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USER COUPLED CONFIRMATION DRILLING PROGRAM
CASE STUDY

CITY OF ALAMOSA, COLORADO
ALAMOSA #1 GEOTHERMAL TEST WELL

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by

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT.....	1
INTRODUCTION.....	2
ALAMOSA AREA GEOTHERMAL SETTING.....	4
Geology.....	4
Structural Setting.....	4
Precambrian Rocks.....	6
Vallejo Formation.....	9
Oligocene (?) Volcaniclastics.....	9
Los Pinos Formation.....	11
Santa Fe Group.....	12
Alamosa Formation.....	13
RESERVOIR EXPLORATORY WELL, ALAMOSA #1.....	13
Site Selection.....	13
Geophysical Data.....	14
Drilling.....	15
Logging.....	17
Well Completion.....	18
Testing.....	21
PROJECT SUMMARY.....	22
CONCLUSIONS.....	22
REFERENCES.....	23
APPENDIX I - Lithologic Log of Alamosa Well.....	25

LIST OF FIGURES

	<u>Page</u>
Figure 1. Index Map.....	3
Figure 2. Rio Grande Rift System in Colorado.....	5
Figure 3. Oil Test Wells and Major Structures in the San Luis Basin.....	7
Figure 4. Alamosa Basin Cross-Section.....	8
Figure 5. Generalized Lithologic Log of Alamosa #1.....	10
Figure 6. Temperature Log of Alamosa #1 Run by the University of Wyoming.....	19

ABSTRACT

A 7118 ft (2170 m) deep geothermal test well was drilled on the south edge of the city of Alamosa, Colorado as part of the Department of Energy's User Coupled Confirmation Drilling Program. The project was selected on the bases of a potential direct heat geothermal resource within the Rio Grande rift graben and resource users in Alamosa. The well site was selected on the hypothesis of a buried horst along which deep thermal fluids might be rising. In addition, there were city wells that were anomalous in temperature and the location was convenient to potential application.

The Alamosa #1 penetrated 2000 ft (610 m) of fine clastic rocks over 4000 ft (1219 m) of volcanoclastic rock resting on Precambrian crystalline rock at a depth of 6370 ft (1942 m). Due to poor hole conditions, geophysical logs were not run. The stabilized bottom hole temperature was 223°F (106°C) with a gradient of 2.6°F/100 ft (47°C/km). Limited testing indicated a very low production capacity.

INTRODUCTION

This report will serve to summarize data acquired from a geothermal drilling project in Alamosa, Colorado. The project is a part of the User Coupled Confirmation Drilling Program (Gray and others, 1980) sponsored by the U.S. Department of Energy. The City of Alamosa and the U.S. Department of Energy were participants in this project through a cooperative agreement dated April 20, 1981.

One exploratory drill hole was completed in the southwest quarter of Section 15, Township 37 north, Range 10 east (Figure 1), in the San Luis Valley, Colorado. The drilling was done from November 11 through December 6, 1981, and finished at a total depth of 7118 ft (2170 m). The primary objective of the drill hole was to encounter, test and produce hot geothermal fluids to be used for process heat in a barley malting operation. Following the primary usage, the fluids were to be used for space heating in buildings of nearby Adams State College.

Many separate agencies and individuals contributed to the project. The Earth Science Laboratory of the University of Utah Research Institute served as advisor to DOE on geotechnical aspects of the project, including during the final re-entry and logging attempts. EG&G, Idaho, served a parallel role by advising on economic and engineering matter. The project was operated for Alamosa by Energy Services, Inc. Valuable geologic contributions were made by Dr. Richard L. Burrough of Adams State College. Drs. James K. Applegate and George V. Keller, of Colorado School of Mines, contributed to an understanding of the available geophysical data.

ALAMOSA AREA GEOTHERMAL SETTING

Geology

Structural Setting

The San Luis Valley (SLV) is a major segment of the Colorado portion of the Rio Grande rift (RGR) with the City of Alamosa located near its center (Figure 2). The remainder of this discussion will refer specifically to the SLV which began rifting about 27 m.y. ago (Chapin, 1979) based on isotope age dating of geologically implicated volcanic rocks. By about 26 m.y. ago the SLV had sagged sufficiently to be a receiving basin for mafic flows, volcanic ash beds and minor alluvial deposits (Chapin, 1979). Tweto (1979) and Chapin (1979) indicate that this regional extension resulted in the reactivation of faults many of which had originated in Precambrian, late Paleozoic or Laramide times. Much of the RGR is represented by simple grabens. The SLV, by contrast, is a major graben within which is a concealed axial horst of Precambrian rocks (Tweto, 1979; Figure 4).

Fault movement in the SLV as recently as 4700 years ago has been documented (Tweto, 1979). Elsewhere in the Colorado portion of the Rio Grande rift, movement along rift faults has occurred within historic time (Tweto et al., 1970).

According to Chapin (1979), further evidence for continual rifting along the RGR is given by the "abundant fault scarps cutting Pleistocene deposits, high heat flow, modern elevation changes, modern magma bodies and geophysical evidence for anomalous crust and upper mantle beneath the rift."

Tweto (1979) states that much of the SLV is located where the late Paleozoic Uncomphagre-San Luis highland was located as a positive feature. Isopach

Figure 2. Rio Grande rift system in Colorado. Neogene fault movements (heavy lines), Neogene sedimentary rocks shaded; Precambrian rocks patterned; Cambrian through Oligocene rocks white (from Tweto, 1979).

and distribution maps of Haun and Kent (1965) give evidence that the SLV was above sea level and subject to erosion during much of geologic time. In the project drill hole, Mid-Tertiary volcanic rocks rest directly on a Precambrian metamorphic sequence with no rocks of intervening age present.

The SLV is filled with a series of intercalated Tertiary volcanic and sedimentary rocks overlain by Quaternary alluvium. Numerous workers have written about the stratigraphy involved. The interested reader is referred to Burroughs (1981) for the most recent detailed discussion of stratigraphy. The discussion in this report will center on lithologies encountered in the project drill hole with minor reference to the stratigraphy of the local area. The lithologic log by the senior author (J.Z.) is given as Appendix I.

Much of what is known of the stratigraphy in the SLV has been learned from interpreting the data from oil tests (Figure 3). These stratigraphic data indicate a structural division of the SLV into a western Monte Vista graben and an eastern Baca graben with an intervening Alamosa horst (Figure 4). The configuration of the horst and grabens is considered in detail in the gravity and magnetic surveys of Mackelprang (1983).

Precambrian Rocks

Biotite gneiss with a trace of garnet forms most of the 700 ft of Precambrian rocks drilled between a depth of 6400 ft and total depth (Figure 5; lithologic log is Appendix I). The upper 200 ft of the crystalline basement rock is granitic with less biotite than the gneiss below. The top 80 ft is hematite-stained, disaggregated granitic grus which probably is a paleoweathering zone.

Above the Precambrian rocks, cuttings were lost for an interval of 250 ft

A-B and C-D section lines, see Figure 4.

For well names see Figure 4.

Faults - bar and ball on downthrown side.

Approximate limit of blue clay.

Outcrop of Fish Canyon and Carpenter Ridge ash-flow tuffs.

Outcrop of Los Pinos Formation.

Pre-Miocene Subcrop Line with direction of dip.

Figure 3. Oil test wells and major structures in the San Luis basin (from Burroughs, 1981).

above which basalt and other volcanic lithologies were drilled (Figure 5). The zone of no returns may be volcanoclastics or an unconsolidated clastic sedimentary unit overlying the basement rocks.

The oldest mapped sediments resting on the Precambrian in the Alamosa portion of the SLV are nonvolcanic red arkose and mudstone which Tweto (1979) correlates with the Echo Park alluvium in the vicinity of Salida, Colorado.

Vallejo Formation

The basal sedimentary formation throughout the eastern and southeastern parts of the SLV is the Vallejo Formation of probable Oligocene age or older. The presumed minimum age is based on a K-Ar date of 34.4 ± 1.4 m.y. obtained from cuttings of what is believed to be a sill near the base of the Vallejo in the Mapco-Amoco well (Burroughs, 1981). According to Upson (1941), the red-bed Vallejo is composed of fine-grained, unconsolidated but compact silt and clay with thin lenses of cemented sand and fine gravel, and thick layers of coarse gravel containing rounded cobbles". The coarser clastic units were deposited by permanent streams flowing across flood-plains on which were deposited the clay and silt components of the formation. Since the Vallejo is the first deposited unit following a long period of erosion, its distribution and geometry contributes greatly to the understanding of the early tectonic history of the SLV. The thinning of the Vallejo (or its apparent absence in the case of this project) over the Alamosa horst and its angular relationship with the Santa Fe Group to the east gives evidence that the Alamosa horst continued to be an active positive structural element during and following the deposition of the Vallejo.

Oligocene (?) Volcanoclastics

In the Alamosa #1 hole, these volcanoclastics overlie a regolith on the

Figure 5. Generalized lithologic log of Alamosa #1.

Precambrian metamorphic basement. The Oligocene (?) volcaniclastics are interpreted to be flows and erosional products derived largely from volcanic terrain of the San Juan Mountains and to a limited extent from the San Luis Hills (Burroughs, 1981). This unit is composed of volcaniclastic sedimentary rocks interbedded with lava flows, flow breccias and tuffs. West of the Alamosa horst, the upper contact is placed at the base of the Fish Canyon-Carpenter Ridge (FCCR) tuffs. The FCCR tuffs are not reported to occur on the Alamosa horst. An interval of crystal, lithic tuff and flows in the Alamosa #1 well is here interpreted to be FCCR tuffs. With only contaminated cuttings from one drill hole to use, it would be difficult to say positively whether this tuff is an eastern tongue of the FCCR or not. In favor of that hypotheses, however, are: 1) the occurrence of its outcrops along the Rio Grande drainage by Del Norte; 2) the occurrence of the problematic lithology on the Alamosa horst at a position where geophysical evidence (Mackelprang, 1983) indicates a narrow, low density feature across the horst that is interpreted to be a down-dropped, east-west graben filled with low-density material such as alluvium or unconsolidated tuff; and 3) tying 1 and 2 together is the commonly observed fact that major drainage ways of the Tertiary have often been long-lived and coincide with major present drainages. Thus, it is theorized that the Fish Canyon-Carpenter Ridge tuff crops out along the Rio Grande drainage and beneath the Rio Grande at Alamosa today because it was deposited in a paleo-valley of the Rio Grande at Del Norte and at Alamosa.

Los Pinos Formation

The Los Pinos Formation was deposited in an environment of coalescing alluvial fans shed from the San Juan Mountains into the developing San Luis Basin (Lipman, 1975). The Los Pinos can best be characterized as being highly heterogenous. It contains sandy gravel, siltstone and occasional relatively

thin beds of cobble and boulder conglomerate. All units carry varying amounts of tuffaceous material. Having accumulated adjacent to the San Juan volcanic center, the Los Pinos contains lava flows, volcanic breccias, and tuffs interbedded with alluvial clastic deposits. The composition of the conglomerate clasts is similar to the composition of the contemporaneous volcanics, suggesting that the clastics were locally derived. Burroughs (1981) indicates that the Los Pinos age is from late Oligocene to Pliocene (dated volcanic units ranged from 28 m.y. to 5 m.y.).

Santa Fe Group

The Santa Fe Group, in the project area, is represented by a sequence dominated by pinkish-orange clayey siltstone, and lesser amounts of coarser clastics of sand and grit size. In contrast to the underlying Los Pinos, the Santa Fe contains clasts of plutonic and metamorphic rock fragments. Those fragments reflect the emergence of the Sangre de Cristo Mountains as a source area.

As with other stratigraphic units in the SLV, the thickness variations in Santa Fe Group provide clues about the tectonic history of the SLV during Santa Fe time. The Mapco-Amoco well (Fig. 4) penetrated 2800 ft (853 m) of Santa Fe sediments. In the Alamosa #1 well only approximately 1000 ft (305 m) were encountered (possible thickness range is 920 ft to 1240 ft due to missing sample intervals at the upper and lower contacts of the formation). One interpretation of this dramatic thickness difference is the relative uplift of the Alamosa horst or the sagging of the Baca graben during deposition of the Santa Fe. An alternative interpretation, given by Burroughs (1981), is that a thick Santa Fe deposit in the Baca graben is equivalent to a thick section of Los Pinos on the horst with a thin interval of Santa Fe present over the Los

Pinos at the close of Los Pinos/Santa Fe time. In view of the paucity of data points, either interpretation is acceptable. However, based on the continuous sagging of the Baca graben through pre-Santa Fe time as demonstrated by geophysical and subsurface geologic data, it seems more likely that the thicker Santa Fe found there reflects further subsidence in that part of the SLV.

Alamosa Formation

The Alamosa Formation is a sequence of pale olive green claystone, within which are interfingered fine-grained, loose sands. In the project well, the Alamosa sediments penetrated were approximately 700 ft (213 m) thick. By contrast, 2050 ft (625 m) were encountered in the Mapco-Amoco well. Thickness variations of the Alamosa thus support the theory of a subsiding Baca graben and the continuing positive nature of the Alamosa horst.

The reduced fine-grained sediments represent a relatively quiet depositional environment. Common ostracods and occasional gastropods in the drill cuttings indicate that much of the Alamosa Formation was of lacustrine origin.

Over much of the SLV, Quaternary alluvium constitutes the surface unit present. At the project site, 95 ft of alluvial sand and gravel was drilled. It was very heterogeneous but was dominated by volcanic lithologies.

RESERVOIR EXPLORATORY WELL, ALAMOSA #1

Site Selection

The site chosen for the project well was based on a compilation of available geological and geophysical data (Energy Services, Inc., 1981). The site selection was based on the location of the industrial park property available for the well, and the economic constraints of not piping the geothermal fluid more than 3 miles to the industrial park.

The hypothesized geothermal target model was based on the interpretation of the geologic data discussed above and geophysical data (Mackelprang, 1983). The Rio Grande rift is thought to have geothermal potential in general due to high heat flow (Burroughs, 1981; Figure 6) and recent volcanism along the rift in New Mexico. The geothermal potential of the area has been discussed by Burroughs (1981) and Zacharakis and others (1983). Several Alamosa city wells are warm with temperatures up to 98°F (Energy Services, Inc., 1981). There are also several hot springs and other thermal wells in the valley (Coe, 1980). At conception of the project, it was postulated that the thermal water flows up along faults bounding the Alamosa horst.

Geophysical Data

Geophysical surveys in the San Luis Valley have been done to obtain an understanding of the basement structure. Several energy companies had conducted scattered seismic and gravity lines in the course of investigating limited specific areas (Davis, 1979). Those data are for the most part not available to the public. At the time of this project, the Colorado School of Mines had partially completed a gravity survey in the Alamosa area. Also, Colorado School of Mines summer students, at the request of the City of Alamosa, ran a seven-mile long reflection seismic line to the northwest of Alamosa along highway 285. At the same time, they obtained a few extra gravity readings along highway 180 east of Alamosa. The interpretation of those new data is given by Energy Services, Inc. (1981, p. 23-29). The major element highlighted by the reflection seismic data is the normal fault separating the Monte Vista graben and the Alamosa horst.

Previous workers had provided aeromagnetic (Zietz and Kirby, 1972) and gravity (Behrendt and Bajwa, 1974) maps of Colorado based on wide-spaced data

and Davis (1979) prepared a regional gravity study of the San Luis Valley. None of these earlier studies had a high density of data points in the Alamosa area.

Based on the need to have a better understanding of the subsurface setting to aid in siting the project well, the Idaho Operations Office of the U. S. Department of Energy requested UURI to perform a detailed gravity survey of the Alamosa area. That survey, which tied into Colorado School of Mines data, was completed and the resulting interpretations were given to the project consultant. The study contributed a Bouguer gravity map and a three-dimensional gravity model (Mackelprang, 1983). The study confirmed and refined the inferred local structurally-low areas crossing the Alamosa horst. Those low areas were interpreted as paleo-valley and/or small, local down-dropped fault blocks. The recommendation based on Mackelprang's (1983) work was that the drill site should be sited toward the edge of the structural low in a location where it could take advantage of:

1. space sediments filling the paleo-valley or graben which would possibly be a more favorable potential reservoir than the adjacent uplifted volcanic blocks; and,
2. proximity to graben-bounding faults along which geothermal fluids were theorized to be migrating.

Drilling

This brief account is derived from a detailed discussion of the drilling operations given by Phetteplace and Kunze (1983) which contains a daily log of drilling activities as Appendix C.

In advance of moving-in the drilling rig, a 300 ft square location was prepared and rig anchors installed. For surface hole protection, 14 ft of 36

in. conduit and 52 ft of 20 in. conductor pipe were cemented in place (these depths are from ground level; all depths mentioned below are from the Kelly Bushing which was 16 ft above ground level).

Following competitive bidding, the CRC Colorado Well Company was chosen as the project drilling contractor. The rig and auxillary equipment moved-in on November 2, 1981. The drill bid specifications stipulated a minimum derrick capacity of 300,000 pounds; the rig supplied by CRC had a rating of 375,000 pounds.

Drilling commenced on November 8, 1981, with the 17 1/2 in. diameter surface hole which was drilled to 2006 ft (611 m) depth. To maintain control of a known artesian aquifer at approximately 1600 ft depth the drilling fluid was kept at ≥ 8.9 lb./gal.

The 13 3/8 in. surface casing was to be run to approximately 2006 ft. However, it became inextricably stuck at 1194 ft (364 m) by swelling claystone and was cemented in place at that depth. Figure 8 in Phetteplace and Kunze (1983) shows the casing of the final well profile. A blowout preventer, hydril and other well head equipment were installed and pressure tested to 1000 psig after the cement had set-up.

Below the surface casing point of 1194 ft a 12 1/4 in. hole was drilled to 4232 ft depth. Using a Brown Oil Tool 9 5/8 in. x 12 1/4 in. liner hanger, the 9 5/8 in. intermediate casing string was set at 4182 ft (1290 m) depth. The liner hanger was set at 1045 ft (319 m) depth providing an overlap of 149 ft (45 m). Following cementing, the 9 5/8 in. casing was successfully pressure tested to 1900 psig. A normal drilling fluid of bentonite gel was used during the intermediate interval of the hole.

From 4182 ft (1225 m) to total depth of 7118 ft (2170 m) an 8 3/4 in. hole was drilled using water as the drilling fluid. Exceptions to the water drilling fluid were a five sack sweep of mica lost circulation material at 5652 ft (1723 m) and a sweep of bentonite gel at 6443 ft (1964 m).

Logging

Logging efforts on this well included lithologic and geophysical methods. In addition, a typical oil field mud log was maintained during the drilling operations.

As originally planned, the project called for the well to be logged by one of the major oil field logging companies. The logs were to include acoustic velocity, natural gamma ray, neutron, compensated density, resistivity, self-potential, temperature and caliper. As TD neared and project funds dwindled, the project consultants decided that "it was more beneficial to drill for the resource than to expend funds for logging" (Phetteplace and Kunze, 1983). Consequently, the well was not logged at the conclusion of drilling when it would normally have been done.

During well clean-out and testing efforts six months later, logging attempts met with failure. Following conditioning of the drill hole and repeated drilling-out of a bridged interval (5232 ft (1595 m) to 6130 ft (1868 m) depth from ground level), Schlumberger logging tools were twice stopped by bridged drill hole cavings while being run downhole and before logging began. The accessible open hole between 4812 ft (1467 m) and the bridge at 5232 ft was not logged. Thus, other than incomplete temperature logs, there were no geophysical borehole logs obtained from the Alamosa #1 well.

Temperature logs were run periodically during drilling and near the end

of well completion operations 6 months later by Energy Services with equipment of their own manufacture. Unfortunately that equipment was limited by cable length to recording at a maximum depth of 6294 ft (1918 m) where a temperature of 190°F (87.8°C) was recorded. The only other temperature data obtained from the well, at that time, was from a maximum-reading thermometer which was part of the Schlumberger logging tool. That temperature was 152°F (66.7°C) at 5175 ft (1577 m).

The University of Wyoming ran a thermal log of the drill hole (Figure 6) on Sept. 1, 1982 after the well should have equilibrated to the equivalent of pre-drilling temperature. That log indicated a maximum of 223°F (106°C) at 6340 ft (1932 m) which was at the total depth the log was run. The gradient of the uniform temperature profile between 1500 ft (457 m) and 6340 ft (1932 m) is 2.6°F/100' (47.4°C/km).

Lithologic logging of the drill cuttings was done at the completion of drilling by this author (Figure 5; detailed log included as Appendix I) and by Dick Pearl formerly of the Colorado Geological Survey and Roger Stoker of Energy Services, Inc. The drill cuttings were examined by binocular microscope. From 60 ft to 6630 ft (2021 m) drill cuttings were collected at 30 ft intervals: from 6630 ft to 7118 ft (2170 m) the collection interval was reduced to 15 ft. Petrographic thin-sections (noted on lithologic log in Appendix I) were prepared and analyzed to aid in describing and/or identifying problem lithologies or mineralogy.

Well Completion

Since there was a decision to drill ahead with remaining funds rather than collect well logs, the project well was not adequately logged or tested when first drilled. Therefore, the City of Alamosa and DOE deemed it

Figure 6. Temperature log of Alamosa #1 run by the University of Wyoming.

appropriate to allocate additional funds to re-enter the well for the purpose of logging and testing. To that end, a Remedial Test Plan and Cost Estimate were presented to DOE by the City of Alamosa. That plan, approved on April 12, 1982, resulted in an ammendment to the original Cooperative Agreement on the project. The testing part of the remedial work included plans for air lifting the well to clean out bridged portions of the hole and to develop whatever geothermal reservoir there might be. The results of the air-lift testing were to aid in designing a later pump-test procedure.

CRC Colorado Well Service won the bid for the workover operations. The rig was moved in May 18, 1982 and work began May 19th. Redrilling and washing through a severely bridged interval continued for six days using a single crew for 12 hours each day. The progress made each day was lost during the intervening nights. On May 25, 24-hour operations were begun using two crews. With the improved progress made by using two crews, it was felt that the hole conditions were as good as they ever would be, so geophysical logging was attempted. Logging efforts by Schlumberger over two days were thwarted by continued bridging in the well bore, as discussed above.

To gain any additional information possible on the well, it was believed necessary to control the bridging area through the emplacement of a 7 in. liner, which required the casing plan had to be modified. A Brown Oil Tool liner hanger was obtained which would tolerate the right-hand rotation needed to drill the casing into place. Additionally, 200 ft of 7 in. casing was bought to replace the 200 ft of Johnson Well Screen which was not sufficiently strong to be drilled through the bridged intervals. Figure 8 in Phetteplace and Kunze (1983) illustrates the final well profile, and Figure 11 in Phetteplace and Kunze (1983) details the solid versus slotted portions of the

production liner. Following emplacement of the production liner, limited air-lift testing was performed.

Testing

The following is taken from Phettesplace and Kunze, 1983:

"5.3 Fracture Test

On December 6, 1981, during the production drilling, a fracture test was done to try to stimulate flow in the well. The formation accepted approximately 18,000 gallons of water in 70 minutes and returned most of it to the surface. No flow was stimulated with this test."

"5.4 Air Lifting

On December, 1981, an air lift at 562 ft (171 m) was done in conjunction with the fracture test discussed in Section 5.3. Another air lift was done on December 21, 1981. Neither air lift had any significant effect on generating flow or developing the geothermal resource.

The Remedial Work Phase II

Two large air compressors supplied by Western Air Drilling were on location during the Remedial Work Phase II. An air lift was done prior to the installation of the 7-inch liner in an effort to clear and flush out the bridged area. On June 6, 1982, some preliminary hole cleaning and flushing was done prior to starting a controlled air lift. An air lift was done on June 6 and 7, 1982, to evaluate the productivity of the well.

During the air lift of June 6, 1982, the well was air lifted from the 2,000 ft level for nearly 12 hours. The method used was to blow the well dry and then allow it to recover for 20 to 30 minutes. Usually the head was removed in 10 to 15 minutes. However, the last air lift was for a 6 hour period, during which, the flow continued and fluctuated from 100 gpm to 200 gpm. The flow then continued to decrease for another hour and the test was terminated. The specific production index was then estimated to be approximately 50 ft of drawdown per gallon per minute of flow, i.e., extremely poor production.

The static water level was estimated at 250 ft below ground level after each time the well was blown dry.

It was hoped that the air lift would stimulate the well and develop some soft of flow for evaluation purposes. Since this did not occur, no pertinent information was attained."

PROJECT SUMMARY

The Alamosa City project had many of the components of a good project. The city, Adams State College and the proposed barley malting operation were potential users and the Rio Grande rift and thermal city wells suggested a possible resource. Although deep oil test wells in the basin suggested only 240°F (116°C) at 8000 ft (Burroughs, 1983), it was thought that upflow within the Precambrian rocks of the Alamosa horst or along the bounding faults might bring thermal water of usable temperature to shallower depths than in the deeper parts of the basin.

During drilling of the well, wide sample spacing, conscious decisions by the drilling consultants and poor hole conditions resulted in little usable data and no geophysical logs from the well. Attempts at airlift of the well suggested that the formations are very tight. Although the bottom hole temperature is higher than for comparable depths in oil test wells in the basin, the low temperature and low flow rate combined to make the project a failure.

CONCLUSIONS

A geothermal resource of sufficient temperature and flow for direct heat application does not appear to be present in the Alamosa, Colorado area.

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APPENDIX I
DETAILED LITHOLOGIC LOG OF ALAMOSA #1

EARTH SCIENCE LABORATORY

LITHOLOGIC STRIP LOG

DRILL HOLE ENERGY SERVICES ALAMOSA #1
 STATE CO COUNTY ALAMOSA PROJECT CITY OF ALAMOSA
 SEC. 15 TWP. 37 N RGE. 10 E ; LOC. 3900' FNL, 1060' FWL
 TD 7120 BOTTOM HOLE FORMATION PE SURFACE FORMATION Qal
 LOGGED BY Jon Zeisloft DATE 3/82 SAMPLE INTERVAL(S) 30' TO 6630'/15' TO T.D.
 LITHOLOGIC LOG CORRECTED FOR LAG YES ☐ NO ☒
 SPUD DATE 11/8/81 COMPLETION DATE 12/6/81
 DEPTH DATUM KB ☐ DF ☐ GR ☒ ELEV. 7535'
 DRILLING FLUID(S) MUD TO 4232 - WATER TO T.D.
 REMARKS SEE NOTES FOLLOWING T.D.

DRILL
 SITE IN
 SECTION

DEPTH	ALTERATION <small>1. WEAK 2. MOD. 3. STRONG</small>							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME MIN. / <u>1</u> FT. SCALE 1 2 3 4 5 6 7						
	123	123	123	123	123	123	123									
									Alluvium, Sdy Grvl., mixed liths. ^{of} welded tuff & rhyolite flows with lesser plutonic rocks - Tr. Jasper.							
100									Stat. yel. gy. - gn. gy., com. ostracods, occ. gastropod; Tr. wh. Purice and Tr. micas. - Lacustrine.							
200									AA - inc. m. gr. Qz Sd and plutonic + vol. Rk frags.							
300									AA - Sd largely gone.							
400									Stat. yel. gy., no ostracods.							
									Stat. yel. gy., Tr. ostracods; Tr. Sd (of Qz & VRF's)							
									Stat. yel. gy., Tr. → com. ostracods; occ. gastropod frag.							
500																
600									AA. one pc. fossil (bird or rodent) bone - Tr. pyr. as vfg agg's inc. plutonic and vol. clasts, crs Sd → grit size.							

DEPTH	ALTERATION							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME MIN./1 FT. SCALE
	1. WEAK 2. MOD. 3. STRONG									
	Sulfide									
	123	123	123	123	123	123	123			
700									Congl, sdy, brn. gy - lt. olive gy, sub ang-sub rd, VRF's & ang to sub ang Qz; and clasts of ss, lt. olive gy, vfg. AA: VRF's of intermed. flows and tuffs; sl. calc.	
800									Top SANTA FE GROUP in this interval of no samples.	
900									Stst with minor vfg ss, grayish orange pink, calc; Tr f-mgr Qz sd, sub ang-sub rd; occ ostracods; non calc. to sl. calc., carrying Tr plutonic & VRF's. Lacustrine.	
1000										
1100									v. crs. sd-grit, olive gy, in f.g. sd matrix, med. sort.; dom clasts are vol flows and welded tuff.	
1200									Tr pyr. as v.f.g. aggs.	
1300									Stst, sdy, grayish orange pink; Tr m-f.g. Qz, sub ang-sub rd. decreasing grit from above; sl. calc.; occ plant cast.	
1400									generally as above, becoming silty f.g. ss.	
1500										

 13 3/8"
 csg at
 1007'

[illegible]

DEPTH	ALTERATION						GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME MIN. / 1 FT. SCALE Logarithmic
	1. WEAK 2. MOD. 3. STRONG								
	FeOx	Silica							
123	123	123	123	123	123	123			5 10 15 20 25
2500							Pumice, wh - occ. pale pink pc. - v. porous glassy, perlitic base of pumice flow, beginning at 2450 Siliceous tuff, pale brn. - mod. yellowish brn., angular. Pumice, wh. AA.		
2600							Pumice-rich, non-compacted, crystal, lithic ash flow tuff, grayish orange pink; mod. porosity; small to perlitic clasts.		
2700							N.S. Crystal-rich pumice & tuff, v. pale orange; mod. porosity. N.S. AA, inc. vol. clasts & decreasing pumice; Tr Qz sd.		N.B.#3 CWTN-12 1/2"
2800							inc. Qz sd, clear, angular, f-m.gr. Lithic sd, of various vol. liths; abnd terminated and doubly terminated Qz xls Congl, sdy, (tuff, porph. flows and granite clasts) Tuff, non-welded, v. lt. gy, sl. xl rich, mod. por, sl. silica coatings in microvugs; Tr. vol. peb's as cavings(?)		
2900									
3000							AA - virtually no porosity.		
3100							N.S. Tuff, AA N.S.		
3200							Gravel, misc. brn's & gy's, various flows & welded tuffs; minor Qz sd matrix, stained weakly with limonite (gravel not stained).		
3300							N.S. AA		

DEPTH	ALTERATION						GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME				
	1. WEAK 2. MOD. 3. STRONG								MIN./	FT.			
	Secondary Clay	Fe Ox			Silica	Zeolites							
	123	123	123	123	123	123			5	10	15	20	25
							AA						
							N.S.						
3400							AA plus 1/3 gy-pink non-welded tuff, mod-por. (poss. cavings from tuff above); Tr silica in microvugs and possible zeolites.						
3500													
							Sd, lt olive-gy, v.fg, silty & clayey.						
							Grit & grav, mixed br & gy, flows & welded tuff; occ. qz, sd, gr; Tr celadonite.						
3600							T.S.* Dacite flow, gy-red to dk. reddish brn, largely devitrified.						
							AA, becoming m. gy to m. brownish gy.						
3700													
							AA - much finer cuttings; Qz sd, crs gr, comm; w/ sporadic celadonite.						
3800													
							Peb's + peb. chips, misc. vol. + tuff lith's (gravel zone or cavings?)						
							AA w/ free grs of hbck + pyrx.						
3900													
4000							mixed vol. lith's - vol. congl. or breccia?						
4100							Basalt flows, olive black, v.fg, olivine and pyroxene phen's in part glassy.						
							Andesite, m-dk. gy, v.fg, prominent pyroxene; probable flows and flow breccia.						
4200													

N.B. #4 - DGT - 12 1/4'

N.B. #5 - DGT - 12 1/4'

N.B. #6 - J-44 - 12 1/4' rerun

DEPTH	ALTERATION							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME				
	1. WEAK 2. MOD. 3. STRONG									MIN./	FT.			
	123	Standard Clay	123	123	123	123	123			SCALE Logarithmic				
	123									5	10	15	20	25
4232'														
					</									

N.B. #7
SAFE 8 3/4'

Bit #7 Rotor

DEPTH	ALTERATION								GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME				
	1. WEAK 2. MOD. 3. STRONG										MIN./	FT.			
	Secondary Clay	FeOx	Silica	Zeolites							SCALE Logarithmic	5	10	15	20
	123	123	123	123	123	123	123	123							
5200										AA					
5300															
5400										T.S.* Xl tuff, pinkish gy, non-welded, not devitrified - acc silicified lithic clast; Tr az, bio & other ferro-mag minerals.					
5500										AA w/ xenolith of med-basic vol-flow having mod.vugular per partially infilled w/ v.f. Xls & botrioidal zeolites					
										T.S.* Lithic tuff, v.pale orange, rounded Qz & felds clasts, glass coated.					
										AA w/ com. irreg red-orange flecks of alt'd min's					
5600										T.S.*					
										AA w/ 50% varied, aphanitic vol. rocks.					
5700										Andsite, grayish red purple, com. wh.chalcedony veins, vug & breccia fillings probable to dike.					
										Andsite, olive gy, Tr celadonite					
5800															
										AA w/strong increase in "off white" lithic tuff as at 5500'					
5900										AA w/ v.com. pyroxene frags, & Tr rutile euhedras and Tr magnetite tetrahedrons.					
										Andsite, dk-gn-gy, com pyroxene; TR Celadonite.					
6000										Lithic Tuff, v.pale orange, glass coated Qz & fids clasts.					

DEPTH	ALTERATION							GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME				
	1. WEAK 2. MOD. 3. STRONG									MIN. / 1 FT.				
			FeOx				Chlorite			SCALE Logarithmic				
	123	123	123	123	123	123	123			5	10	15	20	25
								T.S.X	Basalt, olive gn.					
6100									very mixed sample - diverse vol. liths w/ abnd lithic tuff; probably much cavings					
6200								N.S.						
6300														
6400									granite debris angular Az, ortho, plag, musc w/ lesser % mod. hem stn. - suggests weathered granite on top of bsmt.					form mag mins. no. trans'n.
									AA w/ inc. bio., here to T.D.					
									Granite, sharp, ang., chips					
6500									inc. multi-mineral grains $\Rightarrow$ drilled granite. Especially strong hem. stn.					N.B. #9 M89F 8 3/4"
6600									AAA w/ Tr pink garnets.					
6700									GRANITE / GRANITE GNEISS. inc. bio content, to 20%; bio partially bent suggesting meta. rock. 1 ps. pyr. in granite rock frag. badly contaminated Spl. - ran deviation survey @ 6710'.					N.B. #10 M89F 8 3/4"
6800								N.S.	mod. % bio.					
6900									5% bio.					

DEPTH	ALTERATION						GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	DRILLING TIME MIN. / <u>1</u> FT. SCALE Logarithmic
	1. WEAK 2. MOD. 3. STRONG								
	123	123	FeOx	123	123	123			
7000								AA 10% bio. AA 20% bio. - Probably represents Gneiss AA bio inc. to 25-30%	
								20% bio. Decrease in bio to 10% Increasing bio to T.D.	
7100								40% bio	
									DRILL T.D. 7120'
									5 10 15 20 25
								FORMATION TOPS:	
								Gal 0'	
								Alamosa Fm. 90'	
								Santa Fe Gp. 785'-840' (in missing spl. interval)	
								Los Pinos Fm. 2050'	
								Oligocene (?) Volcaniclastics 5310'	
								Weathered Precambrian 6370'	
								Precambrian 6450'	
								TS * INDICATES THIN SECTION	