GL02182

GEOTHERMAL RESERVOIR ASSESSMENT
CASE STUDY
NORTHERN BASIN AND RANGE PROVINCE
STILLWATER PROSPECT
CHURCHILL COUNTY, NEVADA

FINAL REPORT
FOR THE PERIOD
APRIL 1979 - JULY 1981

D.L. ASH, R.F. DONDANVILLE, AND M.S. GULATI

AUGUST, 1981

WORK PERFORMED UNDER CONTRACT
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UNION OIL COMPANY OF CALIFORNIA
GEOTHERMAL DIVISION
UNION OIL CENTER
461 S. BOYLSTON STREET
LOS ANGELES, CALIFORNIA 90017

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ABSTRACT

During 1979 and 1981 Union Oil Company of California drilled two exploratory geothermal wells in the Stillwater geothermal prospect area in northwestern Nevada to obtain new subsurface data for inclusion in the U. S. Department of Energy's geothermal reservoir assessment program. Existing data from prior investigations, which included the drilling of four earlier deep temperature gradient wells in the Stillwater area, was also provided.

The two wells were drilled to total depths of 6946' and 10,014' with no significant drilling problems. A maximum reservoir temperature of 353°F was measured at 9950'. The most productive well flow tested at a rate of 152,000 lbs/hr with a wellhead temperature of 252°F and pressure of 20 psig. Based upon current economics, the Stillwater geothermal prospect is considered to be subcommercial for the generation of electrical power.

This report is a synopsis of the exploratory drilling activities and results, and it contains summary drilling, geologic, and reservoir information from two exploratory geothermal wells. Detailed information and data for each of the wells is available through the University of Utah Research Institute Earth Science Laboratory (UURI/ESL), Salt Lake City, Utah.

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U.S. DEPARTMENT OF ENERGY
DIVISION OF ENERGY TECHNOLOGY
NEVADA OPERATIONS OFFICE
UNDER CONTRACT DE-AC08-79 ET-27012

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INTRODUCTION

The Stillwater Prospect Final Report has been prepared to summarize results from two exploratory geothermal wells drilled on the prospect, DeBraga #2 and Richard Weishaupt #1. The general location of the Stillwater Prospect area is shown in Figure 1. Specific well locations are shown in Figure 2.

Prior to drilling the two geothermal exploratory wells described in this report, existing data was delivered which included:

1. Dipole-dipole resistivity survey - four lines covering about 20 miles.

2. Telluric survey - four lines covering about 23 miles.

3. Gravity measurements - 48 stations observed resulting in a Bouguer gravity map and a number of computed depth estimates of Valley fill.

4. Temperature data from 16 temperature gradient holes with an average depth of about 275 feet each.

5. Complete drilling history including all subsurface data such as lithological, temperature, wireline, and penetration logs from four existing deep temperature gradient wells, Weishaupt #1 and #2, DeBraga #1 and Wisnefski #1. Total depths of these wells are 3450', 5532', 2672', and 3637' respectively.

All depths are measured from the drilling rig kelly bushing datum unless otherwise specified.

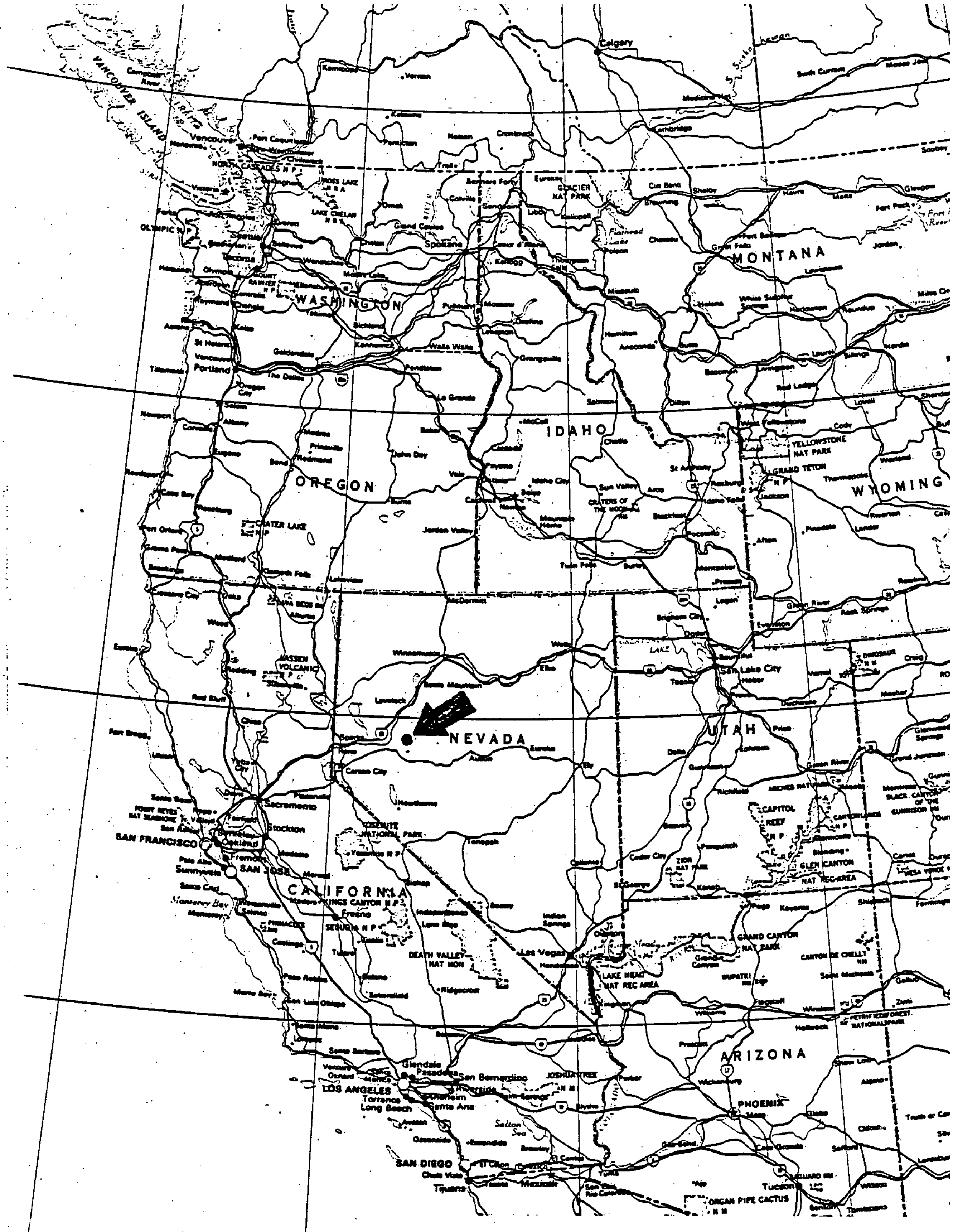


FIGURE 1
MAP SHOWING LOCATION OF
STILLWATER PROSPECT AREA
CHURCHILL COUNTY, NEVADA

(INDICATED BY ➡)

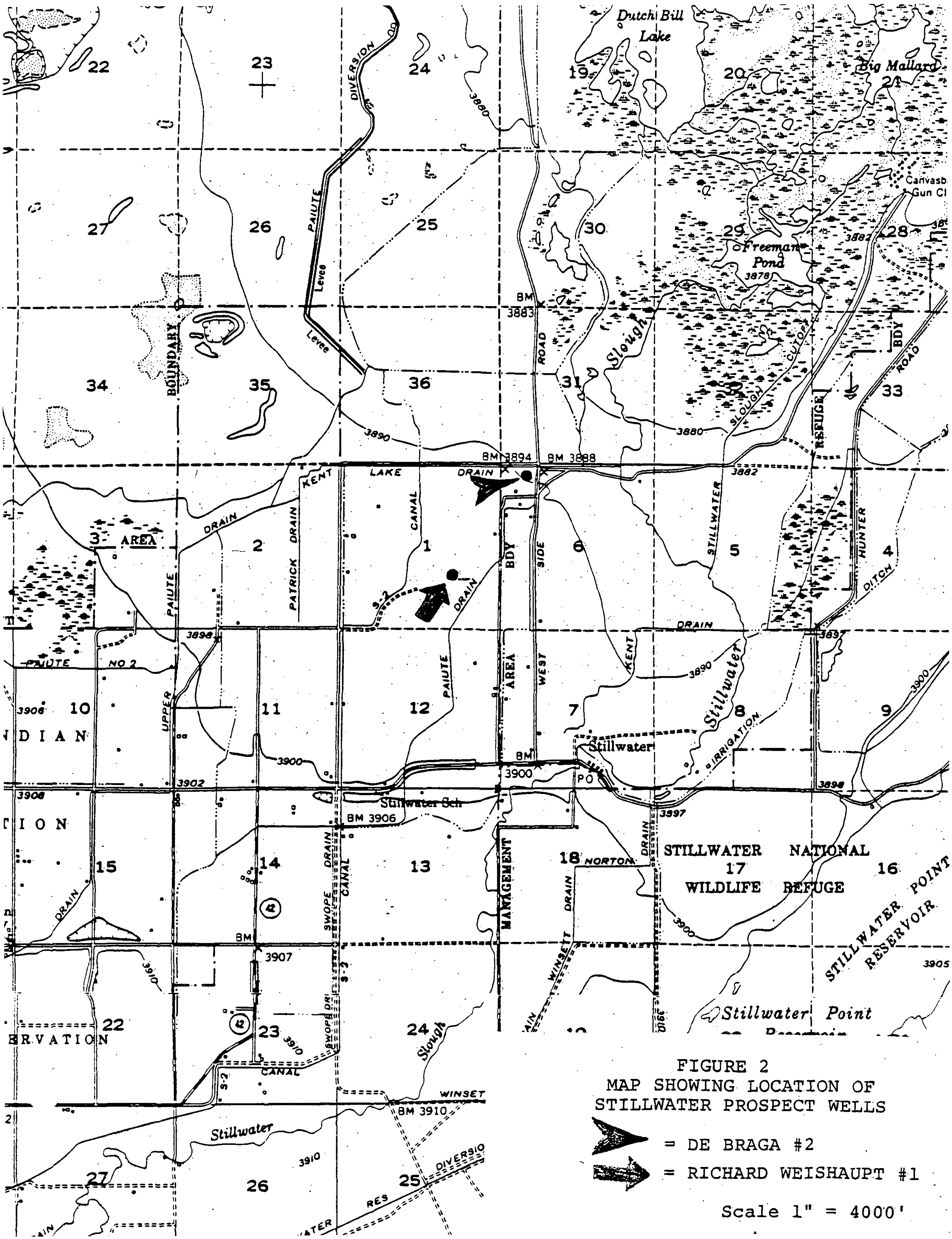


FIGURE 2
MAP SHOWING LOCATION OF
STILLWATER PROSPECT WELLS

= DE BRAGA #2

= RICHARD WEISHAUPT #1

Scale 1" = 4000'

DISCUSSION OF DRILLING OPERATIONS

EXPLORATORY WELLS - STILLWATER PROSPECT

CHURCHILL COUNTY, NEVADA

Each of the Stillwater prospect geothermal exploratory wells was drilled and completed with relatively few problems. Thirty-two days and $568,000 were required to complete DeBraga #2 at 6946'. Forty-six days and $1,230,000 were required to complete Richard Weishaupt #1 at 10,014'.

Casing Program

DeBraga #2 was drilled to evaluate the reservoir to a total depth of 6946'. The casing program was implemented with 20" conductor at 94', 13-3/8" surface casing at 310', 9-5/8" intermediate casing at 1194', and a 7" slotted liner from 987' to 6940'. Richard Weishaupt #1 was drilled to evaluate a deeper portion of the reservoir to a total depth of 10,014'. Because it was deeper, an additional string of casing (cemented blank liner) was required. Each casing size had to be increased in order that a 7" slotted liner could still be run at total depth. The casing program was implemented with 30" conductor at 76', 20" surface casing at 299', 13-3/8" intermediate casing casing at 1390', a cemented blank liner from 1182' to 5078', and a 7" slotted liner from 4972' to 9995'.

Cementing

With the exception of the slotted liners, all casing strings were cemented over their entire length. In most cases the slurry volume was selected by adding 100% excess to the theoretical calculated volume. Casing strings were usually cemented with a low density lead slurry of class "G" cement with 1:1 perlite, 40% silica flour, 3% bentonite, 0.5% CFR-2 and accelerators or retarders as required. The lead slurry was followed by a small volume of higher density tail slurry of class "G" cement with 40% silica flour, 0.5% CFR-2 and accelerators or retarders as required. Water spacers and sepiolite mud flushes were normally pumped ahead of the cement slurries.

In Richard Weishaupt #1 a cement squeeze was required to seal off a water flow from the 9-5/8" x 13-3/8" liner lap. Slurry composition was the same as the tail slurries used on casing cement jobs.

In DeBraga #2 six cement plugs were required to seal off lost circulation. Slurry composition for five of these plugs was the same as the lead slurries used on casing cement jobs with the exception that class "B" cement replaced class "G" cement. The fifth plug used two slurries, the second of which was class "B" cement with 25 lbs/sack gilsonite and 0.75% CFR-2. The sixth plug was mixed with class "G" cement and 0.75% CFR-2.

Drilling Fluid

Both wells were drilled with a drilling fluid consisting mainly of bentonite, water, caustic, and lignite. As problems were encountered during the drilling operation, other mud products were added.

Four water flows occurred, two in each well, when the mud weight was less than approximately 67 lbs/ft^3. The water flows were easily killed by increasing the mud weight with barite to 72 lbs/ft^3.

Lost circulation occurred in DeBraga #2 while killing a water flow. Lost circulation material was added with little effect and six cement plugs were required to seal off losses. No lost circulation occurred while drilling Richard Weishaupt #1, although surge pressures developed while running in the hole caused the formation to break down twice. Each time 200 to 300 bbls of mud were pumped before the hole filled and full returns were regained. Lost circulation material was added on the first occasion but not on the second.

Rotating torque in Richard Weishaupt #1 in the 8-3/4" hole section was above average. Drilling detergent, walnut hulls, and mica were added in attempts to reduce rotary torque. Although these additions did not noticeably reduce rotary torque, there was no increase in torque with depth after additions were begun.

Differentially stuck pipe in Richard Weishaupt #1 was successfully freed with a Pipe-Lax and diesel pill. In order to prevent further sticking problems, 2% diesel was added to the mud.

Drill pipe corrosion was not significant while drilling the Stillwater Prospect wells. H_2S was not encountered in either well.

Directional Drilling

DeBraga #2 was drilled as a straight hole. No problems were encountered in keeping the drift angle to within 4° of vertical.

Richard Weishaupt #1 was directionally drilled toward a target objective 2400' due west of the surface location at 9500' true vertical depth. The bottom hole location reached was 357' south and 2306' west of the surface location at 9569' true vertical depth. A turbodrill and bent sub were used to kick the well off. Three bit runs using the turbodrill were required to obtain the desired well course. Rotating bottom hole assemblies were then adjusted as necessary to build the drift angle to 22° from vertical and maintain it at that value until total depth was reached. The maximum drift angle reached was 24.75°.

DRILLING DATA TABLE

EXPLORATORY WELLS - STILLWATER PROSPECT

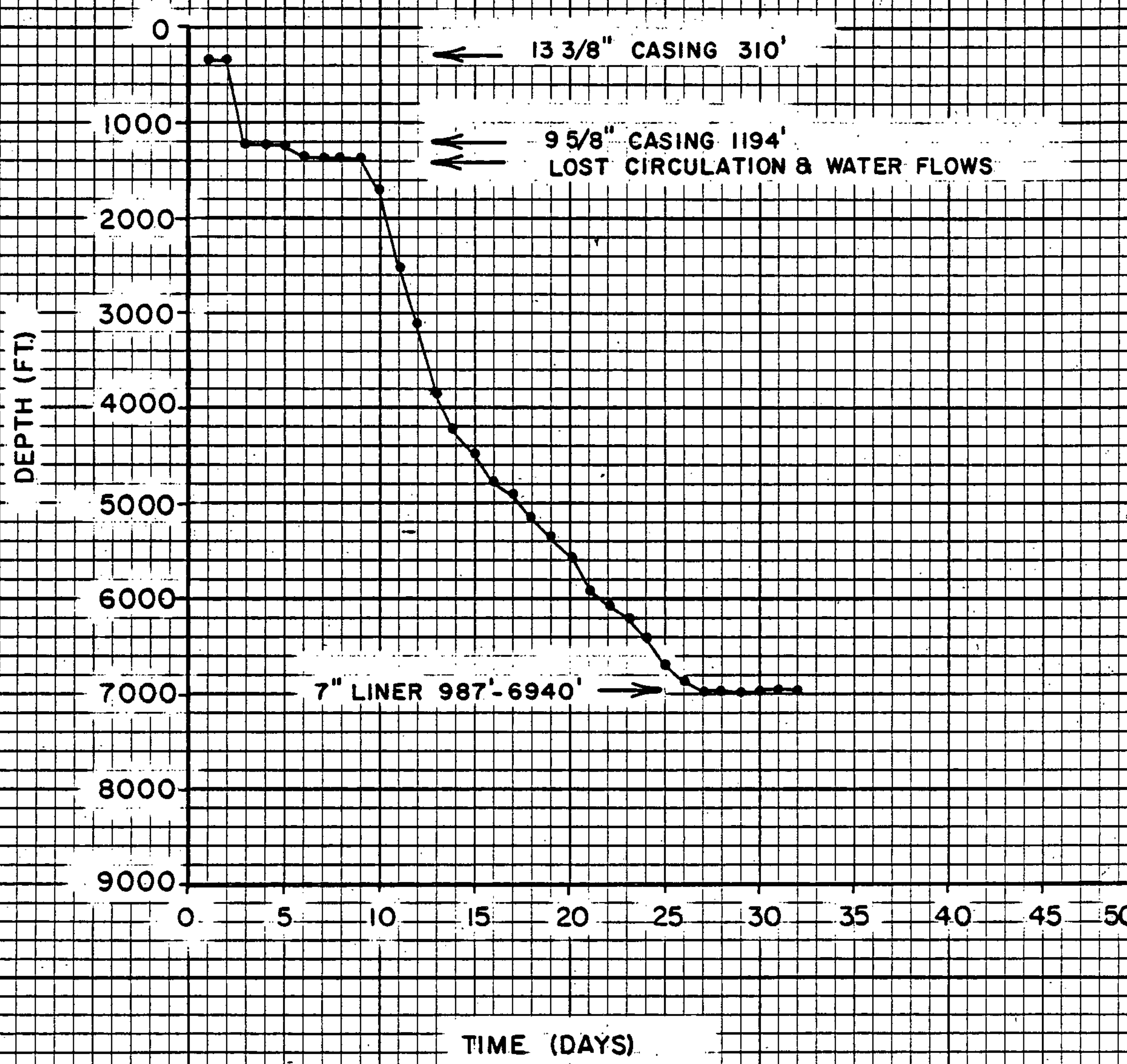
CHURCHILL COUNTY, NEVADA

	De Braga #2	Richard Weishaupt #1
Spud Date	04-06-79	05-14-81
Completion Date	05-07-79	06-29-81
Rig	Coastal Drlg Rig #2	Brinkerhoof-Signal Rig #2
Total Depth	6,946'	10,014'
Total Days	32	46
Total Cost	$568,000	$1,230,000
Water Flows	1205', 1309' to 1355'	1404', 9-5/8" x 13-3/8" liner lap (1390')
Lost Circulation	1309' - 1450' (6 cement plugs)	None
Differential Sticking	None	8850' (Bit at 9544') Freed with PipeLax Diesel
Fishing Jobs	Twist Off at 6946' Recovered fish on first attempt	None
Bottom Hole Location	31' South and 240' East of Surface Location	357' South and 2306' West of Surface Location
True Vertical Depth	6940'	9569'
Maximum Drift Angle	4°	24.75°

TIME VS. DEPTH PROGRESS CURVE

DE BRAGA NO. 2

STILLWATER PROSPECT, CHURCHILL COUNTY, NEVADA



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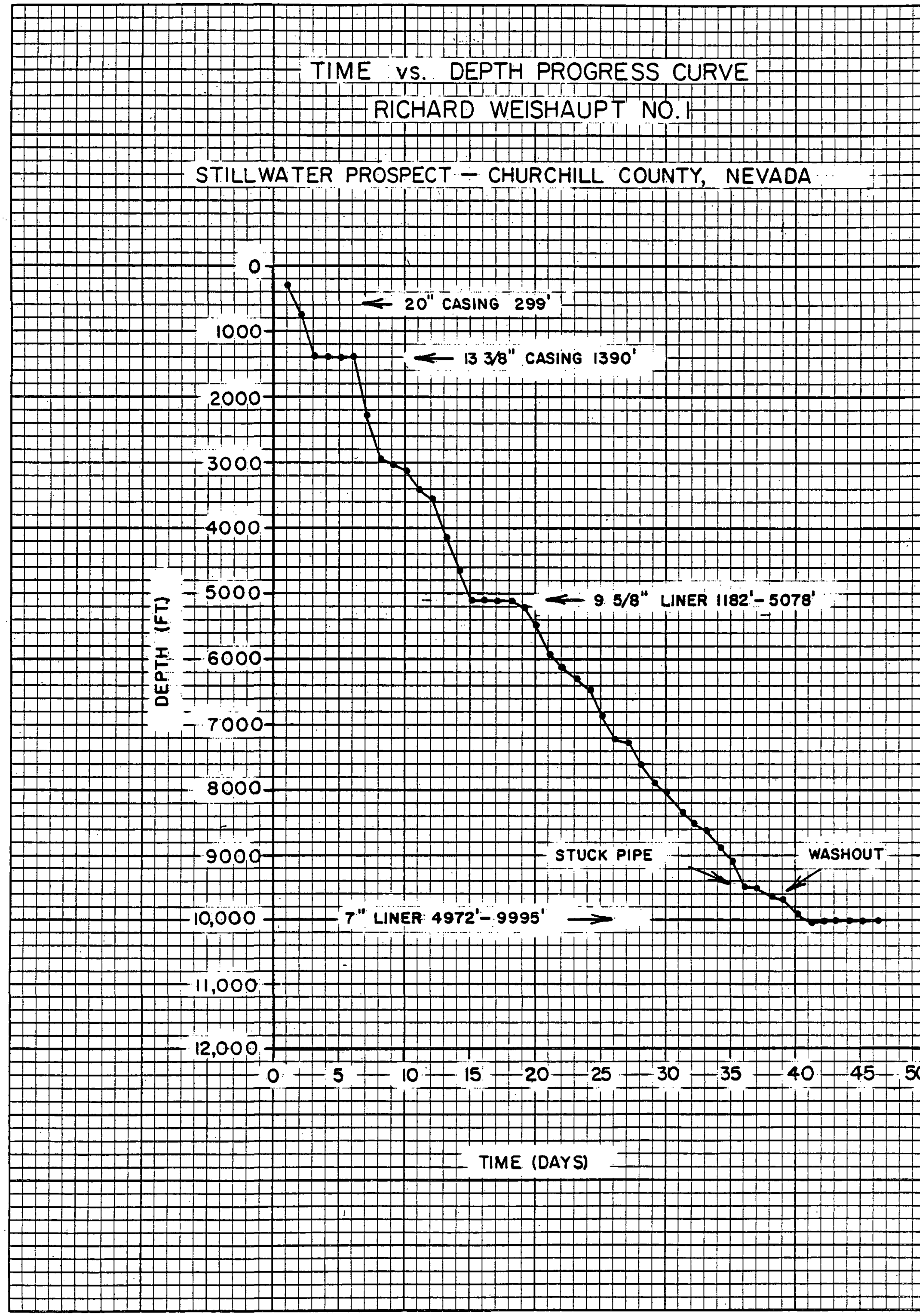
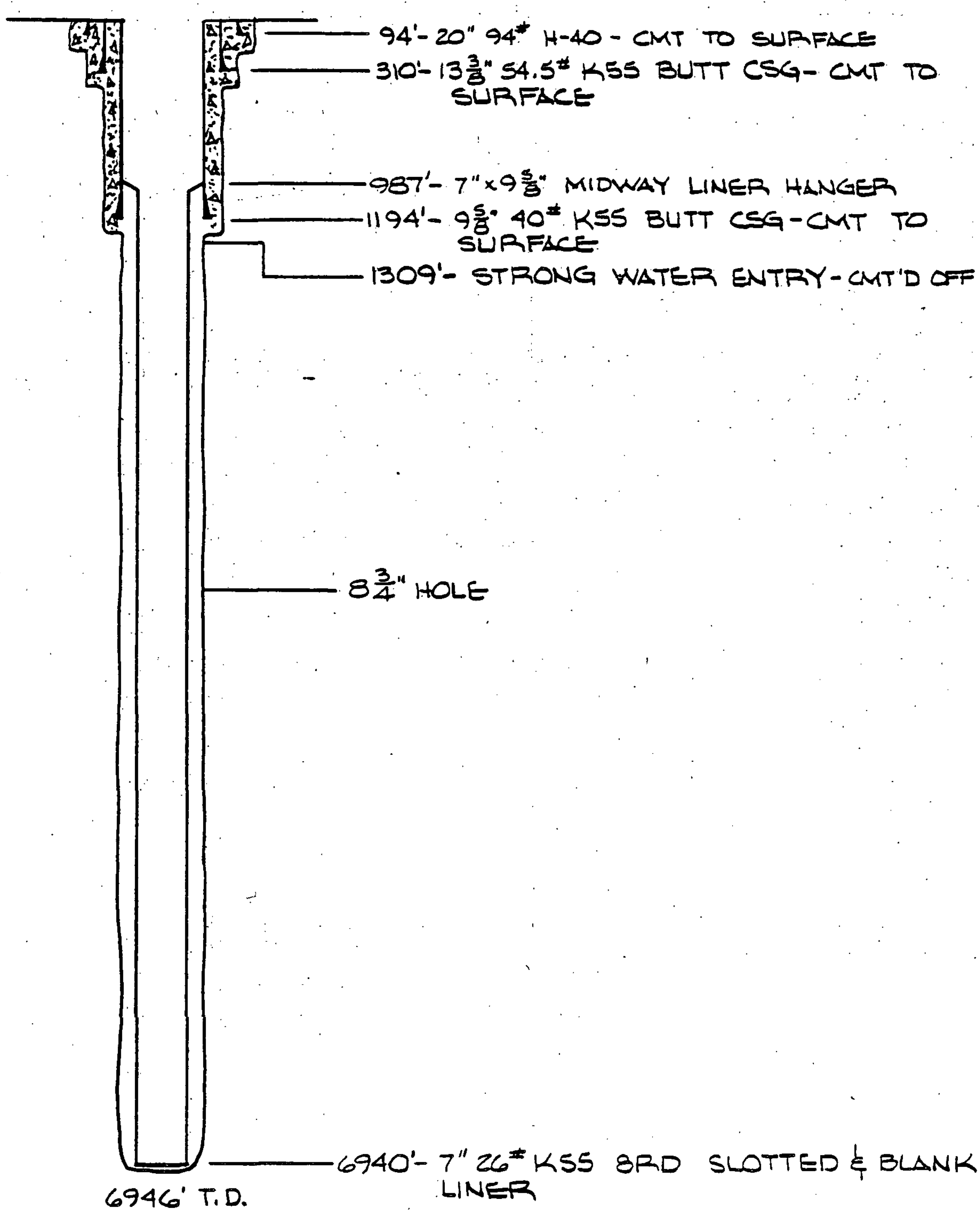
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.



46 0782
K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

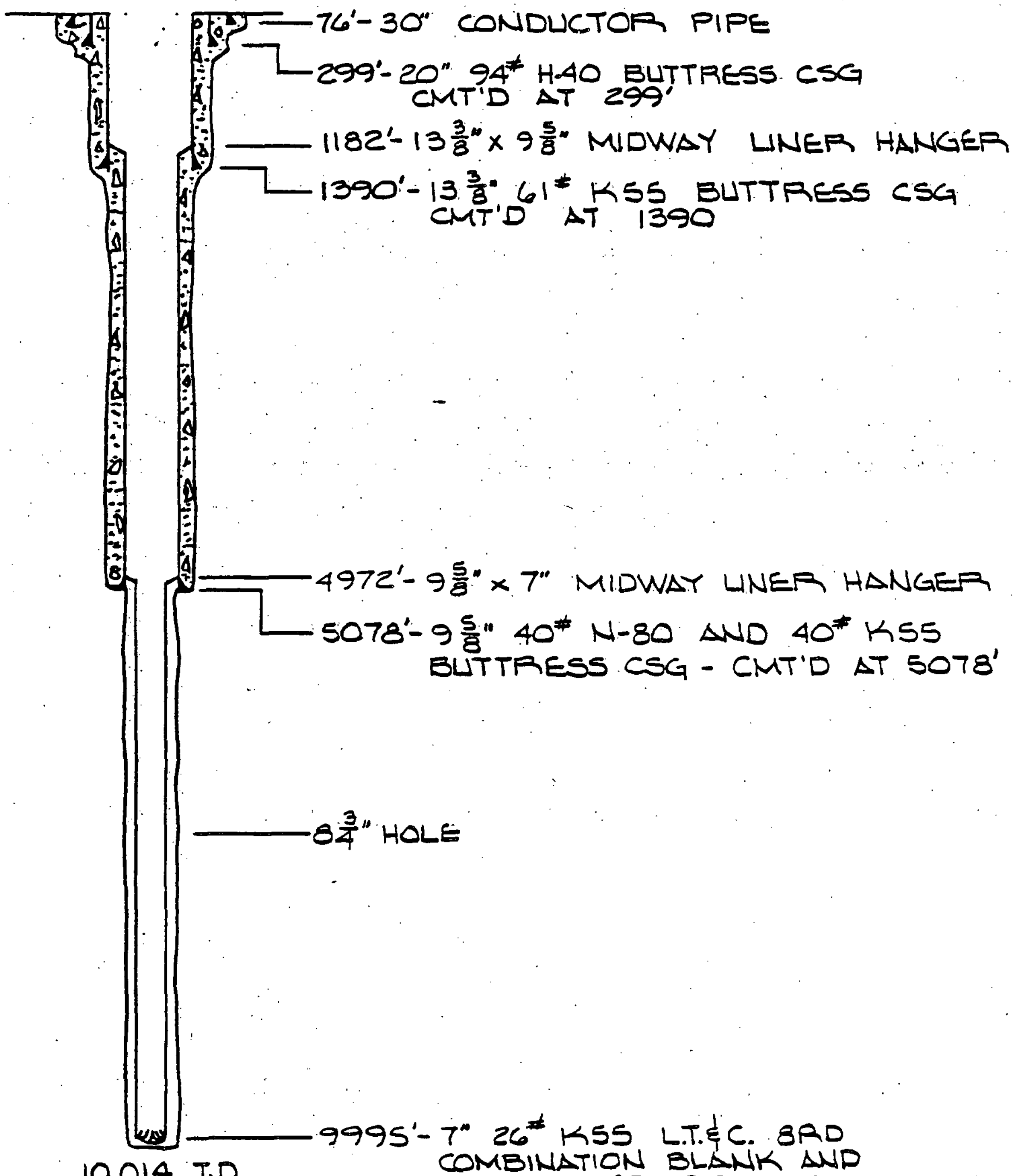
WELL COMPLETION SCHEMATIC
DE BRAGA NO. 2

KELLY BUSHING 11'
GROUND ELEVATION 3885'



WELL COMPLETION SCHEMATIC
RICHARD WEISHAUPT - 1

KELLY BUSHING 27'
GROUND ELEVATION 3895'



7" PERFORATIONS

4972' TO 5062' - BLANK
5062' TO 5219' - 16-2-6-80
5219' TO 5347' - 16-2-6-250
5347' TO 7344' - 18-2-6-150 } APPROX. EVERY OTHER
7344' TO 9995' - 20-1.5-1/4-R.H. } JOINT BLANK

CASING PROGRAM

EXPLORATORY WELLS - STILLWATER PROSPECT

CHURCHILL COUNTY, NEVADA

	DeBraga #2	Richard Weishaupt #1
Conductor Casing	26" Hole to 94' 20" 94# K-55 Buttress at 94' Cemented to Surface	36" Hole to 76' 30" 106# Plain End @ 76' Cemented to Surface
Surface Casing	17-1/2" Hole to 312' 13-3/8" 54.5# K-55 Buttress @ 310' Cemented to Surface	26" Hole to 315' 20" 94# K-55 Buttress @ 299' Cemented to Surface
Intermediate Casing	12-1/4" Hole to 1205' 9-5/8" 40# K-55 Buttress @ 1194' Cemented to Surface	17-1/2" Hole to 1404' 13-3/8" 61# K-55 Buttress @ 1390' Cemented to Surface
Liner		12-1/4" Hole to 5095' 9-5/8" 40# N-80 and K-55 Buttress from 1182' to 5078'. Cemented over Entire Length
Slotted Liner	8-3/4" Hole to 6946' 7" 26# K-55 8-round LT&C From 987' to 6940' Not Cemented	8-3/4" Hole to 10,014' 7" 26# K-55 8-round LT&C From 4972' to 9995' Not Cemented

GEOLOGIC SUMMARY OF THE STILLWATER PROSPECT

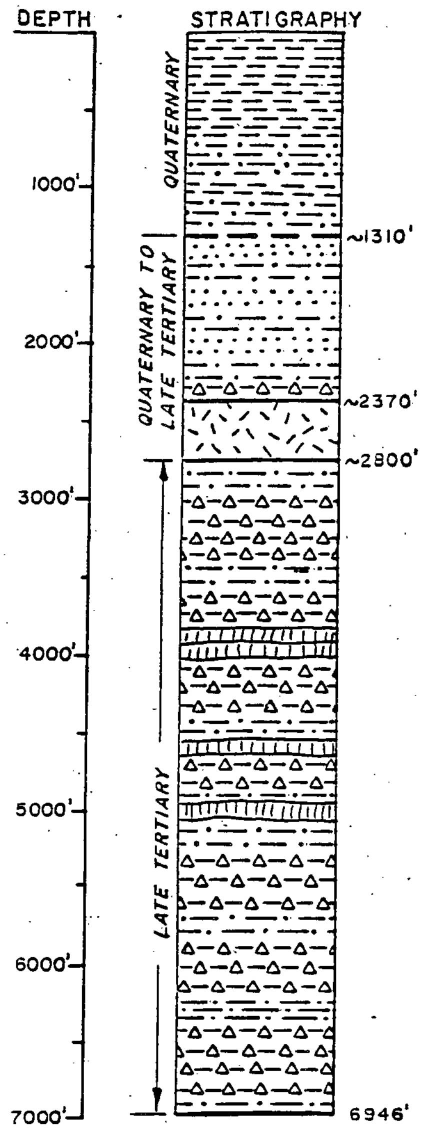
The two deep production wells, DeBraga-2 and R. Weishaupt-1, defined features of the geological and geothermal framework of the Stillwater Prospect, but failed to establish the existence of an electrical resource base. Both wells penetrated Cenozoic rocks to total depth (stratigraphy summarized in the stratigraphic columns). The upper portion of the stratigraphic section is composed primarily of Quaternary clay along with minor interbedded sandstone and siltstone. These Quaternary strata are poorly consolidated and generally characterized by high conductivity, high porosity, and low density (logging data summarized in the logging tables). Conformably underlying these strata is an interval of early Quaternary to late Tertiary interbedded sandstone, siltstone and clay. These rocks are distinguished from the Quaternary strata by a higher sandstone + siltstone/shale ratio, better induration and the presence of tuffaceous horizons in the lower part of this interval. The sedimentary strata are underlain by late Tertiary (possibly to early Quaternary) igneous rocks which consist of (in descending stratigraphic order) a mafic sill complex, basaltic to andesitic volcanics, and felsic volcanics. The depth to the top of the Mesozoic basement complex was not determined. Furthermore, the presence of a shallow intrusive complex which is characterized by high density and susceptibility precludes defining deep structural complexities of the basin using gravity and magnetic modeling techniques.

Characteristics of the thermal profiles of DeBraga-2 and

R. Weishaupt-1 are summarized in the profile of geothermal framework. Both wells contain temperature reversals at about 1400 to 1500 ft. with the upper portions of the reversals typified by gradients of ∿50-60°F/100 ft. Since these high thermal gradients generally occur within the unconsolidated clays of the Lahontan Valley Group, it seems likely that these strata are relatively impermeable and act as a caprock over the reservoir. The occurrence of lost circulation and evidence for the incursion of thermal fluids into the well bore suggests that the highest permeability is located at depths of ∿1300-3000 ft. As this permeable zone occurs at nearly the identical depths in both wells, this permeable zone is probably a stratigraphic interval. Therefore, the temperature reversals probably reflect lateral flow of thermal fluids. Negative to nearly isothermal gradients occur from ∿3500-4500 ft. while the lower portions of both wells have positive gradients of 0.4-1.6°F/100 ft. The maximum temperatures recorded in both wells (336-353°F) are comparable to the lower range of estimates of formation temperature using chemical geothermometry techniques.

The productivity and temperature of both DeBraga-2 and R. Weishaupt-1 are insufficient for electrical power generation. However, the presence of >300°F fluids and high permeability at ∿1300-3000 ft. perhaps indicates that this prospect could be utilized in a direct-heat project.

STRATIGRAPHIC COLUMN-DE BRAGA $\#_2$ WELL



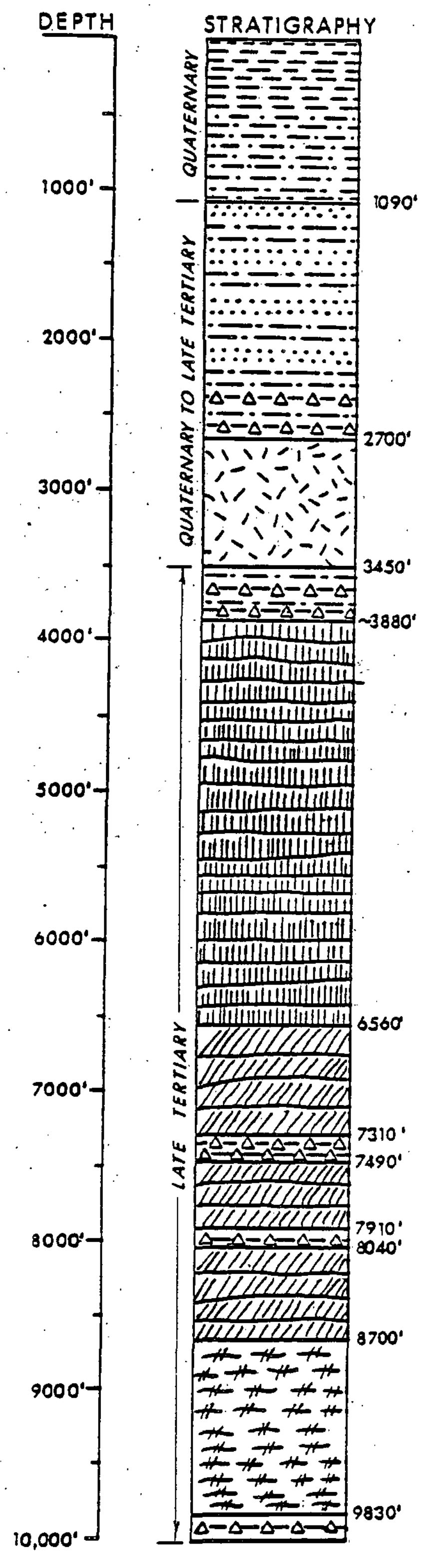
LAHONTAN VALLEY GROUP (thickness = 1310') - composed primarily of unconsolidated shale along with minor amounts of siltstone + sandstone; coarser sediments are quartz-rich and fine-grained (<1.0mm); calcite cement is common.

PRE-LAHONTAN VALLEY GROUP (thickness = 1060') - composed primarily of sandstone + siltstone along with minor shale; well-indurated; quartz-rich; locally tuffaceous near base.

BASALTIC HYPABYSSAL SILL (thickness = 430') - medium-grained (1-2mm) hypidiomorphic granular texture; composed of clinopyroxene, magnetite, olivine and plagioclase.

INTERCALATED MAFIC FLOWS, TUFF, TUFFACEOUS SEDIMENT AND SEDIMENTARY STRATA (thickness = ~4140') - includes:

1) basaltic to andesitic flows - plagioclase phenocrysts; vesicles which are filled with calcite + quartz; matrix is very fine-grained.
2) tuff, tuffaceous sediment - very fine-grained; clastic texture; locally calcareous.
3) sedimentary strata - quartz rich; fine-grained.



STRATIGRAPHIC COLUMN - R. WEISHAUPT #1 WELL

LAHONTON VALLEY GROUP (thickness = 1090')- interbedded clay, siltstone and minor sandstone; poorly consolidated; coarser sediments are quartz-rich and fine-grained (< 1.0mm);calcite cement is common; pyrite and chlorite are secondary minerals.

PRE-LAHONTON VALLEY GROUP (thickness = 1610') - interbedded sandstone, siltstone and minor clay; moderately well consolidated; coarse-grained sediments are quartz-rich; quartz overgrowths are locally abundant; intercalated with tuffaceous sediment and tuff near the base of this unit.

BASALTIC HYPABYSSAL SILL (thickness = 750') - hydromorphic granular and ophitic texture; fine-grained (1-2mm); composed of plagioclase, pyroxene, olivine and magnetite.

INTERBEDDED TUFFACEOUS SEDIMENTS AND VOLCANICS - (thickness = 420') - v. fine grained tuff which is locally rich in quartz + plagioclase fragments; volcanics have a mafic composition, are aphanitic, and do not have a clastic texture.

AMYGDULAR BASALTIC TO ANDESITIC VOLCANICS - (thickness = 2,530') - very vesicular (filled with quartz, chlorite, cu-minerals (?), and calcite); rare plagioclase phenocrysts; matrix locally contains abundant plagioclase microlites, is very fine-grained, and always hematite-stained.

BASALTIC TO ANDESITIC VOLCANICS (thickness = 690') - fine-grained, minor vesicles (filled with quartz + chlorite); plagioclase, pyroxene and olivine phenocrysts set in a matrix of granular plagioclase + chloritized mafics.

ANDESITIC TUFF (thickness = 170') - very fine-grained, well-bedded tuff and lithic-rich (pumice clasts) tuff.

BASALTIC TO ANDESITIC VOLCANICS (thickness = 390') - Same as above

ANDESITIC TUFF (thickness = 130') - Same as above

BASALTIC TO ANDESITIC VOLCANICS (thickness = 625') - Same as above

FELSIC VOLCANICS (thickness = 1,050') - plagioclase, hornblende and rare quartz phenocrysts set in very fine-grained matrix; plagioclase microphenocrysts locally present in matrix; perlitic cracks are abundant; epidote (?)- calcite-quartz-chlorite veins are common.

MIXTURE OF ANDESITIC TUFF AND BASALTIC TO ANDESITIC VOLCANICS (thickness = 170')- Same as above

LOGGING TABLES

The following tables summarize logging runs in the
De Braga-2 and R. Weishaupt-1 wells
Logs will be available from:

Rocky Mountain Well Log Service
P.O. Box 3150
Denver, Colorado 80201
(303) 825-2181

DE BRAGA-2 WELL

SCHLUMBERGER LOGGING DATA

DATE	TYPE OF LOG	LOGGED INTERVAL	TOTAL DEPTH
9 April 79	Dual Induction-Laterolog	320-1207'	1205'
9 April 79	Compensated Neutron Log-Formation Density	90-1213'	1205'
9 April 79	Temperature Log	0-1205'	1205'
9 April 79	Dipmeter Log	320-1212'	1205'
3 May 79	Dual Induction-Laterolog	1192-6938'	6946'
3 May 79	Compensated Neutron Log-Formation Density	1192-6944'	6946'
3 May 79	Temperature Log	0-6946'	6946'
3 May 79	Dipmeter Log	1196-6944'	6946

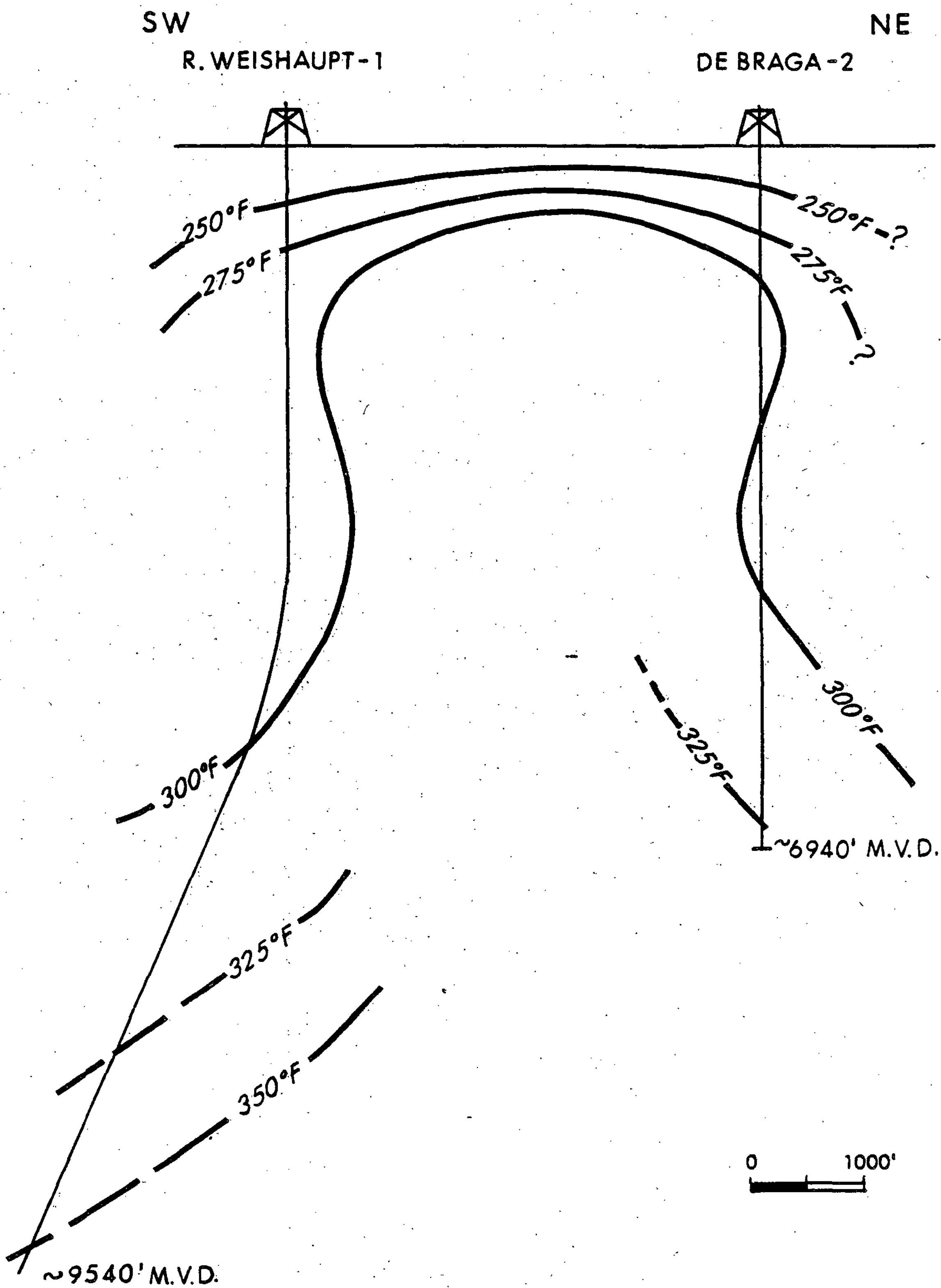
R. WEISHAUPT -1 WELL

SCHLUMBERGER LOGGING DATA

DATE	TYPE OF LOG	LOGGED INTERVAL	TOTAL DEPTH
17 May 81	Temperature Log	298-1396'	1404'
17 May 81	Sonic Log with Caliper and S-P	298-1390'	1404'
17 May 81	DIL-SFL with Linear Correlation log	298-1388'	1404'
17 May 81	CNL-FD with Gamma Ray and Caliper	298-1386'	1404'
18 May 81	Continous Dipmeter	298-1386'	1404'
29 May 81	DIL-SFL with Linear Correlation log and S-P	1389-5090'	5092'
29 May 81	Sonic Log with Caliper and Gamma Ray (computer failed at 3500')	3500-5089'	5092'
24 June 81	DIL-SFL and Sonic Log with S-P, Gamma Ray and Caliper	Both tools failed at depth of 9500-10,000'	10,014'
24 June 81	Temperature Log	Tool could not be calibrated	10,014'
24 June 81	DIL-SFL with S-P	5080-10,000'	10,014'
25 June 81	Sonic Log with Caliper and Gamma Ray	Tool failed at depth of 9500-10,000'	10,014'
25 June 81	Sonic Log with Caliper and Gamma Ray	Tool failed at depth of 9500-10,000'	10,014'

R. WEISHAUPT-1 WELL
continued

25 June 81	CNL with Gamma Ray	1306-5080'	10,014'
25 June 81	CNL-FD with Gamma Ray	5080-9997'	10,014
25 June 81	Temperature Log	Tool failed at about 2500'	10,014
25 June 81	Temperature Log	Tool failed at about 1500'	10,014



PROFILE OF GEOTHERMAL FRAMEWORK
STILLWATER PROSPECT

RESERVOIR SUMMARY

STILLWATER PROSPECT

Pressure and temperature surveys have been conducted in DeBraga-2 and Richard Weishaupt-1. Production tests have also been attempted on both wells. A comparison of the information from these tests is provided in well test data table.

Richard Weishaupt-1 flowtest, conducted on July 15, 1981, indicated mass flow rate into the empty well bore to be 190 pounds per hour. The mass flow was calculated using the assumption that the flowtest emptied the wellbore and approximately 21 hours later it was full again. It should be noted that during drilling one drilling break was encountered. The lack of flow suggests that the fracture is not connected to the reservoir.

The DeBraga flowtest on May 22, 1979 lasted 3-1/2 hours. The average flowrate during the flowtest was indicated to be 150,000 pounds per hour at 5 percent flash, 20 psig wellhead pressure and 252°F.

The pressure buildup following the flowtest on DeBraga-2 indicated a kh of 10,000 md-ft and a skin coefficient of +0.1. The buildup was recorded by gauges at 2,600 ft.

Both wells' temperature profiles are compared in the temperature survey plot. The two wells had temperature reversals between 1500 ft and 3500 ft. The temperature peak at 1500 ft. was slightly higher in DeBraga-2 : 310°F v.s. 290°F. Following the drop in temperature, a temperature gradient in both wells led to bottom hole temperatures of 336°F and 350°F for DeBraga 2 and Richard Weishaupt-1, respectively.

The pressure survey plot illustrates the pressure profiles for DeBraga-2 and Richard Weishaupt-1. Both gradients illustrate a saturated profile with a .4 psi/ft gradient. The saturated profile in both wells indicate that the well bore is full of liquid.

Testing on DeBraga-2 indicates that the fractures encountered during drilling are connected with a permeable region in the resource. Richard Weishaupt-1 did not seem to encounter the same permeable region. The similarity in the temperature profiles indicate that the wells are using the same heat source. Stimulation of Richard Weishaupt-1 might allow the fractures to enter a permeable region similar to DeBraga-2.

The low temperature profiles would suggest that the Stillwater resource is not feasible for electrical generation.

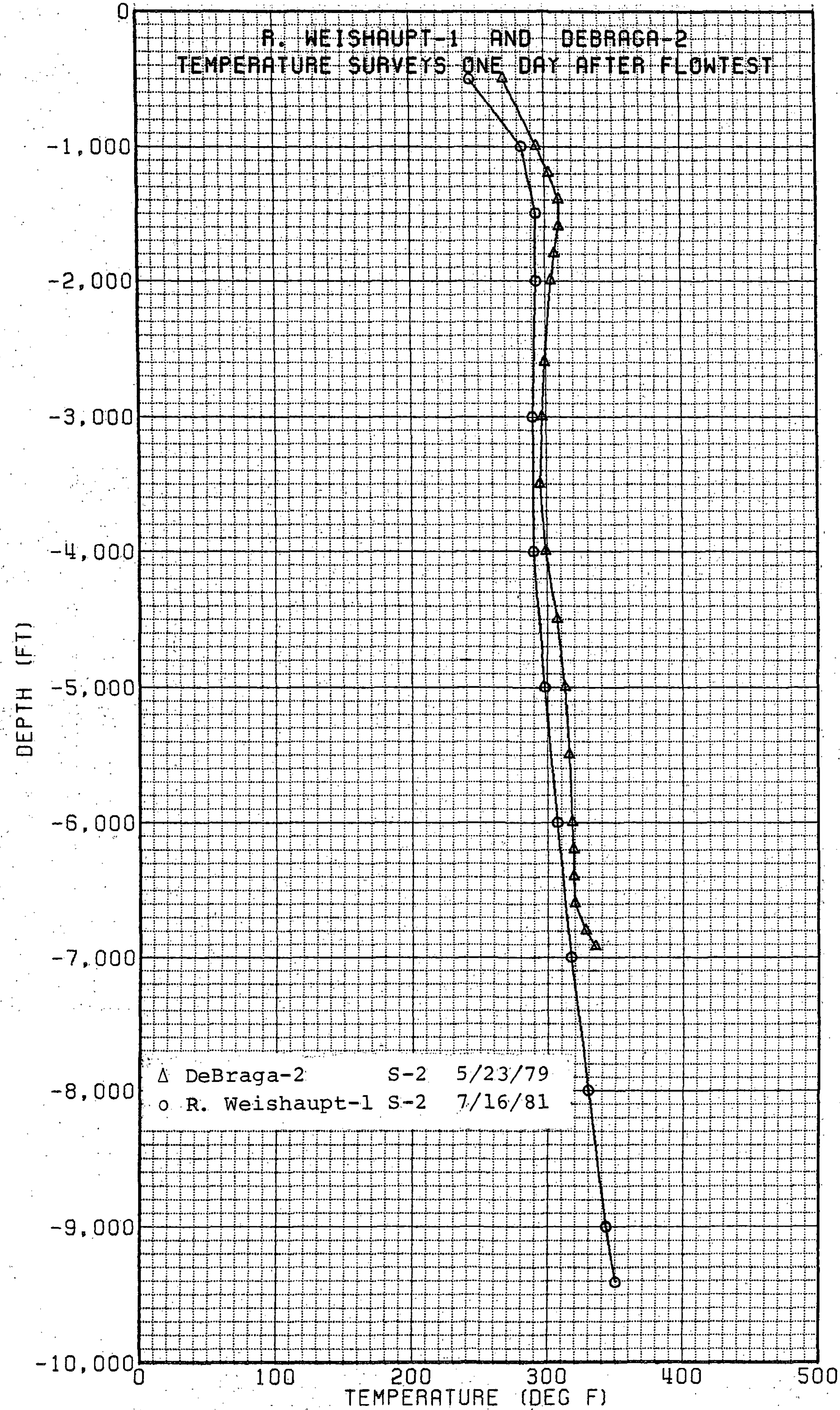
WELL TEST DATA TABLE

STILLWATER F1 D, NEVADA

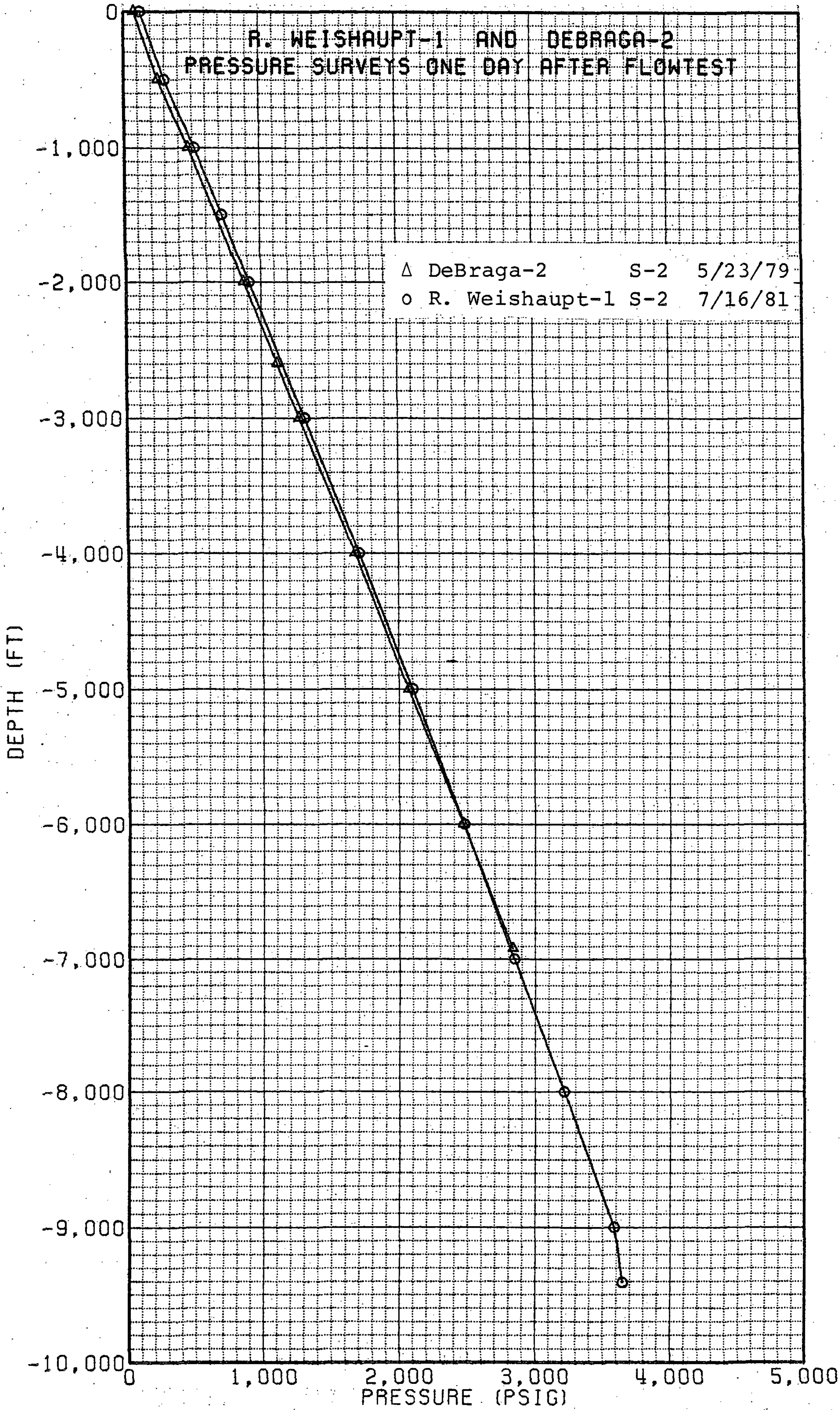
COMPARATIVE WELL TEST INFORMATION

AS OF JULY, 1981

	DeBraga No. 2	R. Weishaupt No. 1
DATE COMPLETED	5-08-79	6-29-81
TOTAL DEPTH	6,946	10,000
PRODUCTION STRING	7", 26# liner	7", 26# liner
SLOTTED INTERVAL	2,724-6,940	5,000-10,000
TEMPERATURE ANOMALY		
Max. Temp., ^{o}F	310	290
Depth Interval	1,200-1,800	1,000-2,000
FLOW TEST		Unable To Flow
Avg. Rate (lb/hr)	152,000	--
WHP,PSIG	20	--
WHT, ^{o}F	252	--
Bottomhole Press, PSIG	925	--
Depth, Feet	2,600	--
% Flash	5%	--
BUILD UP TEST		
Kh, md-ft	10,000	--
S	0	--
Max. Temp., ^{o}F	336	350
Depth, Feet	6,920	9,410



TEMPERATURE SURVEY PLOT



PRESSURE SURVEY PLOT