FINAL TECHNICAL REPORT
GEOTHERMAL RESOURCE EVALUATION
AND DEFINITION (GRED) PROGRAM — PHASES I, II and III
for
THE ANIMAS VALLEY, NM GEOTHERMAL RESOURCE

United States Department of Energy
Albuquerque Operations Office
Cooperative Agreement No. DE-FC04-00AL66977

By:

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ABSTRACT

This report contains a detailed summary of a methodical and comprehensive assessment of the potential of the Animas Valley, New Mexico geothermal resource leasehold owned by Lightning Dock Geothermal, Inc. Work described herein was completed under the auspices of the **Department of Energy (DOE) Cooperative Agreement DE-FC04-00AL66977, Geothermal Resource Evaluation and Definition (GRED) Program**, and the work covers the time span from June 2001 through June 2004. A relatively minor segment of this overall program was funded through the DOE Cooperative Agreement DE-FC07-01ID14203 for the Enhanced Geothermal Systems Technology (EGS) Program, and covered completion of two intermediate-depth temperature gradient holes. The Final Report on that segment was released in December 2003, under the report title, "Final Report, Enhanced Geothermal Systems Technology Phase II, Animas Valley, New Mexico." Total DOE plus LDG program funding for the two Cooperative Agreements was $2.2 million, with DOE providing 54 percent and LDG furnishing 46 percent.

Included in this new report are detailed results from the GRED Program, including: geophysical and geochemical surveys, reflection seismic surveys, aeromagnetic surveys, gravity and electrical resistivity surveys, soil thermal ion and soil carbon dioxide flux surveys, four temperature gradient holes, and one deep exploratory well. Summary results from the drilling program are shown below:

WELL NAME	LOCATION	DEPTH (m)	BHT (^{o}C)
TG12-7*	1.0 km N of TFD55-7	305	69
TG56-14*	4 km SW of TFD55-7	381	36
TG36-7	0.5 km SW of TFD55-7	305	90
TG57-7	0.5 km SE of TFD55-7	278	108**
TG52-7	0.5 km N of TFD55-7	771	137

Gradient holes designated with an asterisk were completed under the EGS Cooperative Agreement
Double asterisk for TG57-7 indicates this value is maximum temperature

Results from the deep exploratory hole TG52-7, completed to 771 m (2,528 feet) are: a) Hole spudded on 25 June 2003, and drilling completed on 15 October 2003; b) geophysical and temperature logs and short-term controlled flow test completed, and c) water samples acquired and preliminary reservoir hydrology assessments completed.

Results from the final seismic traverses completed to tie together lithology from gradient and deep exploratory holes, and to develop an integrated resource model are summarized as follows:

> A seismic traverse oriented in a NW-SE alignment portrays a chaotic subsurface regime that contains numerous dipping structures, and likely folded and compressed structures. Two principle faults appear to bound and create a graben, with the graben strata folded and compressed. An E-W traverse depicts a structural setting in which the mapped surface expression (eroded fault scarp) of the old Animas Valley Fault (a Recent, basin-bounding fault along the eastern margin of the valley) cannot be directly tied to the subsurface structures creating the intense shallow geothermal anomaly.

Overall resource assessment is that the potential commercial reservoir contains minimum of 15 MW net to the grid. This compares favorably with the earlier assessment, completed before the drilling and final seismic traverses, that the resource comprised 5 to 15 MW reservoir capacity.

ACKNOWLEDGMENTS

The authors acknowledge the support of several individuals and their contributions to this project:

- Mr. Dan Sanchez, DOE Albuquerque Operations Office, for his firm but friendly management as the program evolved through many twists and turns over four years,
- Dr. Norm Warpinski, Sandia Labs, for invaluable technical assistance through out the completion of the program,
- Mr. Allan Sattler, Sandia Labs, for his technical contributions and a firm "friend in court" for the many problems and technical challenges that arose during the program,
- Dr. David Blackwell, Southern Methodist University, for many contributions too numerous to list,
- Mr. Kirby Mills, MAG-1 Geoscience, for his technical assistance and pilot skills during the aeromagnetic survey, and Dr. James Fink, hydroGEOPHYSICS, Inc., for his technical and field assistance during the aeromagnetic survey and as a consultant for the reflection seismic survey program.

Our thanks to Mr. Dale Burgett and Mr. Tom McCants for allowing us access on their private land. Special thanks to Mr. Burgett for his cooperation and support during drilling operations and also during the completion of the final seismic surveys.

During the long course of this program, both authors suffered serious medical problems that required surgery and long recovery periods, thus delaying completion of the project. Our sincerest thanks to Dan Sanchez, Norm Warpinski, and Allan Sattler for their patience, understanding, and continued support of our efforts.

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INTRODUCTION

BACKGROUND

Lightning Dock Geothermal, Inc. ("LDG") is the owner of Federal Geothermal Lease NM-34790, comprising about 2,501 acres, in the Animas Valley of Hidalgo County, New Mexico. In addition, in February 2003, LDG filed an application for a second lease comprising some 640 acres adjoining NM-34790. These leases include a shallow and relatively high-temperature geothermal resource that has been developed for direct heating of greenhouses and a fish farm. A deep well drilled by Steam Reserve Corporation in 1984 found high temperatures (>150°C) and significant water flow at a depth of about 350 meters (1,150 feet). Earlier geothermal and geophysical data suggested that the Animas resource was arguably the best prospective geothermal resource for commercially developable electrical power production in New Mexico, but little was known about the lateral extent and deeper characteristics of the reservoir.

The project area covered more than one hundred fifty (150) square kilometers centered more or less on the developed geothermal resource in the northern part of Animas Valley in Hidalgo County. Cotton City is at the southwest corner of the project area.

RESEARCH PROGRAM FUNDING

The DOE program, "GeoPowering the West", provided LDG with the opportunity to further explore and define the resource. Work described herein was completed under the auspices of the Department of Energy (DOE) Cooperative Agreement DE-FC04-00AL66977, Geothermal Resource Evaluation and Definition (GRED) Program, and covers the time span from June 2001 through June 2004. A relatively minor segment of this overall program was funded through the DOE Cooperative Agreement DE-FC07-01ID14203 for the Enhanced Geothermal Systems Technology (EGS) Program, and covered completion of two intermediate-depth temperature gradient holes. The Final Report on that segment was released in December 2003, under the title, "Final Report, Enhanced Geothermal Systems Technology Phase II, Animas Valley, New Mexico."

Total DOE plus LDG program funding for the two Cooperative Agreements was $2.220 million, with DOE providing 53 percent and LDG furnishing 47 percent. Distribution of this funding, by fund source and program, is shown as follows, with dollar amounts listed in millions of dollars:

Cooperative Agreement	DOE Funds	LDG Funds	Total Funds
GRED	$ 0.979	$ 0.821	$ 1.800
EGS	$ 0.200	$ 0.220	$ 0.420
TOTALS	**$ 1.179**	**$ 1.041**	**$ 2.220**
	(53 %)	(47 %)	

SCOPE OF THE REPORT

This report includes a detailed summary of a comprehensive and methodical geothermal assessment of this major geothermal resource. This new assessment had the key objective of developing a unified structural model of the geothermal resource to provide a foundation for ultimate commercial development. This objective was achieved through the use of multiple geophysical surveys and the drilling of deep temperature-gradient and test holes. Using a cost-shared Cooperative Agreement with the Department of Energy under the Geothermal Resource Evaluation and Definition (GRED) Program, LDG conducted work in three phases.

- Phase I was conducted during the time frame from June 2001 through May 2002, and work included field surveys and analytical work covering gravity, dipole-dipole electrical resistivity, and high-resolution aeromagnetic surveys.

- Phase II activities commenced in June 2002 and extended to June 2004. In this phase, reflection seismic surveys were completed, a soil thermal ion survey was conducted, soil gas studies for carbon dioxide flux were completed, and four intermediate-depth temperature gradient holes were drilled to depths ranging from

970 to 1,250 feet (295 to 381 m). (Two gradient holes were partially funded through an Enhanced Geothermal Systems ("EGS") Cooperative Agreement, and two were funded by this GRED Cooperative Agreement.) As a final major exploratory activity, a deep test well was completed to a depth of 2,528 feet (771 m), and this well was analyzed through multiple temperature surveys and water sampling at discrete break points in the drilling.

- Phase III comprised two separate tasks. The first was completion of an abbreviated controlled flow test of TG52-7. The final action was completion of two new reflection seismic surveys to integrate subsurface lithology from gradient holes into a unified structural model.

This report also summarizes the integration of new data with previously acquired geophysical data and interpretations of the thermal data. The integration of new and old data has led to new thermo/structural models of the geothermal circulation system that will serve as a foundation for future development of the resource.

The report is organized with a brief summary section providing the locale and geological setting of the Animas Valley geothermal anomaly. Following this introductory section, each of the sequential research tasks is summarized in detail. The tasks are presented in chronological sequence. Each separate task includes a brief summary of methodology followed by a succinct summary of the key findings from completion of that task.

LOCATION

The Lightning Dock Known Geothermal Resource Area (KRGA) is on the east side of Animas Valley, approximately thirty (30) km southwest of the town of Lordsburg, New Mexico and sixteen (16) km south of Interstate Highway 10 (figure 1). Although the KGRA covers several square kilometers, the known shallow geothermal resource is primarily in Sections 6 and 7 of Township 25 South, Range 19 West, NMPM. The KGRA area is covered by the Cotton City, Steins, Swallow Fork Peak, and Table Top

Mountain 7.5-minute series U.S. Geological Survey topographic quadrangle maps (scale 1:24,000), the Lordsburg 30' x 1°-series metric map (scale 1:100,000), and the Silver City 1° x 2°-series map (scale 1:250,000).

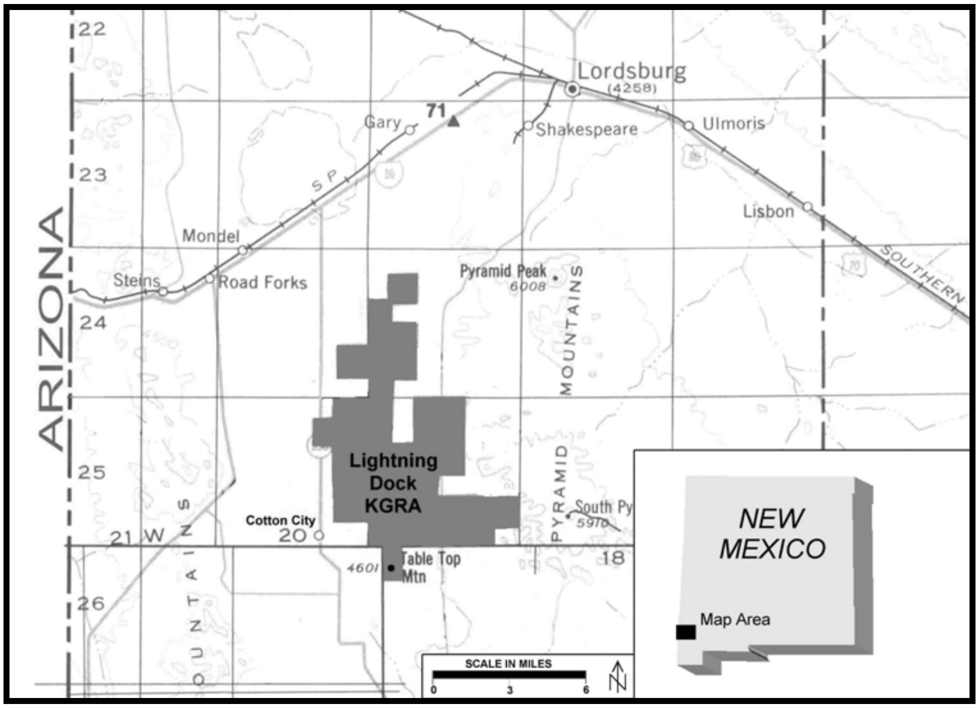

Figure 1. Lightning Dock Known Geothermal Resource Area.

GEOLOGIC SETTING

The Animas Valley of southwestern New Mexico is in the Mexican Highland part of the Basin and Range Province of the Western United States. The complexity of the Animas Valley area is demonstrated by the widely differing structure, stratigraphy, and ages of rocks exposed in the surrounding mountain ranges. The Animas Valley is a topographic low and a structural graben, and is bounded on the west by the Peloncillo Mountains and on the east by the Pyramid Mountains (figure 2). The primary structural trends in the area are the north-trending Basin and Range features and an inferred caldera ring-fracture zone. Relatively young basaltic volcanism is widespread in the area with the most recent activity being a small cinder cone dated at 140,000 years ago on the west side of the valley. These Cenozoic features are superimposed on a Laramide thrust belt setting that in turn occurs at the edge of the Paleozoic cratonic region of North America (Chang et al, 1999; Corbitt and Woodward 1973, and Woodward and Duchene, 1981). Elston, et al, (1983) give a good overview of the geology and provide a thorough geochemical analysis of the waters of the Lightning Dock KGRA.

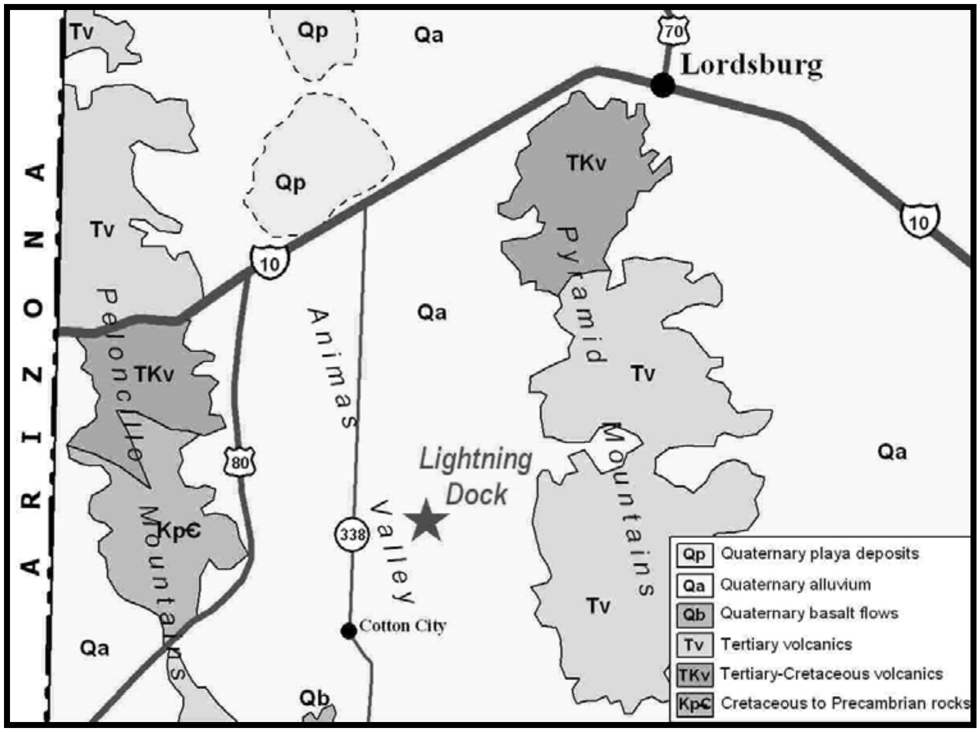

Figure 2. Geologic map of the Animas Valley region.

According to Blackwell and Wisian (2001), gravity data illustrate the basement and fault structure of Animas Valley. North-trending, range-bounding faults define the valley on the west and east. An east-northeast-trending fault with a right-lateral component appears to cut across the valley through the production area. Blackwell and Wisian also filtered and inverted the gravity data to produce a depth-to-basement map that highlights the northeast-southwest structural trend across the Animas Valley.

Rocks exposed in the bordering mountain ranges include Precambrian granodiorite, Paleozoic and Mesozoic sedimentary rocks, Tertiary/Cretaceous volcanic rocks, Tertiary intrusive rocks, Tertiary conglomerate, Quaternary/Tertiary basalt flows, and

Quaternary/Tertiary conglomerate (O'Brien and Stone, 1984). The Pyramid Mountains, composed of rocks primarily of Cretaceous age and younger (Flege, 1959), form a complex volcanic sequence known as the Muir cauldron (Deal and others, 1978, and Elston et al, 1983). In contrast, the Peloncillo Mountains consist of a Precambrian granite core, a complete Paleozoic section, Cretaceous sedimentary rocks, and Tertiary intrusive and eruptive rocks (Gillerman, 1958, Dane and Bachman, 1961, and Dane and Bachman, 1965).

PREVIOUS WORK

Smith (1978) summarized geophysical data available as of the late 1970's. Blackwell and Wisian (2001) described and modeled the thermal data and integrated the data with available geophysical information, particularly gravity data compiled by Dr. George R. Keller at the University of Texas at El Paso (2000). Blackwell and Wisian analyzed the public-domain gravity data as part of the EGS (Enhanced Geothermal Systems) DOE Cooperative Agreement with LDG and Ormat, Inc. Cunniff and Bowers (2001) summarized the pertinent previous work and discussed implications of structural controls. Cunniff and Bowers (2003a) provided a comprehensive review of all facets of prior work, including the new fieldwork completed in GRED Phase I and the initial reflection seismic surveys. This document presented an assessment of likely reservoir productivity completed in advance of the gradient hole drilling program and final reflection seismic surveys described herein.

GEOPHYSICAL SURVEYS – 2001

To initiate Phase I work, a limited gravity survey was conducted in April 2001. Three additional geophysical surveys, namely gravity, high-resolution aeromagnetics, and dipole-dipole electrical resistivity, were conducted concurrently during October 2001.

GRAVITY SURVEYS

Location

Two separate gravity surveys were conducted by LDG as part of this GRED Cooperative Agreement. The first survey was conducted in April 2001 and consisted of 77 stations in the north half of Section 7 and south half of Section 6, both sections being in Township 25 South, Range 19 West. A second and much larger survey was conducted in October 2001. This survey consisted of 227 new stations in nine linear traverses that covered more than one hundred (100) square kilometers centered on the known resource area in Section 7 (figure 3). The following data acquisition and data processing descriptions pertain to both surveys.

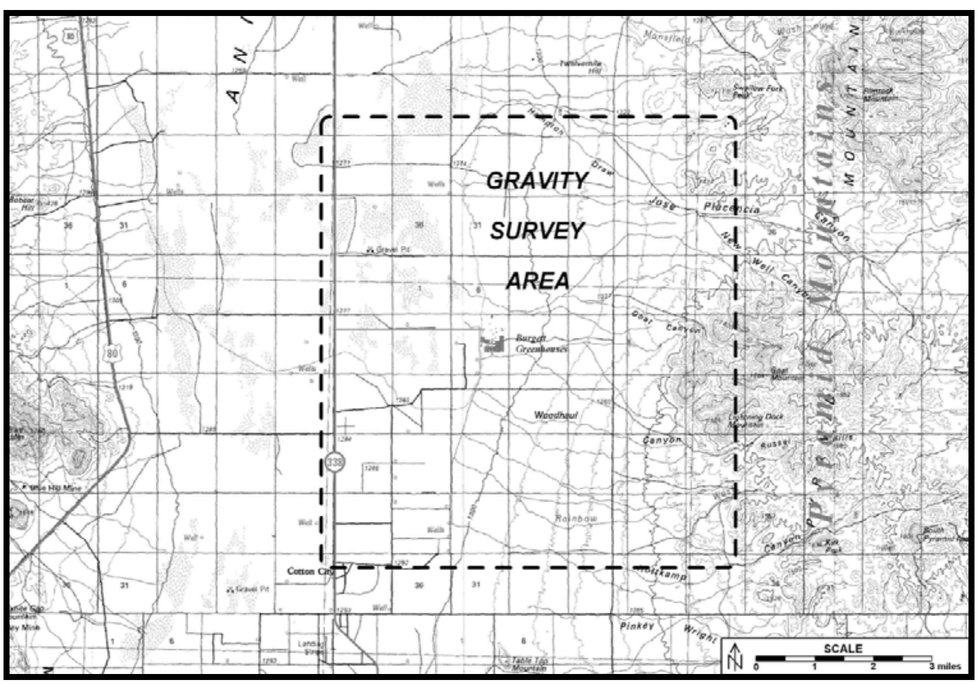

Figure 3. Gravity survey area.

Data Acquisition

The gravity station layouts were planned in advance and plotted on maps. After flagging and surveying each station location, gravity measurements were taken with a LaCoste and Rhomberg Model G gravimeter. Base stations were initially established from public-domain data of previous surveys obtained from Keller (2000). Multiple measurements were taken at the base stations throughout the conduct of the surveys. All gravity measurements of the April 2001 survey were taken by Roger Bowers of LDG and the data were later reduced by Claron Mackelprang (2001) of Consolidated Geophysical Surveys in Cedar City, Utah. All gravity measurements of the October 2001 survey were taken by Claron Mackelprang and all data were reduced by him.

Field Procedures

Several base stations were established and the observed gravity for these base stations were taken from public-domain regional data obtained from Keller (2000). Data were also obtained from the U.S. Geological Survey and the National Geophysical Data Center of NOAA. The observed gravity values for the base stations were taken from the public-domain stations.

All gravimeter counter readings were corrected in the field for the instrument calibration factor. Spring tension, the measure of all components of acceleration when the beam is in its null position, was converted into milligals by multiplying by the meter constant, which is unique for each instrument. LaCoste and Rhomberg calibrated the gravimeter and the calibration factor was supplied with the instrument.

Data Processing

All field data for both surveys were processed by Claron Mackelprang (2001). He used a computer program, written by the LaCoste and Rhomberg Company, that applies drift, free-air, and theoretical (latitude) corrections to the field data to obtain the Simple Bouguer values for a range of rock densities. The software gives Bouguer gravity values for four rock densities of geologic range: 1.80, 2.10, 2.40, and 2.67 g/cc. Bouguer values for the rock density of 2.67 g/cc were used in this report. The topographic relief of the survey area is minimal; therefore no terrain corrections were applied to data of these surveys.

Results

Gravity data were reviewed and interpreted by Blackwell and Leidig (2002), who concluded: "The prominent nose on the residual gravity pattern has been interpreted to indicate a horst on the pre-valley-fill units." This gravity horst also correlates with the regional gravity data, which also shows a gravity high "nose" extending northward from the south that appears to terminate in the area of the shallow thermal anomaly. It was hoped that this survey would pinpoint the location of the Animas Valley Fault in the thermal anomaly area and the tighter contour spacing trending northeast from well TFD55-7 may indeed indicate a fault. However, it is believed that the gravity survey primarily delineated the northern edge of the buried Laramide overthrust as mapped and described by Woodward and Duchene, 1981 (figure 4).

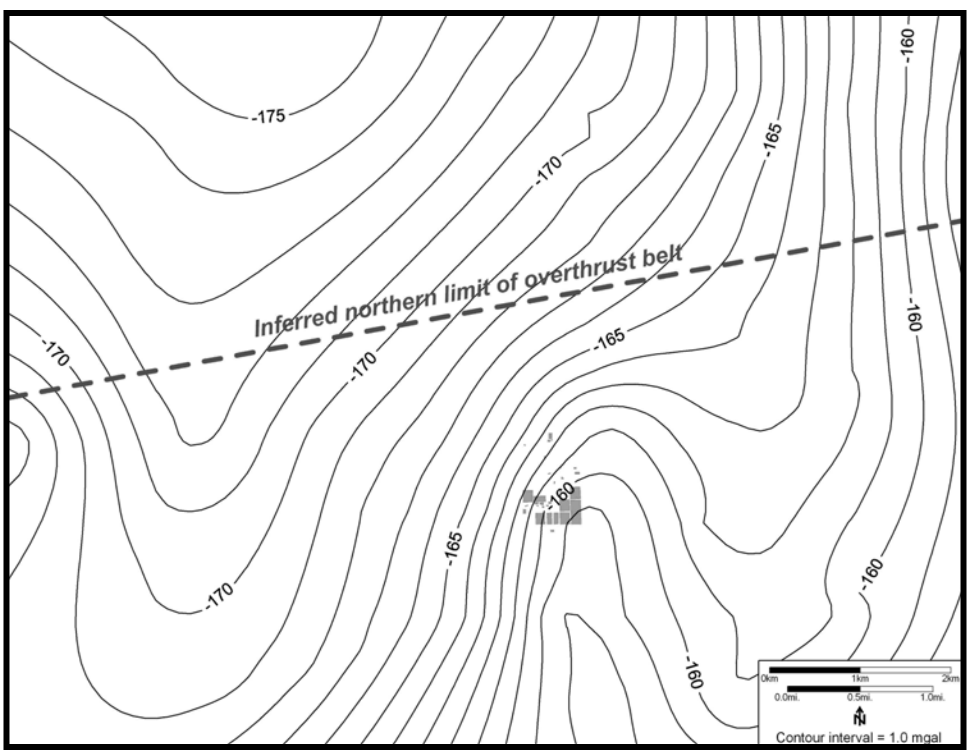

Figure 4. Simple Bouguer gravity contours.

ELECTRICAL RESISTIVITY SURVEY

Location

Claron Mackelprang (2001) of Consolidated Geophysical Surveys, Cedar City, Utah, conducted the electrical resistivity dipole-dipole survey in October 2001. Two electrical resistivity survey lines were run in the project area: a southern east-west line along Caliche Road, and a northern east-west line in the south half Section 6, T25S, R19W (figure 5). The Caliche Road line is located south of the greenhouse complex and was run along the road, which was also used for a gravity traverse. The northern line, named "Church Road", was parallel to the east-west road and gravity traverse, but was offset northward more than 500 feet to avoid the producing geothermal wells and other man-made cultural effects in the area. The locations for these two resistivity lines were selected from the gravity data in an attempt to cross the Animas Valley Fault.

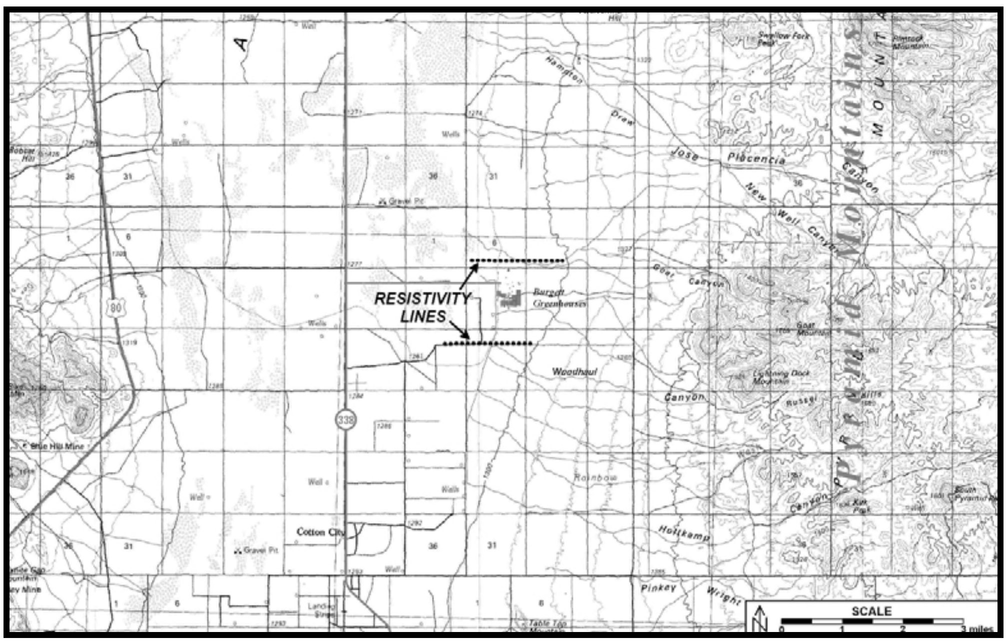

Figure 5. Location of dipole-dipole electrical resistivity lines.

Data Acquisition

The electrical resistivity data were acquired using a 7-spread, dipole-dipole array with 500-foot spacings. Data were collected to sounding depths of n = 6. Once the dipole center location was selected, the wires were laid out and all locations were surveyed. Electrodes were dug into the ground and conductivity was insured with salt and water. After all electrodes were in place, the generator was started and readings began.

Results

Caliche Road Line

A theoretical block model of the subsurface along the resistivity line was derived using a 2-dimensional, finite element, forward modeling algorithm. The model generates resistivity values that agree to within +/- 10 percent of the observed values. An exact fit is not realistic since a 2-D model is used to match 3-D data. The advantage of being able to generate a block model is that thickness and position of resistivity features can be better identified. The block model for the Caliche Road line is shown in Figure 6.

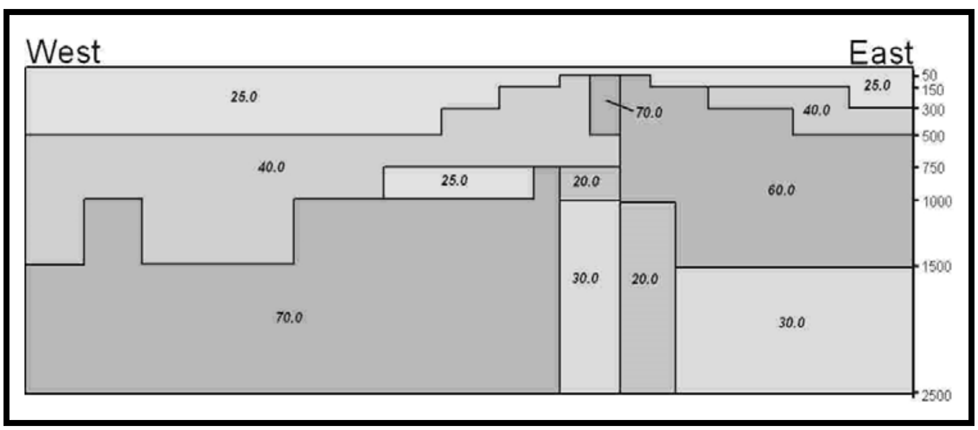

Figure 6. Resistivity block model for the Caliche Road line (from Mackelprang, 2001).

Church Road Line

The resistivity block model of the Church Road line show a shallow zone of very low resistivities (<10 ohm.m) in the central part of the line (figure 7). The nearby producing geothermal well is within this interval; hence, a shallow geothermal plume is probably associated with these low resistivities. A thick section of low resistivity in the range of 10 to 20 ohm.m is present under most of the eastern side of the line. This most likely represents unconsolidated valley fill. A fault is indicated near the east end of the line.

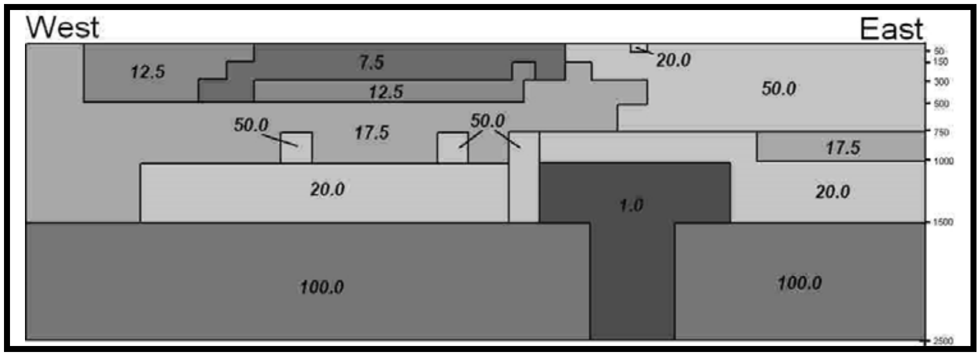

Figure 7. Resistivity block model for the Church Road line (from Mackelprang, 2001).

HIGH-RESOLUTION AEROMAGNETIC SURVEY

In the late 1990's, the U.S. Geological Survey conducted high-resolution aeromagnetic surveys of the Albuquerque Basin in central New Mexico. These detailed surveys successfully identified subsurface faults in shallow volcanic rocks under thin alluvial cover. The geologic setting of Animas Valley is similar in that shallow volcanic rocks cover the geothermal area, but faults are obscured by thin alluvium. Based on the success of the Albuquerque Basin surveys and the similarities in geology at Animas, LDG completed this type of survey at the Lightning Dock geothermal resource.

In October 2001, TerraCon, Inc. (2001) of Arlington, Texas conducted the high-resolution aeromagnetic survey that was designed to explore the known, shallow geothermal resource and surrounding area. Shallow-subsurface Tertiary volcanic rocks were used as a magnetic basis for mapping structures.

Survey Description

The survey was planned to cover the project area (figure 8) with east-west flight lines spaced 200 meters apart and flown at approximately 200 meters above ground level (AGL). North-south tie lines were planned at 1,000-meter spacing. It was anticipated that this flight line configuration would provide maximum definition of the known north-south Animas Valley fault zone and of suspected en echelon structures, including a north-south tending gravity high or possible horst structure. Evidence of local structures included previous regional gravity surveys, regional geologic trend analysis, and proprietary studies of air photos.

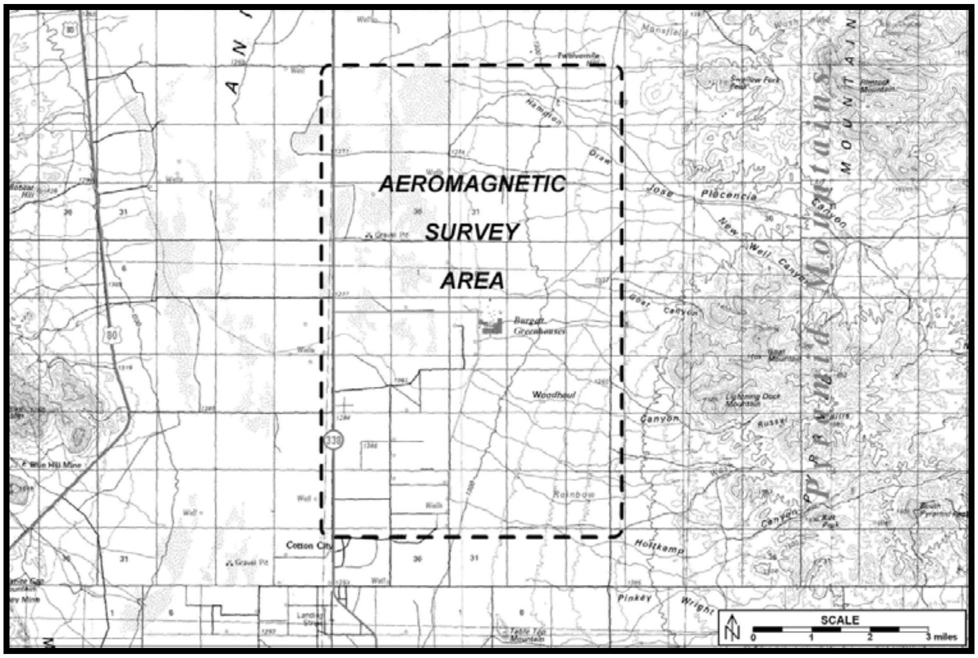

Figure 8. Aeromagnetic survey area.

The magnetic data were acquired at a fixed barometric altitude of 4,800 feet above mean sea level (MSL), which is approximately 200 meters AGL of the main target area in Section 7, Township 25 South, Range 19 West. This fixed flight altitude also provided a stable data set and facilitated data processing. Some flight lines on the east side of the project area had to be modified for safety reasons, since the topography rises abruptly on the flank of the Pyramid Mountains.

After most of the 4,800-ft MSL data had been acquired, the project was expanded to include flight lines at a lower altitude of 4,500 feet MSL or approximately 100 meters AGL. These additional flight lines covered a much smaller area around the thermal anomaly and southward. The lines could not be extended too far east and south due to the flight safety concerns of being too close to the ground and windy weather conditions. For flight safety reasons, the flight lines were re-oriented from east-west to north-south.

Data Acquisition

All field and flight operations were managed by Mr. Kirby Mills of MAG-1 Geoscience, Rome, Georgia. The assembly of data and field quality control were performed by Dr. James Fink of hydroGEOPHYSICS, Tucson, Arizona. A single-engine fixed-wing aircraft (Cessna 172) was used to acquire the magnetic data. The Geometrics 826A magnetometer was installed in the Cessna and was sampled at 10 Hz. The data acquisition unit, including GPS receiver, memory and power source, was housed in the cabin. All magnetic data were collected at a 0.1-second sample rate.

A Geometrics Model G856 magnetometer was located on the ground near the center of the survey area and set to record the magnetic diurnal variation during airborne data acquisition. This location was selected for its distance and remoteness from cultural disturbances, including vehicle traffic and roaming cattle, and yet ease of access and safety. All base station magnetic data were collected at a 5.0-second sample rate. The airborne data were later corrected with this base station information. At the same location, a Trimble Pro XR GPS base station recorded deviation used in processing to provide differential error correction of the aircraft navigation. GPS readings were recorded at a 30.0-second sample rate.

Flights were made during early morning hours in wind conditions of less than 10 mph. As thermal heating throughout the morning hours created increasing turbulence near the ground, it was too difficult to maintain a fixed flight altitude. Overall, the weather conditions were very windy throughout the entire survey. Flights started at sunrise, but commonly lasted only two or three hours before winds increased to unacceptable or unsafe speeds.

Solar Terrestrial Index and magnetic disturbance were monitored by telephone daily with the Solar Physics Lab in Boulder, Colorado. During the first week of the survey, the diurnal magnetic field activity increased from K-3 (quiet to unsettled) to significantly larger disturbances from solar storms. Most international and domestic aeromagnetic surveys were suspended for several days due to the extreme disturbances.

From October 11 through October 24, 2001,Terracon acquired high-resolution airborne magnetic data comprising a total of 2,361 line-kilometers, representing 209 separate flight lines, flown and field processed for quality control. Covering the area of the Lightning Dock KGRA and approximately centered on the known shallow thermal anomaly, the data are divided into four specific sets (total line-kilometers flown):

- 834 line-kilometers north-south at a constant flight altitude of 4800 feet MSL (approximately 200 meters AGL) and 500-meter line separation,

- 1,190 line-kilometers east-west at a constant flight altitude of 4800 feet MSL (approximately 200 meters AGL) and 200-meter line separation,

- 228 line-kilometers north-south at a constant flight altitude 4500 feet MSL (approximately 100 meters AGL) and 200-meter line separation, and,

- 109 line-kilometers east-west at a constant flight altitude 4500feet MSL (approximately 100 meters AGL) used as tie lines.

Data Processing

All survey data collected by Terracon, Inc. were processed by Pearson, deRidder, and Johnson, Inc. (PRJ), Engelwood, Colorado, under the supervision and direction of Dr. Richard Hansen. The GPS base station readings were used to correct the airborne GPS data, utilizing full differential GPS processing. This processing gave accurate latitudes and longitudes (World Geodetic System 1984 datum) of the magnetic readings.

The magnetic data were edited by PRJ to take out erroneous data points that could alter the final products. The IGRF (International Geomagnetic Reference Field) was calculated and applied along with Diurnal and Heading corrections. PRJ then adjusted the leveling to correct some of the miss-ties between flight lines. Data were gridded separately for the 4,800-foot MSL (200-m AGL) and 4,500-foot MSL (100-m AGL) data sets. In addition, each data set was filtered to remove shallow magnetic sources.

Results

The residual magnetic map for the 200-meter AGL survey is shown in Figure 9 and the residual magnetic map for the 100-meter AGL survey is shown in Figure 10. Blackwell and Leidig (2002) analyzed and interpreted the magnetic data:

> *"Both of the contoured magnetic maps show essentially the same information. The main features are very high amplitude positive anomalies at the southeast, east, and northern edges of the survey caused by the exposed igneous rocks in the ranges. These anomalies are accentuated by the fact that the flight lines are closer to the ground in these areas due to elevation increases into the ranges bordering the Animas Valley. The western half of the map is dominated by low amplitude relatively smooth patterns due to the thick cover of alluvium over any volcanics that occur in the valley areas. The center of the map area is occupied by a positive/negative anomaly pair in the south that grades into a negative only anomaly in the north central part of the area."*

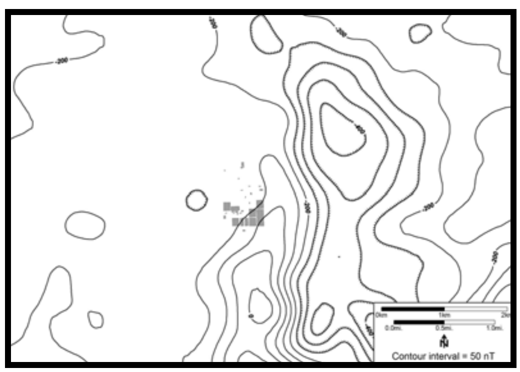

Figure 9. Residual magnetic contours (in nT) for the 200-m AGL survey.

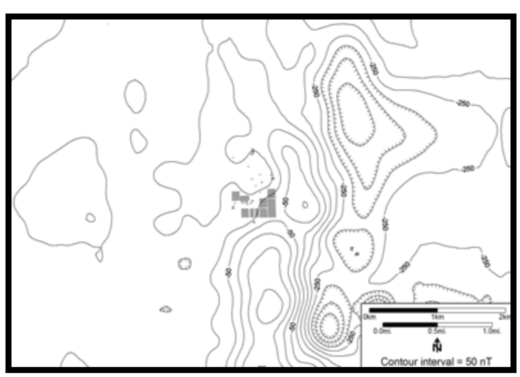

Figure 10. Residual magnetic contours (in nT) for the 100-m AGL survey.

SUMMARY OF GRAVITY AND MAGNETIC DATA

All gravity and magnetic data were reviewed, interpreted, and modeled by Dr. David Blackwell and Mark Leidig of Southern Methodist University, Dallas, Texas. According to their report (Blackwell and Leidig, 2002):

> *"The models through the 55-7 well that fit the magnetic data best share the common feature in that they all put the 55-7 well to the west of the Animas Valley fault, which appears responsible for the narrowing of the magnetic anomaly near the wells by thinning the volcanics. But this sort of model is hard to reconcile with the geologic section in the 55-7 well that has Paleozoic basement at 400 m depth. The gravity data at the 55-7 well indicates that the horst is 2 km wide, but the magnetic data indicates the uplifted volcanics are only 1 km wide and on the east side of the horst. If the fault is assumed to go through the 55-7 well at the temperature overturn at the base of the volcanics then it must have a very low dip from the surface position. Matching the magnetic data and well lithologies with a geologically realistic model and a shallowly dipping Animas Valley fault is extremely difficult if even possible. It is more likely that there is another structure to the west of the 55-7 well bounding the west side of the horst. This westward fault would be the major horst bounding structure while the Animas Valley fault runs through the middle of the horst and thins the volcanic layer on the west side. The magnetic data indicate that the volcanics on the horst around the 55-7 well have been thinned, but the geologic section shows 300 m of volcanics down to 400 m depth. It is difficult to thin the volcanics and match the well lithology simultaneously, but may be possible with two or more faults.*
>
> *The cause of the uplift in the basement of Animas Valley is unknown, but it is likely that the uplift is fault bounded on both sides for most of its length. The mapped Animas Valley fault runs through the gravity nose and does not bound the west side of the uplift north of 3,558,000 N. There appears to be a different fault bounding the west side of the uplift and a third unmapped fault probably bounds the uplift on the east. The faults appear to converge north of the 55-7 well. It is unclear how the structure changes and continues beyond this convergence. The high temperature wells including 55-7 are west of an eastward bend in the magnetic anomaly. It is also not clear why the magnetic anomaly bends and thins out while the gravity anomaly continues northward.*

Blackwell and Leidig (2002) identified numerous lineaments in the mapped magnetic data. Some of these “magnetic linears” correlated with ground features visible on air photos and with structural trends inferred from other geophysical and geochemical surveys. Blackwell and Leidig produced a composite map of the gravity contours, magnetic intensity, temperatures at a depth of 50 meters, the Animas Valley Fault, and air photo linear features (figure 11).

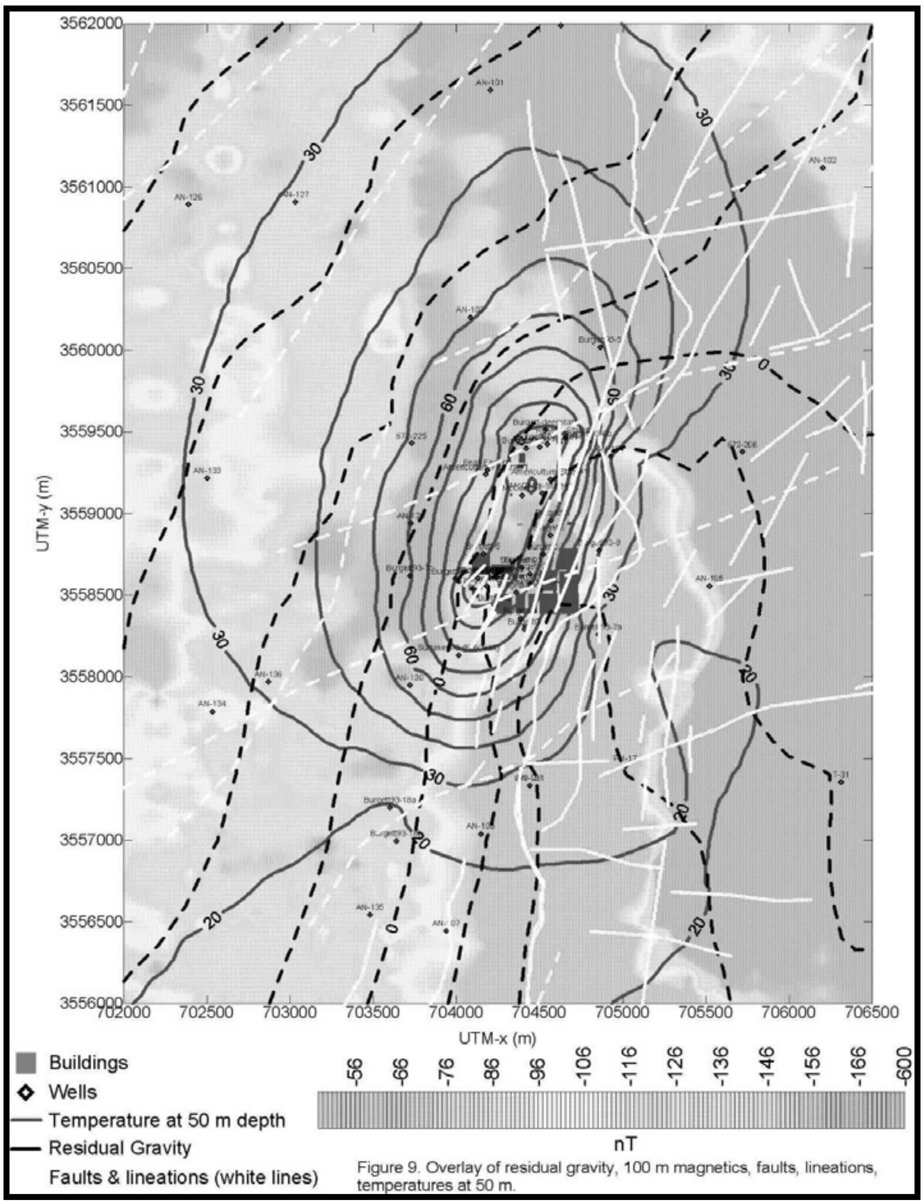

Figure 11. Composite geophysical map (from Blackwell and Leidig, 2002).

SEISMIC SURVEYS – 2002

Phase II of the overall GRED Program included several actions, as follows: Acquiring new seismic data both from industry sources as well as new field traverses, conducting soil-ion and soil-carbon-dioxide measurements, completing two nominal 330-m-deep temperature gradient holes, and drilling a deep exploratory well. The following section provides details covering the seismic program completed in 2002.

OLD INDUSTRY DATA.

LDG negotiated with the trustee for Cockrell Corporation for the purchase of some 16 lineal miles of 6-fold vibroseis data acquired in the early 1960's. After review of the available field notes and data acquisition techniques, LDG chose not to buy the data.

Harvey Seismic Services, Inc. completed almost 65 line miles of seismic vibroseis surveys in the lower Animas Valley in 1982. These are 12-fold data, and the location and measurement methods meet modern standards. To determine if these older data could give useful structural information using modern data processing techniques, LDG purchased a license for five (5) line miles of the Harvey seismic data, which is the northernmost portion of Harvey Line 26. Subsequently, after reviewing the data as processed by Excel Geophysical Services, Lakewood, Colorado, LDG purchased a license for a total of 45 lineal km (27 miles) of the Harvey data.

NEW SEISMIC TRAVERSES

After reviewing bids from six firms, LDG contracted with Bird Geophysical Services ("Bird") to conduct a test to determine if relatively small, spring-assisted, drop weights could be used to successfully acquire deep reflections. This test showed that the contractor could produce usable data to depths of more than 1,500 ms two-way travel time. (For a given velocity model, this two-way travel time is equivalent to several kilometers of depth penetration.) Subsequently, LDG used Bird's services to acquire new traverses totaling about 27.6 km (17.2 mi.) along roads leading through the center of the

LDG lease and the center of the shallow geothermal anomaly. This total included four new traverses across the putative Animas Valley Fault using 1-2-km traverses in four different locations.

Data Acquisition

To acquire the field data, Bird initially surveyed in the planned traverse, with planned "drop" points located on 50-foot (17 m) centers. Then, the geophone array was deployed; depending on the length of the each traverse, the geophone array covered from 1.0 to 1.5 lineal miles. At each drop point, the spring-assisted weight was deployed, and the resulting "ping" was checked for data quality on the geophone array. Then, at the same drop point, five more drops were recorded, so that the final processing could use an arithmetic mean of the signal intensity and reflected energy for that point. The drop equipment then was moved to the next drop point, and the acquisition continued apace. Using this technique, the reflected energy was sampled some 60 times at each geophone location, so that the reflection represents 60-fold data acquisition.

Preliminary Assessment of Structural Implications from Seismic Data

The seismic traverses revealed a very complex subsurface structure. Generally, major faults appear downthrown to the west; however, at depth, there is a trend of significant faults downthrown to the east.

At the eastern end of Caliche Road where it intersects inferred surface expression of the Animas Valley Fault, several hundred meters of vertical displacement appear downthrown to the west. At other places in the western part of the valley, vertical displacement could be as much as 3650-4260 m (12,000 to 14,000 feet) along the basin bounding faults.

Analyses discerned deep bedrock faults extending to more than 2,400 ms of two-way travel time, and this travel time is suggestive of bedrock faults extending to depths of 4570-4870 m (15,000 to 16,000 feet). Circulation along these deep bedrock faults in a Basin and Range setting is believed to be the cause of the intense shallow geothermal anomaly at Burgett's greenhouses.

In the northern reaches of the mapped Animas Valley Fault, minor displacement can be discerned at locations more than 9.6 km (6.0 miles) north of the shallow geothermal anomaly. Further to the south, the vertical displacement is much more pronounced, and reaches its maximum at Caliche Road. Figure 12 depicts the locations of seismic traverses within the LDG geothermal leasehold.

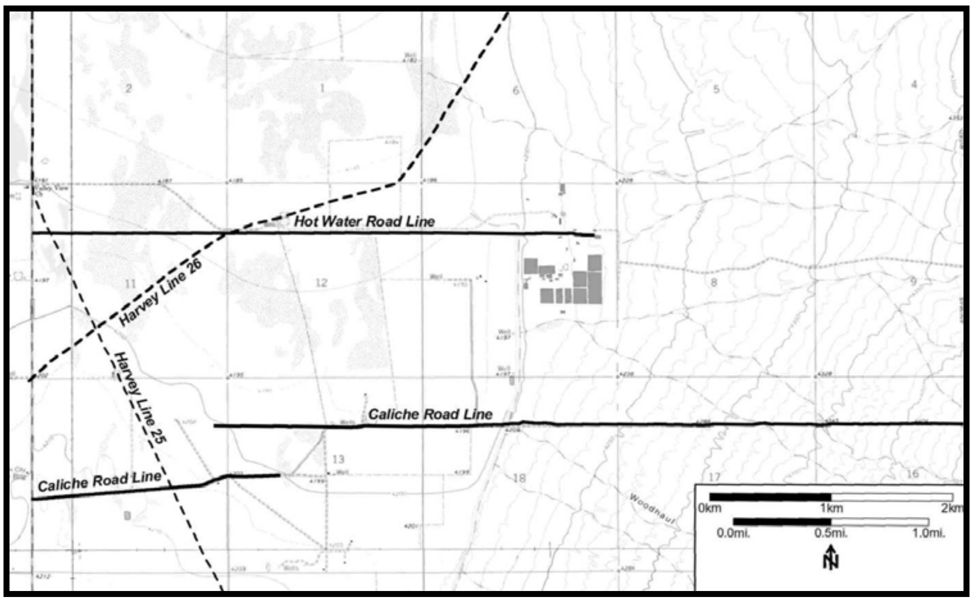

Figure 12. Seismic lines.

GEOCHEMICAL SURVEYS – 2002-2003

CARBON DIOXIDE SOIL-GAS STUDIES

Initial work was performed by a LDG-sponsored graduate student, Dylan Canales, working under the supervision of Dr. David Norman of New Mexico Tech (NMT). Canales used a portable LICOR unit to measure values for CO_2 flux in shallow soils. The initial survey was conducted north and east of Burgett's greenhouses and results showed possible leakage of CO_2 along the mapped Animas Valley Fault.

In January 2003, a second LDG-sponsored NMT graduate student, Kristie McLin, started a second phase of the CO_2 survey. This second phase was designed to verify the initial work and to establish other sampling parameters and techniques necessary to determine if the survey method is useful for geothermal resource delineation. The survey locations were coordinated with Burgett to be completed on his land, and he was very cooperative.

Based on Canales' early work, there appeared to be a strong correlation between the CO_2 results and the NE-SW magnetic linear that runs through the greenhouse complex. This correlation suggested that the thermal plume extends at depth to the southwest, an area of the thermal anomaly that has never been explored by deep drilling.

McLin took additional CO2 measurements during 2003 and early 2004 to fill in previously unsampled areas and to extend the survey along the mapped surface expression of the Animas Valley Fault (AVF), and to determine if a positive correlation could be made between the known faults and CO_2 flux. In addition, McLin reviewed earlier computations by Canales to determine if sampling controls and methodology met rigorous protocol procedures. Based on all of the data, McLin concluded that there was little to no correlation between values for CO_2 flux and known or postulated faults, and between the CO_2 flux and the shallow thermal anomaly. Instead, the flux values appeared to depict a completely random pattern throughout the study area. Notably, absolute values for CO_2 flux were elevated throughout the surveyed areas (McLin, 2004).

A possible explanation not considered by McLin, is that the generally random but uniform CO_2 flux could represent leakage from the massively fractured subsurface formations delineated in the final reflection seismic traverses completed in 2004 after the gradient holes were drilled. If this is a correct assessment, then it is unlikely that a single major fault or faults could provide the vertical conduit for CO_2; instead, vertical leakage could occur ubiquitously through the soil overburden.

THERMAL ION DISPERSION

Thermal Ion Dispersion (TID) is a method used by the precious-metals industry to determine the movement of hot, mineral-bearing waters through rocks, gravels, and soils. The survey involves collection of soil samples and analyses of ions by an enzyme leach process done by commercial laboratories. The method utilizes the property of elements to be dissolved, transported, or deposited depending on the temperature of the thermal waters. The TID method has not been applied to geothermal exploration before.

In July 2002, LDG contracted MagmaChem of Sonoita, AZ to conduct a TID survey in the greenhouse area. The goals of the soil sampling were: 1) to test whether or not the technique could detect the overall thermal anomaly, and 2) if the overall thermal anomaly could be detected, then to examine whether or not surface geochemistry could define geothermal features or distinctive zones within the overall thermal anomaly.

A total of 77 soil samples were collected in the greenhouse area by Dr. Earl Abbott and Roger Bowers in July 2002. The sampling program was designed to cross the known surface thermal anomaly mapped by Kintzinger (1956). The resulting data were then interpreted by MagmaChem using a proprietary procedure that identified six unique metal assemblages at the geothermal anomaly. These assemblages, along with individual element species, were mapped and contoured individually.

The results depicted a new "picture" of the surface thermal anomaly. The data not only detected the thermal anomaly and showed zonation of mineral assemblages outward from the hottest area, but the results also suggested a much more specific fluid flow path for shallow geothermal leakage. In this regard, the resulting maps of assemblages suggest the occurrence of Riedel shear zones that may control the upflow of hot water near the surface. Notably, a significant Riedel shear zone appears to strike in a north-south alignment near, but offset to the west, from the greenhouse complex.

Among the conclusions reached by MagmaChem (2002) from the TID survey, the following two provide a useful geochemical insight not seen in the voluminous water sampling done in the past by others:

> *"…all of the element dispersion is arranged as a halo to an area within the thermal anomaly that is characterized by a complete lack of metal assemblage development. Significantly, this negative anomaly correlates with the part of the anomaly where production of thermal waters from past and existing wells has occurred. Consequently, we interpret this area of negative assemblage development as the area underlain by highest temperature thermal water."*

> *"With respect to cooler waters, hotter geothermal waters are anomalously enriched in sodium, potassium, sulfate, fluorine, boron, iron, and silica and somewhat enriched in chlorine and bicarbonate. Significantly, all of the above elements are components of element assemblages sequentially arranged in various element assemblage halos lateral to the depleted zone."*

TEMPERATURE GRADIENT HOLES – 2003

GRADIENT HOLE PERMITTING PROCESS

Initial Permit Applications

LDG expected that the permitting process would be difficult and time consuming because of the lack of geothermal drilling activity in New Mexico in the past 20 years. The permitting agencies had no current experience for reviewing and approving geothermal gradient holes drilled on federal lands. This problem was magnified by the fact that permits are required from three separate agencies; namely, the Bureau of Land Management (BLM) for federal geothermal gradient holes, the State of New Mexico Oil Conservation Division (OCD) for all gradient holes drilled on privately-owned surface or State land, and the State of New Mexico Engineer for all wells drilled into a Declared Underground Water Basin or Closed Basin (with the Animas Valley designated in both categories).

Each of these permitting actions required lead time for processing; moreover, the State Engineer Permit Application required submittal to that office of the approved OCD Permit. To further compound the difficulties, both the OCD and the State Engineer Permit Applications required identification of the driller to be used, with the State Engineer also requiring identification of the NM Drilling License for the chosen driller. Hence, permit applications had to wait for completion of the bidding and selection process for the contracted well driller.

The Drilling Plan and Sundry Notice for the initial gradient hole, TG12-7, were submitted on December 29, 2002 to the BLM Las Cruces Field Office. Concurrently, on the same date, LDG submitted a permit application to the New Mexico OCD. Subsequent coordination was made with the BLM, and LDG was provided information that BLM wanted the drilling permits submitted on an older form. This revised permit application was submitted on January 31, 2003. Concurrently, to assure that OCD would be acting on the same information, LDG submitted a new application to that office, and this permit was approved on February 6, 2003.

LDG was required to submit a second revised Drilling Plan transmitted to the BLM on February 20, 2003. In the interim, the BLM had conducted a preliminary environmental investigation and concluded there was minimal to no environmental impact from the proposed drilling. Subsequently, on February 25, 2003, the BLM provided LDG with approval for the proposed drilling activity.

Permit Application for an Exploratory Well (the State Engineer has no category for a gradient hole, per se) was submitted to the NM State Engineer on March 13, 2003. This application finally was approved on March 20, 2003, some two days after the driller had mobilized to the site for TG12-7. From initiation to completion, the permitting process for gradient hole TG12-7 required almost three months.

Subsequent Permit Applications

A different strategy was adopted for subsequent permits. As part of the GRED Program, two additional gradient holes were nominated by LDG. Hence, the continuing permitting process entailed acquiring permits for three additional gradient holes (two GRED holes and one EGS hole), with provisions to change locations based on results from initial drilling as data were acquired from each successive gradient hole.

The decision was made by LDG to use a batch-type process for permit applications. Accordingly, a new Plan of Operations and Drilling Plan were developed and submitted to the BLM; these documents identified a total of eleven (11) separate locations for which environmental clearance and drilling permit approval were needed, with the caveat that only three of the locations would be drilled. Concurrently, LDG used acceptable procurement policies, and contracted with a single driller for all three new gradient holes.

Simultaneous transmittal was made to OCD for all eleven permit applications. The OCD approved the multiple permits on April 12, 2003, and BLM approval for the multiple gradient holes was issued on April 25, 2003. Separate permit applications for each actual drilling location were submitted to the New Mexico State Engineer, with the initial application for TG56-14 submitted on April 4, 2004 and approved by the State Engineer on April 22, 2003. Subsequently, State Engineer permits were obtained for the remaining two GRED gradient holes. These permits were obtained individually as each new location was confirmed.

Figure 13 shows the locations for the total of 12 gradient holes, with eleven of those representing potential locations for the three new gradient holes, for candidate gradient holes for which BLM and New Mexico OCD approval was given.

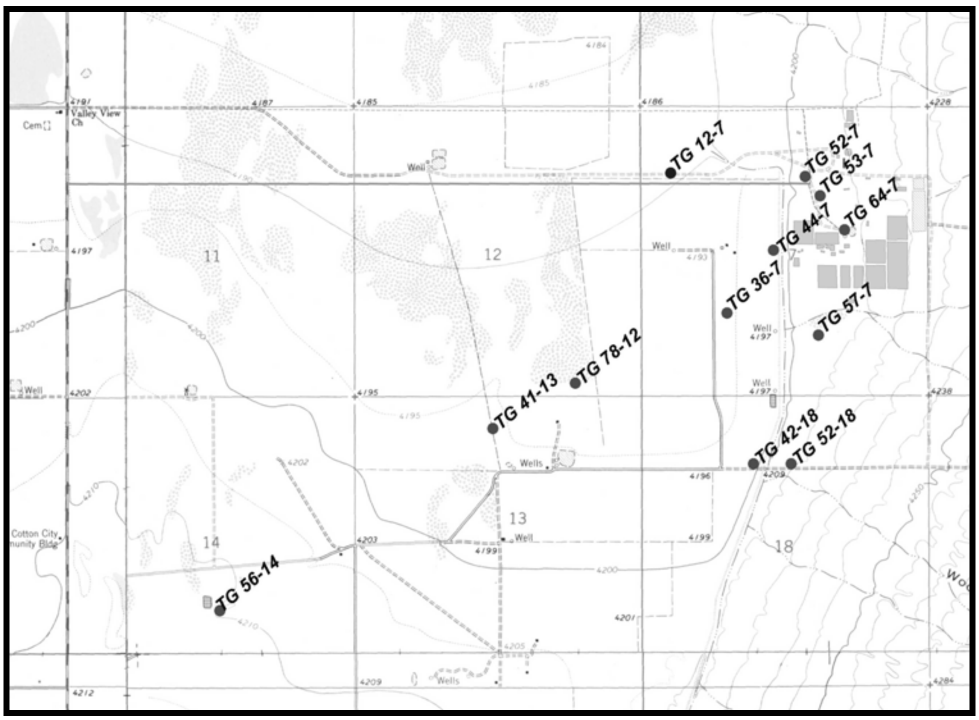

Figure 13. Approved gradient hole locations.

SUMMARY OF THE EGS GRADIENT HOLE DRILLING PROGRAM

The following information is excerpted from the LDG Final Report on the EGS Cooperative Agreement (Cunniff and Bowers, 2003b); the information is repeated here to show the continuity that LDG maintained for the fieldwork completed for these GRED and EGS Agreements.

The two gradient holes were sited on federal geothermal leases owned by Lightning Dock Geothermal, Inc. and both were drilled into lakebed sediments some distance from the intense shallow geothermal anomaly located in the eastern half of Section 7, Township 25 South, Range 19 West.

- Gradient hole TG12-7 was sited about one kilometer to the west of the shallow thermal anomaly. The hole was completed to a total depth of 305 meters (1,000 feet). Bottom-hole temperature was 69°C (156°F),

- Gradient hole TG56-14 was sited about four kilometers southwest of the center of the shallow thermal anomaly. The hole was completed to a total depth of 381 meters (1,250 feet). Bottom-hole temperature was 36°C (96°F).

Lithologies encountered in the two EGS holes were predominantly lakebed sediments deposited in the Pleistocene and Recent Lake Animas. Unconsolidated sand and gravel beds averaged about two feet thick and were interbedded with thin layers of greenish clay. Some of the clay beds were rich in organic material and had a distinctive organic odor. Sand and gravel sediments were volcanic in origin, commonly andesitic and rhyolitic in composition, and derived from source rocks in the Pyramid Mountains.

Final report to the regulatory agencies for these two EGS gradient holes was completed on August 1, 2003. On March 22, 2004, TG56-14 was sold to D. Burgett and TG12-7 was sold to T. McCants for use of the surface casing as a water well. The follow-on reporting, if any, and all liability for these holes are the responsibility of the new owners.

GRED TEMPERATURE GRADIENT HOLE TG36-7

<u>Drilling Summary</u>

Hole TG36-7 was sited in an old cotton field that had not been planted for years, thus a minimal amount of site preparation was required. The New Mexico State Engineers Office issued the drilling permit on May 15, 2003 and the hole was spudded the same day. Seven-inch steel casing was then run to a depth of 48 meters (158 feet) and grouted. On May 17, 2003, Blow-Out Prevention Equipment (BOPE) was installed on the casing and pressure tested. After successfully testing the BOPE, drilling continued to a depth of 134 meters. Drilling progressed through May 21, 2003 to a depth of 305 meters. After conditioning the hole, 2-3/8-inch-diameter steel tubing was run to total depth and filled with water.

Lithology

The entire hole was drilled in unconsolidated sediments that consisted primarily of coarse-grained sand. Minor thin beds of gravels and lakebed clays were also encountered. Mineralogically, the sand grains consisted of volcanic sediments, including tuff, andesite, and rhyolite. Lakebed clays were commonly greenish in color and very sticky and plastic. A schematic diagram of well construction and lithology is shown in Figure 14.

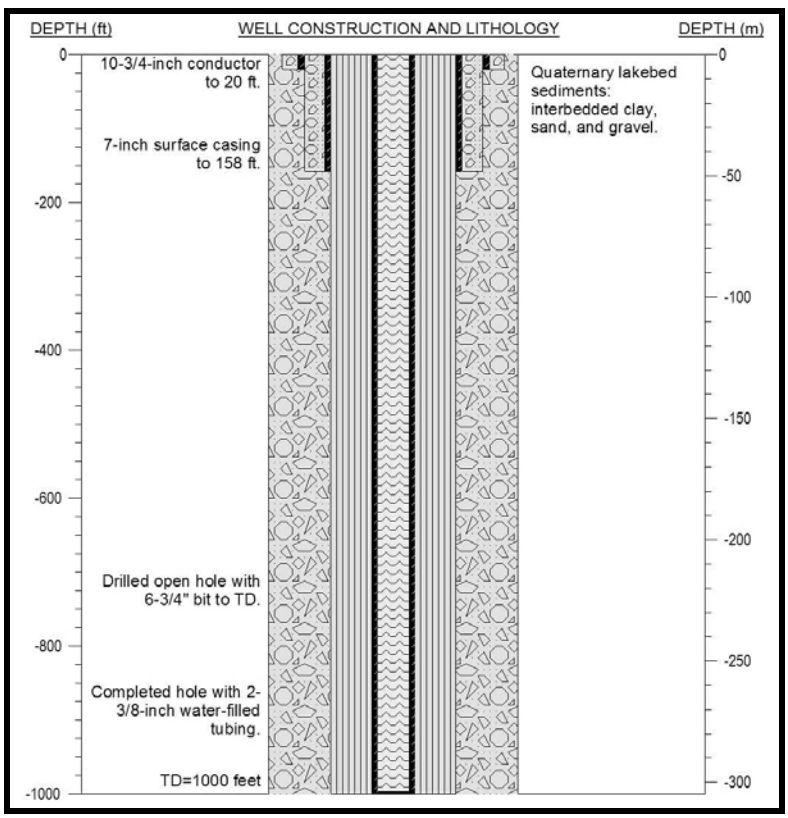

Figure 14. TG36-7 completion schematic.

Temperature Surveys

A total of five temperature surveys were run in hole TG36-7. The first was run on May 21, 2003, just a few hours after completion of the hole. Subsequent surveys were run on May 30, June 5, August 2, and September 17, 2003. The first three surveys were run with a hand-cranked, high-temperature probe provided by Dr. David Blackwell of Southern Methodist University. The fourth survey was run by Dr. Jason McKenna of Southern Methodist University using the SMU Geothermal Laboratory's logging trailer. This trailer is a motorized, wireline logging unit with a tool that provides both precision temperature and gamma ray logs.

The final survey of September 17, 2003 was run by Well Analysis Corporation (Welaco) of Bakersfield, California. This final survey was run with a combination tool that provided temperature, pressure, and gamma ray. The tool hit an obstruction in the tubing at 118 meters (387 feet) and several attempts to get below this obstruction were unsuccessful.

The temperature/depth profile for TG36-7 shows a conductive gradient from 30 meters to total depth. The hole did not intersect the shallow thermal outflow commonly seen in other wells. Bottom-hole temperature was higher than 90°C

Disposition of the Hole

Final report to the regulatory agencies was completed on August 1, 2003. On March 22, 2004 the hole was sold to D. Burgett for use of the surface casing as a water well. The follow-on reporting, if any, and all liability for this well are the responsibility of Mr. Burgett.

GRED TEMPERATURE GRADIENT HOLE TG57-7

Drilling Summary

The drill rig was moved to hole TG57-7 on June 3, 2003. This drill site is a few hundred feet south of the Burgett greenhouses and site preparation consisted simply of clearing some sagebrush and digging a mud pit. The hole was spudded on June 4, 2003 and drilled with air to a depth of 45 meters. On June 5, 2003, the hole was cleaned and seven-inch steel casing was run to 44 meters and grouted. BOPE was installed on June 6, 2003 and successfully tested.

Drilling operations included both air and mud, and the hole eventually was completed to a depth of 278 m. After circulating to clean the hole, steel tubing was run to 278 meters on June 14, 2003. On June 15, 2003, the rig was moved and the hole was capped.

Lithology

From surface to a depth of about 73 meters, the hole was drilled primarily in coarse sands and gravels. The lost circulation zones yielded only partial samples, but those consisted of gravels of rhyolite and andesite. Below 73 meters, the lithology changed to volcanic tuffs and flows. The tuffs range from partially welded to densely welded, and from rhyolitic to andesitic in composition. A schematic diagram of well construction and lithology is shown in Figure 15.

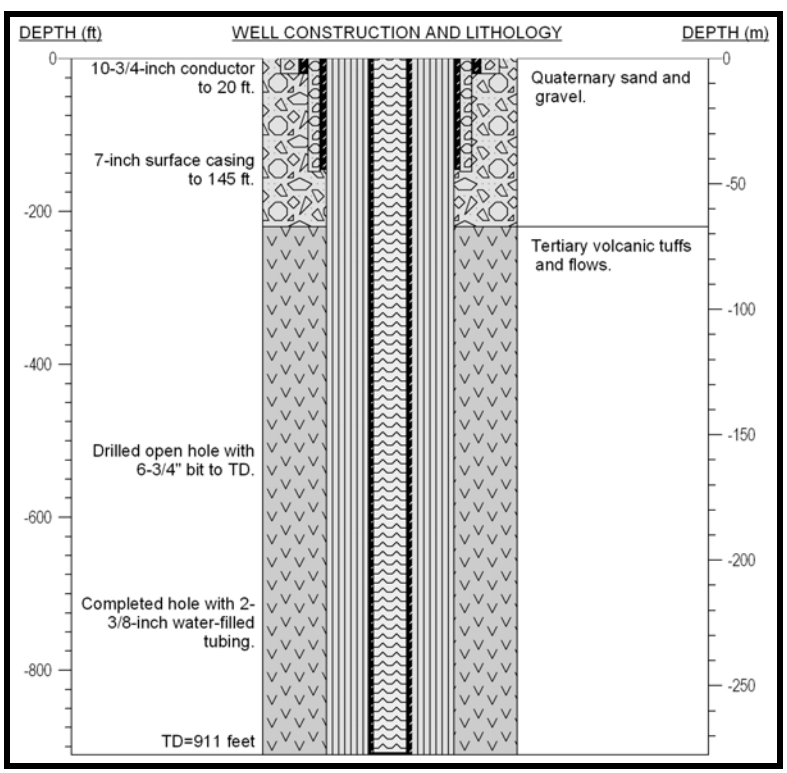

Figure 15. TG57-7 completion schematic.

Temperature Surveys

Two temperature surveys were run in hole TG57-7. The first survey was run on July 3, 2004, approximately 2 weeks after completion of the hole. This survey was run by Dr. Jason McKenna using SMU's logging trailer. The logging tool could not get through an obstruction in the tubing and the survey was completed with a smaller-diameter probe on a hand-cranked cable reel. The second and final survey was run by Welaco on September 17, 2003.

The temperature surveys show that the hole penetrated the shallow hot-water outflow zone at a depth of approximately 50 meters. The peak temperature of this outflow zone at that depth correlates with the major lost-circulation zones encountered during drilling. Maximum temperature in the hole was 108°C.

Disposition of the Hole

Final report to the regulatory agencies was completed on August 1, 2003. On March 22, 2004 the hole was sold to D. Burgett for use of the surface casing as a water well. The follow-on reporting, if any, and all liability for this hole are the responsibility of Mr. Burgett.

DEEP TEST HOLE TG52-7

SITE SELECTION AND PERMITTING

Site Selection

A prime factor in the decision to site the deep exploratory well at this specific location was seismic imaging data from the traverse along Hot Water Road. At this location, seismic image depicts a buried fault dipping steeply to the north or northwest, likely at a depth of 600 to 900 meters (2,000 to 3,000 feet). In addition, a probable Riedel shear, deduced from the soil ion assessment, has been mapped as traversing this area on a north-south alignment. The likely dip direction of the subsurface fault mapped by the seismic work also correlated with probable depth to rhyolite tuff encountered in the shallow geothermal production wells.

These hints of probable subsurface structures were the best available geophysical data that a deep exploratory well at this location had a reasonable chance of intersecting highly faulted and fractured rock at a target depth of 915 meters (3,000 feet).

Well Permits

Permitting for TG52-7 followed a process similar to that used for the gradient holes. There were notable differences, however, with those changes driven by BLM requirements. The deep exploratory hole represented by TG52-7 required preparation of a Drilling Plan and a Geothermal Drilling Permit (GDP). Key to this Drilling Plan (and for the similar plan developed for the gradient holes) was the requirement that the Plan, if approved, would not cause environmental degradation. An internal BLM Environmental Assessment was completed as part of the approval process for the GDP.

LDG originally filed a Drilling Plan and GDP application in January 2003 for a well at the final site for TG52-7. Final approval of the GDP was provided by BLM on May 5, 2003. Concurrently, LDG filed with the NM OCD the necessary permits for surface disturbance, and also filed the Exploratory Well permit with the NM State Engineer.

Actual drilling operations were conducted in three different stages, with a resulting need for changed permits.

- Stage one represented drilling activity to a total depth of 2,223 feet. Drilling operations in this stage were approved by each of the three permitting agencies.
- In stage two, the well was flow-tested using airlift for 23 hours. New approvals were required from the BLM and the NM OCD. The latter agency controlled the surface discharge plan for disposal of produced water, and the agency required proof that surface disposal would not cause degradation of potable ground water. To meet this test, LDG completed an airlifted drill-stem test from the open hole to 676 meters (2,220 feet). The analyses showed that produced water was near potable, and would cause less degradation than has resulted from the 25-year history of surface disposal of the effluent from the shallow wells. Accordingly, OCD permitted surface disposal of produced water from the flow test.
- In the third stage, drilling operations were completed to total depth of 2,528 feet, with separate approvals from each permitting agency.

Final completion reports were filed with each of these agencies. The completed well was retained as a permanent monitoring well for future temperature observations.

DRILLING OPERATIONS SUMMARY

The hole was spudded on June 20, 2003, and drilled to 20 feet, and 10-3/4-inch conductor casing was set and cemented. Seven-inch (6.5-inch inside diameter) surface casing was set to 470 feet and cemented from 470 feet to surface. Drilling proceeded with good success to 663 feet. At that depth, significant water entry was encountered, and air drilling could not continue because the hole was making large volumes of boiling water (estimated to be about 250 gpm or more). Accordingly, drilling was switched back to mud rotary for the duration of drilling activities. During the period from June 26 until July 2, average footage drilled was about 150 feet per day.

Intermediate Temperature Survey 1

At a depth of 1,912 feet (about 583 m), an attempt was made to acquire an open hole temperature survey using the crew and equipment from Southern Methodist University (SMU) under the direction of Dr. Jason McKenna. The temperature tool was in the SMU van logging system manufactured by Madden Systems, Odessa, Texas. The tool assemblage included a natural gamma tool module in tandem with the temperature tool.

A partial log was attained to a depth of 1,548 feet (472 m) before the tool failed because of loss of signal. This survey measured an isothermal zone from about 200 to 700 feet, and a positive temperature gradient below 700 feet of depth. The elevated temperature and the positive thermal gradient were both encouraging signs for deeper drilling.

Continuation Drilling

After the temperature survey was completed, drilling resumed. Drilling progressed at normal penetration rates of 25-30 feet per hour to 2,000 feet. Drilling continued over the 4th of July holiday weekend and penetration rates declined steadily below 2,000 feet. Below 2,150 feet, the penetration rate declined to less than 10 feet per hour; below 2,200 feet the penetration rate was less than 6 feet per hour.

Well Conditioning, Logging

On July 6, LDG made the decision to suspend drilling and bring in Southwest Geophysical Services (SGS) to log the hole. To safeguard SGS's tools, the hole had to be conditioned and cooled to less than 140°F (60°C). A hole cooling test was successfully completed on July 6 by pumping 20,000 gallons of cold water down the hole. Return temperatures were less than 120°F (49°C).

The hole was successfully conditioned and cooled on the morning of July 7. The drill pipe was pulled out of the hole and SGS started logging operations about noon. The sonic log was run first because the tool was most sensitive to high temperatures. The tool was run to bottom and logging was started, but signal from the tool started to fail about

200 feet off bottom. The tool was pulled out of the hole and a second sonic tool was substituted. The signal from this second tool failed before the tool ever got to bottom. Southwest did not have another sonic tool available.

Two separate logging runs were then successfully made for gamma ray/neutron and electric logs (resistivity). Despite the disturbed condition of the hole, LDG insisted on getting a bottom-hole temperature. SGS's temperature tool gave erratic signals at about 300 feet and was pulled from the hole. A second temperature tool failed at about 200 feet. These two temperature tools were supposedly rated to 300°F, but were only calibrated to 160°F. No explanation was given by SGS for failure of four of the six tools.

Conference Call to SNL

On the afternoon of July 7, Alan Sattler of Sandia National Laboratories (SNL) set up a conference call for LDG with two drilling bit experts from private industry. After much discussion, it was concluded that an appropriate bit was being used and drilling parameters (rpm's, weight on bit, etc.) were within recommended ranges. The volcanic formation (welded tuff) was simply difficult to drill. Two provisional recommendations were made by the industry experts: 1) purchase a special rotary bit at a cost of nearly $7,000 (a "10% discount" was offered on the cost) with no guarantees of faster penetration rates, or 2) drill with an air hammer. Air drilling was not possible because of the significant boiling-water entry at 663-670 feet.

Air-Lift Test

Given the likely delays if a new bit were to be purchased, uncertainty of success with a new bit, and the uncertain but worsening condition of the hole, LDG made the decision to conduct a limited short-term air-lift test to obtain estimates of flow rate and flowing temperatures, and to acquire water samples for chemical analyses. Open-ended drill pipe was run to a depth of about 460 feet to stay within the casing and to avoid further damage to the deeper open hole. The air-lift test was conducted on July 8 for one hour. During that test, five sets of water samples were collected at 15-minute intervals. An estimated flow rate of more than 250 gallons per minute was sustained throughout the test period.

Water samples were immediately chilled and shipped that afternoon to Las Cruces for delivery to the New Mexico State University Soil Water, and Air Testing (SWAT) Laboratory.

Temporary Shut-in

After completion of the air-lift test and acquisition of water samples, 2-3/8-inch steel tubing was run to at depth of 2,211 feet. The well was capped and locked.

LOGGING AND FLOW TEST OPERATIONS

Summary of Test Operations

Coordination with Sandia National Laboratories provided the services of Welaco for logging surveys on all LDG's holes and also for support during the controlled airlift test on TG52-7. The unit mobilized to the site on September 16 and logging runs were completed on four gradient holes and one test well owned by LDG.

After the Welaco temperature survey was completed for TG52-7, preparations were completed for a controlled airlift test. This test was completed in the period from 19-20 September 2003 for some 23 hours. The well produced steady state flow of about 320-325 gpm at a wellhead temperature of 126.7°C (260°F). This production rate is equivalent to about 162,000 pounds per hour, with the production temperature producing usable heat content of about 26 million Btu per hour, or about 2.5 $MW_{thermal}$. Because of excessive friction loss in the small diameter well bore (6-3/8-inch) resulting from turbulent flow caused by the airlift, the flow rate attained is not considered to be representative of likely resource potential. A larger well casing with mechanical pumping should produce higher yields.

The test did not meet all of the test objectives because of equipment malfunctions. The Welaco data recorder malfunctioned mid-way through the test, and pressure recovery values could not be attained. In addition, test objectives to evaluate reservoir hydraulic properties by measuring potential communication between TG52-7 and other nearby geothermal wells also were degraded by equipment problems and by the lower flow rate which meant that observation wells were too far distant to be able to detect any communication with the test well.

Controlled Airlift Test

Scope

An airlift flow test was completed for hole TG52-7. Test objectives were:

1. Determine produced water characteristics, including flow rate, flowing temperature, and water quality;

2. Determine well characteristics, including pressure loss (proxy for drawdown during airlift, pressure recovery after flow stopped), and acquire data to determine coefficients of storage and transmissivity for the hole;

3. Evaluate geothermal reservoir characteristics, to include effects on adjacent geothermal wells resulting from fluid withdrawal at TG52-7.

Wellhead Control System

A wellhead surface piping and control system was fabricated to enable safe control of high temperature fluid. This apparatus provided capability of measuring flow rate and flowing temperature, and also provided a mechanism to safely acquire water samples for laboratory analyses. To measure flow rates, use was made of an open-top design steel tank with a known volume of 21,000 gals (500 barrels), rented from Baker Tank Company. The tank was modified by LDG to accept two sets of sight-glass gage isolation valves and two boiler sight glasses, each 48 inches long, mounted so they could measure fluid levels for the critical nine feet of fill levels. The tank also was modified with a one-inch sampling port that terminated in a riser dropping down to slightly above ground level for use in acquiring water samples

Air supply was a trailer-mounted unit capable of delivering 1,150 CFM of air at a pressure of 350 psig. The air supply unit was connected to the wellhead unit by a combination of rigid and flexible piping, which in turn connected to the rigid steel airline. Capability was installed to regulate delivered air pressure; however, air volumetric requirements would be controlled by two valves in series, which could be manipulated by trial-and error until a balanced geothermal discharge flow was attained.

Rig-up for Airlift Test

Coordination with Welaco indicated that they were confident their down-hole pressure recording tool would function satisfactorily in the downhole ambient condition of 260°F for the expected test duration of 24 hours, plus an estimated six hours afterwards for pressure recovery tests on the well. The Welaco tool was inserted first, and the pressure tool was suspended at the optimal depth of 700 feet below the top of the surface casing and 130 feet below the bottom of the surface casing.

The 1-1/2-inch airline was successfully inserted so that the bottom of the airline was at 600 feet. This depth was chosen to assure sufficient fluid above the air jet under probable maximum withdrawal rate of up to 700 gpm. The air line terminated in a special fitting that was custom built with multiple ports, each fabricated so they would direct the air flow near-vertically after exiting the air line.

Test Operations

When the Welaco tool had been inserted and the air line installed, the test was started. Initially, two false starts resulted from equipment failures; these false starts thus compromised the data needed for evaluating reservoir and well hydrology at start-up. After start up, air volume rate was reduced to minimize turbulence in the flow stream, and the air compressor supply pressure was reduced to about 214 psig. This supply pressure was maintained for the duration of the test. Back pressure on the wellhead was maintained at a rate of 60-65 psig, and wellhead temperature was steady at 260°F. Flowing temperature was measured with a laser/infrared thermometer by measuring the metal wellhead surface temperature at several points. Four timed fill tests were completed. Before the first three timed fill tests, the Baker tank was filled with cold water to a depth of about 4 feet, or until the water level was observable in the bottom of the lower sight glass tube. (Approximate initial volume was 7,500 gallons.)

Discharge into the Baker tank caused violent surging created by both air release and boiling as the water cooled from 260°F to about 205°F (boiling point at the altitude of the well). The extreme surges caused water to slop out of the partially opened roof hatches. A similar procedure was used for the second and third timed fill tests, with a cold-water partial fill. For the last three fill tests, the roof hatches were closed on the side directly above the sight-glass tubes. These two timed tests also were continued for 23 minutes.

For the fourth timed fill test, which also was a water sampling run, the test started with an empty tank so that the samples would not be diluted with fresh water. Because there was no cold-water blanket, discharge from the wellhead into the tank caused violent surges, which resulted in large amounts of boiling water spilling out of every roof hatch opening, even with the hatches closed. This test was terminated after 42 minutes because more boiling water was being expelled than was being contained in the tank. Figure 16 shows the surface equipment used during the flow test.

Figure 16. Pictures from flow test of TG52-7.

Water samples were taken using the sample port located on the back of the tank. In addition, immediately after the timed fill test was ended, an attempt was made to get a "hot" sample by using steel flasks suspended in the tank using a wire basket. Multiple samples were taken, and the samples were submitted to the Soil, Water, and Air Testing Laboratory at New Mexico State University.

For each of the first three timed fill tests, fill volume in the 23-minute duration averaged about 7,500 gallons. This total fill is equivalent to a steady state flow rate of about 320-325 gpm (162,000 pounds per hour). Productivity of the well is a function of flow rate and drawdown. From the Welaco downhole tool, indicated pressure was about 239 psig for each of the three tests. This pressure is equivalent to a drawdown of about 122 feet. However, this indicated pressure, hence drawdown, is not real. Because of the large amounts of entrained air, the fluid average density is much lower than pure water and this "frothy" condition biases the pressure to the low side. Thus, the calculated well specific yield of about 2.67 gpm/foot of drawdown is severely understated, and true specific yield would be higher by an unknown but undoubtedly large amount. Accordingly, true formation productivity, would be expected to be much higher using a mechanical pump.

During the middle of the night at about 1:00 AM, after about 11 hours of testing, the Welaco data recorder took itself off line. Welaco and LDG personnel were immediately notified, and it was determined that the down-hole tool was functioning, but data entries were being recorded only for a few minutes before the data recorder would shut down. A procedure was established to manually turn the data recorder on and off throughout the night until the problem could be fully analyzed. Even though this action resulted in numerous data gaps, LDG made an assessment that incomplete data were better than no data, a result that would have occurred if the tool had been left undisturbed. Early in the morning on 20 October, the problem was reviewed and the decision was made to continue the test. This problem worsened as the test continued, so that shortly before the test was terminated, the tool was kicking off line after only a few milliseconds of measurements, and the tool then required at least 5 minutes to be manually reset.

Because the tool was not functioning properly, LDG terminated the air lift test at 2:12 PM on 20 September after some 23 hours in duration.

When the air supply was cut off, an attempt was made to complete a pressure recovery test. The well continued to free flow at a significant flow rate, estimated to be about 75 to 100 gpm. Because the Welaco data recording problems continued to worsen and Welaco personnel believed data retrieval might end at any moment, and because the well continued to flow free, decision was made to kill the flow by injecting cold water through the air line. After only a few minutes of cold water flow, the well was shut in.

The most plausible cause of the free flow is that an inadvertent gas lift was given to the reservoir from the use of compressed air for the airlift test. A sizeable pressure differential could have been caused by air under pressure of about 218 psig entering a water column under a pressure of less than 200 psig from the weight of the water column over the air line exit point. Under these conditions, large volumes of the air could have been forced into micro fissures and cracks in the subsurface material.

Immediate temperature rebound occurred when the air supply was shut off, and this fact suggests that the air lift operation possibly was withdrawing water from at least two different zones. One zone would have a somewhat higher temperature (based on temperature logs the in situ temperature is 283°F or higher from 1,600 feet to TD) and the second zone would have a lower temperature (260°F from the fracture at about 690 feet of depth). The cooler zone would predominate when airlift was in progress, with the hotter zone then the predominant influence when extraction efforts ended.

The geothermal anomaly is marked by numerous fractures, and possible flow paths have not been mapped. Some of the many fractures have been mapped by LDG prior research, but little is known as to the subsurface strike and dip of these many potential flow conduits. To more fully understand the nature of the geothermal resource will require many more wells and several different, longer term flow tests, using tracer materials to map the flow pathways.

Temperature/Pressure/Spinner Surveys

Pressure log:

a. After operations had been underway for about 60 minutes, the pressure curve was essentially flat and stable for about 4 hours, with a slow decline in pressure as the test progressed.

b. Starting at about tool time 13.5 hours, data become very irregular. These irregularities are artifacts probably caused by the tool dropping off line, and correspond to the procedural action to manually turn the tool on and off to reset it.

Temperature log:

a. For the official flow test start, after two false starts, temperature spiked to about 274.5°F and then rather rapidly declined to about 265°F. From that value, temperature slowly declined to about 261°F at the end of the test.

b The temperature increase at test end is of interest because of the shape of the curve. The plotted increase is relatively gradual and rounded in form, as if a relatively slow infill of warmer water was causing the temperature to rise.

Spinner log:

a. When the actual test was started, the tool recorded a brief spike to a value slightly higher than 10 rps, and this value declined to a value of about 7 rps within 60 minutes. Thereafter, the tool response (average value) was relatively flat and consistent at a value of about 9 rps until very near the end of the test. Starting at about tool time 18.7 hours, a gradual decline in the spinner log resulted in an ending value of about 8.5 rps. Because the spinner tool (along with the other tools) was suspended some 60 feet below the fracture at about 690 feet, this spinner tool undoubtedly was measuring flow originating deeper in the well rather than from the shallow fracture zone.

b. Notably, the spinner log provides the best insight into the tool problem of dropping off line. At tool time of about 9.2 to about 9.27 hours, the data response is blank. Starting at about tool time 13.5 hours, and continuing to the end of the test, data entries are marked mostly by voids in which no data were reported. That pattern is very pronounced until about tool time 19.9 hours, when more data were reported.

Analyses of Reservoir Hydraulic Properties

To assess reservoir hydraulic properties, it is necessary to have one or more observation wells relatively close to the pumped well. When properly instrumented, data observed in these wells at key times will help provide data from which reservoir hydraulic properties can be estimated. Several key assumptions are made in evaluating effects on nearby observation wells when the test well is pumped, and again when the pumping action terminates. These assumptions are:

1. The fluid extraction rate is large enough to produce measurable influence on water levels some distance from the test well.

2. It is possible to acquire precise measurements of the amount of drawdown in observation wells located relatively close to the test well.

3. Observation wells, ideally, should penetrate the same water-bearing subsurface formations as the pumped well; as a minimum, the observation wells should be as close as possible to the same depth as the pumped well.

4. The reservoir is homogeneous, confined or semi-confined, and radial flow conditions are present so that analyses of reservoir hydraulic properties can be completed using the Theis equations and methodology.

Little information is available concerning measured flow tests on shallow geothermal wells within the intense shallow anomaly. Only one properly designed and executed flow test is documented in the literature. That test was performed on a very shallow well (200 feet deep) and was performed in 1981. Reported data include a transmissivity value of 19,000 gpd/ft, and a well specific yield of about 23 gpm/ft. of drawdown (Lansford, 1981).

Another shallow geothermal well (AmeriCulture State #1, reported depth 400 feet, with the lowest 110 feet an open hole) also was flow tested in late 2000. A consultant report was prepared by Jim Witcher, but has not been released. In a separate public report, Witcher reported only that the transmissivity was larger than 25,000 gpd/ft. (Witcher, et al, 2002). Absent a complete public report, limited anecdotal (and unverified) information is available. AmeriCulture State #1 reportedly was flow tested for at about a 48-hour period at a flow rate of about 1,100 gpm (66,000 gph) and drawdown was less than 20 feet (Dave Duchane, personal communication, Dec 5, 2000). Given this unverified information, the specific capacity of the well would be about 53 gpm per foot of drawdown, which is an exceptionally high capacity considering that the production zone likely consisted of alluvial gravels of volcanic sediments.

It is unknown whether or not the pumped flow test on AmeriCulture State #1 was accompanied by instrumentation placed in nearby wells to measure and record possible effects on those wells of the large fluid extraction from the test well. Anecdotal information supplied by the nearby surface landowner suggests that there was measurable drawdown ("dozens" of feet) in his own State geothermal wells located about 600-700 feet north of the test well, and several feet of drawdown in well TFD 55-7. The land owner used a crude measurement device consisting of a wooden block fastened to the bottom of a steel tape to estimate drawdown during the AmeriCulture test pumping.

To gain valid data for calculating reservoir properties, normally it is preferable that the observation well or wells are located very close to the test well, or at a distance of about 400-500 feet. More distant observation wells can be successfully used if the fluid extraction rate is high enough so that the cone of depression resulting from fluid withdrawal is relatively large, and the influence of fluid extraction can be measured relatively soon after pumping starts and ends.

Very few geothermal wells are within a radius of about 2,500 feet from well TG52-7. Five candidate geothermal wells were considered, as follows:

1. AmeriCulture No. 1 Federal. This is the closest well, and is located about 600 feet north of TG52-7. The well was completed to a depth of 195 feet in unconsolidated gravels and clays, and contains perforated casing from groundwater (60 feet) to total depth (TD). However, the owner posed unacceptable conditions on the use of this well for monitoring drawdown, so the well was eliminated from further consideration.

2. McCants No. 1 State. This well was drilled about 1993 to an approximate depth of 180 feet, and was completed with perforated casing from 60 feet to TD. It is located about 1,200 feet east of TG52-7. This well had an old down-hole heat exchanger requiring removal. Questions regarding liability for the well were unresolved; therefore, this well also was removed from further consideration.

3. Burgett No. 1 State, called "Rosette 1" and also termed by Burgett as "Discovery Well." This well is 440 feet deep, with 8-inch casing to 180 feet and open hole 7-7/8-inch to TD. The well intersected tightly cemented rhyolite at about 380 feet of depth. This well is located about 1,770 feet north-northeast from TG52-7.

4. Burgett Greenhouse No. 2, southeast corner. This well is termed "#2 SE" and is 440 feet deep with 8-inch casing to 300 feet and 7-7/8-inch open hole to TD. The well intersected tightly cemented rhyolite at about 80 feet of depth. It is located about 1,270 feet almost due south of TG 52-7.

5. TFD55-7. This well was drilled in 1984 by Steam Reserve Corporation to a depth of 7,000 feet, and was plugged in 1985. Surface casing, 13-3/8-inch diameter was set at 1,050 feet. The well is now open to about 1,365 feet, with 12-7/8-inch open hole from 1,050 to TD in volcanic rocks and a formation identified as the "Gila Conglomerate" by other researchers. The well is located about 1,600 feet south-southwest from TG52-7.

Based on good reasons for rejecting the nearest two wells, decision was made to use the two Burgett wells and TFD55-7. The following Figure 17 depicts locations for the three monitoring wells used for the airlift test on TG52-7.

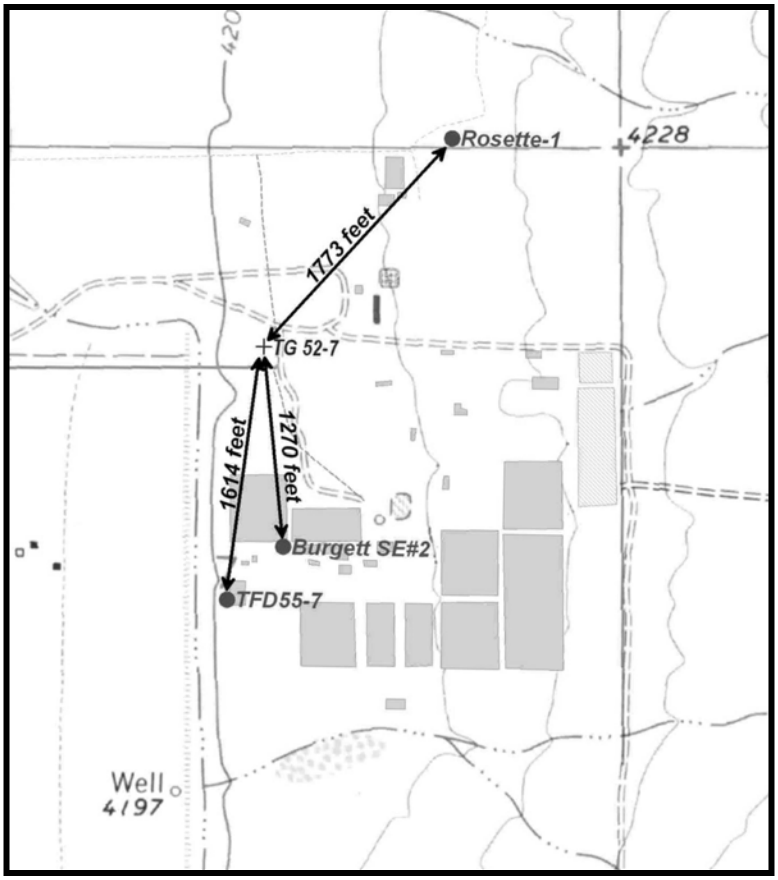

Figure 17. Candidate monitor wells.

For two of the three monitoring wells, one-half-inch rigid stainless steel air line was inserted into the wells to a precisely determined depth. For the third well, the air line was one-quarter inch, because that was all the space available. At the surface, the air line terminated at a tee, with one branch of the tee equipped with a special valve for connecting the compressed air source. The other branch terminated in an isolation valve and pressure gauge. The gauge used was a Dwyer Model 103, with a range of 0-30 psig. Accuracy of the gauge was warranted to be plus or minus 0.25 percent of full scale, which for this pressure range would be 0.075 feet or 0.9 inches of water.

The air line was set at 126 feet of depth in Burgett's Discovery Well, and was set at 84 feet of depth in the remaining two observation wells. Installation was completed one week before the planned air-lift test on TG52-7 so that daily readings would provide background information on possible influences caused by tidal forces and barometric pressure.

During the week preceding the flow test, initial daily readings were widely variable, and it appeared that the pressure gauges had a slow but significant leak rate. Although this leak could be compensated for by charging the air line before each reading, this process would be too slow to catch instantaneous changes in the water level. Contact was made with the supplier, and Dwyer Instrument Company advised that the unit was so new to their inventory, they had not as yet completed the necessary testing of the unit to determine what would be considered a normal and expected leak rate. For this reason, the gauge isolation valve had to be in the closed position between pressure readings.

With a compromise on the method and timing for water level measurements in the observation wells, the test set-up was deemed adequate to assess potential effects, if any, on these observation wells when fluid was extracted from TG52-7. Two other factors subsequently interacted to limit usefulness of the observations:

- First, AmeriCulture was completing drilling actions on its No. 2 State well during the flow test on TG52-7. At unknown intervals, they pumped water from their No. 1 Federal well (the well nearest to TG52-7) to the water storage tank at the new drill site. Each unknown pumping action extracted about 20,000 gallons of geothermal fluid.

- The second factor caused even greater potential impact on LDG observations. To provide greenhouse heating for the cooler September nights, Burgett required geothermal fluid from his State Well "B" located about 400 feet east of the Discovery Well observation well. Burgett provided information as to the duration of each pumped interval, and also provided information on the production rate of 600 gpm.

From changes in water levels at these three observation wells covering a 12-day period, several conclusions can be reached, as follows:

1. Changes in water levels resulting from tidal and barometric pressure either did not occur, or were too small to be detected by the instrumentation.

2. Effects created by pumping action on Burgett well "B" undoubtedly mask any effects created by fluid extraction from TG52-7.

3. The relatively large change on 24 September at TFD55-7 and #2 SE could be an effect of the pumping action on Burgett well "B", or fluid extraction from TG52-7, or a combination of the two causes. Exact relationship cannot be ascertained.

4. If hydraulic communication was established between TG52-7 and the other wells, either the effects were too small to detect, or the effects were masked by pumping actions on Burgett well "B".

5. It is possible that there was mutual interference between pumping action on Burgett "B" and the fluid extraction on TG52-7 that caused a decline in the observed slight productivity decline from the latter well during the flow test.

RE-ENTRY AND DEEPENING

Drilling Summary for Continuation Drilling

After evaluation of data and conferences with DOE, LDG made the decision to re-enter and deepen TG52-7. After extended delays, the drill rig finally mobilized from Texas and arrived at the Animas well site on October 23, 2003. The new inner casing string (4-1/2-inch steel casing) previously had been delivered to the well site. Mud pits were dug, and the casing was landed at 2,220 feet and cemented. The on-site steel Baker tank was filled with 20,000 gallons of cold water to provide a large quantity of water for killing the well in the event uncontrolled steam was encountered which the BOP equipment could not control. BOP equipment was delivered to site, the cellar was dug and the BOPE was installed on October 27, 2003.

Drilling operations resumed on October 28. The drill stem was run into the hole and tagged cement at 2,097 feet. Using air and a down-hole hammer bit, the cement plug was drilled out to a depth of 2,175 feet (or some 45 feet up inside the 4-1/2-inch casing). After rig repairs, using air and a down-hole hammer bit, the well was drilled to depth of 2,320 feet. On November 2, drilling continued using air and a down-hole hammer bit. After only 2 feet of drilling, the well bore intersected a water infiltration zone, and the hole could not be blown down. Drilling operations were converted to mud drilling, and drilling continued to total depth of 2,528 feet.

Below 2,350 feet, the penetration rate dropped to less than 15 feet per hour with water (compared to more than 40 feet per hour in the overlying volcanics), and drilling fluid-return temperatures had cooled. Return fluid temperatures ranged from about 93 to a maximum of 105°F. This change in temperature for the fluid circulating out of the hole was some 55 to 75 degrees cooler than return temperatures during the initial drilling on this hole in July 2003.

Drill Stem Test

Drilling operations to deepen the hole from 2,223 to 2,528 feet intersected a lost circulation zone at about 2,322 feet of depth. This zone was evaluated by completing a short-term (3-hour) drill stem test. Water samples were taken, and later were submitted to the New Mexico State University Soil, Water, and Air Testing (SWAT) Laboratory.

Final Hole Completion

On November 6, 2003, telephonic contact was made with representatives from DOE and SNL. During those discussions, the results of the drilling and short-term flow test were summarized, and the representatives were advised that LDG believed there were no apparent technical factors favoring a continuation of drilling activities. The penetration rate had dropped to less than five feet per hour and mud return temperatures were steadily decreasing. Further, in LDG's opinion, continued drilling would be a waste of time and money.

At the well site, the decision was made to reenter the hole and tag bottom. Accordingly, after the drill bit was checked to determine its condition, a check valve was inserted just behind the bit, and operations proceeded to regain the hole bottom. After about eight hours of slowly drilling and cleaning the hole, the driller was able to regain 2,528 feet of depth. The drill stem and bit were left in the hole to serve as gradient pipe. The final well completion diagram is shown in Figure 18.

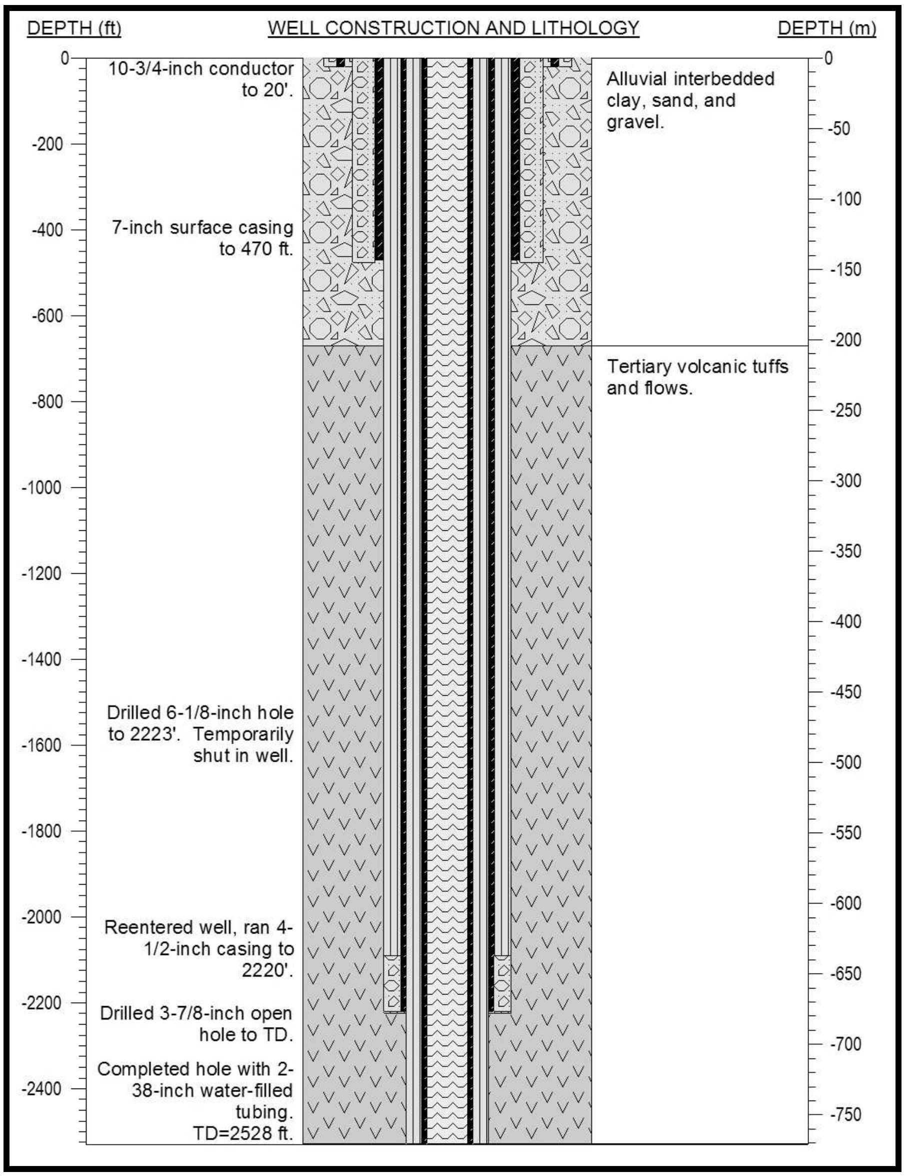

Figure 18. TG52-7 final completion schematic.

Final Well Disposition

Test well TG52-7 is presently shut in, and has been permitted by LDG as an observation well for potential future operations. Final report to the regulatory agencies was submitted on September 28, 2004.

TEMPERATURE SURVEY SUMMARY

Temperature surveys were completed on this hole using several different instruments. An initial survey was completed by the Southern Methodist University geothermal team to a depth of 1,500 feet on July 3, 2003, and again to a depth of 2210 feet on August 2, 2003. Using Welaco, a survey was completed to 2,210 feet on September 17, 2003, and a second survey was completed by the same tool immediately following the flow test on September 20. A final equilibrium survey was completed on December 17, 2003 by the team from Sandia National Laboratories.

In summary, the four surveys to 2,220 feet or deeper, measured a final bottom-hole temperature of about 137°C (280°F), with a slightly higher temperature at shallower depths.

WATER ANALYSES

Water samples were acquired at three distinctly separate zones during the drilling of hole TG52-7. Initial sampling was completed in July 2003 when the hole had reached 2,220 feet of depth. A short drill stem test was completed to acquire samples for analyses to meet regulatory constraints relative to surface disposal during the controlled flow test scheduled for September 2003. Multiple samples were taken during the 23-hour airlifted flow test, with water produced from the open hole to then total depth of 2,220 feet and additional samples were taken during the short drill stem test of the zone at about 2,322 feet.

All of the water samples were chilled to maintain the temperature below 40°F, and were submitted to the New Mexico State University SWAT Laboratory. The "hot" samples acquired during the 24-hour flow test were given special analytical treatment.

Examination of the measured values for dissolved mineral species indicates that probably only the sample acquired from the lost circulation zone at 2320 feet is noticeably different from the samples taken from more shallow zones. In comparison with earlier samples, the deep zone has sharply elevated values for total dissolved solids, chlorides, sulfates, sodium, molybdenum, iron, boron and barium. In addition, the deep zone has an alkalinity value almost three times higher than the shallower water samples.

However, this deep zone sample is the only sample that had not boiled before sampling; hence, possibly this is the best measure of in situ water in the Animas Valley at a depth of about 2,300 feet. However, this sample is depleted in silicon dioxide (SiO_2) and fluoride relative to temperature, and the Na-Ca-Mg geothermometer for this water produces an inferred temperature of only 90.6°C (195°F). Since this temperature is substantially cooler than the in situ temperatures measured in the completed borehole, and also is substantially cooler than the temperature measured by the Welaco tool at about 600 feet of depth during the 23-hour flow test, it is unlikely that this sample accurately reflects in situ geothermal fluid before mixing and cooling occurs.

All of the samples can be characterized as carbonate waters, and the influence of the underlying sedimentary rock appears to be present in the in situ water. Notably, however, the waters are relatively enriched in selected mineral assemblages (sulfates, calcium, sodium) compared to those concentrations normally expected to be present for waters originating in or with long dwell time in volcanic rock such as water from the Geysers area of Iceland. Notably, all of the samples had measured values of SiO_2 at concentrations (50-60 mg/l) roughly one-third of the values measured for the shallow hot wells located in the greenhouse complex. This datum suggests that all of the samples taken from TG52-7 represented mixed water as a combination of the hotter geothermal fluid and the cooler valley groundwater.

Notably, all of the samples were at an elevated pH (range of 9.3 to 9.6). This elevated pH value is strongly suggestive of a mechanism whereby dissolved carbon dioxide (CO_2) is suddenly released because of reduced pressure resulting from air entrained boiling, and this release in turn triggers a change in the pH from slightly acidic (less than 7.0) to strongly basic (pH values higher than 8.5). This pH change also triggers a solubility decrease for dissolved iron, sulfates, silica and carbonate species that causes portions of these species to precipitate. (Cunniff, 1989.)

It is noted that the geothermal water sampled from TG52-7 had a pH of between 9.24 and 9.33, and these values are sharply higher than the comparative model analyzed by Cunniff (1989). Moreover, the Animas water had a significantly higher temperature, which could act to increase the solubility of CO_2. Accordingly, it is likely that the Animas Valley geothermal water contains a significant dissolved CO_2 content. Among other factors, if this inference is correct, there should be a significant gas lift to add to the elevated pieziometric head caused by elevated temperature. Because of the mechanical constraints imposed by airlift, it was not possible to obtain a pressurized water sample. Accordingly, although interesting, the water analyses do not provide for an accurate gauge of in situ geothermal fluid.

RESOURCE MODELS

SUMMARY OF AVAILABLE RESOURCE INFORMATION

LDG in Phase I of the GRED program conducted airborne magnetic surveys, and ground surveys using gravity, electrical resistivity, and seismic instrumentation. In addition, LDG completed numerous temperature surveys in existing shallow geothermal and irrigation wells. Additionally, LDG owns temperature surveys and other data to a depth of 7,000 feet in well TFD55-7 completed on federal geothermal lease NM 34790 in 1985. LDG also has completed an extensive analysis of the drill cuttings from both well TFD55-7 and an oil and gas test well drilled in 1969 about 2 miles north of well TFD55-7. Moreover, LDG has an extensive library of more than 300 chemical analyses of both geothermal and irrigation wells in the Animas Valley.

Significant additional and definitive geophysical data were acquired and integrated during subsequent phases of the overall GRED program. New information included and extensive array of seismic traverses, soil carbon dioxide and soil ion surveys, gradient hole drilling and logging, deep exploratory well drilling and testing, and a final suite of seismic traverses. All of this new resource information is integrated with earlier regional studies to develop a new model for the structural and thermal controls for the LDG geothermal resource.

In the following sections, a discussion of overall regional geology is followed by a discussion of the results from the final seismic traverses in context of earlier aeromagnetic and gravity surveys. Then, the data are interpreted in a series of three different structural models that are portrayed based on an interpretation of the data from separate phases of the overall program. These three models are summarized as follows:

1. An initial model was developed by Blackwell and Wisian (2001) using information available before the start of the GRED exploration and definition program.

2. The next model was developed by Blackwell and Leidig (2002) using additional data derived from the GRED Phase I aeromagnetic and gravity surveys, and in context of the multiple seismic traverses completed in GRED Phase II.

3. The final model represents a synthesis of new information developed in GRED Phases II and III, including lithology and thermal data produced by the gradient hole drilling program and deep exploratory well drilling and testing. Then, the final seismic traverses were completed to integrate lithologic data from the gradient hole drilling into a unified structural interpretation.

Regional Structure

For many years, the primary hypothesis to explain the intense shallow thermal anomaly was that the geothermal fluids ascended at the intersection of the AVF and the outer ring fracture of the Tertiary Muir Cauldron (figure 19). This hypothesis was developed and described by Elston, Deal, and Logsdon (1983), and AMAX/Steam Reserve used it in their exploration plan and resource model. Research and exploration surveys conducted by LDG under the GRED and EGS programs now form the basis for different hypotheses.

The geologic complexity of the Animas Valley area is demonstrated by the widely differing structure, stratigraphy, and ages of rocks exposed in the bordering mountain ranges. As mentioned above, a major geologic feature of southwestern New Mexico is the overthrust belt that formed during the Laramide Orogeny. The thrust belt was mapped and studied during the 1960's and 1970's as part of the search for petroleum. Numerous wildcat wells were drilled in the region, but most were dry holes, including the Cockrell Pyramid Federal No. 1 which was drilled about 3.5 km north of the geothermal area. Corbitt and Woodward (1973) mapped the approximate northern limit of the thrust belt as depicted in Figure 19. The mapped northern limit of the overthrust belt goes through the geothermal area and very close to well TFD55-7, which had not been drilled when the overthrust belt was mapped. The Cockrell Pyramid Federal No. 1 was drilled just north of the overthrust limit and did not encounter a thrust block, hence the northern limit is south of the Cockrell well, but north of TFD55-7.

The following Figure 19 is composite of several geologic maps and studies. The base figure is a map modified from Corbitt and Woodward (1973) showing the northern limit (dotted line) of the "thrust and fold belt". The map was modified to show the Animas Valley Fault (AVF), the shallow thermal anomaly (star), and a regional northeast-southwest linear trend (crosshatch area). The inset contour map is depth to basement generated from gravity inversion by Blackwell and Wisian (2001).

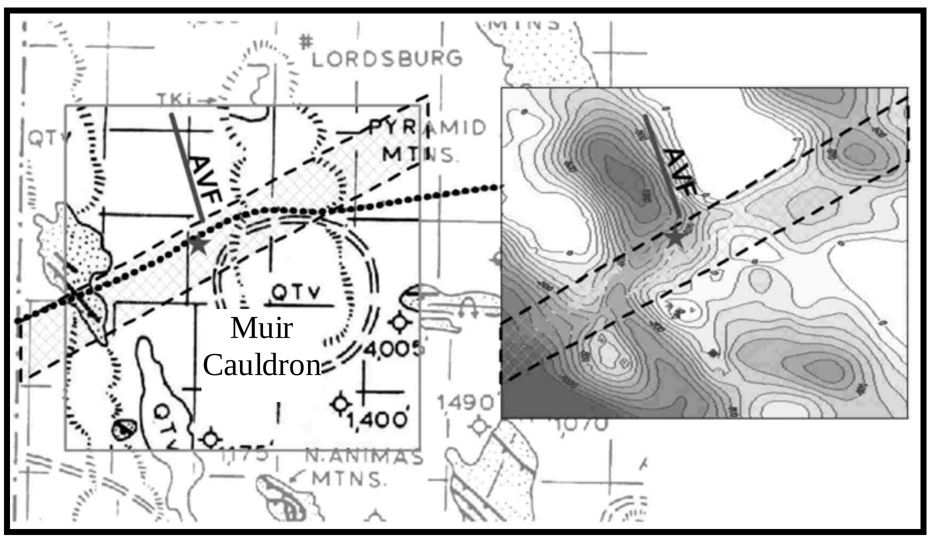

Figure 19. Integrated regional geology.

The surface trace of the AVF from the thermal anomaly area northward is a distinct and easily mapped scarp that has a general topographic relief of from one to three meters. From the area of the thermal anomaly and greenhouses southward, however, there is no surface expression of the fault and its trace has been inferred only from speculative "streaks" of vegetation and slight changes in soil color.

The "disappearance" of the AVF southward from the lateral offset, along with other evidence including the regional gravity and depth-to-basement maps generated by Blackwell and Wisian (2001), suggest that the major vertical displacement component of the range-front faults in Animas Valley may have shifted from the AVF on the eastern side of the valley to the west side of the valley. In very simple terms, the northern part of the Animas Valley is a half graben with the vertical displacement being on the AVF as far south as the latitude of the thermal anomaly. From this latitude southward, the valley is a half graben with the major vertical displacement on the west side of the valley. The zone of the lateral offset marks the transition of the major range-front faults from the east side of the valley to the west side. This hypothesis is illustrated in Figure 20A below.

Although a major fault has not been mapped on the west side of the valley where most of the land has been farmed, the gravity data suggest its existence. Another piece of evidence for a major fault on the west side of the valley is the linear belt of Quaternary basalt along the geophysical trends south of Cotton City (figure 20A).

The southern part of the mapped fault scarp near the thermal anomaly also shows a pronounced right-lateral offset of up to 500 meters. Similar right-lateral offsets of the fault trace occur north of the thermal anomaly. These lateral offsets have a common east-northeast strike and could be explained by hypotheses such as differential erosion along the fault scarp, or differential vertical displacement along the dipping fault plane. However, the lateral offsets appear to extend for many tens of kilometers, crossing not only Animas Valley, but also the Pyramid and Peloncillo mountain ranges. These lateral "shifts" form a regional "grain" that is evident on maps, air photos, satellite imagery, and regional gravity and magnetic surveys. Figure 20B illustrates this regional "grain".

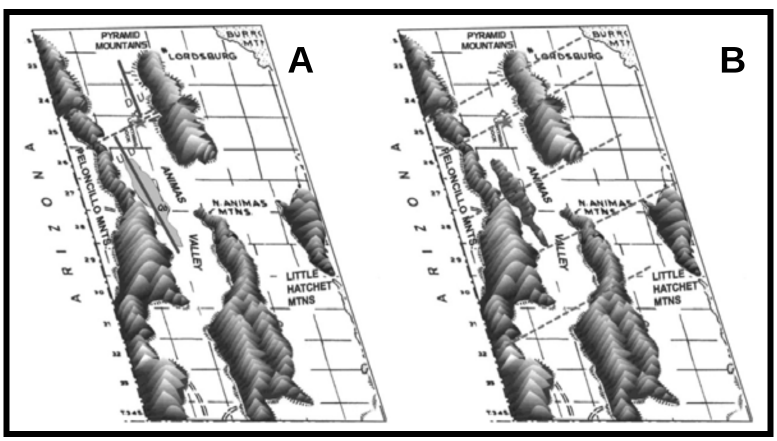

Figure 20. Fault pattern (A) and regional "grain" (B) of the Animas Valley area.

The linear trends identified in the aeromagnetic survey, as discussed earlier in this report, also trend parallel to the east-northeast-striking lateral shifts or regional "grain". The lateral offsets appear to be very young features, especially if they truly displace the AVF. Perhaps they simply reflect the buried Laramide structures and the overthrust belt. However, it is suggested here that the lateral offset of the AVF at the thermal anomaly is quite young. The AVF fault scarp is truncated, and the age of the thermal anomaly is very young as determined by the work of Blackwell and Wisian (2001) and Blackwell and Leidig (2002). The new seismic traverses conducted by LDG as part of this GRED program also support the hypothesis of a very young structural setting, one in which even the Recent lakebed sediments of Lake Animas have been displaced. The Soil Thermal Ion survey conducted by LDG, suggested a set of Riedel shears along this lateral offset.

In summary, it has become evident from new work performed under this GRED program that the intense shallow thermal anomaly of the Lightning Dock geothermal resource is more than just a point source upwelling along a single fault. Instead the reservoir seems to be either a pervasively fractured zone or a series of small faults and shears in the shallow volcanic rocks and deeper sedimentary rocks, created by the relatively recent possible lateral offset of the AVF resulting from strong tectonic extensional forces.

New Seismic Traverses

In April 2004, LDG completed two new reflection seismic traverses. The first (Line 8) of these two traverses was an extension to the east along the original Hot Water Road seismic traverse to map the AVF near the greenhouse complex. As completed, the traverse started about 100 m west of TG12-7, continued to the east to intersect TG52-7, and then was extended past TG52-7 about 0.6 miles (965 m). Total surveyed distance was about 1.2 miles (about 1.9 km). The survey was conducted from the west to the east so as to gain seismic reflections into the face of the putative AVF projected as downthrown to the west.

The second traverse, Line 7, started northwest of TG12-7, and extended to the southeast about 1.3 miles (about 2.1 km) to terminate south of the greenhouse complex. This traverse was designed to approximately intersect TG12-7, TFD55-7, pass relatively closely to TG36-7, intersect TG57-7 and terminate to the southeast about 100 m beyond TG57-7. This orientation also placed the traverse roughly orthogonal to the postulated northern limit of the buried Laramide overthrust structure. Moreover, this positioning of the traverse provided seismic tie points to Harvey Line 26, the original LDG Hot Water Road traverse, and the new east-west Line 8 traverse defined above. Both traverses crossed private surface land, and the landowners gave permission for the work.

Data Acquisition

The new seismic traverses were completed by Bird Geophysical, Inc. in late March 2004, and the data were processed by EXCEL Geophysical Services, Inc. in mid April 2004. Figure 21 depicts the 2004 seismic lines and the various gradient holes and wells.

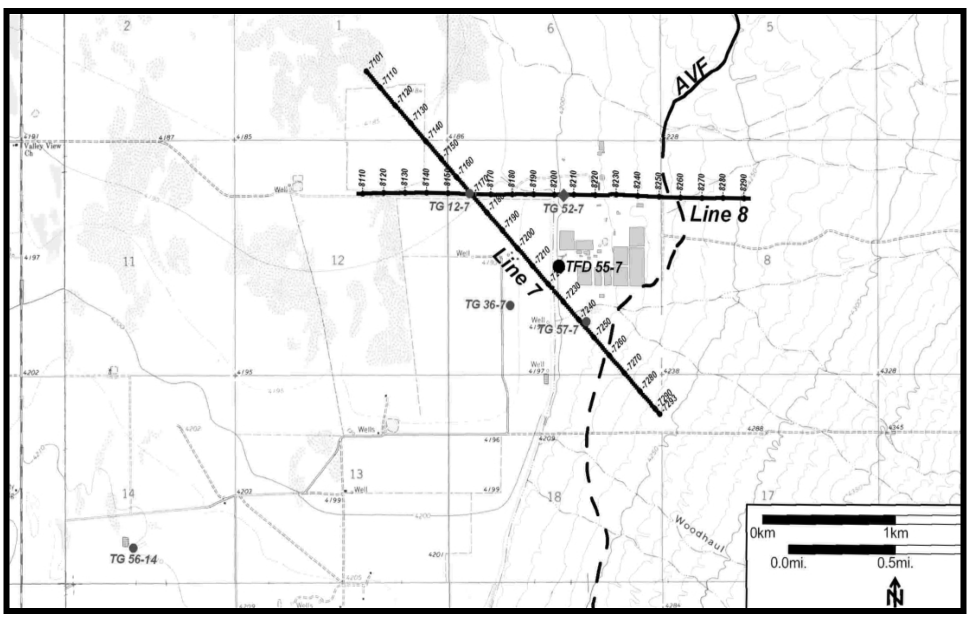

Figure 21. Seismic lines, 2004.

To evaluate the seismic data, EXCEL provided processed data and the stacking velocities used to process the data. LDG also had the synthetic log from TFD55-7 in which the sonic log was evaluated in terms of the velocity of sound at key lithology horizons in the well. A weakness of this data base is that there was no information on sonic velocities in the interval from ground surface to the bottom of the surface casing at 1,050 feet of depth in well TFD55-7. General lithology for this interval is available from a temperature gradient hole completed several years prior to drilling activity on TFD55-7. However, in neither the gradient holes nor in the well drilling activity was a sonic log completed to 1,050 feet. In the drilling sequence for LDG's new deep test well, TG52-7, drilled and tested in 2003, an attempt was made to acquire a sonic log from ground level to 1,650 feet. The contractor's tools failed because of elevated hole temperature.

Methodology for Analyzing Seismic Data

By an iterative process, subsurface velocities were adjusted based on observed factors. The final adjustment assigned a velocity of 12,000 fps to the "cemented alluvium" found in all of the gradient holes except TG56-14. Using this adjustment in the numerical model produced reasonably good correlation with the seismic reflectors imaged on both new traverses. There is a sound basis for using velocity in the range of 12,000 fps or higher. According to Ackerman, who performed reflection seismic surveys in the Animas Valley in the late 1960's (reported in O'Brien and Stone, 1983), valley fill has a seismic velocity ranging between 8,000 and 12,000 fps, with the faster velocity assumed to represent the "basement rock" as used by O'Brien and Stone. In their model of the hydrological properties of the Animas Valley, O'Brien and Stone were focused on water-bearing shallow alluvial fill, and they assumed that seismic velocities greater than 10,000 to 11,000 ft/s indicate a dense, low-porosity geologic unit that would not yield significant quantities of water from shallow irrigation wells. Hence, their basement rock represented the transition of seismic velocity from about 8,000 ft/s to about 11,000, with this transition occurring at the base of the potential water-bearing sediments at a depth of about 2,000 ft (about 610 m).

Next, an estimate was made as to the two-way travel time to the first fracture in each of the holes for which this information is available. Specifically, drilling history for TFD55-7 suggests fractures were intercepted at about 660 feet and 1,450 feet. For TG52-7, a fracture likely was intercepted at about 660 feet, and for TG57-7, a likely fracture was intercepted at about 160 feet.

Evaluation of Processed Data Images

As an example of the process used, consider drilling data from TFD55-7. Using velocities from the synthetic log, a most-likely total drilled depth was positioned on the seismic image. Precambrian granite was penetrated at about 6,865 feet of depth. For Line 7 at closest approach to TFD55-7, the processed data image shows a series of relatively weak reflectors in depths ranging from about 750 ms to about 850 ms. A somewhat stronger reflector is imaged at about 790 ms. The horizon above that reflector likely could be the granite contact, since the synthetic log for TFD55-7 depicted the granite velocity as being considerably slower than the velocity in the overlying El Paso dolomite.

From about 700 ms to 1300 ms, a series of reflectors is imaged, all dipping to the west at an angle of about 70 degrees. These reflectors could represent en echelon Riedel shear, likely down-dip to the west from the Riedel shear mapped along the west margin of the greenhouse complex. The orientation of these en echelon faults down-dip to the west is an inference derived from gravity and magnetic survey data.

Evaluation of Magnetic Linear Features

From the aeromagnetic surveys, a notable feature was an interpretation of a series of linear features generally striking northeast-southwest, although several of these linears are oriented more nearly north-south. Line 7 was oriented in part on the need to conduct a seismic traverse orthogonal to these linear features to help determine whether or not the features represented real faults. Line 7 intersected five of these linear features, and Line 8 intersected one linear on an oblique angle and was orthogonal to a second linear. For each of the magnetic linears previously mapped, a review of the seismic images was made. From this review, there is reasonably good correlation between the fractures from the seismic images and most of the mapped magnetic linears.

Inspection of the seismic image for Line 7 suggests the presence of a series of reflectors dipping to the west for the southeast segment of Line 7, but dipping to the east near the northwest end of Line 7 traverse. Inspection of the processed image for Line 8 shows a similar pattern of dipping reflectors although the dip angle is shallower for Line 8 than is depicted for Line 7.

Speculatively, these layered reflectors could be Gila Conglomerate grading into highly silicified volcanic alluvium, similar to that formation exposed on the surface at Table Top Mountain. As speculation, to the northwest the very deep reflectors could be imaging the lateral extent (northern edge) of the Laramide overthrust in which significant thicknesses of Horquilla limestone were thrust to the north-northeast. In addition, if the Precambrian horizon in TFD55-7 is located at about 780 ms, the layering of reflectors below this depth could represent folded layers within the granite.

Evaluation of Other Possible Faults

Multiple fractures are imaged on Line 7 so that one fracture intercepts TFD55-7 at about 40 ms and dips down to the east. This highly fractured region also represents an intersection between Line 7 and the Riedel shear mapped by MagmaChem (2002). There also appears to be one or more nearby faults, dipping down to the west, with one fault intersecting TFD55-7 at about 172 ms, and then intersecting ground level at about station 227. These faults can be traced downward to more than 1500 ms of two-way travel (likely to a true depth of more than 15,000 feet).

A major linear feature shows up clearly on the aeromagnetic surveys and also is a pronounced photo lineament feature. A likely buried fault cutting through the shallow volcanic rock can be discerned on the seismic image for Line 7. The suspected fault or fracture lies in the bottom of the graben produced by the apparent pattern of steeply dipping strata at depths ranging from about 350 ms to 1300 ms. It seems likely that there must be a near-vertical fault where each of the southeast-dipping strata intersects the northwest-dipping strata. In addition, there is a disturbed region at a shallower depth. This perceived near-vertical fault coincides generally with the linear feature deduced from aerial photography and which is mapped generally coincident with the magnetic linear.

Assessment of the Animas Valley Fault

Another, rather surprising, deduction made by reviewing the traverse for Line 8 is the absence of any subsurface feature that clearly depicts the AVF. The surface expression of this fault has been well mapped, at least to the vicinity of Section 8 (northeast of the greenhouse complex). Line 8 traverse deliberately was extended to the east for at least 0.8 kilometer (one-half mile) into Section 8 to provide sufficient traverse to the east of the purported fault.

The purported AVF is not clearly imaged. Instead, Line 8 images a likely case in which two faults are nearly coincident. One fault is downthrown to the west, and the second fault, with much less pronounced expression, is downthrown to the east. Moreover, these deduced faults are located almost ¼-mile to the west of the section boundary line between Sections 7 and 8 (and west of the location for Americulture State #2). Thus, these imaged faults are located more than ¼-mile to ½-mile to the west of the mapped surface expression. If the AVF is an older fault, it might be reasonable to assume that the eroded surface fault-line scarp would be located some distance from the subsurface fault plane. However, the AVF is believed to be very young, and one analysis of the slope of the fault-line scarp suggests an age of not more than 6,000 years. Thus, the probable young age of the fault-line scarp correlates poorly with the seismic imagery.

CONCEPTUAL RESERVOIR MODELS

Initial Model

Blackwell and Wisian (2001) developed a qualitative thermal model for the Lightning Dock resource. The model assumed thermal upflow along a fault that was intersected by well TFD55-7. At the time the model was developed, well TFD55-7 was the only deep well within the thermal area; four intermediate-depth temperature gradient holes had been drilled by AMAX, but only one (672-227) was in the known shallow thermal anomaly. The Blackwell and Wisian model shown in Figure 22 includes the following features:

- Flow up a steeply dipping fault or fault intersection from depth and intersecting well TFD55-7 at a depth of about 400 m (1,310 ft), and

- Discharge of the flow (at 110°-120°C, 230°-248°F) into a permeable zone below the water table, with movement down slope into the valley (to the northwest) and further cooling and dilution.

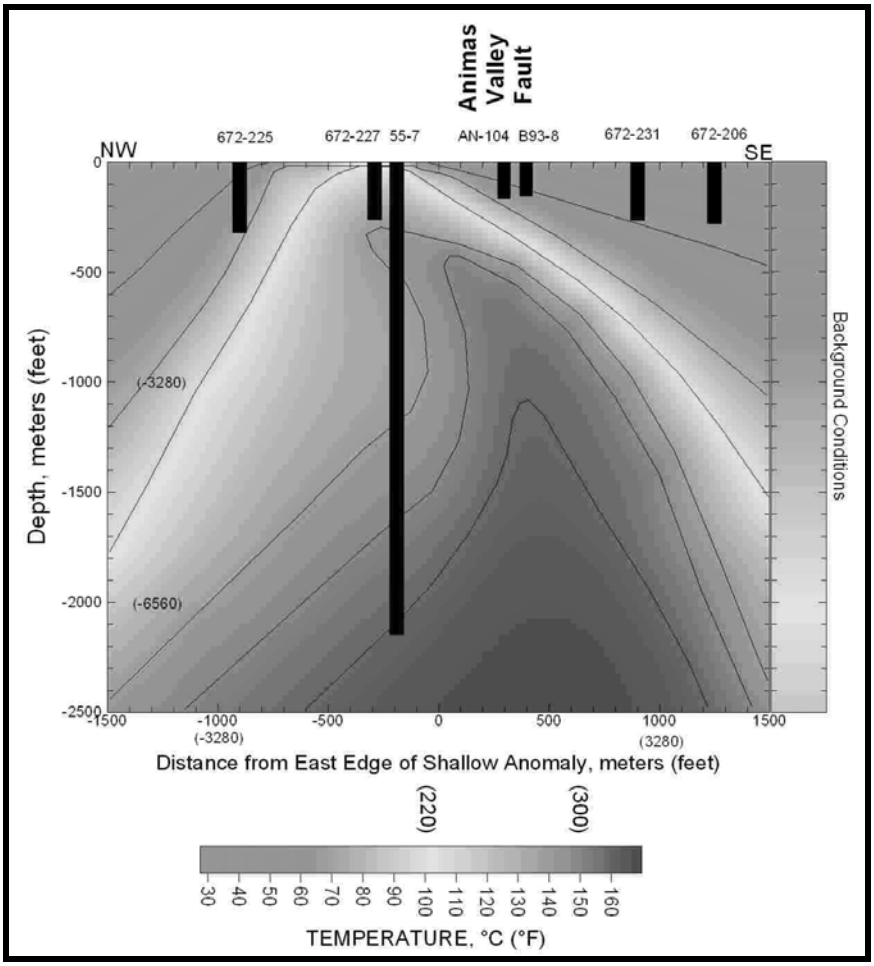

Figure 22. Initial conceptual model by Blackwell and Wisian (2001).

Intermediate Model

Following completion of the Phase I geophysical surveys and the seismic program completed in Phase II, Blackwell and Leidig (2002) completed a new series of analyses. In addition, this 2002 report included an evaluation of all of the available data, to include the thermal data from the report prepared by Blackwell and Wisian (2001).

Figure 23 is also excerpted from their 2002 report. This figure is a synthesis of thermal modeling overlaid on interpretations derived from the Phase I geophysical surveys including gravity, high-resolution aeromagnetic, and dipole-dipole electrical resistivity surveys, and Phase II seismic studies.

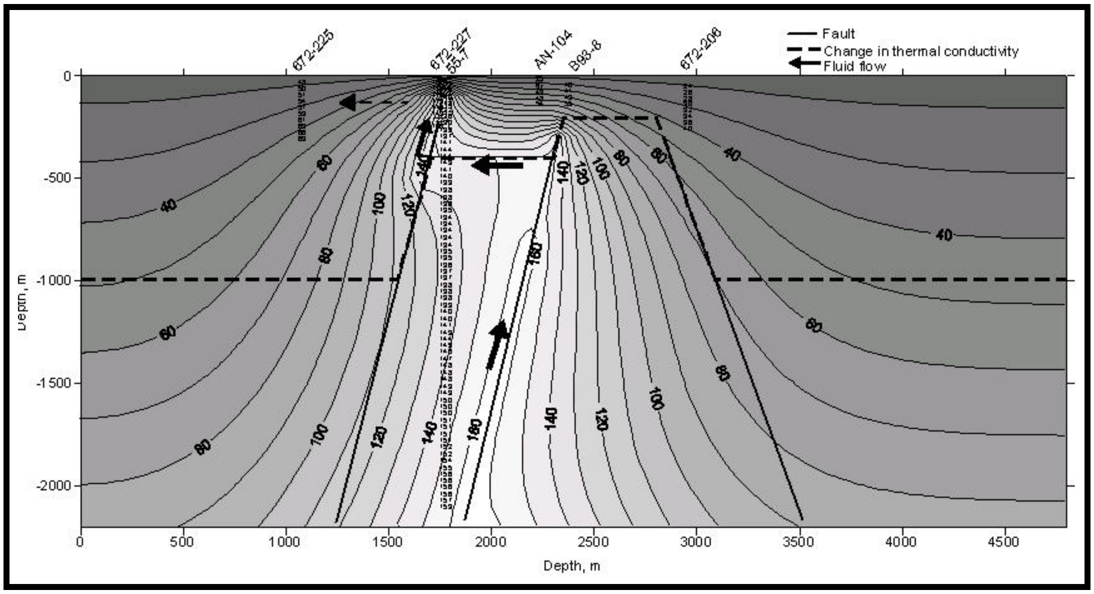

Figure 23. Intermediate thermal model by Blackwell and Leidig (2002).

Constraints for Developing New Model

All of the new information acquired in the past four years can be integrated to produce a final conceptual model of the geothermal reservoir. This concept would meet the following constraints and criteria:

- It must satisfy the thermal regime parameters established by Blackwell and Wisian (2001) as modified by new thermal data developed from the 2003 drilling program.
- It must meet the geologic constraints and factors summarized in preceding sections concerning gravity, resistivity, aeromagnetic measurements, and soil thermal ion data. In particular, the model must fit within the integrated structure

developed by Blackwell and Leidig (2002), as potentially modified by lithologic data developed from the 2003 drilling program.

- The model must incorporate findings from the seismic surveys, including the final traverses for Lines 7 and 8 completed in 2004.

- The model must be capable of being tested against new information that could be developed from either new geophysical work or new deep drilling, or a combination.

In the following sections, information is developed for structural implications from seismic traverses and the combined gravity and magnetic surveys. This section is followed by information developed from the thermal data newly acquired. The final section provides a concept resource model embodying all the lines of evidence acquired to date.

Conclusions from Seismic Traverses and Gravity and Magnetic Surveys

The AVF as now mapped appears to be striking generally north-south until it reaches the vicinity of Section 7; at that point Riedel shear zones are offset from the mapped AVF. These Riedel shear zones are mapped as striking north-south through the center of Section 7 at the western margin of the greenhouse complex. Turning to the middle portions of the valley, at least as far west as Highway 338, seismic traverses oriented principally north-south image what could be a series of horst and graben structures trending possibly east-west, although they could be oriented southwest-northeast.

At the west end of Caliche Road, the seismic image depicts a strong reflector trending westward to a more shallow depth. Similarly, for Line 25, the image defines a horst and graben structure with the graben centered about 1.6 km north of the location for TG56-14. Line 25 images the buried structure trending steeply southward to a shallow bedrock high which reaches its most shallow depth about 4 km south of TG56-14. Thus, the buried structure appears to be trending more shallowly to the south and to the west of TG56-14, and extends northward for several kilometers.

TG56-14 was sited at a point on the juxtaposition of a southwest trending magnetic linear feature and a photo lineament; accordingly, if a shallow horst and graben structure is oriented to the southwest, then TG56-14 likely would have been sited over the graben. TG56-14 was drilled to a depth of 1,250 feet (381 m), and intersected lakebed deposits and zones of cemented aggregate. Because the hole was drilled at possibly the deepest point for the putative graben, it was too shallow to intercept volcanic rock.

In the models developed by Blackwell and Leidig (2002) using the GM-SYS computer model for gravity and magnetic data, an interpretation is that the gravity and magnetic data provide an image of two distinct bedrock layers (volcanic rock and Paleozoic sedimentary rock) that underlie Caliche Road. Near the eastern end of Caliche Road (south-southeast of the TFD55-7) both layers sharply steepen and become shallower at a point where the shallowly buried horst trends north-south underneath the greenhouse complex. Both layers tend to sharply shallow near the western end of Caliche Road. Seismic data analyses confirm the general hypothesis.

These two independent estimating techniques provide converging estimates for the possible depths to volcanic rock and Paleozoic sedimentary rock for the western portions of the Caliche Road traverse. Moreover, these techniques correlate with the depth of saturated sediments derived by O'Brien and Stone (1983).

From gravity and magnetic data, Blackwell and Leidig (2002) modeled the data to show that along the Caliche Road seismic traverse, Paleozoic sedimentary rock underlies volcanic rock, with this layered structure very shallow south of the greenhouse complex where the data indicate the north-south magnetic and gravity high structure is imaged. The layered structure then dips farther to the west, and reaches a low point at which the limestone has a modeled depth of about 1.7 km. The image from Line 8 seismic traverse depicts a somewhat different structure. The layered structure is most shallow approximately 300 m east of TG52-7, and the shallow structure dips relatively slightly to a low point approximately 200 m to the east of TG12-7. At its deepest, the Paleozoic sedimentary rock layer likely is at a depth less than one km.

Combining information from the two seismic traverses, the aeromagnetic linear features, and gravity data suggests that a deep trough is oriented roughly north-south, with the trough sharply deepening to the south at or near Caliche Road and its intersection with a strong magnetic linear feature striking from the southwest. South of that point for several tens of km, seismic traverses fail to delineate any evidence for the putative AVF. Moreover, Blackwell and Wisian (2001) used a gravity inversion technique to map a series of faults trending southwest-northeast in general alignment with this magnetic linear. These lines of evidence suggest that the AVF transitions across the valley to the west side on an alignment at or near the magnetic linear feature.

Conclusions from Thermal Data

A summary review of the thermal data from the gradient hole drilling program includes the following salient facts:

- All of the holes displayed positive gradients at depth, and in all cases the temperature gradients were above background values for cooler valley ground water.

- For selected holes, notably TG52-7, TG12-7, and TG36-7, the deeper gradients were very large.

- Even the coolest hole, TG56-14, showed a positive gradient to depth.

- All of the temperature gradient holes showed evidence of, surprisingly in some cases, large amounts of heat.

Seismic and gravity/magnetic data depict a massively fractured subsurface within both the volcanic rock and the deeper limestone rock. At multiple points, the fractures can be clearly traced up through the cemented alluvium and into the shallowest loose alluvial fill. Widespread distribution of subsurface heat at distances as much as 4 km southwest of the greenhouses indicates the geothermal anomaly at depth likely extends far to the southwest. Hence, the geothermal anomaly appears to be comprised of multiple sources all with geothermal heat. Prospects are strongly enhanced for intersecting power plant grade geothermal heat at numerous locations.

New Conceptual Model

Synthesis of all of the information now available indicates that a working reservoir model consists of multiple points of geothermal fluid upflow, which might merge into a sheet upflow at depth. One such point is the intense shallow anomaly around and near well TFD55-7. The strong likelihood exists that wells drilled within a few hundred meters of either TG52-7, TG36-7, or TFD55-7 would be productive, and would be hot from near surface to total depth.

Farther to the west, wells drilled on the flanks of the imaged horst and graben structure likely would intersect power plant grade resources at depths ranging from about 600 m (ca 2,000 feet) to about one km (3,280 feet) in the center of the putative southwest-trending graben. Confirmed temperature data are lacking for these more speculative wells, although the temperature profile for TG12-7 suggests that such step-out wells should have a reasonable success rate.

A new conceptual thermal model across seismic Line 7 and adjacent terrain is illustrated in Figure 24. Comparison of the area under the 140°C (285°F) contour interval in Figure 24 with the earlier model illustrated in Figure 23 suggests that the area is significantly larger for Figure 24. Thus, a far larger heat source is illustrated in Figure 24 for the area at the northeasterly portion of the geothermal anomaly. A similar cross-section cannot be derived for points farther to the west, but the anomalously elevated temperatures for TG56-14, drilled at the low point near the center of the putative southwesterly trending graben, strongly suggests that a potential production grade geothermal anomaly is at reasonable production well depths for all of LDG's leases.

The new conceptual model illustrates not only isotherms from drilling data, but also geology interpreted from drilling data and the seismic lines. As discussed earlier in this report, the new reflection seismic lines show significant shallow fracturing and faulting in the volcanic rocks and overlying older alluvium.

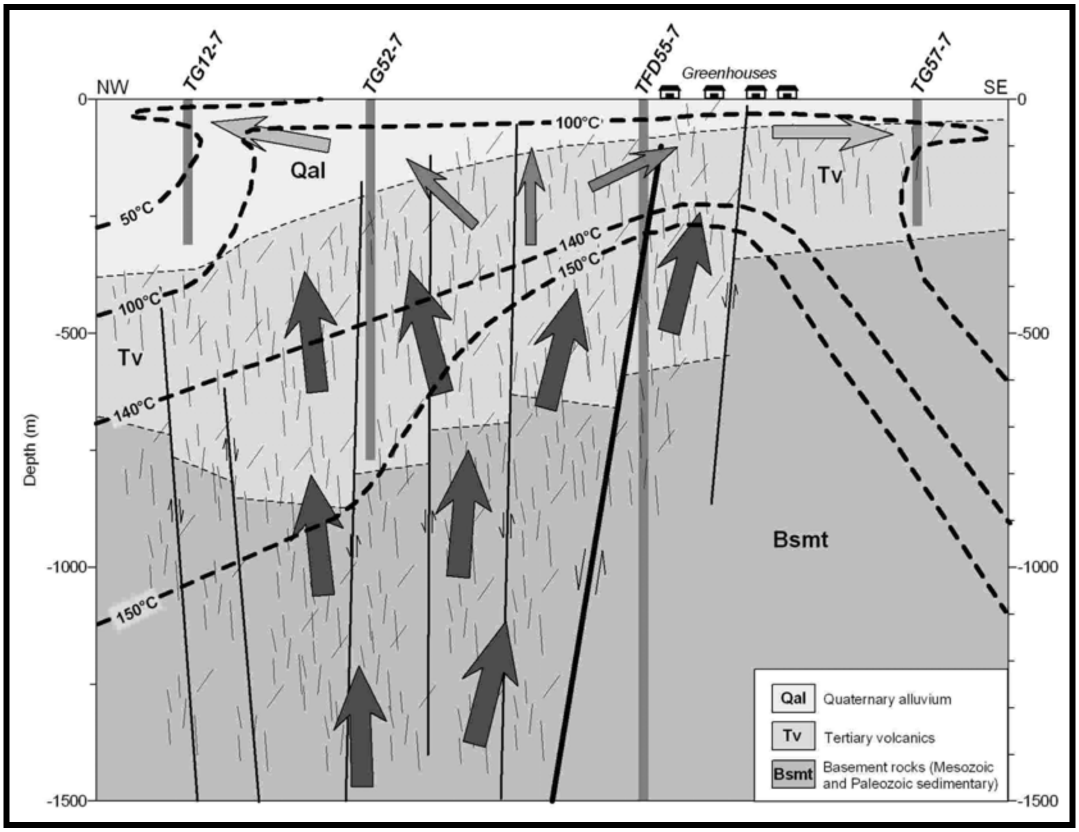

Figure 24. New conceptual model.

ESTIMATED RESERVOIR PRODUCTIVITY

General

Reservoir engineers conventionally use volumetric information together with measured subsurface temperatures to model estimated reservoir productivity of geothermal systems. These techniques work well in practice, but only when sufficient information is available from test drilling to establish key parameters. For Basin and Range systems, however, there is doubt that a fault-dominated system can be accurately portrayed by such methodology. Simply stated, in order for the volumetric method to have a high order of precision, an implicit assumption underlies the calculations; that is, that the reservoir is massively fractured with many lateral and vertical flow paths.

The reservoir productivity for the Animas Valley has been estimated using both the volumetric and thermal methods and the results of these estimates are summarized in the following section.

Summary of USGS Work

Productivity of the Animas geothermal resource was estimated by using volumetric methodology developed by Muffler, in the Assessment of Geothermal Resources of the United States –1978: U.S. Geological Survey Circular 790 (Muffler, 1979). At that time (1978), the only known information was temperatures of three very shallow wells at the hot spot. Muffler also had limited information about an "…oil test well 3 km north of the area recorded at 122°C at 2.2 km." (This well is Cockrell Pyramid Federal No. 1 completed in 1969 to a reported depth of 2.25 km.) Muffler estimated the volume of the Lightning Dock geothermal resource to be a default value of between 1 and 3 km^3, with a most likely volume of 2 km^3. From the observed shallow well temperatures and his estimated reservoir volume, Muffler assumed that the resource could produce recoverable thermal energy of about 4 percent of the reservoir thermal energy, which he estimated was about 0.8 to 1.5 x 10^{18} joules. Using his methodology, his 1978 values represent an electricity potential of about 24 MWe for 30 years. Notably, this estimate implicitly assumes a reject temperature of 15°C.

GeothermEx Estimate, January 31, 2001

As part of a comprehensive proposal for continuation funding under the DOE Idaho Falls Enhanced Geothermal Systems Program (EGS), LDG commissioned GeothermEx to develop an estimate of the potential productivity of a small portion of the Lightning Dock KGRA (GeothermEx, 2001). The reservoir was purposefully restricted to the Horquilla limestone rock intersected by well TFD55-7 from about 1,900 feet to about 4,000 feet of depth, and with a surface areal extent of 2 km^2. This conceptual EGS reservoir would contain about 1.1 to 2.4 km^3. From the temperature surveys on TFD55-7, they assumed the temperature of this reservoir was 285°F (140°C). Using these values, GeothermEx concluded the most likely productivity was 9.3 MW from this narrowly constrained EGS conceptual reservoir. Notably, GeothermEx also assumed a reject temperature of 15°C.

Estimated Productivity Based on Thermal Regime

Blackwell and Wisian (2001) used the net flow-through methodology to derive an estimate of potential reservoir productivity. They reviewed the available thermal and hydrologic data, and believed that the Animas geothermal resource is typical of relatively small Basin and Range geothermal systems. They concluded that an intense shallow anomaly about 1.2 km long had been delineated by drilling data prior to 2001. Using data from all available deep wells (well TFD55-7 and four gradient holes about 300 m deep), they created several models of the subsurface thermal regime that met all of the temperature and structural geologic constraints imposed by actual measured temperatures. Key to the modeling analyses is the estimated reservoir parameters. Blackwell conservatively used the one deep wellbore represented by TFD55-7 to indicate that there is a minimum volume of ±1 km around the wellbore that should be productive. His calculations show that there has likely been a minimum of 1 to 2 km of subsurface rock that has been heated by the geothermal flow since the likely faulting that created the intense shallow anomaly.

They conservatively estimated that conductive heat loss was 2-3 MW, with an average intensity of about 200,000 W/km^2. Using a conservative source temperature of 140°C (285°F), they estimated that the normal flow through the system at depth was about 6.7 liters per second (about 5,000 gallons per hour). In turn, this large flow-through rate makes the system a candidate for moderate temperature hydrothermal development. They also added that commercially developed hydrothermal systems generally produce from 10 to 1,000 times the natural flow-through rate. They concluded that comparison with other Basin and Range systems suggests that the system should be capable of sustaining power production at a rate of 5 to 15 MW.

Productivity Calculations for Well 55-7

Cunniff (2003) used data developed from a 24-hour flow test conducted on well TFD55-7. Based on observed drawdown for a production rate of about 375 gpm, the well specific yield was used to estimate overall well productivity. Depending on the pump setting depth, the well appears to be capable of producing from 7 to 8 gross MW, and after subtracting well pumping electricity, the well could produce 5.5 to 7 net MW to the grid. This productivity should be confirmed by conducting an extended and carefully instrumented long-duration flow test.

Revised Productivity Estimate Based on New Drilling Data

Modifications for Reservoir Volume

Based on the thermal record from all of the well drilling in the past 20 years, including the five new gradient and deep holes drilled in 2003 by LDG, a more current, and presumably more correct, volume can be estimated. From well TFD55-7, the depth to Precambrian bedrock is about 2.5 km, and this depth interval has a measured average temperature of about 145°C. The area enclosed by the new LDG and older AMAX gradient holes contains about 6 square km. Using these dimensions produces an estimated volume of about 12-18 km^3, or a volume one-half to one order of magnitude larger than estimated by Muffler or GeothermEx.

Modifications for Reject Temperature

Note that the calculations by Muffler and GeothermEx do not represent electricity that could be generated by binary cycle machinery. Muffler and GeothermEx used a reject temperature of 15°C as the reference standard, whereas the reject temperature for typical binary cycle equipment is in the range of 70 to 85°C. If this latter temperature were to be used, the more correct value for commercial hydrothermal electricity potential would be in the range of about 60 percent of the values estimated by Muffler and GeothermEx.

Substituting this higher reject temperature in the calculated estimates for Muffler and GeothermEx, and also substituting new estimates for the possible reservoir volume produces newly estimated volumetric-based productivity in the range of 86 to 130 MWe (for Muffler) and 30 to 50 MWe (for GeothermEx, but using the larger reservoir).

Modification of the Productivity of the Thermal Regime

The thermal-based productivity estimate by Blackwell and Wisian (2001) can be considered to be very conservative. Their assumed conductive heat flow is roughly only one-third the rate calculated by Kintzinger (1956), who based his calculations on measurements from a grid of shallow thermistors arrayed over more than three square miles. Kintzinger made temperature measurements at a depth of 1 m and he calculated the natural heat flow as "approximately 7500 kW for the area enclosed by the 18°C contour line." (This area is roughly 0.5 square miles in extent, or about 1.3 km^2.) This rate of heat flow represents about 650,000 W/km^2, or a value roughly three times higher than the conservative value estimated by Blackwell and Wisian.

<u>Conclusions</u>

The volumetric-based productivity estimates are noticeably much larger than those based on the thermal regime. In this regard, the thermal regime is a more conservative estimating technique; however, precision calculations from this method require much more thermal data which can be acquired only by drilling multiple deep wells.

New information was obtained from the LDG drilling program completed in 2003. However, only one of those wells (TG52-7) was deep enough to assure penetration below the shallow outflow from the shallow geothermal system. Two of the gradient holes were sited so that new drilling data did represent partial or total penetration of the shallow outflow system. However, only the one deep well (TG52-7) gave a thermal datum point fully useable in the thermal-based methodology.

Given the estimated productivity from a single well (TFD55-7) of 6 to 8 gross MW, it is reasonable to project a 2- or 3-well program easily should produce enough geothermal heat to generate 15 MW or more.

Based on the drilling program and the flow test for well TFD55-7, the most likely scenario for the LDG geothermal system is that the productivity likely will be at least 15 MW. From the volumetric-based calculations, a high probability exists that the geothermal anomaly can produce at least 25 MW. Either of these two production rates, if achieved, would represent a viable commercial-scale geothermal power plant.

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