in resistivity with decreasing frequency, as compared to the other stations which decrease in resistivity to 4 Hz. (the transition zone notch) and then increase in resistivity normally. These stations appear to be very near to or directly on the north-south fault mapped by the University of Utah. This area is also coincident with a topographic low. Note that the change in curve shape occurs between stations 3 and 4 of Line 18, and that stations 23 and 13 (west and east of station 3) are similar to station 3, indicating the high resistivity feature is at least 1000 feet wide. Station 13 is topographically much higher than the other high resistivity stations, however, which would seem to contradict the correlation between this high resistivity feature and the topographic low.

CROSS-SECTION C-C'

Cross-section C-C', extending along Line 17, through the grid and on to Line 12, verifies the low resistivity "regime" (characterized by the 2 Hz. notch) west of the main grid, and crosses the high resistivity area on the southern edge of the grid. No low resistivity regions similar to the production area are seen along this cross-section. The well-defined high resistivity feature centered on station 1 of Line 7 may be correlatable to the topographic low in that area, or at least to the geologic cause of the topographic low. (Normally, a topographic low such as a valley will cause a low resistivity related to this north-south fault. (It should be noted that the high resistivity feature does not extend through the grid, but terminates somewhere in the central portion of the grid, possibly west of the production region.)

RECOMMENDATIONS

The results of the survey are extremely encouraging, particularly in light of the drilling costs in this area. Any future CSAMT work should be done with a tighter station density, however, since the 500 foot interval appears to smooth (and possibly miss entirely) many of the changes that occur over very short distances. Despite this problem, several areas at the site have been identified as being interesting, potential targets, and many other areas can be safely ruled out as target areas. Magnetics and SP may be developed into useful reconnaissance tools, but the variations with depth evident in the CSAMT data suggest that these tools probably should be used as extra verification tools rather than primary exploration methods.

Correlation of the data with known geology and drill hole information should be the next priority, in order to allow differentiation of the various changes in the data. Resistivity lows may be created by geothermal fluids and changes; changes in mineralization, rock types, and near surface groundwater may also be causing some of the changes seen in the data. Thus it is not sufficient to simply identify resistivity lows; it is necessary to identify resistivity lows at appropriate depths and in the appropriate environment. The data gathered is more than sufficient to suggest that this is possible in this environment, and several attractive targets have already been identified. To fully utilize the data gathered, however, correlation with other geological data should done.

Norman R. Carlson
Zonge Engineering & Research Organization, Inc.

Line A-A'
SULPHURDALE
for
]THER EARTH INDUSTRIES

618
Y.CPLOT 4.20
D 23 Sep 87

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

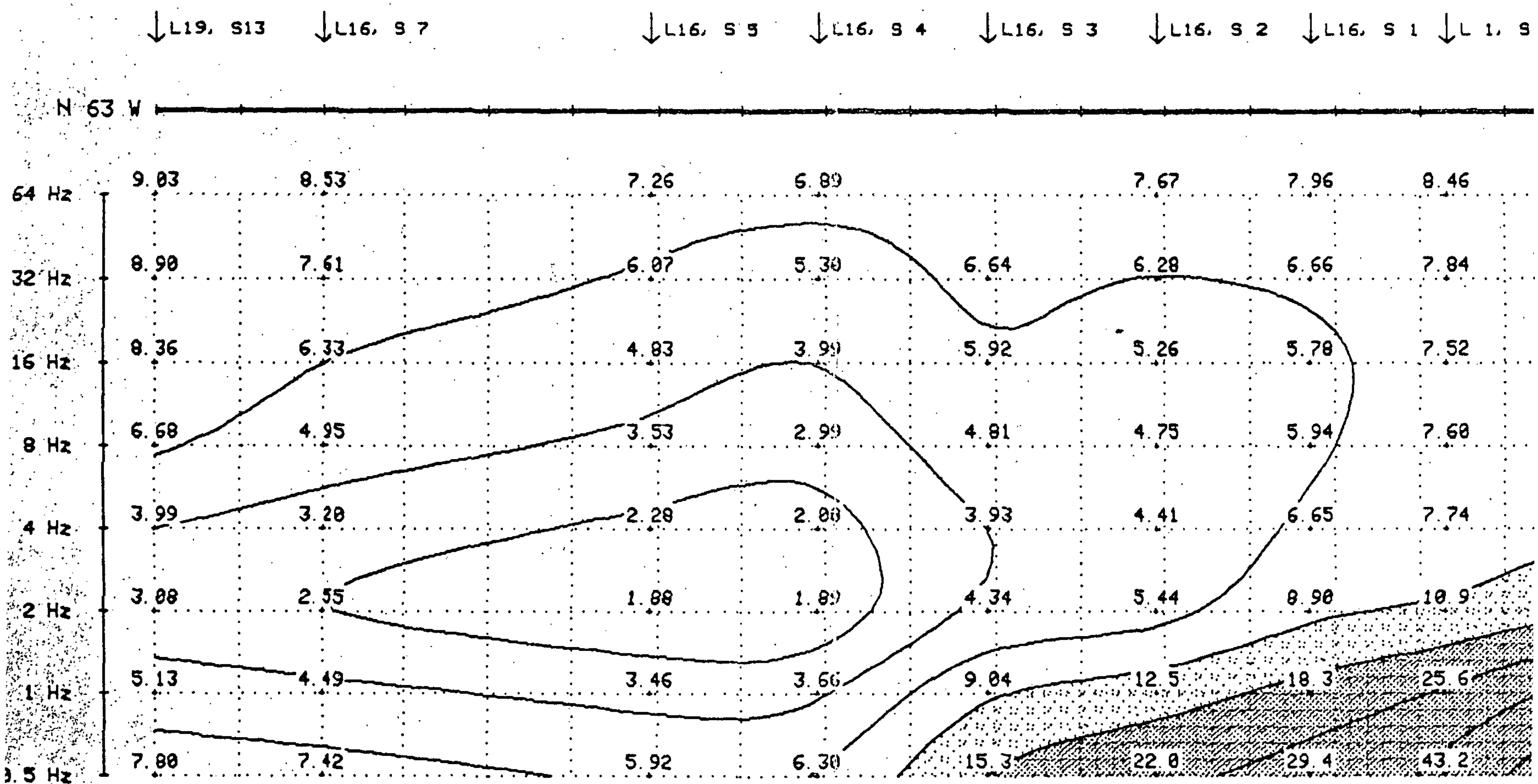
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Shading limits] an
< Interval: 0
[1.70]
2.51
3.98
6.31
10.0
15.8



Line B-B'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

E # 618
BY CPLOT 4.20
TED 23 Sep 87

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

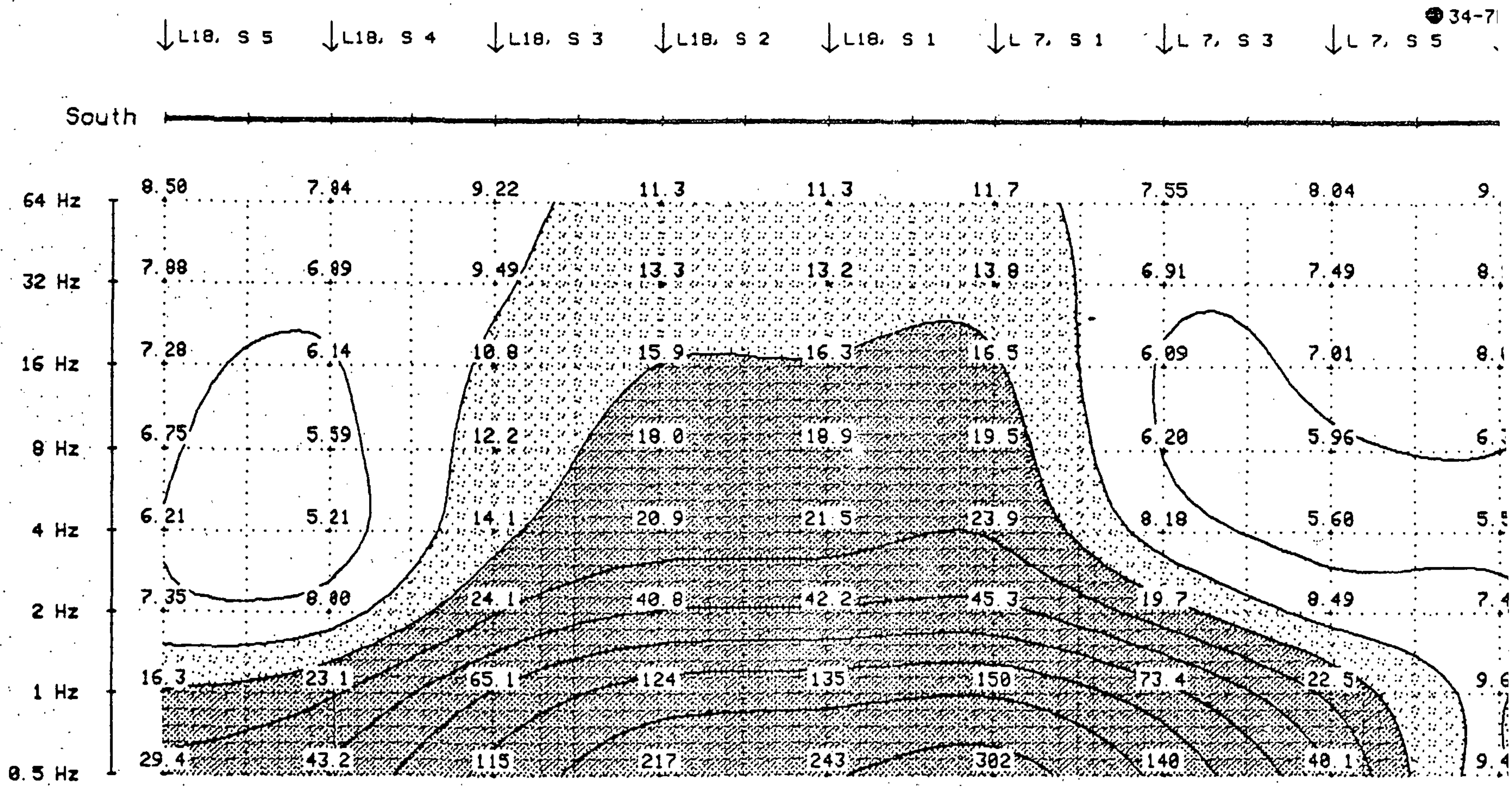
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250.ft Line : N 27 E
Spacing: 250.ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Shading limits
(Interval:
[2.9
3.9
6.3
10.
15.
25.



Line C-C'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

GE # 618
T BY CPLOT 4.20
TTED 23 Sep 87

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

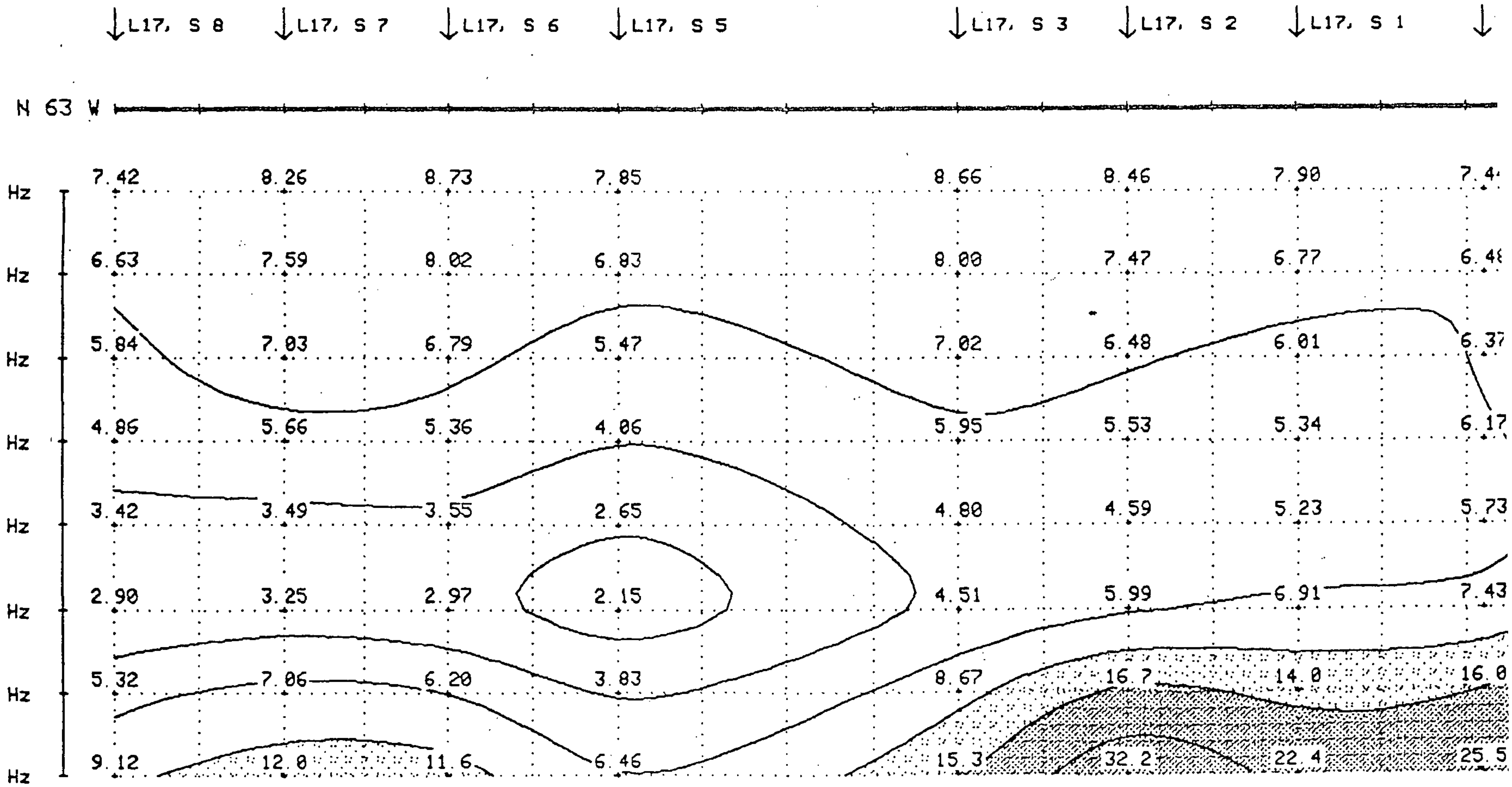
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Shading limi
(Interva
[2
2
3
6
1
1
2



A LITHOLOGIC EVALUATION OF CUTTINGS FROM WELLS S-87-1 AND S-87-4

J.N. Moore

Sept. 1987

SUMMARY AND CONCLUSIONS

S-87-1 and S-87-4 penetrated variably altered and faulted ash-flow tuffs belonging to the Three Creeks Tuff Member of the Bullion Canyon Volcanics. The ash-flow tuffs can be separated into two distinct stratigraphic units in S-87-1. The upper unit is characterized by coarse phenocrysts of biotite, quartz and andesine. The lower unit is finer grained but mineralogically similar. Only the upper unit was penetrated in S-87-4.

Steam production in S-87-4 appears to be controlled by the intersection of two distinct fault zones. The oldest of these fault zones is characterized by strong silicification and argillic alteration. Geologic relationships suggest that this fault zone is a steeply dipping, pre-geothermal structure that is disconnected from the underlying geothermal reservoir. Thus, this fault zone cannot represent the primary conduit that feeds the shallow portions of the steam cap. Instead, this fault zone may form a shallow steam trap where recent fracturing of brittle rocks has resulted in locally increased permeabilities. North trending faults bounding the eastern margin of the Sulphurdale pit are more likely zones of upwelling. These faults are younger than the gravitational glide blocks and control the present surface expression of the geothermal system at Sulphurdale.

Mercury surveys may provide additional information on the locations of these young fault zones. This technique may be particularly effective since reconnaissance studies of drill hole cuttings have shown that anomalous concentrations of mercury are associated with geothermal alteration at Cove Fort and

Sulphurdale (Ross and others, 1982). Exploratory holes drilled along these fault zones and at their intersections should, if possible, be planned to penetrate the base of the glide blocks (approximately 2000 feet) and the underlying reservoir.

STRATIGRAPHIC RELATIONSHIPS

The rocks penetrated in drill holes S-87-1 and S-87-4 consist entirely of the Three Creeks Tuff Member of the Bullion Canyon Volcanics. Within the Cove Fort-Sulphurdale area, the Three Creeks Tuff overlies a heterogeneous sequence of locally derived lava flows, flow breccias, and minor ash-flow tuffs. The Three Creeks Tuff is in turn overlain by silicic ash-flow tuffs and intruded by latite to quartz-monzonite dikes and stocks.

The Three Creeks Tuff was erupted from a caldera located in the southern Pavant Range 27 m.y. ago (Steven and others, 1977). Within the source caldera, the tuff can be divided into three cooling units which differ primarily in the degree of welding they exhibit. The lower and upper units consist of red to gray densely welded ash-flow tuff. The middle unit is poorly welded and white in color. The oldest unit is the most widely distributed and the only one recognized in the Cove Fort-Sulphurdale area (Ross and Moore, 1985).

The lower cooling unit penetrated in the wells consists of approximately 50% phenocrysts of andesine (33%), biotite (10%), quartz (5%), and minor hornblende, sphene, and magnetite in a matrix of densely welded shards and ash. Near Sulphurdale, the lower cooling unit of the Three Creeks Tuff can be further divided into two parts. The upper part is dark gray when fresh and is characterized by plates of biotite up to several millimeters across, and euhedral quartz crystals with beta morphology. The lower part ranges from gray to red-brown in color, is much finer grained, more variable in the degree of welding (moderate to densely welded), and commonly contains numerous lithic fragments. The contact between the upper and lower units was encountered at a depth of 780 feet in S-87-1. Only the upper unit was encountered in S-87-4.

HYDROTHERMAL ALTERATION

The alteration in S-87-1 and S-87-4 is similar to that occurring in wells 42-7, 34-7 and 34-7B. Weak to moderate argillic alteration is the most common alteration type encountered in the wells. The rocks in these intervals are characterized by partial to complete replacement of the feldspar phenocrysts by clay minerals and carbonate, alteration of hornblende to chlorite and carbonate, and minor alteration of biotite to hematite and clays. More intense argillic alteration is characterized by the replacement of biotite by pyrite and clays. Increasing argillic alteration is typically accompanied by a progressive bleaching of the matrix of the ash-flow tuffs.

Silicified and in places, brecciated ash-flow tuff is associated with the argillically altered rocks between 100 to 170 and 440 to 900 feet in S-87-4 and between 140 to 290 and 640 to 650 feet in S-87-1. In addition, intensely silicified breccias occur in the lower 40 feet of both wells and between 440 and 460 feet in S-87-4. With the exception of the interval between 440 and 460 feet in S-87-4, the silicified cuttings are characterized by variable quantities of pyrite (up to approximately 5%) and the complete replacement of all primary minerals by quartz. In contrast, the silicified cuttings from 440 to 460 feet in S-87-4 are characterized by strong hematite development which give the samples a deep red color.

Veins and aggregates consisting of variable proportions of carbonate ± hematite ± chlorite and quartz ± pyrite ± hematite ± chlorite ± carbonate occur in trace amounts throughout both wells. The aggregates of these minerals are interpreted as vein fragments. Textural relationships at the base of S-87-1 suggest that carbonate veining in these rocks in part postdates the silicification. Here, silicified fragments containing pyrite occur in a matrix consisting dominantly of carbonate.

SIGNIFICANCE OF THE SECONDARY MINERAL ASSEMBLAGES

Temperature and Age Relationships

Geologic mapping and analyses of cuttings from wells in the Sulphurdale area suggests that the hydrothermal alteration of the Three Creeks Tuff is controlled primarily by two factors, the temperature of the fluids during alteration and the distribution of faults and fractures (Moore and Samberg, 1979, Ross and Moore, 1985, Moore, unpub. rept. to MEI). In addition, Moore and Samberg (1979) recognized two distinct periods of hydrothermal alteration of the Three Creeks Tuff. The earliest alteration occurred approximately 24 m.y. ago and accompanied the intrusion of quartz-monzonite stocks beneath the Sulphurdale area. Alteration related to this thermal event is characterized by quartz-sulfide mineralization. More recent alteration, related to the present geothermal system is characterized by surficial acid alteration and possibly the formation of anhydrite in 42-7. Significantly, it has not yet been demonstrated that a high-temperature brine related to the present geothermal system ever reached the surface in the Sulphurdale area.

The hydrothermal alteration documented in S-87-1 and S-87-4 is typical of moderate to high-temperature thermal regimes. The presence of clays and chlorite, and the absence of epidote in these rocks suggests that temperatures were probably in the range of 175 to $250^{\circ}C$ during alteration. Similar alteration assemblages, associated with base metal sulfides and fluorite, have been observed in 34-7 and 34-7B. While these observations indicate that high-temperature liquids circulated throughout this area in the past, the incompatibility of these assemblages with the modern, shallow thermal regime suggest that the alteration occurring the geothermal wells is related to the emplacement of the quartz-monzonite and not to the present geothermal system. Nevertheless, the association of steam with silicified zones in 34-7, 34-7B and S-87-4 demonstrates that zones of intense silicification act as important conduits for the steam in the glide blocks capping the deeper portions of the geothermal reservoir.

Previous geologic and geophysical studies have demonstrated that the strongly silicified and argillically altered fault zones near Sulphurdale are steeply dipping and that the intensity of the alteration decreases with distance from the major fault planes (Moore and Samberg, 1979; Ross and Moore, 1985, Moore, unpub. rept to MEI). Although the number and directions of the faults encountered in S-87-1 and S-87-4 cannot be uniquely defined from an analysis of the cuttings, several inferences can be made with respect to their distribution, thickness, and direction of movement. The widespread occurrence of silicified cuttings and moderate to strong argillic alteration in S-87-4 suggest that the well closely followed a major, nearly vertical fault zone. The fault planes encountered within this zone are marked by silicified breccias. These breccias were intersected at depths of 150 to 160 feet, 430 to 460 feet and below 910 feet. Furthermore, the stratigraphic relationships in S-87-1 and S-87-4 indicate that S-87-4 penetrated a block that is downdropped relative to S-87-1. It is likely that this fault zone is part of the east-west trending zone of structures that is prominently developed near the production wells.

Hydrothermal alteration of the rocks in S-87-1 is significantly less intense, suggesting that the well was drilled primarily through the footwall of the fault zone penetrated by 34-7 and 34-7B. The only major fault planes penetrated in this well occur below a depth of 1050 feet.

REFERENCES

Moore, J.N., and Samberg, S.M., 1979, Geology of the Cove Fort-Sulphurdale KGRA: Univ. of Utah Res. Inst. Rept. 18, 44p.

Ross, H.P., and Moore, J.N., 1985, Geophysical investigations of the Cove Fort-Sulphurdale geothermal system, Utah: Geophysics, v. 50. p. 1732-45.

Ross, H.P., Moore, J.N., and Christensen, O.D., 1982, The Cove Fort-Sulphurdale KGRA-a geologic and geophysical case study: Univ. of Utah Res. Inst. Rept. 90, 47p.

Steven, T.A., Cunningham. C.G., Naeser, C.W., and Mehnert, H.H., 1977, Revised stratigraphy and radiometric ages of volcanic rocks and mineral deposits in the Marysvale area, west-central Utah: U.S.G.S. Open-File Rept. 77-569, 45 p.

DEPTH	ALTERATION (1. WEAK 2. MOD. 3. STRONG): Feld Alt, Silic, Pyrite, Bio Alt, Chl	GRAPHIC GEOLOGY	VEINLETS (1. WEAK 2. MOD. 3. STRONG)	DESCRIPTIONS
				20-750 - Three Creeks Tuff: upper part of lower cooling unit; crystal rich containing 50% phenocrysts of andesine, biotite (1-2mm across), quartz (beta morphology), hornblende, spheno
50				20-120 weak to moderate argillic alteration, Matrix bleached, minor carbonate
			Cc+Chl+H	
100				
			Cc+Chl	120-310 moderate to strong argillic alteration, matrix bleached, partial to complete destruction of biotite, pyrite and hematite after biotite, minor carbonate, traces of silicification
150				
200			Q+Cc+H	
			Q	
			Cc	
250			Q	250-260 - silicified breccia
			Q	
			Q+Py; Cc	
300			Clay+Py	
				310-780 - weak to moderate argillic alteration, minor carbonate,
			Cc	
350				
400			Cc+Chl	
450				
			Cc+Chl+H	
500				

DEPTH	ALTERATION (1. WEAK 2. MOD. 3. STRONG): Feld Alt, Silic, Pyrite, Bio Alt, Chl	GRAPHIC GEOLOGY	VEINLETS (1. WEAK 2. MOD. 3. STRONG)	DESCRIPTIONS
500				
550				
600				
650			Cc+Chl+H	
700				
750			Cc+Chl	
				780-1100 - Three Creeks Tuff lower part of lower cooling unit, gray to red-brown, similiar in mineralogy to upper part but much finer grained; coarse grained biotite and quattz absent 780-1040 - weak to moderate argillic alteration, minor carbonate, minor hematite, traces of silicification
800			Cc Cc+H Cc+H Cc+H	
850				
900			Cc+Ch	
950			Cc Cc+H	
1000				

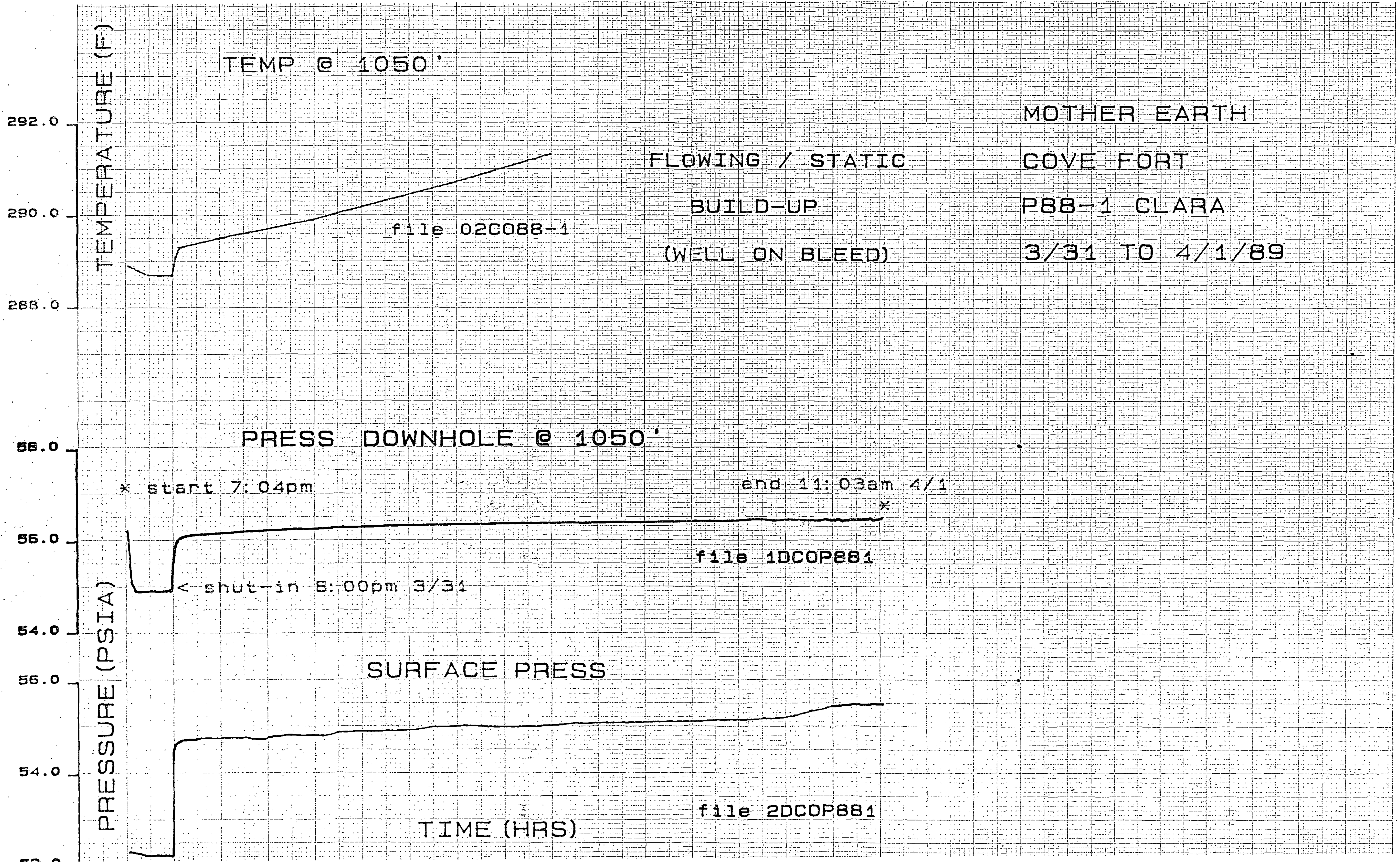
DEPTH	ALTERATION (1. WEAK 2. MOD. 3. STRONG): Feld Alt / Silic / Pyrite / Clay Alt / Chl	GRAPHIC GEOLOGY	VEINLETS (T. TRACE 1. WEAK 2. MOD. 3. STRONG)	DESCRIPTIONS
1000				
1050				1040-1100: silicified breccia fragments cemented by carbonate
1100				

DEPTH	VEINLETS (1. WEAK 2. MOD. 3. STRONG)	DESCRIPTIONS
500	Q+H	
	Q+H	
	Q+H	
550	Cc+H	
	Cc; Q+Chl+Cc	
	Cc	
	Cc	
600	Cc	
	Cc+Chl; Q+H+Ch	
650		
	Cc; Clay+H	
	Q; Cc+Ch	670-910 - moderate to strong argillic alteration, minor carbonate, traces of silicified breccia common
700	Cc+H; Clay+H	
	Cc	
750	Cc+H	
	Cc	
800		
850	Q+Py; Cc	
	Q	
	Cc	
900		
	Q+Py+Chl	910-950 - silicified breccia
	Q+Py	
950	Q+Py	

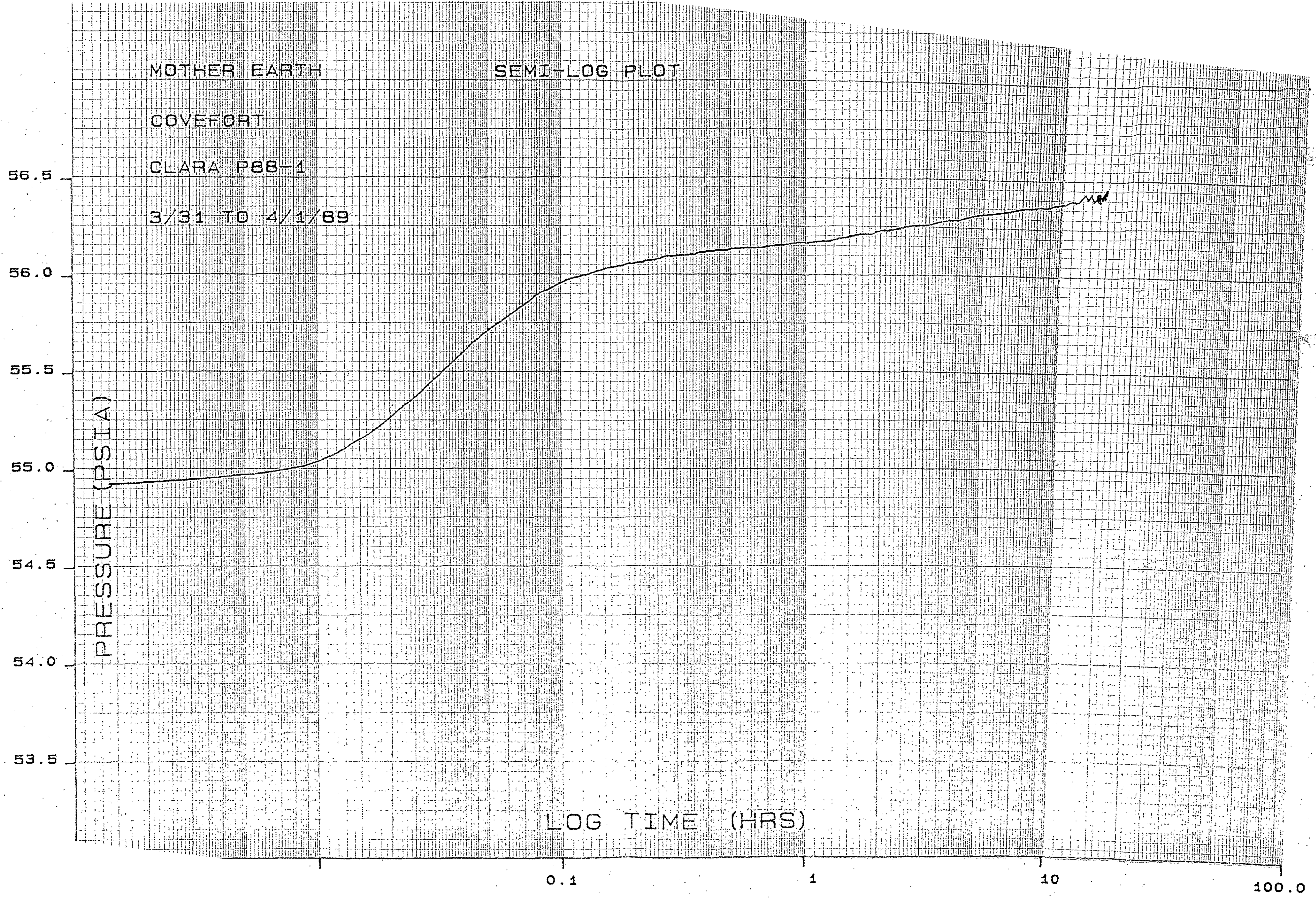
ALTERATION (1. WEAK 2. MOD. 3. STRONG): Feld Alt. | Silic. | Pyrite | Bio. Alt. | Chl.

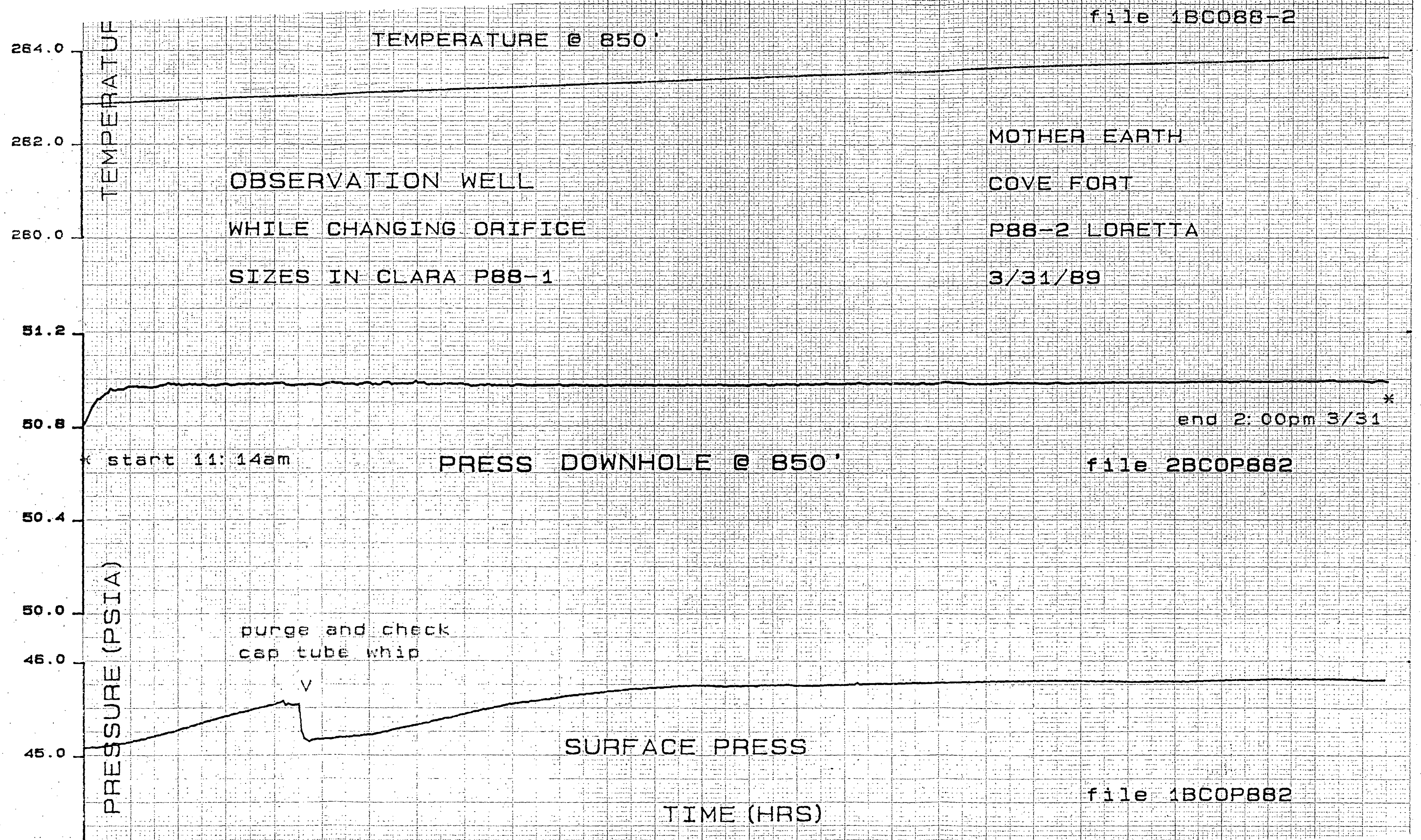
GRAPHIC GEOLOGY

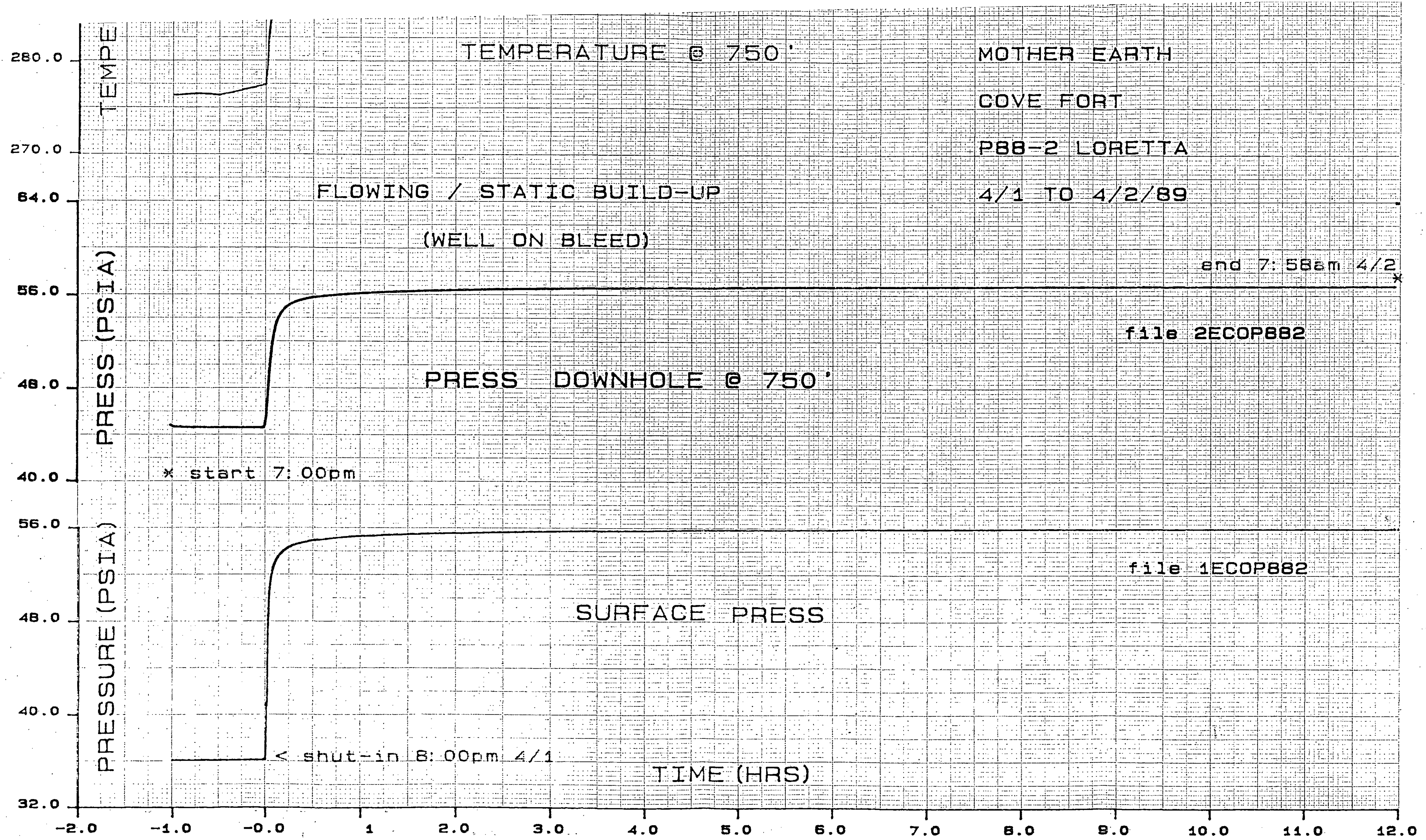
DEPTH	ALTERATION (1. WEAK 2. MOD. 3. STRONG): Feld. Alt. / Silic. / Pyrite / Bio. Alt. / Chl.	GRAPHIC GEOLOGY	VEINLETS (1. WEAK 2. MOD. 3. STRONG)	DESCRIPTIONS
		N.S.		10-950 Three Creeks Tuff: upper
				part of lower cooling unit. crystal
				rich containing 50% phenocrysts
				of andesine, biotite (1-2mm across)
50				quartz (beta morphology), hornblende
				sphene
				10-60 weak to moderate argillic
				alteration, matrix bleached
			Cc+Chl+H	40-60 sample contaminated with
100				gravel
			Q+Py	80-190 moderate to strong argillic
			Q+Py	alteration, matrix bleached, partial to
				complete destruction of biotite minor
				carbonate, minor silicification
150				
			Q	
			Q	
200				190-430 - weak to moderate
				argillic alteration, minor carbonate
			Q+Cc+H	
250				
300			Cc+H	
			Cc+Chl+H	
			Cc+Chl+H	
			Cc+Chl+H	
350			Q	
			Cc+H	
			Cc+H	
			Cc+H	
			Cc+H	
400			Cc+H	
			Q	
			Q	
				440-460 - silicified, hematite stained
450			Q	breccia
				460-670 - weak to moderate argillic
				alteration, minor carbonate, traces
				of silicified breccia common
500				



TEMP @ 1050'
TEMPERATURE (F)
292.0
290.0
288.0
file 02C088-1
FLOWING / STATIC
BUILD-UP
(WELL ON BLEED)
MOTHER EARTH
COVE FORT
P88-1 CLARA
3/31 TO 4/1/89
PRESS DOWNHOLE @ 1050'
58.0
56.0
54.0
* start 7:04pm
end 11:03am 4/1
file 1DCOP881
< shut-in 8:00pm 3/31
SURFACE PRESS
56.0
54.0
PRESSURE (PSIA)
file 2DCOP881
TIME (HRS)

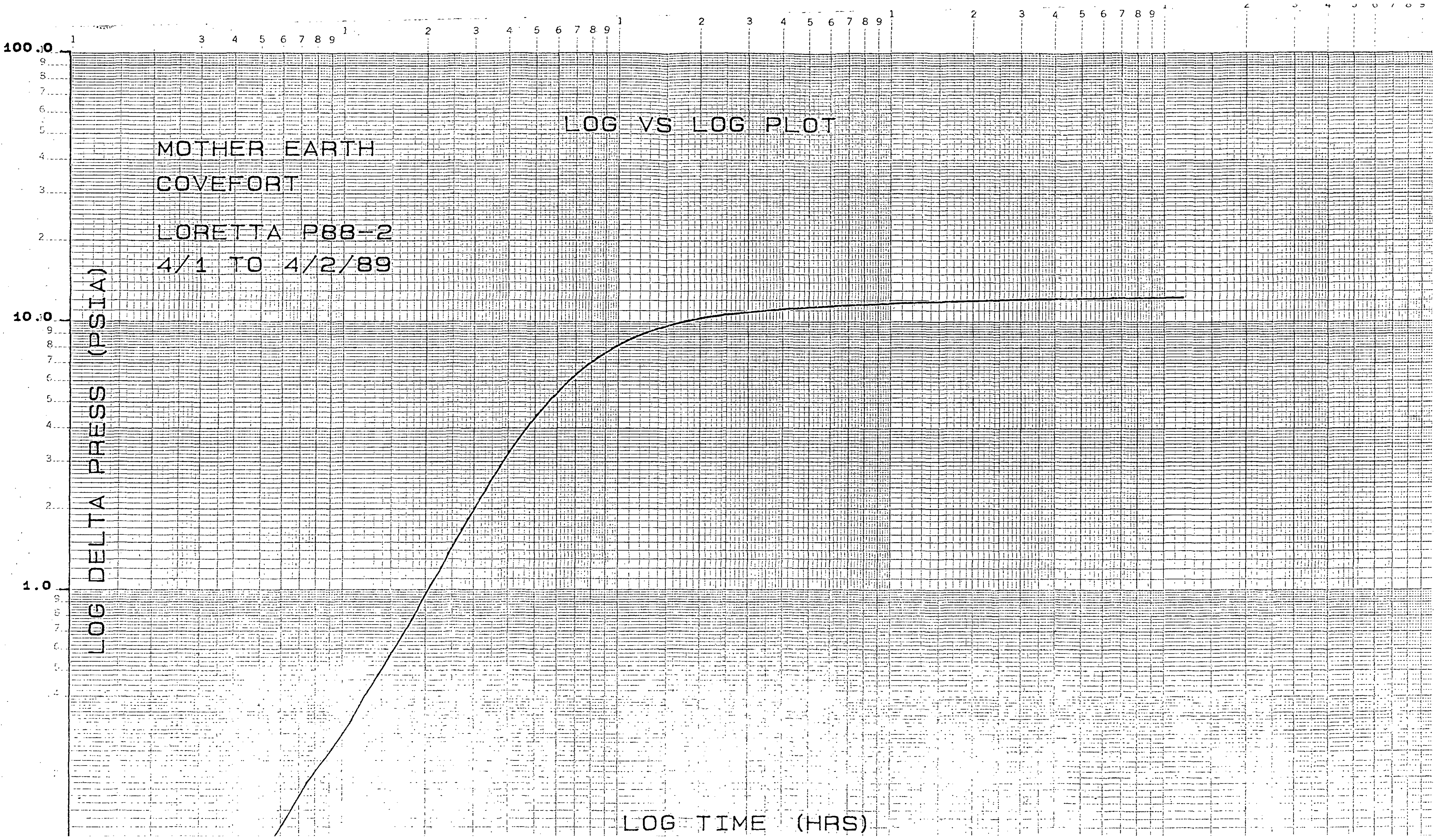

MOTHER EARTH
SEMI-LOG PLOT
COVEFORT
CLARA P88-1
3/31 TO 4/1/89
PRESSURE (PSIA)
56.5
56.0
55.5
55.0
54.5
54.0
53.5
LOG TIME (HRS)
0.1
1
10
100.0


file 1BCO88-2
TEMPERATURE @ 850'
TEMPERATU
264.0
262.0
260.0
MOTHER EARTH
COVE FORT
P88-2 LORETTA
3/31/89
OBSERVATION WELL
WHILE CHANGING ORIFICE
SIZES IN CLARA P88-1
51.2
50.8
50.4
50.0
46.0
45.0
end 2:00pm 3/31
start 11:14am
PRESS DOWNHOLE @ 850'
file 2BCOP882
PRESSURE (PSIA)
purge and check
cap tube whip
SURFACE PRESS
file 1BCOP882
TIME (HRS)



BAKERSFIELD, CA (805) 589-2768

10 x 10 to ½ INCH 10 x 14 INCHES



LOG VS LOG PLOT
MOTHER EARTH
COVEFORT
LORETTA P88-2
4/1 TO 4/2/89
LOG DELTA PRESS (PSIA)
LOG TIME (HRS)
100.0
10.0
1.0

SUB-SURFACE TEMPERATURE SURVEY

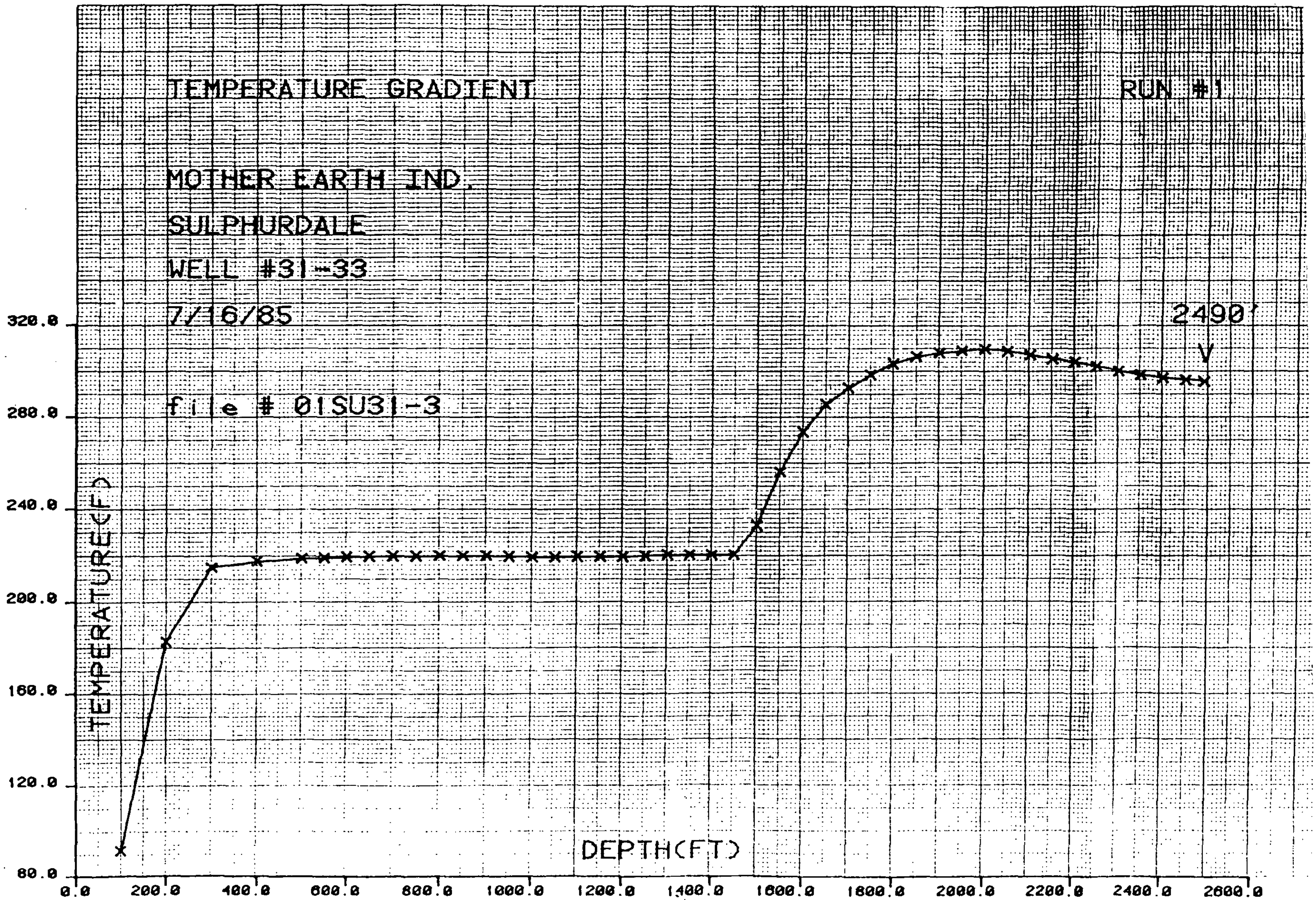
CO.	MOTHER EARTH IND	RUN 01 FIELD	SULPHURDALE	WELL	31-33
EFF DEPTH	2600'	WELL STAT	STATIC	TOOL	HUNG
CASING	13 3/8 TO -1733'	CASING PRESS		ON BOTTOM	14:12
LINER	-	TUBING PRESS		OFF BOTTOM	14:17
DATE	071685	ELEMENT RANGE	57 - 490	ZERO POINT	20'
ELEVATION		ZONE		SHUT-IN	
MAX TEMP		PICK-UP		ON-PROD	
PERF	1733'-2600'	CAL SER NO.	31	MPP	
TUBING	-				
UNITS	ENGLISH	PURPOSE	TEMPERATURE GRADIENT 7/16/85		

SURVEY DATA

CO. MOTHER EARTH IND RUN 01 FIELD SULPHURDALE WELL 31-33

TIME	DEPTH	P/T	GRAD	TIME	DEPTH	P/T	GRAD
1:00	100	91.2	0.000	1:00	1450	220.4	0.000
1:00	200	182.3	.911	1:00	1500	232.7	.248
1:00	300	214.6	.324	1:00	1550	256.0	.464
1:00	400	217.4	.026	1:00	1600	273.5	.350
1:00	500	218.6	.013	1:00	1650	285.4	.239
1:00	550	218.9	.004	1:00	1700	292.6	.144
1:00	600	219.1	.004	1:00	1750	298.4	.115
1:00	650	219.5	.008	1:00	1800	303.3	.098
1:00	700	219.5	0.000	1:00	1850	306.4	.063
1:00	750	219.5	0.000	1:00	1900	308.0	.031
1:00	800	219.7	.004	1:00	1950	309.0	.020
1:00	850	219.7	0.000	1:00	2000	309.7	.016
1:00	900	219.7	0.000	1:00	2050	308.8	-.019
1:00	950	219.5	-.004	1:00	2100	307.2	-.031
1:00	1000	219.3	-.004	1:00	2150	305.4	-.035
1:00	1050	219.3	0.000	1:00	2200	304.1	-.027
1:00	1100	219.5	.004	1:00	2250	302.1	-.039
1:00	1150	219.5	0.000	1:00	2300	300.1	-.039
1:00	1200	219.5	0.000	1:00	2350	298.4	-.035
1:00	1250	219.9	.009	1:00	2400	297.2	-.024
1:00	1300	220.4	.009	1:00	2450	296.2	-.020
1:00	1350	220.4	0.000	1:00	2490	295.6	-.015
1:00	1400	220.4	0.000	0:00	0	0.0	0.000

BY S.WILSON/B.DAILY



TEMPERATURE GRADIENT
RUN #1
MOTHER EARTH IND.
SULPHURDALE
WELL #31-33
7/16/85
file # 01SU31-3
2490'
TEMPERATURE(F)
DEPTH(FT)
320.0
280.0
240.0
200.0
160.0
120.0
80.0
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
2000.0
2200.0
2400.0
2600.0

-E HWY. -RIES INC
(805) 589-2768 BAKERSFIELD, CA. 93308

SUB-SURFACE TEMPERATURE SURVEY

CO. MOTHER EARTH IND
EFF DEPTH 2600'
CASING 13 3/8 TO -1733'
LINER -
DATE 071685
ELEVATION
MAX TEMP
PERF
TUBING 1733'-2600'
UNITS -
ENGLISH

RUN 01 FIELD SULPHURDALE
WELL STAT STATIC
CASING PRESS
TUBING PRESS
ELEMENT RANGE 57 - 490
ZONE
PICK-UP
CAL SER NO. 31

PURPOSE TEMPERATURE GRADIENT 7/16/85

WELL 31-33
TOOL HUNG
ON BOTTOM 14:12
OFF BOTTOM 14:17
ZERO POINT 20'
SHUT-IN
ON-PROD
MPP

CO. MOTHER EARTH IND

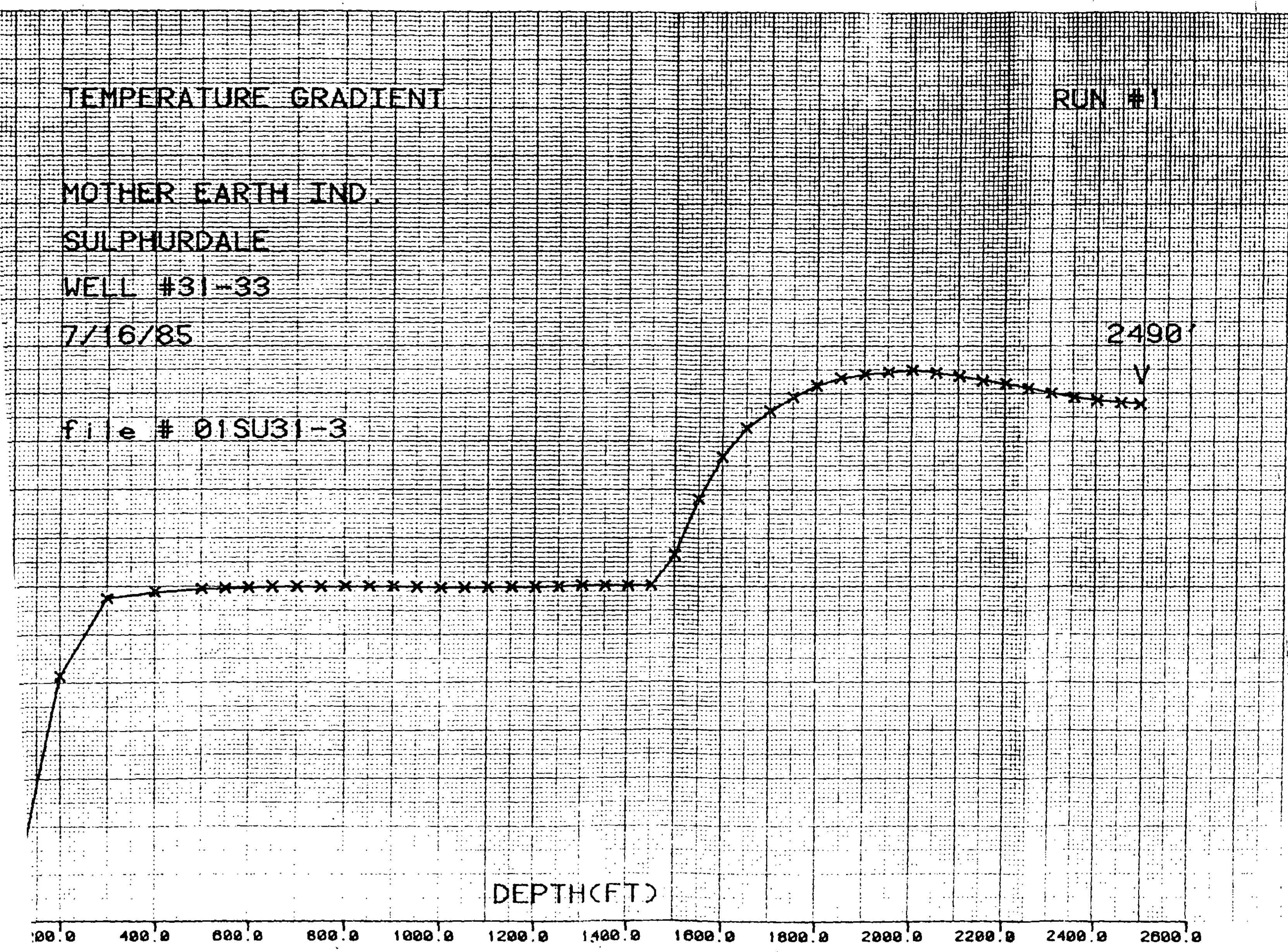
SURVEY DATA

RUN 01 FIELD SULPHURDALE WELL 31-33

TIME	DEPTH	P/T	GRAD
1:00	100	91.2	0.000
1:00	200	182.3	.911
1:00	300	214.8	.324
1:00	400	217.4	.026
1:00	500	218.6	.013
1:00	550	218.9	.004
1:00	600	219.1	.004
1:00	650	219.5	.008
1:00	700	219.5	0.000
1:00	750	219.5	0.000
1:00	800	219.7	.004
1:00	850	219.7	0.000
1:00	900	219.7	0.000
1:00	950	219.5	-.004
1:00	1000	219.3	-.004
1:00	1050	219.3	0.000
1:00	1100	219.5	.004
1:00	1150	219.5	0.000
1:00	1200	219.5	0.000
1:00	1250	219.9	.009
1:00	1300	220.4	.009
1:00	1350	220.4	0.000
1:00	1400	220.4	0.000

TIME	DEPTH	P/T	GRAD
1:00	1450	220.4	0.000
1:00	1500	232.7	.248
1:00	1550	256.0	.464
1:00	1600	273.5	.350
1:00	1650	285.4	.239
1:00	1700	292.6	.144
1:00	1750	298.4	.115
1:00	1800	303.3	.098
1:00	1850	306.4	.063
1:00	1900	308.0	.031
1:00	1950	309.0	.020
1:00	2000	309.7	.016
1:00	2050	308.8	-.019
1:00	2100	307.2	-.031
1:00	2150	305.4	-.035
1:00	2200	304.1	-.027
1:00	2250	302.1	-.039
1:00	2300	300.1	-.039
1:00	2350	298.4	-.035
1:00	2400	297.2	-.024
1:00	2450	296.2	-.020
1:00	2490	295.6	-.015
0:00	0	0.0	0.000

BY S. WILSON/B. DAILY


TEMPERATURE GRADIENT
RUN #1
MOTHER EARTH IND.
SULPHURDALE
WELL #31-33
7/16/85
2490'
file # 01SU31-3
DEPTH(FT)
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
2000.0
2200.0
2400.0
2600.0