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Recent Drilling Activities at the Earth Power Resources Tuscarora Geothermal Power Project's Hot Sulphur Springs Lease Area

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Sandia Contract No. 370258

Abstract

Earth Power Resources, Inc. recently completed a combined rotary/core hole to a depth of 3,813 feet at it's Hot Sulphur Springs Tuscarora Geothermal Power Project Lease Area located 70-miles north of Elko, Nevada. Previous geothermal exploration data were combined with geologic mapping and newly acquired seismic-reflection data to identify a northerly tending horst-graben structure approximately 2,000 feet wide by at least 6,000 feet long with up to 1,700 feet of vertical offset. The well (HSS-2) was successfully drilled through a shallow thick sequence of altered Tertiary Volcanic where previous exploration wells had severe hole-caving problems. The "tight-hole" drilling problems were reduced using drilling fluids consisting of Polymer-based mud mixed with 2% Potassium Chloride (KCl) to reduce Smectite-type clay swelling problems. Core from the 330°F fractured geothermal reservoir system at depths of 2,950 feet indicated 30% Smectite type clays existed in a fault-gouge zone where total loss of circulation occurred during coring. Smectite-type clays are not typically expected at temperatures above 300°F. The fracture zone at 2,950 feet exhibited a skin-damage during injection testing suggesting that the drilling fluids may have caused clay swelling and subsequent geothermal reservoir formation damage.

The recent well drilling experiences indicate that drilling problems in the shallow clays at Hot Sulphur Springs can be reduced. In addition, average penetration rates through the caprock system can be on the order of 25 to 35 feet per hour. This information has greatly reduced the original estimated well costs that were based on previous exploration drilling efforts. Successful production formation drilling will depend on finding drilling fluids that will not cause formation damage in the Smectite-rich fractured geothermal reservoir system. Information obtained at Hot Sulphur Springs may apply to other geothermal systems developed in volcanic settings.

Acknowledgements

I would like to thank Ron Barr, President of Earth Power Resources, Inc. for providing the support for the exploration operations at Hot Sulphur Springs. Dr. Peter van de Kamp has provided all of the geologic evaluation and interpretation along with seismic data interpretation for the Hot Sulphur Springs Area. Mr. Roger Magee from Boart Longyear/Lang Exploration was of great assistance with a can do mentality for drilling design and operations for well HSS-2. I would also like to thank Sandia National Laboratory for funding to bring this exploration operation experience at Hot Sulphur Springs to the general geothermal community.

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1.0 Background

The Earth Power Resources, Inc. (EPR) 30 MWnet Tuscarora Geothermal Power Project (TGPP) is located near the town of Tuscarora in Elko County, Nevada approximately 70 miles north of the city of Elko (see Figure 1). Mining operations are the major industrial activity in Elko County with several large gold mines operating at various periods over time. Interstate Highway 80 is the major thoroughfare through Elko. Nevada Route 226 runs within 3-miles of the Lease Area.

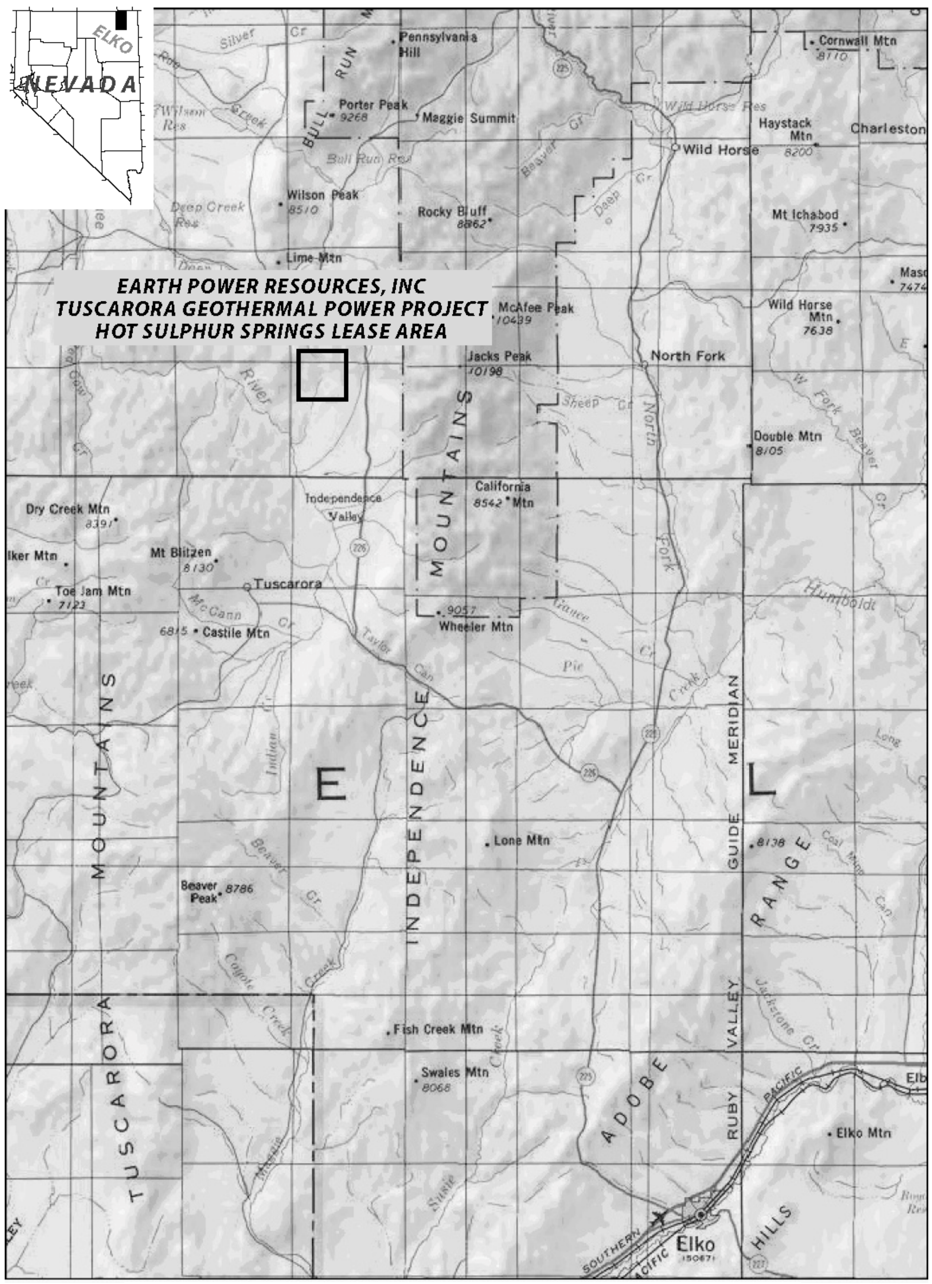

Figure 1. Location of the Earth Power Resources, Inc. Tuscarora Geothermal Power Project and the Hot Sulphur Springs Lease Area

EPR has an existing Contract to sell 30 MWnet of electrical generation developed from geothermal resources at it's Hot Sulphur Springs Lease area to Nevada Power Company. The 30 MWnet binary TGPP project will consist of approximately four (4) production wells producing approximately 12,000 gpm (5,400 kph) of 330°F fluid supplying a 30 MW water-cooled binary power plant. The binary plant will utilize iso-butane as a working fluid. A maximum of three (3) injection wells will return the spent geothermal brine back to the geothermal system. All of the produced geothermal fluid will be returned to the subsurface geothermal system.

The TGPP will be located on the EPR Hot Sulphur Springs Lease Block which covers ≈7,500-acres (≈12 square-miles) of Fee and Federal Leases (see Figure 2). The Lease is named after the "Hot Sulphur Springs" hot springs that currently discharge approximately 1,000 gpm of geothermal fluids into Hot Creek through silicified-alluvium in a bedrock outcrop area located in the northwest corner of Independence Valley.

The Lease Area is located at an elevation of ≈5,800 feet in the northeastern Basin and Range Physiographic Province. Local climatic conditions are semi-arid with moderate rainfall and moderate temperatures. Grasses and sagebrush cover the Lease Area proper. Hot Creek flows through the lease area in a southerly direction terminating at the South Fork of the Owyhee River, the main hydrologic drainage path for Independence Valley (see Figure 2).

2.0 Geothermal Exploration Activities in Northern Independence Valley

Geothermal investigations in the Hot Sulphur Springs area began in the Late 1970's with a ≈5-year exploration program conducted by AMAX Exploration, Inc. Geothermal fluids were known to exist in the area due to the Hot Sulphur Springs hot springs discharging ≈1,000 gpm of geothermal fluid into Hot Creek (see Figure 2). A distinct smell of Sulphur is noted near the hot springs, which likely led to their naming. In addition, a large silica-rich hot-spring mound (siliceous sinter), covering approximately 100-acres, lies directly to the east of Hot Creek. This is one of the largest surface silica deposits in Nevada (Steamboat Springs currently being the largest). Other geothermal mineral deposits exist to the south of Hot Sulphur Springs in the Independence Valley (e.g., Tuscarora Epithermal gold deposit, Jerritt Canyon Calcium Carbonate deposit).

Portions of the 1970's AMAX geothermal exploration program were funded by the DOE through the User Coupled Drilling program and with DOE funding to other groups (mainly UURI). The AMAX geothermal exploration program included, geologic, geophysical and geochemical investigations along with exploration drilling activities.

The AMAX exploration program included the drilling of thirty-two (32) shallow (±300 feet) temperature gradient wells and nine (9) intermediate-depth (±1,000 feet to ±3,000 feet) slim-holes in northwestern Independence Valley (see Figure 2 for well locations). Limited data are available for twenty-six (26) of the drilled wells.

The AMAX exploration program also included the drilling of one deep (≈5,454 feet) exploration-production size well (well 66–5, see Figure 2 for location).

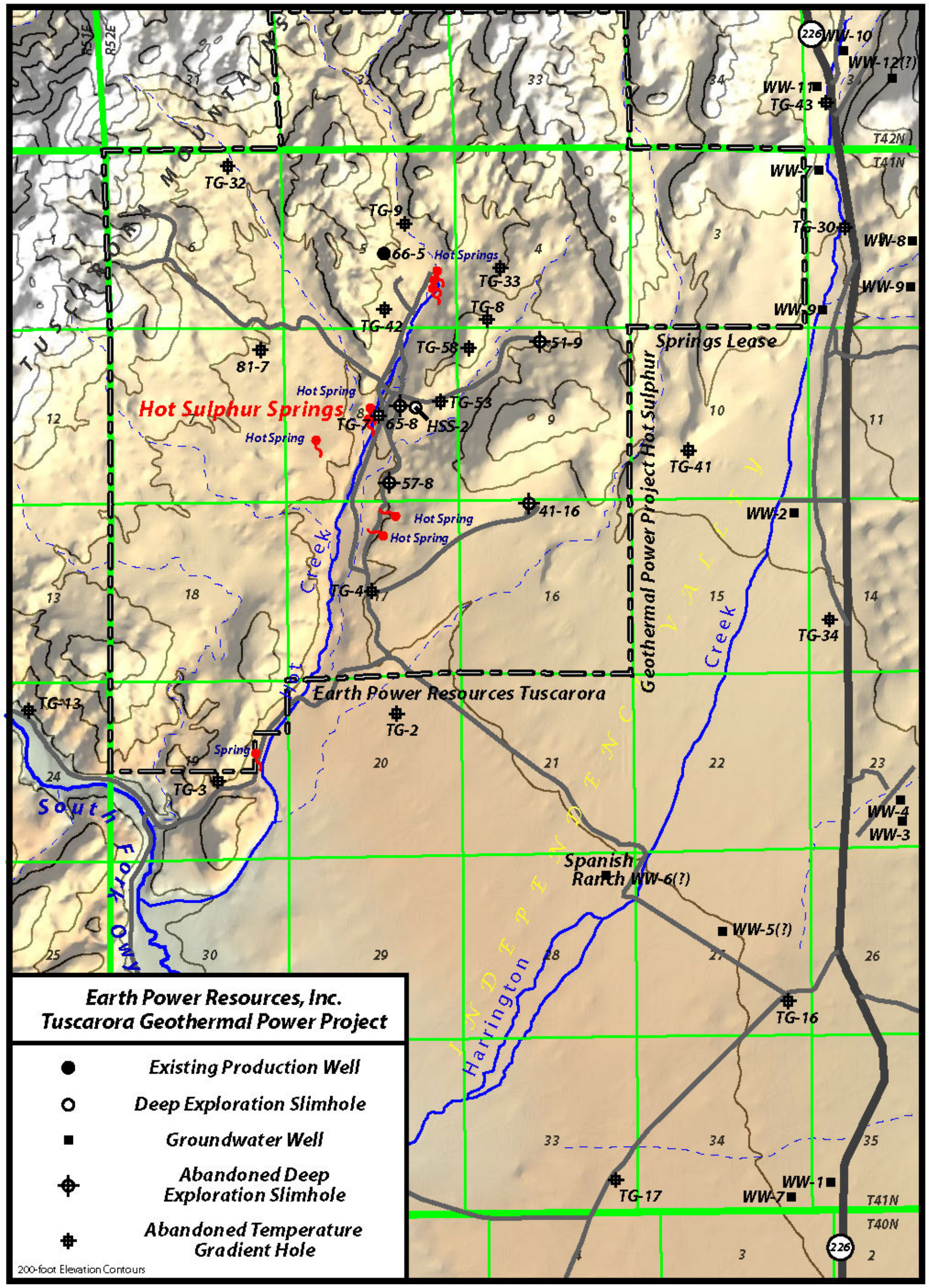

Figure 2. EPR Lease Area, Geothermal Exploration Wells and Water Wells in Northern Independence Valley

This well encountered a productive geothermal system located in permeable/faulted/fractured (?) Paleozoic rocks. Well 66-5 was discharged under air assist during drilling. Reported flow rates were ≈850 gallons per minute (gpm) [≈400 thousand pounds per hour (400-kph)] during air-assisted flow. Reported flowing wellhead temperatures were 222°F at ≈20 psig wellhead pressure. The subsurface producing zone was not identified. The well-bore collapsed during drilling at a depth of ≈2,500 feet. Well 66-5 is still accessible (current Plugged Back Total Depth ≈2,400 feet); all of the other wells drilled by AMAX in the Independence Valley area have been abandoned.

EPR began geothermal exploration operations in June 2003. The EPR investigations included a compilation and evaluation of all available data related to geology, geophysics, hydrology, drilling, temperature distributions, etc. In addition, EPR ran approximately five (5) linear-miles of reflection-seismic surveys, drilled one exploration corehole to a depth of 3,813 feet (well HSS-2 in Figure 2), mapped geologic structures and obtained water samples from hot springs and groundwater wells for fluid geochemistry analyses confirmation.

3.0 Geology of the Hot Sulphur Springs Area

Sibbett (1982) mapped the geology of an area covering ≈90 square miles centered on Hot Sulphur Springs as part of the AMAX exploration operations. Paleozoic, Tertiary and Holocene deposits underlie the Hot Sulphur Springs geothermal prospect area. Ordovician to Mississippian siliciclastics, volcanics and limestones all occur in the subsurface and are known from wells drilled in the AMAX exploration program (and recent core drilling by EPR). Oligocene and Miocene volcanic rocks occur at the surface and subsurface. Holocene alluvial deposits are found in topographically low areas. Partly overlying and partly interlayered with Holocene alluvium are calcareous and siliceous sinter deposits from extinct hot springs.

The Tertiary Volcanic Rocks are mostly Oligocene felsic to andesitic pyroclastic deposits with up to 20% by volume of andesitic and basaltic flows, dikes and intrusive plugs. The pyroclastic rocks are very-fine to coarse grained, in some cases, gravelly to coarse breccias and bedded deposits. Quartz-filled fractures have been observed in these Tertiary rocks. The fractures/faults through these volcanics are steeply dipping, as noted in cores from well HSS-2 and seismic data obtained by EPR. These steeply dipping fractures were also encountered in corehole HSS-2 within the Paleozoic rocks located directly below the Tertiary Volcanics.

In the shallow subsurface the originally glassy (non-crystalline) Tertiary volcanic rocks have been variably altered to montmorillonite and kaolinite clays, as identified by X-Ray Diffraction and thin-section analysis of cores from well 57-8, near the Hot Creek area. This argillic (clay) alteration covers a large area around the Hot Springs and is identified in downhole electrical well logs and in seismic reflection data obtained by EPR. Drilling data for well HSS-2 shows the Tertiary Volcanics being predominately altered to clay near the surface with clay-alteration gradually decreasing to a depth of ≈1,350 feet. Below this depth, argillic alteration is predominately confined to fracture and fault zones. The Tertiary Volcanic rocks have relative densities of 1.7 to 2.5 and sonic velocities of

4,000 to 12,000 feet per second. Density and sonic velocity are depth-dependent in the Volcanics, reflecting alteration and fracturing in the Volcanics.

Unconformably beneath the Tertiary volcanic rocks are Ordovician to Mississippian (Paleozoic) sedimentary and volcanic rocks of unknown thickness but probably greater than 10,000 feet. Found in drilling of the Paleozoic Rocks are quartzites, chert, argillite, limestone, dolomite and greenstone (altered basalt). These are well-indurated rocks that have been mineralogically altered under greenschist facies metamorphism. The Paleozoic Rocks have resistivities of tens to hundreds of ohm-meters and sonic velocities of 16,000 to 20,000 feet per second (fps). Drilling data, recovered core and seismic reflection data indicate that the Paleozoic Rocks are fractured and faulted.

Sibbett's geology mapping noted several faults in the Hot Creek Area. EPR combined Sibbett's mapping with its own geologic reconnaissance data to develop a fault/fracture/lineament map of the Hot Sulphur Springs and Northern Independence Valley area (see Figure 3). Also shown in Figure 3 are the large siliceous sinter (hot spring) deposits that lie to the east of Hot Creek and several Andesitic intrusive rock outcrops near the northern Hot Sulphur Springs.

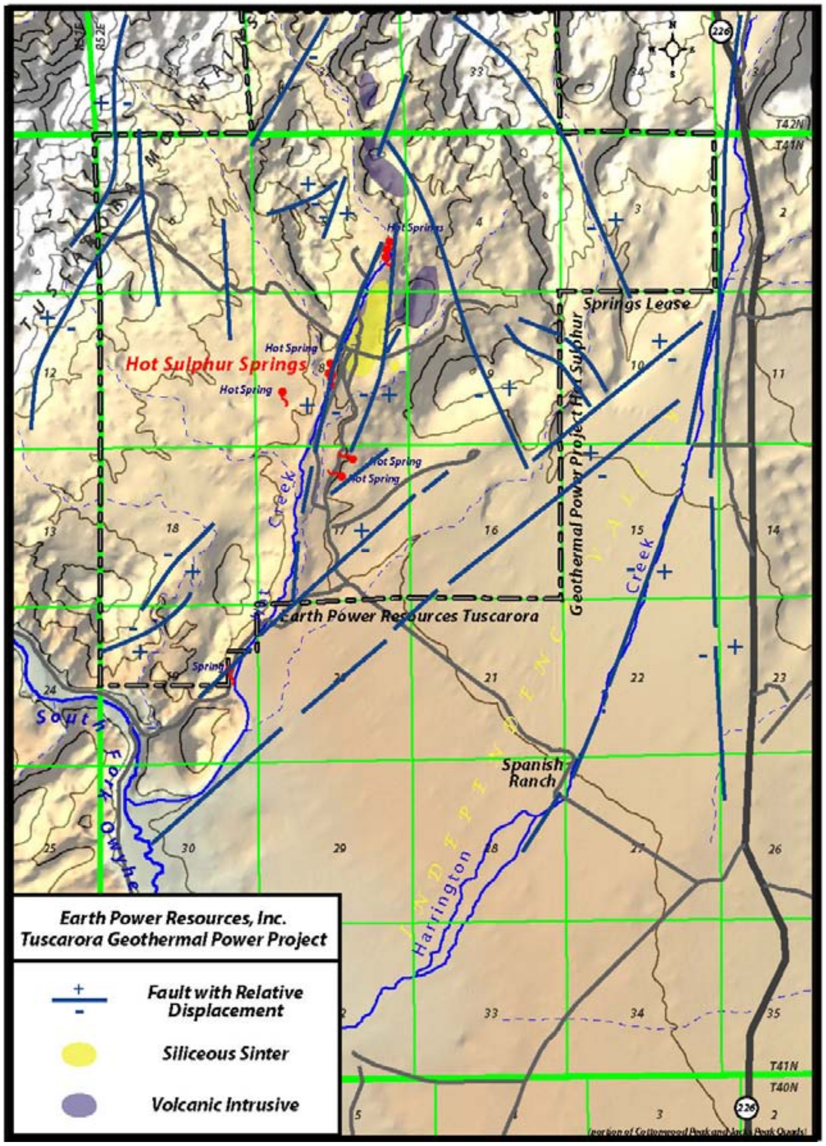

Figure 3. Surface Fractures/Faults, Lineaments and Geologic Features in the Hot Sulphur Springs Lease Area

4.0 Geophysical Data in the Hot Sulphur Springs Area

The AMAX geophysical exploration program included gravity, airborne magnetics, ground-resistivity, magneto-tellurics, self-potential and passive seismic. Much of the data was gathered on a regional scale. No raw data are available, only reports on activities. In summary, the gravity data shows a density low in the center of the valley (as would be expected) and a density high beneath the Hot Sulphur Springs Section 5 area. Magnetic data shows no significant anomalies. Electrical resistivity survey data in the Hot Creek area imply several conductive zones at depth. How these low resistivity areas relate to the subsurface structure, as delineated by drilling and seismic data, will require off-structure drilling and further analyses. Passive (micro) seismic data shows major activity along the

Independence Valley Range Front Fault that bounds the eastern edge of Northern Independence Valley (east of Highway 226 in Figure 2) and no activity in the HSS Lease Area.

EPR carried out reflection-seismic surveys in late 2003 along three (3) separate lines totaling ≈5 linear-miles (see Figure 4 for Line locations). The seismic data indicate that a northerly trending Horst-Graben structure with vertical offsets up to 1,700 feet exists in the Hot Creek Area. A cross-section of the Horst-Graben Structure along seismic Line-3 is shown in Figure 5. Step-faults located along the East and West sides of the Graben structure align with faults mapped at the surface in the Hot Creek area by Sibbett (see Figure 3 and Figure 4 for mapped fault/fracture/air photo lineament locations).

The seismic analysis indicates that a shallow (<1,000-foot depth) low-velocity layer (≈4,000 fps) underlies all of the seismic-lines. This low-velocity layer is interpreted to be argillic (clay) alteration of the Tertiary Volcanics. This a large area/volume of clay alteration and reflects on the duration/size of the geothermal anomaly at Hot Sulphur Springs in that the argillic alteration of the Tertiary Volcanics is most likely caused by acid-rich fluids supplied by the geothermal system.

5.0 AMAX Exploration Well Drilling Activities

The AMAX exploration program included the drilling of approximately 45-wells in northern Independence Valley. Data for twenty-six (26) of the wells in the Hot Sulphur Springs area are available. Six (6) of the wells had daily drilling summaries available. The locations of these wells (for which some data are still available) are shown in Figure 2.

The locations of wells pertinent to the current geothermal development activities are shown in Figure 4. Some lithology and temperature versus depth data are available for these wells. In addition, one production-exploration (large diameter) well, 66-5, was drilled to a total depth of 5,456 feet but collapsed during drilling to a Plugged-Back Total Depth (PBTD) of ≈2,400 feet (as of July 2003). Downhole geophysical logs are available for this well (to 2,200 feet) and for abandoned exploration hole 65-8. The most recent rotary/core hole, HSS-2, was drilled to a depth of 3,813 feet in 2003 by EPR (see Figure 4 for locations).

Temperatures versus elevation data for wells whose location is shown in Figure 4 are shown in Figure 6. Maximum measured downhole temperatures, prior to the drilling of well HSS-2, were ≈300°F. Most of the well temperature profiles are convective and, therefore, not conclusive for extrapolation of temperature to depth. In addition, some of the temperature profiles show zones of fluid flow away (out-flow) from the geothermal up-flow zone(s) (e.g., TG-33, TG-8, 41-16).

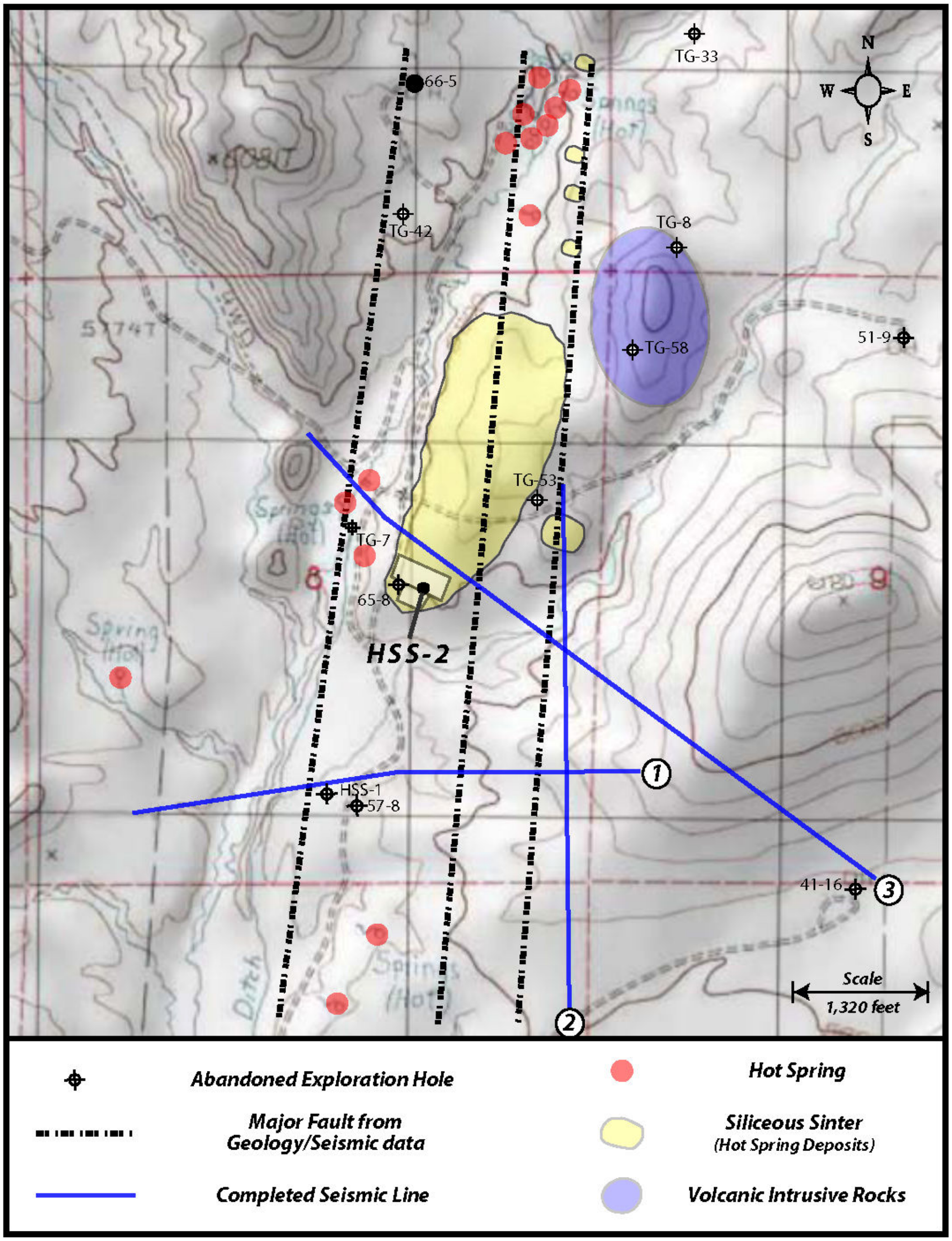

Figure 4. Location of Slim Hole HSS-2, Seismic Lines, Abandoned Wells and Pertinent Geologic Features

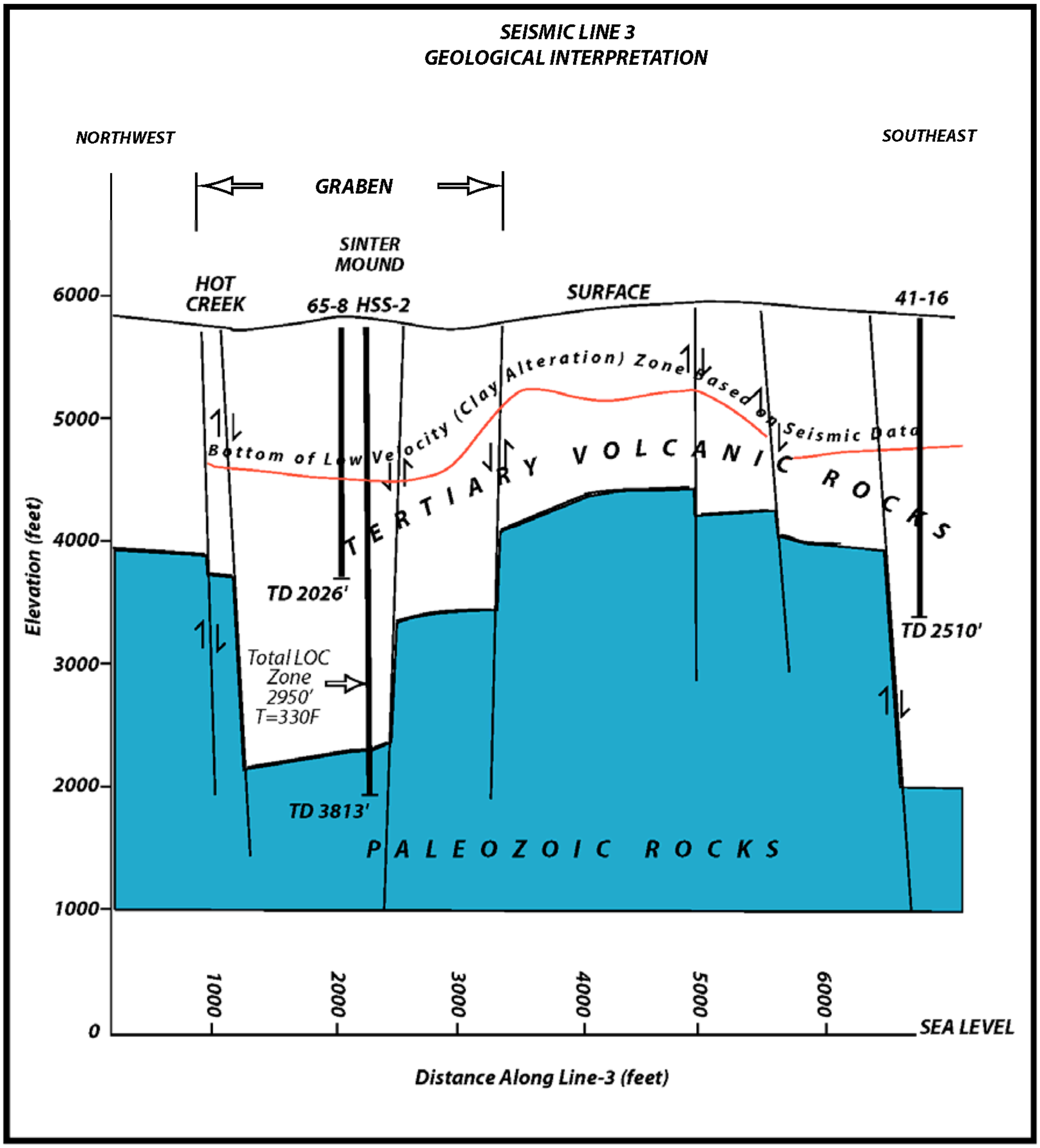

Figure 5. Geologic Cross-Section Based on Well and Seismic Data along Seismic Line-3 (see Figure 4 for Line Location)

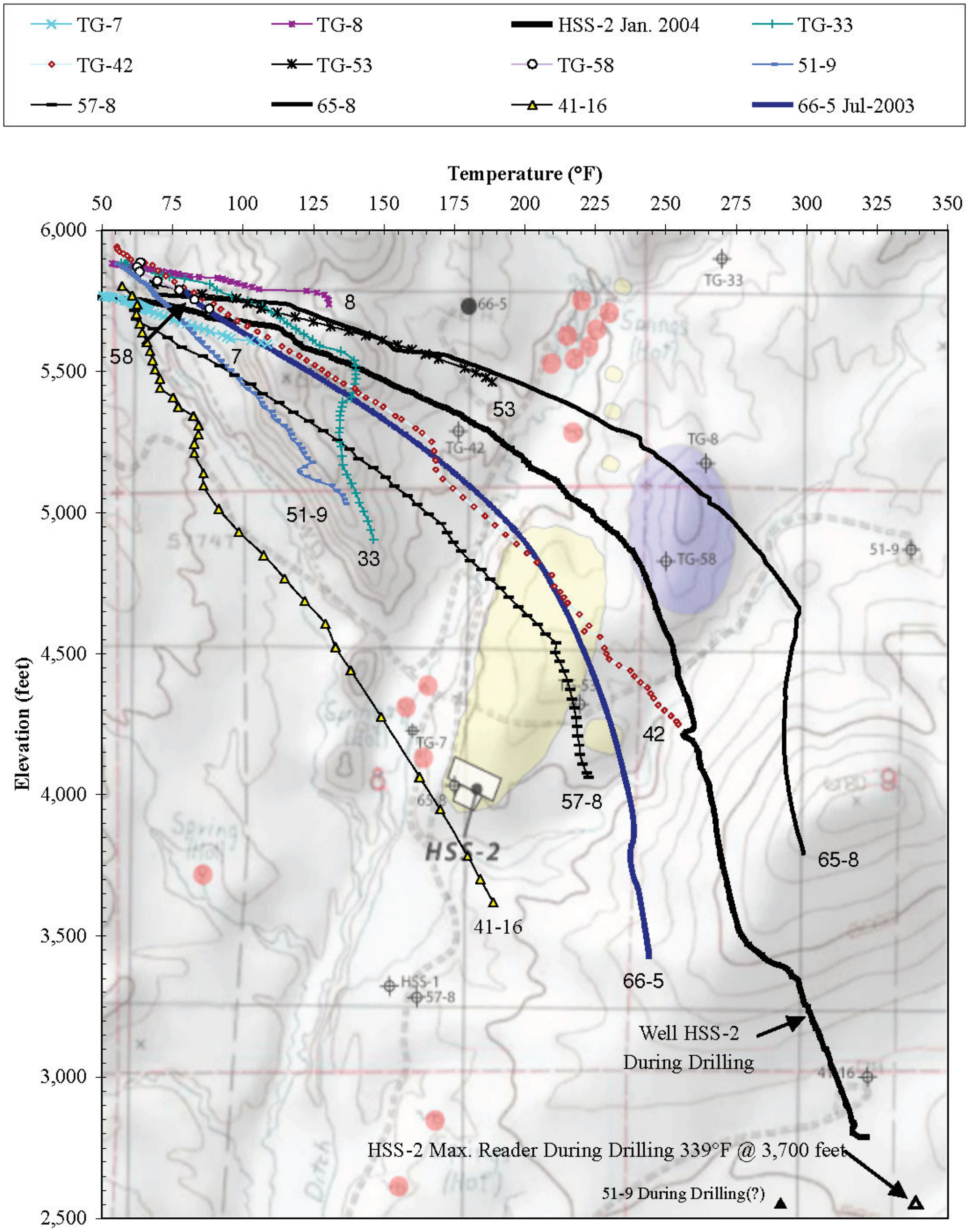

Figure 6. Temperatures versus Elevation for Wells Whose Location is Shown in Figure 4

Many of the wells drilled during the AMAX exploration program suffered hole-collapse, tight-hole (partial wellbore collapse), twist-offs and severe-to-complete loss of circulation during drilling. All of the AMAX exploration wells drilled to depths below 1,000 feet had some form of hole (drilling) problems: Well 66-5 collapsed at a depth of 2,400 feet, well 51-9 could not be completed, well 65-8 had major fill problems on connection requiring early completion, well 57-8 had tight hole problems and well 41-16 had severe hole caving problems.

6.0 EPR Rotary/Corehold HSS-2 Well Drilling Activities

The AMAX drilling experiences and other data obtained, the EPR geological analyses of the Hot Sulphur Springs area, the seismic data obtained by EPR, along with previous experience drilling in other volcanic areas, led to the conclusion that swelling clays would be a major problem in the shallow portion of wells drilled at Hot Sulphur Springs. Conductive temperature gradients (along with geochemistry data from the nearby hot springs) indicated that geothermal fluids at temperatures of ≈330° F should exist in the subsurface at depths below ±3,000 feet. In addition, given the typical low permeability of the rocks to be encountered, it was assumed that the productive horizons would be located in fractured Tertiary Volcanics and/or fractured Paleozoic Rocks. Therefore, the geothermal reservoir "target'" was fractured rocks within/along the Hot Sulphur Springs Horst-Graben Structure at temperatures of ±330°F below depths of ±2,500 feet.

6.1 HSS-2 Well Drilling Design

The shallow argillic zone was an expected drilling problem. Volcanic rocks can alter to Montmorillonite (Bentonite) type clays. These Smectite Group clays, when in contact with fresh-waters, are known to swell and lose cohesion. This loss of cohesion can cause wellbore stability problems that manifest themselves as tight-holes, drill-pipe twist-offs, bottom hole fill-on-connection and hole collapse, all of which were problems during the AMAX exploration drilling operations.

The shallow swelling-clay problems were addressed in the drilling program by using Polymer-based drilling mud mixed with 2% Potassium Chloride (KCl). The Polymer-based mud would allow for wall-cake development and hole stability control along with drilled clay-particle coating to reduce swelling. The Polymer mud would also allow for better viscosity control and a reduction in drill bit balling, which assist in hole cleaning and penetration rate, respectively. Viscosity control of the mud is also essential in reducing drilled solids build-up in the well thereby reducing the chance of over-pressuring the penetrated formations with subsequent loss-of-circulation. All of these points were deemed especially important in the shallow altered Tertiary Volcanic zones (weak clay-section) present in the Hot Sulphur Springs area.

Potassium Chloride (KCl) was added to the mud to control clay swelling that could occur from fluid leakage through the wall-cake or from fluids lost to the formations (loss of circulation). KCl assists in this regard in that typical Smectite clay swelling can occur when Potassium is leached (removed) from the clay-structure. This is due to the fact that Potassium provides a charge balance in Smectite clays, removal or substitution by other elements allows for the clay structure to breakdown. This clay-structure breakdown can cause tight-hole (wellbore-squeezing) and hole collapse. The addition of KCl assures (somewhat) that any fluids entering the clay zones/formation(s) will be rich in Potassium, reducing the chance of Potassium leaching and/or replacement.

The drilling mud composition for the deeper portion of the well (below the shallow clay-rich altered Tertiary Volcanic rock section) was, initially, not deemed important. This portion of the well was to be cored and loss of circulation in fractured intervals was the main area of concern. A Polymer-based mud was chosen for the coring operation based on its lubricity. The addition of KCl to the drilling fluid system was not required, given that no swelling-clays were expected at core depths (based on >300°F reservoir temperature estimates).

In hindsight the assumption that drilling fluid choice was not important in the deeper fractured portion of the hole was in error. The assumption was based on the fact that temperatures in the deeper portion of the well (productive horizons) were expected to be greater than 300°F. In the petroleum drilling industry it is typical to assume (and documented) that swelling clays are not a problem at temperatures above 300°F. This is due to the noted conversion of Smectite and mixed-layer Smectite-Illite (swelling) clays to Illite at temperatures above 300°F (for example, Abercombrie, et al 1994). Various investigations actually use the transition from Smectite (swelling-type clays) to Illite-type (non-swelling clays) as a geothermometer in oil exploration activities in sedimentary basins (Huang, et al. 1993). In addition, the Smectite-Illite transformation temperature dependence has been used in geothermal operations to determine casing setting depths (Gunderson, et al 2000).

Core drilling was not considered possible in the shallow altered Tertiary Volcanic (clay) section. This was due mainly to the type of bit (diamond) used, the small annular area between the core-pipe and the wall of the hole (<1/2" in width) and previous experience in coring through clay formations.

It was also not clear whether coring was possible in fractured zones below the shallow (<1,300 feet) "clay" layer. Other wells previously drilled in the area to depths of ≈2,000 feet reported "tight-holes" at depths below 1,300 feet. It was not possible to determine from previous drilling reports whether the tight-hole sections were at depths below 1,300 feet or created from problems in the shallow section of the hole (in the earlier exploration effort casing was set to <300' in several of the holes that exhibited drilling problems at depths below 1,300').

The HSS-2 drilling program was designed to drill rotary to 1,300' and then core from 1,300 feet to TD at ±3,000'. Coring operations had to be performed within a maximum hole-diameter of 4" due to stability problems with high-speed rotation of core-pipe during coring operations. This necessitated that coring had to take place within 4 ½" casing. Minimum rotary-hole diameter was set at 6 ¼" diameter to allow for setting of 4 ½" casing for core drilling operations. 6 ¼" was also minimum diameter for rotary drilling operations based on well depth and rock-bit availability for hard/abrasive formations. In addition, the well had to be designed so that if coring was not possible at depths below 1,300', due to formation problems, then the well design would have to allow for re-setting the Rotary drill-rig back on the hole to drill to depths below 1,300 feet with a 6 ¼" hole to a point where formations were competent enough for coring operations to re-commence after setting of 4 ½" casing.

The final EPR well HSS-2 exploration-drilling program (see Appendix A for the as-submitted HSS-2 drilling program) was designed to rotary drill through the upper altered Tertiary Volcanics to a depth of ±1,300 feet, the bottom of the low-velocity zone noted in seismic data. 7" casing would then be set at 1,300 feet with 4 ½" casing then hung from surface to 1,300' within the 7" casing. This 4 ½" casing string would allow coring from 1,300' to ±3,000'. The 4-½" casing string could be removed (if there were coring problems below the 7" casing shoe at 1,300') to allow for a continuation of rotary drilling with a 6 ¼" bit. The bottom 100' of the 4 ½" casing was to be cemented inside the 7" casing. The BOP/wellhead was designed to add a set of hydraulic rams capable of pulling >10,000-pounds to allow for tensioning of the 4 ½" unsupported casing string during coring operations. In addition, a Chevron-type packer assembly was included in the BOP design to allow for the 4 ½" casing string to expand inside the 7" casing and to allow for pressure control on fluids trapped in the 7" x 4 ½" annular area, if necessary (see Appendix A for schematic drawings). After setting of the 4 ½" casing at 1,300' core drilling operations would take place to proposed TD of ±3,000 feet.

6.2 HSS-2 Rotary Drilling Operations

The final well completion varied from design and is diagramed in Figure 7. A 14 ¾" hole was drilled to 150' where welded 10 ¾" line pipe was set and cemented with a Tremie line. An 8 ¾" hole was then drilled with a long-tooth Mill-Tooth Bit to 1,350' where 7" casing was set and cemented thru the casing using the rig mud pump. Cement mixing equipment was provided with the drilling rig.

Formations in this shallow section were altered Tertiary Volcanics with approximately 100% clay at the surface linearly (approximately) varying to 0% clay at 1,300 feet. (*Note that the percentage clay was based on visual inspection of cutting returns on the shale-shaker*). There were several hard layers within the altered volcanics where only partial alteration of the volcanics to clay had taken place. These partially altered argillic zones yielded pea-gravel size materials.

Penetration Rate during rotary drilling operations, based on time to drill-down one (1) 20' joint of drill pipe, and Mud Temperature-Out is shown in Figure 8 along with other pertinent information. Penetration rates were high through the clay materials to depths of 500' with penetration rates up 110 feet per hour (fph). Below 500' several zones of partially altered volcanics were encountered and drilling rates reduced. Loss of Circulation (LOC) was encountered at 890' where ≈1,500 gallons of mud were lost to the formation. This zone sealed itself and no LOC materials were used. Penetration rates were reduced through this zone due to wellbore stability problems that required some reaming of the hole. Drill Bit#3 was added below this point although it should be noted that drill Bit#2 was still in pristine condition and could have been re-run. Bit#3 was a shorter-tooth Mill-Tooth Bit that reduced penetration rates in the soft formations. Dye was added to the mud prior to setting 7" casing at 1,350' and return times showed the hole to be near gauge (±).

After setting of the 7" casing, waiting on cement and setting the Blowout Prevention Equipment (BOPE), cement was drilled out from within the 7" casing. It was decided to drill ahead with a 6 ¼" bit to determine formation integrity prior to hanging the 4 ½"casing string from surface and beginning coring operations.

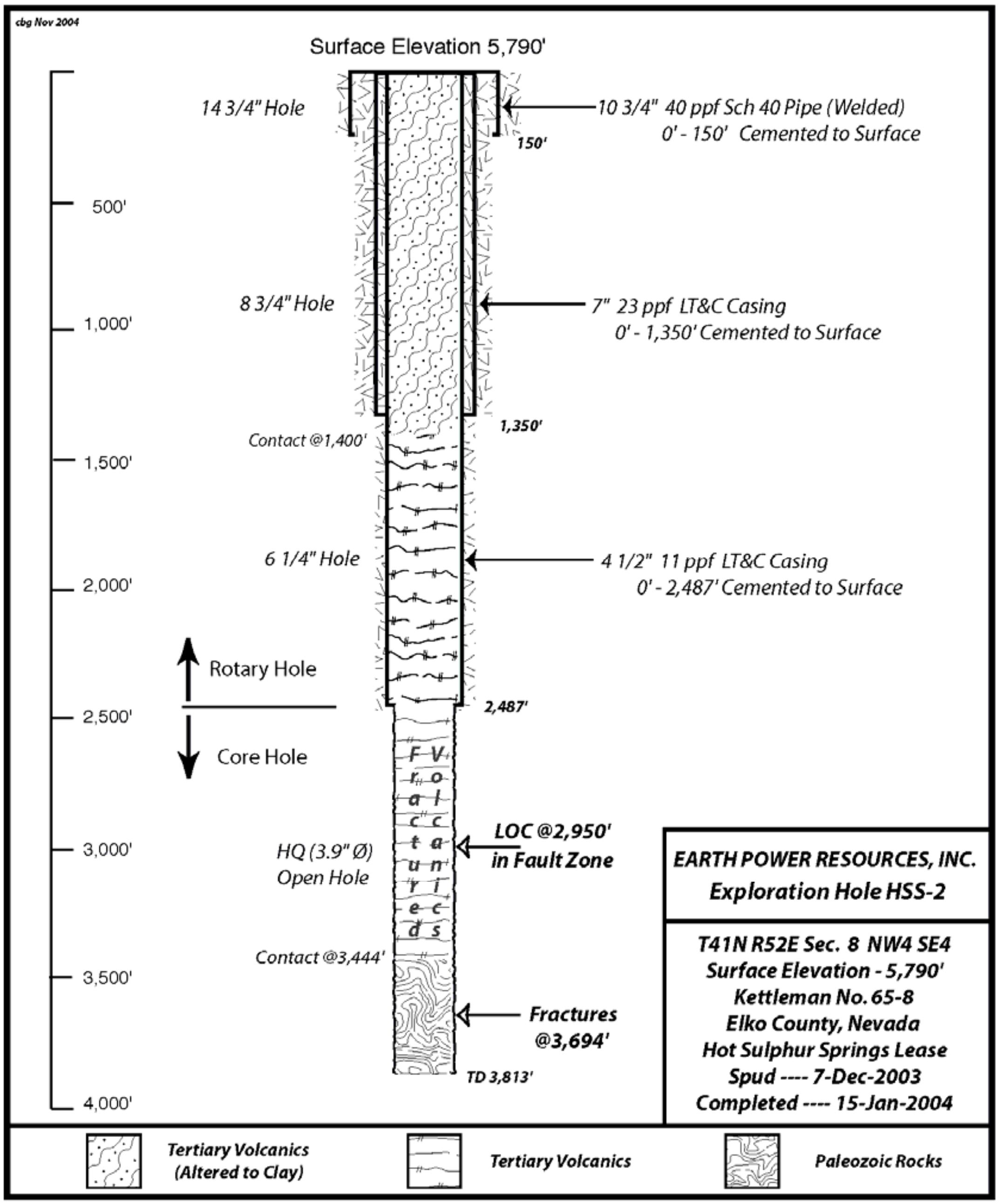

Figure 7. Completion Diagram for Earth Power Resources Exploration Well HSS-2

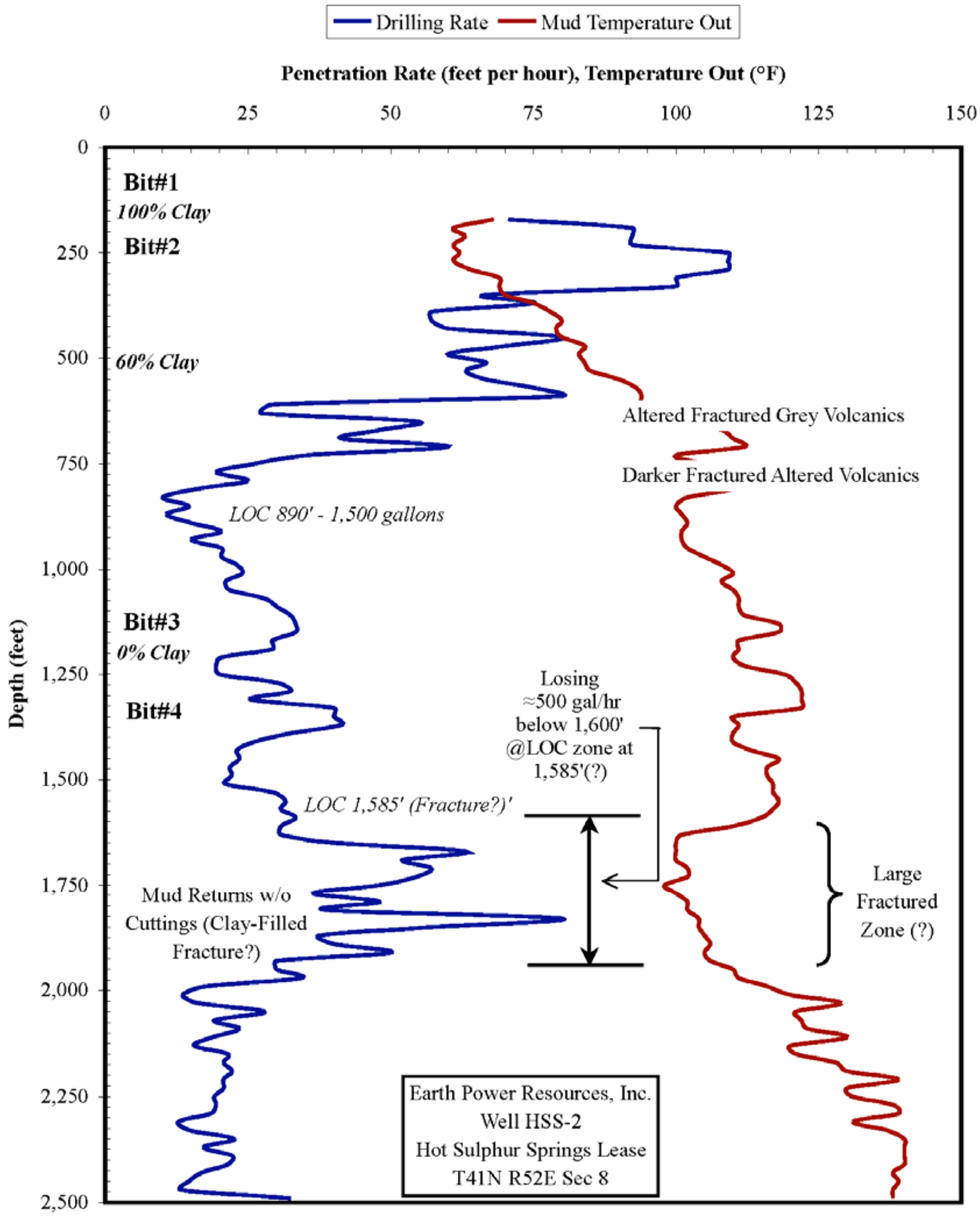

Figure 8. Penetration Rates, Mud Outlet Temperatures, Bits Used, LOC Zones and % Clay Content (Visually Determined) for Well HSS-2 during Rotary Drilling Operations

(*Note: At this point in the exploration program, coring was important in defining the geothermal reservoir(s) structural characteristics (below 2,500') and for determining the depth to Paleozoic Rocks in the well HSS-2 area for use in seismic/geologic data modeling. Since Rotary operations were proceeding without any major problems below* *the 7" casing point, and with respectable penetration rates, it was decided to continue the rotary operations to ±2,500'. Core through the reservoir caprock (depths between ±1500' to ±2500') is still important with respect to the overall geothermal resource characterization. Structural characteristics of the caprock will be addressed in future coring operations*).

A 6 ¼" hole was drilled from 1,350' to 2,487' where 4 ½" casing was set and cemented in place. Cementing operations were through casing using the drill-rig mud pump and rig cement-mixing equipment. Rock types consisted of Altered Tertiary Volcanics with various degrees of alteration (based on cuttings and penetration rates). Drilling mud consisted of Polymer (Drispac) mixed with 2% KCl. Penetration rates varied with degree of rock alteration (see Figure 8).

A partial LOC zone was encountered at a depth of 1,585'. Approximately 500 gallons per hour were lost between the depth of 1,585' to ≈1,800'. No LOC material was added and LOC ceased at a depth of ≈1,800'. Of note was that at several depths within this 1,585' to 1,800' LOC section mud-returns without cuttings were observed. This lack of cuttings, along with the observed high penetration rates (see Figure 8), suggests that a large fracture zone, with volcanics partially altered to clay, was encountered. Coring through this zone, in the future, may offer additional insight with respect to the caprock structure.
Drilling time versus depth during rotary (and core) operations is shown in Figure 10. Eleven (11) days were required to rotary drill to a depth of ≈2,500 feet. Six (6) of the drilling days were required for setting of casing strings, cementing and BOPE installation.

6.3 HSS-2 Core Drilling Operations

Coring operations began after Christmas break (December 18-29, 2003). During cementing of the 4 ½" casing string, prior to the Christmas break, problems developed in that the cement plug did not "Bump" (cause a pressure increase when it reached its landing point inside the 4 ½" casing). However, it was believed that sufficient mud volume had been used to displace the plug to the float collar (landing point). Coring operations began after break and the top-of-cement was determined to be at ≈2,000', approximately 500' above the casing shoe. Cement clean out required ≈4-days of rig time.

After cement clean out, coring operations began at 2,487'. Polymer-based drilling fluids were used. Maximum reading thermometers were run on the wireline during core retrieval every 50' of cored-hole (10-foot core barrels were used). The maximum reading thermometers were allowed to sit at bottom hole for 30-minutes without fluid circulation before retrieval.

Downhole temperatures obtained from the maximum reading thermometers as a function of depth during coring are shown in Figure 9. Time versus Depth for coring (and Rotary) drilling operations is shown in Figure 10.

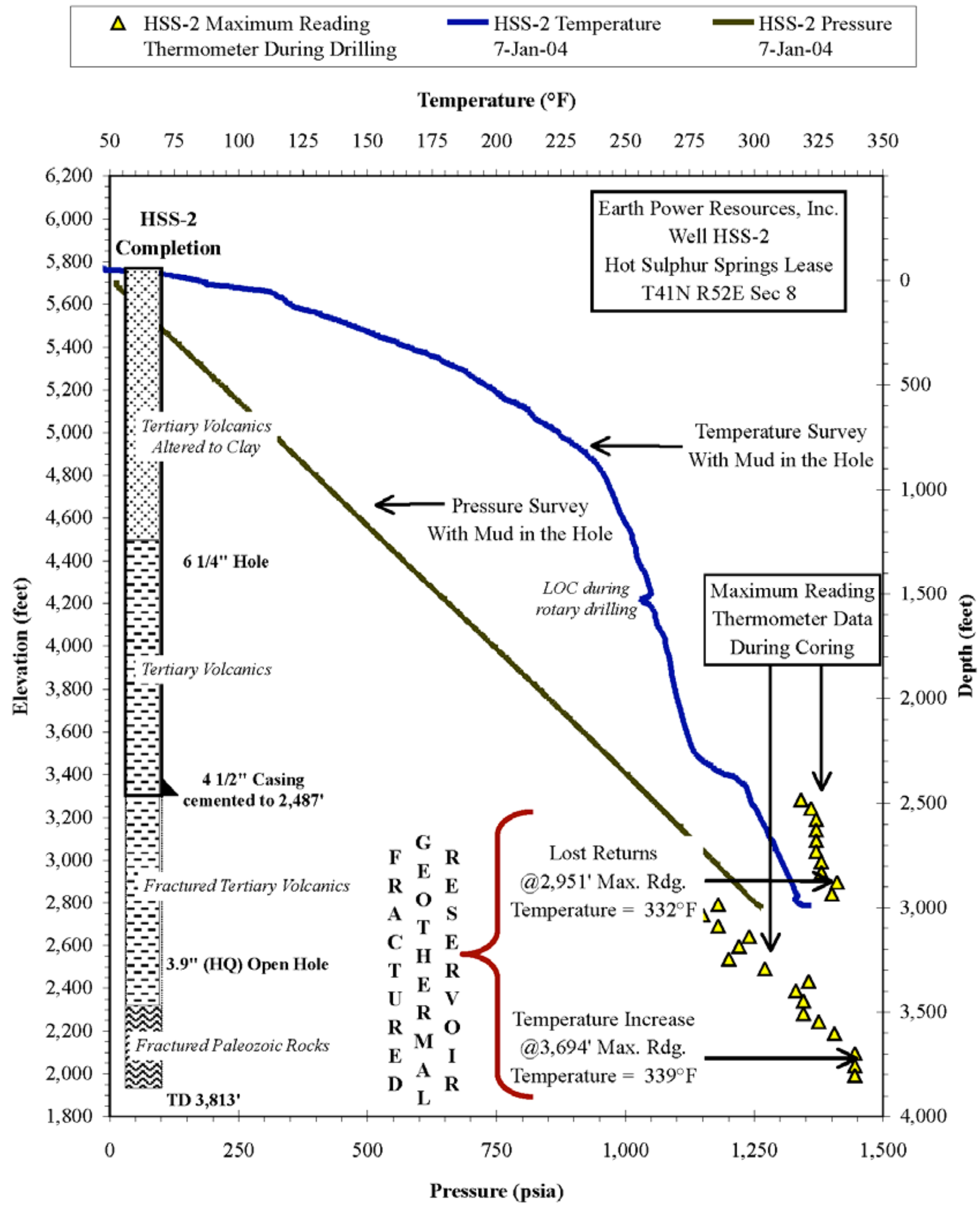

Figure 9. Temperature versus Depth during Coring and Static Temperature/Pressure Survey Data to 3,000 feet during Drilling of Well HSS-2

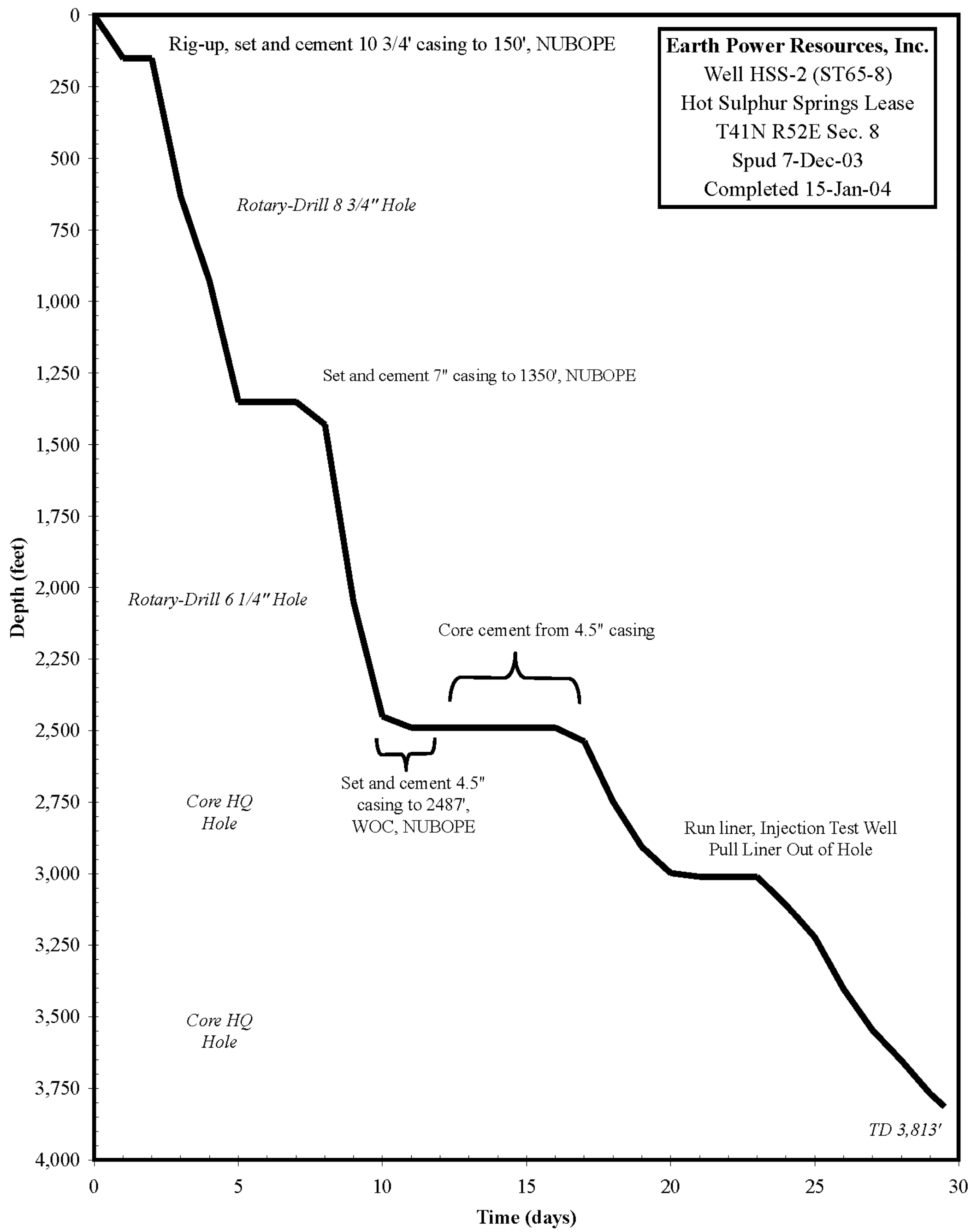

Figure 10. Depth versus Time for Earth Power Resources, Inc. Well HSS-2

Fractured and Altered Volcanics were encountered beginning at 2,500'. Numerous fractured intervals were cored to Total Depth at 3,813' (see Appendix B for photos of several fractured intervals).

Maximum reading thermometer (MRT) data showed temperatures in the 325°F range during coring from 2,487' to 2,950'. At a depth of 2,950' a complete LOC zone was encountered (note that mud circulation rates were ≈10-15 gpm during coring operations). The core bit "fell" (cored without any weight-on-bit or torque) approximately 4-feet though this interval. LOC material was added to the drilling mud but circulation could not be regained. Measured temperature data, from the downhole MRT's, showed a temperature increase from 326°F to 332°F when coring into this interval at 2,950 feet.

It was decided to drill ahead to ±3,010 feet and then injection-test the zone at 2,950 feet. To insure hole stability (and protect the downhole pressure, temperature and spinner equipment, value ≈$50k) a slotted liner was run from 2,400' to current TD at 3,010'. The liner was set on bottom. A "hand-made" liner-setting tool was used. Water was then used to displace the Polymer mud in the wellbore prior to injection testing.

The surface injection test system utilized a centrifugal pump capable of 250 gpm at 120 psig, along with wellhead pressure and temperature measurement devices (analog). Injection rates were monitored using measured water-tank levels versus time.

A static pressure, temperature and spinner (PTS) survey was obtained prior to injection testing (see Figure 9). The static pressure survey data indicated that the zone at 2,950' was above hydrostatic (artesian) with measured downhole temperatures at 2,950' of ≈328°F (downhole temperatures had not equilibrated).

After the static PTS survey data was obtained, the PTS tool was set at 2,400'. Water level was approximately 10' feet below surface at startup of injection. Injection began with the wellhead and downhole pressure immediately rising by 120 psig (see Figure 11). Average injection rate was ≈40 gpm. After cessation of injection, complete pressure Fall-off (pressure decrease to original static pressure at 2,400') required only 4-minutes, indicative of a highly damaged near-wellbore reservoir/zone.

The liner was removed from the well and coring operations were resumed to TD at 3,813'. Circulation was never regained with drilling fluids apparently still exiting at the 2,950-foot depth fracture zone. Paleozoic rocks were encountered at 3,444'. Several additional fractured zones were encountered to TD. It is unknown whether additional fluid-loss zones were encountered in fractured rocks below 2,950' given that drilling fluid was known to be exiting at the 2,950' zone.

Downhole MRT data (see Figure 9) increased linearly(±) from 2,950' to TD. A maximum temperature of 339°F was measured at a depth of 3,694' where a fractured Paleozoic rock interval is noted in the core. The final well completion is shown in Figure 7. Overall core-recovery was ≈95%.

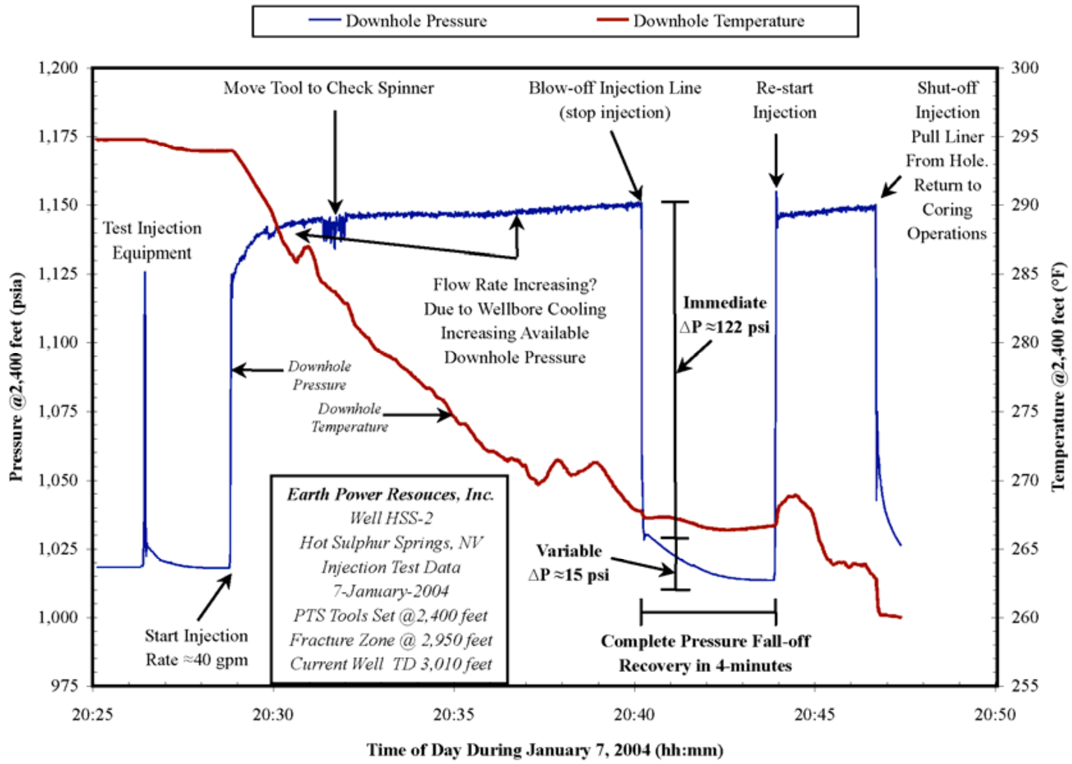

Figure 11. Well HSS-2 Downhole Pressure and Temperature Data at 2,400 feet versus Time during Injection Testing. Wellhead Injection Pressure ≈ 120 psig, Injection Temperature ≈80ºF, Injection Rate ≈40 gpm

7.0 Discussion and Conclusions

In summary, prior to the drilling conducted by EPR, drilling problems had severely impeded the development of the Hot Sulphur Springs lease area of Elko County NV. The area was determined in the 1970s to have adequate resource, but the lack of suitable drilling technology left the area undeveloped. Recent drilling, including the use of 2% KCl to stabilize the clays, has identified both the problem and the solution of how to drill this resource. The benefit of demonstrating how to drill Sulphur Hot Springs resource goes beyond Elko County. There is evidence suggesting the same clay problems exist at other geothermal resources, particularly in the Basin and Range geologic province.

Seismic and geologic data indicate that a Horst-Graben structure with at least 1,700 foot of offset underlies the Hot Sulphur Springs/Hot Creek area. Well HSS-2 encountered fractured and altered Tertiary Volcanics to a depth of ≈3,444 feet. Fractured Paleozoic Rocks were encountered below the Tertiary Volcanic Rocks to TD at 3,813 feet.

Well HSS-2 encountered a productive fractured geothermal system below 2,500 feet with temperatures in the 330°F range. Maximum measured temperature (with MRT's during drilling) was 339°F at 3,694 feet (within the Paleozoic section). Well HSS-2 is artesian with shut-in wellhead pressures of ≈35-psig. The well will discharge ≈150 gpm under steady-state natural (un-assisted) flow conditions.

Rotary-drilling operations to a depth of 2,487' required eleven (11) days. This included the setting of three (3) casing strings (≈6-days of rig-time). Three (3) LOC zones were encountered, one within the shallow argillic Tertiary Volcanic section (shallow clay-section), one in altered Tertiary Volcanics within the caprock(?) system and one within a fractured and altered Tertiary Volcanic section with measured temperatures of ≈330°F. Additional Loss of Circulation (permeable) zones may exist below 2,950 feet.

The drilling fluids program using Polymer-based mud mixed with 2% KCl allowed for high-penetration rates and wellbore-stability control through the altered volcanic sections above 2,500 feet. The information obtained from the rotary drilling operations has greatly reduced the estimated costs of production/injection wells to be drilled in this area (and other areas in Volcanic settings).

It was not clear, originally, why the injection-tested fracture zone at 2,950' exhibited such a highly damaged injection pressure versus rate condition. As it turns out, the Smectite-Illite conversion temperature dependency (mentioned above) may not hold true in geothermal systems with silica-saturated fluids. X-ray diffraction work on cores from the major fracture zone in well HSS-2 at a depth of 2,950 feet (See Appendix B for a photo of the "gouge" zone), with in-situ temperatures of ±330°F, indicated ≈30% by weight Smectite in the clay materials (fault gouge?) located within the fracture zone. Therefore, the assumption used in the drilling program design that drilling fluid type was not important in the drilling of "reservoir" zones was ill conceived.

Why Smectite exists at these temperatures is unclear at this time. A cursory investigation (see Abercrombie, et al 1994) suggests that the conversion of Smectite to Illite is controlled by fluid silica-activity. In order to change the clay-structure from Smectite to Illite silica must be removed from the matrix of the Smectite (along with other modifications). Given that the geothermal fluids are saturated with respect to silica (which is why the geothermal-fluid silica geothermometer can be used for estimates of resource temperature) suggests that the reservoir fluids may not be able to remove silica from the Smectite clay matrix and, therefore, the transformation of Smectite to non-swelling Illite-type clay may not be complete.

The fact that Smectite-type clays exist at temperatures above 300°F is a very important point in that many geothermal wells are drilled with fresh-water after loss of circulation occurs in zones at temperatures sufficient for economic electrical power generation. In the past, this change over to water from bentonite-based drilling fluids was done to 1) reduce drilling costs associated with mud and additives lost to formations and 2) to reduce the chance of formation-plugging associated with bentonite-based mud loss to permeable strata. However, this fresh water, if lost in Smectite-rich fractured-zones or any Smectite-rich formation zone, may cause clay-swelling and subsequent plugging of the fracture/porous fluid flow paths.

It is important to note that permeability in fractures is directly related to the cube of the aperture. Therefore, even a small (1/4") fracture has a Transmissivity of >6,000 Darcy-feet, a very-productive zone from a geothermal development standpoint. Any clay swelling in fractures near to the wellbore-face may completely plug the fracture-zone off from the wellbore causing the well to be non-productive (a "dry-hole" in the literature). Moreover, many of the fractures noted in geothermal systems (observed in core and in borehole imaging logs) are vertical to near vertical. It is not clear whether fresh-water based drilling fluids, lost in a fracture zone at a shallow depth, has the ability to migrate downwards along fractures. This can especially be a problem in areas where the well is drilling parallel to or within a steeply dipping fracture zone as it is drilled deeper into the formation.

In any case, this Smectite appearance at temperatures above 300°F is an important problem that needs to be addressed for successful (productive) completions at the Hot Sulphur Springs area and possibly at other areas where Volcanics are the intended geothermal fluid production horizon. (Note: The appearance of Smectite at temperatures greater than 300°F was also noted by the Author in a corehole drilled in the Lake City, California geothermal area in 2001. However, it was thought to be a special condition of that area (Lake City) given the rock type (Volcanic mud-flows). However, the occurrence of Smectite at Hot Sulphur Springs at producible reservoir temperatures suggests that this problem may be prevalent in Volcanic areas where fluids are saturated with silica and subsurface temperatures are in the 300°F to 350°F range.)

8.0 References

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Gunderson, R., Cumming,W., Astra, D., Harvey, C., 2005 Analysis Of Smectite Clays In Geothermal Drill Cuttings By The Methylene Blue Method: For Well Site Geothermometry And Resistivity Sounding Correlation, 2005 World Geothermal Conference, Japan, p. 1175-1181

Huang, W-L., Longo, J.M., Pevear, D.R.. 1993, An Experimentally Derived Kinetic Model For Smectite-to-Illite Conversion and Its Use As A Geothermometer. Clays and Clay Minerals v. 41, p. 162-177.

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APPENDIX A

WELL HSS-2

DRILLING AND COMPLETION PROGRAM

EARTH POWER RESOURCES, INC

TUSCARORA GEOTHERMAL POWER PROJECT
HOT SULPHUR SPRINGS LEASE AREA

ELKO COUNTY, NEVADA

(November 2003)

Earth Power Resources, Inc

Tuscarora Geothermal Power Project
Tuscarora, Nevada

Well HSS-2 (65-8) Proposed Rotary and Core Hole Drilling Program

Earth Power Resources, Inc. (EPR) is the operator of the exploration, drilling, testing and production activities at the Tuscarora Geothermal Project. EPR offices are located at:

Earth Power Resources, Inc.

2407 South Troost.

Tulsa, OK 74114

The rotary drilling contractor for these activities has not been chosen at this date. Boart-Longyear will provide core-drilling equipment.

Well HSS-2 (Kettleman 65-8) will be located in T41N R52E Section 8 NW4 SE4.

The drilling program will combine rotary drilling operations with core drilling. This drilling and completion method will allow for the reservoir system below 1,300 feet to be explored using core drilling (to allow for reservoir rocks to be obtained) while still allowing for the well to be drilled with conventional rotary drilling equipment if problems are encountered in core drilling (as occurred in well previously drilled corehole HSS-1 at Tuscarora, Nevada). Problems occurred in HSS-1 due to the fact that the shallow volcanics had been completely altered to clay. Seismic data in the HSS-2 area suggest that similar conditions may exist in the subsurface. If coring operations cannot be completed, the 4 1/2" casing will be removed from the well (with the bottom 4 1/2" casing milled out from the bottom 7" casing). The 7" casing will be pressure tested prior to setting the 4 1/2" casing so that conversion from the 4 1/2" BOPE to 7" BOP system can proceed easily.

The drilling program summary is as follows:

1) Drill 14 3/4" hole to 150 feet.
2) Set and cement 10 3/4" casing (with Tremie line).
3) Drill 8 1/2" hole to 1,300 feet.
4) Set and cement 7" casing to 1,300 feet.
5) Pressure test 7" casing.
6) Drill out 7" float collar and 10 feet of cement in the 7" casing.
7) Run 4 1/2" casing to 1,290 feet.
8) Cement bottom 30 feet of 4 1/2" casing within the 7" casing string.
9) Nipple up 4 1/2" BOPE.
10) Core hole to TD at 3,000 feet.
11) Run 2,500 feet of 2 3/4" (NQ Rod)
12) If problems develop during coring, back-off 4 1/2" casing above bottom cement plug.
13) Cement bottom 20 feet above the 4 1/2" casing stub at bottom of 7" casing.
14) Nipple up 7" BOPE
15) Wash-over and pull or mill out bottom portion of 4 1/2" casing.
16) Drill ahead with 6 1/4" bit.

<u>The following information will be obtained and recorded by the drilling contractor:</u>

Monitor the following data every 30 feet, unless otherwise noted, and write into tour sheets.

1) Fluid temperature in/out.
2) Fluid pit levels.
3) Fluid pump volumes/rates.
4) Mud density, viscosity, solids content, etc.
5) Drilling rate.
6) Samples will be taken at 20 foot intervals during rotary drilling operations.
7) Cores will be obtained, boxed and labeled.
8) Run maximum readers when removing core barrel.
9) Note any drilling breaks, fractures, LOC zones and brief discussion of material encountered.

10) All equipment allowed below ground level will be measured for diameter and length prior to running into hole.

11) All subsurface depths will be based on predetermined point of reference at surface.

12) Deviation surveys may be run at 500 foot intervals.

The hole completion is as indicated in Figure 6. The following drilling program will be adhered to under normal drilling conditions:

1) Well HSS-2 will be drilled on an existing pad. Well location is given in Figure 1. Well completion diagram is shown in Figure 6.

2) Move in and rig up rotary drilling rig, water tanks, storage tanks, communications, mud storage, site trailers, flow test equipment, sanitary facilities, etc. **Notify DOM 24 hours prior to spudding well.**

3) Drill 17 1/2" hole to ±20 feet. Run 16" conductor and cement with neat cement.

4) Drill 14 3/4" hole to ±150 feet.

5) Run 150 feet 10 3/4" 32 ppf H-40 casing. Cement hole with neat cement, 3% $CaCl_2$ using tremie line. WOC. **Notify DOM at (775) 684-7040 or (775) 721-1774 24 hours in advance of BOP test.**

6) Nipple up 10 3/4" 3000# Double Gate BOP, kill line, blow down line as per attached Figure 2.

7) Drill 8 1/2" hole with mud to ±1,300 feet.

8) Run 1,300 feet of 23 ppf 7" ST&C casing with float shoe on bottom and float collar one joint up. Use centralizers on bottom joint and two joints up. Tack weld bottom three joints.

9) Cement 7" casing using stab-in with 250 cf (50% excess) mixed with 20% Silica Flour. Use retarder in cement dependent on mud temperatures (expected downhole temperature is >250°F). **Notify DOM at (775) 684-7040 or (775) 721-1774 24 hours in advance of BOP test.**

10) WOC. Nipple up 7" 600# flange, 2" Side outlets with 7" Blind Flange with 2" Valve located on top (see Figure 3). Pressure test 7" casing for 30 minutes to 500 psi.

11) Drill out float collar and 10 feet of cement within the 7" casing.

12) Run 1,290 feet of 4 1/2" casing in hole. Cement bottom 30 feet of 4 1/2" casing inside the 7" casing with 6.4 cf cement mixed with 20% Silica Flour (see Figure 4). WOC 8-hours.

13) Set 4 1/2" casing with collar on 7" blind flange bored for 4 1/2" casing. Nipple up 4 1/2" Annular preventer with casing shutoff valve below (see Figure 5). Pressure test Annular preventer and casing shut-off valve to 500 psi for 30 minutes **Notify DOM at (775) 684-7040 or (775) 721-1774 24 hours in advance of BOP test.**

14) Drill out cement in 4 1/2" casing and core hole 3.9" diameter hole to ±3,000 feet.

15) Run pressure, temperature and spinner logs. Perform flow/injection tests dependent on hole conditions and data obtained during drilling.

16) 2 3/4" tubing is to be run from surface to TD after logging and testing operations have been completed. Tubing is to have bull-nose attached to bottom and bottom ±10 feet of tubing is top be torch slotted for circulation. Weld bottom three joints.

17) Flow and/or injection tests will be carried out when permeable zones are encountered. **Notify DOM at (775) 684-7040 or (775) 721-1774 prior to flow testing.** Flow test procedure requires pulling drill string from hole and rig up flow test equipment. If slim hole does not flow, perform injection test. Injection test may also be conducted if corehole flow test operation is successful. Air may be injected down drill pipe to initiate well flow. (Estimated test program duration ≈12 hours). Flow test surface equipment design to be determined based on conditions encountered.

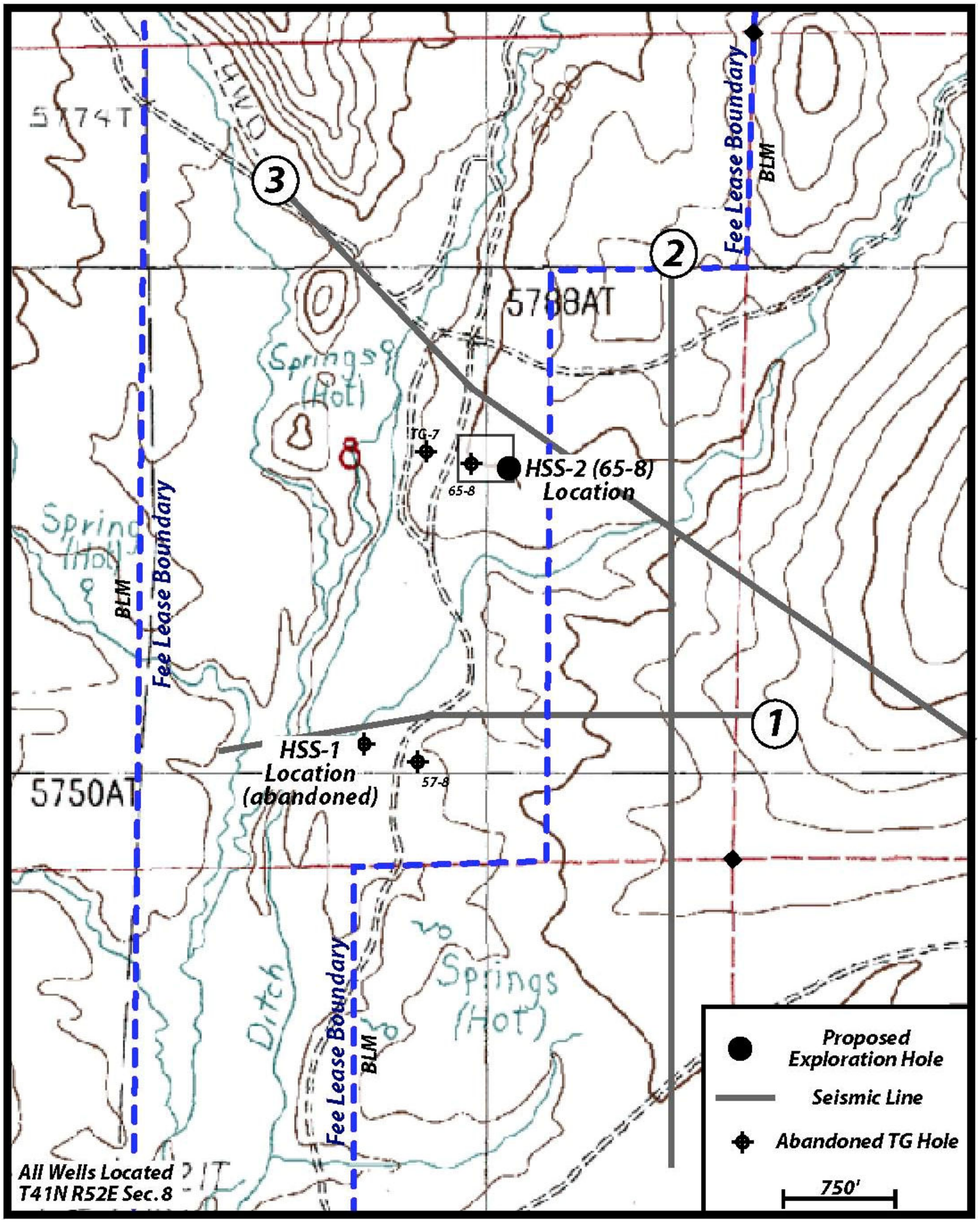


Figure 1) Location of the Earth Power Reources Hot Sulphur Springs Exploratory Well

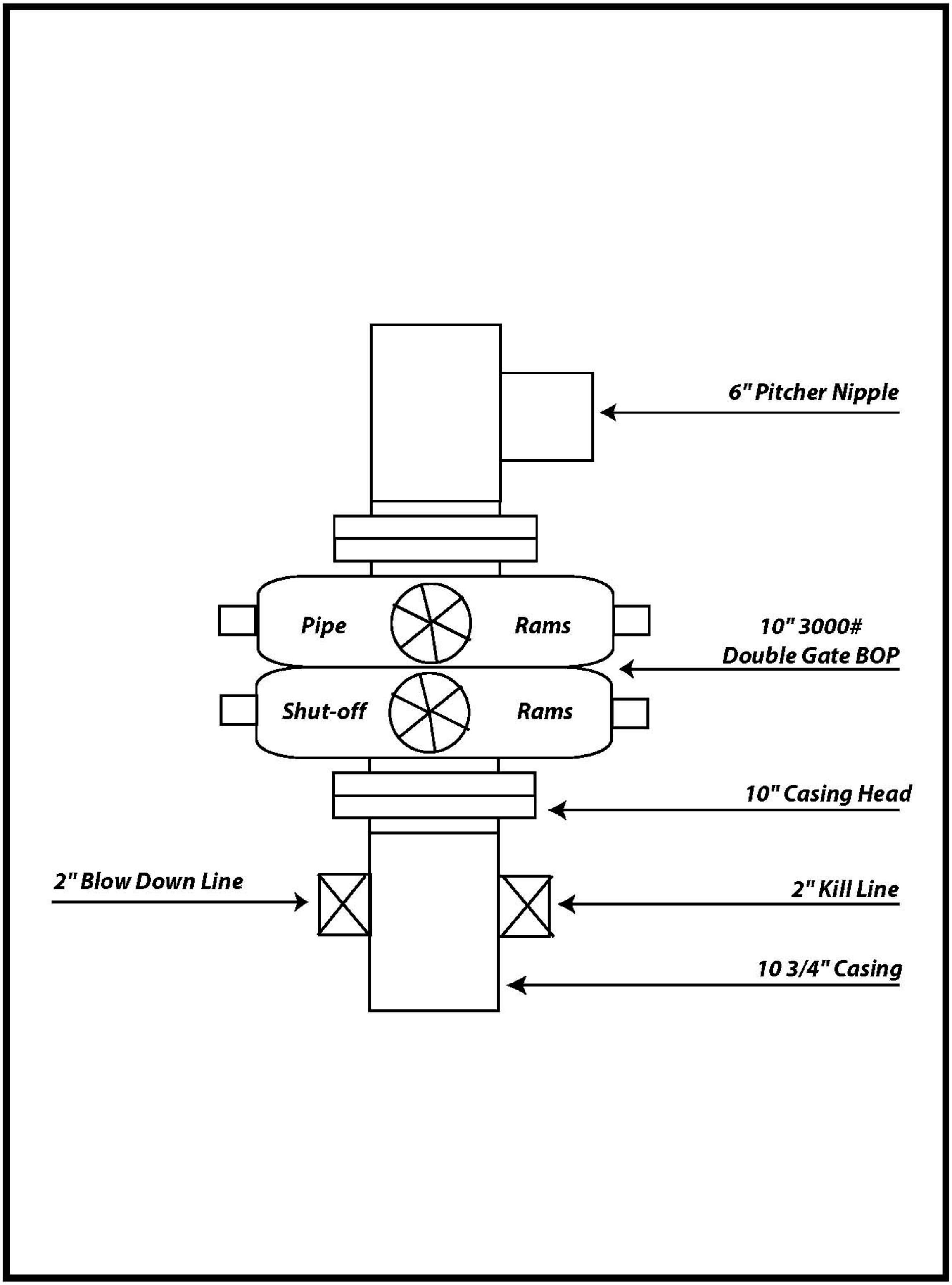


Figure 2) 10" 3000# Double Gate BOP

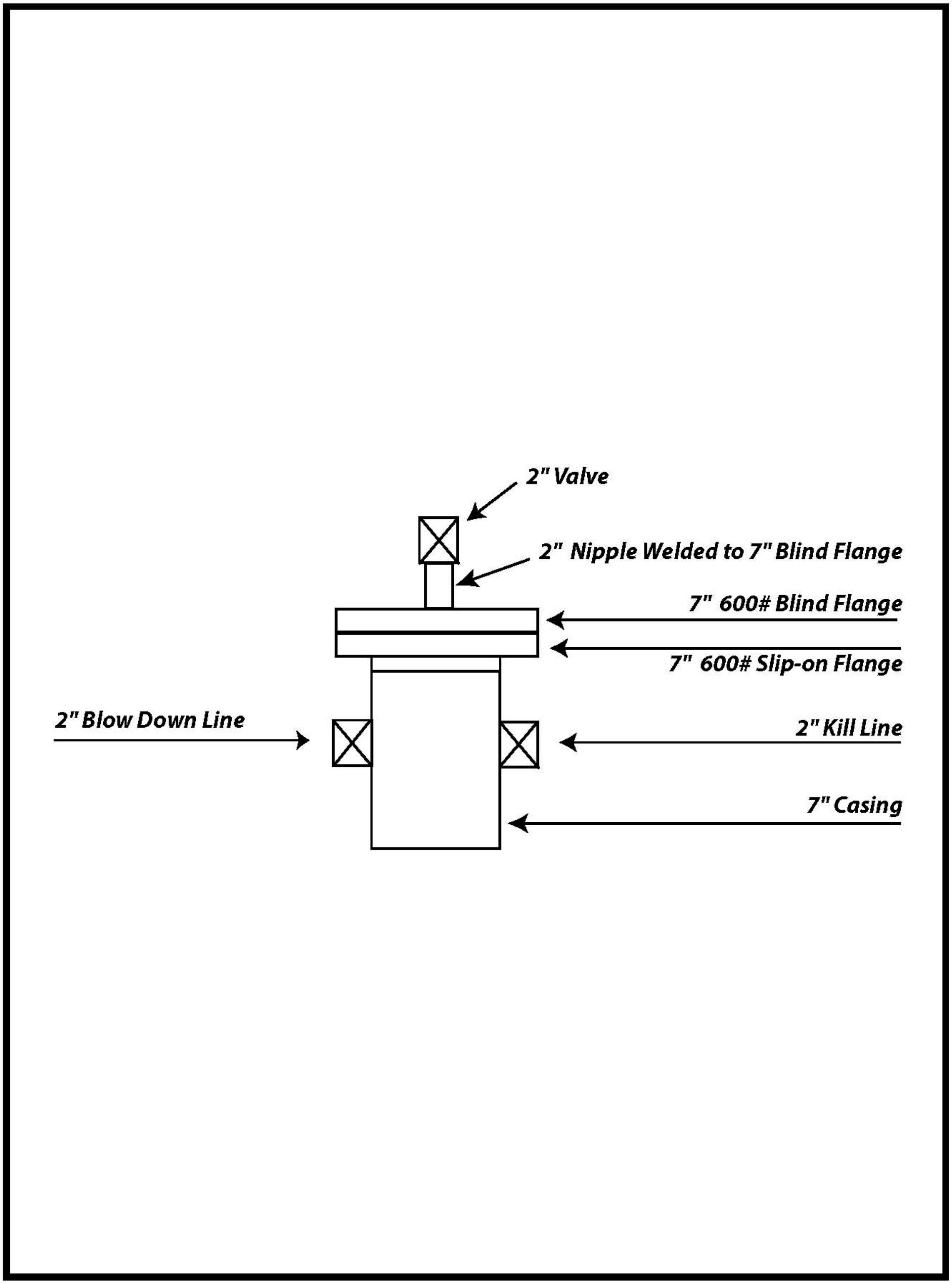


Figure 3) 7" Wellhead Completion and Casing Test Equipment

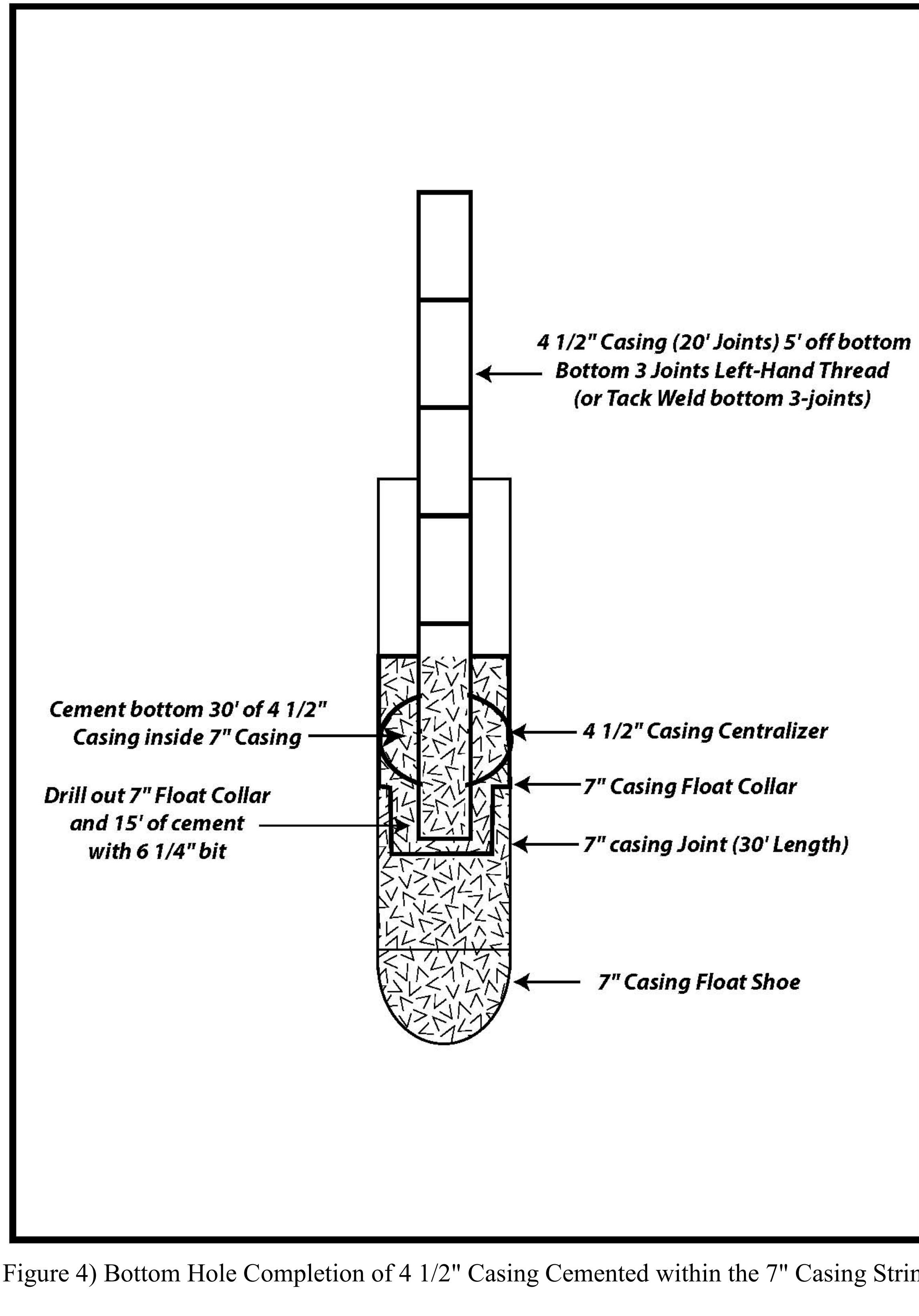
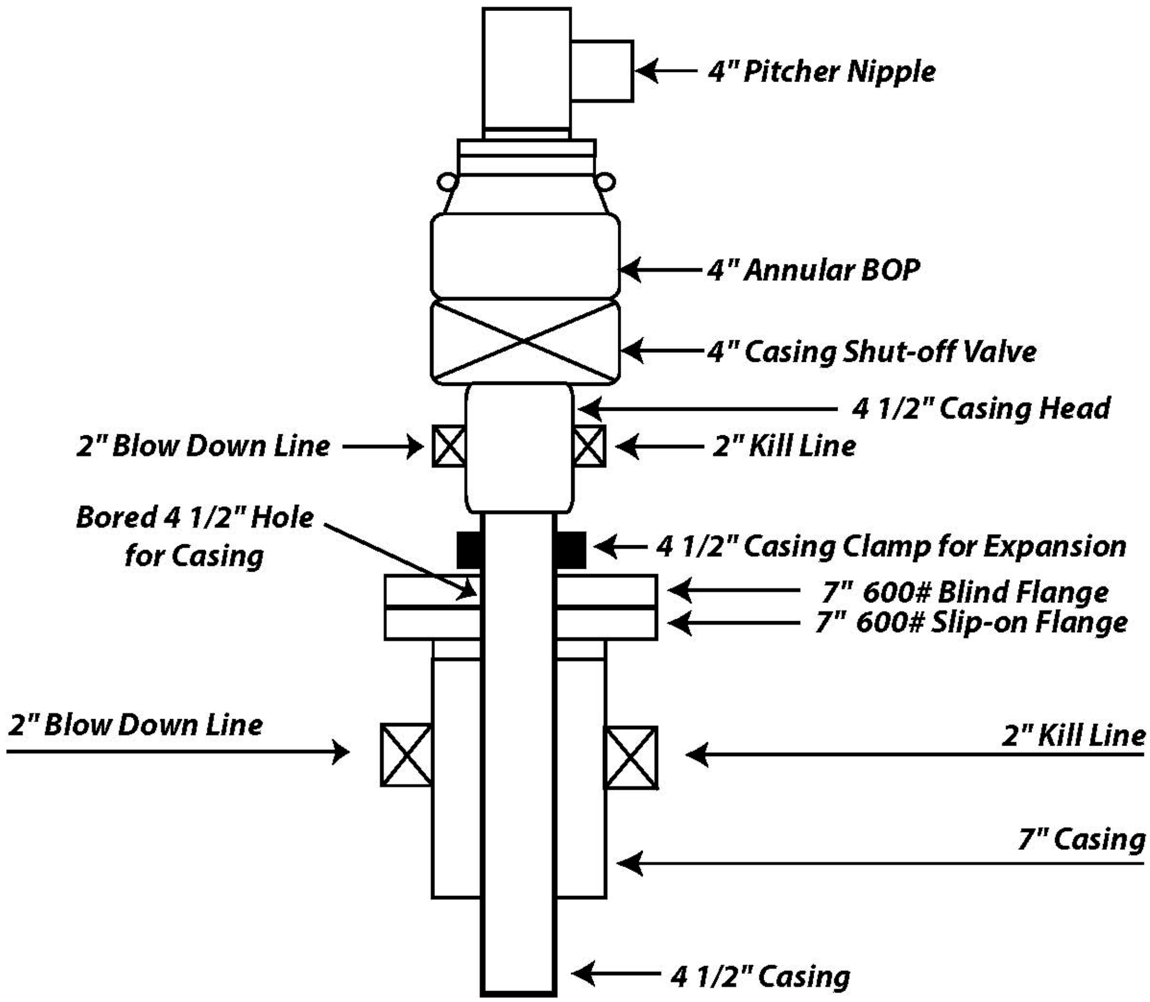


Figure 4) Bottom Hole Completion of 4 1/2" Casing Cemented within the 7" Casing String



See Figure 4 for 4 1/2" Bottom Hole Completion

Figure 5) 4 1/2" BOPE Used in Core Drilling Operations

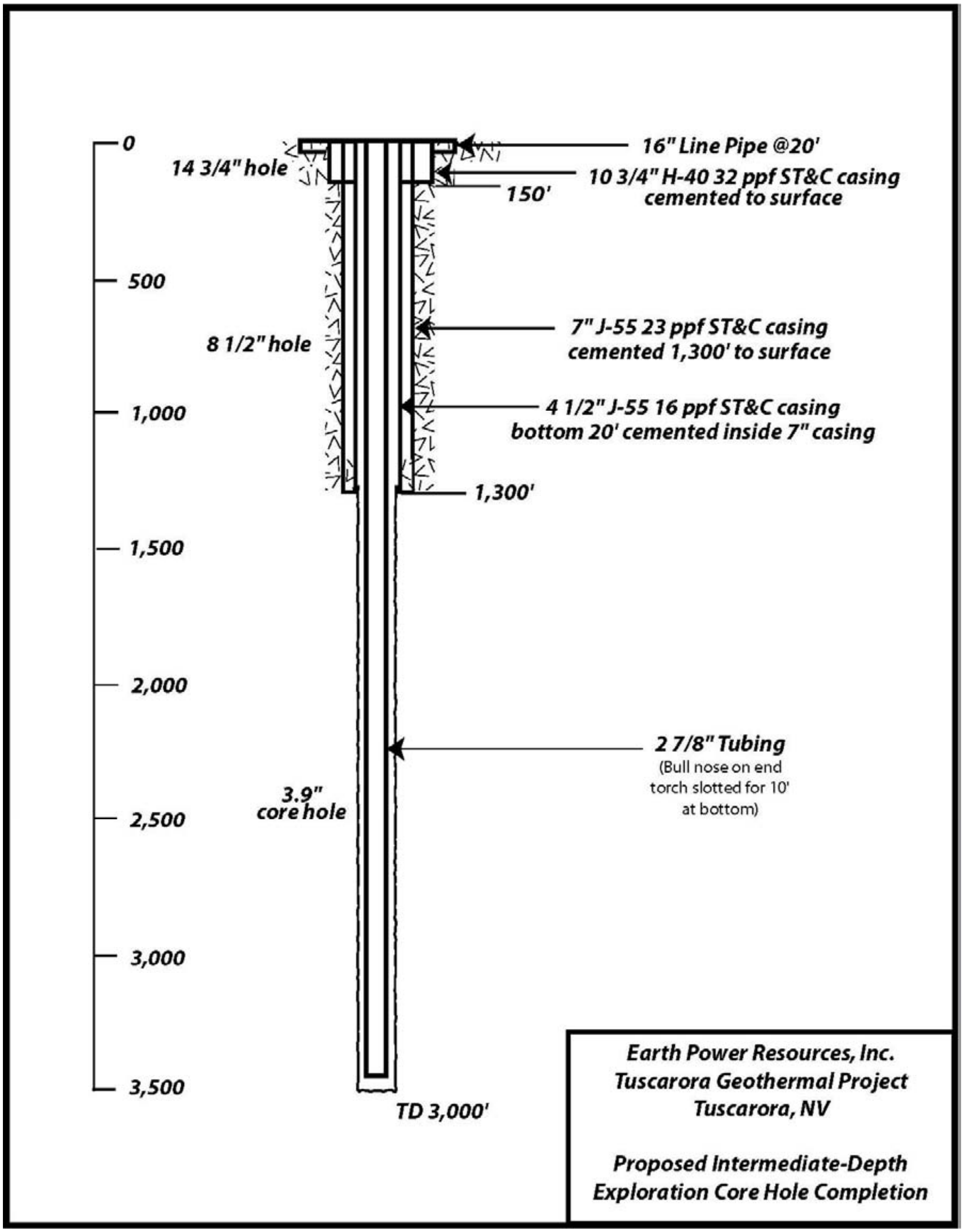


Figure 6) Earth Power Resources Hot Sulphur Springs Small Diameter Exploration Hole Completion

APPENDIX B

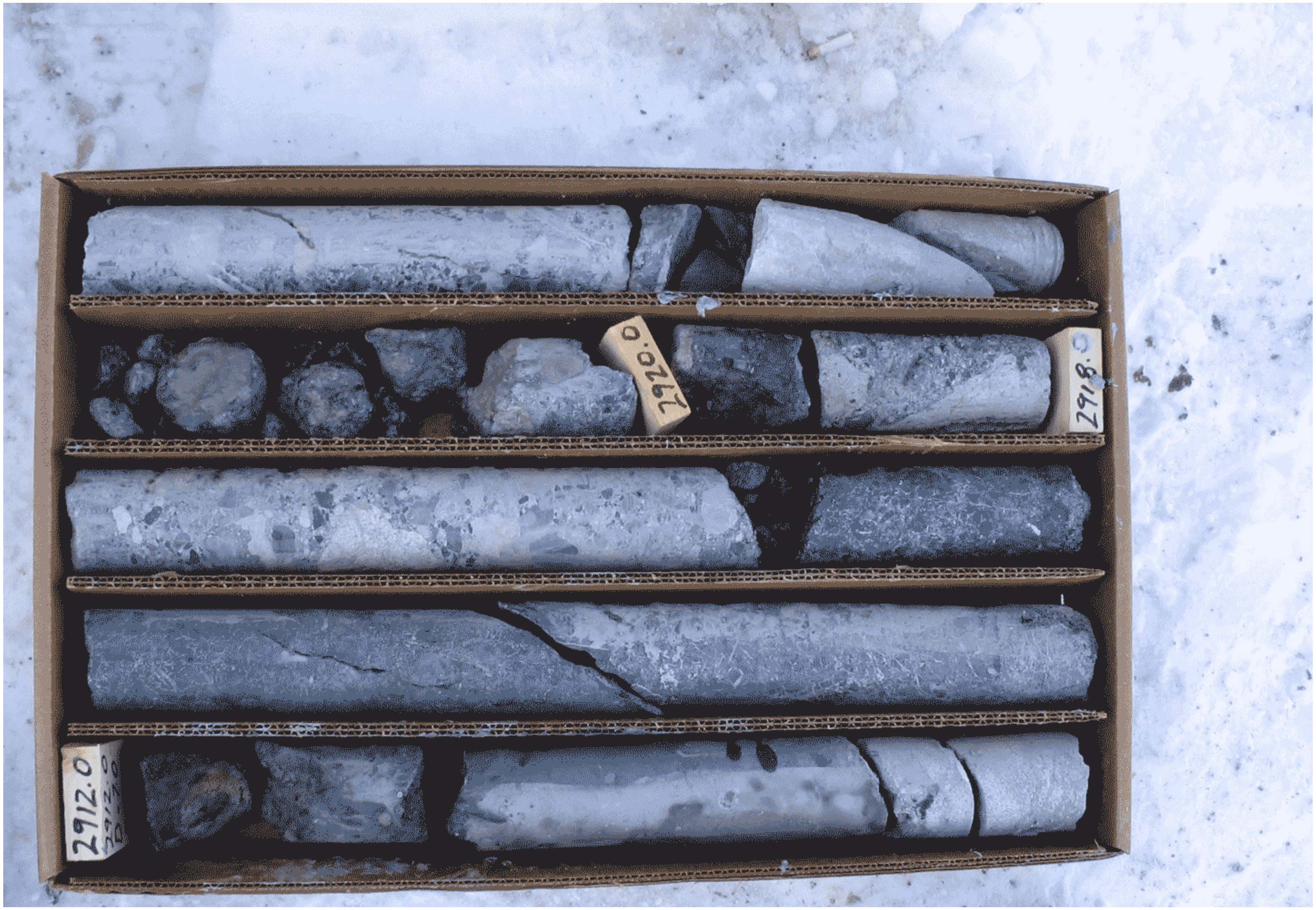
WELL HSS-2

PHOTOS

FRACTURED ZONE IN TERTIARY VOLCANIC ROCKS

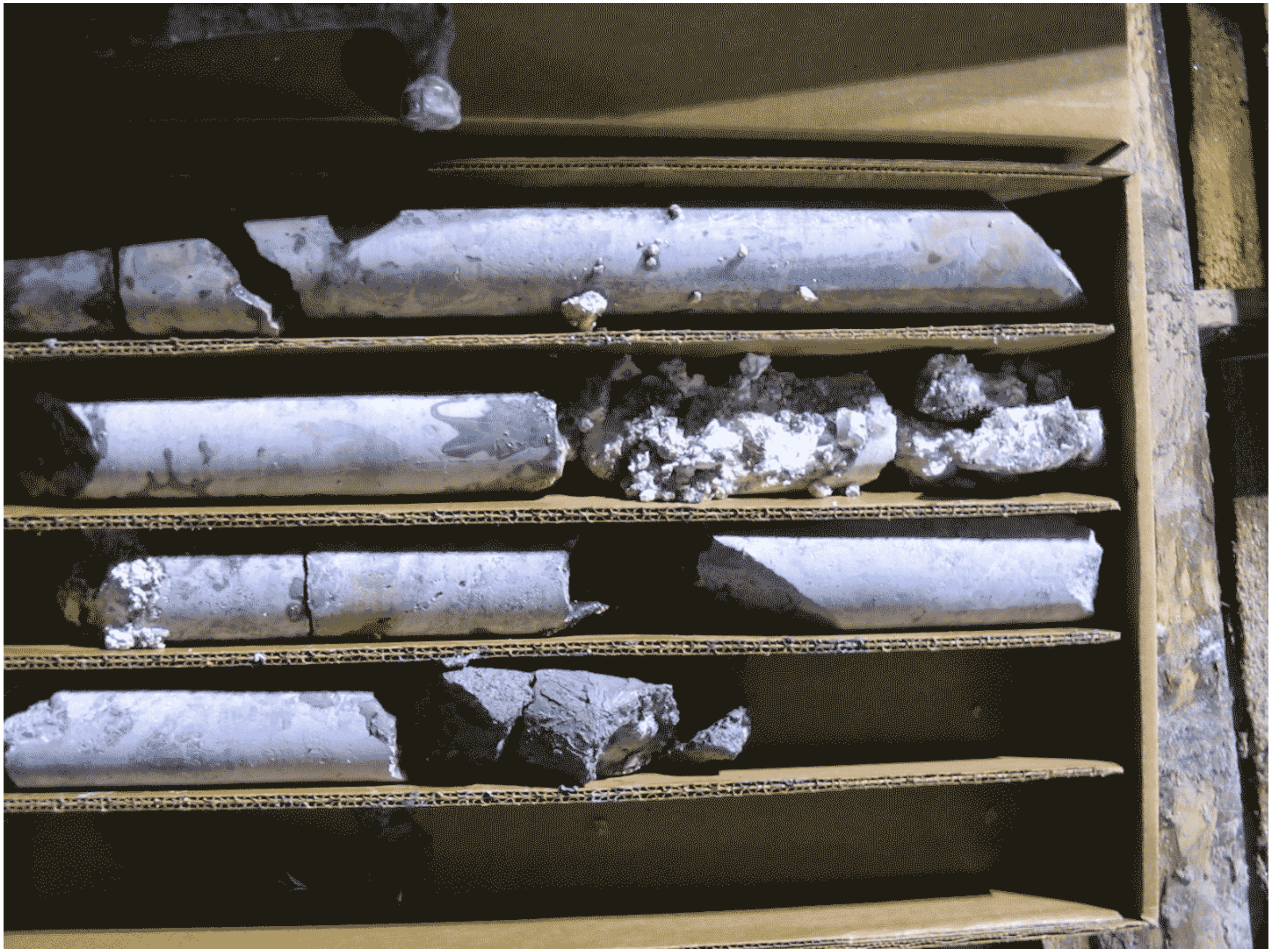
2,912 FEET TO 2,950 FEET

January 2004



Fractures and Rubble @2,915'

Quartz-Filled Fractures @2925'



Fractures @2950' (Total Loss of Circulation Zone).

Core Recovery75%. X-Ray Diffraction Analysis Yielded 30% Smectite Clay in Soft Gouge Zone.

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